Zbornik 15. mednarodne multikonference

INFORMACIJSKA DRUŽBA – IS 2012

Zvezek A

Proceedings of the 15th International Multiconference

INFORMATION SOCIETY – IS 2012

Volume A

Uredili / Edited by
Marko Bohanec, Matjaž Gams, Dunja Mladenić, Marko Grobelnik,
Marjan Heričko, Urban Kordeš, Maja Smrdu, Zvezdan Pirtošek,
Olga Markič, Jadran Lenarčič, Leon Žlajpah, Andrej Gams,
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8.–12. oktober 2012 / October 8th–12th, 2012
Ljubljana, Slovenia

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PREDGOVOR MULTIKONFERENCI INFORMACIJSKA DRUŽBA 2012

V svojem petnajstem letu je multikonferenca Informacijska družba (http://is.ijs.si) med drugim z organizacijo konference ob **stoletnici Turingovega rojstva** še bolj utrdila mesto ene vodilnih srednjeevropskih konferenc, ki združuje znanstvenike z različnih raziskovalnih področij, povezanih z informacijsko družbo. Od leta 2012 dalje se bo nagrada za življenjske dosežke podeljevala v čast Donalda Michija in Alana Turinga. Letos smo v multikonferenco povezali deset odličnih neodvisnih konferenc, s čemer naša multikonferenca izstopa po širini in obsegu tem, ki jih obravnava, po akademski odprtosti in širini, ki spodbuja nove ideje, predvsem pa po tem, da ni tradicionalna konferenca, ampak se pogumno loteva vizionarskih tem, pogosto v interaktivni ali delavniški obliki.

Na multikonferenci predstavljamo, analiziramo in preverjamo nova odkritja in pripravljamo teren za njihovo praktično uporabo, saj je njen osnovni namen promocija raziskovalnih dosežkov in spodbujanje njihovega prenosa v prakso na različnih področjih informacijske družbe tako v Sloveniji kot tujini. Še bolj kot prejšnja leta smo prepričani, da sta stroka in vizija najpomembnejši za izhod iz stagnacije, v katero sta zašli Evropa in Slovenija.

Na vzporednih konferencah bo predstavljenih čez 210 referatov, vključevala pa bo tudi okrogle mize in razprave. Referati so objavljeni v zbornikih multikonference, izbrani prispevki pa bodo izšli tudi v posebnih številkah dveh znanstvenih revij, od katerih je ena Informatica, ki se ponaša s 35-letno tradicijo odlične znanstvene revije.

Multikonferenco Informacijska družba 2012 sestavljajo naslednje samostojne konference:

- 100 let Alana Turinga in 20 let SLAISa
- FORSEE - tehnološko predvidevanje na področju IKT
- Inteligentni sistemi
- Jezikovne tehnologije
- Kognitivne znanosti
- Robotika
- Rudarjenje podatkov in podatkovna skladišča (SiKDD 2011)
- Sodelovanje, programska oprema in storitve v informacijski družbi
- Soočanje z demografskimi izzivi
- Vzgoja in izobraževanje v informacijski družbi.

Soorganizatorji in podporniki konference so različne raziskovalne institucije in združenja, med njimi tudi ACM Slovenija in SLAIS. Zahvaljujemo se tudi Agenciji za raziskovalno dejavnost RS ter Ministrstvu za izobraževanje, znanost, kulturo in šport za sodelovanje in podporo. V imenu organizatorjev konference se želimo posebej zahvaliti udeležencem za njihove dragocene prispevke in priložnost, da z nami delijo svoje izkušnje o informacijski družbi. Zahvaljujemo se tudi recenzentom za njihovo pomoč pri recenziranju.

V letu 2012 sta se programski in organizacijski odbor odločila, da bosta podelila posebno priznanje Slovencu ali Slovenki za izjemen življenjski prispevek k razvoju in promociji informacijske družbe v našem okolju. Z večino glasov je letošnje priznanje pripadlo dr. Francu Solini. Priznanje za dosežek leta je pripadlo dr. Juretu Leskovcu. V letu 2012 drugič podeljujemo nagrado »informacijska limona« in »informacijska jagoda« za najbolj (ne)uspešne poteze v zvezi z informacijsko družbo. Limono je dobila ACTA, jagodo pa Urbana in Bicikelj. Čestitke nagrajencem!

Niko Zimic, predsednik programskega odbora
Matjaž Gams, predsednik organizacijskega odbora

FOREWORD - INFORMATION SOCIETY 2012

In its 15th year, the Information Society Multiconference (http://is.ijs.si), among others with the conference devoted to **Alan Turing**, further established itself as one of the leading conferences in Central Europe gathering scientific community with a wide range of research interests in information society. For 2013 and further, the award for life-long outstanding contributions will be delivered in memory of Donald Michie and Alan Turing. This year, we organized ten independent conferences forming the Multiconference, delivering a broad range of topics and the open academic environment fostering new ideas makes which our event unique among similar conferences, promoting key visions in interactive, innovative ways.

The major driving forces of the Multiconference are search and demand for new knowledge related to information, communication, and computer services. We present, analyze, and verify new discoveries in order to prepare the ground for their enrichment and development in practice. The main objective of the Multiconference is presentation and promotion of research results, to encourage their practical application in new ICT products and information services in Slovenia and also broader region. We are more confident than ever that science and vision are the two most important issues to break the stagnation of Europe and Slovenia.

The Multiconference is running in parallel sessions with over 210 presentations of scientific papers. The papers are published in the conference proceedings, and in special issues of two journals. One of them is Informatica with its 35 years of tradition in excellent research publications.

The Information Society 2011 Multiconference consists of the following conferences:

- 100 years of Alan Turing and 20 years of SLAIS
- FORSEE - technological forecasting in ICT
- Intelligent Systems
- Language technologies
- Cognitive Sciences
- Robotics
- Data Mining and Data Warehouses (SiKDD 2011)
- Collaboration, Software and Services in Information Society
- Demographic Challenges in Europe
- Education in Information Society.

The Multiconference is co-organized and supported by several major research institutions and societies, among them ACM Slovenia, i.e. the Slovenian chapter of the ACM. We would like to express our appreciation to the Slovenian Government for cooperation and support, in particular through the Ministry of Education, Science, Culture and Sport.

In 2012, the Programme and Organizing Committees decided to award one Slovenian for his/her life-long outstanding contribution to development and promotion of information society in our country. With the majority of votes, this honor went to Dr. Franc Solina. In addition, a reward for current achievements was pronounced to Dr. Jure Leskovec for his research on mining and modeling large social networks at Stanford. The information strawberry is pronounced to Urbana and Bicikelj, and the information lemon goes to ACTA. Congratulations!

On behalf of the conference organizers we would like to thank all participants for their valuable contribution and their interest in this event, and particularly the reviewers for their thorough reviews.

Niko Zimic, Programme Committee Chair
Matjaž Gams, Organizing Committee Chair

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100 Years of Alan Turing and 20 Years of SLAIS

Uredili / Edited by

Dunja Mladenić, Marko Bohanec

http://is.ijs.si

11. oktober 2012 / October 11th, 2012
Ljubljana, Slovenia

PREDGOVOR

100 YEARS OF ALAN TURING AND 20 YEARS OF SLAIS

The conference is motivated by the centenary of Alan Turing's birth and the 20-years anniversary of the Slovenian Artificial Intelligence Society.

Alan Mathison Turing (1912 - 1954) was an English mathematician, logician, cryptanalyst, and computer scientist. He was highly influential in the development of computer science, providing a formalisation of the concepts of "algorithm" and "computation" with the Turing machine, which played a significant role in the creation of the modern computer. Turing is widely considered to be the father of computer science and artificial intelligence.

Slovenian Artificial Intelligence Society (SLAIS) is an association of researchers and practitioners in the field of Artificial Intelligence in Slovenia. Most of them come from universities and research institutes, but there are members from industrial and commercial organizations as well. The society promotes theoretical and applied research as well as the transfer of AI technology to industrial and commercial environments. SLAIS was founded in 1992 and is a member society of European Coordinating Committee for Artificial Intelligence (ECCAI).

The first theme of the conference is related to the Turing's unique impact on mathematics, computing, computer science, informatics, artificial intelligence, philosophy and computational aspects of physics, biology, linguistics, economics and the wider scientific world. The second theme of the conference is related to the 20-years anniversary of SLAIS, with the aim to report on the achievements of Slovenian researchers that importantly contributed to the field of AI in the national and international context, both in theory and practice.

The program of the conference consists of six invited talks and seven conference papers. Among the invited talks, we are honored to host a talk by a pioneer of Slovenian AI, Acad. Prof. Dr. Ivan Bratko. All the other invited speakers, coming from Australia, UK, Spain and Portugal, are in some way connected with the Slovenian AI research. The conference papers on Alan Turing and outstanding Slovenian AI achievements were contributed by leading Slovenian researchers from Jožef Stefan Institute, Ljubljana, and the Faculty of Computer and Information Science of the University of Ljubljana. All the papers were reviewed by two reviewers.

Dunja Mladenić in Marko Bohanec

PREFACE

100 LET ALANA TURINGA IN 20 LET SLAIS

Konferenco organiziramo ob stoti obletnici rojstva Alana Turinga ob dvajseti obletnici ustanovitve Slovenskega društva za umetno inteligenco.

Alan Mathison Turing (1912 - 1954) je bil angleški matematik, kriptograf in računalnikar. Pomembno je prispeval k razvoju računalniške znanosti. Matematično je opredelil pojem algoritma in njegovega izvajanja na Turingovem stroju, kar je močno vlivalo na razvoj sodobnih računalnikov. Turinga štejemo za očeta modernega računalništva in umetne inteligence.

Slovensko društvo za umetno inteligenco (SLAIS, iz angl. Slovenian Artificial Intelligence Society) je združenje raziskovalcev in drugih udeležencev s področja umetne inteligence v Sloveniji. Večina članov društva prihaja z univerz in raziskovalnih institutov, ki delujejo na področju umetne inteligence v Sloveniji, nekateri člani društva pa so tudi iz gospodarskih organizacij. Namen društva je pospeševanje teoretičnega in uporabnega raziskovanja na področju umetne inteligence ter prenos umetne inteligence v tehnologijo in industrijo. Društvo je bilo ustanovljeno leta 1992 in je član Evropskega društva za umetno inteligenco (ECCAI, iz angl. European Coordinating Committee for Artificial Intelligence).

Prva tema konference je povezana s Turingovim izjemnim vplivom na matematiko, računalništvo, informatiko, umetno inteligenco in filozofijo, pa tudi na računske vidike fizike, biologije, lingvistike, ekonomije in drugih znanosti nasploh. Druga tema je povezana z dvajseto obletnico SLAIS, njen namen je predstaviti teoretične in praktične dosežke slovenskih znanstvenikov, ki so pomembno prispevali k razvoju umetne inteligence doma in v tujini.

Program konference obsega šest vabljenih predavanj in sedem referatov. Med vabljenimi predavatelji ima častno mesto akad. prof. dr. Ivan Bratko, pionir slovenske umetne inteligence. Vsi drugi predavatelji – ti prihajajo iz Avstralije, Velike Britanije, Španije in Portugalske – so na tak ali drugačen način povezani z raziskavami umetne inteligence v Sloveniji. Referate o Alanu Turingu in pomembnih slovenskih dosežkih na področju umetne inteligence pa so prispevali vodilni slovenski raziskovalci z Instituta Jožef Stefan in Fakultete za računalništvo in informatiko Univerze v Ljubljani. V prispevki so bili strokovno pregledani s strani dveh recenzentov.

Dunja Mladenić and Marko Bohanec

Editors and Program Chairs /Urednika

- Dunja Mladenić
- Marko Bohanec

FOUR DECADES OF ARTIFICIAL INTELLIGENCE IN SLOVENIA

Ivan Bratko
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and J. Stefan Institute, Jamova 39, Ljubljana
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Today there are at least ten research laboratories in Slovenia that can be counted as being importantly involved with Artificial Intelligence research, with solid funding that comes mainly from the Slovenian and EU research programs and projects. There are about 150 researchers involved in this research.

In this talk I will describe how all this started about four decades ago with a few researchers, and how it developed into the present, rather sizable Slovenian AI community. I will tell some memorable stories, largely from my own personal perspective, of exciting research ideas and scientific achievements in the process. I will also describe the immense benefit that Slovenian AI enjoyed from the collaboration with Donald Michie, one of the pioneers of AI and a co-worker of Alan Turing during the 2nd World War, and other excellent researchers, including Claude Sammut and Stephen Muggleton, who once worked at Donald's research institutions Edinburgh University and Turing Institute in Glasgow.

Alan Turing and the Development of Artificial Intelligence

Stephen Muggleton
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During the centennial year of his birth Alan Turing (1912-1954) has been widely celebrated as having laid the foundations for Computer Science, Automated Decryption, Systems Biology and the Turing Test. In this talk we investigate Turing's motivations and expectations for the development of Machine Intelligence, as expressed in his 1950 article in Mind. We show that many of the trends and developments within AI over the last 50 years were foreseen in this foundational paper.

In particular, Turing not only describes the use of Computational Logic but also the necessity for the development of Machine Learning in order to achieve human-level AI within a 50 year time-frame. His description of the Child Machine (a machine which learns like an infant) dominates the closing section of the paper, in which he provides suggestions for how AI might be achieved. Turing discusses three alternative suggestions which can be characterised as: 1) AI by programming, 2) AI by ab initio machine learning and 3) AI using logic, probabilities, learning and background knowledge. He argues that there are inevitable limitations in the first two approaches and recommends the third as the most promising. We compare Turing's three alternatives to developments within AI, and conclude with a discussion of some of the unresolved challenges he posed within the paper.

ALAN TURING - EINSTEIN OF COMPUTER SCIENCE

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ABSTRACT

Achievements of Alan Mathison Turing (AMT) in computer science and informatics resemble those of Albert Einstein in physics. Turing's contributions are presented through most important events and achievements, and in particular through the concept of hypercomputers. Several AI and human-intelligence related concepts are analyzed. A short text is devoted to Donald Michie, Turing's co-worker and contemporary, an honorary member of the Jozef Stefan Institute. Even though his centenary, Turing remains largely unknown to an average citizen of the world. An appeal for his full recognition is proposed.

1 INTRODUCTION

In Wikipedia, one finds: Alan Mathison Turing, (23 June 1912 – 7 June 1954), was a British mathematician and computer scientist. He invented a formalisation of the concepts of "algorithm" and "computation" with the Turing machine, which can be considered a model of a general purpose computer.

Upon Turing's centenary, all over the world there were events related to Alan Mathison Turing. There have already been lectures and publications about Turing in Slovenia, e.g. (Gams Turing lecture 2012, Gams Oz 2012).

Lectures about Turing typically highlight the following dates:

1912 – Turing's birth
1936 – publication of the Turing machine
1932-42 – Enigma decoded
1950 – the birth of AI, Turing test
1954 – Turing's death
2007 – death of Donald Michie
2009 – official rehabilitation
2012 – centenary

Some of these dates and the related events will be analyzed in the next sessions.

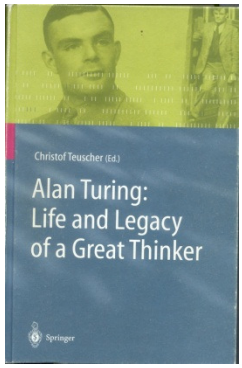

Figure 1: One of the many books about Alan Turing.

2 IMPORTANT CONCEPTS

2.1. Turing machine, TM

In 1936 Turing published a paper about a Turing machine, also a universal Turing machine, and the halting problem. He was interested in undecidability of formal systems, as was his professor Hilbert. An undecidable problem is a decision problem for which it is impossible to construct a single algorithm that always leads to a correct yes/no answer. A decision problem is any arbitrary yes/no question on an infinite set of inputs.

Formally (Reiter 2012), a decision problem A is called decidable or effectively solvable if A is a recursive set. A problem is called partially decidable, semidecidable, solvable, or provable if A is a recursively enumerable set. Partially decidable problems and any other problems that are not decidable are called undecidable. In computability theory, the halting problem is to decide whether the program finishes running or will run forever given a description of a program and a finite input.

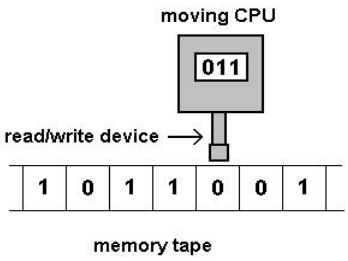

Figure 2: The Turing machine.

Alan Turing proved in 1936 that a general algorithm running on a Turing machine that solves the halting problem for all possible program-input pairs necessarily cannot exist by constructing a counterexample. Since there are algorithms (programs) that no other algorithm can decide whether it will stop or not, the halting problem is undecidable for Turing machines.

Gödel published his incompleteness theorems (Raguni 2012) already in 1931. A weaker form of his first incompleteness theorem is a consequence of the undecidability of the halting problem. This weaker form differs from the standard statement of the incompleteness theorem, meaning that the axiomatic system is a necessity if one wants to prove all true statements about natural numbers. To be a bit more specific, there are two issues: provability and truth. In the first case the issue is just about proving, in the second about being true but not provable. In both cases, in a formal system there are statements that are true and cannot be proven, even though there are sentences (algorithms, programs, theories), that cannot be proven regardless of their truth value (Bojadzijev 1999). Turing's contribution was in proving the concept in the computability, i.e. computer field.

In the process of proving the halting problem Turing introduced the Turing machine as presented in Figure 2. This simple and basic computing model represents the best ever known model of computing and also digital computers we use today. Theoreticians are quick to point out that the Turing machine needs a sufficiently long tape, i.e. data storage equivalent, and therefore computers are not true equivalents of Turing machine but rather finite automata (of huge kind), but the author of this paper finds this argument superficial. If the computer memory is big enough, then the difference is meaningless in all but the theoretical terms.

The essence is that the Turing-machine concept represents such a basic concept or a computing principle that it can be compared to the Einsteins' relativity principles. Indeed, both are neither axioms nor theorems, but computing mechanisms or principles, one describing digital or symbolic computers and the other time-space relations.

2.2. Hypercomputing

One would imagine that new, improved versions of computing mechanisms, i.e. advanced Turing machines, were invented since 1936. If models of computation are in principle »stronger« than the Turing machine, meaning that they can solve tasks that the Turing machine cannot, then such machines are called hypercomputers or super-Turing computational models. The second term usually denotes physically realizable mechanisms. These computing mechanisms include computation of non-Turing-computable functions, following super-recursive algorithms. The term "hypercomputation" was introduced by Copeland and Proudfoot (1999).

There are several issues often discussed in relation to the hypercomputing. One is the Church-Turing thesis (Wikipedia 2011). It states that any function that is algorithmically computable can be computed by a Turing machine. Hypercomputers compute functions that a Turing machine cannot, therefore are not computable in the Church-Turing sense. There are publications indicating that no physical machine can be designed to surpass the Turing machines, and that it is not possible to construct a counterproof. In other words, the hypercomputers ideas might be hypothetical in nature.

Several authors such as Roger Penrose (2002) oppose the notion that computers are as powerful as digital computers directly indicating that humans either possess

- Stronger mechanisms than Turing machines (hypercomputing, often proposed as some stronger semi-mental process) or
- Mechanisms that are not in principle stronger, but so different in practical computer terms that computers cannot compete with them under real-life circumstances. In other words, the human brain is not in principle stronger, but in reality stronger for the majority or the real-world tasks.

An example of a problem a Turing machine cannot solve is the halting problem. Some proposed hypercomputers can simulate the program for an infinite number of steps and tell the user whether or not the program halted. It is claimed by some authors that the halting problem can be solved by humans even though not using additional information which is known to enable solving the halting problem.

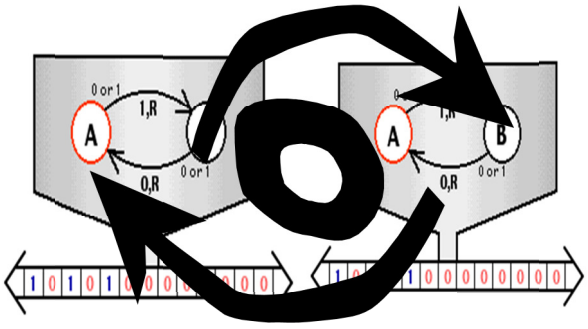

Figure 3: The Multiple Turing machine.

The author of this paper endorses the Multiple Turing Machine, as presented in Figure 3. Unlike multi-tape Turing machine it consists of two universal Turing machines, each writing on each other program at the same time getting information from the open outside world. It is based on the principle of multiple knowledge (Gams 2001). The weak version of the principle states that a sensibly integrated model (or computing mechanism) in general outperforms each single model constituting the basic set of models. The strong version of the principle states that real or human-level intelligence can be achieved only using the multiple algorithms applying the principle. Please note that multiplicity may or may not include parallelism; rather it resonates the interaction concept (Wegner 1997). The principle of multiple knowledge has several manifestations and the Multiple Turing Machine is one of them.

In terms of physical world, the principle of multiple knowledge demonstrates a surprising similarity to the multiple-worlds theory (Deutsch 1998) or the multiverse theory (Ellis 2011). In both theories, there is a huge number of universes like ours in the superuniverse. The controversial theory of multiuniverse is based on physical observations that our universe is expanding ever faster while there is no enough matter or energy of any kind to support this. However, if multiple universes coexist, that would explain the gravity causing the ever faster expanding.

Whatever the case, the Turing machine very well corresponds to digital computers while there is no existing hypercomputer. It should be noted that quantum computers are just as powerful as Turing machines, even they compute based not on 0/1, but on a quantum superposition of the two.

As it turns out, the Turing machine and the halting machine are as fundamental concepts and principles as the other principles humans use, e.g. Einsteins', and have not changed during time.

Figure 4: The disputed multiverse theory there are many universes that pop from nowhere.

2.3. Turing test, birth of AI

In 1950 Turing published a paper describing the Turing test and a debate about artificial intelligence, then named »machine intelligence«. It was only in 1956 that McCarthy coined the »artificial intelligence« term and the field started growing enthusiastically.

Regarding the Turing test (Turing 1950), the best known and discussed test of all times, the issue is in comparing behaviors of two computing mechanisms (originally one human and one computer) and identifying the computing type of each of them. There are tens of different versions of the Turing test, e.g. a Total Turing Test (Harnad 1991) including physical tasks, and a Trully Total Turing test (Schweiser 1998), examining populations of test subjects.

In terms of latest definitions (Gams lecture 2011), intelligent systems and intelligence are defined with the ability to learn. All machine learning systems are therefore intelligent and practically every living being including bacteria and plants. But the Turing test deals with human-level intelligence which includes testing at that level.

In practical terms, the computers have improved their performance by a factor of 100.000 in the last 20 years, yet human interrogators decipher computers from humans in as many questions as before two decades. The reason is that current computers lack any human-level understanding. By verifying understanding of any sentence, all computer programs display tabula-rasa performance. This is the empirical argument of weak AI, claiming that computers need major improvements in order to approach human-level intelligence and computing (Gams 2001).

3 ALAN TURING AND DONALD MICHIE

Donald Michie and Alan Turing were together with other researchers decoding the Enigma, the German encrypting machine (Wikipedia). By use of electronic machines, the

counter-surveillance department was able to decode messages to German submarines. It is claimed that this was the most relevant civil discovery during the second world war and that several 100.000 lives were saved due to this. Due to being a secret, not much was known about this issue until decades later the data went public.

Alan Turing died committing a suicide with a poisoned apple, in an analogy to the Cinderella story. His death and previous sexual behavior led to Turing's legal prosecution, in today's view a major injustice to a loyal and honorable citizen that was undone only in 2009.

Unlike Alan Turing, Donald Michie (Srinivasan 2009) had a successful and long-term career in artificial intelligence. He was also the first one to establish an AI department in any institution in the world. Donald Michie was recipient of several established prices, including the Feigenbaum's medal and IJCAI's award in 2001. Donald Michie is especially important for Slovenian AI, and the Slovenian society SLAIS due to Michie's cooperation with Ivan Bratko. In last decades, Donald often spend one month of a year at the Jozef Stefan Institute in Ivan Bratko's room. The room is now named the Donald Michie room and is close to the central lecture hall at the institute.

4 DISCUSSION

If one types »Lady Gaga« into Google, 400 million hits are found, for »Mozart« around 132 million hits, for »Albert Einstein« 60 million and just 9 million for »Allan Turing«. In Amazon.com, around 10.000 book references are found for »Albert Einstein« in relation to 1.700 of »Alan Turing«. Yet, the Turing Award is generally regarded as the Nobel prize of computer science and Turing himself as »Einstein of computer science« by many scientists, including the author of this paper. Today, several publications refer to Turing as the father of computer science, artificial intelligence and mathematical biology.

It might not be reasonable to compare the fame of Lady Gaga to the fame of Turing, but why on Earth is Turing so unrecognized compared to the other world geniuses like Einstein or Mozart? But to what avail is that Turing is widely recognized in computer science and informatics, if an average European does know him while everybody knows Einstein or Mozart? The fact that Turing was neglected 60 years ago does not discard the fact that he is still neglected now as for example internet hits show.

It should not be only on us, computer science community, but on all scientists to revive the fallen acknowledgement of an extraordinary scientist, demolished by intolerant bureaucrats. It should be only fair for the world to fully accept Turing as one of the most important people ever. If anybody for a second doubts about that, just look around and count the Turing machines embedded in the near-by machines. We should also remember Donald Michie as the Turing companion, in a list of computer geniuses that changed the world as hardly anybody else did.

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Human Factors in the World of Digital Computing and Digital Information

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ABSTRACT

Encoding data and computation in the digital form has enabled us to extend our capability to process information at rates and scales never possible before. However, the digital medium carries inherent risks and poses grand challenges. First, ensuring a long-term and reliable access to digital assets is of paramount importance. Yet, we are still grappling with the meaning of preservation in the face of tight dependences and dynamic nature of the computing ecosystem. Second, interaction of humans and technologies has been fundamentally deficient. Humans cannot consume nor act on digital directly. It requires software to mediate the interaction. Furthermore, the contemporary computing systems are complex and inaccessible to average users. At the same time, the computer interaction models are insufficient to leverage intelligent feedback of an average user. In this presentation we discuss these issues in detail and consider the approaches to address them.

1 INTRODUCTION

History of the human civilization is underpinned by the development of technologies that are used to encode and transfer knowledge across generations and enable innovation. We are in the midst of the digital revolution, where the ability to store and process information in the digital form has extended our computing abilities. But can we pass digital information and technologies onto the next generation? How long-lasting is any digital object, computation, or system?

Furthermore, digital technologies extend the human abilities to compute but still fall short of achieving the full potential. Computational tools and services are built by software engineers and adopted by the end users. While the users can typically absorb the output of computation, the systems' ability to absorb user feedback is limited—it cannot process input that is beyond the original system design. Thus, as users are creative and extend their experience to new situations, the computing technology is limited to a specific set of scenarios. What would it take to bridge this gap and achieve a full symbiosis between computing and human intelligence?

2 PRESERVING DIGITAL ASSETS

2.1 The Nature of Digital

In contrast to other technological advances, digital computation has direct and profound effect on our ability to process information which, in turn, is fundamental to our ability to develop ideas and conceptualize solutions. However, we should not disregard the risks and challenges that are inherent to digital.

In effect, digital is most vulnerable of all the media we have used to store and transfer information. It requires sophisticated infrastructure and technologies to be persisted and reused. Furthermore, it cannot be experienced by humans directly. It requires an intermediary—an application that can render information in the human consumable form. This dependence on the software is problematic because applications cannot be easily sustained over time in the rapidly changing ecosystem. Indeed, software applications normally depend on a stack of technologies that can change at different rate and to different extent. Maintaining contemporary applications is already difficult and costly. Ensuring that any legacy application stays compatible with the changing ecosystem indefinitely is not feasible.

2.2 Digital Ecosystem

Fundamental to the design of digital technologies is a concept of a file which persists information that is essential for repeated use of applications across computational sessions. The structure of a file depends on the software program that produces it and is optimized for its use.

As new technologies emerge and original applications are modified or cease to exist, the old file formats become obsolete and any stored content becomes inaccessible. This poses a serious problem and risk to our intellectual assets. Mediating that risk is, in fact, rather difficult. It is fundamentally caused by the disconnect between the software development and the content production.

2.3 Preservation Methods

In the case of digital documents, preservation efforts have focused on the transformation of legacy formats into formats that are supported by the contemporary ecosystem.

However, that strategy is not suitable when file content is of secondary importance. Indeed, in some instances the files primarily facilitate the continuity of interaction with the application and the value is realized through the user experience rather than content, as in interactive games. In that case, the approach is either to ensure that original application can run within an emulated software environment or to re-write the software to comply with the new environment. In the first case, the software is functioning within an encapsulated self-sufficient environment but may be disconnected from the rest of the ecosystem. In the latter case, it may not be possible to re-implement the applications precisely. Then, we are faced with assessing the utility of the application in the old and the new ecosystem.

2.4 Significant Properties, Value, and Utility

A value of a digital artifact, such as an electronic document record, or data file, depends on the extent that applications in the contemporary ecosystem can access them and use for further processing. At the same time, many scenarios require that, during reuse, the digital artifact retains the properties that were created and applied in the original usage scenarios.

This is particularly the case with electronic documents that are primarily consumed through rendering content on the screen. For example, in the reading scenarios, the significant properties are related to the layout characteristics of the document. If we convert the document file format, we need to apply methods and metrics to characterize the layouts of the original and the converted document and identify possible discrepancies. The significance of these discrepancies, however, needs to be determined based on human input. Indeed, we need to determine which of the discrepancies are relevant to the human perception and to what degree.

3 COMPUTING AND HUMAN INTELLIGENCE

In many computing scenarios the human input is of paramount importance. Yet, we still need to find an optimal way to capture and incorporate human feedback into the computing technologies. In order to understand the depth of the problem we need to reflect on the processes involved in the lifecycle of the digital technologies.

3.1 Human Involvement in the Technology Lifecycle

From the early computing systems, we have observed different roles that humans play in facilitating computations. First, they required special skills of engineers to build hardware, develop algorithms to solve a problem, and then provide instructions to the computer in the machine actionable form. The output was in the form of a printout with computation results that were then interpreted by experts in the problem domain. This then led to further insights and decisions about the next steps which may or may not be supported by the original program. In the case when the programmer and domain expert are the same individuals, the domain expert can modify the program or create another one based on the gained insights and required actions. However, in many instances that is not the case.

Indeed, one important aspect of technological advances is automation of repeated tasks and distribution of tasks across individuals. This is not different with the computing technology, except that the computing results are often in the form of information that serves as an input to the intelligent processing in individual's minds. Since both the computation and the human processing result in information, it is natural to expect a feedback loop that enables humans to communicate information to the computer and continue the cycle. This is to a certain level achieved with all the user interfaces but fundamentally limited by the original design of the application. At the moment the gap is closed by human-to-human communication where the domain experts and software engineers engage in the joint effort of setting the system requirements for further computations, possibly involving a new application. However, this happens at the time scale that is at odds with the speed of computation and expectations of interactive computing systems.

3.2 Human Factors

Established practices typically lead to complex computing systems that are used by a broad and underspecified population of users. The systems are equipped with user interfaces that are expected to deliver the main value to the users. In that approach, large portions of the system and its functionality are not accessible to the end users. The users are also unlikely to have sufficient technical background to understand their intricacies. Thus, the feedback and the control that the user can exert are restricted to the features of the provided interfaces.

This lack of transparency, limited skills, and restricted input facilities are particularly problematic when the system malfunctions. In many instances, the apparent application errors occur because the users do not have a full conceptual model of the system capabilities in relation to the usage scenarios. Information about the tools and features are generic. It is the user creativity in using the tools and features that creates the value in a particular context. However, the context and the user creativity challenge, often inadvertently, the original design of the computing system.

4 CONCLUDING REMARKS

Digital revolution has transformed all aspects of our lives. We have realized its benefits and embraced it. Digital technologies have become critical for our existence and our future. They have caused great disruptions, challenging economic models and defying traditional business practices. From the perspective of the society and human involvement, they have defined new roles and introduced disconnects that we need to consider and reconcile in order to achieve the full potential.

ARTIFICIAL INTELLIGENCE HANDLING TEXT DATA

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ABSTRACT

Text is one of the traditional ways of communication between people. With the growing availability of text data in electronic form, handling and analysis of text by means of computers gained popularity. Handling text data with machine learning methods brought interesting challenges to the area that got further extended by incorporation of some natural language specifics. As the methods were capable of addressing more complex problems related to text data, the expectations got bigger calling for a combination of methods from different research areas including information retrieval, machine learning, statistical data analysis, data mining, natural language processing, semantic technologies. *Nowadays* automatic text analysis is an integral part of many systems, pushing boundaries of research capabilities towards artificial intelligence dream on never ending learning from text aiming at mimicking ways of human learning. The paper presents development of text analysis research in Slovenian that we have been personally involved in, pointing out interesting research problems that have been and are still addressed by the research, example tasks that have been addressed and some challenges on the way.

1 INTRODUCTION

Word expressed as a sound is known as a fundamental phenomena in creation of our world. "Every element of the universe is in a constant state of vibration manifested to us as light, sounds and energy. The human senses perceive only a fraction of the infinite range of vibration, so it is difficult to comprehend that the Word mentioned in the Bible is actually the totality of vibration which underlines and sustains the creation." [1]. Written words are one of the traditional ways of communication over space and time. As electronic media become widely used, the amount of texts in electronic form has grown rapidly and is still growing. While these texts are primarily aiming at human readers, it is not uncommon to use computer programs to manipulate texts. Text handling by computer programs has a wide range of usage from enabling editing, storing and indexing to searching and retrieving, ranking, classifying, extracting information and knowledge, question answering, etc.

In this paper we present development of artificial intelligence research in Slovenia involving handling of text data that we have been personally involved in, pointing out interesting research problems that have been and are still addressed, listing some example tasks that have been addressed in our group and some challenges on the way.

2 HANDLING TEXT DATA

In the 1990s handling of text data by machine learning techniques was inspired mainly by information retrieval, where machine learning methods were used primarily for classification of documents regarding their relevance to a given query (as an alternative to the information retrieval ranking methods). At that time, machine learning was also applied for personalized information delivery on text, such as, learning to filter relevant Netnews, suggesting potentially relevant hyperlinks on Web documents [2], [3], browsing the Web [4], powering intelligent agents [5]. As texts (documents, Web pages, news articles) are often manually labeled by some topic category (e.g., a news on acquisitions, a Web page on artificial intelligence), this is a natural area for applying machine learning methods to train a classifier for topics. However, the problem is far from being a trivial application of machine learning methods to a new domain, as, for instance, the number of classes may get much larger than what was usual at the time for machine learning methods to handle, requiring a careful handling of efficient classifier construction [8] and pruning the space of promising classifiers to be consulted for classification of a new example [7].

Using words as features is, in such a setting, a common way of representing text documents so that machine learning methods can be applied on them. As each word from the vocabulary is assigned a feature with its value being based on the frequency of the word in a document, the number of features easily got to several tens of thousands. Moreover, one can think about some more sophisticated features beyond single words, such as sequences of words [6], additionally increasing the feature space. This requires careful handling of the problem including efficient feature selection [9].

Even though many relevant problems can and have been addressed at the level of documents using machine learning methods and at the level of sentences and words using natural language processing methods, there is still a way to go towards automatically obtaining knowledge from text to be used for ontology extension and reasoning. Extracting knowledge form the text and representing it in logical forms means that a computer can reason on it, provide hopefully some interesting insights and propose new conclusions. One of the earlier attempts included information extraction from Web pages using manually constructed wrappers and forming rules connecting the extracted information [14]. A

step towards extraction of knowledge for ontology generation is presented in [15], where natural language processing is used in combination with semantic technologies. While there are a number of similar efforts in direction of knowledge extraction from text, the problem of obtaining logical statements corresponding to some text remains open.

In general different methods from the area of artificial intelligence can be used for obtaining knowledge from text [16] ranging from classification and clustering, to association rule construction and visualization.

3 EXAMPLE TASKS

When we talk about applying artificial intelligence methods on text data, what we have in mind is a whole range of methods and problems that in some way involve analysis of text data. Many of these problems have been addressed in the area of Text Mining. For the definition of text mining we have adapted the definition of Data Mining from Usama Fayad, so we can say that text mining is about finding interesting regularities in large text data, where interesting means: non-trivial, hidden, previously unknown and potentially useful. Looking from the linguistic and semantic technologies perspective, text mining can be defined as finding semantic and abstract information from the surface form of text.

To make it more concrete, we will briefly look into some example tasks that have been addressed in our group during the last twenty years by applying artificial intelligence methods on text data.

Visualization of text data as given in news articles [10] can be based on named entity extraction, as news are usually mentioning some named entities (e.g., people, countries, organizations) putting them in some relation. Furthermore, the named entities extracted from news or some other text that has time information associated to it can be related over time [11]. General document corpus can be also visualized using clustering methods on text data [12]. Document corpus visualization can be further used in **Semi-automatic construction of topic ontology** using machine learning to cluster document, to map documents onto some existing ontologies, to suggest concept naming [13].

In addition to addressing problems that focus on handling documents as the main units, it is also relevant to split texts into smaller units, such as, paragraphs, sentences, words or even characters. In this way one can **annotate text** on different levels of granularity including topic category of the whole document, extraction of facts mentioned in the text, named entity extraction and resolution (into some ontology such as, DBPedia, OpenCyc) [22]. The text annotations can be also used for **enhancing visualization of text**, for instance on web pages [23].

Extracting triplets from text [17] involves some more or less sophisticated natural language processing to extract what would be considered as subject-predicate-object triplets from sentences. Even though the original approach is by parsing the sentence to get its logical form giving subject-predicate-object [21], reasonable results have been achieved by using predefined patterns, such as noun phrase-verb phrase-noun phrase [22]. The extracted triplets can be also generalized to a kind of templates [20], such as, country – borders – country that can be further used to extend an ontology or to extract information from text.

Document summarization addresses automatic construction of a shorter version of the original text document. It can be performed using different approaches, one of them based on extracting triplets from text to obtain semantic structure of a document feeding features to a machine learning classifier trained to classify triplets for being included in the document summary or not [21].

Question answering [18], [19], such as, "where do tigers live?", can be also based on triplet extraction where the whole document collection used for finding the answers is transformed into a collection of triplets to enable matching with the questions.

Ontology construction and extension is usually performed entirely manually or semi-automatically by applying some methods from artificial intelligence [24]. Annotation of text by the concepts from an existing ontology is limited by the concepts that already exist in the ontology, unless we extend the ontology in which case it is desirable to focus on a domain of interest [25]. When dealing with larger ontologies, a number of editors having different expertise contribute to different parts. Data analysis can be used to gain some insights into their interaction with the ontology, their expertise and the ontology changes by means of social network analysis and visualization [26].

Social network analysis in combination with analysis of text data can provide insights into research collaboration between institutions and countries [27], while semantic technologies have been successfully applied to analyze communication between individuals inside an organization [28], in visualization of temporal data[30]and to support the users in dealing with information overload [29]. It was also recognized that context of the data and the user may be relevant for the addressed problem [33].

4 DISCUSSION

Different Artificial Intelligence methods have been successfully applied on text data addressing a number of relevant problems. Figure 1 shows some of the technologies and the associated prototypes we have developed in our group at J. Stefan Institute ranging from statistical machine learning and data/web/text mining, to analysis of social networks and graphs, complex data visualization, computational linguistics, social computing, light-weighted semantic technologies and deep semantics with reasoning. As the methods in general become more sophisticated, the problems become more complex and researchers are constantly facing new challenges.

As an example, we can point out the fact that each text we have been handling is written is some natural language. The

majority of artificial intelligence approaches focus on a single language, some handle multiple languages and other work in a cross-lingual setting adding to the complexity of the tasks and opening new challenges, as for instance in multilingual document retrieval [31] and multilingual sentiment analysis [32]. There are a number of open research challenges related to developing linguistic resources for different languages and covering multilingual and cross-lingual settings.

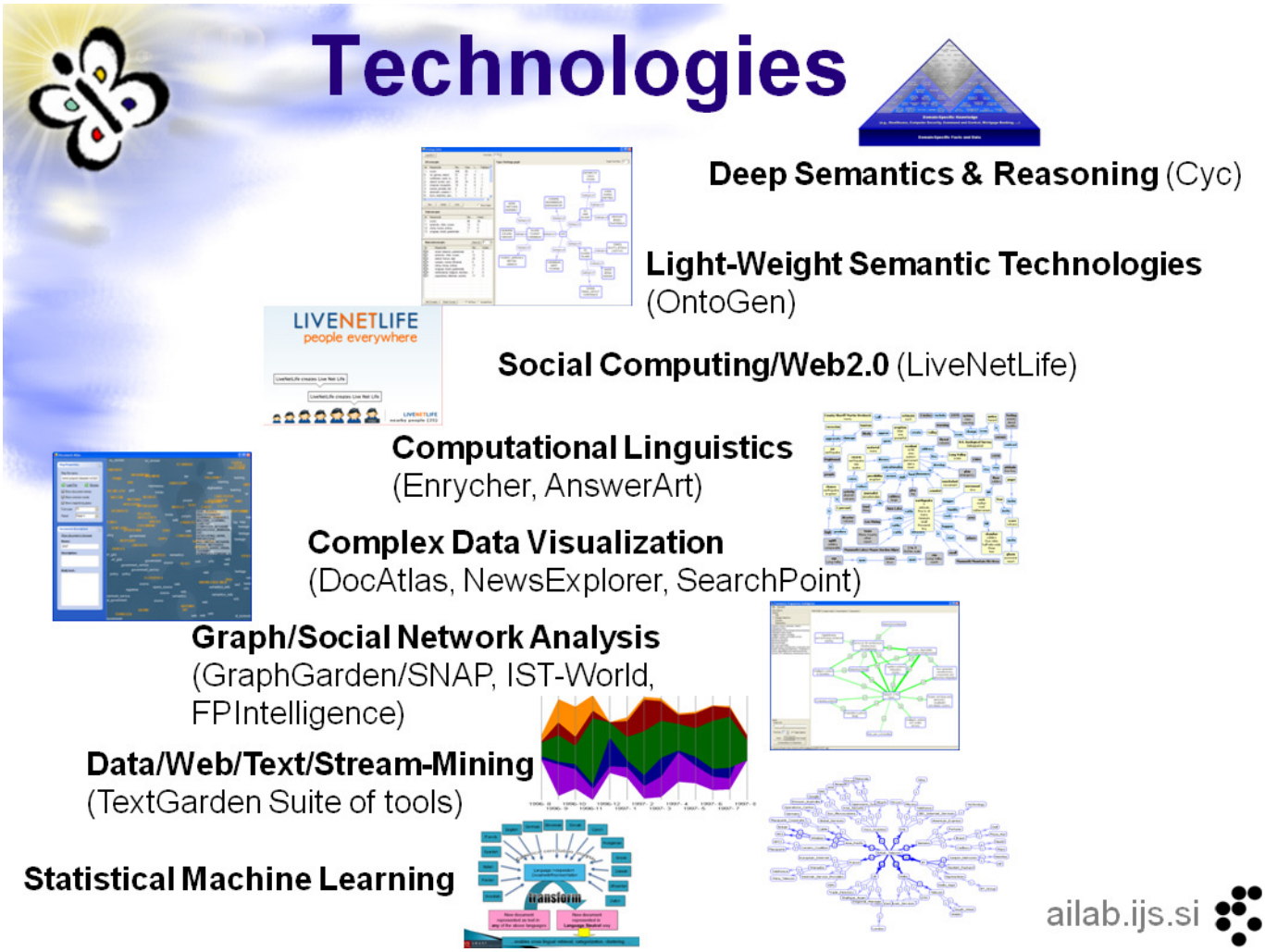

Figure 1: *Diagram showing different kind of technologies involving text data developed by artificial intelligence laboratory.*

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Mining Big Data in Real Time

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Abstract

Streaming data analysis in real time is becoming the fastest and most efficient way to obtain useful knowledge from what is happening now, allowing organizations to react quickly when problems appear or to detect new trends helping to improve their performance. Evolving data streams are contributing to the growth of data created over the last few years. We are creating the same quantity of data every two days, as we created from the dawn of time up until 2003. Evolving data streams methods are becoming a low-cost, green methodology for real time online prediction and analysis. We discuss the current and future trends of mining evolving data streams, and the challenges that the field will have to overcome during the next years.

1 Introduction

Nowadays, the quantity of data that is created every two days is estimated to be 5 exabytes. This amount of data is similar to the amount of data created from the dawn of time up until 2003. Moreover, it was estimated that 2007 was the first year in which it was not possible to store all the data that we are producing. This massive amount of data opens new challenging discovery tasks.

Data stream real time analytics are needed to manage the data currently generated, at an ever increasing rate, from such applications as: sensor networks, measurements in network monitoring and traffic management, log records or click-streams in web exploring, manufacturing processes, call detail records, email, blogging, twitter posts and others [5]. In fact, all data generated can be considered as streaming data or as a snapshot of streaming data, since it is obtained from an interval of time.

In the data stream model, data arrive at high speed, and algorithms that process them must do so under very strict constraints of space and time. Consequently, data streams pose several challenges for data mining algorithm design. First, algorithms must make use of limited resources (time and memory). Second, they must deal with data whose nature or distribution changes over time.

We need to deal with resources in an efficient and low-cost way. *Green computing* is the study and practice of using computing resources efficiently. A main approach

to green computing is based on algorithmic efficiency. In data stream mining, we are interested in three main dimensions:

- accuracy
- amount of space (computer memory) necessary
- the time required to learn from training examples and to predict

These dimensions are typically interdependent: adjusting the time and space used by an algorithm can influence accuracy. By storing more pre-computed information, such as look up tables, an algorithm can run faster at the expense of space. An algorithm can also run faster by processing less information, either by stopping early or storing less, thus having less data to process. The more time an algorithm has, the more likely it is that accuracy can be increased.

The issue of the measurement of three evaluation dimensions simultaneously has led to another important issue in data stream mining, namely estimating the combined cost of performing the learning and prediction processes in terms of time and memory. As an example, several rental cost options exist:

- Cost per hour of usage: Amazon Elastic Compute Cloud (Amazon EC2) is a web service that provides resizable compute capacity in the cloud. Cost depends on the time and on the machine rented (small instance with 1.7 GB, large with 7.5 GB or extra large with 15 GB).
- Cost per hour and memory used: GoGrid is a web service similar to Amazon EC2, but it charges by RAM-Hours.

  Every GB of RAM deployed for 1 hour equals one RAM-Hour.

In [4, 2] the use of RAM-Hours was introduced as an evaluation measure of the resources used by streaming algorithms. Every GB of RAM deployed for 1 hour equals one RAM-Hour.

2 New problems: Structured classification

A new important and challenging task may be the structured pattern classification problem. *Patterns* are elements of (possibly infinite) sets endowed with a partial order relation $\preceq$. Examples of patterns are itemsets, sequences, trees and graphs.

The structured pattern classification problem is defined as follows. A set of examples of the form (t, y) is given, where y is a discrete class label and t is a pattern. The goal is to produce from these examples a model $\hat{y} = f(t)$ that will predict the classes y of future pattern examples

Most standard classification methods can only deal with vector data, which is but one of many possible pattern structures. To apply them to other types of patterns, such as graphs, we can use the following approach: we convert the pattern classification problem into a vector classification learning task, transforming patterns into vectors of attributes. Each attribute denotes the presence or absence of particular subpatterns, and we create attributes for all frequent subpatterns, or for a subset of these.

As the number of frequent subpatterns may be very large, we may perform a feature selection process, selecting a subset of these

frequent subpatterns, maintaining exactly or approximately the same information.

The structured output classification problem is even more challenging and is defined as follows. A set of examples of the form (t, y) is given, where t and y are patterns. The goal is to produce from these examples a pattern model $\hat{y} = f(t)$ that will predict the patterns y of future pattern examples. A way to deal with a structured output classification problem is to convert it to a multi-label classification problem, where the output pattern y is converted into a set of labels representing a subset of its frequents subpatterns.

Therefore, data stream multi-label classification methods may offer a solution to the structured output classification problem.

3 New applications: social networks

A future trend in mining evolving data streams will be how to analyze data from social networks and micro-blogging applications such as Twitter. Micro-blogs and Twitter data follow the data stream model. Twitter data arrive at high speed, and algorithms that process them must do so under very strict constraints of space and time.

The main Twitter data stream that provides all messages from every user in real-time is called Firehose and was made available to developers in 2010. This streaming data opens new challenging knowledge discovery issues. In April 2010, Twitter had 106 million registered users, and 180 million unique visitors every month. New users were signing up at a rate of 300,000 per day. Twitter's search engine received around 600 million search queries per day, and Twitter received a total of 3 billion requests a day via its API. It could not be clearer in this application domain that to deal with this amount and rate of data, streaming techniques are needed.

Sentiment analysis can be cast as a classification problem where the task is to classify messages into two categories depending on whether they convey positive or negative feelings. See [8] for a survey of sentiment analysis, and [6] for opinion mining techniques.

To build classifiers for sentiment analysis, we need to collect training data so that we can apply appropriate learning algorithms. Labeling tweets manually as positive or negative is a laborious and expensive, if not impossible, task. However, a significant advantage of Twitter data is that many tweets have author-provided sentiment indicators: changing sentiment is implicit in the use of various types of emoticons. *Smileys* or *emoticons* are visual cues that are associated with emotional states. They are constructed using the characters available on a standard keyboard, representing a facial expression of emotion. Hence we may use these to label our training data.

When the author of a tweet uses an emoticon, they are annotating their own text with an emotional state. Such annotated tweets can be used to train a sentiment classifier [1, 3].

4 New techniques: Hadoop, S4 or Storm

A way to speed up the mining of streaming learners is to distribute the training process

onto several machines. Hadoop MapReduce is a programming model and software framework for writing applications that rapidly process vast amounts of data in parallel on large clusters of compute nodes.

A MapReduce job divides the input dataset into independent subsets that are processed by map tasks in parallel. This step of mapping is then followed by a step of reducing tasks. These reduce tasks use the output of the maps to obtain the final result of the job.

Apache S4 [7] is a platform for processing continuous data streams. S4 is designed specifically for managing data streams. S4 apps are designed combining streams and processing elements in real time. Storm from Twitter uses a similar approach.

Ensemble learning classifiers are easier to scale and parallelize than single classifier methods. They are the first, most obvious, candidate methods to implement using parallel techniques.

5 Conclusions

We have discussed the challenges that in our opinion, mining evolving data streams will have to deal during the next years. We have outlined new areas for research. These include structured classification and associated application areas as social networks.

Our ability to handle many exabytes of data across many application areas in the future will be crucially dependent on the existence of a rich variety of datasets, techniques and software frameworks. There is no doubt that data stream mining offers many challenges and equally many opportunites as the quantity of data generated in real time is going to continue growing.

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The Child Machine vs The World Brain

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ABSTRACT

I think of machine learning research as building two different types of entities: Turing's Child Machine and H.G. Wells' World Brain. The former is a machine that learns incrementally by receiving instruction from a trainer or by its own trial-and-error. The latter is a permanent repository that makes all human knowledge accessible to anyone in the world. While machine learning began following the Child Machine model, recent research has been more focussed on "organising the world's information". Both are important endeavours, however, incremental learning has been neglected and, we argue, should be revived.

1 INTRODUCTION

In his Mind paper, Alan Turing (1950) famously described the imitation game and he also suggested that to build a computer system capable of achieving the required intelligence, it would have to educated, much like a human child.

> Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education one would obtain the adult brain. Presumably the child-brain is something like a note-book as one buys from the stationers. Rather little mechanism, and lots of blank sheets... Our hope is that there is so little mechanism in the child-brain that something like it can be easily programmed. The amount of work in the education we can assume, as a first approximation, to be much the same as for the human child.

He went on to speculate about the kinds of learning mechanisms needed for the child machine's training. The style of learning was always incremental. That is, the machine acquires knowledge by being told or by its own exploration and this knowledge accumulates so that it can learn increasingly complex concepts and solve increasingly complex problems.

Early efforts in Machine Learning adopted this paradigm. For example, Michie and Chambers (1968) BOXES program learned to balance a pole and cart system by trial-and-error receiving punishments are rewards, much as Turing described, and like subsequent reinforcement learning systems. My own efforts, much later, with the Marvin program (1981b) were directed towards building a system that could accumulate learn and accumulate concepts expressed in a form of first order logic.

At around the same time of Turing's paper on computing machines (Turing, 1936), H.G. Wells speculated on what he called "the world brain" (Wells, 1937), a permanent world encyclopædia that would provide,

> "...a sort of mental clearing house for the mind, a depot where knowledge and ideas are received, sorted, summarised, digested, clarified and compared.... any student, in any part of the world, will be able to sit with his projector in his own study at his or her convenience to examine any book, any document, in an exact replica."

Wells thought that the technology for this repository of knowledge would be microfilm. He could not have known that the World Wide Web, Wikipedia and internet search engines would do far more than he envisaged. Indeed, Google's company mission is "… to organize the world's information and make it universally accessible and useful"[1]. A core technology for such search engines is machine learning. However, it is of a form that is somewhat different form that described by Turing for his Child Machine. Unlike a human child, acquiring new knowledge incrementally, machine learning systems can access the enormous amounts of data available throughout the internet to produce, in some instances, superhuman performance. However, this is "all-at-once" and "single-concept-at-a-time" learning that must still be guided by humans.

The first programs capable of efficiently learning from moderately large numbers of examples began with Michalski's Aq (Michalski, 1973) and Quinlan's ID3 (Quinlan, 1979), both of whom were influenced by Donald Michie. Quinlan was a PhD student studying with psychologist Earl Hunt when he attended a lecture by Michie at Stanford University. Donald challenged the

[1] http://www.google.com/about/company/

students to devise a method of learning to determine a win in a chess end-game and Quinlan responded with the first version of his decision tree learner. The utility of these programs for finding patterns in large data sets encouraged new research into "batch" learning systems, somewhat to the detriment of incremental learning.

However, for machines to behave in ways that we can truly say are intelligent, they must be able to accumulate knowledge just as Turing suggested for the Child Machine. Unfortunately, apart from a few systems, like Marvin, very little research has been devoted to this style of learning. It is useful to be reminded of some important contributions from the past that deserve to be revived. We remind the reader of these in the next section.

2 CUMULATIVE ACTIVE LEARNING

A necessary component of the Child Machine's learning is interaction with the world, which may be physical or virtual, if the agent is embedded in the web. As an agent accumulates experience, it constructs a world model or theory that can be used to predict the outcome of events and to determine actions necessary to solve problems.

2.1 Background Knowledge

The first requirement for cumulative learning is a mechanism for storing and using learned concepts as background knowledge. Representing concepts in the form of expressions in first order logic makes this relatively easy. To my knowledge, Banerji (1964) was the first propose such a mechanism and the first implementation of a learning system that could use learned concepts for further learning was by Cohen (1978). With Brian Cohen, I elaborated this idea to create a learning system in which the concepts were represented as logic programs and were, thus, executable (Sammut & Cohen, 1980). This then evolved into Marvin (Sammut, 1981a) and the use of background knowledge has become an essential part of Inductive Logic Programming (Muggleton, 1991) since. However, even many ILP that use background knowledge to learn new concepts do not close the loop to allow those learned concepts to, themselves, become part of the background knowledge for future learning.

2.2 Detecting Errors

Since, in practice, a learning agent can never be exposed to all instances of a concept, it is prone to making mistakes of two kinds:

- The system may observe an event for which there is no prior knowledge about how to respond.
- The system may observe an event for which there is prior knowledge. However, the known concepts are too general and the system may respond inappropriately.

When the system is learning only one concept at a time, repairing a theory is relatively easy. We just specialise an over-general theory or generalise a theory that is too specific. However, in a system that accumulates knowledge over time, learning many concepts, localising the error is not so easy. We can think of a theory as being a network of interdependent concepts, as in Figure 1, where the definition of concepts S and T rely on the definition of Q, which depends on P and E. Suppose we discover an error in the theory while attempting to use concept, T, but the real error is due to an incorrect definition of concept, E.

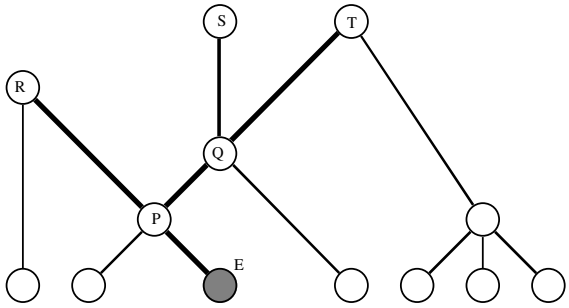

Figure 1: *A theory is a network of concepts*

When we use a logical representation of concepts, a concept description is also an executable computer program, so one way of locating the problem is to trace through the execution of the program that lead to the unexpected result, testing each concept. That is, we debug the program, as Shapiro (1981) did with MIS. To locate an error when an incorrect solution has been given (i.e. the theory contains an over-generalisation) Shapiro's debugging algorithm works backwards through the failed proof of a goal, searching for the procedure that caused the failure. In Figure 1, backtracing would begin with the last goal satisfied, that is, T. The debugger begins stepping back through the proof, i.e. down the dark path to node Q, then P if necessary, asking an oracle if the partial solution at each point is correct. If this is not true, then an erroneous clause has been found. Note that the algorithm assumes the existence of an infallible oracle. In a reactive environment, the learning program may do without an oracle since the program is able to perform experiments to test a concept. Thus, a failure suggests that the initial set of experiments that resulted in the formation of the concepts along the solution path was not extensive enough for at least one of the concepts.

A concept that is too specific may prevent the program from producing any solution at all. That is, the logic program that is supposed to satisfy the goal does not cover the initial conditions of the task. An attempt at debugging the theory can only be made when a correct solution has been seen, otherwise the learner has no indication that the task really is possible. A correct solution may be found, either by "mutating" the current theory in the hope that the goal can be satisfied by the mutant or the learner may observe another agent in the world performing the task. Shapiro's debugging method for programs that fail to produce an answer is equivalent to the second alternative,

that is, the oracle supplies the correct solution. The debugger again tries to work backwards seeking clauses in the program which could have produced the given solution. Once such a clause is found, its body provides further goals that should be satisfied in order to arrive at the solution. The debugger considers each of these intermediate goals to see if they can also be produced by other clauses. Any goal that cannot be achieved indicates where the program or theory is deficient.

2.3 Correcting Errors and Maintaining Consistency

Detecting and repairing an error in a single concept is one thing, but repairing an entire theory is another matter. Remember that in figure 1, we envisaged a world model or domain theory as a network of interconnected concepts. Using a horn clause representation, the head of a clause corresponds to a parent node and the goals in the body correspond to the children. These goals match other clause heads and form links to the rest of the network. Also in Figure 1, we imagined that one concept, represented by the shaded node, E, was in error. When the concept is repaired, what effect will that have on the concepts which referred to the old concept? Since P, Q, R, S and T refer, directly or indirectly, to the erroneous node they must have been learned in the presence of the error. Are they, therefore also in error or will correcting E alone correct them all?

When faced with the problem of ensuring the consistency of its knowledge base, two strategies are available to the learning system.

1. After correcting E, the system may test each of the concepts that depend on E. However revising all of the concepts dependent on one that just been modified could involve a lot of work if the network of concepts is very extensive.
2. The system may wait to see if any further errors show up. In this case, each concept will be debugged as necessary. Although more economical this method requires a method for tolerating errors if the program has been assigned a task which it must continue to perform.

It should also be noted that another source of errors in planning is noise. When a learning system is connected to the physical world, as is a robot, it cannot rely on the accuracy of measurements from vision systems, touch sensors, etc. Thus, a program may fail because the knowledge base does not accurately reflect the outside world. This being the case, the learning system must not revise its domain theory prematurely since there may not, in fact, be any errors. Therefore, the most prudent approach to error recovery is to delay revision of a domain theory until sufficient evidence has accumulated to suggest the appropriate changes.

Let us now give an outline of an error recovery strategy.

1. The robot learner is given a task that it is required to perform. However, its domain theory may be incomplete or incorrect.
2. In the course of performing its task, the robot's plan fails.
3. If the robot is unable to proceed by adopting another plan then it must suspend working on its given task while it debugs its domain theory.
4. If an alternative plan is possible (for example, by reordering goals) then the new plan is attempted while storing the failed plan for future reference.
5. The robot cannot assume that the failed plan is incorrect since the cause of failure may have been due to noise, therefore, as each plan is executed, a history of its performance is maintained, this includes the performance of the individual concepts which formed the plan.
6. The accumulation of histories is input for a theory revision system that effectively summarises the performance of plans when it forms new concepts by generalisation.
7. Since the learning program may generate alternative descriptions for the same concept, we must be able to resolve potential conflicts so that the next time a similar plan is to be created, the appropriate description is chosen.

Richards and Mooney (1991) proposed a system that does that, based on earlier work by Muggleton (Muggleton, 1987; Muggleton & Buntine, 1988). Wrobel (1996) also proposed a first order theory refinement systems The main idea behind these methods is to consider repairing a theory as a kind of compression. That is, the set of clauses that form a theory may be rewritten so that the same or greater coverage is achieved by theory that is more compact in an information theoretic sense. An important operation for this is predicate invention (Muggleton & Buntine, 1988). That is, the learner must have the ability to invent its own concepts when it detects patterns that can be reused in the description of other concepts.

When an experiment does fail, we must not invalidate the concepts used in planning the experiment for, as mentioned earlier, the failure may be due to noise. Instead, we note the circumstances of the failure and augment the failed concept with a description of these circumstances. Several things could happen to the concept when this is done:

- The description of the concept is modified to the extent that it becomes correct. If an alternative, correct description already existed, then the alternative domain theories of which these concepts were components, converge.
- After several failures, there is no generalisation which covers the circumstances of failure. In this case, the failures may be either due attributed to noise or to some phenomenon not yet known to the system. In either case, nothing can be done.

An ATMS (de Kleer, 1986) maintains the network of concepts which form a domain theory and stores dependencies which, when errors are found will indicate

where other potential weaknesses in the theory lie. The ATMS also allows a learning program to experiment with alternative domain theories.

3 SCALING UP

All of the references in the previous section are quite dated. The fact is, that while the methods described have the potential to build a very powerful learning system, they have not, so far, scaled to work with large amounts of data or operate in complex environments. Whereas, simple learning systems have done spectacularly well on "Big Data". Indeed, search engine companies, like Google, have so much data and computing resources that many problems can be turned into machine learning tasks. So far, then, machine learning has facilitated the World Brain but is struggling with the Child Machine. Why is that?

It seems to me that the problem is that we still do not have effective methods for building and maintaining theories that have a deep structure. Yet, even for the World Brain, such theories will be needed. As the quantity of information rises, we will need mechanisms for digesting and summarising data that will require methods such as predicate invention and theory revision. Thus, the title of this talk is not entirely accurate. I do not see the Child Machine in competition with the World Brain. Rather, the both will eventually be needed to make large knowledge bases manageable. So a serious challenge for the future is to make incremental learning scale up to be capable, not only of imitating the learning of a child, but to work with large-scale data mining to manage knowledge on the web.

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Relational and Semantic Data Mining for Biomedical Research

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Abstract

The paper first outlines subgroup discovery and selected relational data mining approaches, with the emphasis on propositionalization and relational subgroup discovery, which prove to be effective for data analysis in biomedical applications. The core of this paper describes recently developed approaches to semantic data mining which enable the use of domain ontologies as background knowledge in data analysis. The use of described techniques and tools is illustrated on selected biomedical applications.

1. Introduction

In data mining and knowledge discovery [1], there are usually large amounts of data available and the data mining expert is confronted with a task of constructing a hypothesis – a predictive model or a set of descriptive patterns – induced from the data. The following steps of the model/patterns construction are usually performed: *Empirical Data* → *Preprocessing* → *Preprocessed Data* → *Data Mining* → *Hypothesis.* Results evaluation and interpretation by the expert can lead to iterative refinements of induced model/patterns.

The starting point for this paper are *subgroup discovery techniques* [2][3]. Subgroup discovery techniques are of interest to biomedical research, as they enable the discovery of patient subgroups from classified patient data, where the induced subgroup descriptions have the form of descriptive rules. Let us illustrate the subgroups in two biomedical applications.

In the first application [4], the induced subgroup descriptions suggest the general practitioner how to select individuals for population screening, concerning high risk for coronary heart disease (CHD). One of the discovered rules describes a group of overweight female patients older than 63 years:

High CHD Risk ← *gender = female &*
age > 63 years & body mass index > 25 kg/m^2

In the second application [5], subgroup describing rules suggest genes that are characteristic for a given cancer type (leukemia), distinguishing it from other 13 cancer types (CNS, lung cancer, etc.):

Leukemia ← *KIAA0128 is diff_expressed &*
prostaglandin d2 synthase is not diff_expressed

We continue by presenting selected approaches to *inductive logic programming* (ILP) [6][7] and *relational data mining* (RDM) [8] which also have a great potential for biomedical research, due to their capacity of using background knowledge in the learning process. From the available background knowledge (encoded as logical facts or rules) and a set of classified examples (encoded as a set of logical facts), an ILP/RDM algorithm derives a hypothesized logic program which explains the positive examples. While ILP focuses on data and background knowledge represented in a logical formalism, RDM assumes that the background knowledge and data are encoded in a unique relational database format. Compared to standard data mining techniques exemplified above, where the input data is typically stored in a single data table (e.g., in Excel), the input to an ILP/RDM algorithm is thus much more complex.

Propositionalization [9] is a RDM approach, which has been applied in several biomedical applications. Consider *relational subgroup discovery,* an approach effectively implemented in the RSD algorithm [10]. RSD generates descriptive rules as conjunctions of terms which encode background knowledge concepts. For instance, an induced description of gene group *A*, discovered by RSD for the CNS (central nervous system) cancer class in the problem of distinguishing between 14 cancer types determines group *A* of differentially expressed genes in CNS as a conjunction of two relational features [11]: *geneGroup(A)* ← $f_i(A)$ & $f_k(A)$, where the two features, $f_i(A)$ and $f_k(A)$, constructed in the propositionalization step of RSD, are $f_i(A)$*: interaction(A,B) & process(B,'phosphorylation'),* and $f_k(A)$*: interaction(A,B) & process(B,'negative regulation of apoptosis') & component(B,'intracellular membrane-bound organelle').*

The next section presents and overview of recently developed approaches to semantic data mining which enable the use of domain ontologies as background knowledge for data analysis, where the use of described techniques is illustrated on a biomedical application. We conclude by describing new challenges in the focus of our current and future research.

3. Semantic subgroup discovery

The presented approach to relational subgroup discovery, which has successfully used RSD to mine bioinformatics data [11], was the first step towards developing a novel data mining methodology, referred to as *semantic subgroup discovery*. The main steps in semantic pattern construction are the following: Empirical Data and Ontologies → *Preprocessing* → Preprocessed Data and Ontological Concepts → *Semantic Subgroup Discovery* → Semantic Descriptions Explaining the Discovered Subgroups.

This proposed methodology enables the generation of descriptive rules explaining the instances of a target class as conjunctions of ontology terms/concepts appearing in bioinformatics ontologies such as the well-known Gene Ontology (GO), KEGG and ENTREZ. An early approach to semantic subgroup discovery, named SEGS, is outlined below, followed by the outline of the recently developed SegMine methodology.

3.1. Semantic subgroup discovery with SEGS

In many biomedical applications the goal of data analysis is *gene set enrichment*, i.e., finding groups of genes—*gene sets*—that are enriched, so that genes in the set are statistically significantly differentially expressed compared to the rest of the genes. Two well-known methods for testing the enrichment of gene sets include: *Gene Set Enrichment Analysis* (GSEA, [13]) and *Parametric Analysis of Gene Set Enrichment* (PAGE, [14]). Originally, these methods take terms (gene sets) from the Gene Ontology (GO), the Kyoto Encyclopedia of Genes and Genomes (KEGG) and ENTREZ interactions, and test whether the genes annotated by a specific term are statistically significantly differentially expressed in the given dataset.

The RSD semantic subgroup discovery approach was adapted to gene set enrichment analysis in the SEGS algorithm (*Searching for Enriched Gene Sets*) [12], a specialized algorithm for semantic subgroup discovery for microarray data analysis.

SEGS employs semantically annotated knowledge sources GO, KEGG and ENTREZ, as background knowledge for semantic subgroup discovery. Based on this background knowledge, SEGS automatically formulates biological hypotheses: rules which define groups of differentially expressed genes. Finally, it estimates the relevance/significance of the formulated hypotheses on experimental microarray data. Compared to GSEA and PAGE, SEGS does not only test existing gene sets (defined by individual GO or KEGG terms), but constructs and tests also new gene sets, constructed by the combination of GO terms, KEGG terms, and also by taking into account the gene-gene interaction data from ENTREZ. The SEGS approach is outlined in Figure 1.

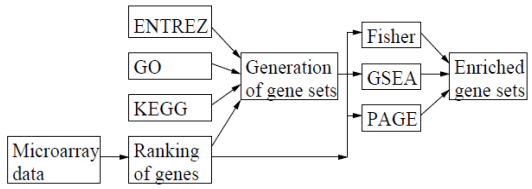

Figure 1. Schematic representation of SEGS.

As it is infeasible to generate all the possible gene set descriptions in the given hypothesis language and evaluate each rule separately in the next step of the procedure, SEGS uses the topology of GO and KEGG to search the hypothesis space in a general-to-specific fashion to be able to reduce the search. Moreover, SEGS includes the ranking of genes (according to their differential expression based on the input microarray experiment) into the gene set generation phase (as shown in Figure 1) and counts the number of differentially expressed genes covered by each generated rule. If the number of covered differentially expressed genes is lower than a predefined threshold, the rule is eliminated and not specialized further, thus pruning large parts of the hypothesis space.

For rule evaluation, SEGS uses three statistical tests to test the significance of the newly generated gene sets: Fisher's exact test, the GSEA method [13] and the PAGE method [14]. It then uses weights to combine the results of the three statistical tests.

Consider the application domain described in [15] and [5], where data instances are gene expression profiles of patients belonging to two cancer classes, AML (acute myeloid leukemia) and ALL (acute lymphoblastic leukemia). Our goal is to uncover interesting patterns that can help to better understand the dependencies between the classes (cancer types) and the attributes (gene expressions values). The rules, shown in Table 1, were generated from data on gene expression profiles obtained by the Affymetrix HU6800 microarray chip, containing probes for 6,817 genes, for 73 instances of AML or ALL class labeled expression vectors. The rules in Table 1 are ranked

according to the enrichment score (ES) measuring the enrichment of differential expression of a set of genes, annotated by the given conjunction of GO, KEGG and/or ENTREZ terms.

Table 1. Enriched gene set descriptions in AML-ALL, together with their enrichment score (ES) [12].

Gene Set Description	ES
Enriched in ALL	
1. ALL ← Func('zinc ion binding') & Comp('chromosomal part') & Proc('interphase of mitotic cell cycle')	0.60
2. ALL ← Proc('DNA metabolism')	0.59
3. ALL ← Func('ATP binding') & Comp('chromosomal part') & Proc('DNA replication')	0.55
Enriched in AML	
1. AML ← Func('metal ion binding') & Comp('cell surface') & Proc('response to pest,pathogen,parasite')	0.54
2. AML ← Comp('lysosome')	0.53
3. AML ← Proc('inflammatory response') & Comp('cell surface')	0.51

3.2. SegMine: Combining SEGS and BioMine

The SegMine methodology [16], developed for exploratory analysis of microarray data, is performed through semantic subgroup discovery by SEGS, followed by link discovery and visualization by Biomine [17], an integrated annotated bioinformatics information resource of interlinked data. The SegMine methodology, illustrated in Figure 2, consists of the gene ranking, hypothesis/rule generation by the SEGS method for enriched gene set construction, linking of the discovered gene sets to related biomedical databases for link discovery with Biomine, and Biomine sub-graph visualization.

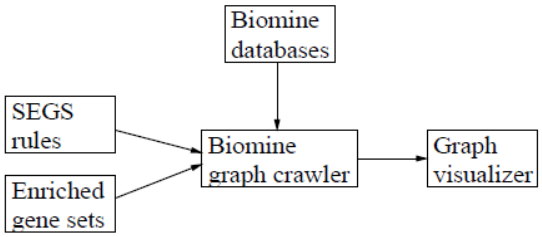

Figure 2. SegMine wokflow (focusing on Biomine, as details of the SEGS workflow are shown in Figure 1).

Biomine service is a valuable addition to SEGS, complementing our semantic subgroup discovery technology by additional explanatory potential due to additional Biomine graph visualization. Biomine is used through its web interface which allows for querying via Biomine named entities, such as a set of GO terms, resulting in a Biomine (sub)-graph, which can be visualized for exploratory purposes. A sample Biomine graph is shown in Figure 3, while the SegMine implementation in the Orange4WS workflow construction and execution platform [18] is shown in Figure 4. In [16], the utility of the SegMine methodology was demonstrated in two microarray data analysis applications: a well-known dataset from a clinical trial in acute lymphoblastic leukemia (ALL), and a dataset about the senescence in human mesenchymal stem cells (MSC). In the analysis of senescence in human stem cells, the use of SegMine resulted in three novel research hypotheses that can improve the understanding of the underlying mechanisms of senescence and identification of candidate marker genes.

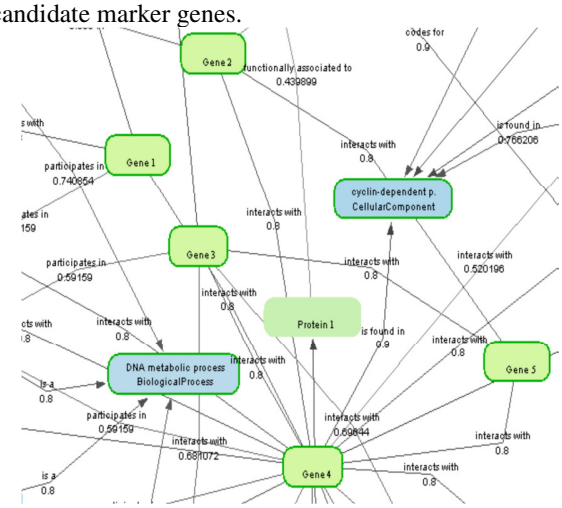

Figure 3. Biomine subgraph related to three genes from the enriched gene set constructed by SEGS.

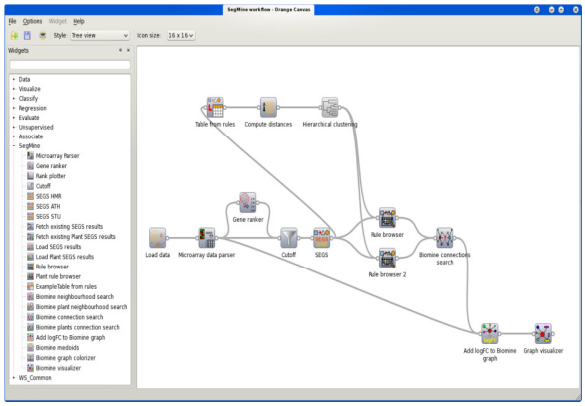

Figure 4. A screenshot of Orange4WS running a workflow of SegMine components [16].

4. Conclusions

SEGS was the first special purpose semantic subgroup discovery algorithm developed. Recently, we developed two new general purpose semantic subgroup discovery systems, SDM-SEGS and SDM-Aleph, and implemented them within a new semantic data mining toolkit, named SDM-Toolkit [19]. SDM-Toolkit has been made publicly available within the Orange4WS service-oriented data mining environment [18].

In [19], we illustrate the use of SDM-Toolkit tools for biomedical workflow construction and their execution in Orange4WS on the same two biomedical problem domains, ALL and hMSC, which were used in the evaluation of the utility of SegMine [16]. A qualitative evaluation of SDM-SEGS and SDM-Aleph, supported by experimental results and comparisons with SEGS, showed that SEGS and SDM-SEGS are more appropriate for data analysis in biomedical domains where rule specificity is desired, while SDM-Aleph is a more general purpose system, resulting in more general rules of higher precision.

Our recent work [20] also addresses semantic subgroup discovery, but focuses on a problem of explaining patient subgroups (e.g., similar patients, possibly all having a certain, yet unexplored cancer subtype) rather than explaining sets of differentially expressed genes characteristic for patients of a given class (cancer type) as a whole. This research is motivated by a real-life problem of breast cancer patient analysis, motivated by the experts' assumption that there are several subtypes of breast cancer.

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DEX METHODOLOGY: THIRTY THREE YEARS OF QUALITATIVE MULTI-ATTRIBUTE MODELING

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ABSTRACT

DEX is a qualitative multi-attribute decision modeling methodology, which is based on an integration of multi-criteria decision modeling with rule-based expert systems. The method was conceived 33 years ago. In its lifespan, it has been implemented in a wide range of computer programs that have been used in hundreds of practical applications. In this paper we report on its main methodological concepts, contributions to the theory and practice of decision support, and present a history of its development and evolution.

1 INTRODUCTION

DEX is a qualitative decision support methodology aimed at the evaluation and analysis of decision alternatives. Conceived more than thirty years ago, the methodology has a long history of scientific, technical and practical contributions. It represents a pioneering approach of combining the "classical" numerical multi-criteria decision modeling with rule-based expert systems. This approach led to a development of new algorithms and techniques for acquisition and representation of decision knowledge and evaluation and analysis of decision alternatives. DEX was implemented in three generations of software – called DECMAK, DEX and DEXi – and embedded into many other computer programs. It was used in hundreds of practical applications, nationally and internationally. Despite its age, DEX is still very much alive: it is actively used in international projects and cited in international scientific publications, it is taught in schools, there are ongoing new developments and strong plans for future work. Taking all this into account, DEX can be rightly considered an important long-term achievement of Slovenian research in artificial intelligence and decision support.

2 ON ORIGINS AND EVOLUTION OF DEX

The foundations of what eventually became DEX were set up in Durham, UK, by Efstathiou and Rajkovič (1979). In their work, which was heavily influenced by fuzzy sets, they advocated for using words rather than numbers in decision models. They proposed a tabular representation of utility relations, one of the key concepts of DEX methodology. Further development continued in Slovenia, mainly through collaboration of Vladislav Rajkovič and Marko Bohanec. In the 1980's, the methodology was called DECMAK (Bohanec et al., 1983). It was conceptually extended to cope with hierarchies of attributes (Rajkovič, Bohanec, 1980) and to facilitate the acquisition and explanation of decision knowledge (Rajkovič, Bohanec, 1988; Rajkovič et al., 1988). The approach was successfully used in several real-life practical applications, such as evaluation of computer systems (Bohanec et al., 1983) and enrollment into nursery schools (Olave et al., 1989).

The name DEX (Decision EXpert) was coined when the method was implemented in a form of an expert system shell for decision making (Bohanec, Rajkovič, 1990). This was a state-of-the-art implementation of the whole methodology. In the 1990's, DEX was used in a series of complex decision making tasks in industry (Bohanec, Rajkovič, 1999), health-care (Bohanec et al., 2000a), project evaluation (Bohanec et al., 1995), housing (Bohanec et al., 2001), and sports (Bohanec et al., 2000b). An important related achievement was also HINT, a method for automatic problem decomposition (Zupan et al., 1999). Used as a machine learning algorithm, HINT is capable of developing DEX models from data.

The third distinctive period started in 2000 with the implementation of DEXi (Jereb et al., 2003), a somewhat stripped-down, but simple and user-friendly computer program, aimed primarily at education. This paved the DEX's way into Slovenian secondary schools and universities (Krapež, Rajkovič, 2003). In spite of its simplicity, DEXi turned out extremely useful even for most difficult decision-making tasks. Some outstanding international applications included European projects *Sol-Eu-Net* on data mining and decision support integration (Mladenič et al., 2003), *Healthreats* on health threats and crises management (Žnidaršič et al., 2009), *ECOGEN*, *SIGMEA* and *Co-Extra* on genetically modified crops (Bohanec et al., 2008; Žnidaršič et al., 2008), and *e-LICO* on data mining workflows (Žnidaršič et al., 2012). There were countless other applications, for example in public administration (Leben et al., 2006), agronomy (Griffiths et

al., 2010; Pavlovič et al., 2011) and tourism (Stubelj Ars, Bohanec, 2010). Methodological advances in this period include a new method for automatic revision of DEX models (Žnidaršič, Bohanec, 2007), a DSS tool for modeling uncertain knowledge called proDEX (Žnidaršič et al., 2006), and new methods for option ranking based on copulas (Mileva-Boshkoska, Bohanec, 2012).

3 PRINCIPLES OF DEX

Intentionally, the basic principles of DEX are kept very simple. The decision maker is requested to define a *qualitative multi-attribute model*, with which decision alternatives are evaluated and analyzed. In principle, the model represents a decomposition of the decision problem into smaller, less complex subproblems The decomposition is represented by a hierarchy of attributes. The DEX model consists of:

- *Attributes*: variables that represent basic features and assessed values of decision alternatives.
- *Scales* of attributes are qualitative and consist of a set of words, such as: 'excellent', 'acceptable', 'inappropriate', etc. Usually, scales are ordered preferentially, i.e., from bad to good values.
- *Hierarchy* of attributes: represents the decomposition of the decision problem and relations between attributes; higher-level attributes depend on lower-level ones.
- *Decision rules*: tabular representation of the mapping from lower-level attributes to the higher-level one. In principle, the table should specify a value of the higher-level attribute for all combinations of values of the lower-level attributes.

Figures 1 and 2 illustrate these components on a simple model for the evaluation of cars (Bohanec, 2011).

Attribute	Scale
CAR	**unacc**; acc; good; ***exc***
├**PRICE**	**high**; medium; ***low***
│ ├BUY.PRICE	**high**; medium; ***low***
│ └MAINT.PRICE	**high**; medium; ***low***
└**TECH.CHAR.**	**bad**; acc; good; ***exc***
├**COMFORT**	**small**; medium; ***high***
│ ├#PERS	**to_2**; 3-4; ***more***
│ ├#DOORS	**2**; 3; 4; ***more***
│ └LUGGAGE	**small**; medium; ***big***
└SAFETY	**small**; medium; ***high***

Figure 1: *DEX model for the evaluation of cars: Hierarchy and scales of attributes*

Decision alternatives are evaluated by an aggregation that is performed from the leaves towards the root of the DEX model hierarchy. Also, the model is typically used for the 'what-if' and sensitivity analysis of alternatives.

Conceptually, DEX is a combination of two approaches: multi-criteria decision analysis (MCDA) and expert systems. From MCDA (Figueira et al., 2005; Bouyssou et al., 2006), DEX takes the idea of evaluation and analysis of alternatives using a hierarchically structured model. DEX departs from using numerical variables and weight-based utility functions by introducing concepts from expert systems: qualitative and linguistic variables, if-then rules, dealing with uncertainty, high emphasis on transparency of models and explanation of evaluation results. DEX has some similarities with two other independently developed approaches: DRSA (Greco et al., 2001) and Doctus (Baracskai, Dörfler, 2003).

	PRICE	TECH.CHAR.	CAR
1	**high**	**bad**	**unacc**
2	**high**	acc	**unacc**
3	**high**	good	**unacc**
4	**high**	***exc***	**unacc**
5	medium	**bad**	**unacc**
6	medium	acc	acc
7	medium	good	good
8	medium	***exc***	***exc***
9	***low***	**bad**	**unacc**
10	***low***	acc	good
11	***low***	good	***exc***
12	***low***	***exc***	***exc***

Figure 2: *Decision rules for PRICE×TECH.CHAR→CAR*

4 IMPORTANT CONCEPTS

Very early in DEX's history it became clear that working directly with model components was not practical; additional tools were needed to acquire and validate model components, as well as to evaluate, analyze and explain the alternatives. Among these, the following were the most important for practical adoption of DEX:

Acquisition of decision rules: Direct definition of tables, such as the one in Figure 2, is tedious and error-prone, and computer-based assistance becomes vital. In its early days, DECMAK offered an interactive ASK/ANSWER dialogue. Now, DEXi supports three strategies for the definition of decision rules: direct, 'use scale orders', and 'use weights' (Bohanec, 2011, p. 35).

Validating rules: In comparison with common expert systems, DEXi rules are simple and restricted by the scales of the corresponding attributes, which makes them suitable for validation of *completeness* (to which extent they define the mapping) and *consistency* (are they in conflict with each other). This improves the overall quality of models.

"The user is always right" principle: In spite of consistency checking, DEX gives precedence to information provided by the decision maker. Thus, any decision rule, even if inconsistent, is taken literally and never modified by DEX. The user is warned, though.

Dynamic aspects of model creation: The model as shown in Figures 1 and 2 is static. However, in practice, such models are continuously modified and improved: parts of the model are created, extended or deleted. There are many such operations, such as deleting or adding an attribute, reordering attributes, removing a scale value, etc. All these operations must be supported by appropriate algorithms so that the information already contained in the model is retained as much as possible after each operation. It is particularly important to properly handle decision rules.

DEX does implement these operations and typically handles them transparently "behind the scenes".

Bridging the gap between qualitative and quantitative MCDA: The traditional MCDA heavily relies on weights to define the importance of attributes. Naturally, there are no weights in decision rules. However, it turned out to be practically important to deal with weights, so these were included into DEX, too. A partial transformation between attribute weights and rules is possible in both ways (Bohanec, 2011): (1) weights are estimated from defined rules by linear approximation, and (2) the values of undefined decision rules are determined on the basis of already defined rules and user-specified weights.

Handling uncertainty in alternatives and rules: An expert system must be able to deal with incomplete and uncertain knowledge. The early DECMAK was already able to evaluate incompletely defined alternatives using fuzzy and probabilistic aggregation (Bohanec et al., 1983). In most of the later software, the uncertainty in rules was only partly modeled by value intervals. Žnidaršič et al. (2008) extended this to using probabilistic distributions.

Transparency and explanation: For practice, it is essential that DEX models appear transparent and comprehensible to the user. DEX always provided mechanisms for presenting decision rules in a user-friendly way, from ID3-based decision tree learning algorithms in the early software, to complex rule generators in the modern DEXi.

Analyses of alternatives: In addition to the mere evaluation of alternatives, the methodology has to provide advanced tools for the analysis of alternatives. For this purpose, DEX includes a number of methods, such as 'what-if' analysis, 'plus-minus-1' analysis and selective explanation.

5 SOFTWARE

Three main generations of qualitative modeling computer programs have been developed so far:

- DECMAK (released in 1981): for operating systems RT-11, VAX/VMS and later MS DOS; command-line interface, supporting a tree of attributes and fuzzy evaluation of alternatives, ASK/ANSWER rule acquisition dialogue, representing rule tables with complex rules and decision trees.
- DEX (1987): for MS DOS, facilitated interactive model creation and editing, probabilistic and fuzzy evaluation of alternatives, report generation, selective explanation of evaluation.
- DEXi (2000): for MS Windows, educational and interactive. Supports model creation and editing, tabular acquisition of rules, value-set-based evaluation of alternatives, "what-if" analysis, "plus-minus-1" analysis, selective explanation and comparison of options, textual and graphical reports. DEXi is publicly available (http://kt.ijs.si/MarkoBohanec/dexi.html) and free for non-commercial applications.

There exists some other supporting software, such as proDEX (implementation of some DEX extensions), JDEXi (an open-source Java library for evaluation of alternatives), DEXiEval (a command-line utility program for evaluation of alternatives), and DEXiTree (a program for pretty drawing of DEXi trees).

Also, DEX was often embedded into other software systems. Typical examples include Talent, a system for advising children into sports (Bohanec et al., 2000b), a system for risk assessment of diabetic foot care (Bohanec et al., 2000a), and traffic management center (Omerčević et al., 2008).

6 APPLICATIONS

Practical applicability is one of the strongest points of DEX. In its early days, we kept records of its applications and counted as many as thirty until 1988 (Bohanec, Rajkovič, 1988). The number of applications continued to grow, but their recording became more and more difficult with the spread of the method and free use of the software. Today, we roughly estimate that there have been hundreds of "serious" real-life applications of DEX. Considering prototypes and student work, the number of all developed DEX models is probably several thousands.

The areas of DEX applications are very diverse. So far, DEX was used to evaluate technologies, companies, projects, and services. Important problem areas include health care, public administration, agronomy, food production, ecology, land use planning, tourism, housing, traffic control, and sports.

Practical experience indicates that DEX is particularly suitable for solving complex decision problems, which require judgment and qualitative knowledge-based reasoning, dealing with inaccurate and/or missing data, as well as the analysis and justification of evaluation results. Typically, these problem require large models (with 15 or more attributes) and/or involve many alternatives (10 or more).

7 FUTURE OF DEX

Currently, the main software for developing DEX models is DEXi. Even after 12 years since its first release, it still seems suitable for education and typical decision making problems, and will – with proper maintenance – serve for these purposes in the future. However, really difficult problems require a more powerful methodology and more advanced software (Žnidaršič et al., 2008). The advances in software engineering require new architectures, such as web-based. There is a need for a DEX library and a set of tools for embedding DEX models into other systems, such as information systems, web pages and mobile devices.

For these reasons, we plan to extend the DEX methodology and implement it in a new generation of software (Trdin, Bohanec, 2012). The most challenging methodological advances are:

- *Introducing numeric attributes*: facilitating the use of both qualitative and quantitative attributes in the same model.

- *Full implementation of probabilistic and fuzzy distributions* for both: decision rules and alternatives.
- *General aggregation functions*: facilitate the use of all types of aggregation functions known in MCDA.
- *Relational models*: extending the methodology from "flat" to relational alternatives, that is, alternatives composed of sets of subcomponents.

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DATA STREAM MINING FOR UBIQUITOUS ENVIRONMENTS

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1 INTRODUCTION

In the data stream computational model examples are processed once, using restricted computational resources and storage capabilities. The goal of data stream mining consists of learning a decision model, under these constraints, from sequences of observations generated from environments with unknown dynamics. Most of the stream mining works focus on centralized approaches. The phenomenal growth of mobile and embedded devices coupled with their ever-increasing computational and communications capacity presents exciting new opportunities for real-time, distributed intelligent data analysis in ubiquitous environments. In domains like sensor networks, smart grids, social cars, ambient intelligence, etc. centralized approaches have limitations due to communication constraints, power consumption, and privacy concerns. Distributed online algorithms are highly needed to address the above concerns. The focus of this presentation is on distributed stream clustering algorithms that are highly scalable, computationally efficient and resource-aware. These features enable the continued operation of data stream mining algorithms in highly dynamic mobile and ubiquitous environments.

2 DISTRIBUTED CLUSTERING

One of the most popular knowledge discovery techniques is clustering, the process of finding groups in data such that data objects clustered in the same group are more alike than objects assigned to different groups [1]. On top of clustering algorithms, several tasks can be computed: profiling, anomaly and event detection, outliers detections, trends, deviations, etc. Sensor networks, smart grids, social cars are paradigmatic examples of ubiquitous streaming data sources. The quality of these clusters is usually called clustering validity, and can be measured in several different ways [2]. But classical methods tend to become obsolete for application in streaming and (especially) ubiquitous settings, due to their high time and space complexity. Hence, new machine learning algorithms are being developed to cope with this new demanding scenario, and different quality indices are being considered (e.g. computation and communication load). There are two different clustering problems in ubiquitous and streaming settings: clustering sensor streams and clustering streaming sensors. The former problem searches for dense regions of the data space, identifying hot-spots where sensors tend to produce data, while the latter finds groups of sensors that behave similarly through time [3]. In the first setting, a cluster is defined to be a set of data points (Figure 1) generated by multiple sources. In the second setting a cluster is defined to be a set of sensors (Figure 2) .

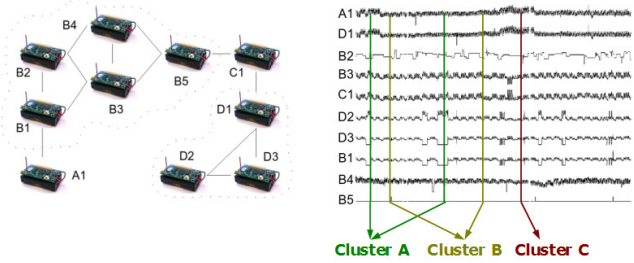

Figure 1: *Clustering Data Points.*

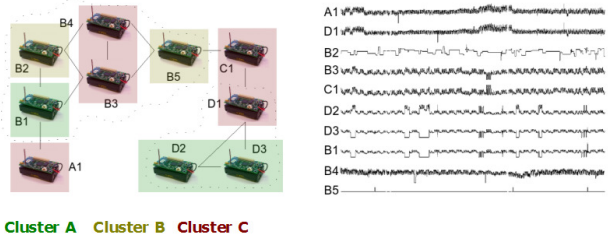

Figure 2: *Clustering Data Sources.*

2.1 GRID CLUSTERING OF DISTRIBUTED STREAMS

Clustering data points is probably the most common unsupervised learning process in knowledge discovery. In ubiquitous settings, however, there aren't many tailored solutions to try to extract knowledge in order to define dense regions of the sensor data space. Clustering examples in sensor networks can be used to search for hot-spots where sensors tend to produce data. In this settings, grid-based clustering represents a major asset as regions can be, strictly or loosely, defined by both the user and the adaptive process [3]. The application of clustering to grid cells enhances the abstraction of cells as interval regions which are better interpreted by humans. Moreover, comparing intervals or grids is usually easier than comparing exact

points, as an external scale is not required: intervals have intrinsic scaling. The comprehension of how sensors are interacting in the network is greatly improved by using grid based clustering techniques for the data examples produced by sensors.

The Distributed Grid Clustering (DGClust) algorithm was proposed for clustering data points produced on wide sensor networks [4]. The rationale is to use: a) online discretization of each single sensor data, tracking changes of data intervals (states) instead of raw data (to reduce communication to central server); b) frequent state monitoring at the central server, preventing processing all possible state combinations (to cut computation) [9]; and c) online clustering of frequent states (to keep high validity and adaptivity) [5]. Each local sensor receives data from a given source, producing a univariate data stream, which is potentially infinite. Therefore, each sensor's data is processed locally, being incrementally discretized into a univariate adaptive grid. Each new data point triggers a cell in this grid, reflecting the current state of the data stream at the local site. Whenever a local site changes its state, that is, the triggered cell changes, the new state is communicated to a central site. Furthermore, the central site keeps the global state of the entire network where each local site's state is the cell number of each local site's grid. Nowadays, sensor networks may include thousands of sensors. This scenario yields an exponential number of cell combinations to be monitored by the central site. However, it is expected that only a small number of this combinations are frequently triggered by the whole network, so, parallel to the aggregation, the central site keeps a small list of counters of the most frequent global states. Finally, the current clustering definition is defined and maintained by an adaptive partitional clustering algorithm applied on the frequent states central points.

2.2 DISTRIBUTED CLUSTERING OF GRID NODES

Clustering streaming data sources has been recently tackled in research, but usual clustering algorithms need the data streams to be fed to a central server [6]. Considering the number of sensors possibly included in a smart grid, this requirement could be a bottleneck. A local algorithm was proposed to perform clustering of sensors on ubiquitous sensor networks, based on the moving average of each node's data over time [8]. L2GClust has two main characteristics. On one hand, each sensor node keeps a sketch of its own data. On the other hand, communication is limited to direct neighbors, so clustering is computed at each node. The moving average of each node is approximated using memoryless fading average [7], while clustering is based on the furthest point algorithm [5] applied to the centroids computed by the node's direct neighbors. This way, each sensor acts as data stream source but also as a processing node, keeping a sketch of its own data, and a definition of the clustering structure of the entire network of data sources.

3 CONCLUDING REMARKS

In this talk we discussed approaches to ubiquitous data mining were both data sources and processing devices are distributed. Algorithms process local data and are able to communicate and interact with other agents to collaboratively construct a global solution. Ubiquitous data mining implies new requirements to be considered: i) the algorithms will have to use limited computational resources (in terms of computations, space and time); ii) the algorithms will have only a limited random access to data and may have to communicate with other agents; iii) answers will have to be ready in an anytime protocol [10, 11]. Ubiquitous data mining is in the core of next generation of data mining systems.

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MACHINE LEARNING FOR SYSTEMS BIOSCIENCES

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ABSTRACT

The above title currently provides the best single label for the topics covered by my research group. Here I provide a brief summary of our current research and some of the research directions we intend to pursue.

Systems biosciences study biological systems in a holistic manner, focusing on the interactions among system components rather than the components themselves. Large amounts of data of increasing complexity are generated in these sciences (which include systems ecology and systems biology): The use of machine learning to make sense of these data is thus a necessity. We discuss two machine learning tasks that appear in this context, predicting structured outputs and automated modeling of dynamic systems. We describe some techniques for solving these tasks and some example application of these techniques in systems ecology and systems biology.

1 THE DATA DELUGE IN SYSTEMS BIOSCIENCES

Systems biosciences study biological systems in a holistic manner, trying to understand their overall behavior. They focus on the interactions among system components rather than the individual components themselves. Systems biosciences include systems ecology and systems biology, both of which have a strong emphasis on systems modeling.

At the macro level, systems ecology studies the behavior of ecosystems, which comprise populations of different organisms. It is part of environmental sciences and strongly related to ecological modeling. At the micro level, systems biology studies the processes that happen in individual organisms, focusing on cellular processes at the molecular level. It is a novel branch of the life sciences and relies heavily on a variety of bioinformatics approaches.

Ecology is concerned with the distribution of species over space and time. Ecological modeling is concerned with constructing and using models of ecosystems, i.e., communities/ populations of different species. Common types of ecological models include habitat and population dynamics models. The former focus on space and predict the suitability of a location for a given species. The latter focus on time and model the changes in time for one or more populations in a given ecosystem.

Data in ecology and environmental sciences can come in large quantities and many varieties. Spatial data can come from remote sensing and geographical information systems. Temporal data describe the time courses of population densities. Communities of organisms present at a sampling site can be represented as hierarchies (subsets of the taxonomy of living organisms). Microscopy images of organisms present at a site are often taken. Graphs can be used to represent the chemical structure of pollutants.

The data deluge is of even larger proportions and variety in systems biology. Systems biology is a new branch of the life sciences that tries to understand organisms as a whole. It attempts to put together an integrated picture of the processes that happen in the system at all levels and their dynamics. The levels of organization of the systems range from the genome to the phenome, with high-throughput data being collected for each of them by the different "–omics" disciplines, such as genomics, transcriptomics, proteomics, metabolomics, and phenomics.

Among the different types of data, genomics data in the form of DNA/RNA sequences are increasingly common, with new genomes being sequenced at a rapidly increasing rate. While spatial data are still rare, temporal data in the form of time courses of gene expression levels, protein and metabolite concentrations are being collected. Hierarchies describe the structure of proteins (classified into folds and families) and protein/ gene function (described in terms of annotation schemes, such as the Gene Ontology). Microscopy images of cellular cultures (or videos thereof), collected within genomic and compound screens are gaining popularity. In the context of studying QSAR (quantitative structure-activity relationships), the structure of chemical compounds is typically represented in the form of graphs.

To make sense of data that come in such large quantity and variety, the use of machine learning (ML) techniques is a must. ML, an essential area of artificial intelligence, studies computer programs that learn from (automatically improve with) experience. A major part of ML (inductive learning) is concerned with learning from examples. This part has a large overlap with the area of data mining, which includes supervised learning (or predictive modeling) and unsupervised learning (including clustering). Machine learning also studies the topic of computational scientific discovery, which includes approaches for automated modeling of dynamic systems.

In the remainder of this paper, we first describe the general task of predictive modeling, concerned with predicting structured outputs, and some approaches to solving it. We then describe the task of automated modeling of dynamic systems and some approaches to solving it. Several example applications of these approaches in systems ecology and systems biology are discussed next. We finally outline some directions for further research.

2 ML FOR PREDICTING STRUCTURED OUTPUTS

The task of predicting structured outputs. The task of predictive modeling is to learn a predictive model from

examples. A predictive model returns an output (i.e., target) property of an example, given input properties (e.g., attribute) of the example. Typically, we need to predict the scalar value of a single variable: The task is called classification when the target is discrete and regression when it is real-valued.

However, there are many real life domains, such as image annotation, text categorization, predicting gene functions, etc., where the input and/or the output can be structured. We will focus here on the latter, namely, on predictive modeling tasks with structured outputs. The inputs will have the form of vectors of attribute values.

We consider three different classes of targets: tuples of discrete/real values, hierarchies of discrete values (classes), and (short) time series of real values. The corresponding tasks of structured output prediction are called multi-target prediction, hierarchical multi-label classification, and prediction of (short) time series.

Descriptive attributes						Target attributes					
Temperature	$K_2\ Cr_2\ O_7$	NO_2	Cl	CO_2	...	Cladophora sp.	Gongrosira incrustans	Oedogonium sp.	Stigeoclonium tenue	Melosira varians	Nitzschia palea
0.66	0.00	0.40	1.46	0.84	...	1	0	0	0	0	1
2.03	0.16	0.35	1.74	0.71	...	0	1	0	1	1	1
3.25	0.70	0.46	0.78	0.71	...	1	1	0	0	1	0

Table 1: An example task of multi-target classification.

Multi-target prediction is the simplest extension of the classical predictive modeling task: Instead of a single discrete/continuous target variable, we need to predict several of these. Typically, all of the targets are discrete (resp. continuous) and we face the tasks of multi-target classification and regression. An example task of multi-target classification is given in Table 1. The attributes, targets, and three instances from a dataset are shown. The descriptive attributes are physical and chemical parameters of water quality, while the target variables denote the presence/absence of bioindicator organisms.

In the multi-target prediction task from Table 1, all targets are binary. In this case, each target can be considered a label, and each example can be assigned more than one label (if a value of one is predicted for the corresponding target). This variant of the multi-target prediction task is called multi-label classification (MLC).

Hierarchical multi-label classification (HMLC) can be considered an extension of multi-label classification. Like in MLC, in HMLC we need to predict a subset of the set of possible labels for each example. However, as the name implies, labels in HMLC are organized in a hierarchy. Labelings (predictions) in HMLC have to obey the hierarchy constraint: If a label is predicted, all of its parent labels have to be predicted as well.

Prediction of (short) time series is the last task we consider here. The (short) time series are sequences of real-valued measurements, taken at consecutive timepoints. The task is to predict such a sequence from the values of a set of descriptive attributes.

Approaches for predicting structured outputs. There are two groups of methods for solving the task of predicting structured outputs: (1) methods that predict component(s) of the output and then combine the components to get the overall prediction (called local methods) and (2) methods that predict the complete structure as a whole (called global methods). The latter group of methods has several advantages over the former. They exploit the dependencies that exist between the components of the structured output in the model learning phase and thus result in better predictive performance. They are also more efficient: the number of components in the output can be very large (e.g., hierarchies in functional genomics), in which case executing a basic method for each component is not feasible.

A variety of methods now exist for predicting structured outputs: An overview of these is beyond the scope of this paper. The majority of approaches to predicting structured outputs can handle only one type of output (e.g., multi-target classication). An exception to this is the approach of predictive clustering: Besides unifying supervised and unsupervised learning (prediction and clustering), predictive clustering also allows for structured prediction of different output types. In particular, all of the three tasks above can be handled by predictive clustering trees (PCTs). An example PCT for the task from Table 1 is given in Figure 1.

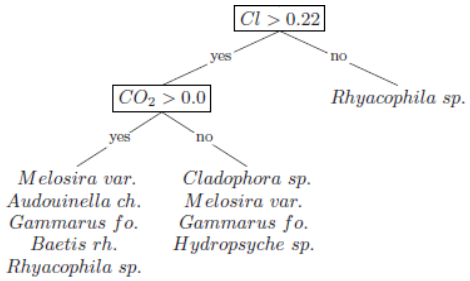

Figure 1: An example tree for multi-target classification.

Recent advances in predicting structured outputs. Among the recent developments, we will focus here on those related to predictive clustering. The predictive power of PCTs has been greatly enhanced by the introduction of ensembles of PCTs. Methods have also been developed for learning predictive clustering rules, as well as rule ensembles. Finally, methods for constrained (e.g. by size and error) induction of PCTs have been developed (cf. Chapters 7 and 15 of Džeroski et al. (2010)).

3 ML FOR MODELING DYNAMIC SYSTEMS

Computational scientific discovery (CSD) attempts to provide computational support for the process of discovery

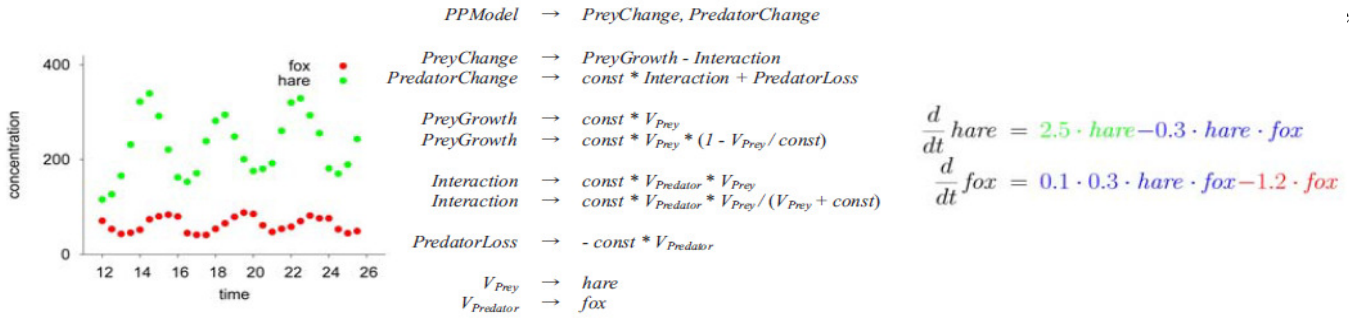

Figure 2: An example task of automated modeling.

of scientific knowledge. The input to CSD approaches includes observations (measured data) and existing scientific (domain) knowledge. The focus in CSD is on using standard formalisms for representing scientific knowledge that are accepted and routinely used by scientists.

The task of automated modeling of dynamic systems belongs to the CSD paradigm. For dynamic systems that change their state over time, models in the form of ordinary differential equations (ODEs) have to be learned, including both the structure of and the parameters in the equations. ODEs are well known, accepted and widely used in science.

The CSD paradigm facilitates the combination of both observational data and existing background/domain knowledge, where different types of domain knowledge can be used. We can start from existing ODE models for the system at hand (that are partial, incomplete, and/or inaccurate) and revise/improve them in light of observed data. We can also provide a set of basic components as building blocks from which ODE models can be built. The domain knowledge can be provided in different forms, including grammars, constraints, and process-based modeling formalisms.

An example input / output for a task of automated modeling of population dynamics with ODEs is given in Figure 2. At the far left, the observed data are given, consisting of the densities of two populations. In the middle, the domain knowledge is given in the form of a context-free grammar specifying the functional form of the ODEs to be considered. At the far right, the output is given, consisting of two ODEs describing three population dynamics processes (prey growth – first term in first equation, predator loss – second term in second equation, and predator-prey interaction – term shared by both equations).

The use of domain knowledge allows for the convergence of the two major modeling paradigms, theoretical (knowledge-driven) modeling and empirical (data-driven) modeling. In the first approach, a domain expert derives a proper model structure based on domain-specific modeling knowledge: Extensive knowledge and little data are needed. In the second approach, different model structures are explored to fit observed data in a trial and error process: Extensive data and little domain knowledge are necessary. The integrated approach to automated modeling allows us to trade between the quantity

Approaches for automated modeling of dynamic systems. These approaches use measured data to identify both the model structure and the values of the constant parameters in the model. They combine heuristic search methods with parameter estimation techniques: While the search methods explore the space of candidate model structures, the parameter estimation techniques find optimal values of a single structure and evaluate its fit against observations. The result of the evaluation in turn guides the search method towards a model (i.e., a structure/parameters combination) with a good fit. Alternative approaches differ in the type and representation of domain knowledge.

Recent advances in automated modeling of dynamic systems. The most recent methods that follow this paradigm use process-based formalisms for representing domain knowledge as well as models. The key concepts here are entities and processes. Entities, which can be of different types, describe the components of the modeled system: Their properties are typically system variables in the ODEs. Processes describe the interactions between entities and give rise to the terms that appear in the ODEs. Process-based domain knowledge lists the basic types of entities and processes in the domain at hand: The types can be organized hierarchically. For each type of process, alternative modeling templates are provided, which can be used in the ODEs. A representative for this class of approaches is LAGRAMGE2 (cf. Chapter 4 of (Džeroski and Todorovski 2007)).

4 ML FOR SYSTEMS ECOLOGY

There are many applications of machine learning to ecological and environmental modeling problems. These range from predicting earthquakes to assessing the state of the environment from remote sensing data: Forest height and density can be predicted in this fashion. Here we will focus on applications of the two classes of ML methods described above to the ecological modeling tasks of modeling habitat and modeling population dynamics.

Methods for structured output prediction can and have been applied to problems of relating environmental conditions to community structure. This is a generalization of the problem of modeling habitat for a single species, as the presence/absence or abundance has to be predicted for several species (or higher taxonomic units) rather than a single one. PCTs have been applied to predict community structure in Slovenian rivers (Table 1 and Figure 1), Lake Prespa in Macedonia and polder lakes in Belgium.

CSD methods for automated modeling of dynamic systems have been applied to many problems of modeling population dynamics. In fact, applications in automated modeling of population dynamics have been the driving force for the development of many of the methods mentioned above. The automated modeling of the dynamics of two populations is illustrated in Figure 2.

Automated modeling approaches have been mainly applied to modeling the population dynamics of aquatic ecosystems. The Lagoon of Venice was the first one to be modeled in this fashion, followed by a number of lakes, including Lakes Glumsoe (Denmark), Bled (Slovenia), and Kasumigaura (Japan), cf. Čerepnalkoski et al (2012), as well as Greifensee (Switzerland) and Kinneret (Israel).

5 ML FOR SYSTEMS BIOLOGY

In systems biology, ML methods for structured output prediction can be used for integrative analysis of high-throughput data being collected by the different "–omics" disciplines. In addition, a variety of knowledge (from different sources) collected by humans and stored in bioinformatics databases can be used in these analyses: These include for example annotations of genes with their functions in terms of the Gene Ontology. The learned model and especially their (in-silico) predictions are often further used by biologists as hypothesis that are examined and validated by experiments in the wet-lab.

Tasks addressed in this context include gene function prediction and relating time course profiles of gene expression level to gene properties (function). The former is an instance of HMLC and has been addressed for several model organisms, including yeast and water cress (Chapter 15 of Džeroski et al. (2010)), as well as the mouse (Schietgat et al. 2010). The latter is an instance of predicting short time series and has been used to relate the function of yeast genes and the time profiles of their response to different types of stress (Slavkov et al. 2010).

A major focus of systems biology is the study of the structure and dynamics of biological networks. After the structure of (links in) the network is determined, the kinetics of its behavior is described with ODE models, which can include different types of kinetics. Approaches for automated modeling of dynamic systems can be applied in this context. Džeroski and Todorovski (2008) give an overview of different methods of this kind, as well as the possibilities of their use in systems biology. They also give an example of using such methods for modeling the process of glycolysis. More recently, Tashkova et al. (2011) have addressed the task of modeling endocytosis, more precisely endosome maturation, an important part of the immune response manipulated by pathogens (e.g., *M. tuberculosis*).

6 FUTURE RESEARCH DIRECTIONS

Predicting structured outputs. Besides multi-target prediction, HMLC, and predicting short time series, we need to consider other task with different, possibly more complex targets (e.g., tuples of hierarchies or time series). Methods for learning PCTs can be extended in several directions, such as integration with semi-supervised lerning approaches or transfer learning. Handling imbalanced distributions is another major challenge in this context. Finally, we also need to explicitly take into account spatio-temporal information, e.g., by considering autocorrelation.

Approaches for automated modeling of dynamic systems. These approaches integrate search through the space of ODE structures with parameter fitting. After decades of using local optimization methods for the latter task, global optimization approaches (meta-heuristics) have been considered recently (Tashkova et al. 2011, Čerepnalkoski et al. 2012). However, much work remains to be done. The use of global optimization methods opens the door to using other quality criteria (and not just mean squared error) for selecting models: Multiple criteria could also be used with multi-objective optimization. This would broaden the possible application areas for CSD methods. Extensions in the direction of incorporating spatial aspects within the temporal models (e.g., by using compartments) are also of practical relevance. Finally, we will explore the avenue of learning ensembles of ODE models of dynamic systems and the use of such approaches in modeling .environmental and biological systems.

Applications in systems biosciences. We anticipate that the number and types of possible applications for the methods described above in systems biosciences will explode over the next decade. In ecology, one task on the horizon is predicting community structure by taking into account the taxonomy of living organisms (a HMLC task). In systems biology, the analysis of data from image screens, either genomic or compound, will need immediate attention: This is a task where data are complex, both in quantity and in quality (structure).

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EXPLANATION AND RELIABILITY OF INDIVIDUAL PREDICTIONS: RECENT RESEARCH BY LKM

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ABSTRACT

We review some recent research topics by Laboratory for Cognitive Modeling (LKM) at Faculty of Computer and Information Science, University of Ljubljana, Slovenia. Classification and regression models, either automatically generated from data by machine learning algorithms, or manually encoded with the help of domain experts, are daily used to predict the labels of new instances. Each such individual prediction, in order to be accepted/trusted by users, should be accompanied by an explanation of the prediction as well as by an estimate of its reliability. In LKM we have recently developed a general methodology for explaining individual predictions as well as for estimating their reliability. Both, explanation and reliability estimation are general techniques, independent of the underlying model and provide on-line (effective and efficient) support to the users of prediction models.

1 INTRODUCTION

In a typical machine learning scenario a machine learning algorithm is used to construct a model of the relationships between the input features and the target variable with the purpose to predict the target variable of new, yet unseen instances. Explaining the learned relationships is also an important part of machine learning. Some models, such as additive models or small decision trees, are inherently transparent and require little or no additional postprocessing (Jakulin et al., 2005; Szafron, 2006). Other, more complex and often better performing models are non-transparent and require additional explanation. Therefore, model-specific explanation methods have been developed for models such as artificial neural networks and SVM.

In practice, dealing with several different explanation methods requires undesirable additional effort and makes it difficult to compare models of different types. To address this issue, general explanation methods are used – methods, which treat each model as a black-box and can be used independent of the model's type. Most general explanation methods are based on marginalization of features (Lemaire, 2008; Zien, 2009). This approach is computationally efficient. It is also effective as long as the model is additive (that is, as long as the features do not interact). However, several widely-used machine learning models are not additive, which leads to misleading and incorrect explanations of the importance and influence of features (Štrumbelj and Kononenko, 2010). Unlike existing general explanation methods, our method, described in Section 2, takes into account not only the marginal effect of single features but also the effect of subsets of features.

In supervised learning, one of the goals is to get the best possible prediction accuracy on new and unknown instances. As current prediction systems do not provide enough information about single predictions, experts find it hard to trust them. Common evaluation methods for classification and regression machine learning models give an averaged accuracy assessment of models, and in general, predictive models do not provide reliability estimates for their individual predictions. In many areas, appropriate reliability estimates may provide additional information about the prediction correctness and can enable the user (e.g. medical doctor) to differentiate between more and less reliable predictions. In Section 3 we describe our approaches to estimating the reliability of individual predictions. Finally, in Section 4 we overview directions of current research, carried out in LKM.

2 EXPLAINING INDIVIDUAL PREDICTIONS

The idea behind our method for explaining individual predictions is to compute the contributions of individual features to the model's prediction for a particular instance by decomposing the difference between the model's prediction for the given instance and the model's expected prediction (i.e., the model's predictions if none of the features' values were known). We adopt, with minor modifications, the notation used in (Štrumbelj and Kononenko, 2011). Let $A = A_1 \times A_2 \times ... \times A_n$ be our feature space, where each feature A_i is a set of values. Let p be the probability mass function defined on the sample space A. Let $f_c: A \rightarrow [0,1]$ describe the classification model's prediction for class value c. Our goal is a general explanation method which can be used with any model, so no other assumptions are made about f_c. Therefore, we are limited to changing the inputs of the model and observing the outputs.

Let $S = \{A_1, ..., A_n\}$ be the set of all features. The influence of a certain subset Q of S for classification of a given instance $x \in A$ is defined as:

$$\Delta(Q)(x) = \mathrm{E}[f \mid \text{values of features in } Q \text{ for } x] - \mathrm{E}[f] \qquad (1)$$

The value of the above function for the entire set of features S is exactly the difference between the model's prediction for a given instance and the model's expected prediction that we wish to decompose. Note that we omit the class value in the notation of f. Suppose that for every subset of features Q the value of $\Delta(Q)$ is known. The goal is to decompose $\Delta(S)$ in a way that assigns each feature a fair contribution with

respect its influence on the model's prediction. In (Štrumbelj and Kononenko, 2010) a solution is proposed that is equivalent to the Shapley value (Shapley, 1953) for the coalitional game with the n features as players and Δ as the characteristic function. The contribution of the i-th feature is defined as follows:

$$\varphi_i(x) = \sum_{Q \subseteq S\{i\}} \frac{|Q|!(|S|-|Q|-1)!}{|S|!}(\Delta Q \cup \{i\})(x) - \Delta(Q)(x)). \qquad (2)$$

These contributions have some desirable properties. Their sum for the given instance x equals $\Delta(S)$, which was our initial goal and ensures implicit normalization. A feature that does not influence the prediction will be assigned no contribution. And, features that influence the prediction in a symmetrical way will be assigned equal contributions.

The computation of Eq. (2) is infeasible for large n as the computation time grows exponentially with n. The approximation algorithm is proposed in (Štrumbelj and Kononenko, 2010; 2011), where we show its efficiency and effectiveness. It is based on the assumption that p is such that individual features are mutually independent. With this assumption and using an alternative formulation of the Shapley value we get a formulation which facilitates random sampling. For a global view on features'contributions, we define the contribution of the feature's value as the expected value of that feature's contribution for a given value. Again, random sampling can be used to estimate the expected value (Štrumbelj and Kononenko, 2011).

Let us illustrate the use of the features' local and global contributions using a simple data set with 5 numerical features A_1,..., A_5 with unit domains [0,1]. The binary class value equals 1 if $A_1 > 0.5$ or $A_2 > 0.7$ or $A_3 > 0.5$. Otherwise, the class value is 0. Therefore, only the first three features are relevant for predicting the class value. This problem can be modeled with a decision tree. Figure 1 shows explanations for such a decision tree. The global contributions of each feature's values are plotted separately. The black line consists of points obtained by running the approximation algorithm for the corresponding feature and its value corresponing the value on the x-axis. The lighter line corresponds to the standard deviation of the samples across all values of that particular feature and can therefore be interpreted as the overall importance of the feature. The lighter lines reveal that only the first three features are important. The black lines reveal the areas where features contribute towards/against class value 1. For example, if the value of feature A_1 is higher than 0.5 it strongly contributes towards class value being 1. If it is lower, it contributes against class value being 1.

For example, the instance x = (0.47, 0.82, 0.53, 0.58, 0.59) belongs to class 1, which the decision tree correctly predicts. The visualization on Figure 2 shows the individual features' contributions for this instance.

The last two features have a 0 contribution. The only feature value that contributes towards class = 1 is A_2 = 0.82, while the remaining two features' values have a negative contribution.

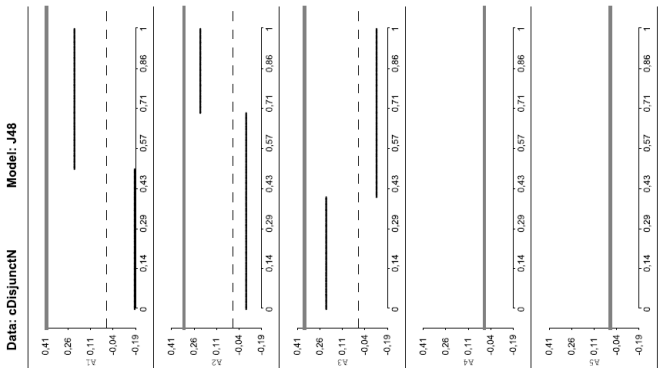

Figure 1: *Explanation of a decision tree*

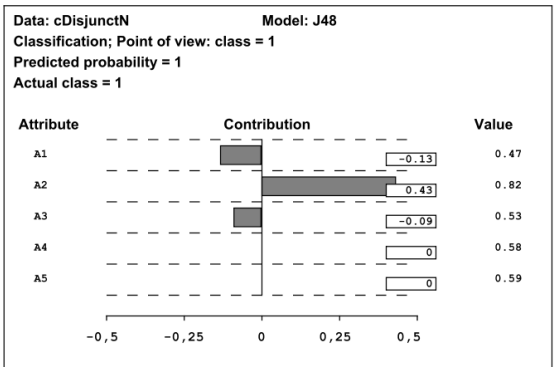

Figure 2: *Visualization of the individual features' contributions for particular instance*

We have successfully applied this research to post-processing tools for breast cancer recurrence prediction (Štrumbelj et al., 2010), maximum shear stress prediction from hemodynaic simulations (Bosnić et al., 2011), and businesses' econonomic results precition (Pregeljc et al., 2012).

3 RELIABILITY OF INDIVIDUAL PREDICITONS

Because model independent approaches are general, they cannot exploit specific parameters of a given predictive model, but rather focus on influencing the parameters that are available in the standard supervised learning framework (e.g. a learning set and attributes). We expect from reliability estimators to give insight into the prediction error and we expect to find positive correlation between the two. The first two algorithms described in this Section arebased on Reverse transduction and Local sensitivity analysis and follow the same transductive idea, though the first is applicable only to classification, and the second to regression models. Other algorithms are general and need only minor adaptations when converted from regression to classification models, or vice versa.

3.1 Reverse transduction and Local sensitivity analysis

Transduction can be used in the reverse direction, in the sense of observing the model's behavior when inserting modified learning instances of the unseen and unlabeled instance (Kukar and Kononenko, 2002). Let x represent an

instance and let y be its class label. Let us denote a learning instance with known label y as (x, y) and let $(x, \_)$ be an unseen and unlabeled instance, for which we wish to estimate the reliability of an initial prediction K. It is possible to create a modified learning instance by inserting the unseen instance $(x, \_)$ into the learning set and label it with the same (*first*) or different class (*second* best or *last*) as predicted by the initial model. The distance between the initial probability vector and that from the rebuilt model forms the reliability estimate. The three reliability estimators for classification models derived from three instances are labeled $TRANS_{first}$, $TRANS_{second}$ and $TRANS_{last}$.

In the regression the procedure is similar except that the predicted label is first slightly corrupted: $y = K + \delta$ and then we insert the newly generated instance (x, y) into the learning set and rebuild the predictive model. We define $\delta = \varepsilon(l_{max} - l_{min})$, where ε expresses the proportion of the distance between largest (l_{max}) and smallest (l_{min}) prediction. In this way we obtain a sensitivity model, which computes a sensitivity estimate $K\varepsilon$ for the instance $(x, \_)$. To widen the observation window in local problem space and make the measures robust to local anomalies, the reliability measures use estimates from the sensitivity models, gained and averaged across different values of $\varepsilon \in E$. For more details see (Bosnić and Kononenko, 2007). Let us assume we have a set of nonnegative ε values $E = \{\varepsilon_1, \varepsilon_2, ..., \varepsilon_{|E|}\}$. We define the estimates as follows:

- Estimate *SAvar* (Sensitivity Analysis local variance):

$$SAvar = \frac{\sum_{\varepsilon \in E}(K_\varepsilon - K_{-\varepsilon})}{|E|} \tag{3}$$

- Estimate *SAbias* (Sensitivity Analysis local bias):

$$SAbias = \frac{\sum_{\varepsilon \in E}(K_\varepsilon - K) + (K_{-\varepsilon} - K)}{2|E|} \tag{4}$$

3.2 Bagging variance

In related work, the variance of predictions in the bagged aggregate of artificial neural networks has been used to estimate the reliability of the aggregated prediction (Heskes, 1997; Carney and Cunningham, 1999). The proposed reliability estimate is generalized to other models (Bosnić and Kononenko, 2008).

Let K_i, $i = 1 \ldots m$, be the predictor's class probability distribution for a given unlabeled example $(x, \_)$. Given a bagged aggregate of m predictive models, where each of the models yields a prediction B_k, $k = 1 \ldots m$, the reliability estimator *BAGV* is defined as the variance of predictions' class probability distribution:

$$BAGV = \frac{1}{m}\sum_{k=1}^{m}\sum_i (B_{k,i} - K_i)^2. \tag{5}$$

The algorithm uses a bagged aggregate of 50 predictive models as default.

3.3 Local cross-validation

The *LCV* (Local Cross-Validation) reliability estimate is computed using the local leave-one-out (LOO) procedure. Focusing on the subspace defined by k nearest neighbors, we generate k local models, each of them excluding one of the k nearest neighbors. Using the generated models, we compute the leave-one-out predictions K_i, $i = 1 \ldots k$, for each of the k excluded nearest neighbors. Since the labels C_i, $i = 1 \ldots k$, of the nearest neighbors are known, we are able to calculate the local leave-one-out prediction error as the average of the nearest neighbors' local errors:

$$LCV = \frac{1}{k}\sum_i |C_i - K_i|. \tag{6}$$

In experiment, the parameter k was assigned to one tenth of the size of the learning set.

3.4 Local error modeling

Given a set of k nearest neighbors, where C_i is the true label of the i-th nearest neighbor, the estimate CNK ($C_{Neighbors} - K$) is defined as the difference between average label of the k nearest neighbors and the instance's prediction K:

$$CNK = \frac{\sum_i C_i}{k} - K. \tag{7}$$

CNK is not a suitable reliability estimate for the k-nearest neighbors algorithm, as they both work by the same principle. In our experiments we used $k = 5$. In regression tests, *CNK-a* denotes the absolute value of the estimate, whereas *CNK-s* denotes the signed value.

3.5 Density based estimation

This approach assumes that an error is lower for predictions in denser problem subspaces, and higher for predictions in sparser subspaces. Note that it does not consider the learning instances' labels. The reliability estimator *DENS* is a value of the estimated probability density function for a given unlabeled example.

3.6 Empirical evaluation of estimators

For testing, 20 standard benchmark data sets were used for classification and 28 data sets for regression problems, gathered from UCI Machine Learning Repository (Asuncion & Newman, 2007) and from the StatLib DataSets Archive (Department of Statistics at Carnegie Mellon University, 2005). We tested the reliability estimators with eight regression and seven classification models, all implemented in statistical package R (decision and regression trees, linear regression, ANN, SVM, bagging, k-nearest neighbors, locally weighted regression, random forests, naive Bayes and generalized additive model). The testing was performed using a leave-one-out cross-validation. For each learning instance left out in each iteration, a prediction and all the reliability estimates were computed. In classification, the performance of the reliability estimates was measured by computing the Spearman correlation coefficient between the reliability estimate and the prediction error. In regression

tests, the Pearson correlation coefficient was used. Figure 3 presents the results for regression, showing the average performance of reliability estimates ranked in the decreasing order with respect to the percent of positive correlations (a similar figure was obtained for classification, except that the order of measures was, from the best towards the worse: LCV, BAGV, CNK, $TRANS_{first}$, $TRANS_{second}$, $TRANS_{last}$, *DENS*). The results indicate that the estimators $TRANS_{first}$, *SAbias*, *CNK*, *BAGV* and *LCV* have a good potential for estimation of the prediction reliability.

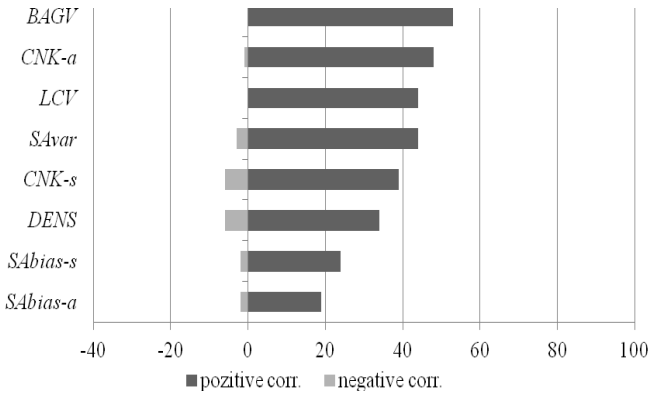

Figure 3: *Ranking of reliability estimators by the average percent of significant positive and negative correlation with the prediction error in regression experiments.*

The proposed reliability estimation methodology has been implemented in several applications of machine learning and data mining, e.g. breast cancer recurrence prediction problem (Štrumbelj et al., 2010), electricity load forecast prediction problem (Bosnić et al., 2011), and predicting maximum wall shear stress magnitude and position in the carotid artery bifurcation (Bosnić et al., 2012).

4 CURRENT LKM RESEARCH DIRECTIONS

Current LKM research is focused on several topics:

- evaluation of ordinal features in the context of surveys and customer satisfaction in marketing;
- learning of imbalanced classification problems;
- applying evolutionary computation to data mining, focused on using ant colony optimization;
- prediction intervals which represent the distribution of individual future points in a more informative manner;
- spatial data mining with multi-level directed graphs;
- employing background knowledge analysis for search space reduction in inductive logic programming;
- profiling web users in an online advertising network;
- employing algebraic methods, particularly matrix factorization for text summarization;
- detection of (non)-ischaemic episodes in ECG signals;
- heuristic search methods in clickstream mining;
- implementation and evaluation of reliability estimators in online learning (data streams);
- adaptation of the explanation methodology for online learning (data streams);
- modelling the progression of team sports matches and evaluation of the individual player contribution.

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ORANGE: DATA MINING FRUITFUL AND FUN

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ABSTRACT

Orange (http://orange.biolab.si) is a general-purpose machine learning and data mining tool. It features a multi-layer architecture suitable for different kinds of users, from inexperienced data mining beginners to programmers who prefer to access the tool through its scripting interface. In the paper we outline the history of Orange's development and present its current state, achievements and the future challenges.

1 INTRODUCTION

The history of general-purpose machine learning software tools is short but eventful. It all started with utilities that implemented a specific induction method and printed out the model in a textual form, to be then scrutinized and admired by the user. Such were implementations of tree and rule inducers C4.5 [1] and CN2[2] in the 1980s. Contender of C4.5 was Assistant Professional [3], but as C4.5 came free with a book, and Assistant Professional was pricy, C4.5 took off and became, in the last century, perhaps the most known machine learning program and, in the spirit of free software, a precursor of open-source toolboxes.

In the 1990s, machine learning community grew substantially and so did the number of different approaches and the desire to have a single toolbox where these could be implemented, used and tested against the same data sets. Packages like IND and MLC++[1] took off, each with set of command-line utilities that also implemented some testing schemes and could report on evaluation scores.

Having a command-line utility and only a textual interface is actually very cumbersome, if, imagine, a medical doctor asks you which patients actually went to some branch of the tree. Or what is their blood pressure? Command-line data analytics is no fun. Thus, systems with graphical user interfaces emerged. Not only systems with data plotting capabilities like R[2], but instead those where graphics was interactive and where a user could query on some graphical element to get the information of what data it represents. SGI's MineSet[4], for one, was a commercial product build on a top of MLC++ and implementing what was for 1990s an advanced exploratory graphical interface. There was one problem: the data analysis pipeline was fixed. Read the data, visualize the tree, explore it. Or show pie charts for naïve Bayesian Classifier.

People are in general inquisitive. That is, given the data, we like to dissect it, build some models, observe its parts, consider their specific data subsets and dissect it further. We like to construct the data analysis pipelines, not just use it. The ideas of visual programming, an interface where pipelines are created by linking pre-defined or even user-designed components, was in early 1990s available from Sun and SGI in packages for data visualization like Data Explorer. Similar idea in data mining took off by Clementine (then bought by SPSS and in 2009 renamed to SPSS Modeler). Open-source toolboxes followed; Weka[3], Knime[4], Yale (what is now a much redesigned RapidMiner[5]), and Orange[6]. Each building on their own favorite programming languages, assembling a different set of core components, and offering their own landmark interface for explorative data analysis.

The authors of this paper are great believers in component-based software. Along came Python, Qt for interoperability and the visual programming. Orange was born in mid 1990s, and is, along Weka and R, a data analysis toolbox with perhaps a longest (short) history. We still enjoy it, and continue to improve it.

2 HISTORY OF ORANGE

Development of Orange began in 1997 by the two authors of this paper, then members of the Artificial Intelligence Laboratory and now at Laboratory of Bioinformatics, at the University of Ljubljana.

Orange as a library of C++ components and command-line utilities. Orange was first conceived as a C++ library of machine learning algorithms and related procedures, like preprocessing, sampling and other data manipulation. We soon found out, though, that we seldom needed to write specialized applications that would require the use of C++ components. Instead, Orange was mostly used for data exploration in which different combinations of preprocessing and learning algorithms were tested and scored using cross validation. The components were packed into programs that could be used via command line interface. As this has soon proven limiting, we decided to provide a scripting interface to these components by exposing them to Python.

[1] http://www.sgi.com/tech/mlc
[2] http://www.r-project.org
[3] http://www.cs.waikato.ac.nz/ml/weka
[4] http://www.knime.org
[5] http://rapid-i.com
[6] http://orange.biolab.si

Orange as Python module. Python is a modern scripting language that was chosen for variety of reasons.

- It has a very clean and simple syntax that is easy to learn not only for a programmer but also for a beginner. (Python is, in fact, becoming the language of choice for basic courses in programming at many leading US universities, including CMU, MIT, Berkeley, Rice and Caltech.)
- Despite its simplicity, Python is an industry-strength language. For instance, Python is behind many of Google's technologies, which is also why Google is one of the major sponsors of Python's development.
- Since programming in Python is fast, it is very suitable for prototyping of new methods.
- Python allows for relatively easy extension with modules written in C or C++. For this reason, Python is occasionally dubbed a glue language due to its use for gluing libraries in C or Fortran. Lately, one seldom needs to implement specialized routines in low level languages due to availability of high quality libraries like numpy and scipy.

From 1999, Orange was used almost exclusively as a Python module. While the C++ core eventually rose to around 140,000 lines of code in C++, most developers have been adding to its Python modules and avoiding C++.

Transition to Python enabled several important developments. More and more of Orange's functionality is implemented in pure Python or by combining the fast functions provided by the Orange core using the glue code written in Python. Since the programs in Python are so readable, they enable collaboration of larger teams without the need to coordinate the development and establish a set of coding standards. The size of the group that develops the system has increased to 10-15 members, mostly from (today's) Laboratory of Bioinformatics. Most importantly, migration to Python simplified the development of the graphical user interface.

Orange Visual Programming. Our group has a tradition of collaboration with partners from other scientific and industrial areas, in particular from biomedicine. We wished to provide them with a data exploration tool where they could design their own data analysis pipelines without any scripting or Python programming [5]. Among a number of different Python libraries for GUIs we decided for Qt, which is a strong cross-platform library available under both GPL and commercial licenses and is behind products as different as Skype and KDE desktop.

Majority of current users now use Orange only through its graphical interface. It consists of a canvas onto which the users place pipeline components called widgets. Each widget offers some basic functionality, like reading the data, showing a data table, selecting features, either manually or based on some feature scoring, training predictors, cross-validating them and so forth. The user connects the widgets by communication channels. The basis strength and flexibility of Orange is in different ways in which the widgets can be combined into new schemata.

Special emphasis in development and design of widget was placed on data visualization and interactivity. For instance, a classification tree viewer allows the user to click a node in the tree. Doing so transmits the data samples that belong to the node to any widgets connected to the tree viewer widget. The user can thus construct a tree and then explore its content by observing, say, a data table with the data instances from interesting nodes, or, for example, by drawing scatter plots for data from different nodes of the tree.

3 ORANGE IN 2012

Currently, Orange is, together with Knime, perhaps one of the easiest-to-use data mining tools around. It can be run on OS X, Windows and Linux, and can also be parallelized on a grid.

The default installation includes a number of machine learning, preprocessing and data visualization algorithms. Opposed to, for instance, Weka, that offers everything there is in machine learning, the goal of Orange was to implement the most useful and commonly used techniques in a way that is flexible and user-friendly; the emphasis of the tool is on data exploration. For instance, the machine learning algorithms in the default installation are limited to naive Bayesian classifier, k nearest neighbors, induction of rules and trees, support vector machines, neural networks, linear and logistic regression, and ensemble methods. Most methods are, however, coupled with a visual representation that allows for exploration of the resulting module; the user can select a node in a classification tree or a rule and explore the training instances covered by them. Naive Bayesian classifier, logistic regression and linear SVM can be explored through nomograms that offer insight into importance of features and their individual values, and can also be used for explaining the model's predictions. Similar goes for unsupervised methods, such as association rules, multidimensional scaling, self-organizing maps and various types of clustering.

For a contrast from the intentionally limited assortment of machine learning methods, Orange has a rich collection of visualization methods: besides the common visualizations, like box plots, histograms and scatter plots, it contains a number of multivariate visualizations such as parallel coordinates, mosaic display, sieve diagram, survey plots and a number of data projection techniques, like multi-dimensional scaling, principal component analysis, RadViz, FreeViz and others. The user can interactively explore the visualizations or connect them to other widgets that send or receive the data from the visualization. Orange can also help the user in finding insightful visualizations by automatically ranking them by interestingness or by organizing them into a network of visualizations.

Orange also contains powerful widgets for visualization and exploration of networks, again with focus on interaction and flexibility.

Orange can be extended with additional modules. We currently provide an extensive collection of methods for

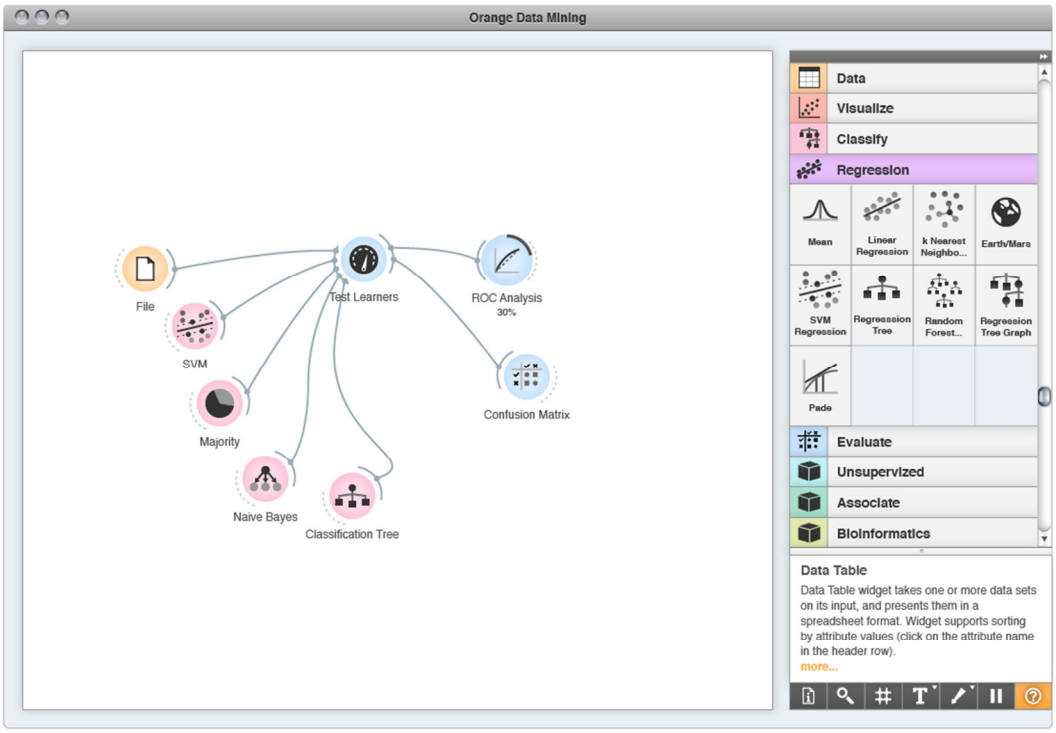

Figure 1. The design of a graphical interface for the upcoming version of Orange (by Peter Čuhalev). The pipeline in the figure reads the data (File widget), sends it to Test Learners which cross validates four different learners on its input and sends it for graphical analysis of an ROC curve and to widget with interactive display of confusion matrix. The data visualizations are not shown in the Figure and are obtained by double-clicking the selected widget.

bioinformatics, as well as modules for text mining and multi-target learning.

The system is being actively developed by a group of about dozen members and collaborators of the Laboratory of bioinformatics, occasionally helped with students of the Faculty of Computer and Information Science and abroad. Development has also been sponsored by Google through its Summer of Code schema.

Orange has been used in science, industry and for teaching. Scientifically, it is used as a testing platform for new machine learning algorithms, as well as for implementing new techniques in genetics and other fields of bioinformatics. At present, the most notable industrial partner is Astra-Zeneca, a pharmaceutical giant, who uses Orange in drug development and sponsors the development of several related parts of Orange. At Jožef Stefan Institute, the visual programming interface has been upgraded in Orange4WS[7] to support service-oriented architectures. Finally, Orange is being used for teaching courses in machine learning and data mining in countries around the world, including the US, Italy, France, Japan, Turkey, Cuba and Peru.

4 FUTURE DEVELOPMENTS

The landscape of Python's libraries has been strongly affected by reorganizing the Numeric and its unfortunate successor numarray into numpy[8]. This has become a standard library for scientific computing in Python. numpy provides arrays of arbitrary dimensions and linear algebra routines from BLAS and ATLAS, and another library, scipy, adds many other common scientific routines, from statistical functions to fast Fourier transforms. A library called scikit-learn is another software that is build on numpy and relies on its fast vectorized operations; scikit-learn[9] contains high quality implementations of most machine learning algorithms and is widely used by the community.

Today we recognize that the power of Orange is not as much in its machine learning algorithms, which should in fact be complemented by several superior ones in scikit-learn, but rather in the way in which these algorithms are packed and exposed to Python scripting in a simpler form. Beyond that, an even stronger feature of Orange is its graphical user interface and visual programming environment, which other Python-based libraries for machine learning lack.

We are intensely working on a new version of Orange in which we will replace the entire C++ core with routines in numpy, scipy, scikit-learn and similar 3rd party open source libraries for Python. This will encourage the contributions from outside of the group, and at the same time allow us to concentrate on development of just those parts in which we are most experienced and in which Orange excels. With it and planned for early 2013 is also a revamped user interface (Figure 1) and http://myflow.io, a platform with a web-based interface to Orange.

[7] http://orange4ws.ijs.si
[8] http://numpy.scipy.org
[9] http://scikit-learn.org

Acknowledgements
Development of Orange is a team effort of many developers and we thank them all for enthusiasm and support. Major contributions to the package were in the past years made by Aleš Erjavec, Gregor Leban, Tomaž Curk, Marko Toplak, Miha Štajdohar, Anže Starič, Matija Polajnar, Lan Žagar, Jure Žbontar, Mitar Milutinović, Lan Umek, Črt Gorup, Martin Možina, Gregor Rot, Aleks Jakulin and designers Peter Čuhalev and Roman Ražman.

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Zbornik 15. mednarodne multikonference

INFORMACIJSKA DRUŽBA – IS 2012

Proceedings of the 15th International Multiconference

INFORMATION SOCIETY – IS 2012

Inteligentni sistemi

Intelligent Systems

Uredila / Edited by

Marko Bohanec, Matjaž Gams

http://is.ijs.si

12. oktober 2012 / October 12th, 2012
Ljubljana, Slovenia

PREDGOVOR

V letu 2012 praznujemo stoletnico Alana Turinga, očeta umetne inteligence in inteligentnih sistemov. Konferenca Inteligentni sistemi je tudi letos, tako kot vsa pretekla leta od 1997 dalje, potekala v okviru multikonference Informacijska družba. Konferenca se ukvarja s pomembnim vidikom informacijske družbe: inteligentnimi sistemi in inteligentnimi storitvami. Ključna tema pa so programski sistemi v informacijski družbi oziroma konkretne tehnične rešitve v inteligentnih sistemih, možnosti njihove praktične uporabe, pa tudi trendi, perspektive, nujni ukrepi, prednosti in slabosti, priložnosti in nevarnosti, ki jih v informacijsko družbo prinašajo inteligentni sistemi.

Tudi letos konferenca Inteligentni sistemi sestoji iz mednarodna dela in delavnice; prispevki so tako v slovenskem kot angleškem jeziku. V osrednjem konferenčnem delu je predstavljenih sedem prispevkov, skupno 27. Vsi ti prispevki so bili recenzirani s strani vsaj po dveh anonimnih recenzentov, avtorji pa so prispevke popravili po navodilih recenzentov. V ločeni sekciji pa so predstavljeni prispevki Delavnice E9. Večina prispevkov obravnava raziskovalne dosežke v Odseku za inteligentne sisteme Instituta Jožef Stefan. Hkrati s predstavitvijo poteka tudi aktivna analiza prispevkov vsakega predavatelja in diskusija o bodočih raziskavah.

Marko Bohanec in Matjaž Gams

PREFACE

This year marks the centenary of Alan Turing, father of artificial intelligence and intelligent systems. The conference Intelligent Systems remains a traditional part of the multiconference Information Society since its beginnings in 1997. The conference addresses an important aspect of information society: intelligent computer-based systems and the corresponding intelligent services. Specifically, it addresses technical aspects of intelligent systems, their practical applications, as well as trends, perspectives, advantage and disadvantages, opportunities and threats that are being brought by intelligent systems into the information society.

As previously, the conference Intelligent Systems 2012 consists of an international event and the workshop, and presents papers written in both English and Slovenian language. The international part of this Proceeding includes seven papers, altogether 27. All these papers have been reviewed by at least two anonymous reviewers, and the authors have modified their papers according to the remarks. In a separate section, papers from the E9 workshop are presented. Most of them present research at the Department of Intelligent Systems at the Jožef Stefan Institute, Ljubljana, Slovenia. Each presentation consists of the classical paper report, and further includes analysis of the researcher's achievements and future research of each presenter in the workshop manner.

Marko Bohanec and Matjaž Gams

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Vabljeno predavanje

Invited lecture

MICRO UAV ROUTING FOR MONITORING OF DISASTER AREAS

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In disaster situation a quickly obtained and regularly updated overview image of an area provides essential information for the rescue mission planning. Such an overview image can be composed from the individual pictures taken by a fleet of Unmanned Aerial Vehicles (UAVs). However, currently drones are remotely controlled by humans during such missions. To the best of our knowledge, no research has been conducted on the problem of UAV routing for such task. Therefore, we propose a method based on the well-known metaheuristic Variable Neighborhood Search. In particular, we developed two new heuristics to construct the initial solution and an additional neighborhood operator. Computational experiments indicate that solutions obtained by our metaheuristic do not exceed the optimum by more than 26.9\% on small scenarios. For the large instances with hundreds of points (where no optimal solution is known) the proposed method constructs feasible solutions in less than one second.

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INTELIGENTNI SISTEMI

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INTELLIGENT SYSTEMS

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SEMI-SUPERVISED LEARNING IN DIVERSE QUANTITATIVE STRUCTURE-ACTIVITY MODELING PROBLEMS

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ABSTRACT

The goal of this study was to compare the performance of semi-supervised and supervised machine learning methods applied to various problems of modeling Quantitative Structure Activity Relationship (QSAR) in sets of chemical compounds. Semi-supervised learning utilizes unlabeled data in addition to labeled data with the goal of building better predictive models than can be learned by using labeled data alone. Typically, labeled QSAR datasets contain tens to hundreds of compounds, while unlabeled data are easily accessible via public databases containing thousands of chemical compounds: this makes QSAR modeling an attractive domain for the application of semi-supervised learning. We tested four different semi-supervised learning algorithms on three different datasets and compared them to five commonly used supervised learning algorithms. While unlabeled data does help for certain datasets, semi-supervised learning is not clearly superior to supervised learning across the QSAR classification problems addressed by this study.

1 INTRODUCTION

Traditional approaches to machine learning are supervised learning (e.g., classification, regression) where all the data are labeled and unsupervised learning (e.g., clustering, dimensionality reduction) where all the data are unlabeled. The semi-supervised learning (SSL) paradigm [16] examines how merging both types of data (labeled and unlabeled) affects learning, with the goal to benefit from the information that unlabeled data bring in the context of the supervised learning tasks. SSL is of important practical value since the following scenario often holds true: labeled data are scarce and hard to get because they require human experts, expensive devices or time-consuming experiments, while, at the same time, unlabeled data abound and are easily obtainable.

Establishing a connection between biological effects and structural and/or physicochemical properties of chemicals is the task of *quantitative structure-activity relationship* or QSAR. Formal studies of such relationships have proven to be the basis for the development of predictive models. The main value of a predictive QSAR model is gaining insight into the biological activity of a molecule without the need to synthesize it. This leads to a number of benefits including savings in the cost and duration of product development (e.g., in the pharmaceutical or pesticide areas), reduction of the need for animal testing, prediction of unwelcome or toxic environmental impact, and overall improvement in the efficiency of drug molecular design.

The application of SSL to the domain of QSAR modeling is particularly attractive since the premise: "labeled data are scarce, while unlabeled data abound" is generally satisfied. Public databases with (hundreds of) thousands of chemical compounds are available (e.g., the human tumor cell line screen database from the U.S. National Cancer Institute's Developmental Therapeutics program), while labeled datasets sizes typically range in tens to hundreds and rarely surpass a thousand molecules.

In this work, we empirically investigate whether we can successfully apply SSL (i.e., whether we can achieve better performance with SSL than with supervised learning) to build predictive QSAR models. To draw reliable conclusions, we use several SSL methods which embody different approaches, together with three QSAR datasets from various domains. We compare the SSL methods to several commonly used supervised learning methods. The results show that the improvements which SSL yields are selective - the degree to which unlabeled data help varies from notable to insignificant, depending on the dataset or SSL method used.

2 SEMI-SUPERVISED LEARNING

In this study, we are concerned with semi-supervised classification, while other forms of SSL, such as semi-supervised regression or semi-supervised clustering are not considered.

In order for SSL to work, the knowledge we gain trough unlabeled data has to carry some information about the class labels. If this prerequisite is fulfilled, we can draw on unlabeled data by making certain assumptions about the behavior of labels with respect to the structure of unlabeled data. Different assumptions inspire different classes of algorithms; therefore, SSL methods can be grouped on the basis of the assumption(s) they implement as follows: (i) *low-density separation methods* assume that the decision

boundary should lie in the region of low density of the data (e.g., semi-supervised support vector machines); (ii) *graph-based methods* use nodes for data representation (labeled and unlabeled) and edges (similarity of the data points) for propagation of the labels through the graph, assuming label smoothness over the graph; (iii) *generative models* assume a probabilistic model of the data and use unlabeled data to estimate the model parameters; (iv) *self-training* and *co-training* are two very often used SSL algorithms, since they can be "wrapped" around any supervised learning algorithm; they iteratively use their own most reliable predictions in the training process.

These assumptions are at the heart of SSL, but also represent the main risk: a bad match of a problem structure to a method's assumption can cause degradation of performance when using unlabeled data [2]. This is a particularly relevant issue since it is not yet clearly understood which SSL method should be used for which problem. We tackled the difficulties of matching problem structure with the right SSL method empirically, i.e., by selecting methods which differ in the approach. We tried to cover most of the groups of methods mentioned earlier. The methods we used will be described in Section 4.

3 QSAR datasets

To better assess the performance of SSL algorithms in the domain of QSAR modeling, we extracted three different datasets from publicly available sources. These are the NCI, Mutagenicity and MUSK dataset. The datasets differ in terms of the biological activity they model, the number and type of molecular descriptors used to represent molecules, and the number of compounds (size of the dataset).

3.1 NCI dataset

The NCI datasets was extracted from the human tumor cell line screen database [9] of the National Cancer Institute's Developmental Therapeutics (NCI-DTP) program (October 2009 release). At NCI-DTP, they measure cytostatic activity of chemical compounds against 60 human tumor cell lines. For representation of a compound's cytostatic activity we used GI_{50} measurements – the concentration that inhibits tumor growth by 50%. Only compounds that have at most 20 missing or default values were accepted. Additionally, cell lines with more than 20% of missing values were removed, leaving 49 cell lines in total. In addition to GI_{50} profiles, the molecules were represented with two other groups of attributes: molecular descriptors describing the structure of a molecule (calculated with DRAGON 3.0 web interface [14]), and with molecular charge densities and charge density-based electric properties of a molecule (calculated with RECON software [4]).

The subject of interest for the NCI dataset is to predict a compound's mechanism of action (MOA) – the specific biochemical reaction in which the molecule interacts with enzymatic targets. The type of MOA influences the pharmacological effects of a molecule; therefore, the drug discovery process will benefit from the early detection of an optimal MOA. The NCI dataset belongs to multiclass classification problem, i.e., we model 12 different classes of MOA, where each molecule belongs to a single class. This dataset is essentially an updated and extended version of the data used in previous analyses of cytostatic activities and MOA in the NCI database using self-organizing maps [11, 12].

3.2 Mutagenicity dataset

The Mutagenicity dataset (obtained from [8]) is the benchmark dataset for modeling of Ames mutagenicity. The Ames test is a standard experimental procedure for assessing the mutagenic potential of a chemical compound. The compound which is positive to the test can cause mutations on the DNA (and consequently can be carcinogenic); an important property of a drug-candidate molecule is not to be mutagenic.

The mutagenicity dataset is a binary classification problem where compounds are classified as mutagenic or non-mutagenic. Molecules from this dataset were represented using DRAGON molecular descriptors [14].

3.3 MUSK dataset

The MUSK dataset was downloaded from the UCI machine learning repository. Musk, a substance secreted by the Asian musk deer (*Moschus moschiferus*), is largely used by the perfume industry. It's one of the most expensive animal products; therefore, synthetic musk compounds are often used instead. The prediction of strength of the synthetic musk compounds has similar properties to the prediction of biological drug activity – the molecules are similar in size and composition to the orally active drug molecules [5].

A single molecule can adopt multiple conformations – different shapes of the same molecule, where some of the internal bonds rotate. The features that describe compounds from the MUSK dataset depend on the exact shape (conformation) of a molecule ("distance features" and displacement of oxygen, for exact description see [5]), where each molecule is represented by several feature vectors. This dataset was assembled by generating low-energy conformations of molecules which were then filtered to remove highly similar conformations. The molecules from the MUSK dataset were categorized by human experts to be musk or non-musk.

4 EXPERIMENTAL SETUP

To evaluate the potential of SSL in a controlled manner, our experiments were carried out using only labeled data. We simulated situations where we have different ratios of labeled and unlabeled data by temporarily ignoring the class label for a portion of the data. The data were randomly split into training and test set. Supervised and semi-supervised methods used the training set for learning and were then evaluated using the test set. For the SSL methods, the test set served as unlabeled data during the learning process. Several different train/test splits were produced where

labeled data ranges from 1% to 66% (i.e., unlabeled data ranges from 99% to 33%). The final results were averaged over 10 different train/test split repetitions. We performed experiments using the Weka [7] machine learning environment and the R [13] environment for statistical computing.

4.1 Datasets

As described in Section 3, we conducted experiments on three different QSAR datasets. The NCI dataset contains 507 compounds, each described with: GI_{50} profiles (49 features), DRAGON descriptors (1497 features) and RECON descriptors (248 features). The Mutagenicity dataset is the largest with 6512 compounds represented with 1497 DRAGON descriptors. The MUSK dataset has 166 features and 476 examples, which correspond to different conformations of 92 molecules.

4.2 Methods

We used publicly available implementations of SSL algorithms. As mentioned in Section 2 we selected the SSL algorithms to cover different groups of SSL methods. The algorithms used are: Yet Another Two Stage Idea (YATSI), Co-training: Fitting the Fits (Co-FTF), Learning with Local and Global Consistency (LLGC) and $TSVM^{Light}$.

The YATSI [6] algorithm, implemented in the Weka Collective Classifiers package, is similar to the self-training concept, since it can be wrapped around any classifier and it uses its own predictions in the training process. As the name implies, YATSI works in two steps. First, a base classifier is trained on the labeled data and then unlabeled data is "pre-labeled". This pre-labeled data is then given weights and used by the nearest neighbors classifier to improve on the initial classifier.

Co-FTF [3] is an implementation of the co-training algorithm in the R programing language. Co-FTF uses two different features sets (views) to train separate classifiers, which iteratively use their most confident predictions as additional labeled training data. It is assumed that views provide different, complementary information about the data. We applied Co-FTF only to the NCI dataset (the other datasets do not meet the prerequisite for different views) with the combination of the descriptors which proved to be the best: RECON and DRAGON. The baseline classifier for Co-FTF was random forests classifier.

LLGC [15] is graph-based method implemented in the Weka Collective Classifiers package. LLGC performs spectral clustering and then propagates labels through the graph using a spreading activation network.

$TSVM^{Light}$ [10] is a representative of the low-density separation methods. It implements a semi-supervised version of support vector machines by finding the locally optimal solution.

The supervised machine learning methods we have compared with SSL methods are: decision trees (J48), k-nearest neighbors (KNN), Naive Bayes (NB), support vector machines (SMO and SVM^{Light}) and random forests (RF).

We used J48, NB and SMO methods with the default parameters and RF with 500 trees. For other algorithms, we searched parameter space for the ones which produce the best classification accuracy.

5 RESULTS AND DISCUSSION

In this section we present the experimental comparison of performance of semi-supervised and supervised machine learning methods. In Tables 1-3, the predictive accuracies for different ratios of labeled and unlabeled data are presented. The best result for each ratio is shown in bold, and whether YATSI exhibited improvement in accuracy over the baseline classifier is marked with an upward (improvement) or downward (deterioration) arrow. The baseline classifier for YATSI is given in brackets. The number of neighbors for the KNN algorithm is indicated (e.g., 1NN).

Semi-supervised methods behave differently over the three datasets. Improvements of semi-supervised over supervised learning are most notable for the NCI dataset with a small percentage of labeled data (≤10%), where LLGC achieves the best overall predictive accuracy and YATSI significantly improves the baseline classifier in most cases. For the other two datasets, Mutagenicity and MUSK, semi-supervised and supervised algorithms show very similar performance with small improvements of SSL over SL in some cases. Generally, the improvements achieved by YATSI over baseline classifier are more frequent and significant for the less complex classifiers (KNN, J48, NB), while for classifiers with greater capacity for learning (RF, SMO) the improvements are not so regular and are sometimes negative, i.e., the usage of YATSI even deteriorates their predictive accuracy.

	Algorithm	Percentage of labeled data				
		5%	10%	20%	33%	66%
Supervised learning	J48	45.93	57.98	69.05	76.31	81.92
	1NN	47.45	67.19	78.14	82.73	86.80
	NB	42.41	51.19	66.13	74.49	84.14
	SMO	62.80	73.15	**83.42**	**87.41**	**92.69**
	RF	56.24	66.32	78.29	84.14	88.64
Semi-supervised learning	YATSI(J48)	55.37↗	68.27↗	78.54↗	83.31↗	84.87↗
	YATSI(1NN)	58.87↗	70.89↗	79.95↗	82.79↗	86.50↘
	YATSI(NB)	54.70↗	65.96↗	75.61↗	81.67↗	83.03↘
	YATSI(SMO)	62.06↘	72.69↘	81.99↘	84.76↘	87.59↘
	YATSI(RF)	58.76↗	68.44↗	79.11↗	83.46↘	86.32↘
	LLGC	**66.50**	**74.95**	82.46	85.46	88.29
	Co-FTF	-	35.78	51.16	65.43	76.45

Table 1 Predictive accuracies of semi-supervised and supervised learning methods on the NCI dataset

	Algorithm	Percentage of labeled data			
		1%	5%	10%	20%
Supervised learning	J48	58.40	63.98	67.08	69.97
	1NN	58.32	64.24	64.71	67.86
	NB	57.80	60.40	61.10	60.79
	SMO	61.86	68.95	72.41	**75.41**
	RF	62.13	68.68	71.27	73.68
	SVM^{Light}	**62.73**	69.29	72.52	75.16
Semi-supervised learning	YATSI(J48)	58.85↗	65.78↗	68.19↗	70.88↗
	YATSI(1NN)	58.45↗	64.57↗	66.77↗	69.30↗
	YATSI(NB)	57.85↗	62.71↗	64.62↗	65.02↗
	YATSI(SMO)	61.53↘	67.84↘	70.35↘	72.73↘
	YATSI(RF)	59.50↘	66.36↘	67.89↘	70.62↘
	$TSVM^{Light}$	61.24	**69.65**	**72.85**	**75.41**
	LLGC	58.75	62.70	63.65	64.86

Table 2 Predictive accuracies of semi-supervised and supervised learning methods on the Mutagenicity dataset

	Algorithm	Percentage of labeled data		
		5%	10%	20%
Supervised learning	2NN	63.89	71.15	77.97
	SMO	66.01	71.65	76.03
	RF	62.70	71.84	78.77
	SVM^{Light}	**69.49**	75.18	**81.02**
Semi-supervised learning	YATSI(2NN)	65.12↗	71.51↗	78.05↗
	YATSI(SMO)	67.83↗	74.42↗	78.07↗
	YATSI(RF)	63.57↗	73.25↗	78.48↘
	$TSVM^{Light}$	66.69	**75.25**	80.50
	LLGC	65.34	73.11	80.39

Table 3 Predictive accuracies of semi-supervised and supervised learning methods on the MUSK dataset

In [1], an extensive empirical study of SSL techniques over various domains (not including QSAR modeling) was performed using real-world and artificial datasets to investigate conditions under which SSL can perform. They observed that SSL methods behave very differently depending on the nature of the datasets, and that no single SSL method consistently performs better than supervised learning. Our findings are consistent with those observations.

6 CONCLUSION AND FUTURE WORK

In this study we performed an empirical comparison of several semi-supervised and supervised machine learning methods on three different QSAR datasets and under different experimental conditions (amount of unlabeled data relative to labeled data). Our results show that SSL can achieve better predictive performance than supervised learning (typically when small portion of the data are labeled), but the improvements depend on the dataset and method used. We cannot claim clear superiority of semi-supervised over supervised learning on the QSAR classification problems addressed by this study, but quite large improvements (general and relative to the baseline classifier) in classification accuracy in certain cases suggest that it is worthwhile to take SSL into consideration when dealing with problems of QSAR modeling.

In further work, we would like to systematically investigate which features of a dataset make it suitable for the SSL. Additionally, we would like to extend experiments to use data which are truly unlabeled. This would enable us to exploit the vast amount of information readily available within the public databases.

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USABILITY TESTING TOOLS FOR WEB INTERACTION: A SURVEY AND EVALUATION

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ABSTRACT

Software design and development following a user-centered approach can greatly benefit from the adoption of adequate usability testing tools. However, the choice of the most suitable tool for a particular purpose can be a difficult task, due to the multiplicity and variety of such tools. This paper surveys usability testing tools for web graphical interfaces, selects a set of appropriate tools and evaluates them. A set of relevant evaluation features is identified and aggregated into criteria. The evaluation relies on the Analytical Hierarchy Process. Results are presented and compared with those obtained previously by a multi-criteria utility model.

1 INTRODUCTION

User-centered design is known to be a process in which end-users should be involved across all the stages of a product development, since the early steps of the design, by specifying their needs and aims, to the later phases, by testing the product usability. In this process, besides the target population, which is the major source of concern, there is also another dimension of human complexity that requires some care: a team of designers able to identify and integrate several analysis and innovations. Designers should cooperate according to some common guidelines built on their experience and a vast literature of recommendations, in a productive way that should provide convergence of results toward the final product [1].

While experienced design teams have their own stabilized strategies, tactics and tools, partly established on the acquired know-how from previous projects, new teams or teams with several new collaborators can take extra benefits from commercial off-the-shelf, well documented frameworks of integrated computer tools. This is particularly true in what concerns user-centered design of web interfaces, where the advanced prototypes, the final product and the users can be obviously directly accessed by these frameworks, as well as these can provide an extra convenient platform of communication among the designers.

Usability testing evaluates a product relying on users' tests. This can be seen as an irreplaceable technique in user-centered design [2-3], since it gives direct input on how real users use the system [4]. There are many usability testing tools (UTT) available nowadays, with different features and capacities. This paper is an attempt to organize the concerned information and choose a suitable usability testing tool for web interfaces [5][6], with particular emphasis on graphical interaction.

The evaluated features and criteria as well as the corresponding evaluation were established by a restricted number of experts working for the World Search Project, that is responsible for the design of web search interfaces for dedicated areas of public concern, namely in the health area. The main goal of this project is the research and development of innovative web search technologies in Portugal as well as the research and development of generic and business information with semantic relevance and with the proper knowledge of the Portuguese language, culture and market.

The second section surveys UTT and presents the set of those selected for evaluation. The third section describes the features considered, the criteria adopted as well as the method adopted for the evaluation. The fourth section presents the results obtained, a comparison with previously obtained results and a discussion. Final section presents some conclusions and future work directions.

2 SELECTION OF UTT

The selection of UTT candidates for evaluation in the present study was inspired by several reviews published as web pages [7-13]. Table 1 displays in the first row our list of 23 candidates and the considered UTT reviews in the first column. Each UTT discussed by a given review is highlighted with an 'x' mark in the corresponding cell.

The list of candidates elected for evaluation was mainly based on the review of Tomlin [7] that extensively describes UTT in terms of features, presenting several plans of prices. Some of the Tomlin UTT are not included in our candidates. The *Clixpy* and *Simple Mouse Track* websites were not found. The *Google Website Optimizer* and the *UserVue* were merged into *Google Analytics* and the *Morae*, respectively. The *Website Grader* was conceived in order to enhance online marketing websites, which is not within the scope defined in this paper introduction. *Fivesecondtest* is now available with two complementary applications *NavFlow* and *ClickTest*, which can be seen as a single UTT (the *UsabilityHub* from *Angry Monkeys*).

Vraa [8] presents and discusses the best "Do's and Don'ts for Web Design and Usability" naming "16 crucial web design and usability best practice compilations and tools".

review | UTT	(1) Concept Feedback	(2) Chalkmark	(3) ClickHeat	(4) ClickTale	(5) Crazyegg	(6) Ethnio	(7) Feng-GUI	(8) Fivesecondtest + NavFlow + ClickTest	(9) Feedback Army	(10) Loop 11	(11) Mechanical Turk	(12) Morae (include User Vue)	(13) Open Hallway	(14) Silverback	(15) Usabilla	(16) Userfly	(17) User Testing	(18) Google Analytics (GoogleWebSiteOptimizer)	(19) Intuition HQ	(20) 4Q Survey	(21) Mouse Flow	(22) Attention Wizzard	(23) Click density
[7]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
[8]										x						x							
[9]		x	x	x				x	x					x		x	x	x					
[10]	x			x	x	x	x	x	x			x	x	x	x	x		x					
[11]		x						x	x	x					x				x				
[12]	x	x	x	x	x		x	x	x	x		x		x	x	x	x			x	x	x	x
[13]		x	x	x				x	x					x		x	x						

Table 1: *Utility testing tools reviews and candidates selected for evaluation.*

Though Vraa only reviews two UTT, the extended discussion on crucial UTT features inspired us in the identification of evaluation criteria and relevant features.

In the same year, Fadeyev surveys ten affordable UTT [9], claiming that "testing for usability is the only reliable way to find out how well a website works". Walker [10] also describes some of the already reviewed UTT and added a few more, whose main goals were to improve the visibility of websites for marketing purposes and thus were not included in our list of candidates. Gube reviews the "22 essential tools for testing your website's usability" [11] by classifying them into six categories.

1. User Task Analysis: *Intuition HQ*, *Usabilla*, *Loop11* and *Fivesecondtest*.
2. Readability: "*Juicy Studio: Readability Test*", *WordsCount* and *Check My Colours.*
3. Site Navigability: *Websort.net*, *OptimalSort*, *Chalkmark*, *WriteMaps*, *NavFlow* and *PlainFrame*;
4. Accessibility: "*Juicy Studio: Local Tools*", *VisCheck*, *W3C Markup Validation Service*, *WebAnywhere* and *Browsershots*.
5. Website Speed: *Pingdom Tools* and *Page Speed Online*.
6. User Experience: *Feedback Army* and *UserVoice*.

OptimalSort was already considered as part of the *Chalkmark* package. Other UTT referred were discarded, mainly because they were designed to evaluate specific aspects and not to support a significant coverage of all required usability issues.

Jules presents the "best website usability testing tools and services" [12], reviewing four UTT of our list that hadn't been previously discussed. The ten "essential website usability tools" discussed by Merle [13] were also analyzed during this study.

Besides the preliminary analysis of the descriptions in [7-13], the official websites for each of the selected candidates were also analyzed. In order to assure the presence (or absence) of the features under assessment, all the content available was analyzed, namely the videos demonstrating the UTT features.

3 EVALUATION MODEL

The evaluation criteria were set up taking into account the main issues relevant for the adoption of an UTT. Figure 1 is a tentative graphical representation of the criteria considered. These were represented as a flow as close as possible from the temporal order where designer's plans must be implemented. The criterion represented as Share was included under the criterion Export Results.

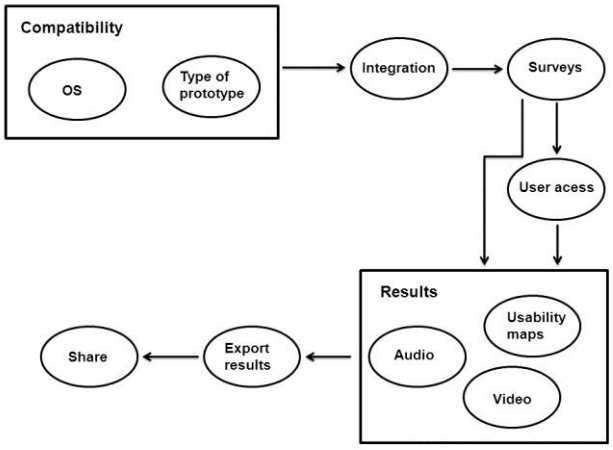

Figure 1: *Usability testing tools evaluation criteria.*

These criteria aggregate features (sub-criteria) according to the following hierarchy:

1. OS Compatibility: Windows; Linux; Mac OS.
2. Supported types of prototypes: Applications; Prototypes; Screenshots of the interface; Wireframes; Mockups.
3. Interface integration with the UTT: Offline program (off-line test generation and managing); Website post (the URL to be tested is submitted to the UTT website); Uploaded images (screenshots submission); JavaScript code (that forwards information to an on-line account of the UTT website); Online wizard (all details of the interface; associated tasks are submitted to the UTT website in a pre-specified order).

4. User access (to the usability tests): Local; Remote; On-line.
5. Creation and submission of surveys and tasks for the users: Complete survey; Screen aligned questions (kind of pop-up with questions during specific passages of the usability test); Screen aligned text (kind of pop-up with questions during specific passages of the usability test);
6. Collecting audio: Record (both user and wizard-of-Oz /prototypes/ etc.); Annotations.
7. Collecting video: Display; Facial Expressions; Eye Tracking; Annotations.
8. Usability maps: Clicks; Mouse move; Scroll reach; Attractive zones; Interest zones; Attention zones; Form inputs.
9. Export: XLS/CSV/TSV; XML; Database; Share (online access management to results for the development team).

In a first preliminary study we used a two level additive utility function (UF) to be maximized:

$$max_{UTT} \quad UF(UTT) = \sum_{j=1}^{m} w_j \sum_{k=1}^{n_j} w_{j,k}\, s_{j,k}\,(UTT).$$

This function linearly weights binary attributes, corresponding to elementary UTT features (0 for inexistent/ 1 for implemented) $s_{j,k}(UTT)$ using two levels.
The first level aggregates the evaluation of m criteria (m = 9) where w_j is the weight determining the impact of the j-th criterion on the evaluation of the given UTT, where $\sum_{j=1}^{m} w_j = 1$. In the second level, $w_{j,k}$ weights the presence of feature k within criterion j, aggregating n_j features, with $\sum_{k=1}^{n_j} w_{j,k} = 1$.
The preferences for the criteria as well as for the features were obtained in two rounds by a team of three experts. In the first round the experts produced individual assessment sheets that were discussed in a meeting until consensus was reached.

After analysis of the preliminary results achieved, we found the need to explicitly consider preferences between criteria as the utility model assumes criteria to be preferentially independent. We opted by the Analytical Hierarchy Process (AHP) [14] that also adopts a linear additive model, but allows for pairwise comparisons of criteria and alternatives. The Expert Choice Comparison software [15] was used (free trial version). AHP considers all scores and makes all weights computations using a percentual scale. The pairwise comparison scale uses a judgment of preferences including nine categories: "extremely" preferred, "very strongly to extremely ", "very strongly", "strongly to very strongly", "strongly", "moderately to strongly", "moderately", "equally to moderately" and "equally" preferred.
A rating scale was used to score sub-criteria: the null value was assigned whenever a feature is absent; otherwise the score was set to 1. Though the AHP model has been criticized due to inconsistencies that can arise from weighting and scoring, we found easy to overcome them through a careful analysis and comparison setting. Again the preferences were set up in a collaborative meeting.

4 RESULTS

Table 2 presents the results obtained from this study. All numbers are displayed as percentages. The first column ranks the UTT according to AHP results. Each of the columns 1-9 displays a criterion, its relative weight (second row) and the importance of each UTT in this criterion. Column "EC results" displays the relative importance of the UTT obtained by AHP, while "EC normalized to max" displays the corresponding normalization considering the best alternative scores 100%. Their counterparts "UT results" and "UT normalized to max" display the same numbers obtained by the utility model.

Criteria	1 OS compatibility	2 Supported types of prototypes	3 Interface integration with the UTT	4 User access	5 Creation & submission of surveys	6 Collecting audio	7 Collecting video	8 Usability maps	9 Export	EC Results	EC normalized to max	UT function relative	UT function normalized to max
UTT /RelWeights	3	7	7	27	7	7	18	7	18				
10. Loop 11	5	4	3	8	13	0	8	9	15	8	100	7	90
12. Morae	2	4	7	1	13	24	16	12	15	7	93	8	100
15. Usabilla	5	6	7	8	8	0	0	4	11	6	77	5	70
23. Click density	5	4	7	4	0	0	8	7	12	6	71	5	62
16. Userfly	5	4	7	4	8	14	8	11	2	6	70	6	74
17. User Testing	5	4	3	4	8	24	11	0	2	6	70	6	78
21. Mouse Flow	5	4	7	4	0	0	8	13	2	5	60	4	58
19. Intuition HQ	5	5	1	4	4	0	11	4	2	5	59	5	61
20. 4Q Survey	5	4	7	4	8	0	0	0	12	5	59	5	59
4. ClickTale	5	4	7	4	0	0	8	12	0	4	57	4	51
18. Google Analytics	5	6	7	4	0	0	0	0	12	4	56	4	53
13. Open Hallway	5	4	3	4	0	14	8	0	2	4	55	4	54
14. Silverback	1	4	7	1	8	24	14	0	0	4	55	5	63
8. Fivesecondtest	5	6	1	4	4	0	0	4	2	3	44	4	49
6. Ethnio	5	4	7	4	9	0	0	0	0	3	42	4	49
5. Crazyegg	5	4	7	4	0	0	0	9	0	3	41	3	42
11. Mechanical Turk	5	4	3	4	8	0	0	0	0	3	40	4	46
2. Chalkmark	5	2	1	4	8	0	0	4	2	3	39	4	49
3. ClickHeat	5	4	7	4	0	0	0	4	0	3	38	3	38
1. Concept Feedback	5	6	1	4	0	0	0	0	2	3	38	3	43
7. Feng-GUI	5	0	1	4	0	0	0	7	5	3	37	3	40
9. Feedback Army	5	4	1	4	4	0	0	0	0	3	36	3	40
22. Attention Wizzard	5	4	1	4	0	0	0	1	2	3	36	3	39
Std deviation										1,4	18,2	1,3	16,4

Table 2: *Final results from AHP and from the utility model.*

The best scored UTT, *Loop 11* (10), presents high preferences for criteria considered crucial (4, 7 and 9). In addition, it reached satisfactory scores for the other criteria. It does not offer the features of criterion 6, however, this will not exclude it from our choice. The second UTT, *Morae* (12), provides limited user access,

which may restraint remote usability tests. However, this UTT presents good scores in almost all the other criteria and, consequently, was not excluded. Considering that this evaluation was mainly supported by industrial advertising information, additional information is needed.

The next four UTT, *Usabilla* (15), *Click Density* (23), *Userfly* (16) and *User Testing* (17) present good scores, offering all the required functionalities, even in a limited way, with the exception of *Click Density* that does not provide audio and video recording.

Sensitivity analysis allowed us to conclude that the "User Access" weight strongly influences the relative importance of *Morae*.

AHP produced results finer tuned than the previously obtained by the utility model, highlighting the relative differences between UTT. This is also disclosed by the standard deviation values displayed in the last line. The pairwise comparison of criteria is also more comprehensive than the normative assignment of marks, either in a quantitative or qualitative scale. Though small differences were found in the relative positions, the most significant difference concerns the first two UTT, which can be explained by the tuned comparison of criteria. These results should be interpreted carefully. Besides the limited type of sampling, most of the features were reduced to binary evaluation. Scalability, for instance in the number of surveys or usability tests, seems often just a question of pricing. However, some of the features, even when present, may have some limitations when compared to a similar implementation in another UTT. Ultimately, some very specific features which can be highly valuable are only provided by few UTT. It should also be noted that all the preferences were defined by a small number of experts and considering the requirements of a specific project (World Search Project). Pricing can obviously be an important restriction for any product, which in this case was decided to be considered separately.

5 CONCLUSIONS

Within a user-centered interaction design approach, UTT are fundamental for the design and development of Web graphical interfaces. To the best of our knowledge our work is the first study providing 1) an exhaustive survey of UTT suitable for testing Web graphical interaction and 2) a quantitative evaluation and comparison of a reasonable number of these UTT.

The AHP method was used to evaluate twenty three UTT. The definition of preferences was performed by a small team of experts. AHP results are discussed and compared with those previously obtained by a linear utility model.

Results should be considered with caution, due to the limited type of evaluation and the type of interfaces to be tested. Future work will include 1) increasing the number of experts involved in the evaluation, and perhaps discovering new features or even new criteria to be considered; 2) verifying UTT features in lab, with an extra concern on usability tests/ UTT features for applications running in mobile devices; and 3) improving specific procedures for usability tests and user-centered interaction design for the World Search Project.

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AN ARCHITECTURE FOR MOBILE PHONE SENSING

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ABSTRACT

This paper presents a sensing system that logs sensor data on an Android-based mobile device and stores it to a remote server for further processing and analysis. This system consists of an application for Android operating system, FTP file server, a PostgreSQL database, an application that reads data from FTP and populates the database, an application that processes data stored on the server, and a web application that displays captured data.

The main purpose of this system is to provide sensing capabilities for applications that provide supervision or assistance with activities of daily living, coordination of services by outside health care providers, or monitoring of user activities to help to ensure their health, safety, and well-being.

KEYWORDS

Sensors, logging, monitoring, ambient assisted living, mobile phone sensing.

1 INTRODUCTION

By 2050, one in every three persons living in the more developed regions is likely to be 60 or older, and about one in every four is projected to be 65 or older [1]. Many of them will need help and there will be even less young people to help them than today. Yet most of them will have electronic devices with them, and we can use those devices to help them.

The aim of human monitoring system is to track user activity, detect interesting events and optionally trigger actions or alarms when needed. This kind of system is helpful in healthcare, ambient assisted living, baby care and many other areas.

This paper describes the Sauron system, an application that collects sensor data on an Android-based mobile device, and stores the data to a database for real-time processing or off-line analysis. The application will (1) speed up the process of creating and testing applications that rely on real world mobile sensing, and (2) provide training data for modelling user activities.

A few examples where the Sauron can be applied: an application that monitors person's everyday life and makes a suggestion if necessary, for example, if you take a walk every morning through the park and one day there is a construction site in the way, the application would alert you before you even left the house and suggest a detour.

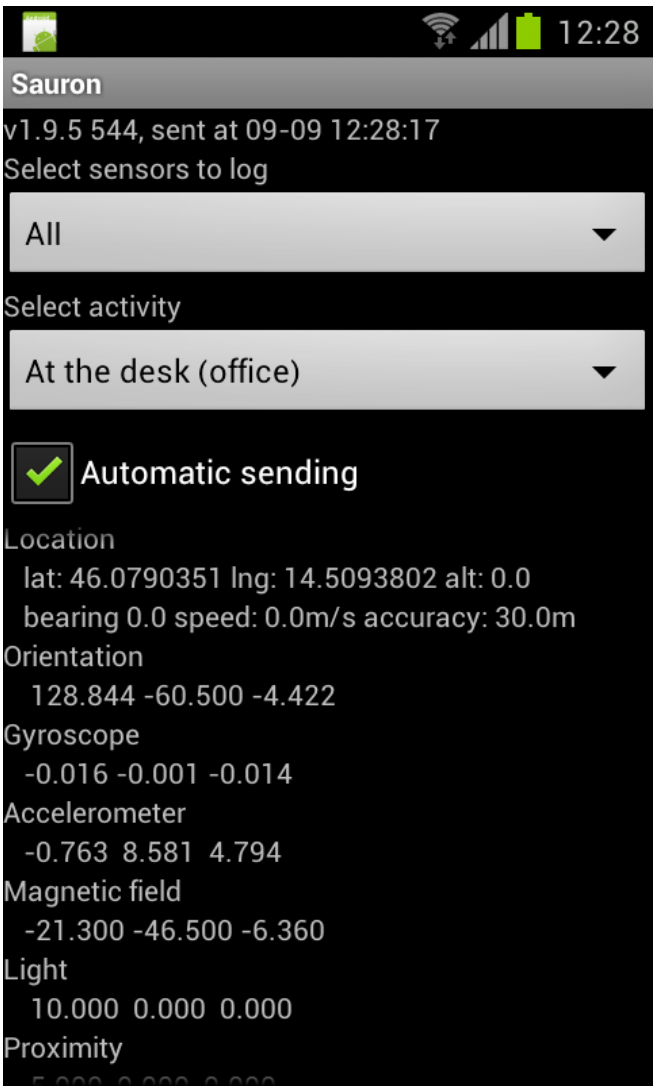

Figure 1: Main view of Android application user interface with status bar at the top and displayed data in the bottom.

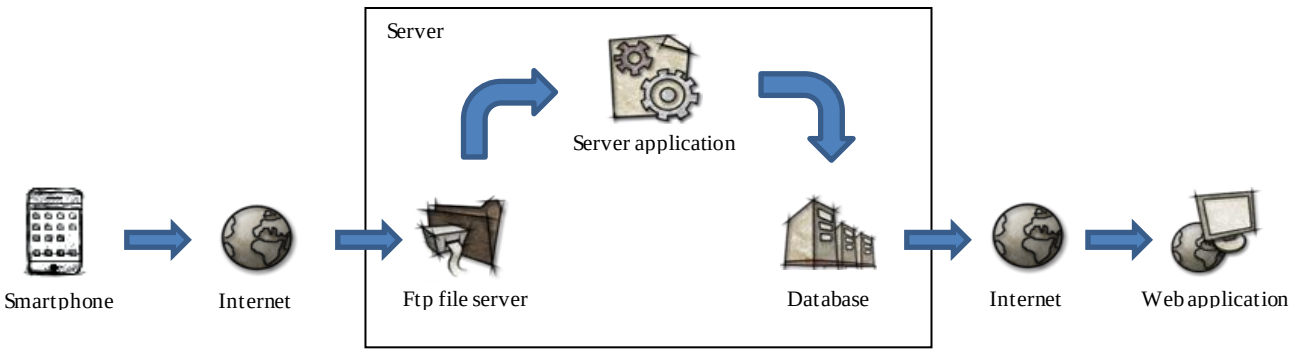

Figure 2: System architecture and its components [7]

Another example would be for specific tasks like fall detection [2], to recognize user's activity and estimate daily energy expenditure [3], or for detection of unusual behaviour based on analysis of daily-living dynamics [4].

The paper is structured as follows. Section 2 will introduce the system architecture and its components. Next, Section 3 described the sensor data – available at a mobile device. Finally, Section 4 concludes the paper.

2 SYSTEM STRUCTURE

System consists of five separate components as shown in figure 2. Each component is an application of its self:

- Android application – gathers sensor data on a mobile device,
- FTP server – used to temporary store the data before it is written to the database,
- Server application – reads the data from FTP server and populates the database,
- Database – where all data is stored and labelled,
- Web application – visualizes data from database.

Part of the applications run on the server side with the following requirements:

- Windows XP or newer
- PostgreSQL server 8.3 or newer
- Java 6 or newer

Android application runs as a client with the following requirements:

- Smartphone with Android 2.3.3 or newer
- GPS, gyroscope and accelerometer sensors
- WiFi internet access recommended

2.1 Android application

Sensor data is acquired with an Android application from a smartphone running Android operating system (shown in Figure 1). It can log and store data from all sensors available to operating system.

Most interesting data is supplied by acceleration sensor, orientation sensor, gyroscope sensor and magnetic field sensor. Application can also log location based on two different services. If GPS signal is available, it logs GPS coordinates. If GPS location is not available (for example inside buildings), it logs coordinates based on a buildings electromagnetic footprint using Qubulus' Cloud Positioning API for Android [5], which estimates the position within building. This is done by creating a radio frequency fingerprint of a building and comparing it to measurements on the device.

The application is designed to be used both in a laboratory environment and in real world. On startup, it requires basic information about user and type of activity being recorded. This is required, to label the data, which is important in longer and complex activities. Then, it starts a service that records all selected sensors and stores the sensor data to a SD card on the smartphone. If it is connected to internet via Wi-Fi, it periodically sends all logged data to FTP server. Wi-Fi is recommended because the application generates big amount of data, but 3G or any other internet connection is supported.

2.2 FTP server

Due to security reasons Sauron cannot communicate directly with an external database, hence the data is stored temporary on a FTP server, and afterwards into a database by an application running on the server side.

2.3 Server application

Now that all data is located on FTP server, system has to permanently store it to database. This is done by an application that reads raw text files, connects to database and stores the data in tables corresponding to particular sensor type. This way it is ensured that only our verified application could modify the database.

2.4 Database

For data storage we used PostgreSQL server. There we stored information for every time a sensor value has

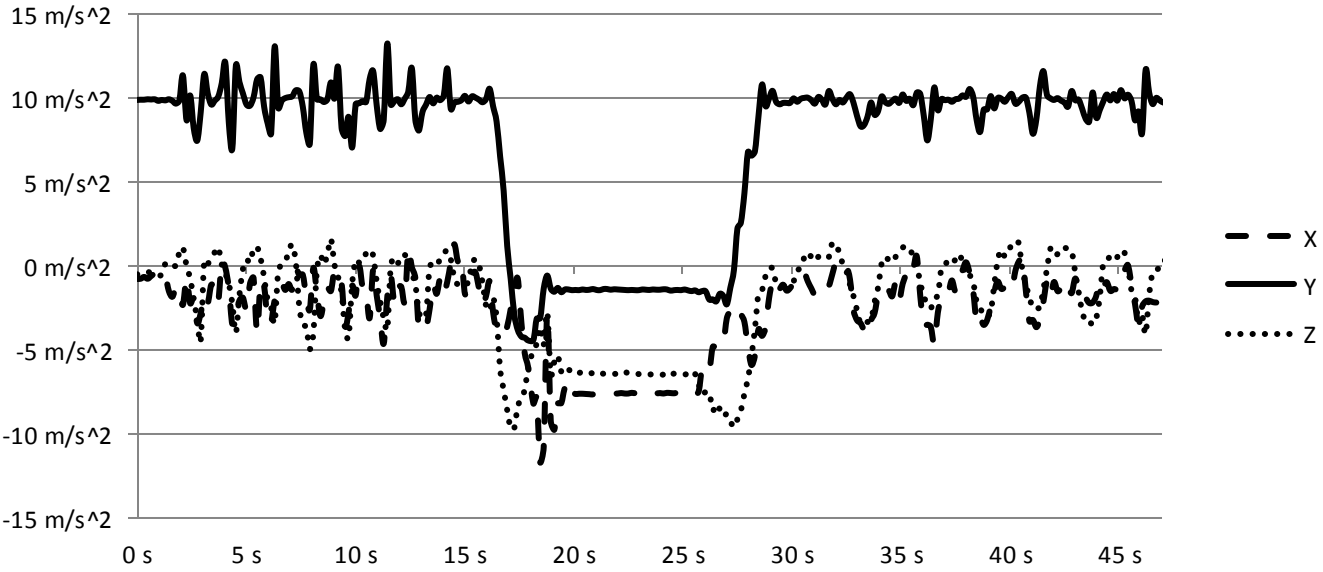

Figure 3: Accelerometer data over time. In this example, subject was walking, then lying down and then at around 30 s started walking again. Gravity acceleration is clearly visible as Y value (solid line).

changed. This includes: timestamp, user, scenario activity and sensors value at the time.

2.5 Web application

At this point all data is stored in the database and we can use any external application to process it. In this example, we developed a web application that plots the data on a chart as seen in Figure 3 or display it on a map.

3 ANDROID SENSORS

Most of the Android devices have a number of sensors attached to the device. Some sensors provide raw values, some values are calculated, some have a coordinate system relative to the device, and some have coordinate system relative to planet Earth. This section will describe how to understand values returned by Android sensors.

3.1 Coordinate system

Accelerometer, magnetic field, gyroscope, gravity and linear acceleration sensors use a coordinate system relative to the telephone. The axes always stay the same, even if the orientation of the telephone changes. Axes point in directions as shown in Figure 4.

Rotation vector and orientation sensor use a coordinate system relative to the Earth as shown in Figure 5.

3.2 Raw sensor data

The data are provided directly from the sensor. Values are stored in an array, where first number is value in direction X, second number is value in direction Y and third number is value in direction Z.

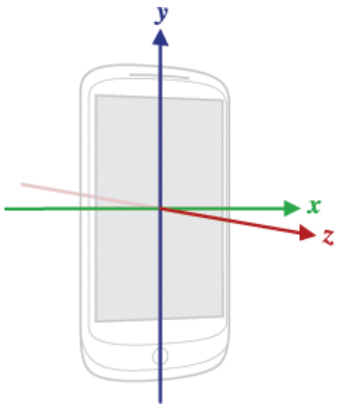

Figure 4: Axes in phone coordinate system [6]

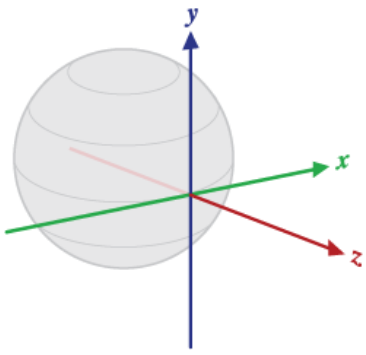

Figure 5: Axes in Earth coordinate system [6]

The unit of measurements are as follows: values for accelerometer are in m/s^2; values for magnetic field are in μT (microtesla); values for gyroscope are in /s (radian per second), where rotation is positive in the counter-clockwise direction, and the output of the gyroscope could be integrated over time to calculate a rotation describing the change of angles over time; value for light is in SI lux (lm/m^2); value for proximity sensor is in centimetres (cm). Some proximity sensors only support a binary near or far measurement. In this case, the sensor should report its maximum range value in the far state and a lesser value in the near state.

3.3 Calculated sensor data

Some values are calculated from values of other sensors to give some new or better information. An example is gravity sensor that shows the direction of gravity acceleration. If the device is stationary, values should be same as accelerometer.

Linear acceleration indicates acceleration along each axis, not including gravity.

The rotation vector represents the orientation of the device as a combination of an angle and an axis, in which the device has rotated through an angle θ around an axis <x, y, z>. The three elements of the rotation vector are <x*sin(θ/2), y*sin(θ/2), z*sin(θ/2)>, such that the magnitude of the rotation vector is equal to sin(θ/2), and the direction of the rotation vector is equal to the direction of the axis of rotation.

4 CONCLUSION

System described in this paper logs values from sensors on an Android smartphone and saves them in a database. This paper focuses on data acquiring and storage, and omits higher-level computation.

The system performs well in logging sensor data, but it generates huge amounts of network traffic and has high demand on server hardware, if it is used for real time processing by multiple clients.

We successfully used it for laboratory measurements with ten users for recognizing basic activities and we combined measurements with other sensors. This will allow us to create a smartphone application that will inform the user about the energy expenditure. There are also on-going measurements for more complex activities for detecting unusual behaviour that benefits from inside and outside location.

Such a system has great potential for use in healthcare or any other area where real-time mobile sensing is required.

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OPTIMIZACIJA PARAMETROV ALGORITMA ZA STROJNO UČENJE S PRIMERI IZ INDUSTRIJSKE PROIZVODNJE

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POVZETEK

Algoritmom strojnega učenja je za doseganje kakovostnih rezultatov potrebno nastaviti vrednosti več parametrov. Ročno nastavljanje in iskanje optimalnih nastavitev glede na rezultat učenja je časovno zahtevno. Da bi nastavljanje pohitrili in obenem dobili čim boljše rešitve, lahko uporabimo optimizacijske algoritme. V opisanem delu smo v ta namen uporabili večkriterijski optimizacijski algoritem DEMO, ki je razširitev enokriterijskega optimizacijskega algoritma diferencialne evolucije. Z njim smo optimirali parametre algoritma za učenje odločitvenih dreves J48 in pri tem kot kriterija upoštevali klasifikacijsko točnost in velikost odločitvenih dreves. Rezultati optimizacije na treh industrijskih učnih problemih kažejo, da algoritem DEMO uspešno določi vrednosti parametrov za gradnjo nedominiranih odločitvenih dreves.

1. UVOD

Optimizacija je postopek iskanja najboljše rešitve nekega problema glede na dani kriterij. Za reševanje so posebej zahtevni večkriterijski optimizacijski problemi, pri katerih je potrebno sočasno upoštevati več kriterijev. Ti si pogosto nasprotujejo, kar pomeni, da izboljšanje rešitve glede na en kriterij povzroči njeno poslabšanje glede na enega ali več drugih kriterijev. V teh primerih rešitev ni ena sama, ampak gre za množico rešitev, ki predstavljajo kompromise glede na kriterije. Za večkriterijsko optimizacijo najpogosteje uporabljamo stohastične algoritme, v katerih so določeni koraki naključni. Posledica takega načina delovanja so različni rezultati posameznih zagonov algoritma.

Ta prispevek opisuje uporabo algoritma diferencialne evolucije [7] v optimizaciji parametrov algoritma za strojno učenje odločitvenih dreves. Kot optimizacijska kriterija obravnava klasifikacijsko točnost in velikost odločitvenih dreves. Uporabnost pristopa pokaže v gradnji odločitvenih dreves za tri učne probleme iz industrijske proizvodnje.

V nadaljevanju povzamemo sorodno delo, opišemo izvedbo optimizacijskega postopka, predstavimo uporabljene testne probleme strojnega učenja, navedemo in analiziramo rezultate optimizacije in prispevek zaključimo s povzetkom opravljenega dela, rezultatov in usmeritev za nadaljnje delo.

2. SORODNO DELO

Temeljni cilj algoritmov strojnega učenja je avtonomna gradnja modelov iz podatkov. Za gradnjo modelov, ki imajo visoko klasifikacijsko točnost in so hkrati enostavni za razumevanje, je poleg izbire ustreznega algoritma strojnega učenja potrebno tudi zamudno nastavljanje parametrov algoritma.

Večina raziskovalcev pri nastavljanju parametrov algoritmov strojnega učenja ne uporablja optimizacijskih metod. Za vsak algoritem strojnega učenja glede na velikost nabora podatkov obstajajo priporočila, ki določajo okvire za začetne nastavitve vrednosti parametrov. V nadaljevanju izvajanja algoritmov strojnega učenja vrednosti parametrov izboljšujejo ročno, kar je časovno zahtevno, še posebej če algoritem uporablja večje število parametrov.

Boljši pristop k nastavljanju vrednosti parametrov algoritmov strojnega učenja je mrežno preiskovanje. Pri tem imamo vnaprej določene diskretne vrednosti parametrov, ki jih prilagojen računalniški program sistematično preiskuje in ocenjuje odločitvene modele, zgrajene s temi vrednostmi. Mrežno preiskovanje je računsko zahtevno, saj se z večanjem števila parametrov in manjšanjem koraka med diskretnimi vrednostmi parametrov število možnih kombinacij eksponentno povečuje. V primerjavi z ročnim preiskovanjem je ta metoda učinkovitejša, saj zagotavlja gradnjo točnejših odločitvenih modelov v krajšem času [3].

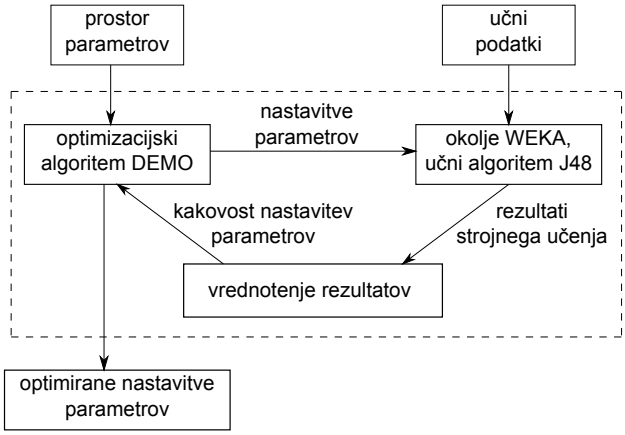
Najsistematičnejši pristop k iskanju ustreznih nastavitev parametrov algoritmov strojnega učenja je uporaba optimizacijskih metod. Problem nastavitve parametrov algoritma strojnega učenja lahko obravnavamo kot optimizacijski problem. Kriterijsko funkcijo lahko definiramo kot klasifikacijsko točnost zgrajenega modela v primerjavi z velikostjo zgrajenega modela. V tem primeru gre za večkriterijsko optimizacijo, ki je računsko zahtevna. Ta pristop zahteva tudi več programerskega dela, vendar se izkaže, da se zlasti v zahtevnejših učnih domenah dodaten trud izplača [10].

3. IZVEDBA OPTIMIZACIJSKEGA POSTOPKA

Za gradnjo odločitvenih dreves smo uporabili programsko okolje za analizo podatkov WEKA [11]. V njem smo se osredotočili na algoritem za gradnjo odločitvenih dreves C4.5 [8] oziroma njegovo implementacijo v okolju WEKA,

imenovano J48. Algoritmu J48 je mogoče nastaviti preko deset parametrov, s katerimi vplivamo na postopek in rezultat gradnje odločitvenih dreves. Za optimizacijo smo izbrali pet parametrov, ki so skupaj z možnimi in privzetimi vrednostmi prikazani v tabeli 1. Za ocenjevanje klasifikacijske točnosti odločitvenih dreves smo uporabljali desetkratno prečno preverjanje, njihovo velikost pa smo merili s številom vozlišč.

Programsko okolje WEKA smo povezali z algoritmom za večkriterijsko optimizacijo DEMO (ang. Differential Evolution for Multiobjective Optimization) [9, 10]. DEMO je algoritem diferencialne evolucije, prirejen za večkriterijsko optimizacijo, omogoča pa reševanje numeričnih večkriterijskih optimizacijskih problemov. Shematski prikaz optimizacijskega okolja prikazuje slika 1.



Slika 1: Shematski prikaz okolja za optimizacijo parametrov algoritma strojnega učenja

Algoritem DEMO najprej tvori začetne nastavitve parametrov algoritma strojnega učenja J48. Ta nato z njimi zgradi odločitvena drevesa z določeno klasifikacijsko točnostjo in velikostjo. Vsako dobljeno rešitev nato DEMO primerja s starševsko rešitvijo in v primeru, da trenutna rešitev ni slabša, to rešitev ohrani. Zatem tvori naslednje vrednosti parametrov in jih uporabi na enak način, dokler ni izpolnjen ustavitveni pogoj, določen s številom ovrednotenih nastavitev. Podroben opis algoritma je dostopen v [10].

Ker uporabniku algoritma strojnega učenja želimo z našim pristopom pomagati pri nastavljanju vrednosti parametrov, moramo biti pazljivi, da od njega ne zahtevamo nastavitev parametrov algoritma DEMO. Zato smo DEMO poganjali s privzetimi nastavitvami njegovih parametrov. Te niso bile posebej prilagojene za noben učni problem, njihove vrednosti pa so bile: velikost populacije 20, število generacij 25, verjetnost križanja CR 0,6, shema diferencialne evolucije DE/rand/1/bin, faktor skaliranja F 0,6 in izbor rešitev z metodo SPEA2.

4. TESTNI PROBLEMI STROJNEGA UČENJA

Optimizacijo parametrov algoritma strojnega učenja J48 z algoritmom DEMO smo preizkusili na treh učnih domenah. Vse tri so iz proizvodnih postopkov v elektrokovinski industriji. Cilj strojnega učenja je bil za vsako domeno zgraditi klasifikacijski model v obliki odločitvenega drevesa, ki bo na osnovi atributov učne primere razvrstil v ustrezne kakovostne razrede. Značilnosti vseh treh domen so prikazane v tabeli 2.

Prvo domeno, *komutatorji*, smo predhodno že uporabljali za gradnjo odločitvenih dreves [4, 5]. Nanaša se na zagotavljanje ustrezne kakovosti predobdelave grafitnih polizdelkov v podjetju Kolektor. Prvi izmed postopkov obdelave grafitnih polizdelkov je plazemska obdelava, katere rezultat mora biti primerna površina polizdelkov za nadaljnjo obdelavo. Težava, ki se pri tem pojavlja, je neenakomerna obdelava površine polizdelka. Naloga je napovedati kakovost površine v odvisnosti od lastnosti polizdelka, zajetih z računalniškim vidom.

Druga domena, *emulzija*, se nanaša na vzdrževanje kakovosti emulzije v postopku valjanja pločevine v železarni Acroni na Jesenicah [2]. Podatki so bili zajeti v procesu hladnega valjanja pločevine. Pri tem se ustvarja veliko toplote, ki jo valjalna naprava odvaja preko hladilnega sistema. V hladilnem sistemu se kot sredstvo za hlajenje uporablja oljna emulzija. Kakovost emulzije je bistvenega pomena za kakovost proizvedenih valjanih trakov. Stanje emulzije je zato potrebno stalno spremljati in ga kakovostno vrednotiti na osnovi podatkov o meritvah njenih fizikalnih in kemičnih lastnosti.

Tretja domena, *pločevina*, za katero smo podatke pridobili iz zbirke UCI [6], vsebuje podatke o napakah na jekleni pločevini. Pločevino je potrebno glede na dane atribute uvrstiti v enega izmed sedmih razredov, ki opisujejo vrsto napake. Atributi opisujejo fizikalne lastnosti pločevine, kot so vrsta materiala, svetlobna odbojnost površine, velikost napake, položaj napake ipd.

5. REZULTATI OPTIMIZACIJE

Odločitvena drevesa za navedene domene smo najprej zgradili s privzetimi nastavitvami algoritma J48. Ta drevesa smo nato primerjali z drevesi, zgrajenimi z optimiranimi vrednostmi parametrov. Rezultat optimiranja ni samo eno odločitveno drevo, ampak množica nedominiranih odločitvenih dreves glede na kriterija klasifikacijske točnosti in velikosti. Rezultati gradenj odločitvenih dreves, tako s privzetimi kot z optimiranimi vrednostmi parametrov algoritma J48, so prikazani na sliki 2.

Pri domeni komutatorji vidimo, da nedominirano fronto predstavljajo samo štiri odločitvena drevesa. Glede na število atributov, ki opisujejo polizdelke, je število rešitev relativno majhno. Ker poznamo ozadje tega problema, lahko trdimo, da je v praksi uporabna rešitev tista z najvišjo klasifikacijsko točnostjo. V konkretnem primeru klasifikacijska točnost z optimiranimi vrednostmi parametrov znaša 98,4 %. Če to rešitev primerjamo z rešitvijo, zgrajeno s privzetimi vrednostmi parametrov, vidimo, da je klasifikacijska točnost podobna (98,0 %), vendar je drevo z optimiranimi vrednostmi parametrov manjše.

Tabela 1: Parametri algoritma za gradnjo odločitvenih dreves J48, uporabljeni v optimizaciji

Parameter	**Možne vrednosti**	**Privzeta vrednost**
M – minimalno število primerov v listih drevesa	1,2, ...	2
U – gradnja neporezanih dreves	da/ne	ne
C – faktor zaupanja pri naknadnem rezanju dreves	[0,01, 0,5]	0,25
S – dvigovanje poddreves pri naknadnem rezanju	da/ne	da
B – gradnja binarnih dreves	da/ne	ne

Tabela 2: Značilnosti testnih učnih domen

Domena	**Število učnih primerov**	**Število atributov**	**Število razredov**	**Delež večinskega razreda [%]**
komutatorji	509	8	4	40,1
emulzija	108	7	5	49,1
pločevina	1941	27	7	34,7

Rezultat gradnje odločitvenih dreves v domeni emulzija s privzetimi vrednostmi parametrov je drevo velikosti 25 vozlišč s klasifikacijsko točnostjo 72,2 %. Če to rešitev primerjamo z nedominirano fronto dreves z optimiranimi vrednostmi parametrov, vidimo, da že manjše odločitveno drevo doseže enako ali celo višjo klasifikacijsko točnost. Drevo z velikostjo 13 vozlišč doseže klasifikacijsko točnost 75,0 %.

Domena pločevina je obsežnejša tako po število učnih primerov kot številu atributov. Rezultat gradnje so zato večja odločitvena drevesa. Podobno kot pri prejšnjih dveh domenah lahko opazimo, da z optimizacijo parametrov učnega algoritma lahko zgradimo bistveno manjša odločitvena drevesa z enako ali višjo klasifikacijsko točnostjo kot pri gradnji dreves s privzetimi vrednostmi parametrov.

Na sliki 2 so prikazane nedominirane fronte po enega zagona algoritma DEMO za vsak učni problem. Da bi potrdili ponovljivost rezultatov optimizacije, smo sicer opravili pet zagonov optimizacijskega algoritma. Za merilo ponovljivosti smo uporabili hipervolumen [1] v posameznih generacijah med izvajanjem optimizacijskega postopka. Na sliki 3 prikazujemo izboljševanje hipervolumna med zagoni optimizacijskega algoritma na domeni pločevina. Kot vidimo, so si poteki zelo podobni in se proti koncu izvajanja približajo isti vrednosti, kar potrjuje ponovljivost rezultatov optimizacije kljub uporabi stohastičnega algoritma.

Analizirali smo tudi optimirane vrednosti parametrov algoritma strojnega učenja. Za domeni komutatorji in emulzija, za kateri je optimizacijski algoritem našel manj nedomininranih rešitev, kot je bila velikost populacije, se je empirično potrdilo znano dejstvo, da lahko z različnimi nastavitvami parametrov učnega algoritma dobimo enaka odločitvena drevesa. Za obširnejšo domeno pločevina to ni prišlo do izraza, ker so bile vse rešitve v končni populaciji nedominirane. Uporabljena velikost populacije (20 rešitev) je primerna z vidika reprezentativnosti dobljene aproksimacijske množice, a če bi jo povečali, bi v njej predvidoma prav tako dobili podmnožice rešitev, ki se razlikujejo v prostoru spremenljivk, a imajo enako preslikavo v prostor kriterijev.

6. ZAKLJUČEK

V prispevku smo obravnavali optimizacijo parametrov gradnje odločitvenih dreves z algoritmom J48. Za optimizacijo smo uporabili algoritem večkriterijske optimizacije z diferencialno evolucijo DEMO. Optimizacijo smo izvedli na treh testnih problemih strojnega učenja iz industrijske proizvodnje. Izkazalo se je, da je optimizacija parametrov v primerjavi z ročnim iskanjem ustreznih vrednosti parametrov mnogo učinkovitejša. V vseh primerih smo z optimizacijo prišli do enostavnejših odločitvenih modelov, ki so imeli enako ali višjo klasifikacijsko točnost kot modeli, zgrajeni s privzetimi nastavitvami učnega algoritma. Optimizacija z algoritmom DEMO se je kljub njegovi stohastični naravi izkazala za zanesljivo, saj smo v ponovitvah zagonov dobili zelo podobne rezultate.

V bodoče bomo opisano optimizacijsko metodologijo preizkusili na zahtevnejših problemih strojnega učenja z večjim številom učnih primerov in večjim številom atributov od dosedanjih. Podrobneje bomo analizirali dobljene rešitve v prostoru spremenljivk (z vidika različnih vrednosti parametrov algoritma strojnega učenja, ki dajo enaka odločitvena drevesa) in v prostoru kriterijev (z vidika zastopanosti razredov v odločitvenih drevesih). Opisani optimizacijski pristop je mogoče razširiti tudi na druge algoritme strojnega učenja in v njem upoštevati dodatne optimizacijske kriterije.

ZAHVALA

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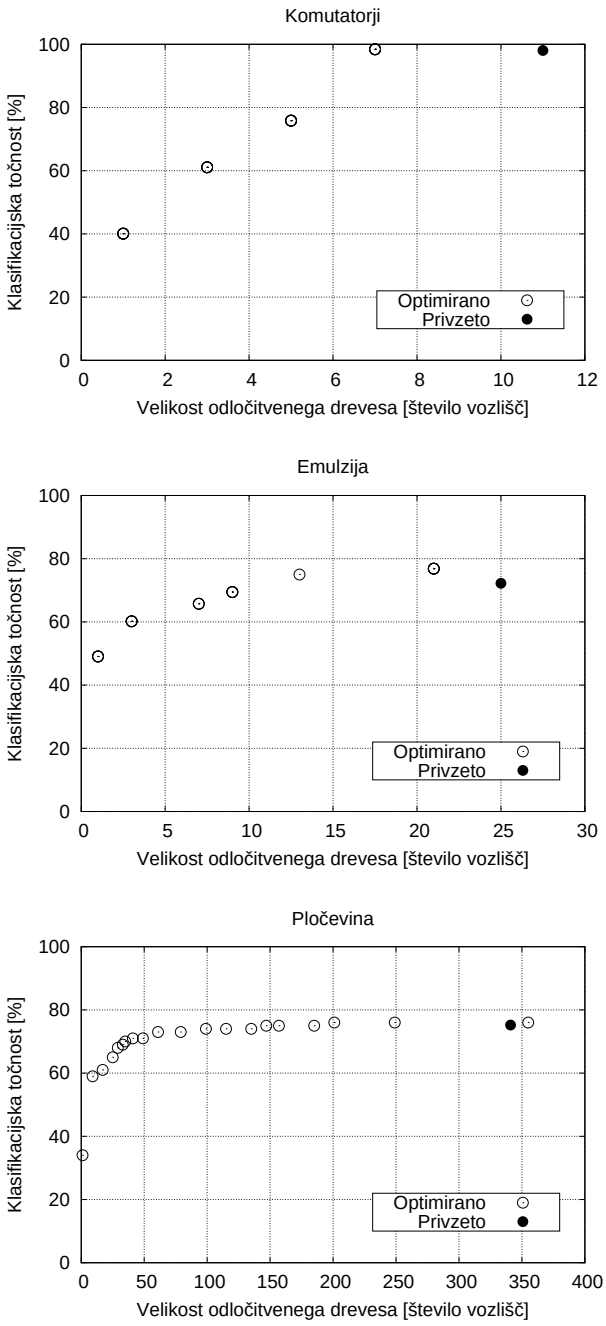
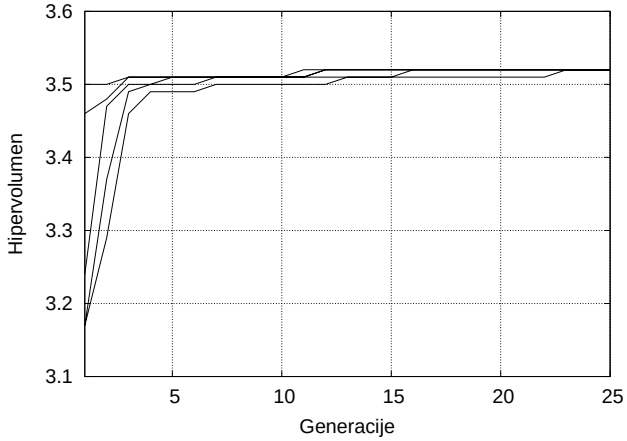


Slika 2: Rezultati gradnje odločitvenih dreves s privzetimi in optimiranimi vrednostmi parametrov algoritma J48 na testnih učnih problemih iz industrijske proizvodnje



Slika 3: Potek hipervolummna v petih zagonih optimizacijskega algoritma na domeni pločevina

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VEČPARAMETRSKO VREDNOTENJE VARIANT V ODVISNOSTI OD KONTEKSTA: MODEL ZA VREDNOTENJE STREŠNIH KRITIN

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POVZETEK

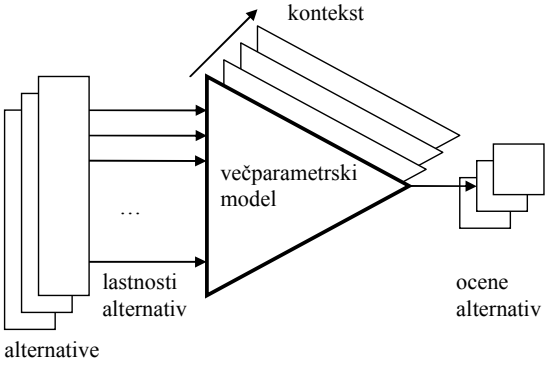
V prispevku predstavljamo večparametrski model za vrednotenje strešnih kritin. Model smo razvili z večparametrsko metodo DEX in ga realizirali z računalniškim programom DEXi. Prispevek ima dva namena. Po eni strani opisuje konkretno praktično uporabo metode DEX, kjer ovrednotimo in analiziramo pet tipičnih strešnih kritin, izdelanih iz različnih materialov: opečnato, betonsko, vlaknocementno in pločevinasto kritino. Po drugi strani pa opisuje splošno tehniko modeliranja, ki omogoča upoštevanje konteksta v kvalitativnih večparametrskih modelih, razvitih z metodo DEX. Pri strešnih kritinah je kontekst opredeljen z naravnimi danostmi okolja in vrsto objekta, za katerega je kritina namenjena.

1 UVOD

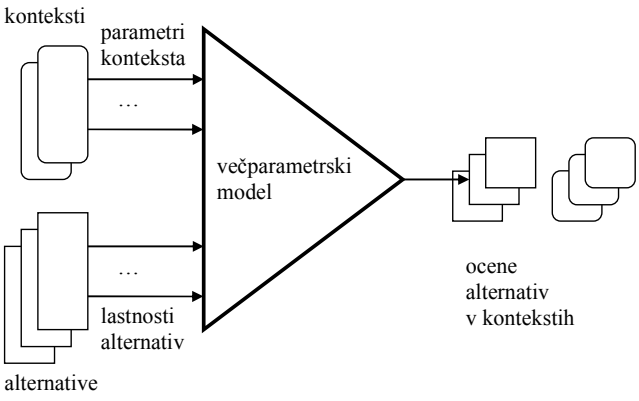
Vsako reševanje problemov poteka v nekem kontekstu [1]. To velja tudi za reševanje odločitvenih problemov [2], kjer tehtamo in vrednotimo različne možnosti in poskušamo izbrati najboljše. *Kontekst* običajno razumemo kot nek okvir, nekaj "kar z določeno stvarjo nastopa, je z njo povezano" [3, str. 428]. Bazire in Brézillon [4] navajata še številne druge definicije tega pojma.

Večparametrsko modeliranje je pristop, ki sodi na področje podpore pri odločanju [5,6]. Pri tem pristopu odločitvene alternative opišemo z več lastnostmi (parametri). Razvijemo *večparametrski model*, ki te lastnosti ovrednoti in jih po nekem postopku združi v končno oceno vsake alternative. Shematično je takšen model prikazan s trikotnikom na sliki 1: vanj z leve strani vstopajo vhodni podatki, ki opisujejo lastnosti alternativ, rezultat vrednotenja na desni strani pa so izračunane ocene alternativ. Čim višja je ocena, tem boljša je alternativa.

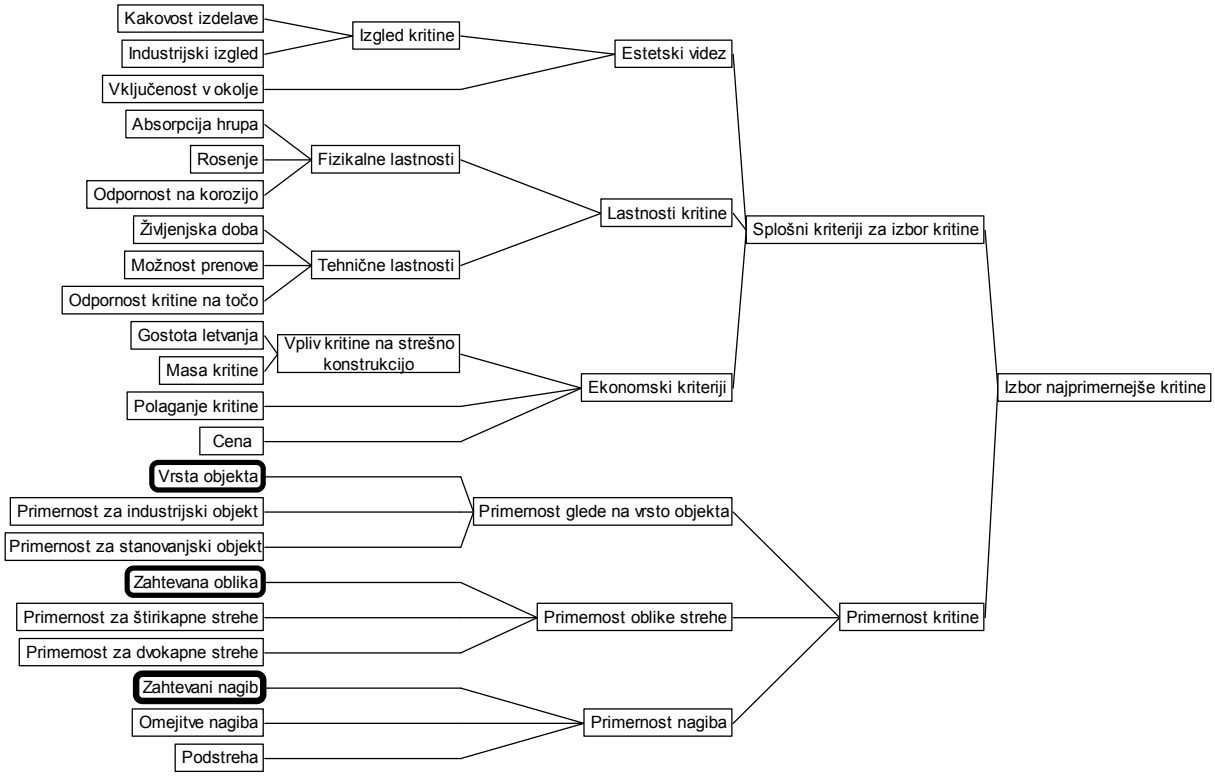
Pri večparametrskem modeliranju kontekst praviloma opredelimo povsem na začetku in še preden se lotimo razvoja samega modela [7]. Opredelimo na primer cilje odločitve ter morebitne upravne, politične, družbene, tehnične in druge omejitve. Opredelimo tudi, kdo so odločevalci, kdo je odgovoren za odločitev in kdo bi bil lahko prizadet z odločitvijo. Model potem razvijemo za tako opredeljen kontekst. To pomeni, da v model vključimo samo parametre, ki opisujejo lastnosti alternativ, ne pa tudi parametrov konteksta, ki jih le posredno privzamemo. To ima dve posledici. Prvič, model je preprostejši, saj se s kontekstom ne ukvarja neposredno. Drugič, tak model je primeren samo za izbrani kontekst. Če pride do spremembe konteksta, je treba model v splošnem razviti na novo (slika 1). Množico modelov za različne kontekste je težko vzdrževati, saj jih je več, poleg tega pa v njih lahko prihaja do podvajanja enakih ali podobnih komponent.



Slika 1: *Večparametrsko modeliranje v različnih kontekstih*



Slika 2: *Pristop s parametriziranjem kontekstov*



Slika 3: *Hierarhična struktura modela za vrednotenje strešnih kritin. Posebej so poudarjeni parametri konteksta.*

V tem prispevku predstavljamo alternativni pristop, pri katerem razvijemo samo en model za različne kontekste. Pri tem moramo kontekst parametrizirati: poleg parametrov, ki opisujejo lastnosti alternative, v model vključimo tudi parametre, ki opisujejo kontekst (slika 2). Na ta način dobimo model, ki je sicer večji od običajnih, vendar je bolj prilagodljiv in uporaben v različnih kontekstih. Tak model je en sam in ga je lažje vzdrževati.

Metodo razvoja takšnega modela opisujemo na konkretnem primeru vrednotenja strešnih kritin [8]. Prav pri izbiri kritine je namreč pomembno, v kakšnem kontekstu jo želimo uporabiti: za kakšne objekte, za kakšne velikosti in nagibe streh, in za kakšne podnebne razmere. Model smo razvili z večparametrsko metodo DEX [6] in ga realizirali z računalniškim programom DEXi [9]. Pomembna lastnost te metode je, da uporablja simbolične vrednosti parametrov namesto numeričnih in da ocenjuje alternative na osnovi odločitvenih pravil. Kot bomo videli v nadaljevanju, so prav pravila tista, ki omogočajo preprosto in razumljivo modeliranje vplivov parametrov konteksta.

2 STREŠNE KRITINE

Strešna kritina ima varovalno funkcijo [10]. Streho varuje pred vremenskimi vplivi, kot so veter, dež, toča in sneg [11]. Biti mora trajna, odporna proti mrazu in ognju ter enostavna za vzdrževanje. Streha poleg naštetega varuje objekt tudi pred hrupom in ognjem [12]. Zato je izbira kritine zelo pomembna za kakovost strehe in uporabnost celotnega objekta [8]. Strešne kritine v naši širši okolici so narejene iz predelanih naravnih materialov. Najbolj razširjene strešne kritine so opečnata, betonska, vlaknocementna, bitumenska in pločevinasta.

V tej raziskavi smo ovrednotili pet tipičnih strešnih kritin, ki jih srečamo na našem tržišču [8]:

1. betonska kritina Bramac Donav [13],
2. vlaknocementna kritina Valovitka V5 [14],
3. pločevinasta kritina Gerard klasik [15],
4. pločevinasta kritina Hosekra Valmetal [16],
5. opečnata kritina Tondach Mediteran Plus [17].

3 MODEL ZA VREDNOTENJE STREŠNIH KRITIN

Osnovni namen modela je ovrednotiti strešne kritine na osnovi parametrov, ki opisujejo (1) lastnosti strešne kritine in (2) kontekst, v katerem se ta kritina uporablja. V skladu s tem ima model hierarhično strukturo, ki se sestoji iz dveh poddreves parametrov (slika 3). Prvo poddrevo, imenovano *Splošni kriteriji*, ocenjuje kritine neodvisno od njihove konkretne uporabe in upošteva tri osnovne podredne kriterije: estetski videz kritine, lastnosti kritine in ekonomski kriterij. Ti se delijo naprej vse do osnovnih parametrov, prikazanih na levi strani slike 3. Drugo poddrevo, *Primernost kritine*, pa vrednoti kritine v odvisnosti od konteksta. Kontekst je v tem modelu opredeljen s tremi vhodnimi parameri, ki so na sliki 3 posebej poudarjeni:

- *Vrsta objekta*: stanovanjski ali industrijski. Strehe industrijskih objektov so večinoma položne in večje, zato so zanje bolj primerne kritine večjega formata.

- *Zahtevana oblika* strehe: dvokapna ali štirikapna. Za izvedbo štirikapne strehe so primernejše kritine manjšega formata, saj se bolje prilagodijo tej obliki strehe.
- *Zahtevani nagib* strehe: (1) 7-15°, (2) 15-22° in (3) 22-45°. Največ omejitev za strešne kritine je v območju položnih streh, ki zajema nagibe 7-22°.

Vpliv kontekstnih parametrov v modelu opredelimo z odločitvenimi pravili. Za primer (tabela 1) vzemimo odločitvena pravila, ki opredeljujejo *Primernost nagiba* v odvisnosti od podrednih parametrov *Podstreha* (ali kritina zahteva podstreho), *Omejitev nagiba* (ali je kritina primerna le za velike nagibe) in *Zahtevani nagib*. Prva dva parametra sta odvisna od lastnosti kritine, tretji pa od konteksta.

Tabela 1: *Odločitvena pravila kriterija Primernost nagiba.*

Podstreha	***Omejitev nagiba***	***Zahtevani nagib***	***Primernost nagiba***
ne	ne	7-15°	***bolj primerna***
ne	ne	15-22°	***bolj primerna***
ne	ne	22-45°	***bolj primerna***
ne	da	7-15°	**neprimerna**
ne	da	15-22°	**neprimerna**
ne	da	22-45°	primerna
da	ne	7-15°	***bolj primerna***
da	ne	15-22°	***bolj primerna***
da	ne	22-45°	***bolj primerna***
da	da	7-15°	**neprimerna**
da	da	15-22°	primerna
da	da	22-45°	***bolj primerna***

Kontekstni parametri so na sliki 3 pomešani s parametri, ki opisujejo lastnosti kritin. Da jih v modelu, ki ga realiziramo s programom DEXi, med seboj ločimo, uporabimo možnost "povezanih parametrov" (angl. "linked attributes" [9, str. 13]): vse kontekstne parametre podvojimo, jih združimo v skupno poddrevo (v našem primeru poimenovano *Kontekst*) ter to poddrevo "posadimo" nekje ob strani glavne hierarhične strukture, brez nadrednih povezav z drugimi deli modela (slika 4).

4 REZULTATI VREDNOTENJA STREŠNIH KRITIN

V raziskavi [8] smo z razvitim modelom ovrednotili strešne kritine v različnih kontekstih, jih na različne načine analizirali, med seboj primerjali in interpretirali rezultate. Na tem mestu zaradi omejenega prostora predstavljamo le dva rezultata.

Slika 4 prikazuje rezultate vrednotenja kritin za kontekst stanovanjskih objektov s štirikapno streho in nagibom strešine 22-45°. Na sliki so podani tako vhodni podatki, ki opisujejo lastnosti kritin in izbrani kontekst, kot tudi rezultati vrednotenja na osnovi odločitvenih pravil. Vhodni podatki so prikazani pri končnih vozliščih hierarhije (listih), medtem ko so rezultati vrednotenja prikazani pri notranjih vozliščih, katerih imena so natisnjena v krepkem tisku. Končni rezultat vrednotenja kritin je prikazan na vrhu tabele, t.j. pri korenu hierarhije.

Kriterij	**Valovitka V5**	**Bramac Donav**	**Tondach Mediteran Plus**	**Gerard klasik**	**Hosekra Valmetal**
Izbor najprimernejše kritine	primerna	bolj prim	bolj prim	sprejemlji	sprejemlji
├ **Primernost kritine**	primerna	***najbolj prim***	***najbolj prim***	bolj prim	sprejemlji
│ ├ **Primernost nagiba**	***bolj primerna***	***bolj primerna***	***bolj primerna***	***bolj primerna***	***bolj primerna***
│ │ ├ Podstreha	***ne***	**da**	**da**	**da**	**da**
│ │ ├ Omejitve nagiba	***ne***	**da**	**da**	**da**	***ne***
│ │ └ ***Zahtevani nagib***	22-45°	22-45°	22-45°	22-45°	22-45°
│ ├ **Primernost oblike strehe**	primerna	***bolj primerna***	***bolj primerna***	primerna	**manj primerna**
│ │ ├ Primernost dvokapne strehe	***bolj primerna***	***bolj primerna***	***bolj primerna***	***bolj primerna***	***bolj primerna***
│ │ ├ Primernost štirikapne strehe	primerna	***bolj primerna***	***bolj primerna***	primerna	**manj primerna**
│ │ └ ***Zahtevana oblika***	štirikapnica	štirikapnica	štirikapnica	štirikapnica	štirikapnica
│ └ **Primernost glede na vrsto objekta**	primerna	***bolj primerna***	***bolj primerna***	***bolj primerna***	primerna
│ ├ Primernost za stanovanjsk objekt	primerna	***bolj primerna***	***bolj primerna***	***bolj primerna***	primerna
│ ├ Primernost za industrijski objekt	***bolj primerna***	**manj primerna**	**manj primerna**	**manj primerna**	***bolj primerna***
│ └ ***Vrsta objekta***	stanovanjski	stanovanjski	stanovanjski	stanovanjski	stanovanjski
└ **Splošni kriteriji za izbor kritine**	primerna	sprejemlj	primerna	**manj prim**	**manj prim**
├ **Ekonomski kriteriji**	prav dober	**sprejemljiv**	**sprejemljiv**	**sprejemljiv**	prav dober
│ ├ Cena	srednja	***nizka***	srednja	**zelo visoka**	***nizka***
│ ├ Polaganje kritine	ugodno	**manj ugodno**	**manj ugodno**	ugodno	***zelo ugodno***
│ └ **Vpliv kritine na strešno konstrukcijo**	srednja	visoka	visoka	srednja	srednja
│ ├ Masa kritine	srednja	**visoka**	**visoka**	***nizka***	***nizka***
│ └ Gostota letvanja	***srednja***	**visoka**	**visoka**	**visoka**	**visoka**
├ **Lastnosti kritine**	***bolj primerna***	***bolj primerna***	***bolj primerna***	**manj primerna**	**manj primerna**
│ ├ **Tehnične lastnosti**	primerna	primerna	primerna	primerna	**manj primerna**
│ │ ├ Odpornost kritine na točo	sprejemljiva	sprejemljiva	sprejemljiva	***odlična***	***odlična***
│ │ ├ Možnost prenove	sprejemljiva	***odlična***	***odlična***	sprejemljiva	**slaba**
│ │ └ Življenjska doba	visoka	visoka	***zelo visoka***	visoka	**srednja**
│ └ **Fizikalne lastnosti**	***odlična***	***odlična***	***odlična***	**slaba**	**slaba**
│ ├ Odpornost na korozijo	***da***	***da***	***da***	**ne**	**ne**
│ ├ Rosenje	***ne***	***ne***	***ne***	**da**	**da**
│ └ Absorpcija hrupa	***odlična***	***odlična***	***odlična***	sprejemljiva	**slaba**
└ **Estetski videz**	dober	prav dober	***odličen***	dober	**sprejemljiv**
├ Vključenost v okolje	primerna	***bolj primerna***	***bolj primerna***	primerna	**manj primerna**
└ **Izgled kritine**	dober	dober	***prav dober***	dober	**sprejemljiv**
├ Industrijski izgled	srednje	***neindustrijski***	***neindustrijski***	srednje	**zelo industrijski**
└ Kakovost izdelave	sprejemljiva	sprejemljiva	***odlična***	sprejemljiva	sprejemljiva
Kontekst					
├ Zahtevana oblika	štirikapnica	štirikapnica	štirikapnica	štirikapnica	štirikapnica
├ Vrsta objekta	stanovanjski	stanovanjski	stanovanjski	stanovanjski	stanovanjski
└ Zahtevani nagib	22-45°	22-45°	22-45°	22-45°	22-45°

Slika 4: *Vrednotenje kritin za stanovanjske objekte, štirikapno streho in nagib strešine 22-45°.*

Tabela 2: *Končne ocene strešnih kritin v odvisnosti od konteksta.*

Kontekst			Strešne kritine				
Vrsta objekta	**Zahtevana oblika**	**Zahtevani nagib**	**Hosekra Valmetal**	**Gerard klasik**	**Tondach Mediteran plus**	**Bramac Donav**	**Valovitka V5**
stanovanjski	dvokapnica	7-15°	sprejemljiv	**manj primerna**	**manj primerna**	**manj primerna**	primerna
stanovanjski	dvokapnica	15-22°	sprejemljiv	sprejemljiv	primerna	sprejemljiv	primerna
stanovanjski	dvokapnica	22-45°	sprejemljiv	sprejemljiv	***bolj primerna***	***bolj primerna***	primerna
stanovanjski	štirikapnica	7-15°	sprejemljiv	**manj primerna**	**manj primerna**	**manj primerna**	primerna
stanovanjski	štirikapnica	15-22°	sprejemljiv	sprejemljiv	primerna	sprejemljiv	primerna
stanovanjski	štirikapnica	22-45°	sprejemljiv	sprejemljiv	***bolj primerna***	***bolj primerna***	primerna
industrijski	dvokapnica	7-15°	sprejemljiv	**manj primerna**	**manj primerna**	**manj primerna**	***bolj primerna***
industrijski	dvokapnica	15-22°	sprejemljiv	sprejemljiv	primerna	sprejemljiv	***bolj primerna***
industrijski	dvokapnica	22-45°	sprejemljiv	sprejemljiv	primerna	sprejemljiv	***bolj primerna***
industrijski	štirikapnica	7-15°	sprejemljiv	**manj primerna**	**manj primerna**	**manj primerna**	primerna
industrijski	štirikapnica	15-22°	sprejemljiv	sprejemljiv	primerna	sprejemljiv	primerna
industrijski	štirikapnica	22-45°	sprejemljiv	sprejemljiv	primerna	sprejemljiv	primerna

Rezultati pokažejo, da sta za izbrani kontekst najbolj primerni kritini Bramac in Tondach, primerna je Valovitka, sprejemljivi pa sta Gerard in Hosekra. Na sliki lahko tudi jasno razberemo razloge za takšno oceno. Strešno kritino Tondach na primer odlikujejo: format kritine, ki je zelo primeren za pokrivanje štirikapne strehe, primernost kritine za polaganje na strme strehe ter primerna ocena splošnih kriterijev, predvsem zaradi tehničnih, fizikalnih in estetskih razlogov.

Tabela 2 prikazuje končne ocene kritin v odvisnosti od konteksta. Na levi strani tabele je prikazanih vseh 12 možnih kontekstov, na desni pa so prikazane ustrezne končne ocene. Med najbolje ocenjenimi kritinami izstopata Tondach in Bramac za stanovanjske objekte z velikim nagibom strehe, ter Valovitka za industrijske objekte z dvokapnico. Kritine Gerard, Tondach in Bramac so občutljive na nagib strehe in so manj primerne za manjše nagibe. Kritina Hosekra ni občutljiva na kontekst in je sprejemljiva v vseh situacijah. Opozoriti velja tudi na kritino Valovitka, ki prav tako ni posebej občutljiva na kontekst in je v vseh situacijah vsaj primerna.

5 ZAKLJUČEK

V prispevku smo predstavili kvalitativni večparametrski model za vrednotenje strešnih kritin, razvit z računalniškim programom DEXi. Posebnost in izvirna novost modela je upoštevanje konteksta, to je različnih situacij, v katerih uporabljamo strešne kritine. Te so v modelu opredeljene s tremi kontekstnimi parametri: vrsta objekta, zahtevana vrsta strehe in zahtevani nagib. Prispevek daje tudi jasne napotke za razvoj podobnih modelov. Potrebno je: (1) parametrizirati kontekst, torej poleg parametrov, ki opisujejo lastnosti odločitvenih alternativ, uporabiti tudi kontekstne parametre, (2) uporabiti odločitvena pravila za opredelitev odvisnosti med obema vrstama parametrov v modelu, in (3) uporabiti možnost "povezanih parametrov" za fizično ločitev obeh vrst parametrov v tabelah in grafičnih prikazih programa DEXi.

Predstavljena raziskava ima tudi uporabne rezultate na področju vrednotenja strešnih kritin. Ovrednotili in podrobno analizirali smo pet tipičnih strešnih kritin, hkrati pa smo razvili prilagodljiv model, ki ga lahko brez sprememb uporabimo za vrednotenje drugih kritin.

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ANALIZA IN IZBOLJŠAVA SPLETNE STRANI ODPRTE PLATFORME ZA KLINIČNO PREHRANO

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POVZETEK

V prispevku je predstavljena analiza in izboljšava spletnih straini ob upoštevanju vpliva vizualnih spremenljivk in z njimi povezanimh smernic. Cilj dela je vizualno podobo spletne strani prilagoditi tako, da postane enostavnejša in preglednejša, kar posledično pripomore k izboljšanju uporabniške izkušnje ob uporabi spletne strani. Obravnavana je spletna stran Odprte platforme za klinično prehrano. S celostno analizo vizualnih informacij podstrani spletne strani in ustrezno prilagoditvijo vizualne podobe, ki je temeljila predvsem na poenotenju in smiselnem uravnoteženju vizualnih informacij, je bilo poskrbljeno, da je spletna stran postala lažje dojemljiva in enostavnejša za uporabo.

1 UVOD

Na delovanje kompleksnih informacijskih zdravstvenih sistemov močno vpliva interakcija z uporabniki, ki je ni mogoče enostavno matematično modelirati in je predmet aktualnih raziskav na področju inteligentnih sistemov [1]. Na to problematiko se navezuje analiza in izboljšava spletne strani Odprta platforma za klinično prehrano (OPKP) na spletnem naslovu http://opkp.si/, razvite na Institutu Jožef Stefan v sodelovanju s Pediatrično kliniko UKC Ljubljana, Onkološkim inštitutom, Biotehniško fakulteto Univerze v Ljubljani in podjetjem Sonce.net. Spletna stran omogoča zbiranje in obdelavo podatkov o prehranskih navadah bolnikov ter upošteva sodobne smernice za zdravo prehranjevanje in individualne potrebe posameznika. Spletna stran ima trenutno približno 3000 aktivnih uporabnikov, katerih število narašča – dnevno se registrira okoli 20 novih uporabnikov. OPKP sta podprli evropska mreža odličnosti EuroFIR, ki oblikuje evropsko zbirko podatkov o sestavi živil, in evropsko združenje dietetikov Diets.

V prispevku se osredotočamo na analizo trenutnega vizualnega prikaza informacij na spletni strani in na poskus izboljšave, tako da postane spletna stran preglednejša, enostavnejša in lažja za uporabo. Pri tem pa ne spreminjamo celostne grafične podobe spletne strani, nasprotno – s spremembami poskušamo čim bolj ohraniti vizualni vtis oziroma slog, ki zaznamuje trenutno verzijo spletne strani. Ne spreminjamo logotipa in izbranih barvnih kombinacij strani, temveč preučimo vizualne informacije, ki jih vsebujejo podstrani, in jih upodobimo tako, da postanejo uporabniku lažje dojemljive. Z vzpostavitvijo jasne in pregledne vizualne strukture informacij poskušamo uporabniku omogočiti, da čim hitreje najde želeno informacijo oziroma čim enostavneje opravi določeno opravilo. Z vizualnimi spremembami, ki hkrati čim manj spreminjajo končni vtis celostne podobe spletne strani, poskušamo izboljšati njeno uporabnost. Tako se obstoječim uporabnikom, ki že uporabljajo spletno aplikacijo, ni treba privajati na novo podobo, izboljšani grafični uporabniški vmesnik spletne strani pa izboljša uporabniško izkušnjo.

Upoštevanje predlogov v praksi je proces, pri katerem je treba skrbno pretehtati in upoštevati navade sedanjih uporabnikov in njihove zmožnosti prilagajanja spremembam, kakor tudi finančni vidik spreminjanja in dograjevanja programske opreme. Pričujoči prispevek povzema dosedanje ugotovitve in predloge, njihovo uvajanje v praksi pa ostaja predmet nadaljnjih usklajevanj. Napotke za izdelavo spletnih strani lahko najdemo v številnih učbenikih kakor tudi v navodilih za podporo spletnih aplikacij sistemov različnih proizvajalcev. Bistveno manj pa je prispevkov, ki bi kritično povzemali predloge izboljšav v stilu “lessons learned”. Iz tega razloga ocenjujemo, da so opravljena analiza in zbrani predlogi predstavljeni v tem prispevku zanimivi tudi za širši krog uporabnikov in načrtovalcev spletnih strani.

2 TEORETSKO IZHODIŠČE

Poznavanje vizualne organizacije slikovnega polja je pri oblikovanju grafičnega vmesnika spletnih strani ključnega pomena. Likovni jezik ima urejeno hierarhično zgradbo. Dobro je, če formalni odnosi v taki ureditvi podpirajo semantične odnose. Ob tej že dobro obdelani problematiki [2] velja omeniti tudi novejše raziskave kompozicije in estetike uporabniških vmesnikov. V študiji [3] so Chek Ling in sodelavci izpostavili 14 značilnosti postavitve elementov, ki vplivajo na vrednotenja estetike uporabniških vmesnikov: ravnotežje, ravnovesje, simetrija, (ustrezno) zaporedje, kohezija, enotnost, sorazmerje, enostavnost, gostota, red, poenotenje oz. varčnost, homogenost, ritem in ureditev (kot združitev vseh naštetih značilnosti). Z raziskavo [4] so Michailidou in sodelavca potrdili, da bolj

prečiščeno, privlačno in organizirano kot spletna stran deluje, tem manjša je njena vizualna kompleksnost. Alsudani in Casey [5] sta dokazala vpliv estetike spletnih strani na uporabnikov vtis o njeni kredibilnosti. Izpostavila sta sledeče glavne faktorje, ki naj bi na to vplivali: enotnost dizajna z elementi v ravnovesju in harmoniji, kontrast ter dominantnost. Estetski učinek vizualne organizacije uporabniškega vmesnika se pozitivno povezuje z odzivnim časom v procesu iskanja informacije, kar so z raziskavo podkrepili Salimun in sodelavci [6]. V raziskavi [7] sta Altaboli in Lin s kontroliranim eksperimentom dokazala, da imajo ravnotežje, enotnost in (ustrezno) zaporedje elementov na ekranu zelo pomemben vpliv na zaznano estetiko dizajna.

Vizualne spremenljivke predstavljajo osnovne enote vizualne komunikacije v grafičnem oblikovanju. Opazovalec jih zazna avtomatsko, brez miselnega napora. Znanje uporabe vizualnih spremenljivk je osnova za učinkovito vizualno komunikacijo informacij, prikazanih na spletnih straneh in ostalih uporabniških vmesnikih [8]. Pri našem delu se opiramo na temeljno delo Bertina [9], ki obravnava naslednje vizualne spremenljivke: položaj, velikost, svetlost, barvni ton, smer, vzorec in oblika. Upoštevamo njihove pomembne lastnosti, kot na primer: selektivnost, asociativnost, zaporednost, kvantitativnost in številčnost. Uporabljamo tudi njegove smernice za izboljšavo zaznanih značilnosti vizualnih informacij na osnovi kombinacij vizualnih spremenljivk. Če za upodobitev ene kategorije uporabimo več vizualnih spremenljivk hkrati, lahko tako povečamo selektivnost njihovih elementov. Lažje namreč med seboj ločimo dve vrsti elementov, ki se med seboj razlikujeta v svetlosti in barvi, kot dve vrsti elementov, ki se med seboj razlikujeta le v svetlosti. Pri upodabljanju zgolj kvantitativnih informacij (oziroma elementov z enako vizualno močjo) so razlike v več vizualnih spremenljivkah znotraj ene kategorije elementov pogosto nepotrebne in odvečne. Pri upodabljanju informacij v hierarhiji (oziroma elementov z različno vizualno močjo) pa nam to omogoča, da upodobimo večje število stopenj take komponente. Uporabnik na primer hitro razlikuje med elementi z zelo majhno spremembo v svetlosti (prva vizualna spremenljivka), v primeru da to spremembo spremlja tudi razlika v barvnem tonu (druga vizualna spremenljivka). Če hierarhično komponento upodobimo z razliko v svetlosti in velikosti elementov (z asociativnima vizualnima spremenljivkama), lahko razliko v vizualni moči elementov okrepimo ali pa omilimo. Pri velikem številu informacij lahko z razliko v vrednosti vizualne spremenljivke zaznamujemo različne kategorije informacij. Na primer: ena kategorija vsebuje elemente, ki se med seboj razlikujejo le v barvnem tonu in imajo enako velikost, svetlost, smeri itd. Če z vsako spremenljivko tako označimo po eno kategorijo, lahko ustrezno upodobimo tudi tiste elemente, ki hkrati pripadajo različnim kategorijam.

V zadnjih desetletjih so bile opravljene različne študije in raziskave, ki so preučevale zaznavanje vizualnih spremenljivk tako v statični kot tudi dinamični upodobitvi. V študiji [10] sta Wolfe in Horowitz povzela več desetletij raziskav o tem, katere značilnosti upodobitve elementov najbolje vodijo oziroma pritegnejo opazovalčevo pozornost. Vizualne spremenljivke barvni ton, velikost in smer sta pri tem navedla kot spremenljivke, ki v statičnih prikazih nedvomno vodijo opazovalčevo pozornost, svetlost in obliko pa kot spremenljivki, ki verjetno vodita opazovalčevo pozornost. V raziskavi sta zajela tudi mnoge druge značilnosti upodobitve elementov in jih razdelila v kategorije: nedvomno vodijo (npr. gibanje), verjetno vodijo (npr. prekinitev črte), mogoče vodijo (npr. število), negotovo vodijo (npr. novost) in verjetno ne vodijo opazovalčeve pozornosti (npr. križanje). V novejši študiji [11] sta Garlandini in Fabrikant s tehnologijo beleženja pogleda preučevala zaznavne značilnosti ob spremembi velikosti, svetlosti, barvnega tona in smeri elementov. Rezultati so pokazali, da opazovalci najhitreje in najučinkoviteje zaznajo spremembo v vizualni spremenljivki velikost, smer pa se je v zaznavah njenih sprememb izkazala za najmanj učinkovito. To se do neke mere sklada z Bertinovo teorijo, ki velikosti pripisuje največ zaznavnih značilnosti – selektivnost, asociativnost, zaporednost in kvantitativnost, smeri pa le asociativnost (in zelo majhno selektivnost). Učinkovitost zaznavanja sprememb v svetlosti in barvnem tonu sta si med seboj zelo podobni, rezultati raziskave pa dokaj ustrezajo rezultatom prej omenjene študije Wolfa in Horowitza.

Od oblikovne podobe spletne strani je odvisno, kako uporabniki pregledujejo našo spletno stran. Način upodobitve menijev, besedila, slik in ostalih elementov vpliva na to, kaj bodo ljudje najprej pogledali, čemu bodo posvetili največ pozornosti in na kaj bodo kliknili. Fiksacija pogleda je namreč prvi korak v procesu uporabnikovega klikanja na elemente spletnih strani [12]. V navedenem delu avtorja podajata smernice za postavitev elementov in smernice za oblikovanje elementov na spletnih straneh.

Hierarhična vizualna upodobitev vsebine spletne strani splošno velja za strukturo, znotraj katere uporabniki lažje poiščejo informacijo kot znotraj nehierarhične ureditve. To tezo sta s pomočjo kognitivnega modela in tehnologije sledenja pogleda empirično potrdila Hornof in Halverson [13]. Johansen in Hansen [14] sta preučevala učinkovitost sledečih alternativnih metod določanja uporabnikove pozornosti na spletni strani. V njuni študiji se je poročanje uporabnikov o lastnih premikih oči izkazalo za pravilno v 70 % (pri čemer se zmeraj niso mogli spomniti ustreznega vrstnega reda ogleda), predvidevanje spletnih dizajnerjev, kateri elementi bodo prejeli uporabnikovo pozornost, pa le v 46 %. Raziskava uporabnikove pozornosti in kvalitete dizajna spletnih strani [15] je pokazala, da so spletne strani z nenatrpano postavitvijo elementov, ustreznimi animacijami, ki pritegnejo uporabnikovo pozornost, in estetskim učinkom za uporabnike privlačnejše. Študija, kako kako uporabniki dojemajo različne načine postavitev elementov na spletni strani, je predstavljena v članku avtorjev Revilla in Crow [16].

3 ANALIZA IN PREDLOGI ZA IZBOLJŠAVO SPLETNE STRANI ODPRTE PLATFORME ZA KLINIČNO PREHRANO

Začetna faza oblikovanja predlogov izboljšave vizualne podobe opkp.si temelji na ustrezni uporabi vizualnih spremenljivk. S tem namreč uporabniku omogočimo, da čim hitreje spozna, kaj je naslov, kaj meni, kaj glavno besedilo, kaj povezava, ne da bi sploh prebiral besedilo na spletni strani. To močno skrajša čas, ki ga uporabnik potrebuje, da dojame strukturo spletne strani in na njej najde želeno informacijo.

Pri vizualni izboljšavi spletne strani opkp.si je bila ustrezna uporaba selektivnih vizualnih spremenljivk ključnega pomena. Uporabnik na spletni strani hitreje najde informacijo, če spletno stran oblikujemo tako, da uporabnik pri zaznavanju avtomatično grupira njene elemente v različne skupine. Čas iskanja informacije se skrajša zato, ker uporabnik s pogledom išče informacijo samo v določeni skupini elementov in ne po celi spletni strani. Na primer: uporabnik znotraj besedila išče povezavo do članka o načrtu prehrane. Če bi povezave upodobili tako, da bi uporabili kurzivno različico pisave (razlika v obliki – ni selektivna spremenljivka), bi moral uporabnik s pogledom preleteti celotno besedilo, da bi našel želeno povezavo. Zato povezave upodobimo z modro barvo (razlika v barvnem tonu – selektivna spremenljivka). Uporabnik bo pri iskanju povezave s pogledom preletel le modre besede in med njimi poiskati želeno povezavo. Ker je se množica elementov, med katerimi uporabnik išče informacijo, manjša, je tudi čas iskanja informacije krajši.

Spletno stran opkp.si zaznamuje dokaj kompleksna struktura informacij. Opazimo lahko, da vsebuje komponente, ki se med seboj prekrivajo – določen element spletne strani pripada več komponentam hkrati. Na spletni strani smo z ustrezno uporabo asociativnih vizualnih spremenljivk poskrbeli, da so komponente kljub temu ostale vizualno enotne. Kot primer lahko spet vzamemo povezave znotraj besedila opkp.si. Take besede morajo hkrati imeti vizualne značilnosti glavnega besedila (prva komponenta) in ostalih povezav na spletni strani (druga komponenta). Če bi povezave upodobili z barvo višje svetlosti kot glavno besedilo (razlika v svetlosti – ni asociativna spremenljivka), bi uporabnik sicer dojel, da gre za povezavo, vendar bi bilo branje glavnega besedila oteženo. Nekatere besede znotraj besedila bi bile manj vidne, celotno besedilo pa bi delovalo neenotno. Zato povezave upodobimo z barvo enake ali podobne svetlosti kot glavno besedilo (razlika le v barvnem tonu – asociativna spremenljivka). Branje glavnega besedila ostane neoteženo, hkrati pa uporabnik dojame, da gre za povezavo.

Ustrezna uporaba zaporednih vizualnih spremenljivk nam je pri izboljševanju spletne strani opkp.si omogočila vzpostavitev hierarhije med vizualnimi informacijami. Spletno stran smo oblikovali tako, da so pomembnejše informacije vizualno močnejše od ostalih, da izstopajo in avtomatsko pritegnejo pogled. Tako vodimo uporabnikov pogled po spletni strani in vplivamo na to, v kakšnem vrstnem redu bo opazoval njene elemente. S tem močno vplivamo na uporabnikovo izkušnjo na spletni strani. V prikazu hranilnih vrednosti neke jedi iz zapisanih podatkov izpostavimo oznake vrednosti tako, da jih upodobimo s temnejšim odtenkom (razlika v svetlosti – zaporedna spremenljivka), jih postavimo na začetek spiska (položaj – zaporedna spremenljivka) oziroma jih zapišemo z večjo velikostjo pisave (razlika v velikosti – zaporedna spremenljivka). Ker so oznake vizualno močnejše od vrednosti, najprej pritegnejo uporabnikov pogled. Uporabnik s pogledom najprej preleti le oznake in lahko, ko pride do tipa informacije, ki ga zanima, s celotnega spiska prebere le eno vrednost, a vseeno dobi želeno informacijo. Ker s tem preskoči velik del informacij, ki zanj niso pomembne, mu to omogoči, da hitreje najde iskano informacijo.

Spletna stran opkp.si vsebuje elemente, za katere je pomembno, da jih lahko uporabnik med seboj primerja po količini. Z ustrezno uporabo kvantitativnih vizualnih spremenljivk smo poskrbeli, da je taka primerjava intuitivna in ne potrebuje posebne pozornosti oziroma miselnega napora uporabnika. Tako pripomoremo k izboljšanju uporabniške izkušnje na spletni strani. Za primer lahko vzamemo upodobitev energijske vrednosti posameznega obroka v primerjavi s celotnim dnevnim vnosom. Če ti dve vrednosti označimo s številko (npr. 400,00 kcal/2000,00 kcal), bo uporabnik porabil več časa, da bo med seboj po energijski vrednosti primerjal različne obroke. Oznake z različnimi številkami lahko smatramo kot elemente z različnimi oblikami (razlika v obliki – ni kvantitativna spremenljivka). Če pa vrednost obroka označimo s tortnim diagramom (npr. 20 % kroga), bo uporabnik lažje in hitreje med seboj primerjal več obrokov. Oznake s tortnim diagramom se namreč štejejo kot elementi z razliko v velikosti oziroma deležu. Ker je razlika v velikosti kvantitativna spremenljivka, je primerjava takih elementov intuitivna.

Naslednja faza izboljšave spletne strani opkp.si je osredotočena na analizo vizualnih informacij. Najprej poiščemo različne skupine informacij, ki se pojavljajo znotraj celotne spletne strani (npr. povezave, oznake, vrednosti itd.) in nato določimo način, kako bomo vsako od teh skupin upodobili. Vizualno podobo spletne strani tako izboljšujemo na vseh podstraneh hkrati. S tem se izognemo temu, da bi bil enak tip informacij na različnih podstraneh prikazan drugače. Če enak tip informacij po celotni spletni strani upodobimo na enak način, dosežemo, da je spletna stran enotnejša, bolj predvidljiva in lažja za uporabo. Uporabnik lahko namreč iz vizualne podobe elementov v hipu predvidi njihovo funkcijo, če so ti podobni elementom enakega tipa s prejšnje podstrani. Tako predvidevanje uporabniku omogoči, da določeno informacijo na spletni strani išče s pogledom v določeni skupini elementov in ne po celotni strani, kar močno zmanjša čas iskanja.

Slika 1. Primer pregleda prvotne verzije Načrta prehrane

Slika 2. Primer pregleda izboljšane verzije Načrta prehrane

Omejitev dolžine prispevka ne omogoča podrobnejšega poročila, zato si za ilustracijo oglejmo le eno od konkretnih predlaganih izboljšav. V obstoječi verziji strani so besedne informacije predstavljene v treh stolpcih. Uporabnik porabi veliko več časa, da jih s pogledom preleti in oceni, ali so zanj pomembne ali ne (Slika 1). Če to strukturo primerjamo s predlogom izboljšave, vidimo, da je besedilo tu podano le v enem stolpcu. Vizualno so izpostavljene le glavne besedne informacije, ki se zvrstijo ena pod drugo, kar uporabniku omogoča, da jih preleti v navpični smeri. Pot pogleda je tako krajša, število fiksacij manjše, uporabnik pa kljub temu izve najpomembnejše informacije na strani (Slika 2).

4 ZAKLJUČEK

Namen prispevka je bil ponazoriti, kako lahko ob upoštevanju vpliva vizualnih spremenljivk izboljšamo spletne strani dane platforme. Opisane prijeme je možno uporabiti tudi v primerih že uveljavljenih spletnih strani, saj omogočajo „mehak" prehod iz obstoječe na izboljšano verzijo. Ker gre za aktualno raziskovalno problematiko, bodo za tiste, ki bi radi izvedeli kaj več, koristne tudi zbrane novejše reference kot izhodišče za nadaljnje poizvedbe. Delo na izboljšanju platforme OPKP še ni končano in ostaja predmet nadaljnjega raziskovalno - razvojnega dela.

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INTELIGENTNI PARAMETRIČNI 3D CAD SISTEM ZA AVTOMATSKO (PRE)MODELIRANJE REZALNIH KOMPONENT BLOČNEGA ORODJA

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POVZETEK

V prispevku predstavljamo inteligentni parametrični 3D CAD-sistem, namenjen avtomatskemu (pre)modeliranju rezalnih komponent bločnega orodja. Gre za predlogo v obliki CAD-sklopa, ki je sestavljena iz modulov 'GAJA1' in 'GAJA2'. Modul 'GAJA1' v prvi fazi (pre)modeliranja omogoča neposreden vnos konstrukterskega problema, kar zadeva obliko in dimenzije rezalnih značilnosti na pločevinskem izdelku, njegovo pretvorbo v geometrijsko obliko ter sinhroni prenos vrednosti parametrov in dinamične geometrije v modul 'GAJA2'. Zatem modul 'GAJA2' razbere vnesene vrednosti parametrov in na tej osnovi, ob upoštevanju konstrukterskih ter proizvodnih standardov podjetja, avtomatsko opravi proces (pre)modeliranja rezalnih komponent. Izgradnja sistema je zajemala uporabo v CATIA V5 vgrajenih modulov, kot so Part Design, Assembly Design in Knowledge Advisor (API); logike, ki povezuje geometrijske značilnosti rezalnih komponent z rezalnimi značilnostmi na pločevinskem izdelku ter internih standardov podjetja. Eksperimentalni rezultati so pokazali, da uporaba predlaganega sistema, v primerjavi s tradicionalnim pristopom, bistveno skrajša čas ter izboljša kakovost postopka (pre)modeliranja rezalnih komponent, prav tako pa predstavlja izvrsten način za šolanje neizkušenih konstrukterjev.

1 UVOD

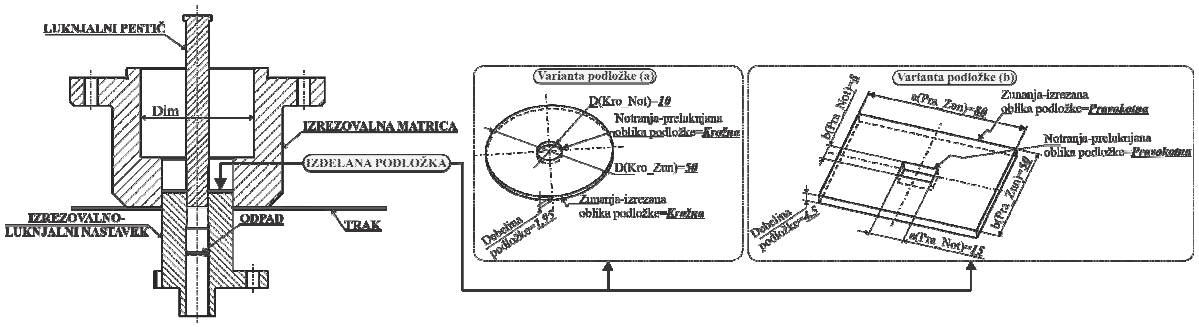
V današnjem času predstavlja uspešno obvladovanje 3D CAD tehnologij znotraj orodjarske industrije eno izmed pomembnejših poti za doseganje konkurenčne prednosti. Kljub številnim prednostim, ki jih v proces konstruiranja prinašajo sodobni 3D CAD programski paketi, pa ti še vedno ne omogočajo potrebne in zadostne podpore v smislu svetovanja ali samostojnega reševanja določenih aktivnosti [1]. Večina od njih namreč omogoča le prenos miselnih procesov (sklepanj) v grafično obliko, tj. formalni geometrijski model [2], zaradi česar morajo konstrukterji večino aktivnosti v orodjarstvu po tradicionalnem načinu opravljati samostojno, ročno ter ponavljajoče. Iz tega razloga so bile do sedaj opravljene številne raziskave s področja razvoja inteligentnih sistemov, ki naj bi prispevali k optimizaciji procesa konstruiranja orodij [3, 4]. Še vedno pa obstaja vrsta problemov, ki se jih omenjene raziskave niso dotaknile.

Eno izmed pomembnejših aktivnosti konstruiranja orodij predstavlja modeliranje rezalnih komponent, ki zagotavljajo neposredno oblikovanje izdelkov. Čeprav so tovrstne komponente znotraj posameznih part-datotek zmodelirane kot parametrične značilnosti [5, 6], pa jih je težko ponovno uporabiti in hitro premodelirati na način, da bodo te ustrezale drugim oblikam in dimenzijam rezalnih značilnosti na pločevinskih izdelkih. Tako se pojavlja velika potreba po nadgradnji funkcionalnosti konvencionalnega 3D CAD-paketa, kot je CATIA V5, s sistemom, ki bi bil sposoben samostojno opraviti omenjeno aktivnost. Osnovo za razvoj tovrstnega sistema predstavlja izkoriščanje parametrične narave sodobnih 3D CAD-programskih paketov, ki omogočajo popis navideznih računalniških predstavitev objektov z različnimi tipi parametrov, katerih vrednosti v celoti opisujejo trenutne značilnosti oziroma modele. Na ta način lahko znanje, ki se nanaša na geometrijo, skozi formalizacijo povezav med parametri (kreiranje omejitev), ponovno uporabimo [7]. S takšnim predpisovanjem dinamičnega obnašanja, ki vodi značilnosti na osnovi znanja, lahko 3D CAD-sistemu omogočimo samostojno izvajanje določenih »inteligentnih« akcij.

2 TRADICIONLANI POSTOPEK MODELIRANJA REZALNIH KOMPONENT ORODJA

Podložke so pločevinski izdelki, ki se pogosto uporabljajo v raznovrstnih industrijah in lahko glede na njihove možne oblike in dimenzije zavzemajo številne različne variante. Iz tega razloga se za njihovo proizvodnjo uporabljajo mnoga bločna orodja, ki v posameznem hodu stiskalnice z istočasnim izvajanjem operacij izrezovanja in luknjanja iz pločevinskega traku proizvedejo podložko. Med raznimi komponentami bločnih orodij so luknjalni pestič, izrezovalno-luknjalni nastavek ter izrezovalna matrica tiste rezalne komponente, ki neposredno izvajajo oblikovanje podložk. Na tej osnovi lahko vzpostavimo Enačbo 1, ki je namenjena konstruiranju teh komponent.

Konstruiranje rezalnih komponent bločnega orodja = f (oblike podložke, dimenzij podložke) (1)

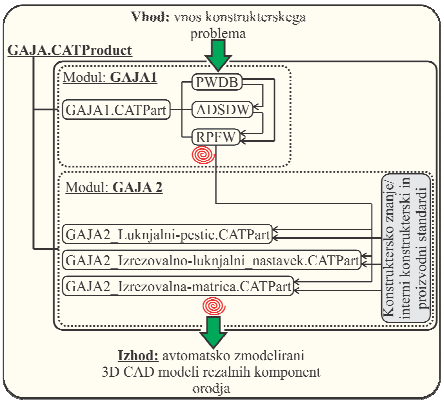


Slika 1: *Rezalni elementi bločnega orodja ter dve možni varianti podložke s pripadajočimi parametri.*

Vsaka oblikovno in dimenzijsko različna varianta podložke (Slika 1) predstavlja nov problem konstruiranja rezalnih komponent bločnega orodja. Ko konstrukter razreši en problem, shrani nekaj znanja znotraj posameznih part-datotek v obliki pripadajočih geometrijskih značilnosti ter z njimi povezanih vrednosti parametrov. Ker pa konvencionalni 3D CAD-sistemi ne zajemajo razumevanja postopka konstruiranja rezalnih komponent orodja, samostojno niso sposobni ponovno uporabiti obstoječih part-datotek ter jih prilagoditi novemu problemu. V primeru da nov problem zahteva samo dimenzijske spremembe, mora konstrukter obstoječe part-datoteke odpreti ter znotraj njih opraviti prilagoditve vrednosti parametrov, ki predstavljajo dimenzijske lastnosti značilnosti rezalnih komponent. V primerjavi z dimenzijsko spremembo, pa je sprememba oblike značilnosti bolj kompleksna [8]. Ponovna uporaba obstoječih part-datotek bi v tem primeru pomenila, da mora konstrukter znotraj njih spremeniti geometrijske značilnosti z izbrisom njihovih oblikovnih profilov (skic) ter nato ročno zmodelirati nove. Ker slednje terja tudi dlje časa, povezanega na preurejanje omejitev, konstrukterji raje ustvarijo nove part-datoteke in začnejo modelirati rezalne komponente orodja povsem z začetka. Zaključimo lahko, da tradicionalni način (pre)modeliranja rezalnih komponent orodja zahteva veliko ročnega, ponavljajočega se in zato časovno potratnega dela, ki je povezano z manipuliranjem značilnosti ter vzpostavljanjem geometrijskih in algebraičnih omejitev. Da bi naredili korak k odpravljanju te problematike, smo razvili sistem, ki je zmožen avtomatsko (pre)modelirati rezalne komponent bločnega orodja. Osnovo za njegov razvoj so predstavljali: izkoriščanje parametrične narave programa CATIA V5, upoštevanje zakonitosti podane z Enačbo 1 ter upoštevanje internih standardov podjetja Emo-orodjarna d. o. o.

3 METODOLOGIJA RAZVOJA SISTEMA

Celotno delovanje sistema je zagotovljeno preko dveh modulov, tj. 'GAJA1' in 'GAJA2' (Slika 2), za izgradnjo katerih smo uporabili v CATIA V5 vgrajene module. Modul 'Part Design' smo uporabili za: modeliranje geometrijskih značilnosti in modelov, izvajanje njihovega parametričnega opisa, vzpostavljanje algebraičnih omejitev ter za ustvarjanje publikacij namenjenih prenosu parametrov skupaj z njihovimi vrednostmi in geometrijskih elementov med predlaganima moduloma. Modul 'Knowledge Advisor' je omogočil zapis konstrukterskega znanja v obliki 'IF-THEN' produkcijskih pravil [9]. Modul 'Assembly Design' pa smo izkoristili za kreiranje sklopa 'GAJA.CATProduct', kamor smo predlagana modula namestili ter s tem zagotovili, da bodo rezultati delovanja sistema prikazani na enem mestu.



Slika 2: *Predlagana zgradba in delovanje sistema.*

Praktični razvoj sistema smo izvedli na osebnem računalniku (Intel® Core™ 2 Duo CPU 2.2 GHz, 4GB RAM) z operacijskim sistemom Windows 7.

3.1 Razvoj modula 'GAJA1' za popolno opredelitev in interpretacijo konstrukterskega problema

Modul 'GAJA1' predstavlja part-datoteko, ki vsebuje parametrično bazo podatkov ‘PWDB’ in pod-modul ‘ADSDW’.

3.1.1 Vzpostavitev parametrične baze podatkov ‘PWDB’ in uporabniškega vmesnika

V prvi fazi razvoja modula 'GAJA1' je bilo potrebno ustvariti popolno in sistematično bazo podatkov s področja opredelitve geometrijskih informacij o podložkah. Ta mora biti vzpostavljena na način, ki bo sistemu v določeni situaciji omogočil neposredno sklepanje o njihovem vplivu na izvedbo konstrukcije rezalnih komponent orodja. Bazo

podatkov smo vzpostavili s pomočjo funkcionalnosti CATIA V5, ki omogoča kreiranje uporabniško-določenih parametrov [10] ter s tem organiziranje podatkov o različnih variantah podložk v obliki drevesne strukture. Uporabniško-določene parametre smo uporabili kot nosilce za shranjevanje in prikaz geometrijskih lastnosti podložk, pri čemer smo uporabljali njihova jasna poimenovanja ter jih strukturirano nameščali znotraj posameznih logično-poimenovanih nizov parametrov. Na ta način smo omogočili preglednejše programiranje ter kasnejšo jasno interakcijo med uporabnikom in sistemom. Zatem smo upoštevali še pričakovano območje problemov, tj. tiste variante podložk, za katere podjetje pričakuje, da bo v prihodnosti potrebno izvajati (pre)modeliranje 3D modelov rezalnih komponent. Te smo opredelili z identifikacijo parametrov glede na vrednosti, ki jih ti lahko zavzemajo (zvezne ali pred-določene). Za spreminjanje oblike podložke smo ustvarili dva večvrednostna parametra tipa '*string*' s poimenovanjema '*Zunanja-izrezana oblika podložke*' in '*Notranja-preluknjana oblika podložke*' ter jima predpisali zahtevane vrednosti. Kombinacije možnih vrednosti omenjenih večvrednostnih parametrov v bazi podatkov omogočajo opredelitev 4 zunanjih oblik ter 6 notranjih oblik, kar skupaj predstavlja 24 različnih problemov, tj. variant podložk. Po vizualizaciji metode za zvezno spreminjanje dimenzij predvidenih oblikovnih profilov podložk, smo dodatno ustvarili še 14 dolžinskih parametrov ter s tem občutno povečali področje opredeljevanja variant podložk. Obstoječo bazo podatkov je mogoče kadarkoli spremeniti ali jo nadgraditi z dodatnimi vrednostmi. Zgrajena baza podatkov hkrati zagotavlja tudi uporabniški vmesnik, preko katerega bo uporabnik lahko vnesel trenutni problem (pre)modeliranja rezalnih komponent neposredno v sistem.

3.1.2 Vzpostavitev pod-modula 'ADSDW' za avtomatsko vodenje oblik in velikosti podložk

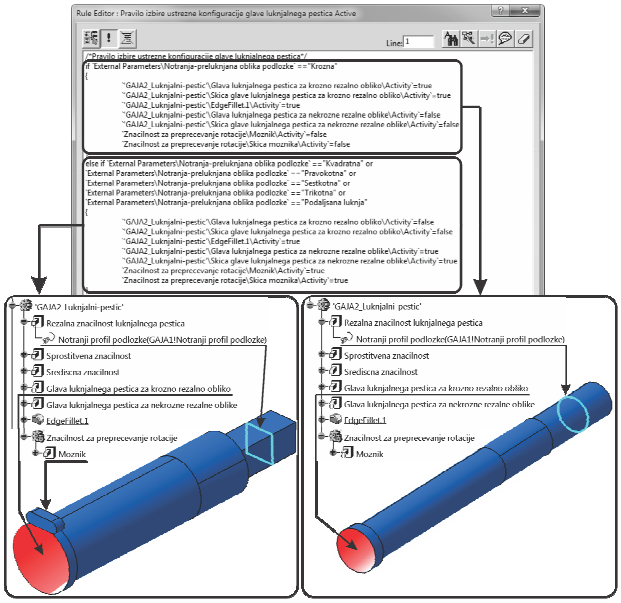
Zgrajena baza podatkov še ne deluje dinamično, kar pomeni, da vrednosti parametrov znotraj nje ne omogočajo manipulacije ali spreminjanja geometrijskih elementov CAD-modelov podložk, saj ti trenutno še ne obstajajo. Zato je bilo po vzpostavitvi ustrezne baze podatkov, potrebno razviti še ustrezen pod-modul 'ADSDW', ki bo omogočal fleksibilno vodenje oblik in velikosti podložk. S tem namenom smo ustvarili ustrezne entitete za predstavitev oblike in velikosti podložk ter razvili metodologijo, ki bo zagotovila njihovo obnašanje v skladu z vrednostmi parametrov v bazi podatkov. Ena izmed zahtevnejših opravil je predstavljala opredelitev algoritma za fleksibilno spreminjanje oblikovnih kontur podložke, ki morajo biti sposobne samo-prilagoditve pred-določenim vrednostim parametrov *'Zunanja-izrezana oblika podložke*' in *'Notranja-'Notranja-preluknjana oblika podložke*' (glej Sliko 1). To smo dosegli z dvema parametroma tipa '*curve*', pri čemer smo njuno obnašanje predpisali s pomočjo pravil, ki omogočajo aktiviranje ustreznih pred-ustvarjenih oblikovnih profilov (skic) glede na trenutne vrednosti zgoraj omenjenih parametrov. Po popisu možnih oblikovnih profilov z dimenzijskimi parametri smo na koncu dosegli, da je celotna geometrija podložke vodena neposredno iz 'PWDB'. Pod-modul 'ADSDW' zagotavlja sistemu dinamično voden geometrijski skelet, ki predstavlja osnovo za (pre)modeliranje aktivnih komponent.

3.1.3 Vzpostavitev pod-modula 'RPFW' za prenos in ponovno uporabo parametrov ter geometrijskih entitet

Informacije o podložkah shranjene znotraj 'PWDB' in njihove geometrijske entitete znotraj 'ADSDW' predstavljajo osnovo za vzpostavitev in delovanje modula 'GAJA2'. Zato morajo biti ti elementi pretvorjeni v obliko, ki bo: omogočila njihovo uporabo znotraj omenjenega modula za tvorjenje omejitev ter geometrijsko modeliranje in skladno z opredelitvijo novega problema omogočila posodobitev vrednosti parametrov skupaj z grafičnimi entitetami. Zato smo izgradnjo pod-modula 'RPFW' izkoristili publikacijski mehanizem, ki znotraj CATIA V5 omogoča nadzor nad ustvarjenimi zunanjimi referencami.

3.2 Metodologija razvoja modula 'GAJA2' za avtomatsko (pre)modeliranje rezalnih komponent orodja

Za vzpostavitev modula 'GAJA2' smo ustvarili tri posamezne part-datoteke 'GAJA2_Luknjalni-pestic', 'GAJA 2_Izrezovalno-luknjalni_nastavek' ter 'GAJA2_Izrezovalna-matrica' in jih namestili znotraj sklopa 'GAJA.CAT Product'.



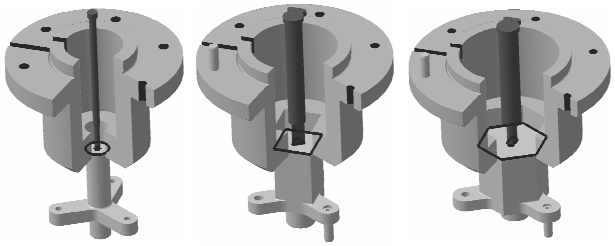
Slika 3: *Pravilo, ki vodi obnašanje značilnosti oblike glave luknjalnega pestiča glede na obliko rezalne značilnosti*.

Vse za izgradnjo potrebne elemente smo kopirali iz 'PWDB' ter jih z ukazom 'Paste Special→As Result With

Link' prenesli v posamezne part-datoteke modula 'GAJA2', kjer smo zatem izvedli postopke geometrijskega modeliranja in programiranja omejitev. Ker so rezalne značilnosti zadolžene za oblikovanje podložk neposredno modelirane s pomočjo parametrov tipa 'curve' iz 'ADSDW', se geometrijske spremembe izvedejo neposredno preko funkcije 'Replace'. Ta preko sinhronizacije z modulom 'GAJA1' omogoča ekstrakcijo rezalnih značilnosti, tj. luknjalnih in rezalnih profilov v modul 'GAJA2'. S parametričnim programiranjem smo zagotovili omejitve, ki vodijo obnašanje preostalih značilnosti rezalnih komponent v skladu s konstrukterskim znanjem in internimi standardi podjetja (Slika 3). S tem ko je obnašanje značilnosti v modulu 'GAJA2' sinhrono povezano z vodilnimi (ang. driving) oz. vnosnimi parametri v modulu 'GAJA1', smo zagotovili avtomatsko modeliranje 3D rezalnih komponent bločnega orodja znotraj sklopa 'GAJA.CATProduct'.

4 UPORABA IN TESTIRANJE SISTEMA

Delovanje sistema so testirali izkušeni in neizkušeni konstrukterji znotraj podjetja Emo-orodjarna d. o. o. Ti so morali zmodeliranja rezalne komponente orodja za tri oblikovno in dimenzijsko različne variante podložke po tradicionalnem načinu in s pomočjo uporabe sistema.



Slika 4: *Tri variante rezalnih komponent bločnega orodja avtomatsko pridobljene preko delovanja sistema.*

Rezultati so pokazali, da uporaba sistema, v primerjavi s tradicionalnim pristopom, skrajša čas konstruiranja za 41% pri ekspertih in za 74% pri neizkušenih uporabnikih. Časovni prihranki se dodatno povečajo pri reševanju več problemov. Rezultate delovanja sistema so na koncu pregledali še visoko usposobljeni konstrukterji, ki so jih, v primerjavi z rezultati tradicionalnega postopka, ocenili za izredno kakovostne. Uporaba sistema istočasno predstavlja odličen pripomoček za šolanje neizkušenih konstrukterjev, ki pridobijo vpogled, kako se uporablja konstrukterska logika pri modeliranju rezilnih komponent ter spoznajo interne konstrukterske in proizvodne standarde podjetja.

5 ZAKLJUČEK

Razvili smo inteligentni parametrični sistem za avtomatsko (pre)modeliranje rezalnih komponent bločnega orodja. Sistem predstavlja »inteligentno« predlogo sestavljeno iz dveh modulov – 'GAJA1' in 'GAJA2'. Modul 'GAJA1' omogoča za neposreden vnos konstrukterskega problema, kar zadeva oblike in dimenzij podložke, njegovo pretvorbo v geometrijsko obliko ter prenos pomembnih parametrov in značilnosti v modul 'GAJA2'. Modul 'GAJA2' razbere trenutne vrednosti vnosnih parametrov in avtomatično opravi proces modeliranja rezalnih komponent ob upoštevanju notranjih konstrukterskih in proizvodnih standardov podjetja. Izgradnja sistema je zajemala uporabo v CATIA V5 vgrajenih modulov, kot so Part Design, Assembly Design in Knowledge Advisor (API); logike, ki povezuje geometrijske značilnosti rezalnih komponent z rezalnimi značilnostmi na pločevinskem izdelku ter internih standardov podjetja. Takšna struktura omogoča razvoj sistema znotraj večine 3D CAD- parametričnih programskih paketov, pri čemer je možno uporabiti specifične standarde podjetij. Eksperimentalni rezultati so pokazali, da uporaba predlaganega sistema v primerjavi s tradicionalnim pristopom bistveno skrajša čas ter izboljša kakovost postopka (pre)modeliranja rezalnih komponent, prav tako pa predstavlja izvrsten pripomoček za šolanje neizkušenih konstrukterjev.

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POVZETEK

V članku predstavljamo meritve vpliva kanala na sistem za samodejno verifikacijo govorcev (SVG) pri različnih kanalih za učno in testno skupino posnetkov. Meritve smo izvajali na slovenskih govornih posnetkih, ki smo jih posneli v laboratoriju preko dveh različnih mikrofonov, telefonije PSTN, GSM in VoIP. Rezultati kažejo, da je uspešnost razpoznavanja pri različnih kanalih za testne in učne posnetke slabša, kot pri okoliščinah razpoznavanja, kjer je kanal za obe skupini posnetkov isti.

1 UVOD

Govor je eden najstarejših, najnaravnejših in v mnogih situacijah najpomembnejših načinov sporazumevanja med ljudmi. Poleg samega sporočila govor vsebuje še druge informacije, ki se nanašajo tako na značilnosti samega govorca kot na lastnosti komunikacijskega kanala, preko katerega se prenaša. Na njegovi osnovi je možno izvajati tudi biometrično razpoznavanje oseb oz. govorcev, ki ima zelo široko uporabno vrednost: za forenzične in obveščevalno-varnostne potrebe, kot dopolnitev varnostnih sistemov kontrole vstopa ali telefonskega bančništva, iskanje po zvočnih arhivih ipd.

Govor je delno določen s človekovimi govornimi organi oz. njihovimi fiziološkimi lastnostmi, delno pa je odvisen od najrazličnejših drugih dejavnikov (npr. spol, starost, zdravje) oz. je priučen iz okolja (izobrazba, kraj bivanja). V današnjem času se govor (na daljavo) najpogosteje prenaša preko različnih oblik telefonije (npr. PSTN, GSM, VoIP). Lastnosti komunikacijskega kanala so pri tem odvisne od uporabljenih mikrofonov s katerimi govor zajemamo, akustičnega ozadja oz. akustičnih pogojev, ki pri tem nastopajo, ter od vplivov uporabljenih prenosnih poti (zmogljivost in kvaliteta prenosa, morebitna popačenja signala).

Uspešnost sistemov za samodejno razpoznavanje govorcev je še vedno precej odvisna od uporabljenega kanala. Njegovim vplivom se skušamo izogniti na različnih nivojih sistema: na nivoju signala oz. značilk, na nivoju statističnega modela ali na nivoju rezultatov prileganja [1]. Gre za enega najtežjih in še nezadovoljivo rešenih problemov, ki je predmet intenzivnega preiskovanja in številnih raziskav.

Vprašanje na katerega želimo odgovoriti je: »kako uporaba različnih prenosnih kanalov pri zajemanju učne in testne množice vpliva na uspešnost razpoznavalnika govorcev?«. V kriminalistični forenziki se namreč največkrat primerja glasove s posnetkov telefonskih prisluhov neznanih oseb z glasovi osumljencev, ki pa so praviloma posneti preko mikrofona snemalne naprave.

V drugem poglavju je predstavljen potek meritev, v tretjem poglavju so podani rezultati, ki jih v četrtem poglavju podrobneje analiziramo. Prispevek se konča s sklepnimi ugotovitvami.

2 MERITVE VPLIVA KANALA NA SVG

2.1. Slovenski govorni posnetki

Meritve vpliva kanala na SVG smo izvajali s slovenskimi govornimi posnetki moških govorcev. Posnetke smo pridobili iz javnih virov in prisluhov telefonskih pogovorov, delno pa smo jih posneli v laboratoriju [2]. Posnetki iz javnih virov in telefonskih prisluhov so bili primerni zgolj za izdelavo modela ozadja. Pri teh posnetkih nismo imeli informacije o identiteti govorcev. Za testiranje in učenje pa smo morali zagotoviti lastne govorne posnetke, posnete preko nadzorovanih okoliščin, ki smo jih lahko medsebojno primerjali v meritvah. Zbirka laboratorijsko posnetih govorcev je torej vsebovala informacije o identiteti govorca, načinu govora in kanalu, preko katerega je bil vsak posnetek posnet.

Na sliki 1 je prikazan način snemanja lastne govorne zbirke slovenskih moških govorcev [3]. Snemanje smo izvajali vzporedno preko petih različnih kanalov: preko telefonije GSM, PSTN, VoIP in neposredno preko mikrofona. Moški so govorili v dva različna mikrofona, slušalko mobilne telefonije GSM, slušalko stacionarne telefonije PSTN in vgrajeni zunanji mikrofon namiznega telefona VoIP.

Ker smo želeli pridobiti posnetke različnih načinov govora, smo govorce snemali med branjem besedila, spontanim govorjenjem in pogovorom. Vsak govorec je med snemanjem bral besedilo v trajanju približno dve minuti, spontano govoril približno pet minut in se pogovarjal z operaterjem snemanja okoli pet minut. Pri spontanem govoru in branju je na posnetkih samo ciljna oseba. Pri pogovoru je na vseh posnetkih poleg govorca, ki ga snemamo, slišen tudi glas sogovornika. Sogovornik je na vseh pogovorih isti.

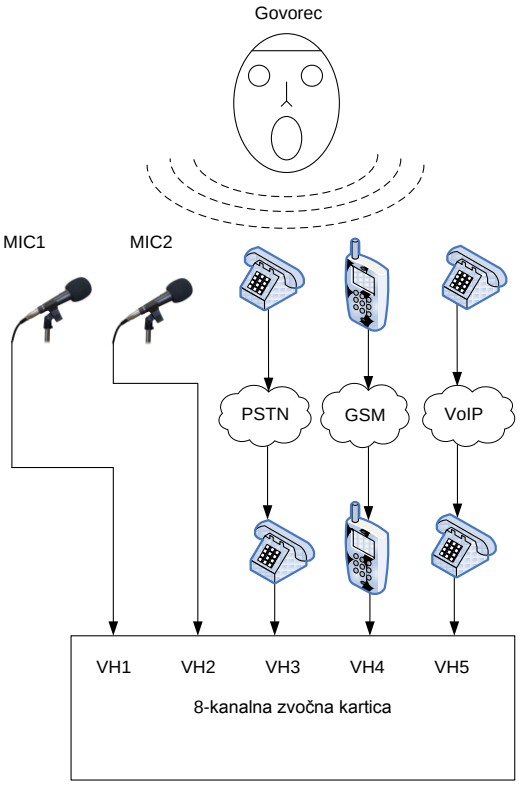
Model ozadja je sestavljen iz dveh skupin posnetkov: 66 posnetkov prek mikrofona in 124 posnetkov prek mobilne telefonije. Vključili smo tudi tiste posnetke, na katerih

govorijo iste osebe kot na posnetkih za učenje in testiranje. Obe skupini posnetkov za model ozadja sta bili sestavljeni iz posnetkov pogovora in spontanega govora. Skupini mikrofonskih posnetkov je dodano še 30 posnetkov moških govorcev iz javnih TV oddaj in parlamenta. Skupini posnetkov prek mobilne telefonije pa je priloženo še 87 posnetkov pogovorov slovenskih moških. V teh posnetkih govori približno 10 različnih oseb, ki so posnete prek prisluhov v mobilnem telefonskem omrežju.

Učenje smo izvajali s posnetki, posnetimi prek vseh petih kanalov. Učenje s posnetki prek mikrofona, smo izvajali s posnetki prek obeh mikrofonov pri branju in spontanem govoru, torej skupno s štirimi posnetki za vsakega govorca. Potem smo izvedli učenje modelov govorcev s 30 posnetki govora slovenskih poslancev, pri čemer vsak poslanec govori samo na enem posnetku. Dodatno smo izvedli učenje še na treh mikrofonskih posnetkih intervjuja.

V nadaljevanju smo izvedli učenje s posnetki, posnetimi prek telefonije GSM, PSTN in VoIP za vseh izbranih 18 govorcev iz lastne govorne zbirke, ki so bili posneti pri branju in spontanem govoru.

Testiranje smo izvajali s posnetki iz lastne govorne zbirke prek vseh petih kanalov, ki so bili posneti pri pogovoru.



Slika 1: Okolje za sočasno snemanje govora prek več kanalov hkrati. Snemanje govora poteka vzporedno prek petih različnih kanalov: dveh različnih mikrofonov, klasične analogne telefonije PSTN, mobilne telefonije GSM in telefonije VoIP [3].

2.2. Izvedba meritev uspešnosti sistema SVG v mešanih okoliščinah

Meritve uspešnosti verifikacije smo izvedli na testni populaciji 18 slovensko govorečih moških, ki so poleg drugih govorcev zastopani tudi v modelu ozadja.

Model ozadja je pri vseh meritvah enak in je zgrajen iz posnetkov istih moških govorcev, ki govorijo na drugačen način kot v testnih in učnih posnetkih. Za učenje smo uporabljali eno vrsto kanala, testiranje pa smo izvedli na posnetkih prek vseh kanalov: mikrofona, telefonije GSM, PSTN in VoIP. Tako smo lahko opazovali obnašanje sistema pri istem modelu ozadja, vendar pri različnih okoliščinah oziroma kanalih za učenje in testiranje.

3 REZULTATI MERITEV

Na slikah 2, 3, 4 in 5 so v obliki grafov DET prikazani rezultati štirih sklopov meritev uspešnosti sistema za SVG [3]. Na sliki 2 so prikazni rezultati za učenje na mikrofonskih posnetkih, na sliki 3 za GSM, na sliki 4 za PSTN in na sliki 5 so rezultati za učenje na posnetkih VoIP. Grafi DET prikazujejo razmerje med napako napačno zavrnjenih (ang. False Rejection Rate), FRR in napačno sprejetih (ang. False Acceptance Rate), FAR [4]. Na osi FAR = FRR opazujemo napako EER (ang. Equal Error Rate).

4 ANALIZA VPLIVA KANALA NA USPEŠNOST SVG

Iz rezultatov lahko ugotovimo, da se SVG pričakovano najbolje obnaša s posnetki, ki so bili posneti na istem kanalu za učenje in testiranje. Pri učenju z mikrofonskimi posnetki dosega EER pod 5% za posnetke, ki so prav tako posneti prek mikrofona. Pri PSTN posnetkih je obnašanje sistema nekoliko slabše, najslabše pa se sistem obnaša z GSM in VoIP posnetki, kjer je EER okoli 20%.

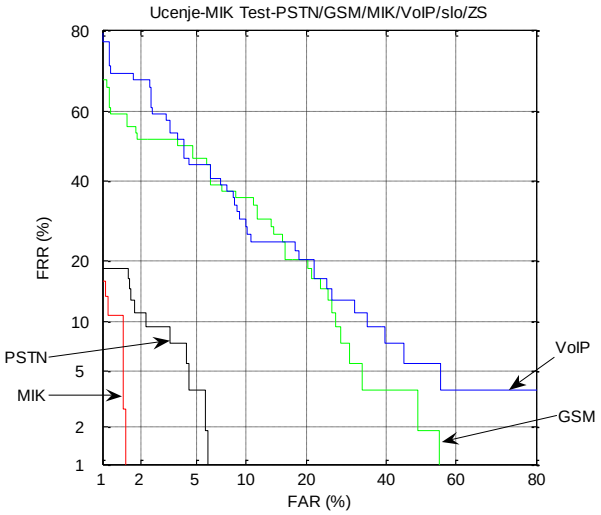
Iz rezultatov zadnjega sklopa meritev S posnetki prek telefonije VoIP, pričakovano lahko ugotovimo, da se sistem najbolje obnaša pri VoIP. Opazimo pa lahko občutno poslabšanje napake pri MIK in GSM z EER okoli 40% in PSTN z EER okoli 50%, kar je enakovredno naključnemu odločanju.

Vse meritve v mešanih okoliščinah kažejo, da sistem SVG pričakovano najbolje razpoznava govorce s posnetki v istih učnih in testnih razmerah. Prav tako ugotavljamo, da je vrednost EER za te posnetke presenetljivo majhna, torej pod 5%, razen pri GSM, kjer je okoli 10%, pri čemer je pri VoIP celo pod 1%, kar zaradi natančnosti grafa ni več vidno na sliki. Vzrok za to lahko iščemo v uporabi testne zbirke posnetkov z dokaj majhno količino posnetkov istih govorcev, delno pa tudi v zastopanosti istih govorcev med testnimi in učnimi posnetki ter v posnetkih za model ozadja. To običajno privede do pretirano dobrih rezultatov, neprimerljivimi z obnašanjem sistema v realnih razmerah delovanja.

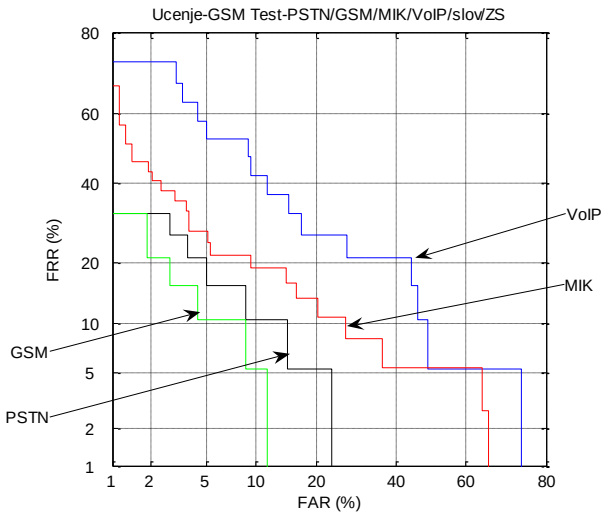
Pri učenju s posnetki GSM lahko ugotovimo podobno, kot pri mikrofonskih, da se sistem za SVG pričakovano

najbolje obnaša s posnetki, pridobljenimi v istih okoliščinah za učenje in testiranje, v tem primeru za GSM posnetke z EER okoli 10%. PSTN posnetki dajejo nekoliko slabši rezultat, nekaj nad 10%, najslabše pa se sistem obnaša z MIK z EER okoli 15% in VoIP posnetki z EER nad 20%.

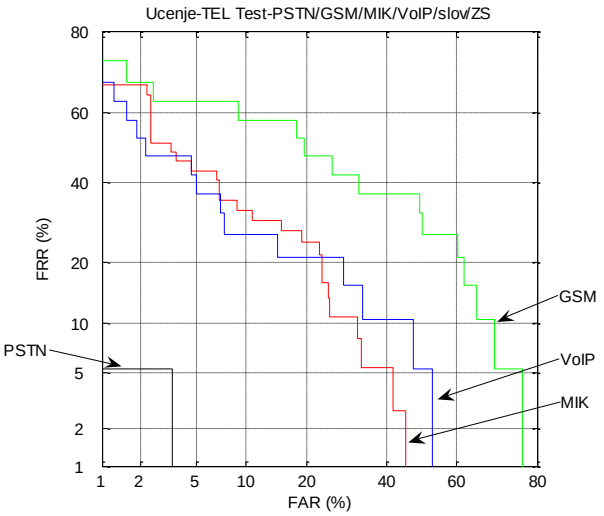
Tudi rezultati uspešnosti s posnetki prek telefonije PSTN, kažejo, da najboljši rezultat prinesejo posnetki pri istih razmerah za učenje in testiranje, torej v tem primeru za PSTN. Občutno slabše pa se sistem obnaša pri VoIP in MIK z EER okoli 20%. Posnetki GSM tokrat prinesejo napako EER blizu 40% .



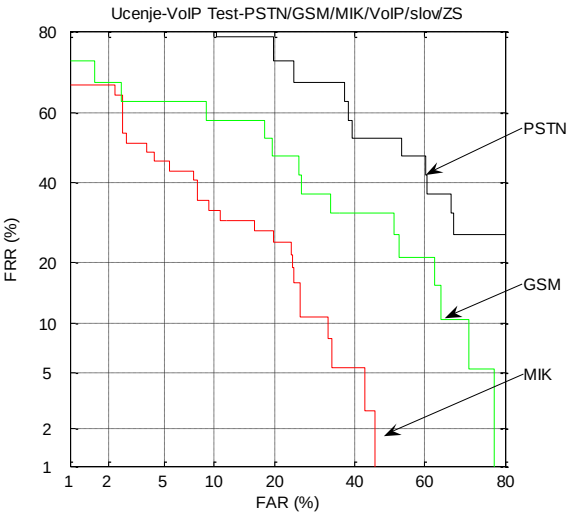
Slika 1: Uspešnost SVG za učenje preko MIK [3]



Slika 2: Uspešnost SVG za učenje preko GSM [3]



Slika 3: Uspešnost SVG za učenje preko PSTN [3]



Slika 4: Uspešnost SVG za učenje preko VoIP [3]

5 SKLEP

Razvili smo testno okolje za proučevanje vpliva uporabe različnih prenosnih kanalov pri zajemanju učne in testne množice na uspešnost sistemov SVG.

Izvedene meritve in njihovi rezultati potrjujejo velik vpliv uporabljenih kanalov na uspešnost prepoznavanja govorcev. Če izvajamo učenje na posnetkih, posnetih prek enega kanala, testiranje pa poteka na posnetkih prek drugega kanala, prihaja do večje napake kot takrat, ko je kanal enak tako pri učenju kot testiranju. Povečevanje napake pri različnih kanalih je različno za različne kombinacije.

Ocenjujemo, da je sočasno snemanje prek več kanalov hkrati prava usmeritev pri gradnji govornih zbirk za forenzične potrebe.

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ALGORITEM LOF KOT METODA V SISTEMU ZA PODPORO ODLOČANJA

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POVZETEK

Sistemi za podporo odločanja imajo večinoma zelo kompleksno arhitekturo. Pomemben del takšnega sistema so eden ali več modulov za oceno tveganja, ki temeljijo na ekspertnem znanju ali na veliki količini označenih podatkov. V tem prispevku bomo predstavili nenadzorovnano metodo LOF in jo predlagali za enega v množici modulov v sistemih za podporo odločanja. Algoritem smo spremenili in dopolnili za namen ocenitve tveganja pri pacientih s srčnim popuščanjem. Predstavljene spremembe so (i) računanje razdalje med nominalnimi atributi, (ii) vrednotenje stopnje nenavadnosti dogodka in (iii) ocena tveganja po parametru. Z eksperimentom smo dobili preliminarne rezultate, ki kažejo na potencialno koristnost spremenjenega algoritma.

1 UVOD

Sistemi za podporo odločanja (SPO) so informacijski sistemi namenjeni asistenci ekspertom pri odločitvenih aktivnostih. Glavni cilj je pospešitev samega procesa odločanja. Zaradi preobremenitve vodilnih profesionalcev v posameznih domenah in pomanjkanja časa za podrobno analizo podatkov, zainteresiranost v takšne sisteme raste. Za nas so zanimivi predvsem inteligentni SPO (slo. ISPO, ang. IDSS (Intelligent Desicion Support System)), ki vsebujejo algoritme umetne inteligence za naprednejšo analizo podatkov. Trenutno lahko najdemo veliko SPO sistemov, ki so razviti za delovanje na različnih domenah kot naprimer: (i) poslovna inteligenca, za hitrejše zaznavanj negativnih in pozitivnih trendov in spremljanje prostih resursov [1], (ii) kriminalne preiskave [2], (iii) klinične preiskave in nadzor pacientov [3] itd.

ISPO sistemi so z visokega nivoja gledano sestavljeni iz baz podatkov, modeliranega znanja in uporabniškega vmesnika. Modelirano znanje je skupek modulov, ki lahko vsebujejo inteligentne metode ali pa tudi ne, končna odločitev sistema pa je agregacija odločitev vseh vsebujočih modulov. Metode, ki se pojavljajo v modulih, so v večini primerov metode nadzorovanega učenja, kot so nevronske mreže, genetski algoritmi, odločanje na osnovi pravil itd. Za zaupanja vredno delovnje teh sistemov je potrebno metodam zagotoviti veliko količino označenih podatkov. Zajemanje označenih podatkov je časovno problematično, prav tako tudi zanesljivost označenih podatkov.

V tem prispevku smo raziskali možnost uporabe metode, ki deluje na osnovi neoznačenih podatkov in omogoča ločitev normalnih od nenormalnih dogodkov. Med takmi metodami smo izbrali Local Outlier Factor (LOF) algoritem [4]. Ta algoritem smo izbrali zaradi njegove enostavnosti in razumljivosti. Dodatno smo algoritem LOF tudi razširili, da bi omogočili vse lastnosti, ki jih dober modul SPO ima. In sicer z: (i) računanjem razdalje med nominalnimi atributi, s tem smo razširili metodo tako da, lahko uporablja več vrst atributov, (ii) vrednotenjem stopnje nenavadnosti, da bo sistem vračal tudi oceno kako tvegan je trenuten dogodek in (iii) oceno tveganja po parametru, da lahko uporabniku svetujemo kateri parametri iz množice mnogih so prispevali k nenavadnosti dogodka.

Algoritem je bil razširjen in uporabljen za klinično podporo odločanja in je le eden od modulov, ki bodo delovali znotraj sistema. Preliminarni rezultati kažejo na uporabnost algoritma LOF za oceno tveganja, ki pa so sicer nastali na sintetičnih podatkih.

Nadaljevanje prispevka je razdeljeno v pet poglavij. V poglavju 2 predstavimo uporabljen algoritem, v poglavju 3 predstavimo razširitev algoritma. Sekcija 4 vsebuje eksperiment in rezultate. S sekcijo 5 zaključujemo prispevek.

2 ALGORITEM LOF

Algoritem LOF je v prvi vrsti namenjen zaznavanju nenavadnih dogodkov z uporabo gruč in iskanjem izjem na podlagi gostote med primeri v posamezni gruči. Za svoje delovanje ne potrebuje označenih podatkov, oziroma na začetku delovanja se določeni podatki samodejno označijo za normalne in porazdelijo po posameznih gručah. Vsak nadaljnji primer, ki ga algoritem analizira se primerja z normalnimi podatki, ki so že vsebovani v algoritmu. Rezultat algoritma je faktor LOF, ki kaže koliko je primer drugačen od ostalih normalnih primerov.

Recimo da je $N_k(A)$, k število najbližjih sosedov instance A in *k-razdalja(A)* razdalja med A in najbolj oddaljeno instanco v $N_k(A)$. Razdalja dosega (ang. reachability distance) med instancami A in B je definirana kot razdalja

me dvema instancama *d(A,B)*, kjer A ni v množici najbližjih sosedov B. V tem primeru je razdalja enaka *k-razdalja(B):*

$$razdalja\_dosega_k\,(A, B) = max\,(d\,(A, B), k\text{-}razdalja\,(B))$$

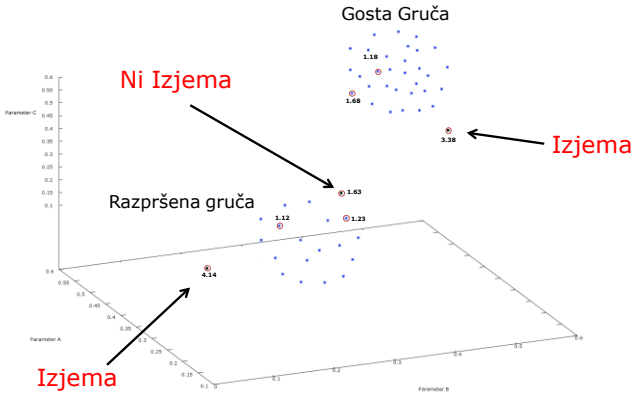
Lokalni doseg instance (lrd) *A* je definiran kot 1 ulomljeno s povprečnim dosegom od *A* do vseh *k* najbližjih sosedov:

$$lrd(A) = \frac{1}{\left(\frac{\sum_{B \in N_k(A)} razdalja\_dosega_k(A,B)}{|N_k(A)|}\right)}$$

Končen lokalni doseg instance A se primerja z lokalnimi dosegi svojih sosedov in to vrne vrednost LOF:

$$LOF_k(A) = \left(\frac{\sum_{B \in N_k(A)} lrd_k(B)}{|N_k(A)|}\right) / lrd(A)$$

Vrednost faktorja LOF okoli ena je primerljiva s sosedi in je privzeta za normalno, LOF z vrednostjo manj kot ena pomeni, da ležijo v zelo gosti gruči. Če je vrednost LOF višja kot ena, pomeni, da je instance izven gruče in potencialno nenavadna. Kolikšna naj bo vrednost faktorja, da je instanca nenavadna, je odvisno od podatkov.
Slika 1 prikazuje vizualno predstavitev dveh različno gostih gruč in detekcijo izjem z algoritmom LOF in njihove vrednosti.



Slika 1: Vizualna predstavitev gruč in detekcija izjem z algoritmom LOF.

Če želimo uporabiti algoritem LOF za oceno tveganja, se mora naučiti na podatkih, ki predstavljajo normalno stanje. Po navadi je to *n* podatkov ob zagonu algoritma. Poleg tega je potrebno določiti kdaj je instanca čudna in za koliko. To bo podrobneje predstavljeno v naslednji sekciji.

3 MODIFIKACIJA ALGORITMA

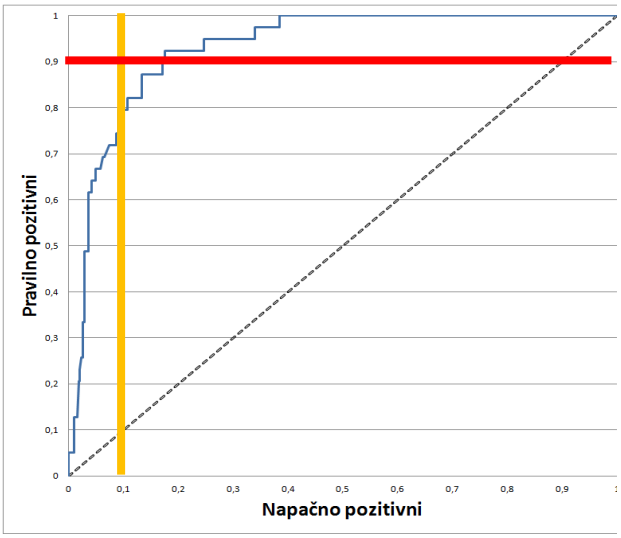
Algoritem LOF po svoji naravi lahko opredeli instanco binarno, normalna ali abnormalna. V našem primeru pa bi želeli LOF vrednost razširiti tako da bi nam povedala tudi stopnjo abnormalnosti. Velikokrat imamo kot atribut nominalno vrednost in v primeru standardnega LOF-a so ti atributi neuporabni. Predstavili bomo metodo, ki opredeli razdaljo med nominalnimi vrednostmi atributov in jih na ta način naredi uporabne.

3.1 Računanje razdalje med nominalnimi atributi

Ustaljena metoda za določanje razdalje med nominalnimi atributi je, da če sta si dva atributa enaka, je razdalja med njima 0, in če sta si različna, je med njima razdalja 1. To sicer velja, vendar če je nominalnih vrednosti atributov več, si želimo da bi razdalja odražala dejansko razdaljo, ki bi bila skladna s pomenom vrednosti.
V našem primeru so nominalne vrednosti rezultat predhodne klasifikacije. Klasifikator je bil naučen na označenih podatkih in ločenih atributih.
Hipoteza je, da lahko iz numeričnih vrednosti atributov, ki se uporabljajo za klasifikacijo določimo razdaljo med nominalnimi vrednostmi. In sicer če imamo *n* razredov, lahko za vsak razred določimo povprečno vrednost vsakega atributa. Nakar lahko z evklidsko razdaljo izračunamo kolikšna je razdalja med posameznimi razredi glede na povprečne numerične vrednosti atributov. V sekciji z eksperimentom bomo pokazali, da na ta način razdalja odraža pomensko razliko med vrednostmi.

3.2 Določanje stopnje nenaormalnosti dogodka in ocena tveganja po parametru

Da bi lahko LOF vračal tudi stopnjo čudnosti smo morali izbrati metodo za določanje pragov faktorja LOF. Že v prejšnjem poglavju smo omenili, da je privzeto, da če je LOF faktor v okolici vrednosti 1 lahko to instanco označimo za normalno. Če želimo razširiti algoritem na več stopenj, v našem primeru tri (nizko, srednje in visoko tveganje), pa je potrebno določiti, kakšne so vrednosti pragov. Tukaj smo uporabili označene podatke.



Slika 2: ROC krivulja in opredeljene meje za pragove za srednje- in visoko tveganje. Rumena premica je za srednje tveganje in rdeča za visoko tveganje.

Za določanje pragov smo uporabili ROC krivuljo in iz nje prebrali odstotek pravilno določenih instanc glede na vrednost postavljenega praga. Na sliki 2 vidimo z modro črto največje AUC področje, ki smo ga dobili, če smo uporabili vrednost ena za število sosedov.
Prag za visoko tveganje je postavljen tako, da pade nad njega 90% primerov označenih kot zelo visoko tveganje. Prag za srednje tveganje je postavljen tako, da lahko 10% primerov označenih kot srednje normalno pade pod prag. Te meje so tudi prikazane na sliki 2, kjer je rumena premica prag za srednje tveganje in rdeča premica za visoko tveganje.
Naslednja modifikacija LOF-a je ocenitev tveganja za vsak parameter posebej. Cilj je, da ko se uporabnika obvesti o tem, da je nek dogodek tvegan, da se mu predlagajo tudi parametri, ki so prispevali k tveganju. Rešitev smo našli v tem, da za vsak parameter posebej izvedemo algoritem LOF. Prav tako je postopek postavljanja pragov identičen kot za pragove tveganja celotnega sistema.

4 EKSPERIMENT IN REZULTATI

Metodo smo poizkusili in evakuirali na sintetičnih podatkih petih ljudi. Cilj je metodo uporabiti na ljudeh s srčnim popuščanjem, vendar takšne podatke bomo dobili v sklopu projekta CHIRON [5] za katerega je bila metoda razvita.

4.1 Podatki

Eksperiment smo izvedli na podatkih, ki so bili posneti za prepoznavanje aktivnosti in oceno porabe energije [6]. Uporabili smo posnetke petih ljudi, ki so imeli na sebi pospeškomere in prsni trak Zephyr, ki meri srčni utrip. Uporabili smo klasifikatorje za oceno porabe energije in prepoznavanje aktivnosti. Poleg teh dveh podatkov smo uporabili tudi srčni utrip in temperaturo kože. Tako da smo za evaluacijo uporabili le štiri atribute, od tega enega nominalnega. Vsaka oseba je posnela pet ponovitev enega scenarija. Scenariji so podrobneje opisani v prispevku o porabi energije [6].
Za metodo smo generirali deset nenormalnih posnetkov tako da smo za eno osebo zamenjali signale. Torej pri scenariju, kjer je bilo ležanje, smo zamenjali srčni utrip s tistim in scenarija tek. Tako smo dobili sintetične nenormalne podatke za srednje tveganje. Za visoko tveganje smo zamenjali dva signala s signali iz drugih scenarijev.

4.2 Rezultati

Razdalja med nominalnimi atributi

V atributnem vektorju smo od štirih atributov imeli en nominalni atribut in sicer aktivnost. Da bi dobili vrednost, ki realno odraža razdaljo med dvema paroma aktivnosti, smo uporabili metodo opisano v sekciji 3.1. Klasifikator za prepoznavanje aktivnosti smo razdelili po razredih in dobili devet podmnožic vrednosti atributov in sicer za naslednje aktivnosti:

- na vseh štirih,
- klečanje,
- kolesarjenje.
- ležanje,
- tek,
- sedenje,
- stanje,
- tranzicija in
- hoja.

Za vsako aktivnost smo izračunali povprečno vrednost atributov in nato izračunali evklidsko razdalo mode vrednostmi atributov za posamezen par aktivnosti. Rezultati so prikazani v tabeli 1.

	Na vseh štirih	Klečanje	Kolesarjenje	Ležanje	Tek	Sedenje	Stanje	Tranzicija	Hoja
Na vseh štirih	0.00	2.12	3.64	2.51	6.42	3.09	2.78	2.80	4.42
Klečanje		0.00	3.08	2.30	6.06	2.0	2.16	2.67	3.69
Kolesarjenje			0.00	2.80	4.55	2.60	2.62	2.49	2.08
Ležanje				0.00	6.28	2.29	2.28	3.61	3.84
Tek					0.00	6.10	6.05	4.78	4.03
Sedenje						0.00	1.05	3.30	3.25
Stanje							0.00	3.09	3.42
Tranzicija								0.00	2.99
Hoja									0.00

Tabela 1: Razdalje med pari aktvinosti.

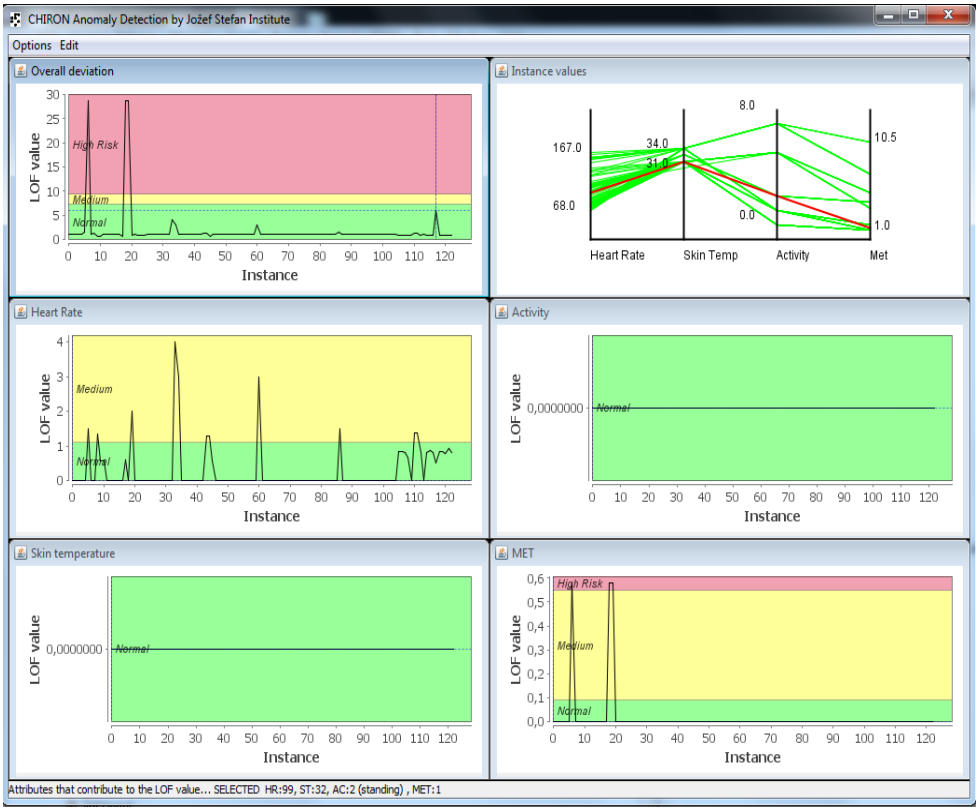
Iz tabele lahko vidimo, da sta si najdlje narazen ležanje in tek, in najbližje skupaj stanje in sedenje. Tranzicija in tek sta si tudi precej blizu. To nakazuje da je metoda računanja razdalje v tem primeru logična in prava izbira. Na ta način lahko dobimo bolj natančen izračun razdalje med instancami, ker imamo med vsakim parom nominalnih atributov unikatno razdaljo.

Ocena tveganja celostno in po parametru

Za oceno tveganja smo uporabili predhodno opisan LOF z vsemi potrebnimi modifikacijami. Uporabili smo štiri atribute srčni utrip, temperaturo kože, aktivnost ter oceno porabljene energije.
Postavljanje pragov je pokazalo, da moramo za vsako osebo postaviti svoj prag. Pragovi po osebi so prikazani v tabeli 2.

	Oseba 1	Oseba 2	Oseba 3	Oseba 4	Oseba 5
Srednje	1.08	7.34	3.49	15.00	4.31
Visoko	1.08	8.00	15.00	20.11	34.00

Tabela 2: Pragovi izraženi v vrednosti LOF.



Slika 3: Prototip LOF-a za oceno tveganja.

Vidimo lahko da so si pragovi med seboj zelo različni, kar nakazuje na to, da so lahko ti pragovi izključno inicialni. V času delovanja jih lahko spremeni ekspert, v našem primeru zdravnik. Pri osebi 1 lahko vidimo, da čiste meje med srednjim in visokim tveganjem ni.

Rezultat te metode je tudi prototip, nenadzorovan modul za končni SPO, ki bo testiran na pacientih s srčnim popuščanjem. Slika 3 prikazuje detekcijo abnormalnega stanja v prototipu. Prototip vsebuje šest panelov. Levo zgoraj je slika ocene tveganja za celoten posnetek enega človeka, na kateri se vidita dve konici ki segata v rdeče oziroma visoko tvegano območje. Spodnje štiri slike kažejo oceno tveganja po vsakem od štirih parametrov, za celoten posnetek. Vidimo lahko, da je parameter za oceno energije nenavaden v primerjavi z ostalimi parametri v instanci in da je ta v dveh zaznanih konicah vzrok za anomalijo.

Zgornja desna slika kaže razporeditev instance po vseh parametrih.

5 ZAKLJUČEK

V prispevku smo predstavili modificiran algoritem LOF za uporabo pri oceni tveganja. Tukaj je predstavljen kot eden od možnih modulov za uporabo v sistemih za podporo odločanju.

Predstavili smo metodo za računanje razdalj med vrednostmi nominalnih atributov. Rezultati izračunanih razdalj med pari aktivnosti odražajo tudi logično pomensko razdaljo med vrednostmi.

Slabost metode LOF je ta, da ko sistem dobi novi vzorec, ki je morda normalen, ta vzorec klasificira kot nenormalnega in s tem se poveča število napačno klasificiranih negativnih primerov. Prednost metode je, da ne potrebujemo označenih podatkov in domenskega eksperta.

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IZVEDBA FILTRA CUSP IN PRIMERJAVA Z OBSTOJEČIM FILTROM V PROGRAMABILNEMU VEZJU

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POVZETEK

Prispevek opisuje razvoj kode digitalnega sistema za obdelavo zajetih podatkov iz detektorja žarkov gama na osnovi programabilnega vezja (ang. Field Programmable gate Array, FPGA). Namen raziskave je primerjava algoritma cusp z algoritmom s pomičnim dekonvolucijskim oknom (ang. *mowing window deconvolution*, MWD) na generatorju eksponentnih pulzov, ki je bil uporabljen kot simulator podatkov iz detektorja žarkov gama. Poleg tega sta bila algoritma preizkušena na germanijevemu detektorju žarkov gama.

1 UVOD

Glavna tema prispevka je obdelava zajetih podatkov iz generatorja eksponentnih pulzov z uporabo programabilnega vezja. Programabilno vezje (*ang. Field Programmable gate Array, FPGA*) je integrirano vezje, ki mu je mogoče določiti strukturo z nizkonivojsko programsko kodo. Programabilna vezja se lahko uporabljajo za izvajanje kakršne koli logične funkcije, ki bi jo lahko izvedli z namensko skonstruiranim integriranim vezjem (ang. *Application Specific Integrated Circuit, ASIC*). Omogočajo hitre in enostavne spremembe funkcionalnosti vezja, medtem ko je to pri namensko zgrajenih integriranih vezjih (ASIC) drago in zamudno. Programabilno vezje vsebuje programabilni logični del, sestavljen iz logičnih blokov in programabilnih povezav. Te omogočajo, da logične bloke lahko med seboj povežemo s potrebnimi žicami. Logične bloke je mogoče konfigurirati za opravljanje kompleksnih kombinatornih funkcij ali zgolj za preprosto izvajanje logičnih vrat, kot sta na primer IN in XOR. V večini programabilnih vezjih sestavljajo logične bloke tudi spominski elementi, ki so lahko preproste spominske celice (ang. *flip-flops* ali Block RAM) ali pa več skupaj povezanih spominskih celic, ki tvorijo večje spominske bloke (ang. distributed RAM). Poleg digitalnih funkcij imajo nekatera programabilna vezja analogne značilnosti. Najpogostejša analogna lastnost je programabilna hitrost drsenja *(*ang. *slew rate)* in tokovna zmogljivost (ang. *drive strength*) na vsakem izhodnem kontaktu. Druga relativno pogosta analogna lastnost so diferencialni komparatorji na vhodnih kontaktih, ki jih lahko priključimo na diferencialne signalne kanale [1]. Generator na programabilno vezje pošilja časovno konstantne in enako visoke eksponentne pulze, ki se na vezju obdelajo z digitalnimi algoritmi kot sta npr. algoritem cusp ali algoritem s pomičnim dekonvolucijskim oknom (ang. *mowing window deconvolution*, MWD). Generator sem uporabil zaradi časovno konstantnih in enako visokih eksponentnih pulzov z manjšim odstopanjem in možnostjo testiranja vpliva različnih dejavnikov na delovanje sistema. V njem sem lahko spreminjal višino pulzov, nastavljal različne čase padanja (ang. *falltime*) eksponentnega pulza, čas naraščanja (ang. *risetime*), frekvenco in testiral

kopičenje (ang. *pile-up*). Vse to je ključnega pomena za ugotavljanje pravilnosti delovanja algoritma. Motivacija za izdelavo digitalnega sistema v primerjavi z analognim sistemom so predvsem enostavna implementacija kompleksnih algoritmov in enako kvalitetni rezultati meritev tako pri manjših kot pri višjih številnih stopnjah.

2 DIGITALNI FILTER

Naprave, ki sem jih uporabil pri razvoju digitalnega flitra so: modul FPGA NI PXI - 7851, modul FPGA NI PXI - 7853R, NI PXIe - 8130 Embedded Controller in generatorja eksponentnih pulzov (Reference Pulser: model 1407, Canberra, 90Hz in Pulse Pair Generator: model 1407P, Canberra, 1Khz) ter germanijev detektor žarkov gama. Pri programiranju programabilnega vezja je bil uporabljen programski jezik *Labview 8.6*.

Digitalni filter izvaja matematične operacije nad digitaliziranim vhodnim signalom. Analogno digitalni pretvornik signal digitalizira in ga zapiše kot niz številk, digitalni filter pa ga preračuna v nov signal, ki je primeren za nadaljno obdelavo. V tej raziskavi je digitalni filter omogočal odmerjanje višin napetostnih skokov. Digitalni filter je običajno sestavljen iz analogno digitalnega pretvornika, ki mu sledi programabilno vezje in nekaj obrobnih komponent, kot je pomnilnik za shranjevanje podatkov.

2.1 Filter s pomičnim dekonvolucijskim oknom (ang. moving window deconvolution filter oziroma mwd filter)

Ta izum predlaga uporabo dekonvolucije ali inverznih filtrov kot podlage za izboljšanje energijske resolucije, hitrega časovnega usklajevanja in zahteva proizvodnjo precizne jedrske elektronike. S tem patentom je bil rešen problem dekonvolucije eksponentnega signala in digitalnega trapezoidnega filtriranja. Postopek je postal znan pod imenom MWD [2].

Spodnje enačbe prikazujejo algoritem s pomičnim dekonvolucijskim oknom:

Če z $F_{ADC}[n]$ označimo n-ti zaporedni izmerek ADC-ja in določimo uteži a z zaporedjem

$a_0 = 1$

$a_i = \frac{1}{\tau}$, $i = 1, L-1$

$a_L = -1 + \frac{1}{\tau}$, je rezultat filtra s pomičnim dekonvolucijskim oknom označen s $F[n]$, enak

$F[n] = \sum_{i=0,N} a_i * FADC[n-1]$.

2.2 Filter cusp

Pri svojem delu sem uporabil algoritem cusp, ki pretvori eksponentni pulz ali stopnico v simetrični pulz, katerega naraščajoča fronta je proporcionalna s t^2+t. Izhod iz filtra cusp je kopasta krivulja, ki je spodaj podobna Gaussovi, zgoraj pa trikotni krivulji [2].
Delovanje algoritma lahko opišemo z naslednjimi rekurzivnimi enačbami:

$d^k(n)=v(n)-v(n-k)$,
$p(n)=p(n-1)+d^k(n)$, $n\geq 0$,
$s(n)=s(n-1)+p(n)-v(n-l)k$, $n\geq 0$,

kjer je $v(n)$ vhodni signal, $s(n)$ pa izhod iz filtra. Privzeto je, da so $v(n)$, $p(n)$ in $s(n)$ enaki 0 za $n<0$. Parameter l določi trajanje naraščajoče in padajoče fronte (ang. *rising and falling edge*), medtem ko je parameter k sorazmeren s parametrom l:

$k=2*l+1$.

Največji problem algoritma, ki je opisan z zgornjimi rekurzivnimi enačbami je, da $p(n)$ postopoma narašča skozi vsak prejeti procesirani pulz. To pomeni, da po določenemu številu iteracij zaide akumulator v nasičenje. Da se izognemo numerični napaki (ang. *overflow)*, algoritem spremenimo tako, da upoštevamo odziv enote dekonvolucijskega visokopasovnega filtra (ang. *high-pass filter deconvolver*, HPD) in ga zapišemo z naslednjimi enačbami:

$d^l(n)= v(n)-v(n-1)$,
$d^k(n)=v(n)-v(n-k)$,
$p(n)=p(n-1)+d^k(n)-kd^l(n-l)$, $n\geq 0$,
$q(n)=q(n-1)+m_2\, p(n)$, $n\geq 0$,
$s(n)=s(n-1)+q(n)+m_1\, p(n)$, $n\geq 0$,

Množilna koeficienta ali ojačenji m_1 in m_2 se med seboj povezujeta z enačbo $m_1/m_2=M$, kjer je M odvisen od časovne konstante τ eksponentnega pulza in periode vzorčenja T_{clk} digitalizatorja. Tako je M enak: $M = \frac{1}{e^{\frac{T_{Clk}}{\tau}}-1}$ oziroma če poenostavimo, zapišemo enačbo kar kot $M=\tau/T_{clk}-0.5$ pri čemer moramo zadostiti pogoju $\tau/T_{clk}>5$ [2].

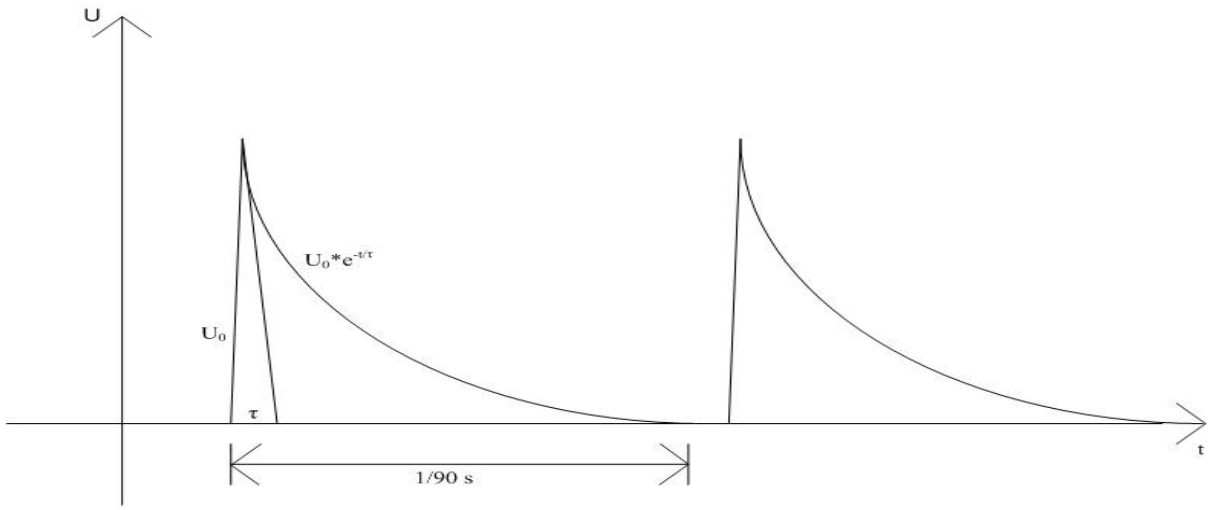
3 EKSPERIMENTALNI REZULTATI

3.1 Primerjava filtra cusp in filtra s pomičnim dekonvolucijskim oknom na generatorju pulzov ob spreminjanju vrednosti nastavitvenih parametrov filtra

Lastnosti digitalnega akvizicijskega sistema sem proučeval s pomočjo generatorja eksponentnih pulzov (Reference Pulser: model 1407, Canberra, 90Hz), na katerem je mogoče spreminjati koeficient eksponentnega upadanja. Obliko pulza po pozitivnem napetostnem skoku opišemo z eksponentnim upadanjem:

$U=U_0*e^{-t/\tau}$, kjer je
$U_0=200mV$

višina skoka, τ pa čas eksponentnega upadanja. Pulzer je deloval s konstantno frekvenco 90Hz.



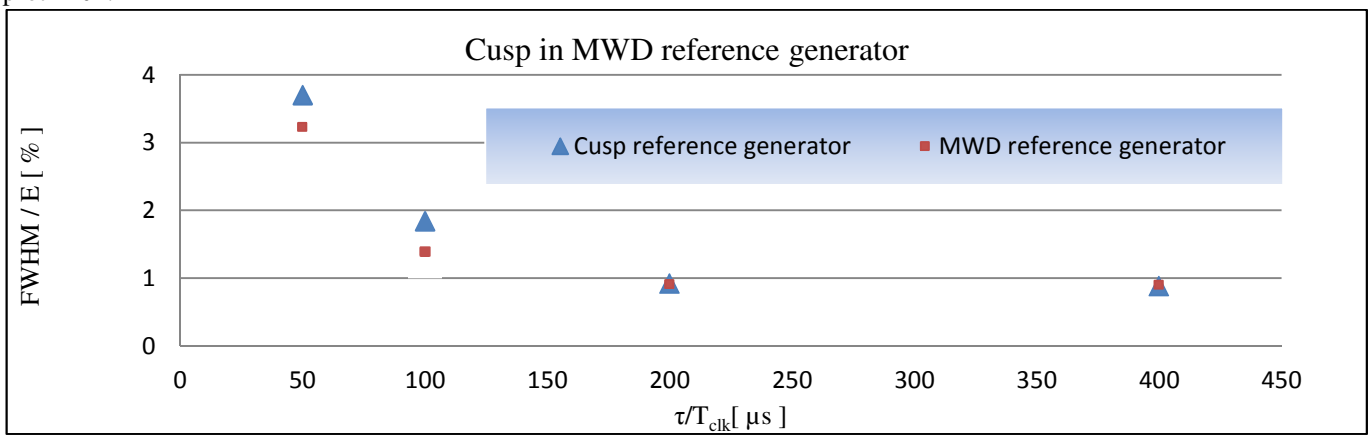
Slika 1: Graf U(t)

Spreminjal sem čas eksponentnega upadanja τ in izbral parametre digitalnih filtrov, ki so dali najmanjšo širino FWHM prenosne funkcije (FWHM/E). Širina na polovici maksimuma vrha (ang. *Full Width at Half Maximum,* FWHM*)* je mera za širino prenosne funkcije spektrometra ali za ločljivost spektrometra. Rezultate prikazuje tabela 1. Meritve so pokazale, da se relativna širina prenosne funkcije *FWHM/E* pri spreminjanju časa eksponentnega upada τ iz 400 sekund na 50 sekund poslabša tako za filter cusp kot za filter s pomičnim dekonvolucijskim oknom. Iz tabele 1 lahko sklepamo, da postane filter cusp pri dovolj velikem razmerju τ/T_{clk} ($\tau/T_{clk}>0$) glede energijske ločljivosti primerljiv filtru s pomičnim dekonvolucijskim oknom.

Iz tabele 1 je razvidno, da oba algoritma konvergirata k vrednosti 0,9. To je posledica dodatnega šuma v pulzerju, ki je onemogočil, da bi rezultati obeh algoritmov konvergirali proti ničli.

τ[μs]	*τ/Tclk [μs]*	Cusp *FWHM/E [%]*	MWD *FWHM/E [%]*
50	17	3,7	3,23
100	33	1,84	1,39
200	66	0,92	0,91
400	132	0,88	0,9

Tabela 1: Rezultati optimizacije parametrov algoritma cusp in algoritma s pomičnim dekonvolucijskim oknom na signalu referenčnega pulzerja Canberra (Reference Pulser: model 1407, Canberra, 90Hz) za cusp in algoritem s pomičnim dekonvolucijskim oknom.

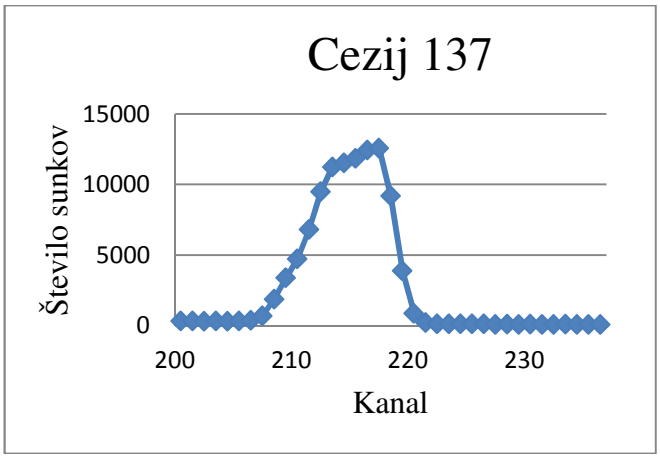


Slika 2: širina prenosne funkcije (ločljivost) FWHM/E v odvisnosti od časovnega koeficienta upadanja τ/T_{clk} za algoritem cusp in algoritem s pomičnim dekonvolucijskim oknom.

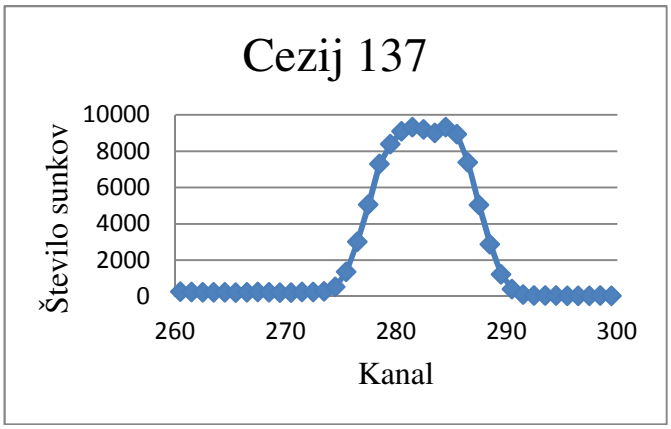
3.2 Preizkus na detektorju žarkov gama

Po izdelavi algoritma in testiranjih na referenčnemu generatorju, sem poskusil izmeriti spektre na germanijevem detektorju žarkov gama. Koeficient eksponentnega upadanja na tem detektorju je 90μs, kar pomeni, da je razmerje τ/Tclk za naš sistem (Tclk = 2 μs) enako približno 25.4. V teh

pogojih ne pričakujemo dobre energijske ločljivosti. Poskus izvedemo zato, da bi pokazali izvedljivost spektroskopije.



Slika 3: Spekter digitalnega sistema z algoritmom cusp, ΔE/E=0,037.



Slika 4: Spekter digitalnega sistema z algoritmom s pomičnim dekonvolucijskim oknom, ΔE/E=0,0387.

4 ZAKLJUČEK

Rezultate cusp in že prej sprogramiranega algoritma s pomičnim dekonvolucijskim oknom sem primerjal med seboj in prišel do ugotovitve, da imata algoritma primerljivo ločljivost v režimu nizkih številnih hitrostih v normalnih pogojih na detektorju, kjer je razmerje med koeficientom eksponentnega upadanja in časom zajema analogno digitalnega pretvornika večje od 70. Algoritem s pomičnim dekonvolucijskim oknom zasede manj prostora na programabilnem vezju in je lažje nastavljiv. Razpoložljivi podatki iz literature kažejo, da se algoritem cusp izkaže z zanesljivim delovanjem v režimu višjih številnih hitrostih.

ZAHVALA

Avtor članka se zahvaljujem mentorju izrednemu profesorju Tomažu Gyergyeku in somentorju Primožu Peliconu in Zdravku Rupniku, ki so me s svojimi izkušnamji usmerjali pri mojem delu.

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DEALING WITH COMFORT AS AN OBJECTIVE IN MULTIOBJECTIVE OPTIMIZATION OF DRIVING STRATEGIES

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ABSTRACT

When a person drives a vehicle along a route, he/she optimizes the traveling time and the fuel consumption. The same problem is tackled by the Multiobjective Optimization algorithm for discovering Driving Strategies (MODS) which we designed and implemented. However, the driving strategies found with MODS change the control actions frequently (more frequently than humans) and, therefore, the driving comfort is reduced. To improve the driving comfort, we introduced it as an objective in MODS, thus obtaining the Multiobjective Optimization algorithm for discovering Comfortable Driving Strategies (MOCDS). The two algorithms were compared on data from a real-world route and the results show that MOCDS finds highly comfortable driving strategies, especially when the fuel consumption is reduced. On the other hand, when the traveling time is reduced, MODS already finds comfortable driving strategies that cannot be additionally improved.

1 INTRODUCTION

Comfort is important when driving a vehicle along a route. Nevertheless, it is not explicitly optimized by humans, i.e., the goal of vehicle driving is not to feel as comfortable as possible. Usually, two other goals are pursued: minimization of the traveling time and minimization of the fuel consumption. Nevertheless, human driving strategies are mostly comfortable. However, this is not the case when driving strategies are found with optimization algorithms, since they do not implicitly optimize the driving comfort. Therefore, the comfort has to be explicitly introduced in the optimization algorithms as the third objective in order to find comfortable driving strategies acceptable from the user point of view.

In our previous work we designed and implemented the Multiobjective Optimization algorithm for discovering Driving Strategies (MODS) [1] which searches for driving strategies by optimizing the traveling time and the fuel consumption. Although it finds good driving strategies (better than relared algorithms [1], such as predictive control [2] and dynamic programming [3]), it fails to find comfortable driving strategies. To overcome this shortage, we introduced the third objective, i.e., the comfort that has to be maximized, or equivalently, the discomfort that has to be minimized, to MODS, thus obtaining the Multiobjective Optimization algorithm for discovering Comfortable Driving Strategies (MOCDS) [4]. The discomfort is measured as the magnitude of the jerk, i.e., the magnitude of changes in acceleration [5]. In this paper we compare the driving strategies obtained with MODS with the driving strategies obtained with MOCDS. The comparison focuses on weaknesses of MODS. More precisely, we analyze the cases where MODS fails to find comfortable driving strategies, i.e., driving strategies similar to the driving strategies found with MOCDS in terms of driving comfort.

The paper is further organized as follows. The MODS and MOCDS algorithms are described in Section 2. Section 3 presents the experiments and the obtained results. Finally, Section 4 concludes the paper with ideas for future work.

2 MULTIOBJECTIVE DISCOVERY OF (COMFORTABLE) DRIVING STRATEGIES

MODS and MOCDS are two-level algorithms where the algorithm at the lower level is a deterministic algorithm that searches for driving strategies, while the upper-level algorithm is an evolutionary algorithm that searches for the best input parameter values for the lower-level algorithm.

2.1 The lower-level algorithm

The lower-level algorithm is a deterministic multiobjective algorithm that searches for driving strategies by minimizing the traveling time (MODS and MOCDS), the fuel consumption (MODS and MOCDS) and the discomfort (MOCDS only). MODS and MOCDS have very similar lower-level algorithms. The only difference is that the lower-level algorithm of MOCDS deals with an additional objective, i.e., the discomfort, while the core of the algorithms remains the same.

The driving strategies are sets of hypercubes [6], where hypercubes are defined with discretization of the vehicle and route state space. Hypercubes store the fuel consumption weights (MODS and MOCDS) and discomfort weights (MOCDS only) that are used to select the best control action, i.e., throttle and braking percentage and gear, when the vehicle and route state correspond to the hypercube. The algorithm searches for the best driving strategies by starting with a single driving strategy with empty hypercubes. Next, it simulates the vehicle driving by steps with several driving strategies until the driving along the entire route has been simulated. At each step, the current hypercube is checked and if it does not contain the weight(s), i.e., the hypercube has not been "visited" yet, the driving strategy is cloned for each discrete value of fuel consumption weight (MODS and MOCDS) and discomfort weight (MOCDS only), and the weights are stored in the hypercubes of cloned driving strategies. When the weight(s) is/are determined, the control action is selected by predicting the vehicle driving for a number of prediction steps ahead and selecting the control action which minimizes the weighted sum of spent time (MODS and MOCDS), consumed fuel (MODS and MOCDS) and driving discomfort (MOCDS only). The cloning of driving strategies increases the number of driving strategies exponentially. Therefore, in order to maintain a constant number of most promising driving strategies, the fast nondominated sorting and the crowding distance mechanisms from the Nondominated Sorting Genetic Algorithm (NSGA-II) [7] are used at each route step.

2.2 The upper-level algorithm

The upper-level algorithm searches for the best input parameter values for the lower-level algorithm, i.e., the discretization of vehicle and route state space, the discretization of weight(s) and control actions, and the number of prediction steps. The algorithm is an evolutionary algorithm [8] that applies selection, crossover and mutation on a population of sets of input parameter values through several generations, and maximizes the hypervolume [9] covered by the driving strategies found with the lower-level algorithm. For more details see [1].

3 EXPERIMENTS AND RESULTS

MODS and MOCDS were tested on data describing a real-world urban route of about 1100 m. The route characteristics are shown in Figure 1.

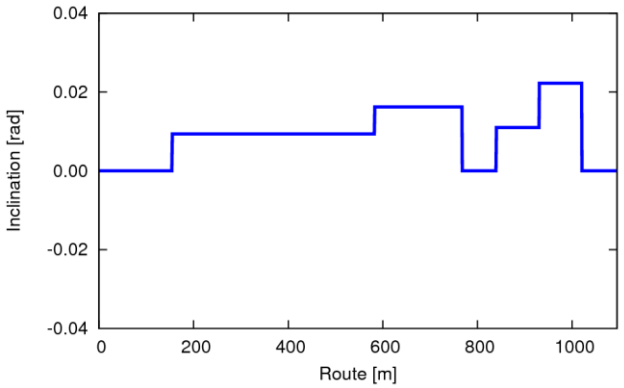

Figure 1: *Inclinations of the test route; the velocity limit is 50 km/h along the entire route.*

Figure 2 shows the driving strategies found with MODS and MOCDS. More precisely, the figure shows only the driving strategies that are nondominated in terms of traveling time and fuel consumption, since such driving strategies are the most interesting ones. The driving strategies on the left side of Figure 2 have short traveling time and high fuel consumption. On the other hand, the driving strategies on the right side of Figure 2 have long traveling time but low fuel consumption. The results show that both algorithms find similar driving strategies in terms of the driving comfort when traveling time is minimized (left side of Figure 2). More precisely, the MODS driving strategies are already comfortable when the traveling time is minimized and cannot be additionally improved by MOCDS. On the other hand, MOCDS finds significantly more comfortable driving strategies than MODS when the fuel consumption is minimized (right side of Figure 2, the driving strategies inside the dashed rectangle). The driving strategies that are significantly more comfortable are the most interesting ones, therefore, four of them labeled with s_1, s_2, s_3 and s_4 in Figure 2 were additionally analyzed. Strategies s_1 and s_2 were obtained with MODS, while s_3 and s_4 with MOCDS. s_1 and s_3 are similar in terms of the traveling time and the fuel consumption. The same holds for s_2 and s_4. Figures 3 and 4 show the control actions and the vehicle behavior obtained by applying these driving strategies. The figures show that in order to increase the driving comfort, i.e., decrease the jerk, the control actions have to change less frequently (see throttle and braking percentage, and gear of s_3 and s_4). Consequently, the vehicle velocity obtained by applying s_3 and s_4 is more constant than the vehicle velocity obtained by applying s_1 and s_2. Finally, the jerk obtained by applying s_3 and s_4 is lower than the jerk obtained by applying s_1 and s_2 along the entire route.

4 CONCLUSION

This paper compares the Multiobjective Optimization algorithm for discovering Driving Strategies (MODS) and Multiobjective Optimization algorithm for discovering Comfortable Driving Strategies (MOCDS). Both algorithms are two-level algorithms, where the lower-level algorithm is a deterministic multiobjective algorithm for discovering driving strategies, and the upper-level algorithm is a single objective evolutionary algorithm that searches for the best input parameter values for the lower-level algorithm. The only difference between these two algorithms is an additional objective used in MOCDS. More precisely, MODS minimizes the traveling time and the fuel consumption, while MOCDS additionally minimizes the discomfort. The algorithms were tested on data from a real-

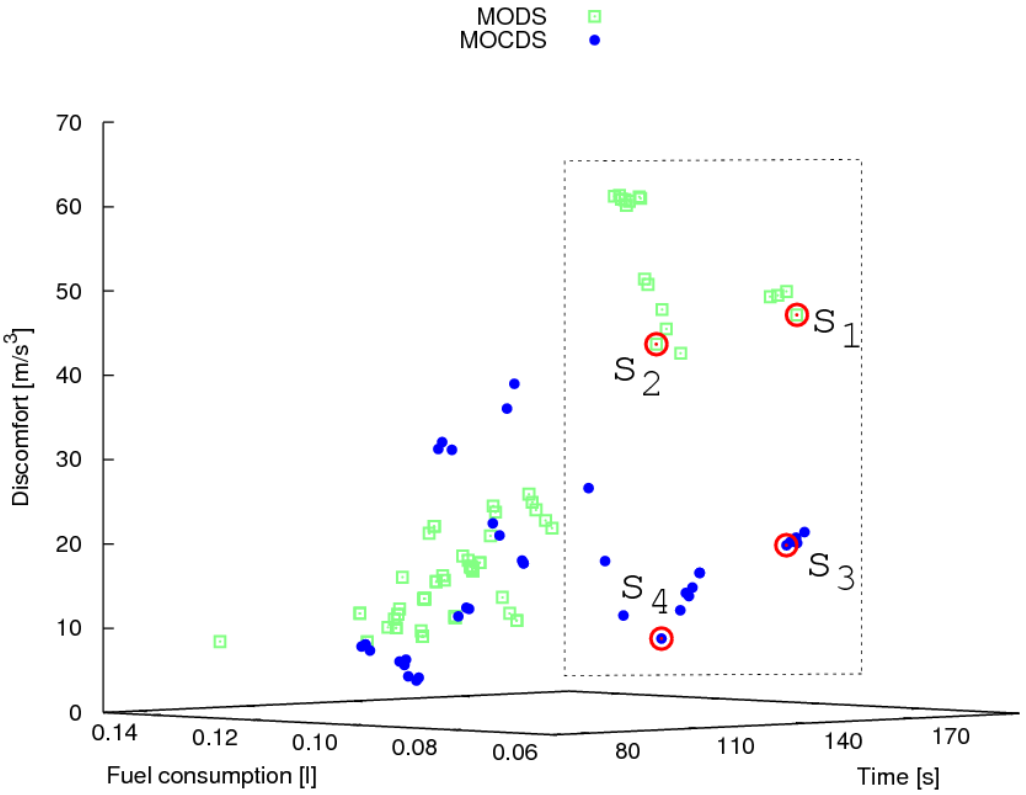

Figure 2: *Nondominated driving strategies in terms of traveling time and fuel consumption obtained with MODS and MOCDS. The dashed rectangle denotes the driving strategies with low fuel consumption.*

world route. The results show that MODS and MOCDS find similar driving strategies in terms of driving comfort when the traveling time is minimized. On the other hand, MOCDS finds significantly better driving strategies in terms of driving comfort than MODS when fuel consumption is minimized. The highly comfortable driving strategies are the most interesting, therefore, four of them were additionally analyzed. The analysis shows that in order to increase the driving comfort, the control actions have to change less frequently.

The future work will include testing additional routes. Moreover, we will test other functions for calculating the comfort. In addition, it would be also interesting to include the third objective in the algorithms of other authors and compare the obtained driving strategies with the MOCDS driving strategies.

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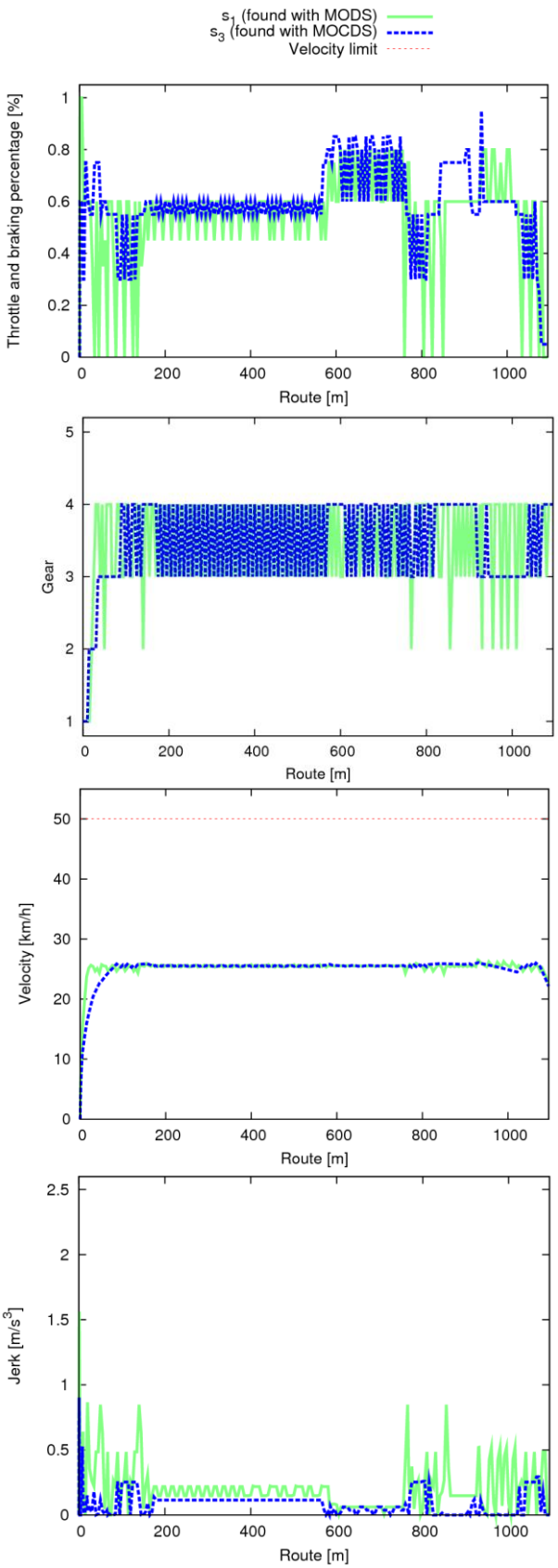

Figure 3: *Examples of vehicle behavior obtained by applying the driving strategies s_1 and s_3 from Figure 2.*

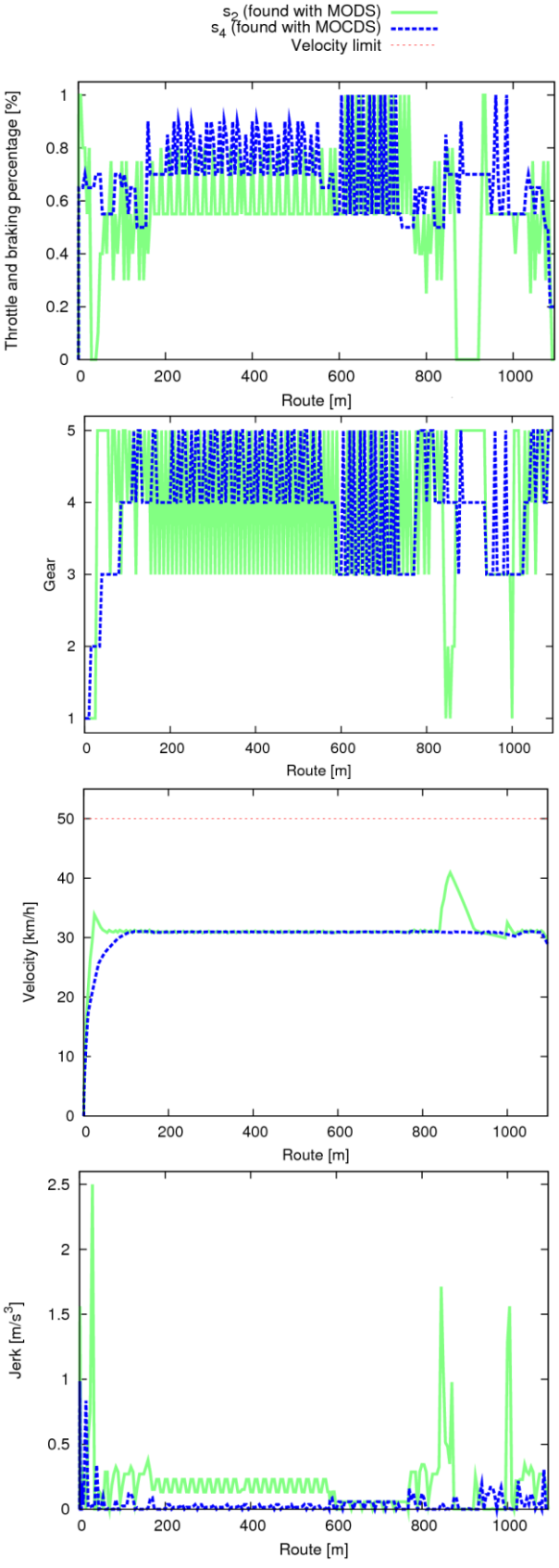

Figure 4: *Examples of vehicle behavior obtained by applying the driving strategies s_2 and s_4 from Figure 2.*

POROČILO S KONFERENCE ECAI IN PREGLED IDEJ

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ABSTRACT

ECAI (European Conference on Artificial Intelligence) je osrednja evropska konferenca s področja umetne inteligence. V letu 2012 je bila 20. zaporedna konferenca izvedena v Montpellieju od 27. do 31. avgusta. V prispevku je podan pregled dogajanj na ECAI 2012. Pregled je podan subjektivno s stališča slušatelja, ki se je udeležil določenih predavanj znotraj delavnic in glavnega programa. Poleg poročil so podane sprotne misli in ponekod potencialne nove ideje.

1 UVOD

ECAI 2012 [1] so organizirali: European Coordination Committee for Artificial Intelligence (ECCAI), French Association for Artificial Intelligence (AFIA) ter Montpellier Laboratory for Informatics, Robotics and Microelectronics (LIRMM). ECCAI sestavlja 29 članic:
ACIA (Spain), Catalan Association for Artificial Intelligence (Associació Catalana d'Intelligència Artificial).
ADUIS (Ukrain), Association of Developers and Users of Intelligent Systems.
AEPIA (Spain), Spanish Association for Artificial Intelligence (Asociación Española para la Inteligencia Artificial)
AFIA (France), French Association for Artificial Intelligence (Association Française pour l'Intelligence Artificielle)
AIAI (Ireland), Artificial Intelligence Association of Ireland
AIIA (Italy), Italian Association for Artificial Intelligence (Associazione Italiana per l'Intelligenza Artificiale)
AISB (United Kingdom), Society for the Study of Artificial Intelligence and the Simulation of Behaviour
APPIA (Portugal), Portuguese Association for Artificial Intelligence (Associação Portuguesa para a Inteligência Artificial)
ARIA (Romenia), Romanian Association for Artificial Intelligence
BAIA (Bulgaria), Bulgarian Artificial Intelligence Association
BCS-SGAI (United Kingdom), British Computer Society Specialist Group on Artificial Intelligence
BNVKI-AIABN (Benelux), Benelux Association for Artificial Intelligence
CSKI (Czech Republic), Czech Society for Cybernetics and Informatics (Ceská spolecnost pro kybernetiku a informatiku)
DAIS (Denmark), Danish Artificial Intelligence Society
EETN (Greece), Hellenic Artificial Intelligence Association
FAIS (Finland), Finnish Artificial Intelligence Society (Suomen Tekoälyseura ry)
GI/KI (Germany), German Informatics Association (Gesellschaft für Informatik; Sektion KI e.V.)
IAAI (Israel), Israeli Association for Artificial Intelligence
LANO (Latvia), Latvian National Organisation of Automatics (Latvijas Automatikas Nacionala Organizacija)
LIKS-AIS (Lithuania), Lithuanian Computer Society--Artificial Intelligence Section (Lietuvos Kompiuterininku Sajunga)
NAIS (Norway), Norwegian Artificial Intelligence Society
NJSZT (Hungary), John von Neumann Society for Computing Sciences (Neumann János Számítógéptudományi Társaság)
ÖGAI (Austria), Austrian Society for Artificial Intelligence (Österreichische Gesellschaft für Artificial Intelligence)
PAIS (Poland), Polish Artificial Intelligence Society (Polskie Stowarzyszenie Sztucznej Inteligencji)
RAAI (Russia), Russian Association for Artificial Intelligence
SAIS (Sweden), Swedish Artificial Intelligence Society
SGAICO (Switzerland), Swiss Group for Artificial Intelligence and Cognitive Science (Schweizer Informatiker Gesellschaft)
SLAIS (Slovenia), Slovenian Artificial Intelligence Society (Slovensko drustvo za umetno inteligenco)
SSKI SAV (Slovak Republic), Slovak Society for Cybernetics and Informatics at Slovak Academy of Sciences (Slovenská spolocnost pre kybernetiku a informatiku pri Slovenskej akadémii vied)

Slika 1: Dvajseta evropska konferenca za umetno inteligenco.

Konferenca je trajala pet dni, prva dva dneva so bile delavnice in seminarji, zadnje tri dni pa je bil osnovni program konference.

2 ZAPISKI S PREDAVANJ

2.1. Ponedeljek in torek

Na delavnici »Computational Logic in Multi-Agent Systems (CLIMA XIII)«, vodji: Michael Fisher and Leon Van Der Torre, so bile najprej predstavljene osnove modalne in epistemske logike in pogojna zaupanja. Ta delavnica je menda postala zanimiva šele v nadaljevanju, v začetku ni nudila dovolj izzivov za nadaljevanje ogleda.

Naslednji seminar (tutorial) na ogledu je bil »Cognitive Robotics«, vodja M. Beetz. Ukvarjal se je z vsakodnevnimi nalogami v kuhinji, npr. pečenjem palačink. Imel je simulator, robote, programe itd. KnowRob: Open Source Knowledge Base. Robot knowledge = Prolog + OWL + computable predicates. CYC, Wordnet za pomen, Google slike za izgled, OpenCzc ali OpenMind za zdravo pamet. WikiHow.org ali eHow.com za opis nalog, npr. kako razbiti jajce. Uporablja kontekts: Naredi če si NaTemMestu, dvojčki akcija-pozicija.

IDEJA 1: Učiš se krivulj gibanja z Masdo in Ubisensom ali Xsensom in se naučiš, kaj človek dela, npr. kuha kavo.

Sledil je seminar (tutorial) Petra Flacha: Unity in diversity: the breadth and depth of Machine Learning explained for AI researchers. Predstavil je tematiko strojnega učenja, ki je tudi ravnokar izšla v knjigi. Osnovni pogled je skozi diagram, kjer je na x osi FP, na y osi pa TP za posamezen klasifikator. Tak način prikazovanja uporabi za razne algoritme, npr. kako se spremeni diagonala po gradnji prvega vozlišča odločitvenega drevesa. Omeni funkcijo za nečistoče koren iz Ginijevega indeksa kot posebej zanimivo.

Na delavnici 3rd International Workshop on Combinations of Intelligent Methods and Applications (CIMA-12), vodji Ioannis Hatzilygeroudis in Vasile Palade, so poročali o kombinacijah metod za doseganje boljših rezultatov. Ena zanimiva aplikacija je bila za svetovanje pri nenavadnih situacijah pri vrtanju, ki se dejansko uporablja v podjetjih, druga kombinira več metod pri učenju otrok z motnjami učenja.

IDEJA 2: Princip mnogoterega znanja je podprt z nekaj analognimi tezami, npr. z mnogoterim vesoljem in multivesoljem [5]. Do sedaj ni bil eksplicitno podprt tudi z geni. V literaturi je pogosto objavljeno, da imajo ljudje z mišmi skupnih okoli 98% genov (podobno velja za druge sesalce). Zakaj smo tako drugačni kot miši? Strokovna literatura to razlaga kot kombinacije med geni in proteini, ki multiplicirajo funkcionalnost. Kot drugo so letošnje raziskave razkrile, da je nadzornikov v razmerju do genov 50:1, tj. milijon nadzornikov na 23.000 genov [3]. To kaže, da je že v genih samih princip mnogoterosti uveljavljen, saj omogoča iz približno enake osnovne strukture izredne variacije. Osnovna ideja je objavljena že v [4] in omogoča strokovno razlago naivnih trditev kot »zelo veliko genov se ukvarja z birokratskimi posli«. To geni niso birokratski, ampak omogočajo kombiniranje oz. mnogoterost, kar je ena ključnih razlik med mišmi in ljudmi, ključna nova sposobnost.

O pravicah in dolžnostih agentov je bilo govora na delavnici RDA2 - Rights and Duties of Autonomous Agents, vodje Olivier Boissier, Grégory Bonnet in Catherine Tessier. Omenjen je Triage Turing test (Sparrow 2004). Nekateri roboti so daleč od Asimovih zakonov, saj npr. ubijajo kot Predator, vendar pod vodstvom ljudi. Roboetika. Države po svetu so rangirane glede na avtonomijo, dostojanstvo itd. Bo oz. je robotski seks dovoljen? Borbe robotov niso tako legalno obravnavane kot borbe živali.

IDEJA 3: Naučiš se etike z Masdo. Imaš simulator odnosov, tako fizičnih kot etičnih, imaš fizično in etično taksonomijo. Naučiš se fizičnih in etičnih pravil. Torej si se naučil etike v tistem simuliranjem okolju. Kje dobiti primerne etične podatke? Kakšna pravila se naučiti? Lahko kloniraš etiko robota oz. človeka, če igra v simulaciji?

Na STAIRS je bilo nekaj predavanj. Npr. kako popraviti napake pri zbirnem odločanju. Imamo tri sodnike, ki ocenjujejo prekršek v ali blizu kazenskega prostora, ali je bil prekršek in mnenje, ali je enajstmetrovka. Zbrano večinsko mnenje daje protislovne rezultate: skupno mnenje je, da je bil prekršek notri in da je dejansko bil, vendar je zbrano mnenje, da ni enajstmetrovka. Posebej zanimivo je bilo predavanje Malteja Helmerta. Dobil je vrsto prestižnih nagrad na IJCI, I itd. ukvarja se s planiranjem, logikami, hevristikami, iskanjem. Mladim raziskovalcem je povedal, zakaj je delo raziskovalca dobro in zakaj slabo: ker ni umirjeno dobro plačano razvojno delo (če je danes še kje) in ker je kreativno in zanimivo. Naštel je 7 osnovnih napotkov mladim: 1. Beri (related work), 2. Pogovarjaj se, komuniciraj (veliko, v raznih okoljih, neformalno), 3. Razumi skaliranje oz. zakaj nek algoritem na nekem problemu dela bolje, 4. Raziskuj v globino, ne v širino (doktorat), 5. Bodi odkrit, ne kritiziraj drugih, če ne razumeš, 6. Piši kvalitetne prispevke, ne poplave, 7. Sodeluj

in objavljaj v raznih mednarodnih skupinah z raznimi soavtorji.

Vabljeno predavanje Wolframa Burgarda, Univerza v Freiburgu, Nemčija: Probabilistic Techniques for Mobile Robot Navigation je temeljilo na robotu Obeliks, ki je sam prehodil 3 km v 1.5h po Freiburgu in je bil na nemški televiziji. Ta robot je del FP7 projekta in je temeljil na prilagajanju verjetnostnih map okolju. Vprašanje je. Če ne bi tudi malce modificirana Roomba naredila nekaj podobnega, vendar je za začetek njegovo telo človeške velikosti. Ima senzorje oddaljenosti, ljudi itd.

2.2. Sreda

V sredo se je začelo normalno delo konference, ki je trajalo tri dni [1] [2].

Adnan Darwiche z UCLA, ZDA, je predaval o : Generalized Decision Diagrams: The game is not over yet!. Pokazal je, da se dajo kombinatorično izredno zapletena dreves izrazov transformirati v polinomskem času.

IDEJA 4: Metoda za rešitev asimetričnega Turingovega testa, kjer je nekaj ljudi in mnogo agentov, ki igrajo Turingov test kot ljudje. Ni pa dejanskih vprašanj, ampak se vprašanja vrtijo o semantičnem grafu, tj. grafu kot pri agentnih nalogah oz. Masdi. Človeški grafi, tj. semantika odgovorov na ista vprašanja so predvidoma bolj kompaktni kot računalniški, ki pogosteje zgrešijo pomen, zato so grafi bolj razdeljeni. Program mora torej samo ločevati med kompaktnimi in nekompaktnimi semantičnimi grafi.

IDEJA 5: Oživiti patent za Confidence/Chiron. Vse kombinacije kontekstov in informacijskih virov se skombinira skupaj. Iz 3 virov dobiš 12 možnosti.

Ideja 6: Na AMI bi lahko imeli podoben demo kot na ECAI – poslati mail organizatorjem. Ali pa vsaj predposnete videje brez oddaljenega prenosa.

Referat »Exploiting Expert Knowledge in Factored POMDPs«, Felix Müller, Christian Späth, Thomas Geier and Susanne Biundo je zanimiv za Violeto, ki naj ga omeni pri sorodnih delih. PO v naslovu pomeni partially observable, tj. omejeno opazovanje sveta s strani agenta. Gre za izboljševanje oz, kombiniranje znanj.

»Creating Features from a Learned Grammar in a Simulated Student« avtorjev Nan Li, Abraham Schreiber, William W. Cohen and Kenneth R. Koedinger uporablja Foil za učenje preprostih slovnic. Rok, Simon?

»Learning to Play Simplified Boardgames by Observing« avtorja Yngvi Björnssona se ukvarja s poenostavljenimi igrami, kjer je možna le ena poteza, tako npr. v šahu ni dovoljena rošada ali napredovanje kmetov za dva.

2.3. Četrtek

Vabljeno predavanje Toma Mitchella »Never Ending Learning« je bilo gotovo zelo zanimivo. Omenil je njihov program Nell, pohvalno govoril o Siriju. Zanimivo za Tomaža in Damjana. 2.5 let se program že zdržema uči 24/7 z interneta. Multi-view learning, co-training. Ontologija, velik graf. Uči se tudi, kako učiti, tj. vzorce oz. sheme za učenje. Kljub temu ostaja plitek KN, ki nima samorefleksije.

V sekciji o Turingu [6], ki je bila vse 3 dni, je v prispevku »Artificial Intelligence in a Historical Perspective« Wolfgang Bibel omeni, da je Zuse napisal prvi šahovski program 1945, omeni tudi Michija, ki je leta 1965 ustanovil prvi AI oddelek. Bibel omeni, da je AI področje razpadlo na mnogo podkonferenc, ki se dogajajo razne čase na raznih krajih, kar ni dobro za področje. AI nima več centralne povezovalne vloge, kot bi jo morala imeti. Tudi Erik Sandewall v »A Perspective on the Early History of AI in Europe« omeni Michija. Malik Ghallab v »Deliberate Action in Robotics: a Perspective« govori o razvoju robotike in kaže videje robota, ki sočasno ulovi dve žogici, vsako v svojo roko.

Nekaj prispevkov je govorilo o reševanju IQ testov, kjer je možno z raznimi metodami odlično rešujejo celo vrsto podobnih testov. Program za glasbo se nauči s poslušanjem in nato zna sam igrati.

Sledijo posterji in demo. Precej ljudi se ustavi pri naši predstavitvi, sprašujejo ali tisti, ki delajo nekaj podobnega, ali tisti, ki jih kaj zanima kar tako. Nekaj znanim strokovnjakom podrobno pojasnimo. Osnovna misel je, da zapletene padce realnega življenja ni mogoče ločiti brez uporabe konteksta in kombiniranja senzorjev. V realnem življenju ni mogoče doseči 100%, mi dosežemo okoli 95% prepoznavanja padcev. Zmagajo robotki, katerih svet sestoji iz dveh ravnih plošč in globeli vmes. V globel morajo vreči dve kocki iz stiropora, da lahko zapeljejo čez. Čehi imajo zelo zanimive simulacije kontrole vodenja avionov na letališču.

2.4. Petek

Vabljeno predavanje Michaela Woodbridga z naslovom »Bad Equilibria, and What to do About Them« je bilo eno bolj zanimivih. Prikaže vrsto videov, med drugim prikaz, kako je prišlo do velikega padca delnic pri trgovanju

računalniških programov, kar se ne bi moglo zgoditi pri človeškem delovanju. Programi pa so padli v zanko poslabševanja in se niso znali izvleči iz tega »slabega ravnotežja«. Zato so potem uvedli zakone delovanja, ki so preprečili ponovitev tega – zaustavitev, upočasnitev ... Drugi zanimiv primer je bil iz igre »Zlata jajca«, kjer se dva igralca pogovarjata med seboj, ali bo vsak izbral »deli« ali »jemlji«. Če oba delita, dobita vsak polovico nagrade. Če obadva jemljeta, ne dobita nič. Če eden deli in drugi jemlje, tisti z jemanjem pobere vse. Na videu se zgodi točno to – eden izigra drugega, čeprav izpade goljuf. To je primer slabega ravnotežja. Potem razvije metode, kako preprečiti pojave slabega ravnotežja, ki škodijo področju, naj bo to trgovanje ali človeška družba. Analogija – bogataši in reveži.

V Turingovi sekciji je imel Stephen Muggleton zelo zanimivo predavanje o Turingu, ki ga bo verjetno vsaj delno ponovil tudi na IJS. Po predavanju sva debatirala o tem, kako bi bilo primerno počastiti Donalda Michija in Alana Turinga. Skupaj sva prišla do predloga, da bi lahko nagrado IS za življenjsko delo nekako navezala na spomin na ta dva velikana umetne inteligence in računalništva, še posebej Donalda Michija, ki je precej časa preživel na Institutu Jožef Stefan, kjer je bil tudi častni član. Bil je tudi častni član SAZU in še marsikaj.

Doktorica Michèle Sebag v svojem predavanju predstavi enega najbolj zanimivih pregledov AI do sedaj, omeni tudi, da je na spletu med najbolj zanimivi predmeti-predavanji o AI Stanfordov.

V sekciji Frontiers in AI omenjam dvoje predavanj. »Lifted Probabilistic Inference« avtorja Kristian Kersting predstavi novejše načine procesiranja informacij oz. sklepanja. Namesto linearnega je sedaj govora o kvadratičnem, s kombiniranjem paralelnih pogledov. Omenja Sirija in ga hvali.

Referat »Robot Skill Learning« avtorjev Jan Peters, Katharina Mülling, Jens Kober, Duy Nguyen-Tuong and Oliver Krömer predstavlja robotske usmeritve. Robot bi moral opravljati vrsto nalog, kot človek, in ne samo ene specializirane. Predstavi vrsto iger, recimo, kako daš žogico, privezano z vrvico, z nihajem na žlico, kako se naučiš udariti s kijem žogo na palici. Naslednja naloga je, da znaš odbijati žogico s ping-pong loparjem, če je privezana na lopar. Njegovi roboti se s strojnim učenjem učijo približno tako kot 5-letnik.

3 ZAKLJUČEK

Obisk največje evropske konference je bil izredno stimulativen. Zelo pomembno je na seminarjih/tečajih obnoviti znanja o tem, kako sedaj predavajo osnovna znanja o umetni inteligenci, vsakič na nekoliko nov način, kot npr. Peter Flach. Zanimive predstavitve prenesemo v odsek na odsečnih poročilih s konference, to se prenese v okolje in tudi v učenje študentov. Vrhunska raziskovalna predavanja so pomembna, ker omogočajo prenos vrhunskega evropskega znanja v slovensko okolje. Na ta način držimo stik z vrhunskim evropskim znanjem.

Dve temi sta bili izpostavljeni. Kot prvo ECAI postaja neka krovna organizacija bolj preglednega tipa, medtem ko se veliko specializiranega znanja seli v specializirane konference, recimo v konference o kognitivni znanosti, agentih, strojnemu učenju in itd. Drugo vprašanje je, zakaj je slovenski delež letos tako upadel. Iz cele Slovenije, ki ima vrsto odličnih AI okolij, je bil udeležen le odsek E9. Ni bilo niti enega sprejetega dolgega referata. Hkrati pa so bili dolgi prispevki na posameznih specializiranih konferencah, npr. na agentni. Celo na delavnicah, kjer bi celo odsek E9 sam lahko objavil nekaj prispevkov, ni bilo nobenega prispevka.

Ta izpad bi bilo dobro nadomestiti z nekaj poslanimi prispevki na IJCAI, tako na glavno konferenco kot tudi na delavnice.

V povzetku je bila konferenca ECAI zelo zanimiva in spodbudna za nove ideje.

Zahvala:

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POSTOPEK ZA DETEKCIJO NENAVADNEGA IN SUMLJIVEGA OBNAŠANJA IZ ČASOVNO-PROSTORSKIH SLEDI AGENTA

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POVZETEK

The problem of learning patterns of human behavior from sensor data arises in many applications including smart environments, surveillance, human-robot interaction, and ambient assisted living. Our focus of interest is detection of behavior patterns that deviate from regular behaviors and might represent a security risk, health problem or any other abnormal behavior contingency. This paper addresses the problem of analyzing agents activities from prior knowledge and external observations to detect deviant behavior patterns, regardless of whether the observed entities are software agents, humans, or even robots. The objective of our analysis is to be able to recognize atomic actions, integrate them into behavior patterns, and decide whether a new behavior pattern deviates. Specifically, this work introduces a framework for suspicious and anomalous behavior detection, and demonstrates how it was applied in three real-world domains.

1 UVOD

Detekcija sumljivega in nenavadnega obnašanja je pomembna v mnogih domenah, kjer je varnost okolja samega ali udeležencev v okolju ključnega pomena. Glavni cilj je detekcija vzorcev obnašanja, ki odstopajo od običajnih vzorcev in lahko predstavljajo varnostno grožnjo, zdravstveno težavo ali kakršno koli drugo nepredvidljivo obnašanje.

V tem prispevku se osredotočimo na domene, kjer so dejanja subjektov opisana z več-dimenzionalnimi, časovno-prostorskimi zaporedji, pa naj gre za gibanje človeka, agenta ali robota. Klasičnih pristopov za klasifikacijo, kot jih poznamo pri reševanju problemov opisanih z vektorjem značilk in razredom, v teh domenah ne moremo neposredno uporabiti, saj je potrebno sledi gibanja interpretirati in obravnavati na več načinov.

Glavni problemi, s katerimi se soočamo, so naslednji: (1) zaznavanje gibanja s senzorji je lahko šumno; (2) gibanje sestoji iz osnovnih akcij, ki jih agent v okolju izvaja, zato jih je potrebno razpoznati iz zaporedja v sledi agenta; (3) sumljivo in nenavadno obnašanje se lahko odraža na različnih pogledih; in (4) v nekaterih domenah je potrebno agenta spremljati dalj časa in kopičiti opažanja preden je mogoče sprejeti odločitev ali je obnašanje kritično ali ne.

V tem prispevku predstavimo splošen postopek za detekcijo sumljivega in nenavadnega obnašanja iz časovno-prostorskih sledi agenta, ki naslovi zgoraj opisane probleme. Podamo opis posameznih komponent postopka in obravnavamo glavne izzive, ki jih posamezna komponenta rešuje. V zadnjem delu prispevka prikažemo uporabo ogrodja na treh realnih domenah: verifikacija vstopa v strogo varovan prostor z biometričnimi senzorji, detekcija poslabšanja zdravja pri starejšemu uporabniku in odkrivanje sumljivih potnikov na letališkem terminalu.

2 OPIS PROBLEMA

Detekcija nenavadnega in sumljivega obnašanja se nanaša na identifikacijo vzorcev obnašanja, ki se razlikujejo od običajnih vzorcev, in lahko predstavljajo varnostno tveganje, zdravstveni problem ali kakšno drugo nezaželjeno obnašanje. Z drugimi besedami, cilj je najti vzorec obnašanja, ki se bodisi ujema s predhodno definiranim nezaželjenim obnašanjem (sumljivo obnašanje) bodisi se ne sklada s pričakovanim obnašanjem (nenavadno obnašanje). Tem vzorcem pravimo tudi izjeme, posebnosti, presenečenja, osamelci, zlorabe, ipd. Običajno se pojavijo relativno redko, vendar ko se pojavijo, so lahko njihove posledice zelo dramatične in pogosto v negativnem smislu. Tipični primeri vključujejo odkrivanje prevar s kreditnimi karticami, kibernetičnih vdorov, povzročene industrijske škode itd.

Ta prispevek se osredotoči na velik razred problemov, kjer so nastopajoči podatki kompleksna, prostorsko-časovna zaporedja. V takih domenah ima gibanje agenta značilno prostorsko-časovno strukturo, določeno s časovno odvisnostjo zaporedja akcij in z relativno pozicijo do statičnih točk v prostoru ter drugih agentov v okolju. Osnovna teza je, da je mogoče to strukuro opisati in uporabiti za detekcijo nenavadnega in sumljivega obnašanja. Primeri uporabe vključujejo detekcijo napadalca, ki poskuša pridobiti dostop do visoko varovanega objekta, morebitno sumljivega potnika na letališču, ki se

izogiba stiku s policistom, ali pa poslabšanje zdravstvenega stanja osamelega starostnika.

V nadaljevanju predstavimo osnovne definicije pojmov, ki jih bomo uporabljali pri opisu postopka za detekcijo. Predpostavimo, da opazujemo agenta v okolju, ki je opremljeno z n senzorji.

Definicija 1. ***Opažanje*** *oz. posnetek stanja x_t je večdimenzionalni vektor izmerjenih vrednosti vsakega izmed n senzorjev v danem časovnem trenutku t.*

V tem trenutku predpostavimo, da je mogoče zajeti opažanje ne glede na frekvenco za zajemanje podatkov, ki jo zagotavlja posamezen senzor.

Definicija 2. ***Vektor opažanj*** $\mathbf{x}^{(k)}$ *je po času urejeno zaporedje k opažanj, pri čemer velja $\mathbf{x}^{(k)} = \{x_t | 1 \leq t \leq k\}$.*

Definicija 3. ***Osnovna akcija*** a_t *je višje-nivojski opis podatkov v opažanju iz množice možnih opisov $\mathbb{A}$. Akcija se določi s funkcijo za razpoznavanje aktivnosti, ki preslika d-dimenzionalno opažanje x_t v akcijo $a_t \in \mathbb{A}$.*

$$f : \mathbb{R}^d \rightarrow \mathbb{A}$$

Definicija 4. ***Sled akcij*** $\mathbf{a}^{(k)}$ *je po času urejeno zaporedje akcij, pri čemer velja $\mathbf{a}^{(k)} = \{a_t | 1 \leq t \leq k\}$.*

Definicija 5. ***Vzorec obnašanja*** $\mathbf{b}^{(u,v)}$ *je zaporedje dvojk $\langle x, a \rangle$ iz sledi akcij $x \in \mathbf{x}^{(k)}$ in vektorja opažanj $a \in \mathbf{a}^{(k)}$, pri čemer velja $\mathbf{b}^{(u,v)} = \{\langle x_t, a_t \rangle | 1 \leq u \leq t \leq v \leq k\}$.*

Definicija 6. ***Profil obnašanja*** *je matrika $\mathbf{B}$, ki se določi s funkcijo za računanje profila in predstavlja vzorec obnašanja z zmanjšanim številom dimenzij ali z agregiranimi vrednostmi. Funkcija za računanje profila preslika vzorec obnašanja $\mathbf{b}^{(u,v)}$ v matriko $\mathbf{B}$ z dimenzijami $d' \times d'$:*

$$f : \mathbb{R}^{2d} \rightarrow \mathbb{R}^{d' \times d'}$$

Definicija 7. *Predpostavimo, da imamo množico nezaželjenih profilov obnašanja $\mathbb{B}_s$.* ***Sumljivo obnašanje*** *je profil obnašanja $\mathbf{B}$ za katerega je velja:*

$$\exists \mathbf{B}_i : d(\mathbf{B}, \mathbf{B}_i) < \epsilon, \mathbf{B}_i \in \mathbb{B}_s,$$

kjer je ϵ predhodno določena minimalna razdalja do najbližjega profila obnašanja.

Sumljivo obnašanje je torej profil obnašanja, ki se ujema z vsaj enim od nezaželjenih profilov v množici $\mathbb{B}_s$.

Definicija 8. *Predpostavimo, da imamo množico zaželjenih profilov obnašanja $\mathbb{B}_n$.* ***Nenavadno obnašanje*** *je profil obnašanja $\mathbf{B}$ za katerega je velja:*

$$\sum_{\mathbf{B}_i \in N(K,\mathbf{B})} d(\mathbf{B}, \mathbf{B}_i) > \lambda,$$

kjer je $N(K, \mathbf{B})$ množica K profilov obnašanja iz $\mathbb{B}_n$, najbližjih profilu $\mathbf{B}$ in λ predhodno določena minimalna razdalja.

Nenavadno obnašanje je torej profil obnašanja, ki relativno odstopa od zaželjenih profilov obnašanja v množici $\mathbb{B}_n$.

Definicija 9. ***Vrednost odstopanja*** *profila obnašanja $\mathbf{B}$ je skalar z realno vrednostjo, ki se določi na podlagi razdalje do ostalih profilov obnašanja:*

$$f : \mathbb{R}^{d' \times d'} \rightarrow \mathbb{R}.$$

Izrazi se kot normalizirana verjetnost, da je profil obnašanja nenavaden oz. sumljiv $s(\mathbf{B}) \in [0, 1]$.

3 POSTOPEK ZA DETEKCIJO

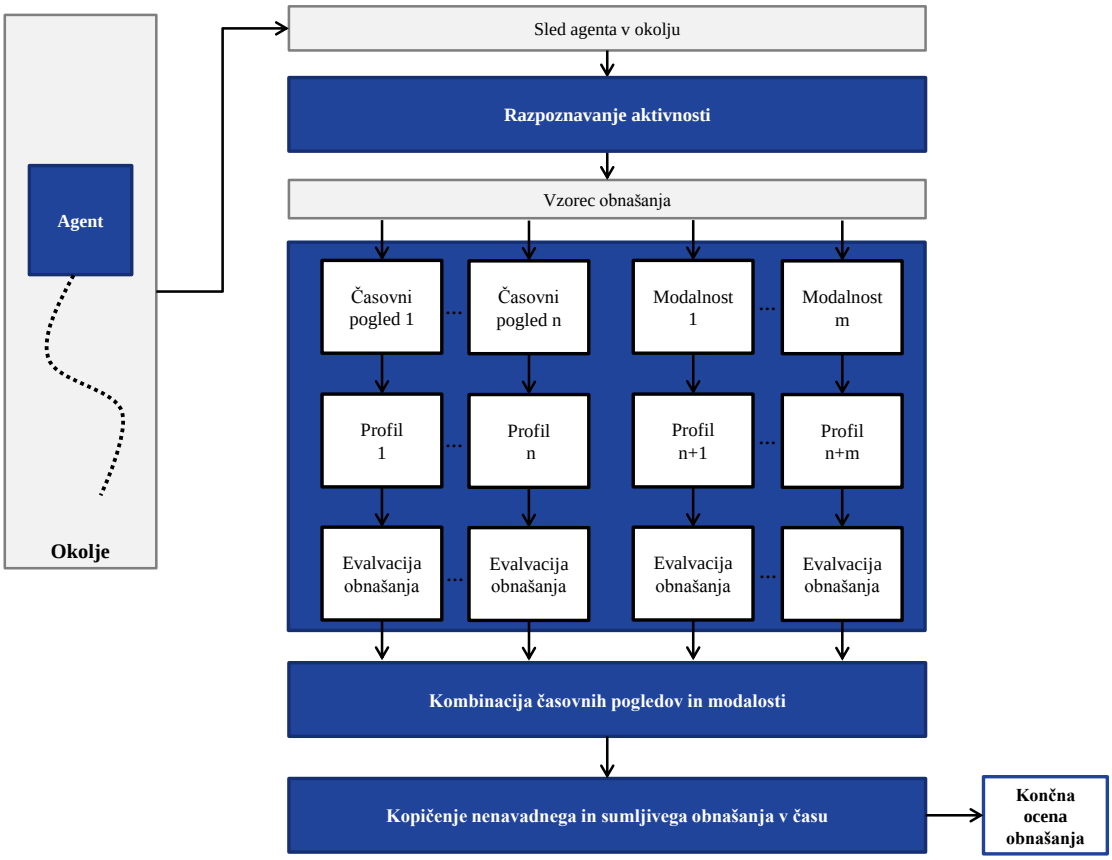
Predlagani postopek za detekcijo nenavadnega in sumljivega obnašanja temelji na predpostavki, da je mogoče uporabiti profile obnašanje, ki vsebujejo prostorsko-časovne vzorce, časovne odvisnosti v sledi akcij in ponavljajoče se vzorce, ter kombinacijo pogledov sesatvljeno iz različih modalnosti in na različnih časovnih enotah.

Prostorsko-časovni vzorci se v nasprotju z obstoječo literaturo, ki se osredotoča na identifikacijo vzorcev, nanašajo na opis vzorca, natančneje na opis dinamike aktivnosti in relacije med prostorsko informacijo in aktivnostjo. Temeljijo na predpostavki, da so prostroskočasovni vzorci opazovanega agenta povečini stabilni v času in se jih je zato mogoče naučiti.

Običajno se postopki osredotočajo na en sam specifičen pogled bodisi v smislu časovne omejitve bodisi v smislu izbranih modalnosti. Z obravnavanjem različnih pogledov in njihovo kombinacijo je mogoče sestaviti boljši vplogled v situacijo in oceniti vrednost odstopanja.

V nekaterih domenah je obnašanje smatrano kot sumljivo oz. nenavadno šele ko se določeni vzorci obnašanja večkrat ponovijo, čeprav je vsak vzorec zase lahko smatran kot popolnoma sprejemljiv. Glavno vprašanje je torej kako kombinirati posamezne vzorce ob različnih časovnih točkah v končno vrednost odstopanja.

Na sliki 1 je predstavljen postopek za detekcijo nenavadnega in sumljivega obnašanja. Sestavljen je iz več korakov, kot je prikazano na sliki 1. Vhod v postopek je sled agent v okolju oz. vektor opažanj, ki je zaznan s pomočjo sensorjev. V prvem koraku sledi razpoznavanje aktivnosti, kjer se vsakemu opažanju dodeli osnovna akcija in izračuna vzorec obnašanja, ki tudi vstopa v naslednji korak. Drugi korak iz vzorcev obnašanja izračuna številne tipe profila obnašanja, ki se razlikujejo v obravnavani časovni enoti in uporabljenih modalnostih. Za vsak posamezen tip se ločeno izračuna vrednost odstopanja in poda v tretji korak, namenjen kombinaciji posameznih profilov in končni oceni vrednosti odstopanja. Zadnji korak je namenjen kopičenju vrednostni odstopanja v času, kjer se upošteva tako trenutna vrednost odstopanja kot tudi odstopanje obnašanja v preteklosti. Postopek vrne končno vrednost odstopanja, ki se lahko ob izbrani mejni vrednosti uporabi za signaliziranje opozorila ali alarma.



Slika 1: Postopek za odkrivanje nenavadnega in sumljivega obnašanja.

3.1 Razpoznavanje aktivnosti

Razpoznavanje aktivnosti je tesno povezano s tipom uporabljenih senzorjev, zato je običajno konkretna izvedba samega modela za razpoznavanje zelo specifična. V nekaterih domenah je mogoče osnovne aktivnosti pridobiti neposredno iz vektorja opažanj, npr. premik *levo*, *desno*, *gor* in *dol*, medtem ko je v drugih domenah potrebno vpeljati številne dodatne korake, ki lahko vključujejo odstranjevanje šuma v vektorju opažanj, razpoznavanje aktivnosti z modelom in zmanjševanje odstranjevanje napak, ki predstavljajo nemogoče prehode med aktivnostmi, in razpoznavanje aktivnosti, ki so rezultat interakcij med več agenti. V sekciji 4 predstavimo nekaj možnih implementacij tega koraka.

3.2 Profil obnašanja in različni pogledi

Različni aspekti obnašanja se odražajo na različnih časovnih skalah in modalnostih, npr. za detekcijo kratkoročnih nevarnih situacij kot so padci, je potrebno spremljati spremembo v pospeških na nivoju sekund, medtem ko detekcija šepanja po lažji obliki kapi zahteva primerjanje profilov hoje na nivoju minut ali celo ur. Prav tako se obnašanje različno odraža preko različnih modalnosti, npr. s pospeškometrom je mogoče zaznati spremembe v izvajanju aktivnosti, medtem ko lokalizacijski senzor omogoča zaznavo spremebe v dnevni rutini.

Izbira števila časovnih in modalnih pogledov je prav tako tesno povezana z izbrano domeno. Za vsak pogled posebej se zgradi profil obnašanja in izračuna vrednost odstopanja. V primeru, da ima domena le en pogled, dodatni koraki niso potrebni, sicer je potrebno vrednosti odstopanja združiti v končno oceno. Pri tem se lahko uporabi ekspertni sistem ali bolj sofisticirane mehanizme odločanja kot npr. Bayesova mreža oz. kombinacijo obeh pristopov.

3.3 Akumulacija nenavadnega in sumljivega obnašanja

V zadnjem koraku se upošteva, da lahko določeni profili obnašanja predstavljajo odstopanje, če se ponovijo. Pristop je splošen in temelji na detekciji planov na podlagi cene morebitne škode. Za vsak profil se izračuna vrednost odstopanja in dodeli cena, ki predstavlja morebitno škodo, če bi takšno obnašanje ostalo nedetektirano. Tako je mogoče hitro detektirati obnašanja, ki so sicer redka in imajo majhno vrednost odstopanja, a so lahko zelo kritična. Poleg tega pristop vpelje časovno odvisne funkcije, ki upoštevajo preteklo obnašanje agenta in di-

namično prilagodijo ceno. Pristop je podrobno opisan v [4].

4 PRIMERI UPORABE

V tem prispevki prikažemo način uporabe predlaganega postopka na treh domenah: (i) obnašanje uporabnikov na kontrolni vstopni točki v visoko varovan prostor; (ii) obnašanje starejšega uporabnika, ki živi sam doma, z namenom zaznati spremembe, ki bi lahko nakazovale poslabšanje zdravstvenega stanja; in (iii) obnašanje potnikov na letališču z namenom detekcije potencialno sumljivih potnikov.

4.1 Varnost na vstopni kontrolni točki

Problem se nanaša na vstopno kontrolno točko, ki je opremljena s kamero, brezkontaktno identifikacijsko kartico, biometričnimi senzorji in senzorjem za odpiranje in zapiranje vrat. Namen je zaznati nepooblaščen dostop v primerih, ko napadelec zlorabi identiteto (ponaredi biometrične podatke ali prisili pooblaščeno osebo v odobritev dostopa) [2].

Ob vstopu se zabeležijo podatki senzorjev in dodatne kontekstne informacije, npr. del dneva, dan v tednu, oseba, ki je predhodno vstopila ipd. Razpoznavanje aktivnosti je v tej domeni trivialno, saj vsaka aktivacija senzorja predstavlja svojo akcijo, zato dodani koraki niso potrebni. Nato se uporabi tri različne poglede, ki se nanašajo na dinamiko premikov (uporabijo se časi med aktivacijo posameznih senzorjev), navade (uporabijo se kontekstne informacije) in fizično premikanje (uporabi se video kamera za analizo gibanja v prostoru). Vsak pogled ločeno poda vrednost odstopanja. V končnem koraku se vse vrednosti odstopanja združijo z uporabo ekspertnega sistema (npr. preveri, če se je vhod zgodil znotraj delovnega časa) in Bayasove mreže, ki združi posamezne vrednosti v končno vrednost odstopanja. Na podalgi te vrednosti se sproži opozorilo ali alarm.

4.2 Spremljanje zdravstvenega stanja starejših

Cilj je s pomočjo senzorjev spremljati zdravstveno stanje starejših, ki živijo sami doma, in s tem podaljšati čas pred hospitalizacijo [6]. Uporabniki so opremljeni z lokalizacijskimi senzorji, ki podajo 3-dimenzionalne koordinate v prostoru. Razpoznavanje aktivnosti je zato zapleteno in vsebuje številne korake [5], ki so predlagani v sekciji 3.1, in označi aktivnosti kot so hoja, sedenje, ležanje itd. Analiza obnašanja je razdeljena na tri poglede [1]: kratkoročna analiza situacije (nanaša se na sekunde, namenjena zaznavanju padcev), srednjeročni profil gibanja (nanaša se na minute in ure, namenjen detekciji šepanja ipd.), dolgoročni profil dnevne dinamike (nanaša se na dneve, namenjen detekciji poslabšanja zdravstvenega stanja [3]). Vsak pogled poda svojo vrednost odstopanja. Zaradi jasne časovne opredelitve posameznega pogleda, posebno združevanje ni potrebno.

4.3 Video nadzor na letališču

Zadnja domena se osredotoča na detekcijo sumljivih potnikov na letališču [4]. Cilj je zaznati potnike, ki kažejo znake živčnosti in nemirnosti. Pristop predpostavlja, da se bodo znaki odrazili tudi na sledi gibanja, npr. izogibanje policistom. Vhod v postopek je zaporedje koordinat gibanja potnika po letališču. Razpoznavanje aktivnosti iz koordinat določi premik osebe (gor, dol, levo, desno). V tej domeni sta uporabljena dva pogleda, interakcije potnik-potnik in interkacije potnik-policist. Vsak pogled poda svojo vrednost odstopanja, združevanje ob posameznem časovnem koraku ni potrebno, saj se hkrati zgodi le en tip interakcije. Posebnost te domene je akumulacija vrednosti odstopanja v času, npr. če se potnik izogne policistu le enkrat, je to morda naključje, če se pa izogne večkrat zapovrstjo, pa vrednost odstopanja naraste.

5 ZAKLJUČEK

V prispevku smo obravnavali problem detekcije nenavadnega in sumljivega obnašanja ter predstavili postopek za detekcijo takšnega obnašanja iz sledi agenta. Podali smo osnovne definicije, opisali postopek za detekcijo in orisali uporabo postopka na treh domenah.

Nekateri koraki v postopku za detekcijo so povsem splošni, medtem ko so drugi tesno povezani z domeno. V nadaljnjem delu bi se bilo smiselno osredotočiti na posplošitev postopka za razpoznavanje aktivnosti.

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ARDUINO V RAZISKOVALNIH IN RAZVOJNIH PROJEKTIH

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POVZETEK

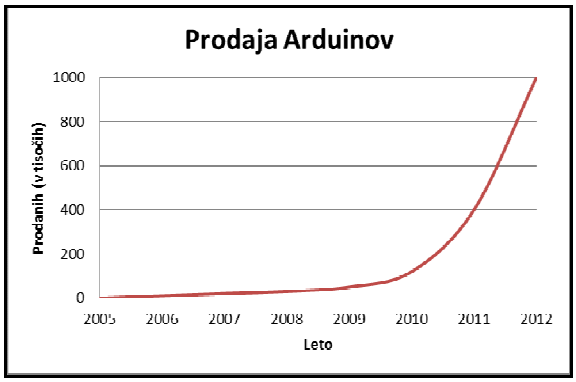
Zaradi velike količine podatkov in njihove kompleksnosti se za obdelavo v raziskovalnih projektih uporabljajo računalniki. Za pridobivanje podatkov iz fizičnega sveta se največkrat uporabljajo namenski merilni sistemi, ki so običajno zelo dragi in neprilagodljivi. Ena izmed cenejših in bolj prilagodljivih alternativ je uporaba odprto-kodne razvojne platforme Arduino. Ta je primerna tako za izgradnjo merilnih sistemov, kot tudi sestavljanje prototipnih naprav. V tem pregledu bomo opisali strojno in programsko opremo platforme Arduino ter podali nekaj primerov uporabe.

1 UVOD

Razvoj prototipnih naprav in namenskih merilnih sistemov je zahtevno, časovno potratno in drago opravilo. Še več. V veliko primerih se od teh naprav ne zahteva popolne stabilnosti ali velike natančnosti. Pri izdelavi prvih prototipnih izdelkov se običajno ne pričakuje, da delujejo brezhibno, saj so namenjeni predvsem preizkušanju idej oz. konceptov. Prav tako se v veliko raziskavah potrebuje namenske merilne naprave, vendar je pri tem pomemben dejavnik cena in čas. V teh primerih se največkrat odločimo za uporabo obstoječih razvojnih platform. Ena od teh je Arduino [1], ki jo bomo v nadaljevanju natančneje opisali.
Arduino je odprto-kodna razvojna platforma, ki temelji na strojni in programski opremi, ki je fleksibilna in enostavna za uporabo. Nastala je kot naslednik platforme Wiring [2], ki je bila razvita z namenom poenostaviti mikrokrmilniške sisteme. Ime "Arduino" je avtorsko zaščiten od glavne skupine, ki je razvila strojno in programsko opremo. Strojna oprema vsebuje enostaven odprto-kodni dizajn s procesorjem Atmel AVR in podporo za vhodno izhodne naprave. Programska oprema je sestavljena iz integriranega razvojnega okolje, standardnega programskega jezika in zagonskega dela (ang. boot loader). Programski jezik temelji na Wiring jeziku, ki je podoben C++ z manjšimi poenostavitvami in spremembami. Arduina integrirano razvojno okolje (Arudino IDE) je prilagojeno za večino operacijskih sistemov in je namenjeno enostavnejšemu programiranju.

Arduino se lahko uporablja za razvoj interaktivnih naprav, ki lahko zaznavajo okolico s senzorji in upravljajo z aktuatorji. Poleg tega lahko razvojne ploščice delujejo samostojno ali komunicirajo z drugim računalnikom. Glavne prednosti platforme Arduino so:

- Cenovno ugodna: razvojne ploščice so relativno ugodne v primerjavi z ostalimi mikrokontrolerski platformami.
- Podpora različnih operacijskih sistemov: programska oprema Arduino IDE teče na Windows, OSX in Linux operacijskih sistemih.
- Enostavno programsko okolje: programiranje Arduinov je enostavno celo za začetnike in hkrati dovolj fleksibilno za napredne uporabnike.
- Odprto-kodna programska oprema: ker je programska oprema v celoti odprto-kodna, so knjižnice in projekti prosto dostopni na spletu.
- Odprto-kodna strojna oprema: tako kot programska, je tudi strojna oprema odprto-kodna, kar pomeni da so celotne sheme brezplačno na voljo na spletu. Tako lahko vsak sestavi tiskano vezje po svojih željah.
- Skupnost Arduino: ker je projekt odprto-koden, lahko na internetu najdemo veliko podpore, ko naletimo na probleme. Na uradnem Arduino forumu [5] je trenutno registriranih preko 146.000 uporabnikov.



Slika 1: *Letna prodaja Arduinov*

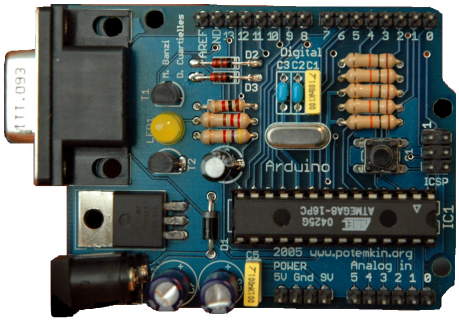
Zaradi vseh teh prednosti se je platforma Arduino postala močno priljubljena. Po nekaterih ocenah je bilo v letu 2011 prodanih okrog 400 tisoč Arduino kompatibilnih plošč, medtem ko jih bo v letu 2012 predvidoma 1 milijon (Slika 1).

2 STROJNA OPREMA

Zaradi Arduinove evolucije danes obstaja veliko različnih Arduino razvojnih ploščic, ki pa jih lahko razdelimo v 9 skupin [6, 7]:

- Arduino Serial (Slika 2)

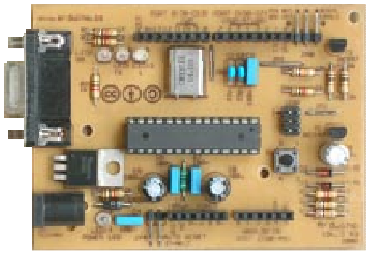
Ta tip Arduino razvojnih ploščic je bil predstavljen prvi in sicer leta 2005. Zgrajen je na osnovi čipa ATmega8 in vsebuje RS232 priključek za programiranje in komunikacijo. Načrtovan je bil tako, da vsebuje elemente, ki so dobavljivi po celem svetu.



Slika 2: Arduino Serial

- Arduino Single-Side Serial (Slika 3)

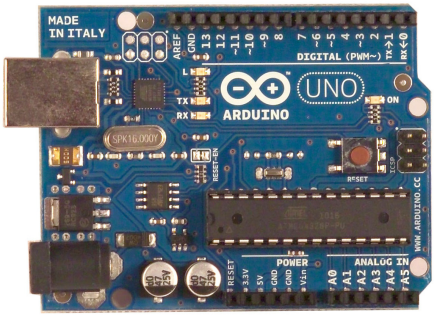
Plošča temelji na Arduinu Serial (verzije 2), vendar je ta načrtovana tako, da jo je mogoče enostavno ročno sestaviti. Dizajnirana je tako, da jo je mogoče narediti na enostranskem tiskanem vezju. Ta verzija nikoli ni bila proizvedena, ampak je bila le objavljena za tiste, ki bi jo želeli sami izdelati.



Slika 3: Arduino Single-Side Serial

- Arduino USB (Slika 4)

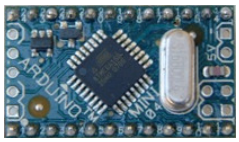
Kot je razvidno iz imena, vse različice plošč iz te skupine vsebujejo USB priključek. Ta je namenjen programiranju, komunikaciji in napajanju vezja. Prav zaradi USB priključka je ta skupina Arduinov najbolj priljubljena. Najnovejša se imenuje Arduino Uno. Sestavljena je na podlagi mikrokontrolerja ATmega328 in jo je mogoče priključiti tudi na zunanje napajanje. Več podatkov si lahko ogledate v Tabeli 1.



Slika4: Arduino Uno R3

- Arduino Mini (Slika 5)

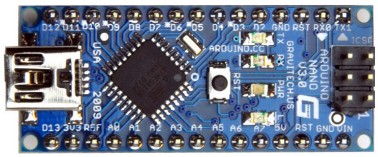
Arduino Mini je majhna mikrokontrolerska ploščica. Zadnja verzija (peta) temelji na mikrokontrolerju ATmega328 in je namenjena uporabi tam, kjer je prostor dragocen. Da bi privarčevali na prostoru ta nima vgrajenega USB priključka, zato za programiranje potrebuje serijski vmesnik. Zaradi tega je programiranje ploščice malce bolj nerodno, zato je ploščica bolj primerna za končne prototipe. Za lažje programiranje je bila izdana dopolnjena verzija Arduino Pro Mini, ki omogoča programiranje preko FTDI kabla in je zato primerna tudi za razvoj prototipov.



Slika 5: *Arduino Mini 04*

- Arduino Nano (Slika 6)

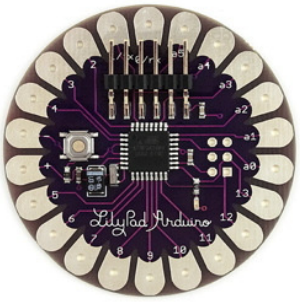
Kljub temu da meri le 18,5x43,2mm vsebuje skoraj vse funkcionalnosti kot Arduino UNO. Zaradi njene majhnosti je primerna za vgraditev v razvojne projekte, kjer je prostor zelo dragocen, poleg tega pa je potrebno neprestano popravljanje programa.



Slika 6: *Arduino Nano 3.0*

- LilyPad Arduino (Slika 7)

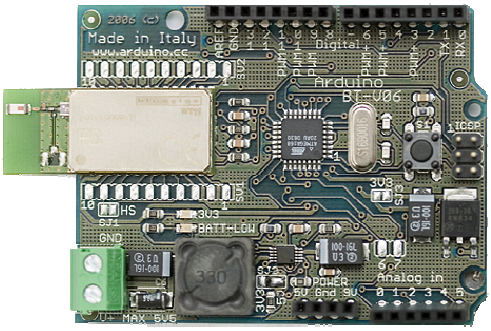
Še ena okleščena izvedba Arduina, ki pa je namenjena izdelavi interaktivnih oblačil. Izdelana je tako, da jo je mogoče prišiti na tkanino. Za delovanje potrebuje zunanje napajanje, potrebne senzorje in aktuatorje. Da bi privarčevali prostor tudi ta verzija nima USB priključka, zato za programiranje potrebujemo dodatni pretvornik, podobno kot zgoraj opisan Arduino Mini.



Slika 7: *LilyPad Arduino*

- Arduino BT (Slika 8)

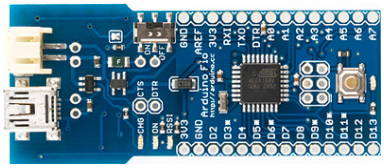
Ta razvojna ploščica je namenjena projektom, kjer je potrebna brezžična komunikacija z zunanjimi napravami. Za komunikacijo je vgrajen bluetooth modul, ki omogoča celo programiranje na daljavo. Glede ostalih specifikaciji je zelo podoben Arduinu USB.



Slika 8: *Arduono BT*

- Arduino Fio (Slika 9)

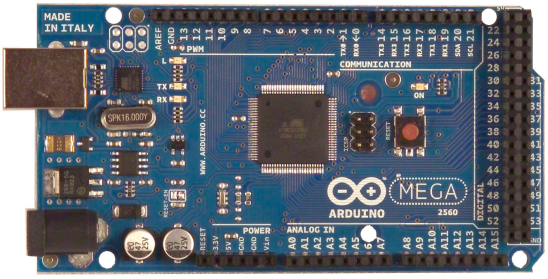
Ta Arduino je prav tako namenjen brezžičnim aplikacijam. Lahko ga uporabimo kot vozlišče v brezžični mreži. Plošča vsebuje XBee modul, priključek za baterijo ter vezje za polnjenje le te. Programirati ga je mogoče z uporabo FTDI kabla oziroma brezžično z uporabo USB-XBee pretvornika.



Slika 9: *Arduino Fio*

- Arduino Mega (Slika 10)

Ta je najnovejši, največji in najzmogljivejši Arduino doslej. Temelji na zmogljivejšem mikrokontrolerju ATmega2560 in vsebuje USB za programiranje. Poleg tega ima dodatne vhode in izhode, serijske priključke, itd. Primerjava Arduina Mega in Arduina Uno je prikazana v Tabeli 1. Pozneje je bila izdana Mega ADK verzija z gostiteljskim USB priključkom, s čimer je postal enostaven za uporabo z Googlovim ADK (Accessory Development Kit) [8].



Slika 10: *Arduino Mega 2560*

Tabela 1: *Primerjava Arduino Uno in Arduino Mega*

Arduino	Arduino Uno	Arduino Mega 2560
Procesor	ATmega328	ATmega2560
Programski spomin	32KB	256KB
Podatkovni spomin	2KB	8KB
EEPROM	1KB	4KB
Število nožic	28/32*	100
Število I/O	14	54
Analogni vhodi	6	16
PWM izhodi	6	14
Serijski porti	1	4

* 28 nožic za DIP verzijo ATmega328 in 32 nožic za SMD verzijo

Dodatna prednost Arduino razvojnih plošč je povezljivost z razširitvenimi moduli in ščiti (ang. shields). Moduli so senzorji oz. aktuatorji, ki jih poljubno dodajamo glede na zahteve projekta. Pri tem smo omejeni s številom in tipom priključkov, ki jih izbrana Arduino platforma ima.
Na spletu lahko najdemo najrazličnejše module, ki so kompatibilni z Arduinom, kot so npr. senzorji temperature, vlage, kvalitete zraka, oddaljenosti, gibanja, pospeškov ter čitalce kartic, kompas, žiroskop, releje, LED, SD kartice, itd.
Ščit je plošča, ki jo nataknemo na Arduia in s tem razširimo funkcionalnost. Tako lahko razširimo Arduina z USB priključkom (če ga ta še nima), žičnim ali brezžičnim internetnim priključkom, Xbee povezavo, TFT zaslonom, GSM/GPRS, GPS, itd.
Modularni način nam omogoča da sami zgradimo primeren sistem, ki vsebuje vse potrebne senzorje in aktuatorje in jih lahko med sabo povežemo brez poznavanja delovanja mikrokrmilniških sistemov. Ker je celotna strojna oprema odprto-kodna, lahko na spletu najdemo povezovalne sheme, tiskana vezja in seznam elementov, kar nam omogoča, da lahko sami izdelamo celotno napravo.

3 PROGRAMSKA OPREMA

Eden izmed pomembnejših razlogov za priljubljenost Arduino platforme je gotovo tudi poenoten programski jezik, prosto dostopne knjižnice in integrirano razvojno

okolje. Zaradi tega je uporaba mikrokontrolerjev Arduino zelo enostavna in primerna tudi za začetnike.
Kot je že v uvodu omenjeno programski jezik temelji na Wiring jeziku, ki podpira več operacijskih sistemov in veliko število mikrokontrolerjev. Prednost tega programskega jezika je v tem, da lahko program zaženemo na kateri koli Arduino kompatibilni plošči, če ta izpolnjuje vse strojne zahteve (dovolj vhodov in izhodov, spomina, itd.). Žal so najbolj podprti le mikrokrmilniki ATmega, vendar je programe mogoče naložiti tudi na nekatere druge (npr. AVR, PIC, ARM).
Pri pisanju programov si lahko pomagamo z že napisanimi knjižnicami, s katerimi lahko razširimo funkcionalnost, kot npr. delo s senzorji ali upravljanje s podatki. Navadno so te knjižnice dobro dokumentirane in enostavne za uporabo, kar omogoča hitro pisanje programa. V primeru ko na spletu ne najdemo primerne knjižnice, lahko te tudi sami napišemo, s čimer lahko funkcionalnost razširimo glede na naše zahteve in potrebe.
Za uporabniku prijaznejše programiranje je bilo predstavljeno Arduino razvojno okolje (Arduino IDE). Programsko okolje podpira različne operacijske sisteme (Windows, Linux in OSX), saj je napisan v Javi, temelji pa na odprto-kodnem programskem jeziku Processing. Poleg tega uporablja odprto-kodni standardni prevajalnik GCC, kar pomeni da je tudi razvojno okolje odprto-kodno. Zaradi enostavne namestitve in poenostavljenega uporabniškega vmesnika je programiranje uporabniku prijazno in enostavno.

4 PROJEKTI

Načinov kako uporabiti Arduino je mnogo. V tem poglavju so opisani le nekateri pristopi, ki so uporabni pri različnih raziskovalnih in razvojnih nalogah. Projekti so razdeljeni v dve skupini. V prvi skupini so projekti, pri katerih je glavna naloga zbiranje podatkov, v drugih pa izdelovanje prototipnih naprav. Ta delitev sicer ni izključujoča, saj lahko naprava poleg merjenja in pošiljanja podatkov tudi ukrepa in se odziva na okolje, vendar bomo zaradi lažjega razumevanja vseeno poskušali razdeliti v te dve skupini.

4.1 Merjenje

Glavna naloga naprav za merjenje je zaznavanje okolice in shranjevanje oziroma pošiljanje podatkov. Tako pri določanju senzorjev, kot tudi načina shranjevanja oziroma pošiljanja lahko izbiramo med široko paleto možnosti.
Katere senzorje uporabimo je odvisno od merjene veličine, vzorčne frekvence in natančnosti, pri čemer smo omejeni s pretočnostjo izbranega vodila. Arduino ponuja že sestavljene senzorje, ki jih enostavno priključimo na razvojno ploščico. Večina senzorjev je podprta s knjižnicami, ki nam olajšajo pisanje programov. Če nam ti senzorji ne ustrezajo, lahko načrtamo svoje glede na naše zahteve.
Prav tako je mogoče pošiljati podatke na večino najbolj pogostih protokolov, kot so Bluetooth, USB, RF, IR, Wi-Fi, Ethernet itd. Podatke lahko tudi shranjujemo, za kar se največkrat uporabljajo razširitvene pomnilniške kartice.
Zaradi svoje majhnosti in enostavnosti je torej Arduino platforma zelo primerna za hitro izgradnjo najrazličnejših merilnih postaj. Na spletu lahko najdemo projekte kot so: vremenske postaje, merjenje čistosti jezer in morji, potresnih sunkov, porabo vode, elektrike, itd.

4.2 Prototipi

Za načrtovanje novih izdelkov in preizkušanje njihove uporabe v realnosti potrebujemo enostaven in hiter sistem, kar Arduino gotovo je. Poleg tega je prehod na majhno do srednje veliko proizvodnjo naprav enostaven.
Pri načrtovanju naprav lahko uporabimo enake senzorje in komunikacijske priključke, kot so opisani v prejšnjem poglavju. Navadno pa se za vplivanje na okolico uporabljajo tudi aktuatorji. Te lahko najdemo na spletu, že sestavljene in pripravljene za uporabo. Izbiramo lahko med elektronskimi stikali, LED, servo motorji, TFT zasloni, itd. Prav tako kot senzorje lahko tudi aktuatorje prilagodimo našim željam in zahtevam, kar omogoča popolno prilagodljivost posameznemu projektu. Z uporabo Arduina je mogoče sestaviti najrazličnejše robote, avtomatizacijo stavb, glasbene inštrumente, 3D tiskalnike, itd.

5 ZAKLJUČEK

Predstavili smo platformo Arduino in našteti pri nekaj načinov uporabe v razvojnih in raziskovalnih projektih. Opisali smo različne izvedbe strojne opreme Arduino, saj je izbira najprimernejšega za posamezen projekt ključnega pomena. Nato smo predstavili programsko oprema in programski jezik, ki se uporablja za programiranje Arduino kompatibilnih mikrokrmilnikov. V zadnjem poglavju smo predstavlili nekaj načinov uporabe Arduina.
Ugotovili smo da je Arduino platforma zelo primerna za projekte, kjer cena in hitrost izdelave zelo pomembna. Manj primerna je za kritične sisteme, kjer se zahteva visoka zanesljivost in natančnost, oziroma kakšna druga posebna zahteva, ki jo platforma Arduino ne more zagotoviti.

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Z REPOZITORIJEM ZA PREPOZNAVANJE AKTIVNOSTI DO BOLJ PRIMERLJIVIH REZULTATOV IN HITREJŠEGA NAPREDKA NA PODROČJU AMBIENTALNE INTELIGENCE

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POVZETEK

Področje ambientalne inteligence se zadnja leta pospešeno razvija. Rezultate razvoja se uporablja v številnih aplikacijah. Eden od ključnih faktorjev takšnih aplikacij je uspešen in zanesljiv sistem sposoben prepoznati aktivnosti, ki jih uporabnik trenutno izvaja in razumeti kontekst, v katerem se to dogaja. Pri razvoju takšnih sistemov se pojavljata dve pomanjkljivosti: (i) prenosljivost, tj., določena implementacija sistema je tesno povezana z izbranim algoritmom strojnega učenja, senzorji, ki so na voljo in domeno, kjer se aplikacija uporablja; in (ii) primerljivost, tj. trenutno ne obstaja referenčna podatkovna zbirka, ki bi omogočala neposredno primerjanje različnih pristopov. Članek na začetku predstavi trenutne poskuse pri snovanju referenčnih zbirk podatkov in nato predlaga centralizirano zbirko podatkov s katero bi lahko primerjali različne sisteme. Glavna ideja je vzpostaviti spletni repozitorij, kjer bi bile shranjene različne podatkovne zbirke, opisane naloge, opravila in rezultati posemeznih zbirk. Tako bi se od donatorjev zbirke podatkov pričakovalo, da bi prispevali tudi kratek opis podatkov, nalog in rezultatov, do katerih so prišli med procesiranjem podatkov, relevantnih člankov in povezav do orodij za implementacijo njihovih pristopov. To bi ostalim raziskovalcem na področju ambientalne inteligence omogočilo hitro napredovanje, enostavno uporabo drugih podatkovnih zbirk in primerjavo razvitih pristopov z namenom čimbolj uspešnega napredka celotnega področja.

1 UVOD

Trenutni napredek na področju ambientalne inteligence (AmI) je izpostavil celo vrsto aplikacij, ki so občutljive in odzivne na prisotnost ljudi. Ena od pomembnejših lastnosti takšnih aplikacij je učinkovito in zanesljivo prepoznavanje aktivnosti ljudi. Le-to mora biti sposobno, glede na dano kontekstno informacijo, tudi razumeti zakaj uporabnik izvaja trenutne aktivnosti. V težnji po razvoju aplikacij, ki bi delovale zanesljivo tudi v realnem življenju, morajo biti testi takšnih aplikacij dobro načrtovani in raznoliki. Večinoma so testi opravljeni na podatkovnih zbirkah, ki jih za določen problem pripravijo kar razvijalci sistema.

Obstaja kar nekaj AmI sistemov, ki so se izkazali za uporabne tudi pri scenarijih iz resničnega življenja [6, 13] vendar je primerjava med njimi skoraj nemogoča zaradi različnih scenarijev testiranja, različnega okolja, senzorjev in pristopa. Kot primer lahko vzamemo problem detekcije padcev, kjer je bilo narejeno veliko študij in razvitih veliko pristopov, ki ugotavljajo padce uporabnikov s pomočjo pospeškov. Vsak od teh sistemov v namen testiranja uporablja lastno podatkovno zbirko. Neposredna primerjava med različnimi metodami nemogoča je tako nemogoča.

V zadnjem času je kar nekaj raziskovalnih skupin začelo s prvimi koraki k reševanje tega problema. Leta 2010 je bilo organizirano tekmovanje »International Workshop on Frontiers of Activity Recognition« [5], ki je vzpodbujalo iskanje novih izzivov in nastanek novih metod za prepoznavanju aktivnosti iz videa. Za potrebe tekmovanja je bila na razpolago zbirka videov VIRAT [11], ki vsebuje scenarije posnete z več kamerami v naravnem, resničnem okolju. Kamere imajo različne resolucije, dinamične frekvence, različne vidne kote in različne stopnje šuma. Naloga je bila razviti algoritem za prepoznavanje aktivnosti, ki je sposoben obravnavati vse zgoraj naštete pomanjkljivosti. Naslednje leto, 2011, je bilo tekmovanje ponovno organizirano (»Activity Recognition Competition Workshop« [4]). Tokrat so bile posnetkom dodane tudi oznake aktivnosti v težnji za boljšo analizo podatkov.

Še eno od tekmovanj za prepoznavanju aktivnosti je »Opportunity Activity Recognition Challenge« [12], katero je bilo organizirano leta 2011 in je del evropskega projekta »Opportunity«. Ta je usmerjen v iskanje in razvoj novih generičnih pristopov, algoritmov in arhitektur sistemov, ki

bi bili sposobni prepoznati višjenivojske aktivnosti in kontekstne informacije kljub temu, da na voljo ni točnih oz. zadostnih informacij o razpoložljivosti in karakteristikah senzorjev [10]. V ta namen je bila ustvarjena podatkovna zbirka v bogatem senzorskem okolju. Skupaj je bilo posnetih 72 senzorjev vgrajenih v okolico in nošenih na testnih osebah. Zbirka je označena tako z višjenivojskimi aktivnostmi kot tudi z atomičnimi aktivnostmi. Tekmovanje je bilo razdeljeno na štiri naloge: (1) prepoznavanje aktivnosti s senzorji pritrjenimi na uporabnika, (2) avtomatska detekcija časovnih intervalov, kjer se ne dogaja nič pomembnega, (3) detekcija in prepoznavanje premikov rok, in (4) detekcija in prepoznavanje premikov rok, ko je testnim podatkom dodan šum.

Zadnji tekmovanji sta bili organizirani leta 2011 in 2012 pod skupnim naslovom: »Evaluating AAL systems through competitive benchmarking« [2]. V nasprotju z ostalimi tekmovanji, so morali sodelujoči sami zagotoviti in priskrbeti strojno opremo in tudi programske komponente sistema, ki so bili nato testirani s pomočjo vnaprej določenega scenarija. Tekmovanji sta bili razdeljeni na dve nalogi: (1) notranja lokalizacija in sledenje uporabnikom, kjer je bil cilj najti najboljši notranji lokalizacijski sistem, in (2) prepoznavanje aktivnosti, katerega cilj je bilo najti trenutno najboljši sistem za prepoznanje aktivnosti.

Cilj tega članka je predlagati centralizirano zbirko orodij, člankov in seveda podatkovnih zbirk, ki bi služile lažji evalvaciji sistemov za prepoznavanje aktivnosti. Naš cilj je vzpostavitev spletnega repozitorija podatkovnih zbirk, ki bi vsebovale vse osnovne informacije o podatkih, vse potrebne informacije in orodja za uspešno uporabo teh podatkov in povezave na sorodne članke. Tako bi se od donatorjev podatkovnih zbirk pričakovalo, da bi prispevali tudi kratek opis podatkov, nalog in rezultatov, do katerih so prišli med procesiranjem podatkov, relevantnih člankov in povezav do orodij za implementacijo njihovih pristopov. To bi ostalim raziskovalcem na področju ambientalne inteligence omogočilo hitrejše napredovanje, enostavno uporabo drugih podatkovnih zbirk in primerjavo razvitih pristopov z namenom čimbolj uspešnega napredka celotnega področja.

V nadaljevanju je predstavljena osnovna ideja spletnega repozitorija in tri podatkovne zbirke, katere le-ta že vsebuje. Glavna ideja ni vsiljevanje naše ideje drugim raziskovalcem na tem področju, temveč začeti diskusijo, kako bi lahko naš repozitorij preoblikovali na tak način, da bi bil primeren za čimširši krog ljudi. Na začetku predstavimo različne tipe podatkovnih zbirk, katere so razdeljene glede na domeno, tip senzorjev in nalogo. Nato predlagamo strukturo repozitorija in opišemo trenutno implementacijo. Na koncu predstavimo še tri podatkovne zbirke, ki so že dodane repozitoriju.

2 TIPI PODATKOVNIH ZBIRK

Področje ambientalne inteligence je zelo obširno, kar pomeni, da se raziskovalci ukvarjajo z množico različnih problemov in še večjim številom podatkov. Podatkovne zbirke lahko kategoriziramo glede na različne kriterije: tip senzorjev, ki so uporabljeni pri snemanju podatkov, problem za katerega so bili posneti podatki in domeno problema. Nekatere zbirke podatkov so seveda lahko označene tudi z več oznakami pri posameznem kriteriju.

V prvi kategoriji ločimo podatkovne zbirke glede na uporabljeno strojno opremo pri snemanju le-teh. Ta kategorija vsebuje naslednje podkategorije: (1) okoljski senzorji, ki so lahko vgrajeni v bivalni prostor (kot primer: senzorji pritiska vgrajeni v kuhinjska tla) ali v/na predmete (kot primer: RFID značke v kuhinjskih napravah); (2) strojna oprema za zajem videa, ki obsega kamere in infrardečo detekcijo gibanja za namen lokalizacije; (3) senzorji, ki jih uporabnik nosi, kot so: lokacijski senzorji, inercialni senzorji, katere sestavljajo pospeškomeri, žiroskopi in merilci magnetnega polja.

V drugi kategoriji delimo podatkovne zbirke glede na problem, ki ga s temi podatki lahko rešimo. V to kategorijo spadajo: atomično prepoznavanje aktivnosti, kompleksno prepoznavanje višjenivojskih aktivnosti in planov, prepoznavanje obnašanja, analiza aktivnosti, poraba energije, ipd. Tretja kategorija opisuje domeno aplikacije, kot primer: nadzorovanje zdravja posameznika, prepoznavanje bolezni, detekcija sumljivega obnašanja, športna analiza, ipd.

Upoštevati bi morali tudi možnost razlikovanja med sintetično generiranimi podatki in podatki, ki so posneti v realnem okolju.

3 REPOZITORIJ

Trenutno je implementirana začetna verzija spletnega repozitorija [1]. Repozitorij je sestavljen iz začetne/glavne strani in strani z opisi posameznih podatkovnih zbirk. Začetna stran ponuja pregled podatkovnih zbirk, ki so organizirane v kategorije, ki so bile definirane v prejšnjem poglavju. Poudariti je potrebno, da tako kategorije kot podkategorije niso dokončno določene, saj lahko po potrebi dodajamo nove kategorije in podkategorije. Prva kategorija, strojna oprema uporabljena pri zajemu podatkov, vsebuje naslednje oznake: RFID značke, lokalizacijski senzorji, pospeškomeri, žiroskopi, merilci magnetnega polja, infrardeča detekcija gibanja in lokalizacijski senzorji. Oznake v drugi kategoriji, ki označuje vrsto problema za katerega je bila podatkovna zbirka posneta so: prepoznavanje aktivnosti, prepoznavanje gest, prepoznavanje položajev, razpoznavanje hoje, detekcija padcev in analiza zdravja. Dodatno smo vključili še kategorijo, ki označuje način učenja iz podatkov tj. ali podatki vsebujejo oznako razreda in lahko uporabimo algoritme za nadzorovano stojno učenje ali podatki ne vsebujejo oznake razreda in moramo uporabiti algoritme za nenadzorovano strojno učenje.

Na začetni strani dobi uporabnik kar nekaj uporabnih informacij, recimo zadnje dodane podatkovne zbirke. Nahajajo se tudi povezave do zanimivih spletnih strani - do spletnih strani ogranizacij, ki so organizirale tekmovanja v prepoznavanju aktivnosti, do konferenc in delavnic s področja ambientalne inteligence in do drugih repozitorijev

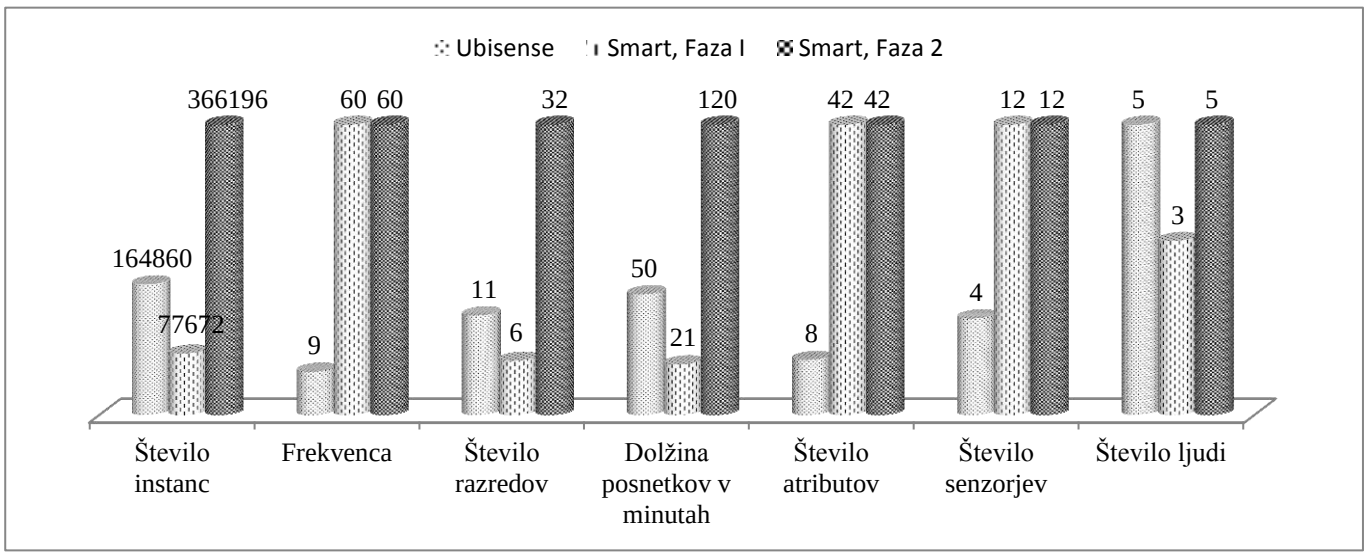
ter virov informacij relevantnih za ambientalno inteligenco [7, 8].
Drugi del spletnih strani vsebuje podatke o posameznih zbirkah podatkov. Vsaka zbirka je opisana z nekaj sekcijami. Prva sekcija vsebuje dve povezavi: do podrobnega opisa podatkovne zbirke in do podatkovne zbirke same, ki naj bi bila v formatu ločenem z vejicami (.csv).
Druga sekcija vsebuje izvleček opisa podatkovne zbirke, njen namen in strukturo le-te. Tretja sekcija vsebuje oznake kategorij: tip senzorjev, tip naloge, domena in učni pristop. Naslednja sekcija je sestavljena iz statističnih informacij o podatkovni zbirki: (1) število instanc, (2) frekvenca pridobivanja podatkov, (3) število razredov za označevanje podatkov, (4) informacija o tem, ali v zbirki obstajajo tudi podatki, ki nimajo vrednosti, (5) skupna dolžina posnetkov v minutah, (6) število atributov, (7) število senzorjev, (8) število ljudi, ki je sodelovalo pri snemanju, (9) datum vpisa podatkovne zbirke v repozitorij in (10) število obiskovalcev in število prenosov zbirke. V prihodnosti bi lahko bile podatkovne zbirke opisane tudi z mero kompleksnosti, kot je bilo predlagano v [14].
Peta sekcija opisuje eksperimentalni pristop do snemanja podatkov. Tukaj donator baze podrobno pojasni postavitve senzorjev, scenarije, ki so jih izvajali pri snemanju in ostale podrobnosti, ki bi pripomogle k boljšemu razumevanju podatkovne zbirke.
V šesti sekciji je opisana struktura zbirke in uporabljena orodja. V polju rezerviranem za strukturo podatkov so podrobno pojasnjeni atributi. V primeru, da podatki niso v standardnem formatu in morajo biti predprocesirani za uporabo v drugih aplikacijah, bi moral orodja za manipulacijo z njimi zagotoviti donator podatkov.
V sedmi sekciji so navedena sorodna dela/članki. V to sekcijo lahko informacije dodajajo vsi uporabniki, ki so uporabili omenjene podatke pri reševanju njihovega problema. Za vsak članek sta na kratko povzeta tudi eksperimentalni pristop (parametri prečnega preverjanja, velikost učne in testne množice, ipd.) in doseženi rezultati.
Zadnja sekcija je rezervirana za zahteve po citiranju. Donator ali avtor lahko poda zahtevo po citiranju njihovega izbranega članka takrat, ko se njihova podatkovna zbirka uporabi pri rezultatih novega članka.
Trenutna implementacija repozitorija ne omogoča avtomatskega vnosa novih podatkovnih zbirk. Vsi zainteresirani donatorji podatkovnih zbirk lahko zaenkrat pošljejo elektronsko pošto avtorjem tega članka. Vsekakor pa je tudi to ena od stvari, ki bodo v prihodnosti implementirane, kakor tudi možnosti urejanja lastnih podatkovnih zbirk.

4 TRENUTNE PODATKOVNE ZBIRKE

Trenutno so v repozitoriju tri zbirke podatkov [6], katere je prispeval Odsek za Inteligentne Sisteme iz Instituta Jožef Stefan in so bile kreirane med izvajanjem evropskega projekta Confidence [3]. Skupna lastnost vseh je uporaba senzorjev, ki jih uporabnik nosi na sebi. Slika 1 prikazuje statistične podatke vseh treh podatkovnih zbirk v repozitoriju. Prvi dve zbirki uporabljata isti tip senzorjev (3D koordinate izračunane iz vidnih značk na telesu) vendar se razlikujeta po posnetih scenarijih. Zadnja zbirka uporablja brezžične lokacijske senzorje. Scenariji so podobni tistim v drugi podatkovni zbirki.

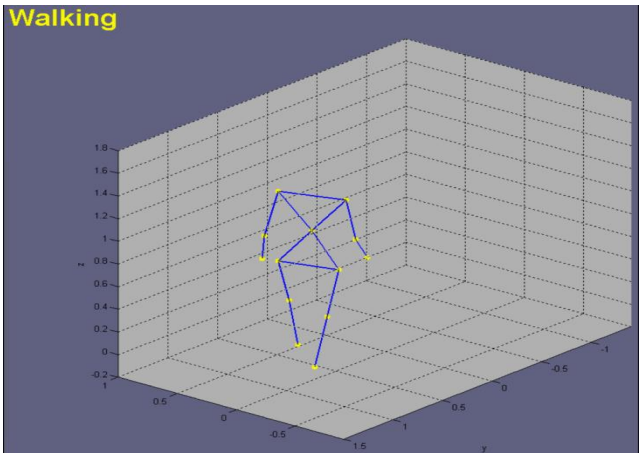
4.1 Aktivnosti in Padci, SMART, Faza I

Podatkovna zbirka vsebuje kratke scenarije primerne za prepoznavanje aktivnosti, prepoznavanje padcev in detekcijo šepanja. Vsebuje koordinate 12 značk pritrjenih na telesa treh prostovoljcev. Posnetki so bili posneti s sistemom Smart [15] in s pomočjo Odseka za avtomatiko, biokibernetiko in robotiko na Institutu Jožef Stefan. Smart je infrardeči sistem za prepoznavo gibanja in deluje s pomočjo šestih infrardečih kamer in infrardečih svetlobnih značk. Trije prostovolji so bili opremljeni z infrardečimi svetlobnimi značkami. Te so bile pritrjene na oba gležnja,



Slika 1: Statistična predstavitev zbirk podatkov trenutno dodanih v repozitorij

kolena, boke, ramena, komolca in zapestja. Infrardeče kamere sledijo značkam in računajo njihovo lokacijo v prostoru na 1 mm natančno. Rekonstrukcija značk med hojo človeka je prikazana na Sliki 2.



Slika 2: Rekonstrukcija telesnih značk med hojo človeka

4.2 Aktivnosti, Padci in Drugi Zdravstveni Problemi, Faza II

Strojna oprema za snemanje te podatkovne zbirke je enaka prej opisani. Razlika med zbirkami je v scenarijih snemanja in številu posnetkov. Ta zbirka podatkov dodatno vsebuje še posnetke specifičnih bolezni kot so: Parkinsonova bolezen, hemiplegija, bolečine v hrbtu, epilepsija, ipd.

4.3 Aktivnosti in Padci, Ubisense

Ta podatkovna zbirka vsebuje posnetke kratkih scenarijev primernih za prepoznavanje aktivnosti in detekcijo padcev. Strojna oprema uporabljena pri zajemu podatkov je bila Ultra-Širokopasovna tehnologija Ubisense [16]. Vsak od petih prostovoljcev je nosil 4 značke, ki so bile pritrjene na obeh gležnjih, prsih in pasu. Vsaka značka vrača podatke o njeni trenutni lokaciji s frekvenco od 6-9 Hz in je natančna na približno 50 cm.

5 ZAKLJUČEK

Članek predlaga spletni repozitorij v katerem bi bile zbrane zbirke podatkov s področja ambientalne inteligence. Obstoječe zbirke podatkov bi pripomogle k hitrejšemu razvoju novih pristopov in lažji primerjavi rezultatov na tem področju. Potencialne darovalce zbirk podatkov vzpodbujamo naj v repozitorij prispevajo le-te.

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PYLOF – IMPLEMENTACIJA ALGORITMA LOCAL OUTLIER FACTOR V PYTHON PROGRAMSKEM JEZIKU

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POVZETEK

Ta prispevek predstavlja implementacijo metode Local Outlier Factor (LOF), ki se uporablja za zaznavanje osamelcev (*outlier*), v programskem jeziku Python, ki za delovanje ne potrebuje zunanjih knjižnic. V prispevku je tudi podan kratek opis same metode LOF ter nekaj primerov uporabe modula pyLOF.

1 UVOD

Barnett in Lewis v svojem prispevku [3] definirata osamelec kot: *»An observation (or subset of observations) which appears to be inconsistent with the remainder of that set of data.«* Osamelec je torej primer, ki se vidno razlikuje od ostalih primerov v dani problemski domeni. Za zaznavanje osamelcev je bilo v literaturi predlaganih več metod, ki jih avtorja prispevka [4] delita v tri osnovne tipe:

- Tip 1, ki zaznava osamelce brez predhodnega znanja in je analogija nenadzorovanemu učenju oziroma rojenju (*clustering*). Takšni pristopi na nek način upoštevajo gostoto primerov ter na njeni podlagi določijo najbolj oddaljene primere kot možne osamelce.
- Tip 2, ki temelji na modeliranju normalnost in nenormalnost in je analogen nadzorovanemu učenju. Takšni pristopi zahtevajo označene pozitivne in negativne primere iz katerih se metode naučijo modela, ki nato služi za označevanje novih primerov.
- Tip 3, ki modelira samo normalnost ter nenormalnost samo v nekaj redkih primerih in je analogija delno nadzorovanemu učenju. Takšni pristopi zahtevajo samo pozitivne primere na podlagi katerega nato izgradijo model normalnosti, ki je zmožen zaznavanja primerov, ki ne sodijo v model normalnosti.

Ta prispevek opisuje implementacijo algoritma Local Outlier Factor (LOF) [1], ki spada v Tip 1 in je implementiran v programskem jeziku Python [2]. Implementacija LOFa v Pythonu je bila izbrana iz več razlogov:

- Samostojna implementacija LOFa po védenju avtorja za Python ne obstaja. Obstaja samo v obliki metod, ki so implementirane v sklopu obsežnejših knjižnic, kot je npr. ELKI [5].
- Python je eden bolj popularnih (med prvimi desetimi) programskih jezikov glede na indeks podjetja TIOBE [6].
- Python je interpretiran visokonivojski programski jezik s poudarkom na berljivosti kode in v povezavi z dodatnimi knjižnicami omogoča raziskovalcem zelo hitro manipulacijo s podatki in implementacijo idej. Prisotnost knjižnice za LOF je zato smiselna za raziskovalno skupnost, ki se ukvarja z zaznavanjem osamelcev.

V nadaljevanju sledi kratek opis metode Local Outlier Factor, podroben opis knjižnice pyLOF v poglavju 3, primer uporabe knjižnice pyLOF v poglavju 4 in opis nadaljnjega dela v poglavju 5.

2 METODA LOCAL OULIER FACTOR

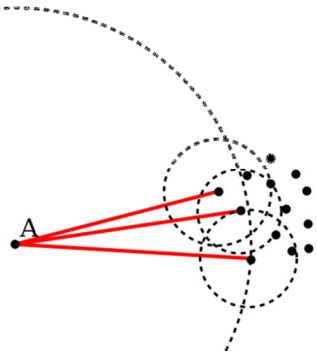
Metoda Local Outlier Factor (LOF) je metoda strojnega učenja za odkrivanja osamelcev (*outliers*) v večdimenzionalnem prostoru. Temeljna ideja LOF-a je, da za določanje stopnje osamelosti (*outlier factor*) uporabi primerjavo o lokalni gostoti (*density*) okoli točke, ki jo preverjamo, ter lokalni gostoti okoli točk, ki so sosednje točki, ki jo preverjamo. S takšno primerjavo ugotavljamo kadar ima se točka nahaja v območju, kjer je bistveno nižja gostota točk, kot je gostota okoli njegovih najbližjih sosednjih točk. Za takšne primere smatramo, da so osamelci. Slika 1 prikazuje primer, kjer je točka A v območju z bistveno nižjo gostoto kot njegovi najbližji sosedi. Rdeča črta prikazuje razdaljo od točke A do treh najbližjih sosedov, črtkana črta prikazuje radij v katerem se nahajajo trije najbližji sosedje točke A ter trije sosedje vsakega od treh A-ju najbližjih sosedov.

Avtor prispevka [1] imenuje razdaljo od točke A do črtkanega radija, ki zaobjema tri najbližje sosede, *k-distance* in je definirana kot razdalja ($d(p,o)$) med točkama p in $o \in D$, kjer:

(1) za vsaj k točk $o' \in D\backslash\{p\}$ velja, da je $d(p,o') \leq d(p,o)$ in
(2) za največ k-1 točk $o' \in D\backslash\{p\}$ velja, da je $d(p,o') < d(p,o)$.

Intuitivna razlaga je, da *k-distance* vrne razdaljo med točko a ter *k*-to najbližjo točko, s tem, da lahko ta razdalja zajema več kot *k* točk v primeru, če na tej razdalji od točke A leži več kot ena sosednja točka. Točneje je množica teh sosednjih točk definirana kot:

$$N_k(p) = \{\ q \in D \setminus \{p\} \mid d(p,q) \leq k\text{-}distance(p)\ \}$$

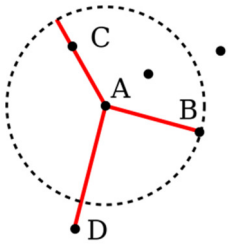


Slika 1: *Primer osamelca (Vir: Wikipedia).*

Za zmanjševanje statističnega nihanja razdalje *d(p,o)* je definirana razdalja dosegljivosti *reach-dist*$_k$*(p,o)*, ki razdalje *d(p,o)*, ki so manjše od *k-distance(o)*, zamenja z vrednostjo *k-distance(o)*, oziroma točneje:

$$reach\text{-}dist_k(p,o) = \max\{\ k\text{-}distance(o), d(p,o)\ \}.$$

Slika 2 prikazuje primer izračuna razdalje *reach-dist*$_k$*(p,o)*. Točka A je referenčna točka. Razdalji do C in B sta manjši ali enaki razdalji *k-distance*(*A*), zato njuno vrednosti zamenjamo z *k-distance*(*A*), medtem ko za razdaljo do točke D tega ne naredimo.



Slika 2: *Primer izračuna razdalje reach-distk(p,o) (Vir: Wikipedia).*

[1] nadalje definira gostoto lokalne dosegljivosti (*local reachability density* ali krajše *lrd*) okoli točke *p* kot inverz povprečne razdalje dosegljivosti na podlagi *k* najbližjih sosedov do točke *p*:

$$lrd_k(p) = |N_k(p)| / \sum_{o \in N_k(p)} reach\text{-}dist_k(p,o)$$

Gostoto lokalne dosegljivosti se nadalje uporabi za izračun lokalnega faktorja osamelosti (*local oulier factor*), ki definirana kot razmerje med gostoto lokalne dosegljivosti točke *p* ter njenih sosednjih točk $o \in N_k(p)$ oziroma točneje kot:

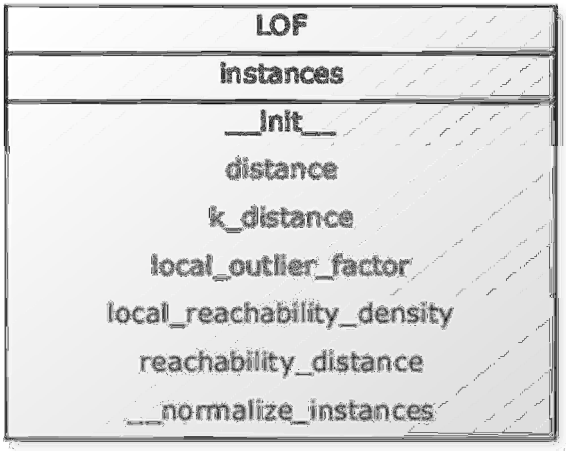
$$LOF_k(p) = \frac{\sum_{o \in N_k(p)} \frac{lrd_k(o)}{lrd_k(p)}}{|N_k(p)|}$$

Vrednosti LOF-a, ki so nižje od 1 nakazujejo, da točka *p* ni osamelec, medtem ko vrednosti višje od 1 nakazujejo, da točka *p* je osamelec glede na njegovo bližnjo okolico.

3 PROGRAMSKA KNJIŽNICA pyLOF

Programska knjižnica pyLOF je sestavljena iz enega Python modula, ki ni odvisen od nobenih drugih nesistemskih Python knjižnic, in je izvedena v čistem (*pure*) Python-u. To zagotavlja, da jo je mogoče uporabljati na vseh platformah, ki jih Python podpira, možna pa je tudi uporaba v sorodnih implementacijah Python-a. Takšen primer Jython, ki je implementacija Python-a v Javi, ki omogoča uporabo Python kode v javanskih programih. S to lastnostjo je pyLOF posredno na voljo tudi za programski jezik Java.

Modul pyLOF vsebuje en razred LOF, ki ima naslednje razredne metode:



Sledi točna definicija in opis posameznih metod.

LOF.__init__(self, k, instances, normalize=True)
Konstruktor __init__ inicializira nov objekt razreda LOF, ki služi za izračunavanje lokalnega faktorja osamelosti. Kot vhod sprejme konstruktor množico točk (*instances*) v obliki gnezdenih n-teric ter logično vrednost (True ali False), ki pove ali naj se množica točk normalizira (*normalize*).

LOF.__normalize_instances(self)
Privatna metoda za normalizacijo množice primerov, ki je podana konstruktorju *__init__*. Metoda prav tako shrani informacije o maksimalnih in minimalnih vrednostih atributov, ki so potrebne za normalizacijo posameznih instanc ob klicu metode *local_outlier_factor*.

LOF.distance(instance1, instance2)

Statična metoda za izračun Evklidske razdalje med točkama *instance1* in *instance2*, ki sta n-terici enakih dolžin z numeričnimi vrednostmi. Kot vhod sprejme dve instanci v obliki n-teric ter vrne numerično vrednost, ki je razdalja med instancama.

LOF.k_distance(self, k, instance, instances)
Metoda za izračun razdalje *k-distance* za podano instanco *instance* na podlagi podane množice instanc *instances*. Kot vhod metoda sprejme *k*, ki je število sosedov, ki so znotraj območja *k-distance*, instanco za katero iščemo *k-distance* ter množico instanc od koder se naj izbira sosede. Metoda vrne *k-distance* in množico *k* sosedov ($N_k(instance)$).

LOF.reachability_distance(self, k, instance1, instance2, instances)
Metoda za izračun razdalje dosegljivosti *instance1* do *instance2*. Metoda sprejme parameter *k,* ki je število sosedov, ki so znotraj območja *k-distance*, *instance1* in *instance2* med katerima računamo razdaljo, ter množico instanc *instances*. Metoda vrne numerično vrednost, ki je $reach\text{-}dist_k(instance1,instance2)$.

LOF.local_reachability_density(self, k, instance, instances)
Metoda za izračun gostote lokalne dosegljivosti za podano instanco na podlagi parametra *k*, ki je število sosedov, ki so znotraj območja *k-distance*, instance *instance* in množice instance *instances*. Metoda vrne numerično vrednost, ki je $lrd_k(instance)$.

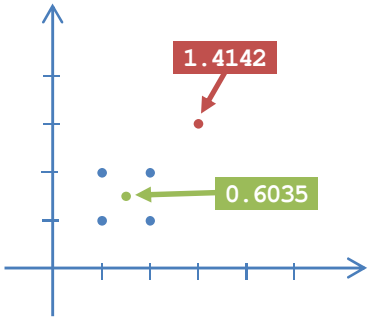
LOF.local_outlier_factor(self, k, instance)
Glavna metoda za izračun lokalnega faktorja osamelosti za instanco *instance* na podlagi parametra *k*, ki je število sosedov, ki so znotraj območja *k-distance*. Metoda vrne numerično vrednost, ki je $LOF_k(instance)$.

4 PRIMER UPORABE

Primer uporabe prikazuje primer, ko imamo domeno z dvema atributoma in množico štirih instanc z vrednostmi (1,1), (2,2), (2,1) in (1,2), ki so prikazane na sliki 3 z modro barvo. Testirani sta dve instanci, in sicer (1.5,1.5), ki je sliki 3 prikazana z zeleno barvo, in (3,3), ki je na sliki 3 prikazana z rdečo barvo. Vrednosti v oblačkih na sliki 3 sta vrednosti LOF za obe instance. Na podlagi izračuna LOF vrednosti sklepamo, da je instanca (3,3) osamelec, saj je njegova vrednost večja od 1, medtem, ko je instanca (1.5,1.5) normalna, kar je v skladu z človeško intuicijo.

Za izračun LOF vrednosti so bili v Python konzoli uporabljeni naslednji ukazi:

```
>>> import pyLOF
>>> instances = ((1,1), (2,2), (2,1), (1,2))
>>> lof = pyLOF.LOF(instances)
>>> lof.local_outlier_factor(1, (1.5, 1.5))
0.60355339059327373
>>> lof.local_outlier_factor(1, (3, 3))
1.4142135623730949
```



Slika 3: *Primer izračuna vrednosti LOF za dve instanci.*

4 NADALJNJE DELO

Pričujoči prispevek opisuje prvo verzijo Python knjižnice, ki je pri računanju LOFa procesorsko neučinkovita, saj se razdalje med istimi instancami večkrat računajo. Glavni cilj nadaljnjega dela je izboljšati hitrost računanja LOFa na račun večje prostorske zahtevnosti, in sicer z uporabo matrike razdalj med instancami, ki se računa samo enkrat.

Zahvala

Razvoj knjižnice pyLOF je bilo podprto s financiranjem v okviru kompetenčnega centra OPCOMM (http://www.opcomm.eu/).

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SUPPORTING CLINICAL PROFESSIONALS IN DECISION-MAKING FOR PATIENTS WITH CHRONIC DISEASES

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ABSTRACT

To deal with the large amount of data produced by telemonitoring of patients with chronic diseases, a decision support system (DSS) was developed. The DSS uses sensor data and the data from a patient's electronic health record as the input. It assesses the risk to the patient's health using three approaches. The first approach exploits the existing medical knowledge, the second approach uses supervised machine learning, and the third approach simply detects anomalies in the values of the monitored parameters. The risk assessment can show the contribution of the individual monitored parameters to the risk, and can be tailored by the doctor to each patient. The assessed risk and the raw input data can be used to trigger alerts. Finally, following the principles of evidence-based medicine, the DSS facilitates the consultation of medical literature when needed.

1 INTRODUCTION

The amount of data produced by telemonitoring solutions can be overwhelming, so using it for clinical decision-making is difficult. When telemonitoring data is combined with data obtained by traditional means, the problem becomes even larger. In a European project aiming to integrate telemonitoring into the clinical workflow, we tackle this problem by a decision support system (DSS).

In the project, a patient is equipped with a wearable ECG, temperature, sweating and activity sensors. The data produced by the sensors is sent to the doctor, where it is combined with the data from the patient's health record. The DSS system uses all the data to automatically assess the risk to the patient's health, helps the doctor understand its assessment, and automatically generates alerts to warn the doctor of adverse events. It also offers personalization, allowing the doctor to tailor the risk assessment and the alert triggers to each patient. Finally, the DSS facilitates the consultation of medical literature when needed. For the most part, the DSS can support the management of any chronic disease. Our test case, however, is the congestive heart failure (CHF), and the choice of sensors and the expert knowledge contained in the DSS reflects that.

The architecture of the DSS is shown in Figure 1. The risk assessment module consists of three submodules using different approaches to risk assessment. The module receives as inputs the values of the monitored parameters from the sensors and electronic health records, and its output can be used to trigger alerts. The parameter values from the sensors and electronic health records can also trigger alerts on their own. The configuration module is used to tailor the risk assessment to each patient. The literature consultation module searches external resources (databases, ontologies ...), but it can also use text from the electronic health records to provide context for the search.

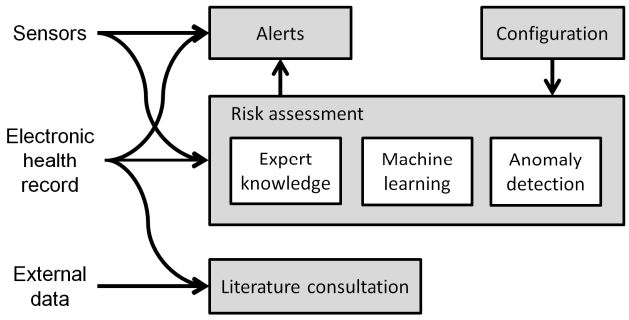

Figure 1. *The architecture of the DSS.*

The DSS supports the clinical workflow as follows:

1. The doctor starts examining the condition of a patient. He/she may do this either because of an alert or on a voluntary basis.
2. The doctor examines the patient's current risk. The risk is computed by the risk assessment module, and its history up till the current moment may be examined.
3. If the risk is high, the doctor looks for reasons. The risk assessment module provides the monitored parameters ordered by their contribution to the risk.
4. The doctor may need further information. In this case the medical literature may be consulted using the relevant module.

The doctor may reconfigure the risk assessment module and the alerts.

2 RISK ASSESSMENT

The risk assessment is performed using three different approaches, each of which has its advantages. The first approach uses existing medical knowledge. This makes it easier for the doctors to understand and trust, but it requires the participation of experts to create it. The second approach uses supervised machine learning (ML), and is appropriate for cases where labeled data consisting of the values of the monitored parameters, and the true risk (based on hospitalizations and other adverse events) are available. The third approach observes anomalies in the values of the monitored parameters. Such anomalies are not necessarily caused by an increased risk, so the approach can be misleading, but it requires only knowledge on relevant parameters and only some data that is not anomalous.

2.1 Expert Knowledge

General Approach. We decided to construct three risk assessment models for different time horizons: long-, medium- and short-term. The following information was required on each monitored parameter:

- The minimum and maximum expected value of the parameter: $p_{\min}$, $p_{\max}$.
- The relation between the parameter value and the risk: (+) if the risk increases with the value, (–) if it decreases, or (U) if the risk is low at moderate values and high at extreme values (in this case the lowest-risk parameter value p_{mid} is also required).
- A low threshold, which separates the parameter values corresponding to low risk (green) from those corresponding to medium risk (yellow), and a high threshold, which separates the latter from those corresponding to high risk (red).
- The importance: low, medium or high.
- The frequency at which the parameter changes: low – fairly static (e.g., age), medium – measured during regular visits to the doctor (e.g., cholesterol level), or high – measured continuously by telemonitoring (e.g., heart rate).

Each parameter value first had to be transformed into a risk value. This was done by linearly scaling the parameter value from the $[p_{\min}, p_{\max}]$ interval to the [0, 1] interval, applying the appropriate sign (+, –). For the U-shaped parameters, the linear scaling was performed separately on each side of the lowest-risk parameter value p_{mid}.

The risk values belonging to individual parameters were combined into an overall risk value. Since the risk values were only human estimates, we used a simple weighted sum. To obtain the thresholds between the green, yellow and red areas for the overall risk, the same summation was applied to the individual risk thresholds.

Each weight in the overall-risk weighted sum was the product of an importance weight and a model-specific weight. The importance weight was 1/3 for low-importance, 1 for medium-importance and 1.5 for high-importance parameters. In the long-term model, the model-specific weight of all the parameters was 1. In the medium-term model, the model-specific weight of the low-frequency parameters was 1/3. For the numeric medium-frequency parameters, the slope of change over time was also included. In the short-term model, the model-specific weight of the low-frequency parameters was 1/9, and of the medium-frequency parameters 1/3. For the medium-frequency parameters, the slope was again included, and for the high-frequency parameters, both the slope and standard deviation were included.

Expert Knowledge on CHF. To gather the expert knowledge on the CHF, first an extensive search of the medical literature was performed. It yielded over 60 parameters considered potential risk factors. The parameters were demographic, clinical, biological, pharmacological, angiographic, ambient and ECG-related. With the exception of the parameter importances, the information required for the risk assessment models was taken from the literature or provided by a reference expert.

To obtain the importances of the parameters found in the literature, a survey was conducted among the European opinion leaders in cardiology. The survey consisted of two parts. The first part dealt with the parameters about which the evidence was weak. The respondents were asked to express their agreement with the literature on the scale of 1–5. The second part dealt with the parameters with strong evidence, and the respondents were asked for disagreement (1) or agreement (5). Based on 32 responses, the parameters importances were assigned as follows: low for those on which the average agreement was below 3, medium for those on which the agreement was between 3 and 4, and high for those on which the agreement was above 4.

2.2 Machine Learning

We used the following five-step methodology for risk assessment using supervised machine learning (ML):

- Training data preparation: patients' data consisting of the values of the monitored parameters, and the true risk (based on actual hospitalizations and other adverse events) were gathered.
- Feature reduction: the most relevant parameters were determined, resulting in a reduced feature set. The training data were decorrelated to avoid dependencies among the features.
- ML model design: the ML architecture was optimized and the hyper-parameters set.
- Training: the ML model was trained using the appropriate ML/optimization methods.
- Validation: the ML model was validated in order to guarantee good predictive properties on unseen data.

The ML model must be able to cope with the non-linear, fuzzy and generally complex relations between the monitored parameters and the risk. ANNs are particularly

suited for solving such problems. They are biologically inspired computational models which consist of a network composed of artificial neurons. Each neuron includes a function which returns an output based on its inputs, each of which is associated with a weight. During training, the weights are adjusted so that the final output best approximates the sought value, in our case the risk. Based on the experience with similar applications [7][8], our ANN used the multilayer perceptron architecture with three layers: the input layer consisting of one neuron for each of the relevant monitored parameters, the hidden layer, and the output layer consisting of one neuron predicting the risk.

The network was tested on a public dataset describing heart disease [4]. The network yielded good predictions, having the accuracy of 85 %.

2.3 Anomaly Detection

When a patient's health is normal, the monitored parameters usually follow recurrent patterns. For example, the heart rate is between 60 and 80 beats/minute, unless the patient exercises, in which case it is higher, but so is the activity level. Such patterns can be learned, and when a new pattern – an anomaly – is detected, the doctor is alerted. If the doctor judges the new pattern to be normal, he/she can indicate this, and the pattern will no longer be considered anomalous.

We used the Local Outlier Factor (LOF) algorithm [1] to detect anomalies. The algorithm compares the density of data instances around a given instance *A* with the density around *A*'s neighbors. If the former is low compared to the latter, it means that *A* is relatively isolated – that it is an outlier. Such outliers are considered anomalous. The LOF algorithm assigns a so-called LOF value to each instance, which indicates the degree of its anomalousness. We extended the algorithm to compute the degree of anomalousness of individual parameters, so that their contribution to the overall anomalousness could be observed. This was accomplished by computing the LOF values in the usual way, except that the density of instances was computed using only their distances with respect to the parameter of interest.

To use the LOF algorithm for risk assessment, it must be trained on a number of instances consisting of the parameters of a patient when his/her risk is normal. After the training data is processed, the parameters of the algorithm must be set: the number of neighbors to consider for estimating the density of instances, the low threshold separating the LOF values belonging to the green area from those belonging to the yellow area, and the high threshold between the yellow and red areas.

The anomaly detection was tested on a dataset of five test subjects performing a range of activities, and a subset of the parameters to be monitored in the project [5]. The performance of the LOF algorithm was tested with 1, 2, 3, 4 and 5 neighbors. They were compared using the area under the ROC curve, and 1 neighbor turned out to be best. This may have been due to the modest amount of data available.

In order to set the thresholds, some anomalous data was needed. Since the test subjects were healthy, anomalous data was generated by randomly replacing some parameter values during one activity with those during another. For example, the heart rate during walking was replaced with the heart rate during running, while the other parameters remained unchanged. The low and the high thresholds were then set so that at most 5 % of the instances in the green area were considered anomalous, and at most 5 % of the instances in the red area were considered normal. As a consequence, roughly 80 % of the instances (depending on the subject) were in their proper area (normal in green, anomalous in red). That way a doctor could be fairly certain that if a patient's condition is green, the risk is low, and if it is red, the risk is high, while the yellow area represented uncertainty.

3 CONFIGURATION AND ALERTS

These two modules deal with the personalization issues, adapting the operation of the DSS to each patient as well as to the doctor's needs.

Configuration. In this module the monitored parameters used by the risk assessment module are set for each patient, since the risk to different patients' health may depend on different parameters. Furthermore, the thresholds between the green, yellow and red areas can be set. The risk assessment module provides default thresholds as described in the previous section, but the doctor may modify them if he/she wishes.

Alerts. The alerts module contains a rules engine implemented on the Drools platform [3]. It was chosen because it is open-source and allows easy implementation of complex rules. The module supports two tasks:

- Rule set configuration, which allows the doctor to configure rule sets to be applied on parameters and risks. The rules are inserted into the Drools engine to raise the corresponding actions.
- Alerts configuration, which allows the doctor to associate the rules with alerts (SMS, email etc.). The doctor can personalize the alerts depending on the rules triggered and the situation of the patient.

4 LITERATURE CONSULTATION

The literature consultation module provides the doctor with information from outside sources when making clinical decisions. In this it follows the principles of evidence-based medicine (EBM). EBM is a scientific method that seeks to assess the strength of evidence of the risks and benefits of treatments (or lack thereof) and diagnostic tests.

The goal of the literature consultation module was to offer an intelligent search engine for scientific literature, which extensively employs the tools and resources of the semantic

web and provides accurate relevance ranking of the search results. The starting point for a search is a query written either in natural language or in a structured format. The query is mapped onto the medical ontology SNOMED [9]. This ontology allows the incorporation of synonyms, antonyms and other related terms to produce a more expressive query. Furthermore, it provides the relationships between different pathologies, diagnoses and procedures, which form a context for the search. Additional context can be provided by an arbitrary natural-language text, which may be derived from a patient's electronic health record. The query is finally used to search multiple databases. Currently included are PubMed/HubMed [6] and The Cochrane Library [10], but other can be added easily.

Once the publications matching the query are obtained, they are ranked by their relevance. This is accomplished using both the frequency of the query terms, and the annotations by the users of the DSS, since the literature consultation module provides tools for the users to evaluate, tag and comment the publications. The publications are also annotated with the terms of the SNOMED ontology.

The information from the literature is presented according to the Haynes pyramid shown in Figure 2. The pyramid has individual published studies at the base. These can be summarized (automatically) into synopses. From them, syntheses are constructed, obtained from systematic reviews, for which the Cochrane Library can be used. On the next level are synopses that present a snapshot of several individual studies, such as those found in secondary journals. The summaries are the next step, obtained by integrating the best available lower levels, and represent clinical guidelines or summary documents, such as those in Clinical Evidence [2]. On top of the pyramid are the systems, with the individual characteristics of the patients linked automatically to the relevant evidence. The DSS presented in this paper is a part of such a system.

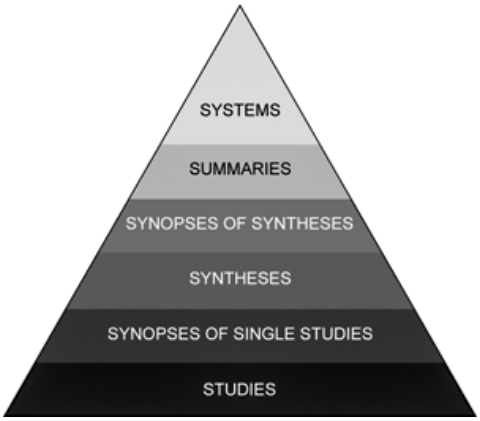

Figure 2. *Haynes pyramid.*

5 CONCLUSION

In this paper we presented a DSS for the management of chronic diseases using telemonitoring. Since the DSS was designed with CHF in mind, the sensors used for telemonitoring (ECG, temperature, sweating and activity) are suitable for CHF patients, and the expert knowledge contained in the system also pertains to CHF. The DSS is otherwise general.

The main module of the DSS deals with risk assessment. It consists of three submodules using different approaches. The three-approach strategy was adopted because each approach has its merits, which will be evaluated during the observational study planned at the end of the project. After the evaluation, the outputs of the submodules may be merged to provide a joint decision, or one or two of the submodules may be removed if their performance proves inadequate. The risk assessment module is supported by a configuration and alerts modules. When the DSS is integrated into a clinical information system, the alerts module can be used to initiate communication with patients, order specific laboratory analyses etc.

The final module facilitates the consultation of medical literature. It follows the principles of EBM by searching external sources for published evidence supporting clinical decisions. This module provides opportunity for future work on better computer understanding of the consulted literature, saving the doctor the time needed for deep reading of the large number of found publications.

Acknowledgments

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GRUČENJE PRAVIL OBNAŠANJA S POMOČJO KOSINUSNE RAZDALJE

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Abstract

In this paper a method for clustering relevant rules from a group of rules is presented. Rules are obtained from algorithm MASDA which generates behaviour rules from the output of the multiagent simulator which simulates interactions between agents in a given environment. Simulator works by using predefined rules. The method is based on the data mining method K-means which uses Cosine distance as a distance function. The approach is a combination of data mining and text mining field. Because a lot of rules which are obtained from simulation is irrelevant for the user our goal is to filter this rules to achieve a set of relevant and readible rules. Filtered rules are finally used in the simulator so we can measure the similarity of the simulator output with original rules and obtained rules.

Povzetek

V članku je predstavljena metoda gručenja relevantnih pravil izmed množice vseh pravil, pridobljenih s pomočjo algoritma MASDA. Algoritem MASDA generira pravila obnašanja na podalgi izhoda več agentnega simulatorja, kateri simulira interakcije med agenti v danem okolju. Simulator deluje na podalgi predhodno vpisanih pravil obnašanja agentov. Metoda temelji na metodi podatkovnega rudarjenja k-means, kot funkcijo razdalje pa za svoje delovanje uporablja kosinusno razdaljo. Pristop je kombinacija podatkovnega rudarjenja in rudarjenja teksta. Veliko pravil, pridobljenih iz simulacije je za uporabnika nerelevantnih, zato je cilj naše metode filtracija pravil, tako da na koncu dobimo zbirko pravil, ki so za uporabnika pomembna in berljiva. Filtrirana pravila so nato tudi uporabljena v simulatorju, saj tako izmerimo podobnost med delovanjem simulatorja z originalnimi pravili in delovanjem na podalgi dobljenih pravil z MASDO.

1 UVOD

Delitev podatkov v skupine ali gručenje predstavlja enega osnovnih pristopov k organiziranju velikih količin podatkov, pri katerih je znana le podobnost med posameznimi podatki. Na podlagi podobnosti se z algoritmi za gručenje podatki razdelijo v gruče, od katerih vsaka vsebuje le med sabo podobne podatke. Matematično gledano je taka razdelitev particija množice podatkov oz. ekvivalenčna relacija, v kateri sta dva podatka ekvivalentna, če sta si podobna [1]. Algoritmi za svoje delovanje potrebujejo funkcijo razdalje, na podalgi katere izračunajo razdaljo med primeri in jih tako uvrstijo v primerno gručo. Med najbolj uporabljenimi funkcijami razdalje sta Evklidska [2] in Manhattnova [3] razdalja. V naši metodi smo uporabili Kosinusno razdaljo [4], katera se večinoma uporablja v metodah za rudarjenje teksta.

Vhodni podatki za našo metodo so rezultati algoritma MASDA (Multi-Agent Strategy Discovering Algorithm) [5], kateri išče strategije in vzorce obnašanja v večagentnih sistemih. Algoritem je bil razvit na Institutu Jožef Stefan, razvili so ga na odseku za Inteligentne sisteme. Kot več agentni sistem smo uporabili simulator, kateri simulira interakcije med agenti v danem okolju. Simulator deluje na podalgi predhodno definiranih pravil obnašanja – behaviour rules.

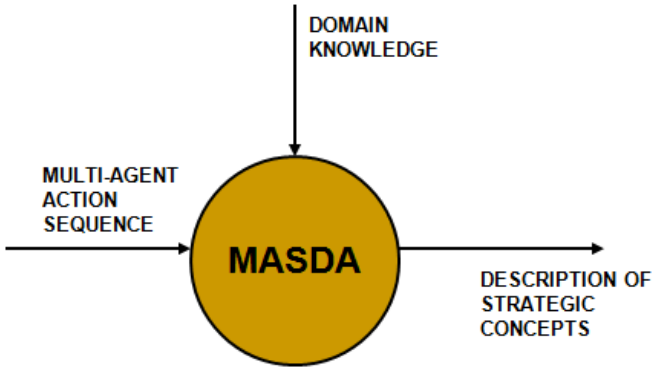

Figura 1: *MASDA algoritem - vhod in izhod*

Kot rezultat algoritma MASDA dobimo veliko število pravil, katera opisujejo vzorce obnašanja agentov iz simulatorja. Po navadi se število vozrcev obnašanja giblje med 50 in 200. Ker je vsak vzorec opisan z najmanj tremi pravili, v veliki večini primerov dobim vsaj 300 pravil, katera so potem predstavljena uporabniku. Veliko the pravil je ne relevantnih in podobnih med sabo, saj so podobni vzorci opisani s podobnimi pravili. Primer pravila si lahko ogledamo spodaj.

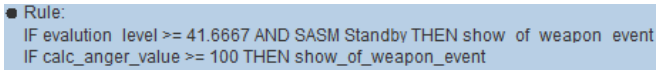

Figura 2: *Primer pravila obnašanja*

Cilj naše metode je s pomočjo gručenja pravil, izbrati predstavnike gruč in tako uporabniku predstaviti najbolj reprezentativna in pomembna pravila izmed množice. Za potrebe evaluacije, smo simulatorju podtaknili dobljena filtrirana pravila in merili podobnost med simulacijami, ki za svoje delovanje uporabljajo predefinirana pravila in pravila filtrirana z našo metodo. Rezultati kažejo na večjo podobnost med originalno simulacijo in simulacijo katera deluje s pravili pridobljenimi z našo metodo.

2 METODA

Glavna ideja metode je izposojena iz domene rudarjenja teksta in iskanja informacij v tekstu. Naloga v tej domeni je gručenje podobnih besedil, ki temelji na njihovih temah. Metoda na kateri temelji naš pristop je Tf-idf (Term Frequency Inverse Document Frequency) [6]. Vsak dokument je tako predstavljen kot vektor identifikatorjev, npr. indeksov.

$$d_i = (w_{1,i}, w_{2,i}, ..., w_{j,i})$$

Figura 3: *Predstavitev dokumenta z vektorjem identifikatorjev*

Vsaka dimenzija v vektorju (Wj,I) predstavlja utež določenega izraza. Ker je Tf-idf med najbolj uporabljenimi metodami v domeni gručenja besedil, smo se tudi mi odločili, da jo uporabimo v naši metodi, za opis atributov pravil. Tf-idf meri pomembnost oz. utež izraza *t* v določenem dokumentu *d* in je definirana kot:

$$tf - idf(t,d) = tf(t,d) \times idf(t)$$

Figura 4: *TFIDF funkcija*

kjer je frekvenca izraza *tf(t,d)* definirana kot število pojavitev izraza v dokumentu in *inverzna frekvenca izraza idf(t),* definirana kot pomembnost izraza (dobljena je z deljenjem števila vseh dokumentov in dokumentov, ki vsebujejo izraz).

Enačbo nato logaritmiramo in dobimo naslednji izraz:

$$idf(t) = \log \frac{|D|}{1 + |\{d : t \in d\}|}$$

Figura 5: *Inverzna funkcija*

kjer je |*D*| celotno število dokumentov v zbirki in |{*d* : *t* € *d*}| pomeni število dokumentov kjer se pojavlja izraz *t.*

2.1 Definicija našega problema

Definicija našega problema je sledeča: vzorci predstavljajo dokumente, pravila predstavljajo paragrafe v dokumentih in atributi v pravilih predstavljajo pomembne izraze v dokumentih.
Predstavljamo si lahko vzorec, kateri vsebuje npr. 50 atributov med katerimi beseda *load_gun* nastopa petkrat. Upoštevajoč prej definirane formule, dobimo frekvenco izraza (TF) za besedo *load_gun* (5 / 50) = 0.1. Zdaj predpostavljamo, da imamo 500 vzorcev in *load_gun* nastopa v petih vzorcih. Sledi izračun inverzne frekvence dokumenta log(500 / 5) = 2. Izračunana Tf-idf vrednost je tako produkt the vrednosti: 0.1 x 2 = 0.2. Tako je tf-idf vrednost poračunana za vsak atribut prisoten v pravilu.

2.2 Gručenje z uporabo Kosinusne razdalje

Kot prvo dinamično generiramo zbirko možnih atributov v pravilih vozrcev. Sledi izračun Tf-idf uteži za vsak vzorec posebej, rezultate pa shranimo v Arff datoteko [7].
Naslednji korak je uporaba gručenja. Za gručenje uporabljamo verzijo K-means algoritma [8], kateri je implementiran v orodju za strojno učenje Weka [9].
K-means algoritem, porazdeli *N* podatkovnih točk v *K* disjunktivnih setov *Sj* kateri vsebujejo *Nj* podatkovnih točk, med katerimi je vsota korenov minimizirana.

$$J = \sum_{j=1}^{K} \sum_{n \in S_j} \left| x_n - \mu_j \right|^2,$$

Figura 6: *K-means*

kjer je *Xn* vector, ki predstavlja n-to podatkovno točko, μ_j je geometrijska centroida podatkovnih točk v S_j in $\left| x_n - \mu_j \right|^2$ je izbrana funkcija razdalje med dvema točkama. Na tak način, algoritem z iterativnim delovanjem, minimizira zgornji kriterij.
Algoritem je sestavljen iz štirih korakov:

1. Naključno izberemo K točk in jih postavimo v prostor sestavljen iz objektov za gručenje. Te točke predstavljajo začetne centroide.

2. Vsak objekt dodelimo skupini katera ima njemu najbližjo centroido.
3. Po dodelitvi, ponovno izračunamo pozicijo K centroid.
4. Ponavljamo koraka 2 in 3 dokler se pozicije centroid ne spreminjajo več.

Če želimo, da algoritem k-means poišče in dodeli gruče posameznim instancam, je potrebno vnaprej definirati mero, ki izračuna podobnost med dvema vektorjema oz. v našem primeru dvema vzorcema.
Kosinusna razdalja je zelo pogosto uporabljena mera v kombinaciji z Tf-idf metodo, saj ima posebno lastnost, ki ji omogoča kompatibilnost z učenjem z matrikami: rezultat podobnosti je vedno med -1 in 1 (-1 pomeni ravno nasprotno, 1 pomeni točno isto, 0 pa pomeni nekaj vmes oz. neodvisnost). Kosinusna razdalja je zaradi te lastnosti veliko boljša za uporabo na visoko dimenzionalnih podatkih kot pa druge razdalje npr. Evklidska [2].
Kosinusna razdalja se na podalgi podanih dveh vektorjev A in B izračuna po naslednji formuli:

$$\cos Sim(\vec{x},\vec{y}) = \frac{\vec{x}\cdot\vec{y}}{|\vec{x}|\cdot|\vec{y}|} = \frac{\sum_{i=1}^{n} x_i \times y_i}{\sqrt{\sum_{i=1}^{n} x_i^2} \times \sqrt{\sum_{i=1}^{n} y_i^2}},$$

Figura 7: *Kosinusna razdalja*

kjer je $\vec{x}\cdot\vec{y}$ produkt dveh vektorjev in $|\vec{x}|$ je obseg vektorja.

3. EVALUACIJA

V razdelku je predstavljena analiza o tem ali lahko z pomočjo gručenja dobimo boljše vzorce obnašanja kot brez uporabe gručenja in tako izboljšamo berljivost vozrcev in podobnost med simulacijo z originalnimi pravili ter simulacijo z dobljenimi pravili s pomočjo gručenja.

3.1 Potek evaluacije

Izvedeni so bili testi z različnim številom gruč. Kot kvalitativno oceno smo izbrali podobnost med originalnimi dnevniki, katere simulator zapiše med delovanjem in dnevniki kateri so se zapisali med delovanjem z uporabo filtriranih pravil dobljenih s pomočjo gručenja.
Prvi del evaluacije je bil pridobiti dnevnike simulacije za izbrane eksperimente.

1. Kot prvo smo pridobili 10 dnevnikov delovanja simulacije z originalnimi pravili.
2. Sledilo je poganjanje simulacije s pravili pridobljenimi s pomočjo MASDE ter brez uporabe naše metode.

Našo metodo smo nad podatki pridobljenimi s pomočjo MASDE pognali za različna števila gruč. (k = 10, K = 15, K = 16, K = 20). Tako smo pridobili štiri manjše knjižnice obnašanja. Sledilo je desetkratno poganjanje simulacije z dobljenimi knjižnicami.
V drugem delu evaluacije smo z uporabo metode DTW (Dynamic time warping) [10] primerjali dnevnike simulacije pridobljene brez uporabe naše metode ter dnevnike simulacije z uporabo naše metode. Rezultati so predstavljeni spodaj.

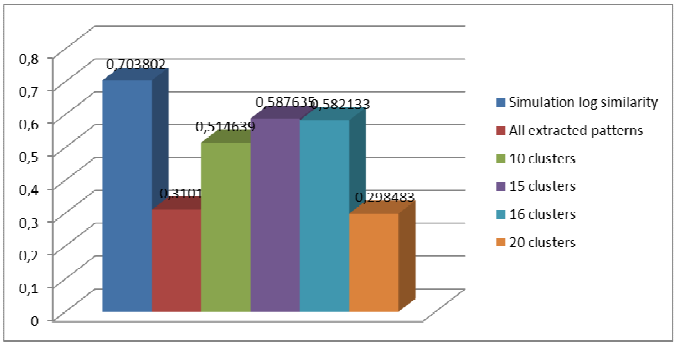

Figura 8: *Primerjava podobnosti za različne velikosti knjižnic obnašanja*

Prva kolona iz leve proti desni predstavlja podobnost med originalnimi dnevniki simulacije in pomeni optimalno delovanje simulacije, saj deluje z predefiniranimi pravili. Vrednost 0.7038 nam služi kot referenčna točka pri primerjanju naslednjih kolon med sabo. Druga kolona (rdeče barve) predstavlja podobnost med originalnimi dnevniki in dnevniki pridobljenimi s pomočjo MASDE ter brez uporabe gručenja. V tem poskusu je bila kot knjižnica obnašanja uporabljena celotna zbirka vozrcev obnašanja. Vrednost podobnosti 0.3101 je majhna, kar nam pove, da je uporaba vseh pridobljenih vozrcev obnašanja nesmiselna in na tak način ne uspemo dobro posnemati originalnih dnevnikov.
Naslednje štiri kolone predstavljajo primerjavo originalnih dnevnikov in dnevnikov pridobljenih, s pomočjo naše metode.
Tretja kolona predstavlja uporabo desetih gruč, četrta kolona predstavlja uporabo petnajstih gruč, peta kolona predstavlja uporabo šestnajstih gruč in zadnja šesta kolona predstavlja uporabo dvajsetih gruč.
Kot je razvidno zgoraj, je najbolj podobno obnašanje simulatorja doseženo z uporabo zmanjšanje knjižnice obnašanja sestavljene iz petnajstih gruč. Dobljeni rezultati dokazujejo, da je gručenje velikega števila vozrcev smiselno in izboljšuje kvaliteto knjižnic obnašanja.

4. ZAKLJUČEK

Razvita je bila metoda za gručenje relevantnih pravil izmed množice vseh pravil, pridobljenih s pomočjo algoritma MASDA [5]. Algoritem generira pravila obnašanja na podalgi izhoda več agentnega simulatorja, kateri simulira interakcije med agenti v danem okolju. Simulator deluje na podalgi predhodno vpisanih pravil obnašanja agentov.
Eksperiment je pokazal, da je uporaba naše metode izboljšala podobnost med delovanjem simulatorja na podlagi originalnih pravil in delovanjem z uporabo pravil dobljenih z našo metodo. Podobnost med dnevniki simulatorja se je z uporabo naše metode povečala za skoraj dvakrat v primerjavi z dnevniki simulacije, kateri so bili generirani brez uporabe naše metode.
V bodoče imamo namen razviti novo funkcijo razdalje, v kateri bi upoštevali tudi kontekst pravil, saj zdaj za enkrat tega ne počnemo. S tem mislimo, da bi lahko podobnost med dnevniki še povečali.

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BEHAVIORAL CLONING OF ASYMMETRIC CONFLICTS IN URBAN ENVIRONMENT USING SUPERVISED LEARNING

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ABSTRACT

This paper presents behavioral cloning in the domain of asymmetric conflicts in urban environment. Training data in the form of sensor input-action pairs is extracted from traces of observed human conduct. Behavior models are created by means of supervised learning.

1 INTRODUCTION

Computer simulations of real-world processes and systems are widely used for the purpose of analysis, performance optimization and training. Examples include simulations for traffic analysis [1], evaluating evacuation scenarios [2] and military training [3]. For credible results, such simulations need a realistic model of human behavior.

Human behavior can be modeled by means of behavioral cloning [4]. Behavioral cloning aims at learning human behavior policies from task demonstrations by means of machine learning. This concept is also termed 'learning from demonstration' [5] and 'imitation learning' [6]. It has been successfully applied in a broad range of applications such as development of Robosoccer software agents [7], helicopter controllers [8] and realistic game characters [9].

This paper presents cloning human behavior in the domain of asymmetric conflicts in urban environment. We create reactive behavior models by means of supervised learning. The focus is to evaluate the fidelity of human behavior models created by supervised learning with respect to simulation outcome metrics. Realistic models would enable replication of human behavior in a simulation of asymmetric conflicts in urban environments, thus enabling credible evaluation of military rules of conduct as well as personnel training in such circumstances.

The paper is organized as follows. Section 2 presents related work in behavioral cloning for reproducing human behavior in simulations. Section 3 encompasses problem and method description. Evaluation results are presented in Section 4. Section 5 concludes the paper and presents future work.

2 RELATED WORK

There are two major approaches for cloning human behavior. The first one models human actions, inducing 'sensor input – action' patterns and learning characteristic sequences of actions taken for achieving a goal of interest. The second is focused on modeling human preferences, instead of the actions that result from those preferences. Since this study is based on the first approach, the rest of this section is devoted to related work for modeling human actions with the purpose of reproducing observed behavior in simulations.

Aler et al. [7] present behavioral cloning in the domain of robotic soccer. An interface was built which displays to the user the objects in the playing field that can be seen according to Robosoccer rules. A human player played several soccer games, out of which situation-action pairs were extracted. Behavior models induced using C4.5 were used for reproducing human behavior in the robotic soccer simulation.

Abbott [10] also presents behavioral cloning for reproducing human behavior in robotic soccer. Data was obtained from real soccer game played by humans by means of four cameras. Input-output pairs were extracted by means of multiple targets tracking application. Representative behavior features were obtained using clustering.

Fabian [11] presents behavioral cloning for reproducing human behavior in the video game Longshot. A human player was let play the game through the game interface several times during which situation-action pairs were recorded. Behavior models were created by means of first-order, relational learning algorithms (FOIL, PROGOL and PROXIMITY).

Thurau et al. [6] presents behavioral cloning in the video game QUAKE II. Human behavior data was obtained from game logs. Behavior models were created in two steps. Firstly, training data in state space was clustered using self-organizing maps. Then, each cluster was assigned two multi-layer perceptrons, one for view angle and one for velocity adjustment.

We are interested in cloning human behavior in the domain of asymmetric conflicts in urban environments. Humans are let control an agent in a simulation. Out of simulation logs, training data is extracted in the form of situation-action pairs. Behavior models are induced using supervised learning. We present and compare the performance of six supervised learning algorithms.

3 BEHAVIORAL CLONING OF ASSYMETRIC CONFLICTS IN URBAN ENVIRONMENT

First, the simulation of asymmetric conflicts in urban environment used for this study is described. Then, the applied method for behavioral cloning is presented.

3.1 Simulation

This study is based on a simulation of the interaction between participants of two asymmetric, opposing groups: (1) civilians and (2) soldiers. The behavior of each participant in the simulation is specified using the PECS model [12]. The interaction takes place at a camp entrance. The civilians are separated in two subgroups, each of which has a spokesman. They are gathering in front of the camp entrance in order to apply for a job. The soldiers are guarding the camp. Two soldiers are located directly at the entrance and two on a watchtower. A squad leader monitors the evolving of the situation also from a watchtower. The soldiers at the entrance proceed the civilians one by one through the entrance. When under pressure, they close the entrance and secure it. A screenshot of the simulation environment is shown in Figure 1. The white circles inside the camp are soldiers and the black circles outside the camp are civilian agents. The black color of the civilians represent that their leading cognitive state is anger. Besides anger, the leading cognitive state of the civilians can be need or fear.

In this simulation, the interaction between the soldiers and the crowd of civilians evolves thus: The spokesman of subgroup of civilians A approaches the soldiers at the entrance and starts negotiating with them to obtain certain benefits for his subgroup. The spokesman of group B also approaches the soldiers, suspecting that the spokesman of group A is trying to influence them to privilege subgroup A when entering the camp. After a while, an aggressive discussion evolves and aggression is directed towards the soldiers. The members of the subgroups A and B join the tussle in support of their spokesmen. At this point, the soldiers close the entrance. Firstly, they try to calm down the crowd verbally. If the crowd calms down the gate is reopened. If not, the soldiers try to calm down the crowd by gestures and verbal warnings. If the crowd does not calm down they start using weapons.

The final goal of the soldiers in this scenario is not only to disperse the crowd, but to adopt such strategy that will minimize/maximize predefined Measures of Effectiveness (MoEs). In this scenario, the MoEs are the number of injured and killed, the level of fear, anger and aggression. Performing effective shots quickly resolves the conflict; however, these actions lead to a high number of injured and killed, a high level of fear and anger and thus to a bad final outcome. The soldiers should act in a way that limits the escalation of the conflict, while avoiding too severe counter actions.

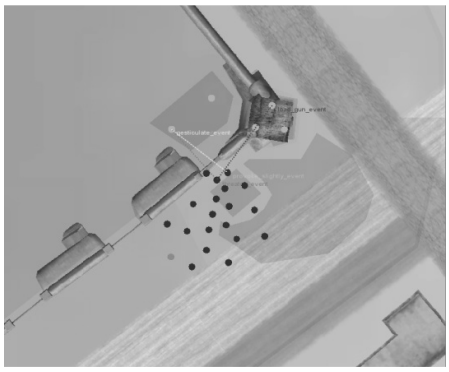

Figure 1: *Simulation environment*

At the end of each simulation a log containing relevant information about the conduct of the simulation is outputted.

3.2 Behavioral cloning

In this study we aim at cloning the behavior of the soldiers. The behavior of a specific soldier, which we want to clone, is firstly represented as a set of situation-action instances. These instances are reconstructed out of the simulation logs. In this study, soldiers executed one of the following actions: gesticulate, communicate calming event, load gun, perform a warning gun shot or an effective one. We describe the situation in which these actions are performed using five sets of attributes encompassing:

- Soldier's mental state: stand by or situation evaluation
- Soldier's place: at entrance, on the tower and similar
- Previously performed soldier actions: previous gesticulation, previous communication of calm event and similar
- Soldier's interaction with the civilian leaders: is any of the civilian leaders near the soldier, the anger value of the civilian leaders, their leading motive, previous provocations by the civilian leaders
- Current civilian state: average civilian anger value

The set of situation-action instances of the soldier of interest, which we want to clone, reconstructed out of the simulation logs represent the training dataset. Supervised learning methods are then applied on the training dataset in order to obtain the behavior model of the soldier of interest. We use six supervised learning methods for this purpose: slipper [13], as well as J48, JRip, RandomForest, NaiveBayes and SMO [14]. Each of them outputs a behavior model which, when incorporated in the simulation, reproduces the behavior of the soldier of interest.

Logs \ Logs		PECS-based model	PECS clones						soldier -no action	soldier - eff. shot	human player	human clones					
			Slipper	SMO	Random Forest	Naive Bayes	JRip	J48				Slipper	SMO	Random Forest	Naive Bayes	JRip	J48
PECS-based model		4	7	4	4	4	8	9	14	16	13	12	15	15	17	15	16
PECS clones	Slipper	7	6	7	6	9	8	12	15	12	11	13	13	15	13	13	
	SMO	2	4	3	8	7	14	16	13	12	15	15	17	15	15		
	Random Forest	5	4	8	8	14	15	12	12	14	15	17	14	15			
	Naive Bayes	3	8	8	14	16	13	12	15	15	17	15	15				
	JRip	9	9	12	18	14	11	13	15	17	14	14					
	J48	9	11	16	13	11	13	14	16	14	14						
soldier - no action		2	14	11	5	6	9	10	9	7							
soldier - eff. shot		0	3	13	10	6	5	8	9								
human player		3	9	7	4	2	5	5									
human clones	Slipper	5	5	9	10	8	7										
	SMO	2	6	7	6	5											
	Random Forest	6	4	6	6												
	Naive Bayes	1	5	5													
	JRip	6	6														
	J48	5															

Table 1: *Evaluation*

4 EVALUATION

The fidelity of the behavior models created by supervised learning is evaluated according the MoEs presented in Section 3.1. In contrast to predictive accuracy which evaluates the ability of the models to correctly predict future actions, MoEs give global judgment of the behavior models' performance in the analyzed environment. Thus the focus is to estimate to what degree are these models capable of reproducing the same outcome as the modeled entities.

4.1 Data

Four types of soldier conducts were recorded using the simulation of asymmetric conflicts in urban environment. The first type logs simulation course when soldier actions are chosen by a PECS-based soldier behavior model (integral part of the simulation presented in Section 3.1). The second logs simulation course when soldiers do not perform any action – the most peaceful soldiers' conduct. The third logs simulation course when soldiers execute only effective shots – the most aggressive soldiers' conduct. Finally, the fourth logs simulation course when a human player selects the action to be executed by the soldiers. The human player followed an aggressive strategy, executing warning shots immediately when the interaction with the civilians is started. Ten recordings were made for each type of soldier conduct. The recordings of the first three types of soldier conduct were 1500 simulation steps long, while the fourth encompassed on average 2772 simulation steps.

Supervised learning was applied for creating a clone of the PECS-based model (PECS clone) and the human player (human clone). Using each of the examined supervised learning methods, 10 clones of both the PECS-based model and the human player were developed (one clone is induced by supervised learning on the data of 9 out of the 10 recordings). The simulation course was recorded for 1500 simulation steps 10 times for each of the induced behavior clones. The second and third recording types were not cloned. They were used only as benchmarks of the two most extreme soldier conducts.

4.2 Results

The simulation outcomes were compared using dynamic time warping. Dynamic time warping is used for estimating the difference between two time series. It determines the ideal warp, i.e. optimal alignment, between two time series by comparing the distance between each possible pair of points of the two time series. In order to compare the MoE values of two simulation runs, a distance metric between two multi-dimensional time points is needed. We calculate this distance thus:

$$dist(moe_1, moe_2) = \sum_{d=1}^{D} (moe_1(d) - moe_2(d))$$

where moe_1 and moe_2 are points on two D-dimensional MoE time series and $moe_i(d)$ represents the value of the d-th dimension of the point moe_i. The sum of the distance of the pairs of points on the ideal warp represents the difference between the two time series.

The test results are presented in Table 1. Each row/column of Table 1 represents one simulation type. As presented in Section 4.1, 16 simulation types were recorded: 4 types represent the outcome of the recorded soldier conducts, 6 types represent the outcome of the PECS clones and 6 types the outcome of the human clones. Each cell in the table represents the average difference between the MoE values of the simulation type in the row and the column of the cell. The difference values belong to the interval [0, 100], where 0 represents no difference and 100 represents the highest difference.

The values along the diagonal represent the difference between the MoE values within one simulation type. The average MoE difference within one simulation type is 4.3. The values off the diagonal represent the MoE difference between two simulation types. The PECS-model outcome is different from the outcome of the other three soldier conducts (average difference is 14). The most peaceful and the most aggressive soldier conduct produce outcomes that differ by 14 points. The outcome produced by the human player is very similar to the most aggressive soldier conduct (the difference is 3 points). This is expected because, as presented in Section 4.1, he followed an aggressive strategy.

The fidelity of the behavior models developed by supervised learning is represented by the MoE difference between the PECS-model and its clones and that of the human player and his clones. The results show that the PECS clones produce similar outcome as the PECS-based soldier model. The difference between the outcome of the PECS-based model and the SMO, Random Forest and Naïve Bayes PECS clones is on average 4. This difference is very close to the average difference between the MoE values of one simulation type, which amounts 4.3. The performance of the Slipper, J48 and JRip PECS clones is lower. Their average difference to the PECS-based model outcome is in the range 7-9. The Random Forest, Naïve Bayes, J48 and JRip human clones produce similar outcome as the human player (the difference is in the range 2-5). The performance of the slipper and SMO human clone is lower (difference 9 and 7, respectively).

5 CONCLUSION

This paper presented behavioral cloning in the domain of asymmetric conflicts in urban environment. Six supervised learning methods were applied for inducing situation-action patterns characteristic for the observed behavior. The credibility of the induced models was evaluated with respect to simulation outcome metrics, presenting to which degree these models are capable of reproducing the same outcome as the modeled entities. Taking into consideration the simplicity of the models, the obtained results are encouraging. As future work, higher level reasoning patterns (e.g. strategic, tactical) need to be added to the behavior models in order to increase their credibility.

Acknowledgements

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POSPLOŠEVANJE VISOKONIVOJSKIH ROBOTSKIH PLANOV IZ PRIMEROV

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POVZETEK

Prispevek opisuje algoritem za posploševanje visokonivojskih robotskih planov iz konkretnih primerov planov, ki jih je npr. izvedel človek, in formalizem za opis omejitev pri reševanju naloge robota. Rezultati preizkusa algoritma na Cranfieldovem primerjalnem poskusu kažejo, da je algoritem sposoben posploševanja iz relativno majhnega števila primerov na model omejitev zaporedja akcij, ki omogoča reševanje naloge na veliko različnih načinov. Hkrati formalizem, v katerem algoritem vrne rezultat, omogoča tudi učinkovito planiranje ali vsaj omeji prostor preiskovanja pri planiranju.

1. Uvod

Planiranje je eno izmed tradicionalnih področij umetne inteligence. Naloga planiranja je podana z začetnim stanjem sveta, v katerem planiramo, ciljnimi pogoji in akcijami, ki jih je mogoče izvesti. Za opis akcij in stanj se uporablja primeren formalizem, cilj planiranja pa je najti zaporedje akciji, ki iz začetnega stanja pripelje do izpolnitve ciljev [3].

Planiranje se pogosto uporablja v robotiki, vendar se tu namesto splošnega (klasičnega) planiranja pogosteje uporabljajo specializirane metode, ki omogočajo učinkovito implementacijo, robustnost in predvidljivost delovanja [1]. Nalogo planiranja za konkretnega robota lahko ločimo na nizkonivojski plan, ki je specifičen za določenega robota, in visokonivojski plan, ki je zaradi višjega nivoja abstrakcije neodvisen od konkretnega robota. Cilj nizkonivojskega plana za robotsko roko je na primer določiti zaporedje rotacij posameznih sklepov robotske roke, ki upošteva omejitve minimalne in maksimalne rotacije sklepov in omogoči izvedbo višjenivojskih akcij, kot sta naprimer prijemanje ali dvig objekta iz mize. Cilj visokonivojskega planiranja je določiti zaporedje akcij na višjem nivoju abstrakcije, ki pripeljejo do izpolnitve ciljnih pogojev brez obzira na samo izvedbo na konkretnem robotu. Če je cilj zapreti steklenico je lahko visokonivojski plan (t.j. zaporedje akcij) naslednji: premakni roko nad zamašek, primi zamašek, premakni zamašek na navoj steklenice, privij zamašek, spusti zamašek, odmakni roko.

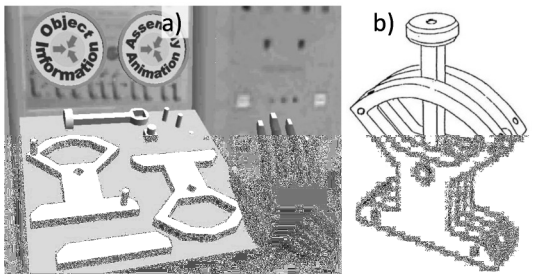
Trenutno je zelo aktivno področje kognitivne robotike, s ciljem obogatiti robota z inteligentnim obnašanjem. To se doseže s pomočjo programske opreme, ki omogoča učenje in sklepanje o obnašanju v odnosu na kompleksne cilje v svetu robota. Za učenje se pogosto uporablja tehnik učenja z imitacijo, pri kateri robot s pomočjo senzorjev opazuje človeka, ki izvede nalogo, nato pa sam skuša imitirati človeške akcije, da bi izpolnil podobno nalogo [4].

Problem posploševanja visokonivojskih planov, s katerim se ukvarja ta prispevek, je eden izmed podproblemov učenja z imitacijo. Prispevek predpostavlja, da so ostali podproblemi (razpoznavanje demonstriranih visokonivojskih akcij [2], planiranje na nizkem nivoju, izvajanja nizkonivojskih akcij) že rešeni. Naloga posploševanja visokonivojskih planov je sledeča: iz danih zaporedij visokonivojskih akcij (razpoznanih planov), ki rešijo dano nalogo, izlušči znanje, ki bo omogočalo planiranje visokonivojskih robotskih akcij. Pri tem je pomembno, da je postopek sposoben posploševanja oz. indukcije splošnih principov iz danih učnih primerov.

Obravnavani algoritem je bil preizkušen na Cranfieldovem primerjalnem poskusu (CPP), ki je opisan v naslednjem razdelku. Razdelek 3 govori o formalizmu za predstavitev znanja, razdelek 4 poda opis algoritma in lastnosti algoritma, v razdelku 5 pa so zbrani rezultati preizkusa algoritma na CPP. Zaključku prispevka so dodani načrti za nadaljnje delo.

2. Cranfieldov primerjalni poskus

Obravnavan algoritem za posploševanje visokonivojskih planov je bil preizkušen na Cranfieldovem primerjalnem poskusu (CPP), ang. Cranfield benchmark, ki je opisan v tem razdelku. Naloga CPP je z robotsko roko sestaviti objekt na sliki 1b iz naslednjih desetih delov (slika 1a): spodnja (SP) in zgornja plošča (ZP) s po petimi luknjami, dva okrogla (Č1, Č2) in dva pravokotna (Č3, Č4) čepa, distančnik (DI), nihalo (NI), glava nihala (GN) in gred (GR).



Slika 1: a) *delno in b) v celoti rešen Cranfieldov primerjalni preizkus.*

Nalogo se opravi tako, da se v spodnjo ploščo v poljubnem vrstnem redu najprej vstavi vse štiri čepe (paziti je treba v katere luknje so vstavljeni) in gred. Nato se na kvadratna čepa nasadi distančnik, na gred pa nihalo. Vrstni red postavitve čepov, nihala in distančnika je lahko tudi

drugačen, vendar je treba paziti, da sta pred nasaditvijo distančnika vstavljena čepa 3 in 4, pred nasaditvijo nihala pa je vstavljena gred. Pred nasaditvijo zgornje plošče je potrebno na svoja mesta postaviti vse preostale dele, glavo nihala pa je treba priviti na nihalo kadarkoli pred nasaditvijo nihala (zadnja omejitev je sicer odvisno od lastnosti robota).

Za rešitev naloge obstaja 5320 planov (oz. 21280, če razlikujemo čepe in luknje enakih oblik), to je zaporedij postavljanja delov na svoja mesta. Postavitev posameznega dela vedno sledi ciklu robotskih akcij: sezi – primi – dvigni – poravnaj – vstavi – spusti (ang. reach, grasp, lift, align, insert, release object) povezanih z istim delom. Zato zadošča, da obravnavamo zgolj zaporedje postavljanja delov in ne samega zaporedja robotskih akcij z deli.

3. Formalizem za predstavitev znanja

Pri sestavljanju plana za reševanja CPP je potrebno upoštevati omejitve vrstnega reda sestavljanja posameznih delov, ki so opisane v prejšnjem razdelku. Primeren formalizem za opis omejitev je binarna relacija *izvedi-pred*, ki jo je mogoče predstaviti tudi z lahko berljivim grafom.

Zaradi lažjega razumevanja bomo v tem razdelku namesto reševanja CPP obravnavali nalogo menjave para baterij. Da bi uspešno zamenjali par baterij, moramo najprej odpreti pokrov prostora za bateriji, kar bomo označili z akcijo O. Nato odstranimo eno izmed praznih baterij, kar označimo z akcijo V_1 ali V_2. Za tem lahko najprej odstranimo še drugo prazno baterijo in v poljubnem vrstnem redu vstavimo novi bateriji (N_1, N_2) ali pa najprej vstavimo prvo polno baterijo in nato zamenjamo še drugo baterijo.

Vse zgoraj opisane omejitve lahko predstavimo z relacijo *izvedi-pred*, ki jo označimo z $ip(x, y)$ in preberemo: akcijo x obvezno izvedi pred akcijo y. Na podlagi zgornjega opisa izpeljemo relacijo *izvedi-pred* za primer menjave baterij: $ip(O, V_1)$, $ip(O, V_2)$, $ip(V_1, N_1)$, $ip(V_2, N_2)$.

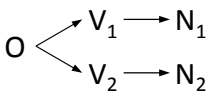
3.1. Lastnosti relacije izvedi-pred

Relacija *izved-pred* je binarna in notranja relacija (ang. endorelation) glede na množico visokonivojskih robotskih akcij A za dan problem. Relacija ima naslednje lastnosti:

- irefleksivnost: $\forall x \in A: \neg ip(x, x)$, saj izvedba akcije x ne more biti predpogoj za izvedbo le-te,
- asimetričnaost: $\forall x, y \in A: ip(x, y) \Rightarrow \neg ip(y, x)$, sicer bi se pojavili cikli, ki onemogočijo rešitev naloge,
- tranzitivnost: $\forall x, y, z \in A: ip(x, y) \wedge ip(y, z) \Rightarrow ip(x, \mathrm{z})$ ki je očitna.

3.2. Grafična predstavitev

Ker za relacijo veljajo zgoraj naštete lastnosti, jo je mogoče prikazati z usmerjenim acikličnim grafom (ang. DAG). Vozlišča grafa so akcije iz množice A, povezave pa vodijo do vsake akcije x iz vseh drugih akcij y s katerimi je x v relaciji *izvedi-pred* $ip(y, x)$. Slika 2 prikazuje relacijo *izvedi-pred* za nalogo menjave para baterij.



Slika 2: *grafični prikaz relacije izvedi-pred za nalogo menjave para baterij.*

Graf relacije *izved-pred* za vsako izvedljivo nalogo je acikličen – pojavitev cikla bi pomenila, da naloge ni mogoče izvesti, saj na določenem koraku ne bo mogoče izvesti nobene izmed akcij v ciklu, ker pred njo ni mogla biti izvedena nobena izmed preostalih akcij v ciklu. Relacijo je v računalniški obliki mogoče učinkovito predstaviti s podatkovnima strukturama usmerjen graf ali matriko sosednosti.

3.3. Uporaba formalizma za planiranje

Predstavitev omejitev pri reševanju robotske nalog z relacijo *izvedi-pred* je poleg berljivosti in enostavne implementacije primerna tudi zato, ker je neposredno uporabna za planiranje. Na vsakem koraku, je mogoče izvesti le akcije, v katere ne vodi nobena povezava na grafu, to je vse akcije x, ki ne nastopajo na desni strani relacije $ip(y, x)$. Take akcije lahko izvedemo, ker so izpolnjeni vsi predpogoji za njihovo izvedbo. Ko se izvede izbrana akcija x, se iz grafa odstrani vozlišče, ki predstavlja akcijo x, in vse pripdajoče povezave, planiranje pa se nadaljuje s tako pridobljenim grafom. Podobno se lahko pridobi novo relacijo z operacijo omejitve (ang. restriction) izhodiščne relacije na množico $A \setminus \{x\}$.

4. Algoritem za posploševanje iz danih planov

Algoritem za posploševanje kot vhod prejme množico zaporedij visokonivojskih akcij, to je množico znanih uspešnih planov. Vsak plan vsebuje zaporedje vseh akcij, ki jih je v določenem vrstnem redu potrebno opraviti za uspešno izvedbo naloge. Kot izhod algoritem vrne minimalno relacijo *izvedi-pred*, ki jo z logičnim sklepanjem izlušči iz dane množice planov. Minimalnost je zaželena zato, ker manjša relacija predstavi bolj splošno znanje o omejitvah pri reševanju naloge – manj kot je restriktivna več različnih planov se lahko iz nje izpelje.

Algoritem deluje iterativno, tako da po inicializacij v vsakem koraku obdela po en plan iz množice danih planov in na njegovi podlagi posploši trenutno relacijo *izvedi-pred* ip_i. Ko obdela vse dane plane pridobi najsplošnejšo relacijo *izvedi-pred*, ki predstavlja znanje izluščeno iz danih primerov.

Slika 3 predstavlja psevdokodo algoritma, naslednji podrazdelki pa ob primeru dodatno pojasnjujejo algoritem.

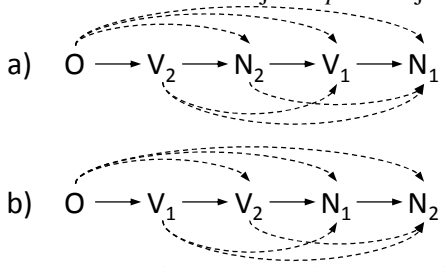
vhod: množica planov P velikosti N
izberi plan $p \in P$
pretvori plan p v relacijo *izdevi-pred* ip_0
naredi tranzitivno ovojnico relacije ip_0^+
odstrani p iz P
$i = 1$
ponavljaj za vsak p iz P
    pretvori plan p v relacijo *izdevi-pred tmp*
    naredi tranzitivno ovojnico relacije tmp^+
    posplošena relacije ip_i je presek ip_{i-1} in tmp^+
    odstrani p iz P
    i++
izhod: tranzitivna redukcija relacije ip_{N-1}

Slika 3: *psevdokoda algoritma za posploševanje.*

4.1. Pretvarjanje plana v relacijo

Dan primer zaporedja akcij $p = (a_1, a_2, \ldots, a_n)$ se pretvori v relacijo *izvedi-pred*, tako da se v relacijo doda vse pare zaporednih akcij $ip = \{(a_i, a_{i+1})\}$. S tem nastane relacija, ki tako strogo omejuje zaporedje akcij, da dovoljuje eno samo zaporedje, ki je identično danemu zaporedju akcij, hkrati pa je v relaciji za to minimalno potrebno število parov akcij. Da se v naslednjem koraku lažje združi znanje pridobljeno iz plana p in nekega drugega plana, se namesto relacije ip uporabi njeno tranzitivno ovojnico ip^+. Tranzitivno zaprtje je operacija na binarni relaciji R, ki kot rezultat vrne novo binarno relacijo, ki je minimalna tranzitivna relacija nad množico A in vsebuje relacijo R. S tem se doseže, tranzitivnost relacije ip^+, kar omogoča lažje združevanje več relacij oz. posploševaje planov (opisano v razdelku 4.2).

Slika 4 prikazuje grafa tranzitivnih ovojnic relacij *izvedi-pred* za dva dana plana zaporedij akcij p_1 = (O, V_2, N_2, V_1, N_1) in p_2 = (O, V_1, V_2, N_1, N_2) naloge menjave baterij. Črtkane puščice predstavljajo elemente, ki so bili relaciji ip dodani za pridobitev tranzitivne ovojnice ip^+ relacije ip.

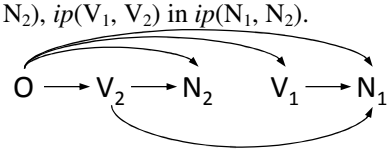


Slika 4: *grafični prikaz tranzitivnih ovojnic relaciji izvedi-pred za a) plan p_1 in b) plan p_2.*

4.2. Združevanje primerov

Ko sta s tranzitivnima ovojnicama relacij *izvedi-pred* (R_1, R_2) predstavljena dva primera planov oz. en plan (R_1) in ena relacija *izvedi-pred* posplošena iz več planov (R_2), se lahko relaciji združita. Združevanje se opravi z operacijo preseka obeh relacij: $R_1 \cap R_2 \subseteq A \times A$, ki je definirana kot $R_1 \cap R_2 = \{(x, y) : (x, y) \in R_1 \wedge (x, y) \in R_2\}$. Ker sta relaciji R_1 in R_2 najbolj restriktivni omejitvi glede vrstnega reda izvajanja akcij, predstavlja njun presek najbolj restriktivno omejitev vrstnega reda glede na možnosti vrstnih redov, izhajajočih iz omejitev in možnosti obeh relacij.

Slika 5 prikazuje unijo tranzitivnih ovojnic relacij *izvedi-pred* za plana p_1 in p_2. Vidimo, da ima relacija, ki predstavlja unijo manj omejitev kot ena ali druga izhodiščna relacija – s tem je bila dosežena posplošitev iz dveh danih planov na večje število planov. Po definiciji unija relacij vsebuje samo povezave med pari akcij, ki so povezani v obeh izhodiščnih relacijah. Tako so iz relacije za plan p_1 izpadli pari (oz. omejitve) $ip(V_2, V_1)$, $ip(N_2, N_1)$ in $ip(N_2, V_1)$, iz relacije za p_2 pa $ip(V_1, N_2)$, $ip(V_1, V_2)$ in $ip(N_1, N_2)$.



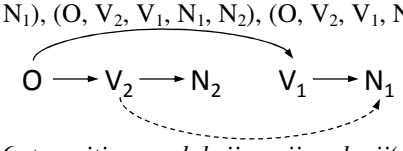
Slika 5: u*nija relacij izvedi-pred za plana p_1 (slika 4a) in p_2 (slika 4b).*

4.3. Poenostavitev grafa omejitev

Ko algoritem po zgoraj opisanem postopku združi vse plane, pridobi najsplošnejše omejitve, ki predstavljajo relacijo, ki dovoljuje izvedbo vseh danih (vhodnih) planov, hkrati pa (razen v posebnih primerih) dovoljujejo tudi mnogo drugih planov. Le-ti so rezultat posplošitve in logičnega združevanja znanja o več različnih možnih planih reševanja naloge.

Zaradi berljivosti grafične predstavitve in minimnalne dolžine opisa relacije *izvedi-pred* je kot rezultat algoritma smiselno vrniti tranzitivno redukcijo relacije ip_{N-1}. Tranzitivno redukcije dobimo z opreracijo tranzitivne redukcije (na izhodiščni binarni relaciji *R)*, ki je definirana kot minimalna relacija, katere tranzitivna ovojnica je enaka tranzitivni ovojnici izhodiščne relacije R. Tranzitivna redukcija relacije ni tranzitivna, je pa zato bolj kompaktna in primerna za uporabo v planiranju, ki je opisano v razdelku 3.3. Originalno relacijo R lahko dobimo tako, da naredimo tranzitivno ovojnico tranzitivne redukcije relacije R.

Slika 6 prikazuje tranzitivno redukcijo unije relacij za plana p_1 in p_2 iz slike 5. S črtkano puščico je prikazana edina odvečna omejitev, ki je algoritem ni mogel odstraniti, ker v danih (vhodnih) planih nikoli ni opazil, da bi bilo mogoče izvesti akcijo N_1 pred akcijo V_2. Če bi algoritmu podali tudi vsaj en primer plana, v katerem je akcija N_1 izvedena pred akcijo V_2, bi bila posplošitev popolna – dobili bi isto relacijo, kot smo jo določili ročno iz opisanih omejitev pri reševanju naloge zamenjave para baterij (slika 2). Edini veljaven plan, ki ga posplošena relacija s slike 6 ne dovoljuje je (O, V_1, N_1, V_2, N_2). Sicer je algoritmu uspela posplošitev iz dveh na pet planov. Dodatni trije plani, ki jih algoritem ni nikoli videl, je pa ugotovil, da so možni so: (O, V_1, V_2, N_2, N_1), (O, V_2, V_1, N_1, N_2), (O, V_2, V_1, N_2, N_1).



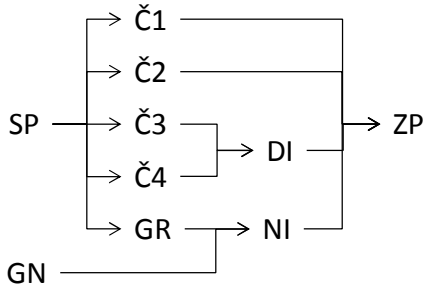
Slika 6: *tranzitivno redukcijo unije relacij(slika 4) za plana p_1 in p_2.*

5. Rezultati preizkusa algoritma

Opisani algoritem je bil preizkušen na Cranfieldovem primerjalni poskus (CPP), katerega naloga je iz desetih delov sestaviti objekt (slika 1). S kombinatorično analizo je bilo pokazano, da za sestavljanje CPP obstaja 5320 različnih planov, ki določajo zaporedje sestavljanja posameznih delov

in s tem zaporedje robotskih akcij. Slika 7 prikazuje omejitve, ki veljajo pri sestavljanju CPP, prikazane z grafom relacije *izvedi-pred*.

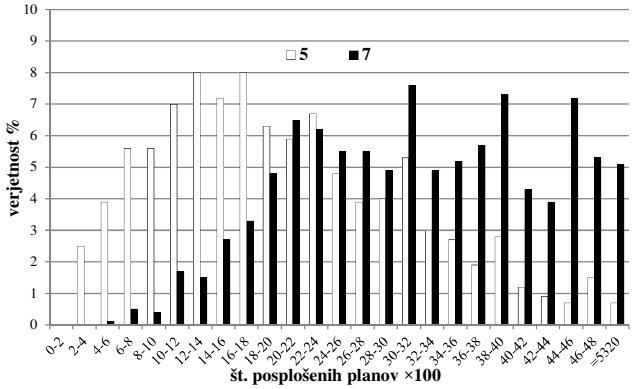
Uporabljena metoda preizkušanja algoritma je naslednja: kot vhod je bilo podanih *n* naključnih planov iz množice vseh veljavnih planov, po učenju pa je bilo preverjeno na koliko planov je algoritem uspel posplošiti omejitve naloge. Poskus je bil za isto število vhodnih planov *n* ponovljen tisočkrat, iz rezultatov pa je bila izračunana verjetnost, da algoritem pri *n* danih planih omejitve posploši tako, da prepozna *m* planov (*m* je enakomerno diskretiziran s korakom 200). Taka metodo preizkusa je bila izbrana zato, ker je eksperimentalno nemogoče izmeriti kakšna je povprečna verjetnost za posplošitev na *m* planov pri vseh možnih izborih *n* danih planov izmed množice vseh možnih planov že za zelo majhne *n*; npr. za $n = 3$ je potrebno preveriti $(5320 \cdot 5319 \cdot 5318)/(2 \cdot 3) > 25 \cdot 10^9$ izborov planov. Poleg tega je bilo eksperimentalno pokazano, da se že po nekaj sto preizkušenih izborih *n* naključnih planov povprečna verjetnost za posplošitev na *m* planov več bistveno ne spreminja.



Slika 7: *omejitve pri reševanju CPP, ki se jih je algoritem skušal naučiti iz danih primerov*.

Preizkus je pokazal, da algoritem z več kot 50 % verjetnostjo uspe posplošiti znanje iz zgolj petih danih planov na več kot polovico vseh možnih planov. Če se za učenje uporabi 10 učnih planov, algoritem v povprečju uspe posplošiti na 80 % vseh možnih planov. Če se za učenje uporabi 20 (oz. 30) učnih planov, algoritem posploši na vse možne plane z verjetnostjo 80 % (oz. 93 %).

Natančnejši rezultati so prikazani na slikah 8 in 9. Abscisna os ponazarja število *m/100* (diskretizirano s korakom 200), ki pomeni, na koliko planov je algoritmu uspela posplošitev. Zadnji stolpec predstavlja posplošitev na vse možne plane. Ordinatna os ponazarja verjetnost posplošitve v procentih. Z različnimi baravami stolpcev so prikazane verjetnosti za posplošitev iz različnega števila danih planov: 5 in 7 na sliki 7 ter 15, 20 in 30 na sliki 8.

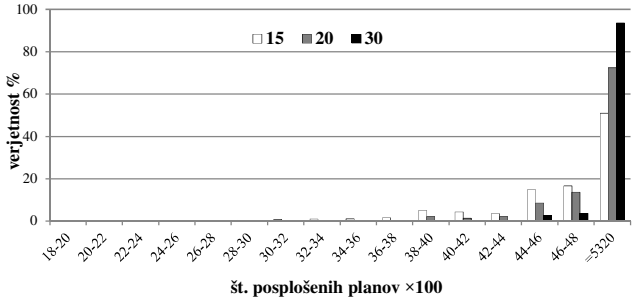


Slika 8: *verjetnost posplošitve na m planov iz 5 oz. 7 danih planov*.

Poleg že opisane sposobnosti algoritma, da iz relativno majhnega števila učnih planov posploši znanje na veliko število novih planov, ima algoritem tudi druge dobre lastnosti. Prva je gotovost, da bodo vsi plani, na katere algoritem posploši, veljavni. Druga pa je nizka časovna zahtevnost, ki je reda $O(n^2m)$, kjer je *n* število akcij v planu, *m* pa število danih (učnih) planov.

6. Zaključek

Prispevek opisuje algoritem za posploševanje visokonivojskih robotskih planov iz danih primerov planov. Dani plani so lahko na primer razpoznani plani, ki jih je kot demonstracijo izvedel človek. Z avtomatskim posploševanjem danih planov algoritem iz konkretnih primerov izlušči znanje, ki se lahko kasneje uporablja za planiranje robotskih akcij. Na tak način se lahko robot od človeka nauči opravljanja določene naloge.



Slika 9: *verjetnost posplošitve na m planov iz 15, 20 in 30 danih planov*.

Algoritem za predstavitev znanja in sklepanje uporablja relacijo *izvedi-pred*, ki določa katera akcija mora biti izvedena preden se lahko izvede neka druga akcija. Algoritem deluje iterativno, tako da v vsakem koraku spremeni po en dan plan v relacijo *izvedi-pred* in jo združi z znanjem pridobljenim v predhodnih iteracijah. Izhod algoritma je graf, ki predstavlja izluščeno znanje (omejitve pri reševanju dane naloge opisane z relacijo *izvedi-pred*).

Opisan algoritem je sposoben posploševanja iz zelo majhnega števila danih planov na znanje o problemu, iz katerega je mogoče izpeljati veliko večje število planov. Poleg tega je algoritem hiter in zagotavlja, da vsi plani, na katere algoritem posploši dane plane, uspešno rešijo nalogo.

V prihodnosti bi bilo algoritem smiselno posplošiti tudi na naloge, v katerih za uspešno izvedbo ni potrebno izvseti vseh možnih akcij (uporabiti vseh delov), in na naloge, v katerih poleg omejitve zaporedja akcij veljajo tudi omejitve drugačnega tipa. Še večji izziv je algoritem posplošiti na naloge, v katerih se prepletajo omejitve različnih tipov.

Zahvala

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RECOGNITION OF HEALTH PROBLEMS FROM MOVEMENT

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ABSTRACT

During the past decade, concern for the elderly, as well as demographic and economic issues, have encouraged research to find assistive technologies for making the lives of elderly people easier and more independent.

The aim of the project introduced in this paper is to analyze different approaches and provide ambient assisted-living services to allow the elderly to live safely at home instead of needing them to go to nursing homes, which are overcrowded. Moreover, young generations would not be overwhelmed by the need to care for these older adults. The research identifies which of the studied approaches could best provide sustainable elderly care.

1 INTRODUCTION AND DESCRIPTION OF THE PROBLEM

The rate of elderly people is increasing worldwide and elderly tend to lead an isolated life away from their children. As a result, they may fear not being able to obtain help if they are injured or ill.

Projections show that the percentage of the population aged over 65 in the developed countries will rise from 7.5% in 2009 to 16% in 2050 [16]. In addition, the ratio of the working-age population (between 15 and 64 years) to the population aged over 65 is predicted to decline from 4.3 to 2.3 [19].

During the past decade, concern for the elderly, as well as demographic and economic issues, have encouraged research to find assistive technologies for making the lives of elderly people easier and more independent.

The aim of this study is to analyze different approaches and provide ambient assisted-living services to allow the elderly to live safely at home instead of needing them to go to nursing homes, which are overcrowded. Moreover, young generations would not be overwhelmed by the need to care for these older adults. The research identifies which of the studied approaches could best provide sustainable elderly care.

The targeted health states, activities and falls for recognition were suggested by a collaborating medical expert. The following five health states: normal (healthy), hemiplegia (usually the result of a stroke), Parkinson's disease, pain in the leg and pain in the back, and the following five activities/falls: accidental fall, unconscious fall, walking, standing/sitting, lying down/lying were chosen.

The movement of the user is captured with an infrared and an inertial motion-capture system. The infrared system consists of tags attached to the body, the coordinates of which are acquired by sensors located in the apartment, and the inertial system consists only of inertial sensors, attached to the body. The output time series of the coordinates are

modeled with the proposed data-mining approaches in order to recognize the specific health problem, activity or fall.
We propose and analyze four data-mining approaches on two domains with the purpose to identify most promising ones:

1) CML – Classical machine-learning approach with raw sensor data,
2) SCML – Classical machine-learning approach with semantic attributes [12],
3) MDTW – Multidimensional dynamic time-warping approach with raw sensor data,
4) SMDTW – Multidimensional dynamic time-warping approach with semantic attributes.

2 RELATED WORK

In related studies the motion is normally captured with inertial sensors [1, 15], computer vision and also with a specific sensor for measuring the angle of joint deflection [13] or with electromyography [17]. In our study an infra-red (IR) sensor system with tags attached to the body [5] was used.

We do not address the recognition of activities of daily living, such as walking, sitting, lying, etc. and the detection of falling, which has been addressed many times [3, 6, 8], but instead the recognition of health problems based on motion data, which represents bigger challenge.

Using a similar motion-capture system to that in our approach, the automatic distinction between health problems such as hemiplegia and diplegia is presented [7]. However, a much more common approach to the recognition of health problems is the capturing of movement that is manually examined by medical experts [4, 10, 13]. Such an approach has a major drawback in comparison to ours, because the movement needs to be constantly monitored by medical professionals.

The paper [9] presents a review of assistive technologies for care of the elderly. The first technology consists of a set of alarm systems installed at people's homes. The system includes a device in the form of a mobile phone, a pendant or a chainlet that has an alarm button. They are used to alert and communicate with a warden. When the warden is not available, the alert is sent to the control center. However, such devices are efficient only if the person recognizes the emergency and has the physical and mental capacity to press the alarm button.

The second technology presented in [11] is video-monitoring. The audio-video communication is done in real time over an ordinary telephone line. The video can be viewed on a monitor or domestic television. The problems of the presented solution are ethical issues, since elderly users do not want to be monitored by video [3]. Moreover, such an approach requires the constant attention of the emergency center.

Miskelly [11] also presented a technology based on health monitors. The health monitor is worn on the wrist and continuously monitors the pulse, skin temperature and movement. At the beginning of the system's use, the pattern for the user is learned. Afterwards, any deviations are detected and alarms are sent to the emergency center. Such a system detects collapses, faints, blackouts, etc.

Another presented technology of Miskelly [11] is the group of fall detectors. They measure the accelerations of the person using tags worn around the waist or the upper chest. If the accelerations exceed a threshold during a time period, an alarm is raised and sent to the community alarm service.

Bourke et al. [2] presented the acceleration data produced during the activities of daily living and when a person falls. The data was acquired by monitoring young subjects performing simulated falls. In addition, elderly people performed the activities of daily living. Then, by defining the appropriate threshold it is possible to distinguish between the accelerations during falls and the accelerations produced during the normal activities of daily living. In this way accelerometers with a threshold can be used to monitor elderly people and recognize falls. However, threshold-based algorithms produce mistakes, for instance, quickly standing up from or sitting down on a chair could result in crossing the threshold, which is erroneously recognized as a fall.

Rudel [14] proposed the architecture of a system that enables the control of users in their homes. It consists of three levels. The first level represents the ill people in their homes equipped with communication and measurement devices. The second level is the information and communication technology that enables the communication with the main server. The third level is the telemedicine center, including the duty operator, doctors and technical support, the center for the implementation of direct assistance at home, and the team of experts for implementing the telemedicine services. Such a system does not provide any automatic detection of unusual behavior but instead requires constant observation by the medical center.

Williams et al. [18] have shown that the ability to perform daily activities is reduced for people that have fallen several times and that this reduction can be detected using accelerometers. They tested elderly people that had not fallen and those that had fallen several times. All of them were asked to perform a predefined scenario, including sentence writing, object picking, etc. The accelerations differ significantly between the two groups of people during the test.

Perolle et al. [11] described an elderly-care system that consists of a mobile module worn by the user all the time that is able to locate the user, detect falls and monitor the user's activity. In addition, this device is connected to a call center, where the data is collected, analyzed, and emergency situations are managed. The mobile module is worn on a belt. It produces an alarm, provides the possibility to cancel it, shows the battery status, etc. In addition, it monitors the user activity and gives it three classifications: low, medium and high. Once a day, the data is sent to the call center for analysis. The user is located

with a GPS, for when it is necessary to respond to alarms and to locate the user if he/she gets lost. The mobile module also provides bidirectional voice communication between the user and the call center in order to communicate critical information immediately.

3 PURPOSE OF THE STUDY

The purpose of the project introduced here is to propose new approaches and analyze different existing and novel approaches, and design new ambient assisted-living services to allow the elderly to live safely at home instead of needing them to go to nursing homes. The research identifies which of the studied approaches could best provide sustainable elderly care.

The purpose of recognizing in each domain:

- **Health-problem recognition**: When the system recognizes one of the four health problems, it notifies the medical service, which can intervene when appropriate.
- **Fall recognition**: When the system recognizes a fall, it notifies the medical service, which can intervene urgently, if necessary.
- **Activity recognition**: useful for the statistics of the movement of the elderly person for the self-assessment of the amount of activity during the day/week/month and if elderly person's activity is not adequate, the system suggests him/her to be more active.

This project addresses the problem of recognizing movement, related to health of elderly, from sensor data, regardless the:

- sensor type (position or inertial sensors)
- task (recognition of health problems, activities or falls should be possible with the same approach and the same attributes).

4 GOALS OF THE STUDY

The goals of the project are to:

- Analyse the challenges of activity, fall and health problem recognition
- Present an overview of state-of-the-art survey of methods related to activity, fall and health problem recognition
- Develop or modify four approaches that address the challenges including development of
    - CML – Classical machine-learning approach with raw sensor data,
    - SCML – Classical machine-learning approach with semantic attributes,
    - MDTW – Multidimensional dynamic time-warping approach with raw sensor data,
    - SMDTW – Multidimensional dynamic time-warping approach with semantic attributes.
- Evaluate the proposed approach on two domains including comparison with competitive approaches and statistical analysis of the results:
    - Health problem recognition
    - Activity/fall recognition

5 HYPOTHESIS

A proper combination of semantic attributes and multidimensional dynamic time warping, such as the SMDTW approach, will outperform the existing methods for activity, fall- and health problem detection; in majority of tests.
In relation to the basic hypothesis, two related hypotheses are:
a) transforming the raw sensor data into the semantic attributes encapsulating properties and knowledge in the investigated domain improves the performance and
b) using semantic attributes which describe the general movement, the same semantic attributes can be used for several domains of movement recognition, such as:

- activity recognition
- fall recognition
- health-problem recognition

.6 CONCLUSION

The aim of the project presented in this paper is to analyze different approaches and provide ambient assisted-living services to allow the elderly to live safely at home instead of needing them to go to nursing homes, which are overcrowded. Moreover, young generations would not be overwhelmed by the need to care for these older adults. The research identifies which of the studied approaches could best provide sustainable elderly care.

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EGOVOREC: GOVORNI BRALNIK SLOVENSKIH BESEDIL ZA POMOČ SLEPIM IN SLABOVIDNIM

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POVZETEK

Predstavljamo projekt eGovorec oz. zasnovo novega sintetizatorja slovenskega govora, ki bo preko inteligentne mobilne aplikacije in e-storitve brezplačno na razpolago širokemu krogu uporabnikov. Za izvedbo e-storitve govornega bralnika slovenskih besedil predlagamo izdelavo uporabniškega vmesnika v obliki sistemskega servisa. Sistemski servis skupaj z jedrom je nameščen na samostojen strežnik. Mobilna ali spletna aplikacija prikazano besedilo na željo uporabnika pošlje sistemskemu servisu eGovorec. Ta pretvori besedilo v govor in vrne njegov zvočni zapis.

1 UVOD

Govor je eden najstarejših, najnaravnejših in v mnogih situacijah najpomembnejših načinov sporazumevanja med ljudmi, zato ne preseneča, da z razvojem tehnologije postaja vse bolj nujno potreben tudi različnim področjem multimedije, v telekomunikacijah, informacijskih sistemih, različnih mobilnih aplikacijah (inteligentni turistični vodnik, navigacija), sistemih pametnih zgradb in pametnih mest (inteligentni govorni vmesniki različnih naprav), sistemih za opozarjanje, virtualnih asistentih in nenazadnje pri pomoči invalidom, starejši populaciji in drugim družbenim skupinam, ki so zaradi svojih fizičnih ali drugih ovir omejeni pri dostopu do e-storitev [2].

Kvaliteta umetno generiranega govora je za nekatere jezike dosegla že precej visok nivo in je rezultat načrtnih dolgoletnih raziskav in interaktivnega sodelovanja strokovnjakov različnih tehničnih in humanističnih ved. Sistemi so jezikovno odvisni, zato tujih rešitev ni mogoče kupiti oz. ustrezno prilagoditi našim potrebam. V Sloveniji se pojavlja čedalje večja potreba oz. povpraševanje po kvalitetnem, čim bolj sprejemljivem in splošno dostopnem govornem bralniku slovenskih besedil. Za angleški jezik in druge večje jezike so takšni govorno podprti sistemi že nekaj časa brezplačno dosegljivi in imajo širok krog uporabnikov. V zadnjem času se čedalje pogosteje uporabljajo tudi v različnih mobilnih aplikacijah, ki pa v našem domačem slovenskem jeziku potem trenutno žal niso dostopne oz. ne delujejo.

Namen projekta je razviti e-storitev, ki bo ponudnikom najrazličnejših e-vsebin omogočala dinamično podajanje informacij v govorni obliki ter v domačem slovenskem jeziku. Večina informacij in storitev v elektronski obliki je danes dosegljiva preko interneta. To nam med vožnjo ali na poti v mestu ponavadi ne koristi. Vizualno podajanje informacij je prav tako manj primerno za nekatere skupine ljudi s posebnimi potrebami (slepi in slabovidni, starejše osebe). Veliko lažje bi bilo, če bi bile te informacije lahko posredovane v govorni obliki. V primeru statičnih (nespremenljivih) besedil se le te lahko prebere in posname vnaprej, pri obsežnejših dinamičnih vsebinah (ki se sproti spreminjajo oz. generirajo) pa je to praktično nemogoče. Splošno sprejeta rešitev v takšnih primerih je uporaba sintetizatorjev govora. Takšna rešitev omogoča oz. razširja možnost uporabe najrazličnejših e-storitev še preko drugih komunikacijskih kanalov, ki podpirajo govor. V svetu ti sistemi predstavljajo enega od temeljnih gradnikov (kot osnova oz. infrastruktura) pri razvoju številnih naprednih inteligentnih storitev in mobilnih aplikacij prihodnosti. Uporaba takšnih aplikacij ne zahteva posebnega predznanja o računalnikih, zato je široko uporabna v vsej populaciji. Ti sistemi prav tako zelo učinkovito omogočajo nemoteno vključevanje nekaterih sicer izključenih skupin ljudi v družbo.

Cilj projekta je izdelati nov sintetizator slovenskega govora in omogočiti njegovo brezplačno rabo čim širšemu krogu uporabnikov preko inteligentne mobilne aplikacije in e-storitve. eGovorec bo tako postal sestavni del slovenske infrastrukture za bodoče mobilne aplikacije in podajanje e-vsebin, kar bo slovenski jezik postavilo ob bok drugim »velikim« jezikom. Rezultati več kot dvajset let raziskav na Institutu »Jožef Stefan« s področja govornih in jezikovnih tehnologij bodo lahko koristno služili vsej slovensko govoreči populaciji.

2 OZADJE PROJEKTA

Pri iskanju projektnih idej oz. rešitev smo sprva izhajali iz potreb slepih in slabovidnih ljudi v Sloveniji. Prav ta populacija ljudi je namreč pri rabi in uvajanju novih tehnoloških rešitev precej napredna in kreativna ter korak pred drugimi primerljivimi skupinami, s čimer učinkovito preskakuje siceršnje ovire oz. dane omejitve pri dostopanju do e-storitev in e-vsebin ter rabi najrazličnejših mobilnih aplikacij.

Med tem so nas kontaktirale šeštevilne druge ustanove, razne organizacije in društva ter številna podjetja in nas

spraševali o možnosti vključitve umetno generiranega slovenskega govora v njihove bodoče storitve oz. mobilne aplikacije. Vsi bi si želeli, da bi bila omenjena storitev oz. aplikacija po vzoru drugih podobnih aplikacij za večje jezike brezplačno dostopna vsem državljanom in državljankam Republike Slovenije. Obstajala je velika želja, da bi bile tudi njihove aplikacije čim bolj dostopne in »prijazne« do invalidov ter starejše populacije.

Skoraj istočasno so nas poklicali tudi iz tujine (podjetji iz Španije in Švedske), kjer so v okviru mednarodnega EU projekta Saapho (http://www.saapho-aal.eu/; AAL projekt – Ambient Assisted Living) želeli ponuditi svojo storitev in uporabniško izkušnjo v slovenskem jeziku naši Zvezi društev upokojencev Slovenije (ZDUS), ki sodeluje pri projektu v vlogi končnega uporabnika. Cilj projekta Saapho je pomagati starejšim osebam pri njihovem sodelovanju v samooskrbni družbi ob ohranjanju in krepitvi samostojnosti s pomočjo uporabe inovativnih IKT tehnologij. Projekt je namenjen podpori aktivnemu staranju, storitve pa so organizirane v treh smereh: sodelovanje (omogočiti socialno vključenost starejših), varnost (zagotavljati varnost in dobro počutje starejših oseb s pomočjo uporabe okoljskih senzorjev; npr. uhajanje plina, merjenje temperature ipd.), zdravstveno varstvo (podpreti starejše osebe pri izvajanju predpisanih zdravstvenih postopkov in zagotoviti dobro zdravstveno stanje s pomočjo ekspertnega sistema). Vsi so se zelo čudili in bili kar malo presenečeni, ko so izvedeli, da za slovenski jezik še ni na razpolago splošno dostopnega in brezplačnega sintetizatorja umetnega govora.

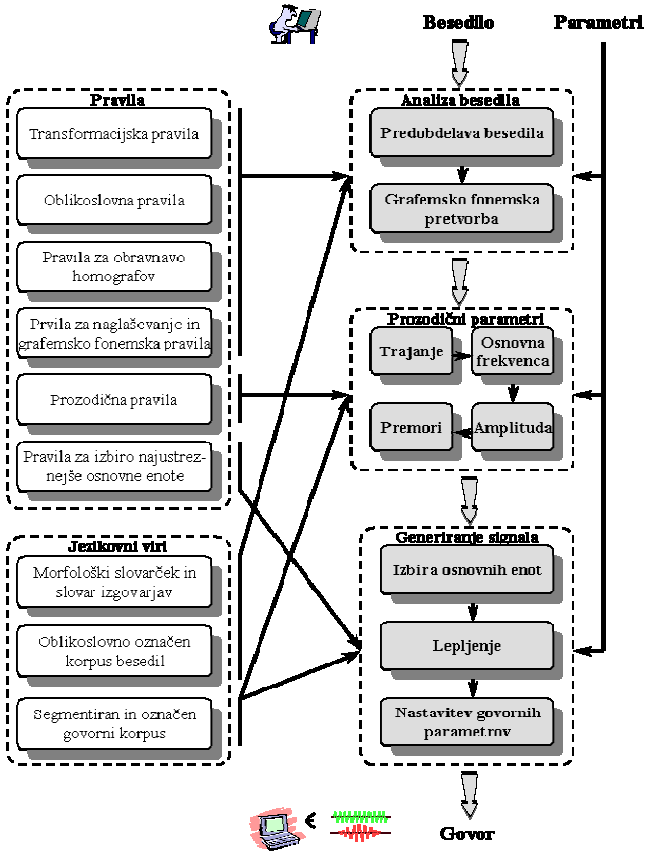
Vse navedeno nas je spodbudilo, da smo vsebino projekta prilagodili, razširili in ga zastavili bolj ambiciozno. Institut »Jožef Stefan« se že več kot dvajset let raziskovalno ukvarja s področjem govornih in jezikovnih tehnologij. V tem času se je nabralo ogromno znanja z obravnavanega področja, prav tako je bilo razvitih večje število prototipov ter cela vrsta govornih in jezikovnih virov (raznih govornih zbirk, slovarjev ipd.). Prav je, da se družbi, ki je v omenjene raziskave vlagala znatna sredstva, slednja tudi povrnejo v obliki nekega uporabnega produkta oz. storitve, ki je na razpolago vsem in to brezplačno. Z nudenjem brezplačne mobilne aplikacije in e-storitve, ki bo omogočala dinamično podajanje informacij v govorni obliki ter v domačem slovenskem jeziku bodo zadovoljene vse predhodno naštete potrebe in povpraševanja. Z izdelavo mobilne aplikacije eGovorec za branje poljubnih slovenskih besedil, delujoče na večjem številu mobilnih platform, bodo dolgoletne vrhunske raziskave z omenjenega področja prenešene v vsakdanjo rabo slehernega Slovenca, še posebej pa kot koristen pripomoček slepim in slabovidnim ter starejši populaciji.

3 eGOVOREC - govorni bralnik slovenskih besedil

Trenutno večina najnaprednejših in najbolj naravno zvenečih komercialnih sintetizatorjev umetnega govora uporablja korpusno sintezo, ki temelji na izbiri najustreznejših govornih enot iz obsežnega in ustrezno označenega govornega korpusa izgovarjav [1, 5]. Uporabnost takega korpusa je zelo odvisna od posnetega besedila, ki mora zajemati čim več različnih osnovnih govornih enot. Razvoj govorne zbirke za korpusno sintezo govora obsega več korakov [4]:

- ustvari se obsežno tekstovno zbirko besedil, ki pokriva različne zvrsti (dnevni časopis, revije, leposlovje ipd.),
- iz zbirke besedil se odstrani vse oznake vezane na oblikovno podobo (glava besedila, tabele ipd.),
- okrajšave, števila ipd. se pretvori v polno besedno obliko (normalizacija besedil),
- besedila se pretvori v predvideni fonetični prepis (grafemsko-fonemska pretvorba),
- optimizira se obseg zbirke glede na vnaprej pripravljene kriterije (metoda požrešnega iskanja); doseči želimo statistično ustrezno vzorčenje izbranega področja govorjenega jezika,
- izbrane stavke se posname (ali pa se izlušči del obstoječih zvočnih zapisov),
- posneto govorno gradivo se fonetično in prozodično označi (samodejno grobo označevanje, fino ročno popravljanje).

Sodobni sintetizatorji govora vsebujejo kompleksno analizo besedila in s številnimi meritvami podprto nastavljanje prozodičnih parametrov.



Slika1: Jedro eGovorca oz. e-bralnika slovenskih besedil

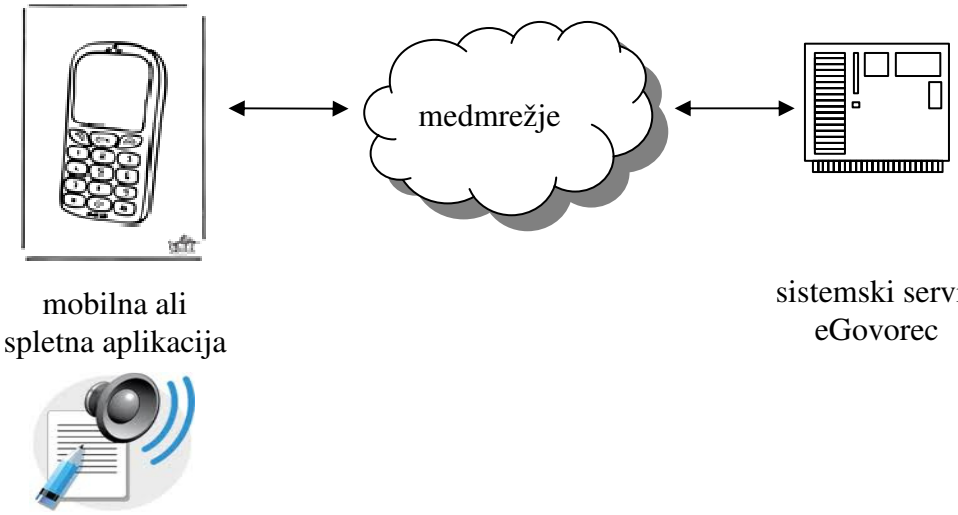
Potreben je primeren združen pomenski in morfološki slovar ter slovar izgovarjav, kar predstavlja osnovo za izboljšave na področju analize besedila, kot npr. naglaševanje sistemu nepoznanih slovenskih besed z metodami strojnega učenja, obravnavo homografov, razvoj okrajšav, številkov in ostalih posebnih zapisov v polno obliko itd. Pravilno naglaševanje slovenskih besed je možno le ob hkratni izvedbi pomenske, stavčne in besedne analize besedila. Sam slovar izgovarjav (brez tesne povezave s pomenskim slovarjem) ne zadošča za učinkovito obravnavo homografov.

Postopki nastavljanja prozodičnih parametrov (trajanje, osnovna frekvenca, premori in glasnost) so izpopolnjeni z natančnejšo statistično analizo konkretnih govornih podatkov.

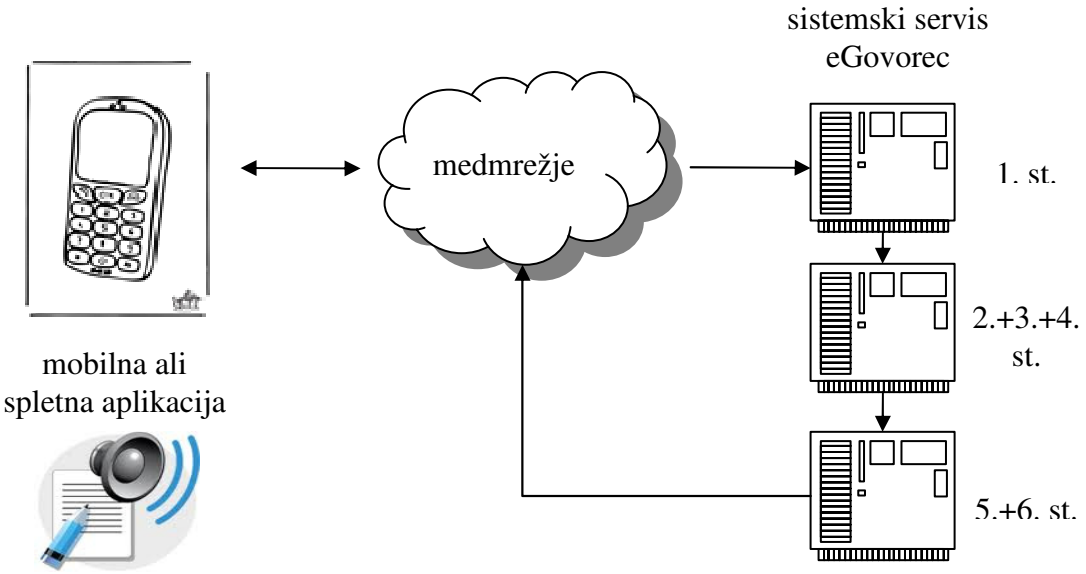
Sistem eGovorec za sintezo neomejenega slovenskega govora sestavlja več med seboj povezanih in hierarhično urejenih modulov (slika 1) [2]:

- analiza besedila (predobdelava besedila, grafemsko fonemska pretvorba) [3],
- nastavljanje prozodičnih parametrov (trajanje, osnovna frekvenca, amplituda, premori) in
- generiranje govornega signala (izbira osnovne enote, lepljenje, sprememba govornih parametrov).

Modularnost ni omejena le na zgornje tri kategorije, ampak se v veliki meri kaže tudi znotraj njih samih. Tako bomo lahko izpopolnjevali posamezne dele sistema neodvisno enega od drugega. Vhod v sintetizator bo predstavljalo poljubno besedilo v slovenskem jeziku, na izhodu pa bomo dobili tekoč, prozodično razgiban govor .



Slika 2 Predlog arhitekturne rešitve na enem strežniku



Slika 3: Predlog arhitekturne rešitve z grozdom

3.1 Predlog arhitekturne rešitve

Jedro eGovorca, ki skrbi za samo sintezo, bo ločeno od uporabniškega vmesnika.

Za izvedbo e-storitve govornega bralnika slovenskih besedil predlagamo izdelavo uporabniškega vmesnika v obliki sistemskega servisa. Sistemski servis skupaj z jedrom bi bil nameščen na samostojen strežnik. Mobilna ali spletna aplikacija prikazano besedilo na željo obiskovalca pošlje sistemskemu servisu eGovorec. eGovorec pretvori besedilo v govor in vrne mobilni (ali spletni) aplikaciji zvočni zapis govora. Komunikacija med spletno aplikacijo (uporaba HTML 5 in spletnih programskih jezikov) ali mobilno aplikacijo in sistemskim servisom eGovorec bi potekala predvidoma z vtičnicami TCP/IP (Slika 2); rešitev podpira IPv6 in IPv4 .

Na takšen način se bo jedro samega sistema eGovorec zelo enostavno posodabljalo s čimer se bo izboljševala tudi kvaliteta umetno generiranega slovenskega govora. Uporabniku glede tega ne bo potrebno narediti ničesar; dovolj bo, da bo uporabil narejeno spletno aplikacijo ali pa si bo na začetku rabe na svojo mobilno napravo naložil v ta namen razvito mobilno aplikacijo, posodobitve pa se bodo brez vednosti in intervencije uporabnika samodejno izvajale na strežniku. Uporaba programa bo zato povsem preprosta in ne bo terjala posebnega vzdrževanja s strani uporabnika.

3.2 Kapaciteta sistema eGovorec

Kapaciteta sistema eGovorec na sodobni enoprocesorski delovni postaji je približno velikostnega reda pet do deset sočasnih sintez v realnem času. Jedro sistema eGovorec je zasnovano tako, da se vsaka stopnja pretvorbe besedila v govor izvajala v ločenih asinhronih nitih. Taka zasnova omogoča zelo hitro vzporedno obdelavo na večprocesorskih računalnikih. V primeru potrebe ga je možno namestiti tudi na grozd računalnikov (v oblaku) tako, da vsak računalnik v grozdu obdela le nekaj stopenj pretvorbe (Slika 3). Programska zahtevnost posameznih stopenj je različna, zato stopnjam, kjer je potrebna večja procesna moč, dodelimo zmogljivejše računalnike.

3.3 Sistemske zahteve

Za jedro sistema eGovorec potrebujemo enega ali več računalnikov z operacijskim sistemom Windows. Operacijski sistem je lahko Server ali Workstation. Računalniki morajo biti povezani v interno mrežo.

Mobilna aplikacija se bo lahko izvajala na več različnih platformah (Android, iOS, Windows Phone, Windows 8), poleg tega bo sistem dosegljiv tudi preko HTML5 in spletnih programskih jezikov, ki so univerzalno dostopni v brskalnikih na vseh platformah. Možna bi bila tudi podpora za Linux.

4 SKLEP

Uporabniški vmesniki, ki podpirajo govorno komunikacijo, omogočajo prijazno uporabniško izkušnjo, kar še posebej pride do izraza pri mobilnih komunikacijskih napravah.

Predstavljeni projekt eGovorec bo omogočil brezplačno rabo novega sintetizatorja slovenskega govora preko inteligentne mobilne aplikacije in e-storitve. Postal bo sestavni del slovenske infrastrukture naslednje generacije mobilnih aplikacij, kar bo slovenski jezik postavilo ob bok drugim »velikim« jezikom. Rezultati več kot dvajset let raziskav na Institutu »Jožef Stefan« s področja govornih in jezikovnih tehnologij bodo tako koristno služili vsej slovensko govoreči populaciji.

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ANALIZA OBNAŠANJA V VEČAGENTNEM SISTEMU

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POVZETEK

V tem prispevku se ukvarjamo z analizo človeškega obnašanja. Predstavljena je adaptacija metode, namenjena analizi obnašanja, kjer se upoštevajo kognitivne interakcije med sodelujočimi agenti. Naloga obsega detekcijo značilnega strateškega obnašanja večjega števila nasprotujočih si agentov, zgolj iz opazovanja njihovih nizkonivojskih premikov (sledi). Strateško obnašanje je definirano kot ponavljajoča se, časovno omejena aktivnost, ki vsebuje relevantne domensko odvisne značilnosti. Programski agenti se tekom simulacije poslužujejo takega obnašanja za dosego določenih ciljev, ki so definirani v domeni. V članku smo aplicirali metodo na domeno mirovnikov, ki skrbijo za nemoten prehod civilistov v vojaško postojanko. Detektirani vzorci obnašanja so predstavljeni v obliki grafičnih strateških sekvenc in ustreznih simbolnih pravil.

1 UVOD

Identifikacija ciljno usmerjenega obnašanja in preferenc agenta, v kompleksnih in dinamičnih domenah, ni enostavna naloga. Čeprav so izvedene sekvence akcij agenta povečini namenjene doseganju zastavljenih ciljev in so v skladu s preferencami agenta, so večkrat prekinjene zaradi potrebe agenta po odzivu na dinamične spremembe v okolju ali zaradi akcij drugih agentov, ki lahko prvemu agentu aktivno nasprotujejo. Zaradi tega je potrebno pri ugotavljanju vzorcev obnašanja upoštevati šumne segmente, ki vsebujejo dele ustreznih sekvenc akcij, pomešane z reaktivnim obnašanjem, ki ni del plana agenta za dosego določenih ciljev in je le odziv na aktivno nasprotovanje iz okolja.

Za reševanje takih problemov smo uporabili metodo CMASDA (angl. Cognitive Multi-Agent Strategy Discovering Algorithm), ki je nadgradnja metode MASDA [1,2]. Osnovna metoda je uspešno detektirala strateško obnašanje agentov med igranjem računalniškega nogometa. MASDA uporablja process abstrakcije, ki omogoča identifikacijo strateških sekvenc, ki jih agenti izvajajo. V primeru robotskega nogometa je to uporaba strategij, ki privedejo do zadetka.

Osnovna metoda večinoma bazira na uporabi fizičnih lastnosti in interakcij med agenti (pozicija, gibanje, utrujenost, itd.), medtem ko spremenjena metoda CMASDA analizira obnašanje dveh velikih asimetričnih skupin agentov: manjša skupina mirovnikov in večja skupina civilistov. Poleg tega pri analizi upošteva tudi kognitivna stanja agentov kot pomemben dejavnik odkrivanja strateških vzorcev.

2 SORODNA DELA

Koncept večplastnega učenja, splošno uporaben koncept strojnega učenja za kompleksne domene, je uvedel Stone [3]. Glavna ideja je uporaba izsledkov učenja nizkonivojskega obnašanja za učenje in detekcijo višje nivojskega obnašanja (strateškega obnašanja). Thurau [4] je kasneje to idejo nadgradil in predlagal, da se pri analizi obnašanja upošteva tri vidike obnašanja: reaktivno obnašanje, ki označuje osnovne agentne premike in uporabo senzorjev za izbiro akcij; taktično obnašanje, za dosego srednjeročnih ciljev in strateško obnašanje, ki opredeljuje dolgoročne cilje.

Kaminka et al. [5] in kasneje Horman et al. [6] sta predstavila metodo analize, ki se uporablja za učenje usklajenega sekvenčnega obnašanja skupin. Sekvence obnašanja, ki ustrezajo značilnim akcijam agentov so grupirana glede na njihovo pogostost pojavitve in glede na statistično odvisnost osnovnih akcij v sekvenci. Gruče posameznih sekvec so prevedena v časovne vrste, kjer poskušajo najti ponavljajoče se sekvence. Njihov pristop temelji na iskanju ujemanj podsekvenc in ne na uporabi grafa akcij, kot v našem primeru.

Kaminka et al. [7,8] je kasneje predstavil metodo razpoznavanja planov za analizo obnašanja. Metoda se poslužuje predefiniranih knjižnic, hierarhično razporejenih vzorcev obnašanja za iskanje ujemajoč se vzorcev. Metoda lahko odkrije le predhodno definirane vzorce in ne more odkriti novih, nedefiniranih vzorcev.

V temu prispevku predstavimo adaptacijo matode MASDA [1,2]. Dodali smo novo taksonomijo, ki vsebuje kognitivna

stanja agentov. Dopolnili smo funkcijo razdalje, da upošteva na novo vpeljano taksonomijo med računanjem razdalje agentov v domenskem prostoru.

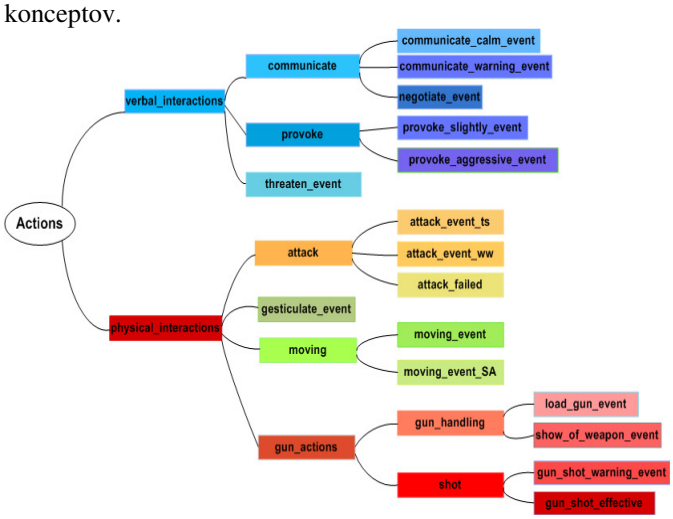
3 COGNITIVE MULTI-AGENT STRATEGY DISCOVERYING ALGORITHM(CMASDA)

CMASDA algoritem odkriva strateško obnašanje skupine agentov. To so lahko ljudje, roboti ali pa programski agenti. Vsem pa je skupno, da z uporabo množice strategij poskušajo uresničiti določene cilje. CMASDA uporablja process abstrakcije, ta omogoča identifikacijo obnašanja, ki je rezultat sodelovanja določenega števila agentov in ne le trenutni odziv agenta na vplive iz domene. Algoritem pretvori večagentne sekvence premikov (sledi izvajanja) in akcij, ki se dogajajo v kompleksnem in dinamičnem domenskem prostoru v grafično in simbolno predstavitev strateških konceptov. Z uporabo hierarhično urejenega domenskega znanja, v obliki taksonomij, lahko algoritem ustvari robustne opise strateških konceptov na različnih nivojih abstrakcije.

3.1 VHODNI PODATKI

Iz opisa sledi, da algoritem zahteva dva tipa **vhodnih podatkov**. Prvi vhod je seznam sledi izvajanja večagentnega sistema. V našem primeru je to log datoteka, ki se ustvari tekom simulacije. Simulacijski log vsebuje vse relevantne podatke, ki se ustvarijo med simulacijo. To so pozicije posameznih agentov, njihovi premiki, izvedene akcije ter njihovo fizično in kognitivno stanje.

Drugi zahtevani vhod je domensko znanje v obliki taksonomij, tj. hierarhična predstavitev domenskih konceptov.



Slika 1: Taksonomija agentnih akcij

Z uporabo hierarhično urejenega domenskega znanja lahko algoritem z večanjem stopnje abstrakcije izlušči višjenivojske strategije.

Na sliki 1 je prikazan primer taksonomije, ki je bila zgrajena za mirovniško domeno. Vse razpoložljive akcije, ki jih agenti lahko v domeni izvedejo smo grupirali in jih povezali v bolj abstraktne koncepte. Tako smo na prvem nivoju taksonomije ločili akcije, ki so v osnovi ali verbalne ali fizične. Na podoben način se akcije nato razdelijo proti listom strukture. Vsak nivo vsebuje bolj specifične koncepte, listi pa vsebujejo akcije, ki jih agenti lahko izvedejo. Algoritmu so poleg taksonomije akcij na voljo še taksonomija vlog in kognitivnih stanj.

3.2 SIMULACIJA

Učne podatke, v obliki dnevniških logov, smo pridobili s poganjanjem večagentne simulacije. V našem primeru je to simulacija mirovniških sil. V njej imamo dve asimetrični skupini agentov. Večja skupina civilistov, ki lahko predstvljajo agresivne protestnike ali mirne opazovalce. Razdeljeni so v dve skupini in vsaka skupina ima svojega vodja ali predstavnika. Vsak agent civilist lahko, glede na njegovo notranje stanje, mirno komunicira z ostalimi udeleženci, ali pa se vede agresivno do mirovniških sil. Naloga slednjih je varovanje vhoda v oporišče in vzdrževanje reda, v primeru nemirov. Sestavlja jo skupina štirih vojakov. Dva direktno pred vhodom in dva nad vhodom, v opazovalnem stolpu.

Sama simulacija se vedno začne na enak način. Civilisti se začnejo zbirati pred vhodom v oporišče, njihova želja je vstop, kjer se lahko prijavijo na neko delovno mesto. Zaradi čakanja in neuspešnosti pogajanj se začnejo med civilisti nemiri. Mirovniki lahko poskušajo posamezne civiliste pomiriti s kretnjami, nato jih opozoriti, sledi proženje orožje, opozorilni strel in onesposobljujoč strel. Glede na izbrane akcije mirovnikov se simulacija lahko izvede na različne načine. Nekateri izidi so ugodnejši, drugi manj.

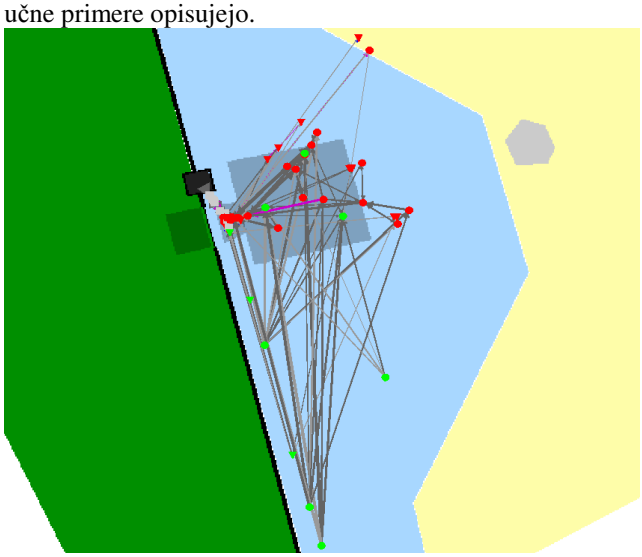
3.3 ANALIZA PODATKOV

Med branjem dnevniških datotek algoritem CMASDA gradi **akcijski graf**. To je usmerjeni graf, kjer vozlišča predstavljajo stanja agentov (pozicija, notranja kognitivna stanja) pred začetkom izvajanja neke akcije in povezave predstavljajo akcije, ki so jih agenti izvedli. Vozlišči a in b sta povezani, če obstaja akcija, ki agenta privede iz stanja a v stanje b. Pozicija vsakega vozlišča znotraj akcijskega grafa je izračunana na podlagi dejanske lokacije v simulaciji. To omogoča lažje pregledovanje in razumevanje grafa. Gradnja akcijskega grafa poteka z uporabo desetih dnevniških datotek. Večje število datotek se uporablja zato, ker agenti le stežka uspejo izvesti vse strateške sekvence v eni igri. Prav tako uporaba večjega števila podatkov poveča zanesljivost najdenih vzorcev.

Tako zgrajeni graf je zelo velik, z nekaj 10.000 vozlišči in razumevanje tako kompleksnih grafov predstavlja veliko oviru, tudi za eksperte. Zato se uporablja postopek hierarhičnega gručenja, ki zmanjša število vozlišč, hkrati pa ohrani večino definiranih akcijskih konceptov. Z iterativnim združevanjem dveh najbližjih vozlišč se generira novo vozlišče, ki vsebuje skupno, bolj splošno vlogo in akcijo agentov. Slednji razberemo iz ustreznih taksonomij. Razdalja med vozlišči je definirana kot linearna kombinacija štirih členov. Fizične razdalje vozlišč v grafu,

razdalje med obema akcijskimi konceptoma v taksonomiji akcij, razdalja med obema vlogama v taksonomiji vlog in razdalja med kognitivnimi stanji v taksonomiji kognitivnih stanj. Ta process se ponavlja, dokler je razdalja med preostalimi vozlišči manjša od določenega praga. Rezultat procesa je **abstrakten akcijski graf (AAG)** (slika 2), kjer vozlišča grafa vsebujejo več osnovnih agentnih akcij. Naslednji korak v algoritmu je pridobivanje relevantnih vzorcev iz AAG. Vzorci so v grafu predstavljeni kot poti in so lahko različnih dolžin. Nekateri so bolj splošni, drugi bolj specifični, eni daljši, drugi krajši, najbolj pomembna pa je mera relevantnosti. Mera pove, kako pogosto se se agenti odločili za izvedbo celotnega vzorca. Pogoste ponovitve sekvenc akcij se smatrajo kot strateško delovanje večagentnega sistema.

Ko smo enkrat pridobili pogoste vzorce ostane še gradnja simbolnih pravil, ki te vzorce opisujejo. CMASDA lahko sama generira učne primere za posamezne akcijske koncepte. Kot smo že omenili, vsebuje vozlišče AAG več vozlišč akcijskega grafa (akcijskih konceptov), ki so bili združeni tekom postopka abstrakcije. Pozitivni učni primeri so vozlišča, ki pripadajo opazovanemu akcijskemu konceptu, negativni učni primeri pa so vsa vozlišča akcijskega grafa, ki pripadajo bilokateremu drugemu akcijskemu konceptu. Iz učnih primerov se generirajo vrednosti za atributni opis. Definirali smo 26 atributov, katerim se za vsak učni primer izračuna vrednost. Nekateri so numerični, drugi nominalni, tretji logični. Zgrajeni atributni opis se poda algoritmu Simple Learner with Iterative Pruning to Produce Error Reduction (SLIPPER) [9]. Izhod algoritma je množica pravil v obliki IF-THEN, ki učne primere opisujejo.



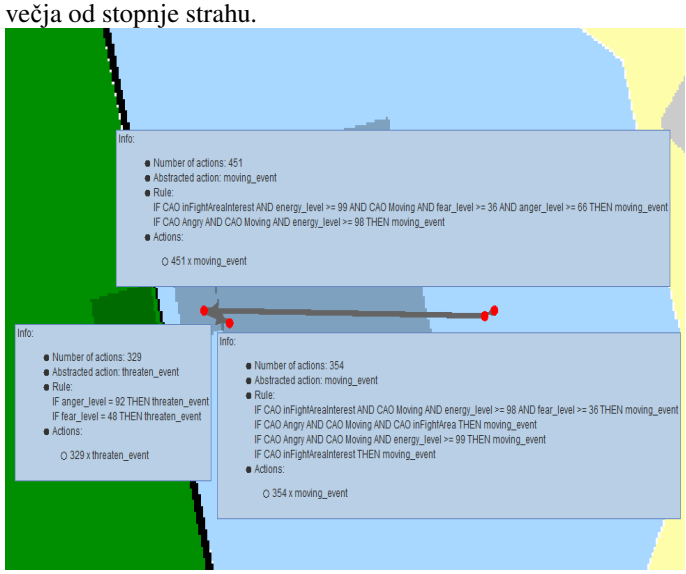
Slika 2: Abstrakten akcijski graf

4 PRIDOBLJENI REZULTATI

Pri analizi nas je zanimala informativnost najdenih vzorcev obnašanja. Osredotočili smo se na grafično in simbolno predstavitev vzorcev. CMASDA algoritem smo pognali na desetih dnevniških datotekah, pridobljenih s poganjanjem simulacije. Za gradnjo vzorcev smo izbrali stopnjo abstrakcije 10, ki se je izkazala kot najboljša, tako po dolžini, kot po informativnosti vzorcev. Generiranje preveč abstraktnih vzorcev ni zaželjeno, saj je pogled na obnašanje agentov preveč splošen in taki so tudi najdeni vzorci. Po drugi strani je uporaba premajhne stopnje abstrakcije podobno nezaželjena, saj ne omogoča razlikovanja med strateškim obnašanjem agentov in premiki, ki so zgolj odziv na spremembe v okolju. V nadaljevanju so prikazani trije relevantni vzorci, ki jih je algoritem našel. Dva za civiliste in eden za mirovnike.

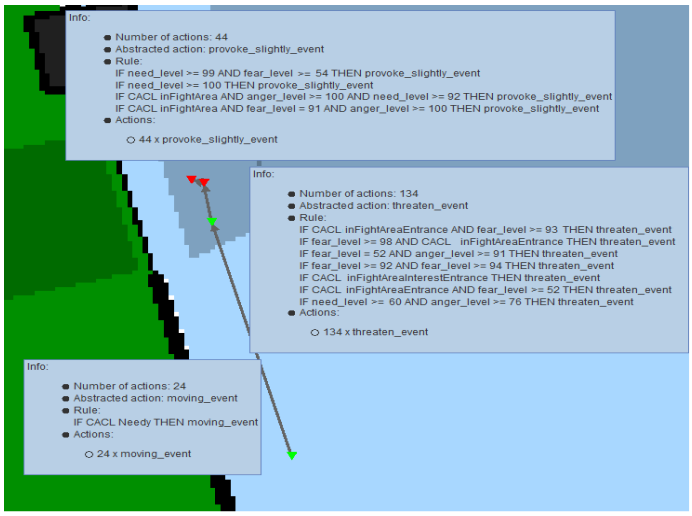
4.1 VZORCI OBNAŠANJA CIVILISTOV

V tem podpoglavju sta predstavljena dva vzorca, ki ju je algoritem označil kot najbolj relevantna. V prvem vzorcu (slika 3) se civilist premika proti vojaku in mu grozi. Pri razlagi si pomagamo tako z grafičnim kot simbolnim delom vzorca. Grafični del prikaže, da se vzorec začne na vzhodnem delu opazovanega območja. Od tam se začne civilist premikati levo, proti vhodu v oporiščem. Pravila ob vsaki akciji nam prikažejo, da je povod za začetek premikanja agenta motiv jeza. Poleg tega je pomembno, da je moč agenta (to je spremenjlivka modela agentov) blizu maksimalne vrednosti. V drugem delu vzorca lahko vidimo, da začne civilist izvajati grožnje, ko je njegova jeza veliko večja od stopnje strahu.



Slika 3: Vzorec premikanja civilista

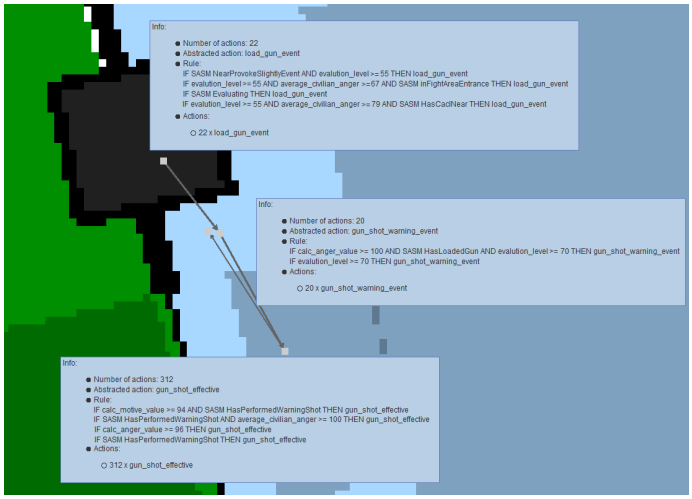
Drugi izbrani vzorec je predstavljen na sliki 4. Ta vzorec opisuje obnašanje vodje civilistov. Vzorec se začne južno od vhoda v oporišče. Zaradi prevladujočega motiva potreba (angl. need) se začne vodja civilistov premikati severno proti vojakom. Ko se vodja približa vojakom jih začne provocirati in jim groziti. Obe ti akciji se zgodita v bližini vhoda v oporišče. Iz simbolnih pravil je mogoče razbrati, da se provokacija s strani vodje običajno zgodi v območju "FightArea", ko je stopnja jeze zelo visoka, prav tako kot stopnja potrebe. Podobno velja za akcijo grožnje (angl. threaten), le da je takrat visoka stopnja jeze in strahu.



Slika 4: Vzorec vodje civilistov

4.2 VZOREC OBNAŠANJA MIROVNIKOV

Na sliki 5 je v nadaljevanju predstavljen vzorec obnašanja mirovnikov.



Slika 5: Vzorec obnašanja mirovnika

Odkriti vzorec je del obnašanja mirovnikov, ki je programiran v simulaciji. Mirovnik pred izvedbo akcije preuči trenutne razmere. Z zaostrovanjem razmer, se zaostrujejo tudi akcije, ki jih mirovnik izvaja. Najprej naproži puško, z namenom ustrahovanja nasilnih agentov. Če to ne zaleže, ustreli opozorilni strel v zrak. V skrajnih okoliščinah pa mirovnik izvede strel v okončine. Podobno kot prej, simbolni del podrobneje opisuje grafični vzorec. Ugotovimo lahko, da mirovnik naproži pištolo, ko ga civilist provocira, ko je povprečna jeza civilistov okoli njega 70-80% in ko je ocena zaostrenosti razmer približno 55%. Ta ocena se računa sproti in temelji na različnih parametrih (jeza civilistov, izvedene akcije, itd.). Bolj zaostrene kot so razmere, večja je ta ocena. Naslednja akcija v vzorcu (opozorilni strel) je izvedena, ko je vodja civilistov v bližini mirovnika in je zelo jezen, vojak je že naprožil pištolo in ocena zaostrenosti je okoli 70%. Mirovnik je v tem primeru ocenil, da so se razmere poslabšale in je potrebno izvesti ostrejšo akcijo. Pravilo za zadnjo akcijo v vzorcu pove, da se učikoviti strel izvede, ko je vodja civilistov zelo jezen, povprečna jeza civilistov v okolici vojaka je na najvišji stopnji in ko je vojak že izvedel opozorilni strel.

6 ZAKLJUČEK

V prispevku smo predstavili medoto CMASDA, ki poleg fizičnih atributov upošteva tudi kognitivne.
Na novo smo definirali tri taksonomije, ki ustrezajo novi domeni in dopolnili funkcijo za računanje razdalje med vozlišči.
Metodo smo uporabili za analizo simulacije mirovnikov, kjer smo se osredotočili na informativnost in razumljivost najdenih vzorcev. Predstavili smo sicer le tri najbolj relevantne vzorce, ampak algoritem najde več kot 50 vzorcev obnašanja. Med njimi je sicer nekaj redundantnosti, saj algoritem ne razloči med semantičnim pomenom posameznih vzorcev. Algoritem namreč klasificira vse vzorce, ki jih agenti večkrat ponavljajo kot pomembne.

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SCALING AND VISUALIZING MULTIOBJECTIVE OPTIMIZATION TEST PROBLEMS WITH KNEES

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ABSTRACT

Knees in multiobjective optimization are regions on the Pareto optimal front where a small improvement in one objective leads to a large deterioration in at least one other objective. Without any additional knowledge on the preference of objectives the points on knees can be preferred to other points on the Pareto optimal front. Consequently, multiobjective optimization test problems with knees are very important as they can be used to test the algorithms' ability of finding solutions on the knees of a Pareto optimal front.

Two existing multiobjective optimization test problems with knees are DEB2DK and DEB3DK with two and three objectives, respectively. This paper introduces their scaled versions with four and five objectives. In addition, Pareto front approximations of these scaled problems are visualized using visualization with prosections. Besides properly visualizing the knees, prosections are able to maintain the dominance relations between most points in the approximation set.

1 INTRODUCTION

Solving a multiobjective optimization problem requires optimization of several conflicting criteria. As a consequence, the solution to such a problem is not a single point, but rather a set of points in the decision space, called *Pareto optimal set*, which corresponds to the *Pareto optimal front* in the objective space. In continuous optimization problems, Pareto optimal sets and fronts contain an infinite number of points.

Multiobjective optimization algorithms try to find a good finite approximation to the Pareto optimal front, called *approximation set*. Only mutually nondominated points are placed in the approximation set, where the dominance relation is defined as follows. Point *a dominates* point *b* if *a* is better than or equal to *b* in every objective and $a \neq b$. To aid the decision maker who selects the preferred solution among those from the approximation set, the points in the approximation sets should have the following properties:

- be located on the Pareto optimal front,
- have the maximum possible spread,
- be well distributed.

While the requirement of a good distribution of points in approximation sets most often translates into a uniform distribution, the desired distribution depends heavily on the shape of the Pareto optimal front. If, for example, the Pareto optimal front has *knees* (regions on the front where a small improvement in one objective leads to a large deterioration in at least one other objective) [2], it is more important that an approximation set contains points on these knees than some uniformly distributed points.

To test whether multiobjective algorithms are able to find points on the knees of Pareto optimal fronts, Branke et al. [2] presented a few benchmark optimization problems with knees (including DEB2DK and DEB3DK), which are based on the well known DTLZ test problem suite [4]. The problems were defined only for two and three objectives. This paper scales the definition of the DEB2DK and DEB3DK problems to four and five objectives and presents also the plots of their approximation sets using the recently proposed visualization technique called visualization with prosections [6, 7].

The rest of the paper is structured as follows. Section 2 presents the formal definition and some example plots of the DEB2DK and DEB3DK test problems, while their scaled versions are introduced in Section 3. Section 4 is dedicated to visualization in 4D and 5D, where prosections are used to visualize their approximation sets. The paper concludes with final remarks in Section 5.

2 DEB2DK AND DEB3DK

The DEB2DK and DEB3DK multiobjective optimization problems with knees are formally defined as:

DEB2DK

$$\min f_1(x) = g(x) r(x_1) \sin\left(\frac{\pi}{2} x_1\right)$$
$$\min f_2(x) = g(x) r(x_1) \cos\left(\frac{\pi}{2} x_1\right)$$
$$g(x) = 1 + \frac{9}{n-1} \sum_{i=2}^{n} x_i$$
$$r(x_1) = 5 + 10(x_1 - 0.5)^2 + \frac{\cos(2K\pi x_1)}{K}$$
$$0 \leq x_i \leq 1, i = 1, 2, \ldots, n$$

DEB3DK

$$\min f_1(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\sin\left(\frac{\pi}{2}x_2\right)$$
$$\min f_2(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\cos\left(\frac{\pi}{2}x_2\right)$$
$$\min f_3(x) = g(x)r(x)\cos\left(\frac{\pi}{2}x_1\right)$$
$$g(x) = 1 + \frac{9}{n-1}\sum_{i=2}^{n} x_i$$
$$r(x) = \frac{r_1(x_1) + r_2(x_2)}{2}$$
$$r_i(x_i) = 5 + 10(x_i - 0.5)^2 + \frac{2\cos(2K\pi x_i)}{K}$$
$$0 \le x_i \le 1, i = 1, 2, \ldots, n$$

Note that all objectives need to be minimized. In both problem definitions, n is the number of dimensions of the decision space and K is a parameter that together with the number of objectives m determines the number of knees in the Pareto front, K^{m-1}. Figure 1 shows the 2D problem with one (a) and three (b) knees, and the 3D problem with one (c) and four (d) knees[1].

In addition, we constructed approximation sets for the problems with one knee. Figure 2 (a) shows an approximation set consisting of 50 points from the known Pareto optimal front of the 2D problem, while Figure 2 (b) analogously presents an approximation set consisting of 500 points from the Pareto optimal front of the 3D problem. The single knee is clearly visible from both plots.

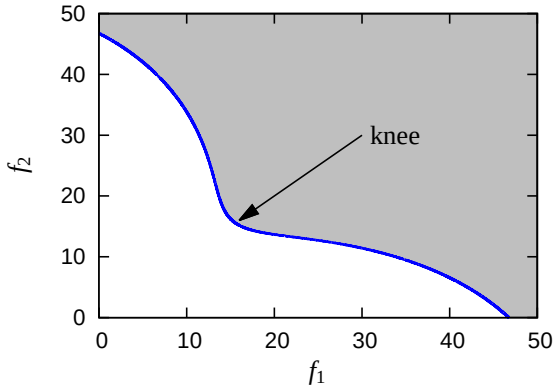
3 SCALING TO 4D AND 5D

As stated in [2], the DEB2DK and DEB3DK problems are based on the scalable DTLZ problems [4] and can thus be in turn scaled to any number of objectives. Here we present their scaled versions in four and five objectives, named DEB4DK and DEB5DK, respectively:

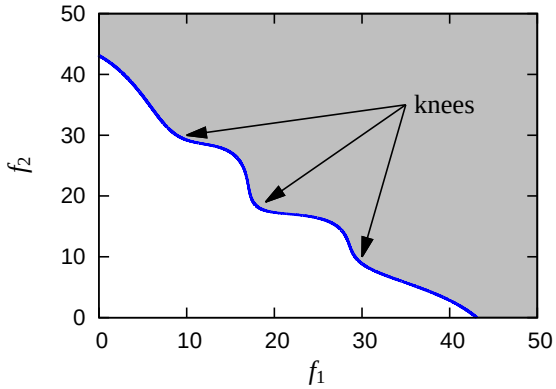
DEB4DK

$$\min f_1(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\sin\left(\frac{\pi}{2}x_2\right)\sin\left(\frac{\pi}{2}x_3\right)$$
$$\min f_2(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\sin\left(\frac{\pi}{2}x_2\right)\cos\left(\frac{\pi}{2}x_3\right)$$
$$\min f_3(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\cos\left(\frac{\pi}{2}x_2\right)$$
$$\min f_4(x) = g(x)r(x)\cos\left(\frac{\pi}{2}x_1\right)$$
$$g(x) = 1 + \frac{9}{n-1}\sum_{i=2}^{n} x_i$$
$$r(x) = \frac{r_1(x_1) + r_2(x_2) + r_3(x_3)}{3}$$
$$r_i(x_i) = 5 + 10(x_i - 0.5)^2 + \frac{3\cos(2K\pi x_i)}{K}$$
$$0 \le x_i \le 1, i = 1, 2, \ldots, n$$

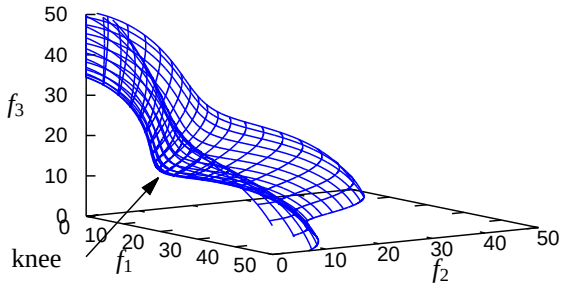
[1]The ranges of objectives of the DEB2DK and DEB3DK problems in this paper differ from the ones presented in [2]. This might be due to an unwanted integer division in the original implementation of these two problems (more specifically, in the calculation of the $g(x)$ function).



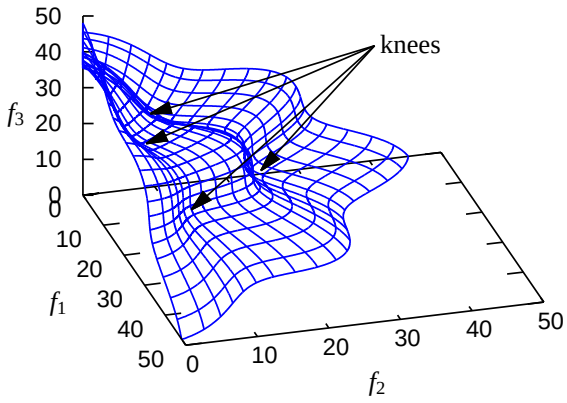
(a) DEB2DK with K = 1 (one knee)



(b) DEB2DK with K = 3 (three knees)

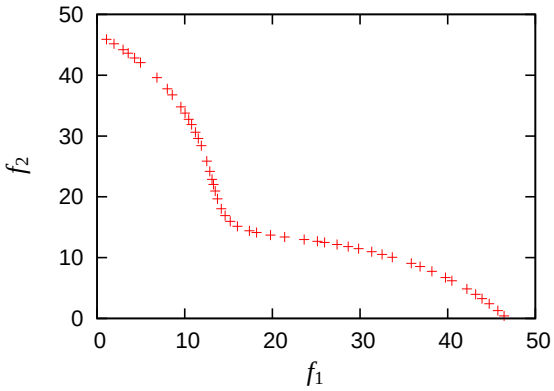


(c) DEB3DK with K = 1 (one knee)

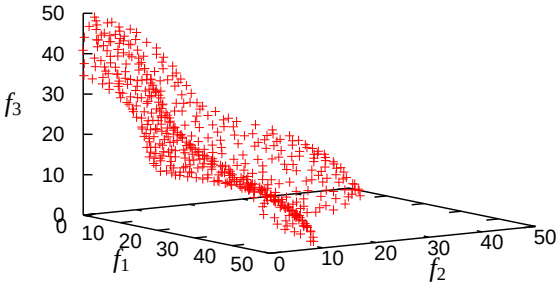


(d) DEB3DK with K = 2 (four knees)

Figure 1: Pareto optimal fronts for different DEB2DK and DEB3DK problem instances.



(a) DEB2DK with K = 1



(b) DEB3DK with K = 1

Figure 2: Approximation sets of the DEB2DK and DEB3DK problems with one knee.

DEB5DK

$$\min f_1(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\sin\left(\frac{\pi}{2}x_2\right)\sin\left(\frac{\pi}{2}x_3\right)\sin\left(\frac{\pi}{2}x_4\right)$$
$$\min f_2(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\sin\left(\frac{\pi}{2}x_2\right)\sin\left(\frac{\pi}{2}x_3\right)\cos\left(\frac{\pi}{2}x_4\right)$$
$$\min f_3(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\sin\left(\frac{\pi}{2}x_2\right)\cos\left(\frac{\pi}{2}x_3\right)$$
$$\min f_4(x) = g(x)r(x)\sin\left(\frac{\pi}{2}x_1\right)\cos\left(\frac{\pi}{2}x_2\right)$$
$$\min f_5(x) = g(x)r(x)\cos\left(\frac{\pi}{2}x_1\right)$$
$$g(x) = 1 + \frac{9}{n-1}\sum_{i=2}^{n} x_i$$
$$r(x) = \frac{r_1(x_1) + r_2(x_2) + r_3(x_3) + r_4(x_4)}{4}$$
$$r_i(x_i) = 5 + 10(x_i - 0.5)^2 + \frac{4\cos(2K\pi x_i)}{K}$$
$$0 \le x_i \le 1, i = 1, 2, \ldots, n$$

Again, n is the number of dimensions of the decision space and K controls the number of knees in the Pareto front. The scaling is performed by adding new objectives in spherical coordinates following the increment of dimension. Also, the $r(x)$ function is updated to include more individual $r_i(x_i)$ functions, while the constant in the $r_i(x_i)$ functions is modified to match the corresponding dimension. The only unaffected function is $g(x)$.

As in the DTLZ problems, the Pareto optimal fronts of all four problems are achieved when the solutions $x = (x_1, \ldots, x_{m-1}, x_m, \ldots, x_n)$ equal $(x_1, \ldots, x_{m-1}, 0.5, \ldots, 0.5)$.

4 VISUALIZING IN 4D AND 5D

There exist many methods for visualizing approximation sets in 4D and 5D (see [7] for a comprehensive review). However, only a few, for example, level diagrams [1], the hyperradial visualization [3] and visualization with prosections [6, 7], are able to show knees of approximation sets. This paper presents the visualization of approximation sets of the scaled problems using prosections.

The term *prosection* means *pro*jection of a *section* [5] and the idea of visualization with prosections is to visualize only a section of the space at a time. All points that fall in this section are projected to one less dimension, while the others are discarded.

The section to be projected is defined using two parameters: angle φ and section width d (see Figure 3). If we wish to perform prosection on the plane $f_1 f_2$ with origin 0, the section is defined as $|f_1 \sin\varphi - f_2 \cos\varphi| \le d$. In the 4D case, all points in this section are mapped using the following function:

$$(f_1, f_2, f_3, f_4) \mapsto (f_1 \cos\varphi + f_2 \sin\varphi, f_3, f_4)$$

In the 5D case, prosection needs to be applied twice (the second time on the plane $f_3 f_4$). Using the angle ψ and section width e, the section now comprehends all points for which $|f_1 \sin\varphi - f_2 \cos\varphi| \le d$ and $|f_3 \sin\psi - f_4 \cos\psi| \le e$. These points are mapped using:

$$(f_1, f_2, f_3, f_4, f_5) \mapsto (f_1 \cos\varphi + f_2 \sin\varphi, f_3 \cos\psi + f_4 \sin\psi, f_5)$$

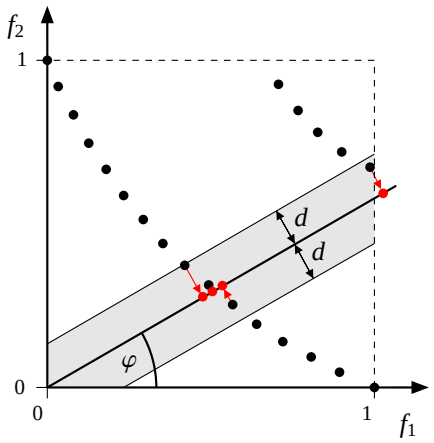
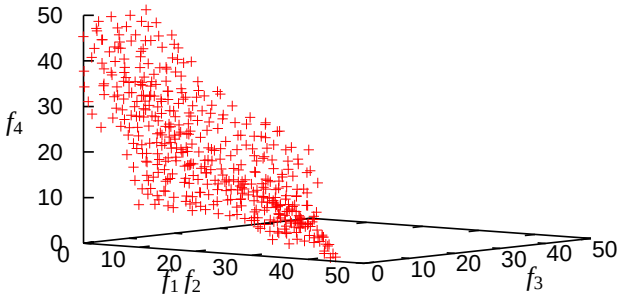
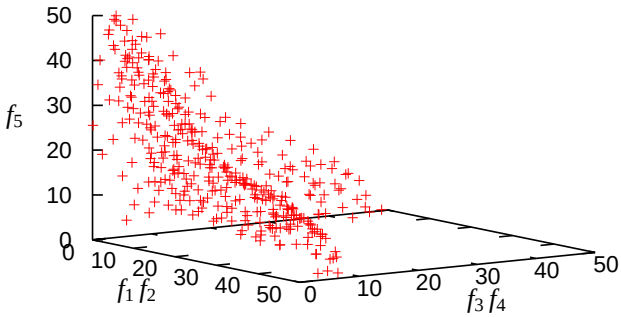


Figure 3: The section and projection used in the visualization with prosections.

The Pareto optimal fronts of the DEB4DK and DEB5DK test problems were sampled using 3,000 and 10,000 points, respectively. These approximation sets are visualized with prosections in Figure 4. In the 4D case, the angle $\varphi = 45°$ and section width $d = 2$ are used. In the 5D case, $\varphi = \psi = 45°$ and $d = e = 3$. As we can see, the knee is clearly visible in both plots, which resemble very much the DEB3DK plot from Figure 2 (b).



(a) DEB4DK with K = 1



(b) DEB5DK with K = 1

Figure 4: Prosections of approximation sets of the DEB4DK and DEB5DK test problems with one knee.

As formally proven in [7], besides maintaining well the shape of the visualized approximation set and the distribution of its points, prosections are able to preserve most of the dominance relations between vectors. This is especially important when comparing multiple approximation set—using prosections, several approximation sets can be visualized simultaneously.

The drawback of prosections is that only a portion of the space is visualized at a time. This requires to explore more than a single angle to gain a full understanding of an approximation set. See [7] for suggestions on how to tackle this issue.

5 CONCLUSION

In [2], the scalable DTLZ test problems were used to form two new multiobjective test problems with knees, called DEB2DK and DEB3DK. While declared scalable to multiple objectives, no formal definition of such scaled test problems was given. This paper presented the scaled problems in 4D and 5D, named DEB4DK and DEB5DK. As the Pareto optimal fronts of 4D and 5D problems cannot be simply plotted (in the way we did with DEB2DK and DEB3DK), we sampled the fronts to obtain two approximation sets. These were then visualized using prosections, which correctly showed the location of knees in the two approximation sets.

ACKNOWLEDGEMENT

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VARNOSTNA VERZIJA INTELIGENTNEGA VRATARJA

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POVZETEK

V prispevku je opisana varnostna verzija inteligentnega vratarja, ki se uporablja za tehnično varovanje prostora. Na trgu obstajajo različne rešitve tehničnega varovanja, pri čemer je njihova slabost ali previsoka cena vezana za naročnino, ali pa kompleksnost uporabe. Predlagana verzija inteligentnega vratarja integrira več funkcij dražjih sistemov in jih implementira na strojni opremi nižjega cenovnega razreda. Prispevek opisuje sistem in ideje za nadaljnji razvoj sistema.

1 UVOD

V sodobni družbi je vse več potreb za nadzor in varovanje prostorov. Podjetja in stavbe z nadstandardnimi stanovanji imajo pogosto vratarje, katerih naloga je, da identificirajo vstopajoče osebe in preprečijo nezaželene vstope v varovani prostor. Problem pri vratarjih je, da so stroški zaposlovanja veliki. Zato so vse bolj priljubljene rešitve tehničnega varovanja.

Na trgu so na voljo različne rešitve tehničnega varovanja. Podjetje Anybots [1] ponuja robota za nadzorovanje vhoda v stavbe, ki omogoča teleprisotnost oddaljenim osebam. Takšen pristop omogoča razdelitev več robotov po različnih lokacijah, pri čemer ena oseba istočasno nadzira več robotov. V primeru nenavadnih dogodkov nadzornik prevzame kontrolo nad določenim robotom, ga premika v prostoru in uporabi za pogovor z namenom identifikacije sumljive osebe. Drugi tip sistema je zasnovan na centralni procesorski enoti, na katero so priklopljeni različni senzorji, kot so infrardeči senzor gibanja, kamera, magnetni kontakti za vrata in okna, senzor dima in vode ipd. [2]. V primeru nepooblaščenega vstopa v nadzorovani prostor, požara ali poplave sistem obvesti uporabnika po telefonu oz. elektronski pošti o nenavadnih dogodkih, uporabnik pa se potem prijavi na spletni portal in pogleda video s kamere. Prednost takšnih sistemov je avtomatsko nadzorovanje prostora, vendar za uporabo potrebujejo dostop do širokopasovnega interneta. Tretji tip rešitev pa najdemo v obliki aplikacij za mobilne naprave. Aplikacije ponujajo možnost zajema gibanja s pomočjo kamere na mobilni napravi [3], možnost snemanja in gledanja videa s kamere mobilne naprave na daljavo [4] ipd. Pomanjkljivost obstoječih aplikacij je, da so večinoma usmerjene na določeno funkcijo nadzora in v primeru, da želimo uporabiti več vrst nadzora prostora, moramo uporabljati več različnih aplikacij.

Na projektu »Inteligentni upravljavski in nadzorni sistem za bivanjske rešitve v lesenih objektih« [7] je varnostna verzija razvita kot prva verzija bolj zapletenega celovitega sistema »Inteligentni vratar«.

Naša motivacija za izdelavo varnostne verzije inteligentnega vratarja je bila, da ponudimo čim več funkcij sistemov tehničnega varovanja za čim nižjo ceno. V ta namen smo uporabili nizkocenovni tablični računalnik kot centralno procesorsko enoto, zasnovan na operacijskem sistemu Android ICS [5]. Za upravljanje s sistemom na daljavo smo uporabili nizkocenovni mobilni telefon, ki je podobno kot tablica zasnovan na Androidu ICS. Na omenjeni platformi smo izdelali dve aplikaciji za tablico in telefon, ki integrirata obstoječe funkcije komercialnih sistemov v enoten sistem. Prednosti našega sistema inteligentnega vratarja je več:

- enkratni stroški nakupa so nizki – aplikacija deluje na strojni opremi iz najnižjega cenovnega razreda,
- kupljena strojna oprema je večnamenska – lahko jo uporabljamo kot navadno tablico oz. telefon takrat, ko ne potrebujemo funkcije nadzora,
- sistem ne potrebuje klicnega centra v ozadju in/ali dostopa do širokopasovnega interneta, ter s tem povezane naročnine – za obveščanje uporabnika o nenavadnih dogodkih in krmiljenje sistema na daljavo zadostuje predplačniški račun,
- sistem ponuja uporabniku številne funkcije po nizki ceni.

Preostali del prispevka je organiziran na naslednji način: v Sekciji 2 je opis sistema, v Sekciji 3 pa predstavljamo ideje za nadaljnje delo.

2 OPIS SISTEMA

Slika 1 prikazuje varnostno verzijo inteligentnega vratarja. Sistem je sestavljen iz tabličnega računalnika in mobilnega telefona brez drugih naprav ali senzorjev. Na tablici deluje aplikacija s funkcijami, opisanimi v nadaljevanju sekcije:

1. nadzor prostora – npr. vhodnih vrat stanovanja,
2. evidentiranje dogodkov,
3. nastavljanje sistema,
4. upravljanje uporabniških računov.

Funkcije aplikacije na telefonu so:

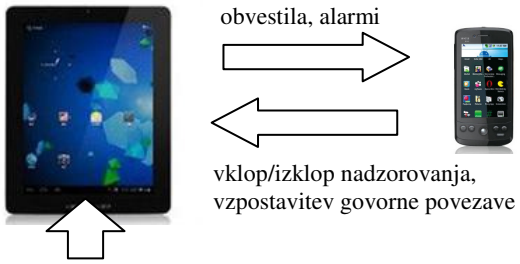
1. krmiljenje sistema na daljavo – vklop in izklop nadzorovanja,
2. klicanje tablice,
3. prejemanje obvestil in alarmov.

2.1 Nadzor prostora

Sistem inteligentnega vratarja implementira več vrst nadzora: video nadzor, nadzor delovanja električnega napajanja, poslušanje dogajanja v nadzorovanem prostoru in ugotavljanje stanja sistema.

2.1.1 Video nadzor

Nadzor se izvaja s pomočjo kamere tabličnega računalnika in algoritma za zajem gibanja [6]. Npr. tablico postavimo na način, da kamera gleda na vhodna vrata stanovanja in vklopimo nadzorni način delovanja. V primeru, ko nekdo vstopi v nadzorovani prostor, sistem zazna gibanje in sproži natančno določeni postopek tihega obveščanja registriranih uporabnikov sistema. Tiho obveščanje pomeni, da sistem na noben način ne pokaže nepooblaščeni osebi, da pošilja obvestila.

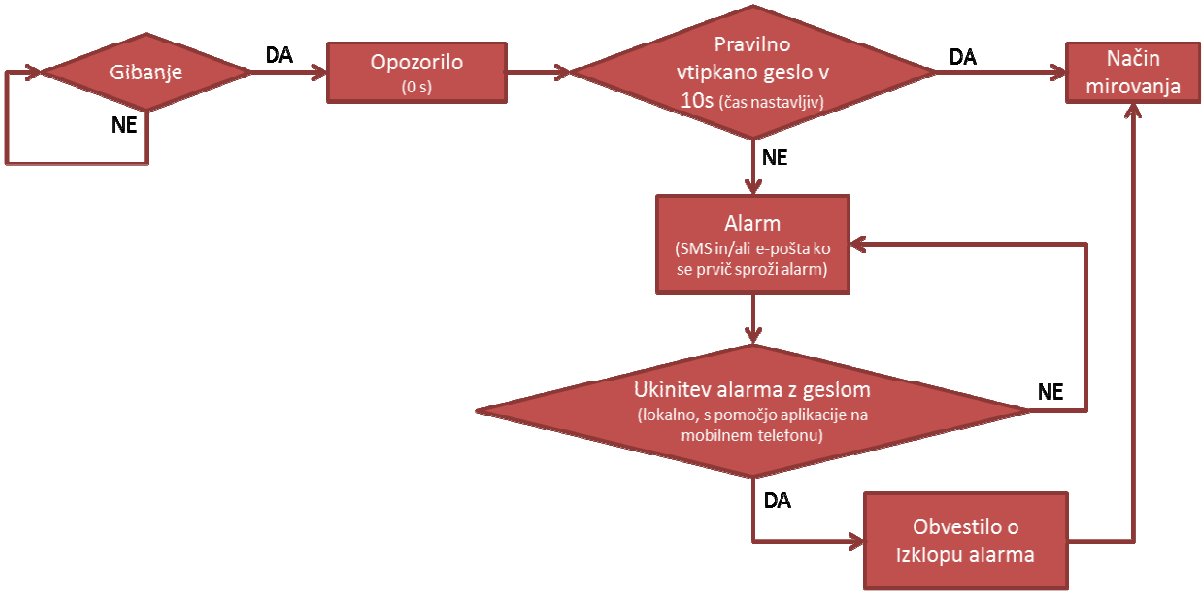


Tablični računalnik:

- vklop/izklop nadzorovanja
- pregled seznama dogodkov
- spreminjanje nastavitev
- upravljanje uporabniških računov

Slika 1: *Shematski prikaz varnostne verzije sistema inteligentnega vratarja.*

Postopek obveščanja je prikazan z diagramom poteka na Sliki 2. Prvi korak, ki ga algoritem izvede, je, da registrirane uporabnike opozori, da je prišlo do nenavadnega dogodka vstopa v nadzorovani prostor. V tem trenutku sistem še ni prožil alarma. Časovno okno med opozorilom in proženjem alarma je namenjeno registriranim uporabnikom, da se identificirajo z veljavnim geslom in izklopijo nadzorovanje brez proženja alarma. V primeru, da se vstopajoči v desetih sekundah (nastavljiv parameter sistema) ne identificira z veljavnim geslom, sistem sproži tihi alarm, oz. registriranim uporabnikom pošlje SMS sporočilo o alarmu in/ali e-pošto z zaporedjem slik, zajetih v obdobju med opozorilom in alarmom. Po obvestilu o alarmu sistem nadaljuje s shranjevanjem slik na tablico vse



Slika 2: *Diagram poteka prikazuje postopek delovanja sistema v primeru detekcije gibanja v nadzorovanem prostoru.*

do trenutka, ko nekdo od registriranih uporabnikov sistema ne izklopi alarm z veljavnim geslom. Vsi uporabniki sistema, ki so bili obveščeni o alarmu, so obveščeni tudi o izklopu alarma.

2.1.2 Nadzor delovanja električnega napajanja

Poleg video nadzora, sistem nadzoruje tudi delovanje električnega napajanja. V primeru, da pride do izpada električnega omrežja, sistem lahko deluje avtonomno več ur, odvisno od kapacitete baterije tablice. Da se tablica ne bi izklopila, s čimer bi se izgubile funkcije varovanja prostora, sistem takoj obvesti uporabnika o izpadu električnega omrežja s pošiljanjem SMS sporočila ali e-pošte. Če uporabnik ne ukrepa in raven baterije pade pod 15%, sistem pošlje dodatno sporočilo, s katerim uporabnika obvesti, da bo sistem kmalu izklopljen.

2.1.3 Zvok

Registrirani uporabnik sistema ima možnost nadzorovanja prostora tudi na način, da posluša zvok v prostoru. To stori tako, da pokliče tablico, tablica pa avtomatsko odgovori. Pri tem tablica na noben način ne pokaže, da je sprejela klic. Če uporabnik izklopi mikrofon na telefonu, lahko posluša dogajanja v prostoru, ne da bi se osebe v bližini tablice tega zavedale.

2.1.4 Stanje sistema

Sistem uporabniku ponuja možnost obveščanja o stanju sistema. V primeru, da sistem zaradi kakršnegakoli razloga preneha z delovanjem (npr. vlomilec je razbil tablico, zmanjkalo je kredita na predplačniškem računu), uporabnik ne bo dobil sporočila o stanju sistema in je to znak za alarm.

Uporabnik ima na izbiro možnosti avtomatskega pošiljanja sporočil o stanju in pošiljanja na zahtevo. Pri avtomatskem pošiljanju uporabnik izbere dan v tednu in uro, ob kateri želi prejemati sporočila. Pri pošiljanju na zahtevo pa uporabi aplikacijo na mobilnem telefonu. V aplikaciji je namenski gumb, ki po SMS sporočilu tablici pošlje zahtevo o stanju. V obeh primerih tablica odgovori s SMS sporočilom in/ali e-pošto z naslednjimi podatki:

- način delovanja sistema – ali je sistem nadzorovanja vklopljen/izklopljen, ali je alarm aktiven ipd.
- zadnji prijavljeni uporabnik sistema,
- delovanje električnega napajanja.

Podobna funkcija je pošiljanje trenutne slike s kamere na zahtevo v primeru, ko uporabnik posumi, da je prišlo do nenavadnega dogodka.

2.2 Evidentiranje dogodkov

Pomembna varnostna funkcija sistema je evidentiranje dogodkov, ki omogoča, da v primeru nenavadnih dogajanj ugotovimo točno zaporedje dogodkov. Zato se pomembni dogodki shranjujejo v bazo in jih je možno pregledovati takrat, ko sistem ni v nadzornem načinu delovanja. Slika 3 prestavlja seznam preteklih dogodkov, ki vsebuje tri tipe dogodkov:

- prijava uporabnika,
- vključitev nadzornega sistema,
- izključitev nadzornega sistema,
- alarm.

Za vsak dogodek je shranjen datum in čas, ter uporabniško ime tistega uporabnika, ki se je zadnji prijavil v sistem. Pregled seznama pa olajša slikovna predstavitev dogodka.

Slika 3: *Seznam preteklih dogodkov.*

2.3 Nastavljanje sistema

Da bi bil sistem čim bolj prilagodljiv končnemu uporabniku, ponuja možnost nastavitve različnih parametrov:

- *izhodna zakasnitev* predstavlja čas med vklopom nadzornega načina delovanja sistema in začetkom nadzorovanja; omogoča, da uporabnik zapusti nadzorovani prostor brez proženja alarma;
- *vhodna zakasnitev* predstavlja čas med zaznavanjem gibanja in vklopom alarma; omogoča, da uporabnik izklopi nadzorni način delovanja sistema brez proženja alarma;
- *obvestilo o zaznavanju gibanja* omogoča uporabniku, da vklopi/izklopi možnost dobivanja opozorila v obliki SMS sporočila ali e-pošte takoj, ko sistem zazna gibanje;
- *ura in dnevi ob katerih se pošiljajo avtomatska obvestila o statusu sistema*;
- *kamera, ki se uporablja za nadzorovanje* – v primeru, ko tablica ima sprednjo in zadnjo kamero, uporabnik lahko izbere, katero bo uporabil za nadzor;
- *občutljivost zaznavanja gibanja* določa odstotek slike, ki se mora spremeniti, da bi sistem ugotovil, da je prišlo do gibanja; v boljših svetlobnih pogojih, kot je konstantna umetna svetloba, je ta prag lahko zelo nizek (1%), v slabših pogojih pa je

treba nastaviti višje vrednosti, s čem se zmanjša verjetnost lažnih alarmov;

- *tip zaznavanja* – uporabnik lahko izbere med dvema algoritmoma za zajem gibanja; v boljših svetlobnih pogojih se bolj obnese algoritem, ki primerja barvne slike, dokler se v slabših pogojih bolj obnese algoritem, ki primerja razlike v svetilnosti slik.

2.4 Upravljanje uporabniških računov

Sistem inteligentnega vratarja je večuporabniški sistem. Vsaki uporabnik določi uporabniško ime in geslo, s katerimi se identificira. Identifikacija se uporablja za aktivacijo sistema inteligentnega vratarja, ter za izklop nadzornega načina delovanja sistema. Prav tako omogoča evidentiranje uporabniških akcij in rekonstrukcijo dogodkov v primeru sumljivih dogajanj.

Uporabniški profili dodatno omogočajo določanje preferenc uporabnikov. Vsak uporabnik lahko določi eno ali več telefonskih številk in e-poštnih naslovov, na katero bo sprejemal opozorila, alarme in/ali obvestila o stanju sistema.

3 ZAKLJUČEK IN IDEJE ZA NADALJNJE DELO

Predstavili smo varnostno verzijo inteligentnega vratarja, ki v primerjavi s obstoječimi komercialnimi rešitvami ponuja nizkocenovno rešitev, ki istočasno integrira funkcije različnih sistemov tehničnega varovanja.

Sistem je v fazi razvoja, ter bo v prihodnosti izboljšan z dodajanjem novih funkcij. Pomembna funkcija bo identifikacija uporabnikov na druge načine poleg tipkanja gesla. Napredne možnosti identifikacije zajemajo poglobljeno analizo videa, analizo pospeškov in identifikacijo z mobilnim telefonom. Druga možnost je omogočanje priklopa na zunanjo strojno opremo kot so elektronska ključavnica in dodatni senzorji. V tem primeru je mogoče implementirati funkcije kot so odklepanje vrat na daljavo ipd.

Zahvala

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MODELIRANJE, SIMULACIJA IN VODENJE DINAMIČNIH SISTEMOV STAVBNE AVTOMATIKE

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ABSTRACT

V prispevku je predstavljen pristop za izvedbo vodenja sistemov stavbne avtomatike s pomočjo programskih agentov. Na kratko je opisano delovanje in uporaba simulacijskega programa EnergyPlus, v katerem smo izdelali dinamični model stavbe vključno z gradniki sistemov ogrevanja in hlajenja. Simulirano delovanje smo izvedli s pomočjo simulacijksega okolja BCVTB, kjer je vključena datoteka z vremenskimi podatki in podatki o prisotnosti uporabnika zgradbe. Simulacijsko okolje povezuje simulacijski model z sistemom vodenja, ki je izveden s pomočjo programskih agentov, razvitih na JADE agentni platformi. Sistem vodenja izkazuje modularnost in deluje decentralizirano, kar omogočajo senzorski in kontrolni agenti, ti pa lahko tečejo na ločenih procesnih enotah. Nazadnje je povzeta arhitektura programskih agentov za vodenje v povezavi z simulacijskim okoljem.

1 UVOD

Sodobni trendi in življenjske navade narekujejo vedno večjo potrebo po udobnem bivanju, česar posledica je večanje poraba energije v gospodinjstvih in poslovnih objektih. Nasprotno pa je v razvitih državah vse več zanimanja za zmanjševanje in optimizacijo rabe energije. Zmanjševanje rabe energije bi bil razlog za manjše onesnaževanje, medtem ko optimalna raba energije pride v poštev pri omejenih in časovno spremenljivih virih energije (sončne, vetrne elektrarne). Podatki iz leta 2010 kažejo, da v Evropi 27% vse energije porabljajo gospodinjstva, 14% komercialne in javne ustanove, 26% industrija, 32% transport [1]. Velika večina energije v gospodinjstvih se porablja za ogrevanje prostorov (57%), ogrevanje sanitarne vode je na drugem mestu (25%), preostali del se porazdeli na razsvetljavo, električne naprave in kuhanje. Glede na statistične podatke, se da z relativno majhnimi prihranki pri vodenju sistemov ogrevanja prostorov in sanitarne vode doseči velike absolutne prihranke pri rabi energije.

Za simulacijo daljšega obdobja delovanja sistema (teden, mesec, leto) je potrebno izdelati model sistema, pri simulaciji pa upoštevati vremenska stanja za čas simulacije. Ker je cilj sodobnih sistemov v pametnih hišah tudi prilagajanje uporabniku, je potrebno v simulacijo vključiti tudi podatke o interakciji uporabnika s sistemom, kot so prisotnost, poraba vode, prižiganje luči, in druge.

V naslednjih poglavjih bodo predstavljena orodja za modeliranje zgradb in sistemov v njih EnergyPlus, okolje za povezovanje simulacijskega modela z sistemom vodenja BCVTB, podatki o vremenu IWEC in podatki o uporabnikovi interakciji z sistemom, pridobljeni iz Tulum in Kastreen baze podatkov. Nazadnje bo predstavljen sistem vodenja s pomočjo programskih agentov, izvedenih v okolju JADE.

2 MODELIRANJE ZGRADB

Stanovanjska ali poslovna zgradba, namenjena bivanju ali delu uporabnika, je skupek množice sistemov. Poznavanje statičnih podatkov, kot so arhitektura zgradbe in materiali, poleg tega pa tudi geografska lokacija (pozicijo in tudi orientacijo) je pomembno za simulacijo, kajti vsaka podrobnost lahko znatno vpliva na kvaliteto dinamičnega modela zgradbe.

2.1 EnergyPlus

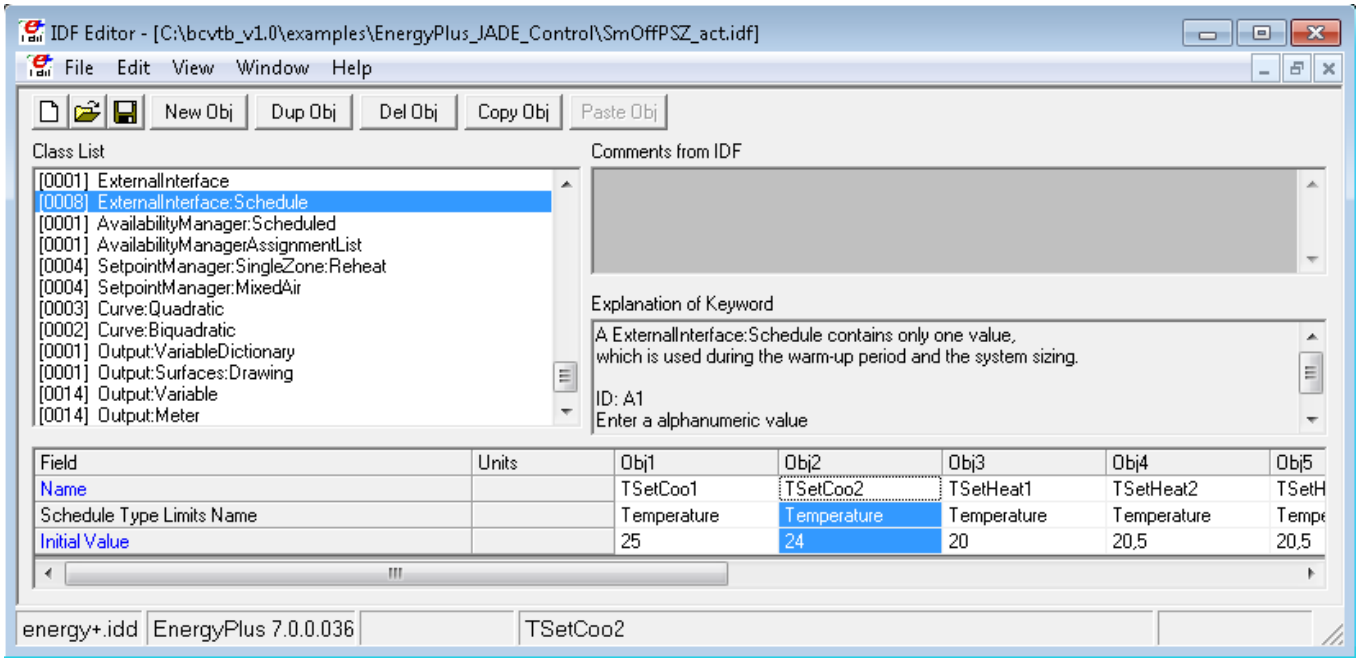
EnergyPlus [2] je prosto dostopen program za modeliranje zgradb z najrazličnejšimi sistemi ogrevanja, prezračevanja, hlajenja (za kar se uporablja angleška kratica HVAC), ogrevanje sanitarne vode, pa tudi razsvetljave in senčenje. S pomočjo programa EnergyPlus je mogoče modelirati dinamične sisteme z uporabo najrazličnejših tehnologij sistemov HVAC – električni grelci, toplotne črpalke, plinske peči in druge.

Končni model vsebuje podatke za potrebe simulacije, kot so časovni korak, ki je lahko najmanj ena minuta, datum začetka ter konca simulacije. Poleg tega model vsebuje tudi podatke o lokaciji in orientaciji objekta, ki so pomembni za simulacijo vpliva sončnega obsevanja, temperature tal in zraka. Pomembni segmenti so definicija konstrukcijskih elementov zgradbe, ki vključujejo definicijo materialov za površine tal, stropov, sten, vrat in oken pa tudi pohištva, ki predstavlja notranjo maso in vpliva na toplotno vztrajnost

* *Operacijo delno financira Evropska unija, in sicer iz Evropskega socialnega sklada.Operacija se izvaja v okviru Operativnega programa razvoja človeških virov za obdobje 2007 – 2013, 1. razvojne prioritete: Spodbujanje podjetništva in prilagodljivosti, prednostne usmeritve 1.1.: Strokovnjaki in raziskovalci za konkurenčnost podjetij.*

prostora. Urnike je mogoče definirati splošno kot kombinacijo dnevnih, tedenskih in letnih urnikov in jih uporabiti za delovanje električnih naprav in prisotnost človeka po posameznih prostorih. Pri definiciji elementov sistema HVAC je mogoče natančno definirati strojne paramtere sistema, termostate in regulatorje za vodenje vključno z referenčnimi vrednosti ter načinom delovanja. Na voljo je tudi obsežno število predlog za najrazličnejše gradnike sistema vključno z izvedbami toplotnih črpalk, grelcev, hladilnih naprav, bojlerjev, shranjevalnikov in drugih elementov, ki jih je mogoče vključiti v celotni sistem.

Slika 1 prikazuje IDF urejevalnik, ki se uporablja za izdelavo modela za simulator EnergyPlus. Levo zgoraj je seznam t.i. razredov, kjer vsak razred predstavlja konstrukcijski ali funkcionalni gradnik stavbe ali definicijo simulacijskih parametrov in podatkov za prikaz. Desno zgoraj je informativni prikaz komentarjev in kratek opis razreda. Spodnji del pa omogoča vnos parametrov za posamezni razred. Primer na zgornji sliki prikazuje definicijo spremenljivk za vodenje ogrevanja in hlajenja - želene vrednosti temperatur posameznih ogrevalnih con, ki jih je mogoče spreminjati s pomočjo zunanjih programov in vmesnika BCVTB. Tekom simulacije je mogoče spremljati spremenljivke stanja in vplivati na referenčne vrednosti termostatov in regulatorjev, kar v povezavi z okoljem BCVTB postane enostavno uporabno z zunanjimi programi za ko-simulacijo ali za vodenje. Obsežen opis posameznih razredov se nahaja v [3].



Slika 1: *IDF Urejevalnik*

2.2 BCVTB

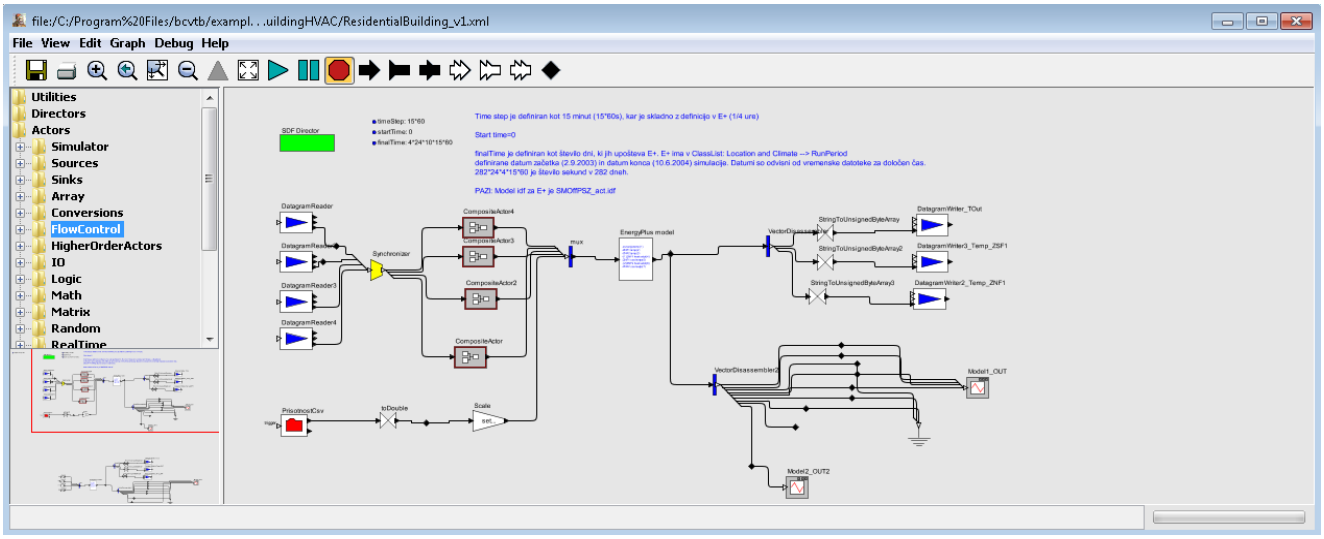
Simulacijsko okolje BCVTB je modularna, odprtokodna programska platforma (Building Controls Virtual Test Bed) in omogoča združevanje različnih simulacijskih programov (EnergyPlus, Modelica, Matlab in Simulink, Radiance in drugih). BCVTB vsebuje grafični vmesnik za izvedbo celotnega modela in skrbi za sinhronizacijo ter grafični prikaz rezultatov med simulacijo [4]. Model zgradbe, izdelan s pomočjo programa EnergyPlus, je vključen v okolje BCVTB, kot prikazuje Slika 2.

Zgornji levi del vsebuje knjižnico elementov, ki jih je mogoče dodati v model in podobno kot v okolju Simulink, vsebuje elemente za prikaz, elemente za pretvorbo, vire signalov, matematične in logične funkcije itd. Desno spodaj pa se nahaja model sistema, ki vsebuje definicijo simulacijskih parametrov – simulacijski čas in časovni korak za integracijo. V sredini se nahaja EnergyPlus model zgradbe, kamor je mogoče vključiti tudi datoteko z vremenskimi podatki. Levo od modela zgradbe elementi predstavljajo komunikacijske vtičnice za prejemanje vhodnih signalov v model (referenčne vrednosti) ter urnike prisotnosti, desno pa komunikacijske vtičnice za pošiljanje izhodnih signalov (stanja sistema) in enote za prikazovanje stanj sistema. Vhodne signale s pomočjo komunikacijskih vtičnic simulacijsko okolje prejema od sistema vodenja, ki bo v našem primeru izvedeno z JADE programskimi agenti, izhodne signale pa simulacijsko okolje pošilja sistemu vodenja.

2.3 Podatki za simulacijo

Za preizkus delovanja sistema smo uporabili obstoječ model hiše, pridobljen z programom EnergyPlus (datoteka SmOffPSZ1.idf), katerega smo priredili za naše potrebe. Vremenski podatki so pridobljeni iz spletne strani Oddelka

za energijo ZDA (US DoE)[2] v formatu IWEC (International Weather for Energy Calculations) za območje Brnika, Ljubljana in so vključeni v okolju BCVTB skupaj z modelom zgradbe. Prisotnost uporabnika ter poraba tople vode je simulirana z uporabo podatkov, pridobljenih iz Kastreen [5] in Tulum [6] podatkovnih baz in je vključena v okolju BCVTB kot vhodni podatek v model sistema, podobno kot vhodni signal v model sistema (Slika 2).



Slika 2: *Okolje BCVTB*

3 SISTEM VODENJA S PROGRAMSKIMI AGENTI

Sistem vodenja je izveden z uporabo programskih agentov, implementiranih v okolju JADE [7]. JADE je javanska platforma, izdelana po specifikacijah FIPA [8] za enostaven razvoj agentnih in večagentnih aplikacij, ki vsebuje orodj za razhroščevanje, spremljanje toka sporočil, sistem rumenih strani, poleg tega pa omogoča modularen razvoj rešitev, enostavno dodajanje, odstranjevanje ter selitev programskih agentov na mobilnih in stacionarnih napravah neodvisno od tipov operacijskega sistema.

FIPA določa referenčni model agentnega sistema. Glede na te specifikacije vsak agentni sistem vsebuje dva ključna agenta: AMS agenta za nadzor nad delovanjem platforme in upravljanje registracij ostalih agentov in DF agenta za storitev rumenih strani. Poleg tega pa JADE vsebuje sloj za prenos ACL sporočil standardiziranega formata in omogoča FIPA Contract net protocol [9], ki omogoča pogajanje med agenti z uporabo medsebojne komunikacije in sporočil, tipa INFORM, REQUEST, REFUSE, QUERRY in drugih.

Za namene vodenja smo razvili dva tipa agentov: senzorski agent in kontrolni agent. Vsak agent ob zagonu vpiše podatke DF agentu, kjer so navedeni: tip agenta (senzor temperature, senzor vlage, senzor prisotnosti, grelec, žaluzija...), lokacija agenta (stavba, nadstropje, soba,..).

3.1 Senzorski agent

Senzorski agent je enostaven tip agenta, katerega naloga je branje senzorskih vrednosti. V našem primeru preko UDP komunikacijskih vtičnic prejemajo stanja sistema, katera pridobivajo iz simulacijskega okolja BCVTB. V primeru, da dobijo zahtevo po podatkih od kontrolnega agenta, lahko pa tudi od drugih agentov, se odziva z posredovanjem senzorskih signalov. V ta namen senzorski agent vsebuje dve niti (JADE agenti praviloma predstavljajo eno procesno nit), pri kateri ena nit skrbi samo za prejemanje sporočil iz simulacijskega okolja, druga nit pa za komunikacijo z drugimi agenti in izpolnjevanje njihovih zahtev. Senzorski agent tako predstavlja fizično napravo – senzor, ki se lahko nahaja na t.i. strežniku nadzornega sistema, lahko pa se nahaja na pravem senzorju, če ta vsebuje procesorske, pomnilniške in komunikacijske zmogljivosti. Ravno tako se senzorski agent lahko nahaja tudi na mobilnem telefonu uporabnika, v kolikor predstavlja npr. senzor prisotnosti človeka.

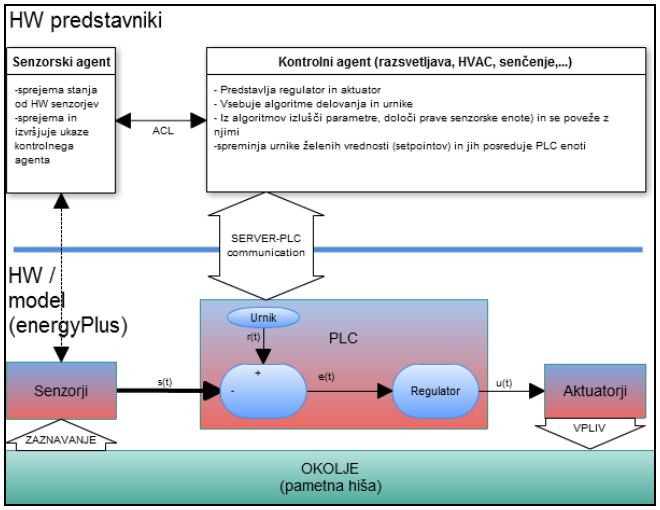
3.2 Kontrolni agent

Kontrolni agent predstavlja enoto za vodenje aktuatorja v sistemu hišne avtomatike. Kontrolni agent vsebuje urnike želenih vrednosti in algoritme za določanje želenih vrednosti sistema.

Kontrolni agent ob zagonu poišče senzorske agente, od katerih želi prejemati stanja sistema za vodenje – izračunavanje referenčnih vrednosti s pomočjo DF agenta. Za tem izda zahtevo po želeni informaciji in frekvenci sporočanja informacij senzorskim agentom. Ko dobi potrditve od senzorskih agentov, prične z vodenjem sistema.

[2]US Department of Energy, spletna stran, http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm, pridobljeno 10.9.2012

Slika 3 prikazuje agentno shemo za vodenje sistemov. Najnižji sloj prikazuje okolje, ki predstavlja dinamični sistem. Senzorji zaznavajo stanja sistema, aktuatorji pa



Slika 3: *Agentna arhitektura v povezavi z sistemom hišne avtomatike in okoljem*

vplivajo na sistem. PLC enota predstavlja programabilni logični krmilnik, ki zagotavlja regulacijo glede na želeno vrednost in napako med dejansko in želeno vrednostjo. Na vrhu se nahajajo senzorski agenti in kontrolni agenti.

4 ZAKLJUČEK IN NADALJNJE DELO

V prispevku so predstavljena orodija za modeliranje, simulacijo in vodenje sistemov v pametnih zgradbah. Modeliranje sistema je izvedeno v programu EnergyPlus. Simulacija dinamike sistema, vključno z vremenskimi podatki za obdobje simulacije in podatki o prisotnosti človeka je izvedena v simulacijskem okolju BCVTB. Vodenje je izvedeno s pomočjo programskih agentov na osnovi JADE agentne platforme, za kar smo izdelali kontrolne in senzorske agente. Nadaljnje delo bo obsegalo preizkus vodenja sistema celotne zgradbe, kar obsega vodenje sistemov hlajenja in ogrevanja ter ogrevanja sanitarne vode, nazadnje pa izvedba nadzornega kontrolnega agenta, ki bo planiral strategijo delovanja sistema z uporabo optimizacijskih metod.

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IMPROVING ACCELEROMETER BASED ACTIVITY RECOGNITION

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ABSTRACT

This paper presents the findings of a research on how to improve activity recognition from data captured with chest mounted accelerometer. Several methods were applied to achieve this purpose, including: simple smoothing technique, hidden Markov models (HMM), extraction of frequency domain features, principal component analysis (PCA) and dynamic time warping (DTW). The paper describes each of the methods and presents the achieved results of our research. The results indicate that these techniques, used separately or in combination, can increase recognition accuracy.

1 INTRODUCTION

Well-performing activity recognition systems have many potential usages. Being able to precisely determine human activity at a certain point in time is potentially useful in many domains. Such systems can help in solving the problem of elderly care [1, 8, 9] and are also valuable for other more mundane usages like: sports, gaming and entertainment industry [2]. Besides being effective, it is also very important, that activity recognition systems strive to be economically feasible for wide spread usage [1]. One of the relatively cheap and widely available technologies, that allow the recognition of activities, is easily accessible wearable accelerometers. However, the person wearing the sensors should also feel comfortable; therefore it is important to keep the number of sensors down to minimum.

For these reasons, we studied different ways of improving the basic machine learning (ML) activity recognition, using data captured with a single chest mounted accelerometer. We tried to achieve greater accuracy by applying various techniques such as simple smoothing technique, hidden Markov models, extraction of frequency domain features, principal component analysis and dynamic time warping. Results show that some of these techniques can potentially improve accuracy, especially if they are combined.

2 CONFIDENCE DATA SET

Our initial data set was created as a part of Confidence project, which is aimed at creating a ubiquitous health care system to support independent elderly living [1]. The recorded activities were: sitting, sitting on the ground, on all fours, lying, standing, walking and transitional activities consisting of going up and going down. We used data captured with a three-axial accelerometer mounted on the test persons' chest. A special test scenario, containing all activities, was created. The scenario was recorded by 11 young, healthy volunteers (7 males and 4 females). It was repeated 5 times by each person, resulting in 55 recordings. Classification accuracy was determined by using leave one person out cross validation technique.

2.1 ML Baseline approach: Random Forest

In order to evaluate our improvement, we first established a baseline approach. The raw sensor data was preprocessed with low-pass filter, which reduced the problem of noise in the collected data. After smoothing the raw sensor data, we applied an overlapping sliding window technique. Inside of every window frame, we computed time domain features such as: standard deviation, mean value and root mean square. The machine learning analysis was made using the application program interface of the software toolkit WEKA. Several algorithms were tested and the Random Forest (RF) was the algorithm that yielded the best results in preliminary tests. RF is an ensemble of decision trees in which the final decision is made by majority vote of the tree models [1]. Baseline classification accuracy was 72.2%. Initially we identified two main problems with this approach. First problem is spurious transitions between activities. Second problem is the inability to distinguish between certain groups of activities such as standing and sitting. Our goal was to address these problems.

2.1 Simple modus classifier output smoothing technique

We first tried to tackle the problem of spurious transitions between classified activities. Results of our ground level RF classification algorithm contained a great amount of erratic transitions from one class label to another. These fast, momentary transitions are impossible to occur in normal day to day activities.

We tried to reduce the problem with a simple technique of changing the activity labels, based on the surrounding labels. Sliding windows of different lengths were used to correct the

recognized activity of the ground level RF classifier. Corrected activity was the majority activity within the observed window. This simple technique presents a variety of other possibilities on how to implement this type of a level two pseudo meta-classifier. Different parameters, for instance length of surrounding window, can be considered. Another version of the same method was also implemented. RF's probability distribution was summed up for each predicted activity within time window. The activity with maximum sum was selected as the corrected activity. However, this variation did not produce any noticeable improvement.

Results of this sliding window smoothing technique showed a slight improvement in accuracy. Classification accuracy increased to 73.8%, which is 1.6 percentage points better than baseline accuracy (Table 1). Although there was an increase in accuracy, this method suffers from a problem of error propagation. In case of miss correcting previous activity labels, we can cause further errors and create sequences of mislabeled activities. Furthermore, it also cannot address the problem of confusion between activities, where chest is in the same vertical or horizontal position, e.g. sitting and standing. These two postures are characterized by chest being in vertical upright position. Easy way to avoid this problem is to combine both types of activities. However, we can argue that this is not a solution per se, but rather a mere elimination of the problem itself.

2.2 Hidden Markov models (HMM)

The problem characterized by spurious class label transitions, lies in the fact, that machine learning algorithms like RF, fail to take into account the continuity of the processes such as human activity. They discretely classify each instance in isolation and assume there is no connection between previous and following instance.

A common way to address this problem, and consequently reduce spurious activity transitions, is to add temporal dependence component by using hidden Markov models (HMM) [3]. HMM observes Markov property, which states that current system state is dependent only on the previous state of the system. The model consists of a number of hidden states and associated transition probabilities between these hidden states. The hidden states emit events with certain emission probability, and these events are observed by the outside observer [4]. Our hidden system states were the true class label sequences, which were unknown. Observed states were RF's predicted class labels. We generated test sequences on our training data. After generating the sequences, we used Viterbi dynamic programming algorithm, which is used to generate the most likely sequence of hidden states given an observation sequence of events [4]. Output of Viterbi algorithm was used to correct the initial RF's erratic predictions.

Using HMM to solve practical problems brings many questions. First question is how to build the initial model. One way is to use Baum-Welch algorithm. Using this approach the obtained classification accuracy slightly increased from 72.2% to 73.9%. We also tried building the Markov model manually, by learning the emission and transition probabilities directly from our training sets. Latter option seems to perform slightly better. As seen in Table 1, classification accuracy increased to 75 %, which is 2.8 percentage points better than our ground classifier. Possible reason, why this later option outperformed the first, is that we were actually learning the distribution of activities in our test scenarios. Building model directly on the training data also brings another potential problem of possible deterioration in performance on new data, since the ratio of our daily life activities and likelihood of transitions between them is not the same. Another question is the selection of the length of training sequences.

To a large degree, we can contribute the improvement in classification accuracy, to the elimination of spurious transitions. Results show slight improvement in accuracy, but the problems of error propagation and inability to distinguish between upright positions like sitting and standing, remain. Next step was an attempt to solve these problems, by improving the classifier on the first level. This effort was based on the notion that, if we get better results with our ground classifier, second level classifier and other techniques, have a bigger chance of performing in a better manner. To achieve this, our next step was to try to improve our feature set.

	Accuracy
Only Random Forest	72.2%
Simple modus smoothing technique	73.8%
Hidden Markov Model	**75.0%**

Table 1: *Comparison of classification accuracy achieved using different techniques.*

3 CHIRON DATA SET

Second part of the research was conducted on Chiron project dataset. Chiron project is an European project whose final goal is to develop reference architecture for personal elderly care [6]. The data set, among other data sources, also contains inertial force measurements captured with three-axial accelerometers. In this section new attributes are derived from the data in order to improve the classification accuracy on the first level.

3.1 Baseline accuracy: Time domain feature set

As in our first experiment, baseline accuracy is evaluated. Raw accelerometer data was preprocessed with low-pass filter. RF was used as a classification algorithm. For the purpose of signal segmentation and time domain feature computation, several lengths of overlapping sliding

windows were used. Feature set contained same time domain features as the ones used in previous section. Due to the fact, that data consists of several different scenarios, we preselected some of them. Selected data contained our target activities: sitting, running, walking, standing, lying, on all fours, standing up and going down. With the exception of adding running activity and removing sitting on the ground activity, target activities are same as in the previous section. Accuracy of ground level classifier, using time domain features, is presented in the first row of the Table 2. Using only information extracted in the time domain, classification accuracy varies from 69.0% up to 72.2%, depending on the length of time window.

3.2 Frequency domain features

In the next step, we tried to enhance the attribute set in the feature vector, consequently increasing accuracy and improving distinction between upright activities. The feature vector includes important cues for distinguishing various activities [2]. Our goal was not to rely solely on time domain features, but to also try to gather addition information from features in the frequency domain. To compute meaningful features in frequency domain over a time window, algorithm needs higher data sampling frequency dataset. This is the reason we used Chiron dataset with 20 Hz sampling frequency. Features focusing on periodic structure of the signal in the frequency domain are also commonly used in other activity recognition studies [2].

We used coefficients derived from Fast Fourier Transforms. Features such as magnitude, spectral energy and maximum magnitude index, were computed for all three accelerometer axis. First we measured accuracy using only frequency domain features. Results are shown in Table 2. Measured accuracy in accordance to our expectations, depends of the length of the overlapping sliding window and ranges from 68.0% up to 76.7%. This time the lower bound is one percentage point less than in the case of using time domain features, but the upper bound is four percentage points better. We also experimented with different combinations of frequency domain feature subsets, but they did not yield significantly better results

3.3 Principal component analysis (PCA)

Principal component analysis (PCA) is a well known and widely used statistical analysis method to transform high dimensional data into a lower dimensional space [2]. It is popular in number of areas ranging from neuroscience to graphics and image compression [5].

Our idea was to extract the information available from the raw signal. By using PCA, we were hoping to utilize the characteristics of the signal. Accelerometer signal consists of x, y and z axis inertial force measurement. If one, for example takes a 64 sample window, this result in 192 attributes, which is a rather big amount of features. Furthermore one can perform PCA on different things. We can take raw signal values, acceleration angles, differences between current acceleration angle and previous angle and other signal characteristics. In order to reduce the number of features we used PCA. Results in terms of classification accuracy of our experiment using PCA are shown in Table 2. We used 3 eigenvectors computed on raw acceleration data. PCA by itself seems to perform worse, than using either only time domain or only frequency domain attributes.

	Sliding window size 16	**Sliding window size 24**	**Sliding window size 32**	**Sliding window size 64**
Time domain features	69.0%	67.6%	72.7%	70.6%
Frequency domain features	68.0%	71.9%	73.0%	76.7%
PCA features	62.8%	63.7%	63.8%	63.0%
Time and frequency domain features	73.4%	73.2%	**76.6%**	71.8%
PCA, time and frequency domain features	**76.8%**	**78.1%**	75.6%	**77.6%**

Table 2: *Table of accuracy of different feature sets and different overlapping sliding window sizes.*

3.4 Comparison of different feature sets

By examining Figure 1, one could draw a conclusion, that using only baseline time domain features (blue line), performs worse than using additional features (red and green line).

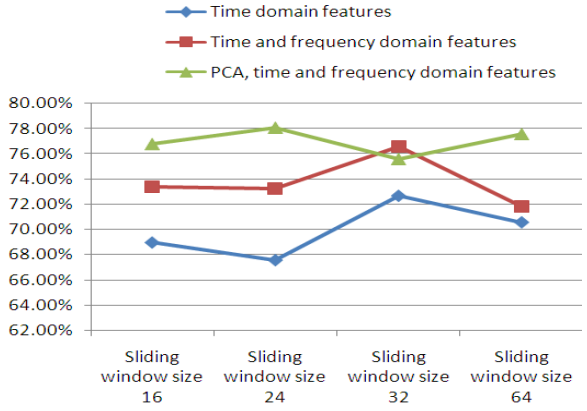

Figure 1: *Comparison of classification accuracy of different feature sets.*

Using all of the available features including frequency, time domain and principal components (green line), at first sight appears to perform better than other feature set combinations, because it achieves greater accuracy for the most of the considered sliding window sizes. It is hard say, if that is really the case, due to the dependence on preprocessing window size and limited number of test

subjects. In an event that this approach would prove to work better, there is still a problem of computational complexity, which increases in accordance to growing number of features. Furthermore, there is also another important thing to consider, since certain other classification algorithms tend to show greater sensitivity to excessive usage of redundant features.

3.4 Dynamic time warping (DTW)

Our basic inspiration for using dynamic time warping (DTW) was to find similarities in the shapes of the accelerometer signal. DTW is a much more robust distance measure for time series, than Euclidean distance measure. It allows similar shapes to match, even if they are out of phase in time axis [7]. This distance measure is widely used in many areas like medicine, science and finance [7].

We implemented an activity recognition system that matched every single test instance, which we would like to classify, against all other instances in our training set and classified the unknown activity to the majority class of the closest n activities. We evaluated our implementation on a small subset of test instances, but it did not perform as well as other previously mentioned techniques and achieved a rather poor classification accuracy of 51.2%. Small subset of instances was chosen, because we stumbled against the problem of high computational time complexity. Issue was mainly caused, because our activity recognition system was designed to match every single test instance, against all other instances in our training set and classified the unknown activity to the majority class of the closest n activities. This implementation also suffers from a similar problem as the lazy k nearest neighbors' (KNN) classifier, since it is always difficult to know how many closest instances one should use in the classification process. Potentially better idea would be to select a subset of exemplary activity of certain target class and compare our unknown activity only against this smaller subset. By implementing our system in this way, the DTW classifier could work faster. The question of how to actually select this smaller subset could present one of the starting points for further research.

6 CONCLUSIONS

It is hard to say with some convincing degree of confidence, which of the used techniques works best. In spite of our endeavors to improve activity recognition, we did not manage to achieve all the expected improvements. One of the problems is the side effect of using different data sets. For this reason results cannot be rightfully compared. Furthermore, research was conducted only on two different data sets. As a consequence of this small verification scale, our findings cannot be generalized to other datasets and it is impossible to say, how well they could perform outside the experiment setting, i.e. in real-time activity recognition setting. It is also very difficult to compare our results with other research findings, since different researches examine different sets of target activities. Furthermore target activities can be defined differently. For instance, the sitting activity can be defined in many different ways e.g.: sitting on the ground, sitting on a chair, sitting with legs crossed etc. This problem of transparency and lack of standard definitions is unfortunately widely present in the field of activity recognition research. However, we can conclude with an optimistic notion that talking small steps is required in order to make a big leap forward. Same principle of gradual progress also applies to making better research and improved activity recognition systems.

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Zbornik 15. mednarodne multikonference

INFORMACIJSKA DRUŽBA – IS 2012

Proceedings of the 15th International Multiconference

INFORMATION SOCIETY – IS 2012

Izkopavanje znanja in podatkovna skladišča (SiKDD 2012)

Data Mining and Data Warehouses (SiKDD 2012)

Uredila / Edited by

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PREDGOVOR / PREFACE

ODKRIVANJE ZNANJA IN PODATKOVNA SKLADIŠČA

Tehnologije, ki se ukvarjajo s podatki so v devetdesetih letih močno napredovale. Iz prve faze, kjer je šlo predvsem za shranjevanje podatkov in kako do njih učinkovito dostopati, se je razvila industrija za izdelavo orodij za delo s podatkovnimi bazami, prišlo je do standardizacije procesov, povpraševalnih jezikov itd. Ko shranjevanje podatkov ni bil več poseben problem, se je pojavila potreba po bolj urejenih podatkovnih bazah, ki bi služile ne le transakcijskem procesiranju ampak tudi analitskim vpogledom v podatke – pojavilo se je t.i. skladiščenje podatkov (data warehousing), ki je postalo standarden del informacijskih sistemov v podjetjih. Paradigma OLAP (On-Line-Analytical-Processing) zahteva od uporabnika, da še vedno sam postavlja sistemu vprašanja in dobiva nanje odgovore in na vizualen način preverja in išče izstopajoče situacije. Ker seveda to ni vedno mogoče, se je pojavila potreba po avtomatski analizi podatkov oz. z drugimi besedami to, da sistem sam pove, kaj bi utegnilo biti zanimivo za uporabnika – to prinašajo tehnike odkrivanja znanja (data mining), ki iz obstoječih podatkov skušajo pridobiti novo znanje in tako uporabniku nudijo novo razumevanje dogajanj zajetih v podatkih. Slovenska KDD konferenca pokriva vsebine, ki se ukvarjajo z analizo podatkov in odkrivanjem zakonitosti v podatkih: pristope, orodja, probleme in rešitve.

Marko Grobelnik in Dunja Mladenić

DATA MINING AND DATA WAREHOUSES (SIKDD 2012)

Data driven technologies have significantly progressed after mid 90's. The first phases were mainly focused on storing and efficiently accessing the data, resulted in the development of industry tools for managing large databases, related standards, supporting querying languages, etc. After the initial period, when the data storage was not a primary problem anymore, the development progressed towards analytical functionalities on how to extract added value from the data; i.e., databases started supporting not only transactions but also analytical processing of the data. At this point, data warehousing with On-Line-Analytical-Processing (OLAP) entered as a usual part of a company's information system portfolio, requiring from the user to set well defined questions about the aggregated views to the data. Data Mining is a technology developed after year 2000, offering automatic data analysis trying to obtain new discoveries from the existing data and enabling a user new insights in the data. In this respect, the Slovenian KDD conference (SiKDD) covers a broad area including Statistical Data Analysis, Data, Text and Multimedia Mining, Semantic Technologies, Link Detection and Link Analysis, Social Network Analysis, Data Warehouses.

Marko Grobelnik and Dunja Mladenić

Vabljeni predavanji

Invited lectures

Social Media Monitoring Tools and Services

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ABSTRACT

Selecting the right social media monitoring (SMM) tool has become a challenging task for organizations as SMM industry has branched out to embrace diverse technologies, data types, and numerous vendors confusing buyers. New tools and services are emerging continually, while already established SMM companies are frequently improving their products with new features and broader data coverage. In this study we provide a comprehensive view of the SMM market, product offerings, and business applications, to assist organizations in choosing and employing the SMM tools to best address their specific business goals.

1 INTRODUCTION

The rapid proliferation of the social media platforms and online communications has profoundly changed the world of traditional marketing, market research, PR, advertising, customer services, and even innovation. It has been disruptive and presented challenges to many businesses. However, it has also opened up tremendous opportunities for business of all sizes. Companies are increasingly investing in social media programs and experimenting with SMM technologies to monitor and solicit public opinion about their brand and products, shape their online presence and develop strategies to leverage social media.

However, most of the businesses are struggling with selecting the right SMM tools and services for their needs and defining success metrics to justify their investments in SM. They are often faced with lack of transparency in SMM product offerings, cumbersome pricing structure, limited data coverage, inadequacy of the user interface, excessive data latency of some tools, low reliability of the data and inability to reach the desired quality of SM analysis. At the same time, the SMM technology providers aim at delivering unique SMM solutions in terms of technologies they use, key features and pricing they offer. This often presents challenges to organizations that are just embarking on SMM or upgrading their existing SMM activities and it is difficult to make an informed decision without having an overview of the current options and new trends.

1.1 Methodology

Through extensive secondary research and interviews with experts and social media vendors, we collected information on 250 SMM technology and services. We carefully examined tool descriptions on the official company and product Web site. We supplemented that information with product reviews, vendors' comments, and market reports in order to create a comprehensive profile for each of the 250 reviewed SMM tools and services.

2 CONSIDERATION OF KEY FEATURES AND BUSINESS APPLICATIONS

Based on the analysis of the profiles we have compiled a list of key features and outlined aspects that are important to take into account when making the selection of SMM products. They include:

- **Data management features** such as data coverage, data latency, alerts, data export, Application Programming Interface integration, data archiving,
- **Data analysis and visualization features**, including sentiment analysis, influencer profiling and analysis, viral content tracking and analysis, trend analysis, topic and theme analysis, word/tag cloud, competitive monitoring and analysis, campaign management and measurements,
- **Process management and user interface**, including dashboard, workflow management, Client Relationship Management (CRM), and
- **Factors influencing purchasing decisions** including pricing, key clients and year when the tool or service was made publicly available.

In addition, we detailed key business applications of SMM technologies that are promoted by the reviewed products. Investment in SMM requires careful consideration, as in order to realize a long term value from SMM one needs to integrate SMM with other business processes. This may include measuring the business impact of social media marketing, strengthening customer engagement, increasing retention and revenue from current customers, or implementing SM campaigns to acquire new customers. By having a clear understanding of how SMM supports business, one can make a transition from experimental, tactical to a more strategic use of SMM.

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Sustainability of Social Media: Design, Engagement, and Business Models

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ABSTRACT

Social media services are complex ecosystems of human and technology where the user engagement and the infrastructure support need to be in balance. Sustainability of social media fundamentally depends on the ability to instigate and maintain the user engagement over time and develop business models that leverage that engagement to support the underlying technology. Thus, it is of paramount importance to develop techniques and metrics to monitor the health of the community and to adopt business models that are effective yet compatible with the users' expectations and established trust. In this presentation we discuss the design challenges of social media, the tools for network analysis, and the implications of the advertising business models for user privacy.

1 INTRODUCTION

In contrast to the traditional computing systems which are focused on computation, social media services fundamentally depend on the human engagement. Social media aim to satisfy and leverage specific user needs that are met through social interactions. This can range from intellectual engagements in online forums and question answering services to role playing in online social games.

Real time monitoring of the service use is important to provide adequate technical support. However, it is equally essential to develop methods for more in-depth analysis of the user engagements. We need to understand the roles of individuals, the community dynamics, and the opportunities for designing new applications to meet the needs and desires of the community. This requires involvement of sociologists, interaction designers, and experts from other non-technical domains. They, in turn, need the means for analyzing data without having to write programs to implement network analysis algorithms.

2 DESIGN AND USER ENGAGEMENT

Designing user interfaces for social media is a challenge. An apparently small feature can have a significant impact on the user activities and the development of the community. Thus, it is essential to develop tools and metrics that are accessible to non-programmers and enable them to observe the impact of designs. Tools like NodeXL (http://nodexl.codeplex.com) exploit the traditional spreadsheet paradigm to enable import of network data and analyses through interactive visualization. While the layout and analysis features may seem simple, the algorithms that support them can be rather sophisticated. Our latest research has focused on novel methods for encoding network propagation events so that one can efficiently identify and visualize dynamic motifs in the propagating networks.

Similar visualization tools can be used to increase self-awareness of individuals within the community. The desire and ability of individuals to shape their persona are fundamental to human beings and the societies establish practices to support self-determination of individuals. We suggest that the designs of social media equally empower digital self-determination of the users since that is a powerful factor in shaping a community.

3 ADVERTISING AND PRIVACY

Dominant business model in social media is advertising although successful businesses have managed to introduce alternative streams of revenue from the distribution of media content to the sales of virtual goods in online games. Underpinning the current advertising practices are extensive user profiling and real time tracking. In many instances the users are not informed about the extent of surveillance they are subject to. The designs of the user interfaces provide no indications of such practices. For example, third-party monitoring based on browser cookies is invisible to the user. Yet, the user is followed across Web sites and the private browsing information is shared among the participating sites. While cookie monitoring is, in principle, anonymous, the social media sites may in fact have information about the physical persona. By cross referencing the data from social media with cookie tracking, the user's online interactions cease to be anonymous.

4 CONCLUDNIG REMARKS

Social media platforms provide opportunities for innovative services that can improve the way our societies function. However, that requires effort by inter-disciplinary teams of experts who can address a wide range of issues, from design to policies and economic models that can ensure sustainability of social media and foster fundamental human values and civil liberties.

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Regular lectures

ARE YOU FOR REAL? LEARNING EVENT FACTUALITY IN CROATIAN TEXTS

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ABSTRACT

There is a certain discrepancy between *real-world events* and their representations in text (*linguistic events* or *event mentions*). The event mentions often refer to future or hypothetical events that have not actually occurred or whose occurrence is uncertain. In this paper we address the problem of predicting event *factuality* in Croatian texts using supervised machine learning. For each event mention, we aim to predict its *polarity* (whether the denoted event has actually happened) and its *certainty* (the level of confidence that the denoted event has happened). We use only lexically-based features, in order to investigate how well this problem may be addressed for a resource-poor language such as Croatian. Our preliminary results suggest that while predicting event polarity using only lexically-based features is feasible, predicting event certainty mandates the use of more sophisticated features.

1 INTRODUCTION

In natural language texts (e.g., news articles) events from the real world (*extralinguistic events*) are represented by means of *linguistic events* or *event mentions*. However, there is a discrepancy between real-world events and their linguistic representations. Not all event mentions in text denote real-world events that actually occurred. Some event mentions indicate the absence of on event happening in the real world (e.g., "The president *didn't visit* Cuba last month") or the uncertainty of an event happening (e.g., "He *suspected* the plane *crashed*"). *Event factuality* has recently been defined as as the level of information expressing the factual nature of eventualities mentioned in text [8]. The factuality of an event may be defined in terms of its *polarity* (not to be confused with sentiment polarity) and *certainty*, as illustrated by the two previous examples. Recognizing the *polarity* of event mentions aims to distinguish between event mentions describing an action or occurrence in the real world from those describing the lack of it. *Certainty*, on the other hand, refers to the level of confidence (*certain*, *probable*, or *possible*) expressed about the occurrence of a denoted real-world event.

Recognizing that an event is being reported as a fact rather than just a possibility, or that an event mention is referring to something that in reality never happened, may be important for many NLP applications, such as question answering, information extraction [5], and textual entailment [4]. In temporal reasoning [10], for example, events are usually placed on a timeline; information about event factuality is important for deciding which mentions may be temporally grounded.

In general, the factuality of events is the result of an interaction of multiple linguistic elements at lexical, syntactical, and discourse levels [8]. In this paper we focus only on lexical sources of factuality (polarity and certainty clues), investigating the feasibility of factuality prediction for resource-poor languages, such as Croatian. We present a supervised machine learning model that combines multiple lexically-based features for polarity and certainty prediction, framing the polarity prediction as a binary classification task (*positive* vs. *negative* events) and certainty prediction as a ternary classification task (*certain*, *probable*, and *possible* events).

The remainder of the paper is organized as follows. In the following section we discuss the related work. In Section 3 we describe lexical features used for detection of polarity and certainty of events. We present experimental results in Section 4 and we conclude in Section 5.

2 RELATED WORK

Event extraction has received a lot of attention in the last couple of years. The interest was sparked by two evaluation campaigns specifically focusing on events: ACE [1] and TempEval [11]. In addition to extraction of event mentions themselves, the TempEval campaign also addressed the problem of automated extraction of event properties, such as tense, aspect, modality, and polarity. Although the notion of event polarity was already considered in the TempEval event extraction task, it was reduced to cases in which the event negation is expressed explicitly (e.g., "She did *not teach* for a year"). In the context of factuality detection, the polarity is considered more broadly and includes the cases in which the absence of an action is expressed implicitly (e.g., "The government *failed* to *increase* stability in the region.").

Karttunen and Zaenen [5] discuss the factuality (or *veridicity*, as they call it) of events from a linguistic point of view, suggesting how information extraction approaches could benefit from their observations. They emphasize the importance of assigning factuality statements and expressions to their sources. E.g., in " The president said that the police *may* have *failed* yesterday", the uncertainty of "police failing", introduced by the factuality marker *"may"*, should be credited to "The president" rather than to the author of the text. Karttunen and Zaenen, however, do not consider polarity and certainty as two separate aspects of event factuality.

Saurí and Pustejovsky [8] extend the linguistic observations made by Karttunen and Zaenen and dissect event factuality

into polarity and certainty. Based on a rich set of linguistic observations they build a rule-based system for identifying event mention's polarity (*positive* or *negative*) and certainty (*certain*, *probable*, and *possible*). As they observed that syntactic subordination is directly involved in the factual characterization of events, their rule-based computational model traverses the tree of syntactic dependencies in a top-down fashion, adjusting the factuality values for events according to polarity and certainty clues found in the nodes of the dependency tree. In this paper, we embrace the notions of event polarity and certainty as defined in [8], classifying event polarity as either *positive* or *negative*, and event certainty as either *possible*, *probable*, or *certain*. Unlike [8], we use supervised machine learning instead of a rule-based computational model. As our goal is to determine whether event polarity and certainty can be efficiently predicted for resource-poor languages, we use only lexically-based features for building our models.

Factuality statements for events mentioned in text always have a source, whether it is implicit (the author of the text) or explicit (usually a subject of predicates such as *say*, *know*, *think*, *believe*, etc.). As observed in [5] and [8], a single event mention can be assigned multiple (possibly even conflicting) factuality assessments coming from different sources (e.g., "I *doubt* that Greece *may* believe Germany *would save* its economy"). Identifying factuality sources and attaching factuality statements to them is out of the scope of this paper. We focus on determining the dominant polarity and certainty value for each event, regardless of factuality source.

3 FACTUALITY PREDICTION WITH LEXICALLY-BASED FEATURES

There are many languages, currently also including Croatian, for which linguistic tools and resources are rather scarce. For such languages, linguistic processing (even at the semantic level) has to rely on low-level, mostly lexically-based features. In this section we describe lexically-based features used for supervised learning of event polarity and certainty.

Polarity and certainty features. The following is a list of features used for both polarity and certainty classification:

1. *Word*, *lemma*, and *stem* of the event anchor – An event anchor is the word bearing the meaning of the event. Lemmatization was performed using the semi-automatically acquired morphological lexicon for Croatian [9]. A very simple stemming was employed; we remove the suffix from the last vowel in the word (or the penultimate vowel if the last letter in the word is also vowel). Words shorter than 5 letters were not stemmed;
2. *Ending* of the event anchor – The suffix of the word after the last vowel (or the penultimate vowel, if the last letter is a vowel);
3. *Morphosyntactic descriptor* of the event anchor – The MULTEXT-East morphosyntactic descriptors [2] are also obtained from the semi-automatically acquired morphological lexicon [9];
4. *Bag-of-words (BoW)* of the left and right context of the event anchor – We use two separate feature sets, one for the left context BoW and one for the right context BoW. We define the context as a token window of size 5;
5. *Lemmas* of the first tokens preceding and following the event anchor;
6. *Event type* – The TimeML-based type of the event (cf. Section 5);
7. *Verbal and deverbal noun* – A binary feature indicating whether the event anchor is a verbal or a deverbal noun (e.g., *trčanje – running*). This feature is motivated by the observation that events expressed as (de)verbal nouns tend to be more hypothetical;
8. *Interrogative sentence* – A binary feature indicating whether the sentence containing the event is interrogative. In an interrogative sentence something is unknown (hence the question), thus events in interrogative sentences are more likely to be uncertain;
9. *Argument of another event* – A binary feature indicating whether an event anchor is an argument of another event. Events that take another event as argument are of *intentional action* (I_ACTION) type [7]. We do not use a syntactic parser, thus we cannot detect event arguments based on syntactic relations. Instead, we consider that event e_1 has another event e_2 as its argument if e_1 is of I_ACTION type and e_1 occurs in a two-token left context of e_2. This will be wrong in a small number of cases in which two events are close to each other and there is no syntactic relation between them. Events that are direct arguments of other events tend to be non-factual more often. E.g., in "Napadač je *propustio postići* pogodak" ("The striker *failed* to *score* the goal"), the governing event (*propustio – failed*) indicates non-occurrence of *"scoring"*, while in "Kofi Annan je *pokušao uspostaviti* mir u Siriji" ("Kofi Annan *attempted* to *establish* peace in Syria"), the governing event (*pokušao – attempted*) indicates the uncertainty of *"establishing"*;

Polarity features. The following is the list of features used only for polarity classification:

1. *Negativity clues* found in the left context – The left context of the event consists of all the sentence tokens preceding the event anchor. We compiled a set of most frequent negativity clues in Croatian (inflectional forms of *not to be* and *not to want*, and additionally the words *no*, *noone*, *nothing*, *nowhere*, *never*, and *neither*): *ne*, *nisam*, *nisi*, *nije*, *nismo*, *niste*, *nisu*, *neću*, *nećeš*, *neće*, *nećemo*, *nećete*, *nikad*, *nigdje*, *nikome*, *ništa*, *ni*, *niti*;
2. *Negativity clues* found in the immediate left context – The same negativity clues as above, but restricted to those occurring closer (within a three-token window) to the event anchor. Considering both the immediate and more distant context, we aim to recognize the influence of both immediate and long-distance polarity modifiers on event polarity;
3. *Distance* between the event anchor and the closest negativity clue.

Certainty features. The following is the list of features used only for certainty classification:

1. *Conditionality clues* found in the left context – A set of conditionality clues found in the event anchor's left context. We compiled a set of frequent conditionality clues (the words *if* and *whether*, and the inflectional forms of the verb *would*): *ako*, *ukoliko*, *bih*, *bi*, *bismo*, *biste*. The conditional clues strongly indicate hypotheticality of events and are therefore potentially important for predicting event possibility;
2. *Conditionality clues* found in the immediate left and right context – Two binary feature sets, one for each context side (left and right) of the event anchor. We look for the same conditional clues as above, but closer (within a three-token window) to the event anchor;
3. *Distance* between the event anchor and the closest conditional clue;
4. *Future tense clues* found in the left context – A set of future tense clues occurring in the left context of the event anchor. Future events have not occurred yet, hence by definition they introduce some uncertainty. We compiled a set of clues used for expressing the future tense (inflectional forms of the verb *will* and the perfective present tense forms of the verb *to be*): *ću*, *ćeš*, *će*, *ćemo*, *ćete*, *budem*, *budeš, bude*, *budemo*, *budete*, *budu*;
5. *Future tense clues* found in the immediate left and right context – Two sets of features, one for each context side (left and right) of the event anchor. We look for the same future tense clues as above, but closer (within a three-token window) to the event anchor;
6. *Distance* between the event anchor and the closest future tense clue;
7. *Possibility clues* found in the left context – A set of clues whose core meaning is closely related to uncertainty and possibility. We compiled a set of clues indicating possibility (inflectional forms of *can/could*, and the words *maybe* and *possible*): *moći*, *moglo*, *mogao*, *mogla*, *možda*, *moguće*;
8. *Possibility clues* found in the immediate left and right context – Two sets of features, one for each context side (left and right) of the event anchor. We consider the same possibility clues as above, but closer (within a three-token window) to the event anchor;
9. *Distance* between the event anchor and the closest possibility clue.

All features were computed respecting the sentence boundaries. All numeric features (distances from sets of clues) were z-score standardized on the training set.

We used support vector machines (SVM) [3] for both polarity and certainty classification. Because in our case the number of features is much larger than the number of examples (as a result of using predominantly lexical features encoded as sparse binary vectors), we used a linear kernel.

4 EVALUATION

We selected a set of 90 documents from the newspaper corpus *Vjesnik* previously annotated by five annotators for event and temporal relation extraction [6]. The set totals 4596 event mentions, annotated by two annotators (each annotated half of the dataset) for polarity (*positive* or *negative*) and certainty (*certain*, *probable*, or *possible*). As expected for the newspaper genre, the majority of events (78.6%) were labeled as *positive* and *certain* (Table 1).

Table 1: *Dataset event factuality statistics*

	Positive	Negative	
Certain	3613	139	3752
Possible	450	39	489
Probable	330	25	355
	4393	203	

4.1 Polarity Evaluation

We evaluate the performance of our lexically-based model against two baselines. The first baseline is a simple majority class baseline, predicting every event to be of *positive* polarity. For second baseline we use a simple rule-based method that predicts an event to be of negative polarity if only if one of the negativity clues is found in the immediate left context of the event mention. We estimate the prediction performance using a 10-fold cross validation on the set of annotated events. The results are presented in Table 2.

The difference in performance between the supervised model an the rule-based baseline for both positive and negative polarity classes is not statistically significant at 0.05 level. We credit this to the limited size of the training set in which there is an insufficient number of negative polarity events expressed by lexical units other than the negativity clues (e.g., "Napadač je propustio postići pogodak" – "The attacker failed to score the goal"). Supervised models based on lexical features usually require larger datasets, and we believe that our supervised polarity classifier would benefit from annotating more data. Overall, it seems that both rule-based baseline and the supervised model are capable of recognizing events of negative polarity at satisfactory rates.

4.2 Certainty Evaluation

The performance of our supervised model on the certainty classification task is also evaluated against two baselines. The first baseline is a majority class baseline that predicts every event to be *certain*. The second is a rule-based baseline that predicts every event to be *possible* if one of the *conditional clues* is present in its context, and *probable* if any of the *future clues* is present within its context. As in polarity classification, we estimated the prediction performance using 10-fold cross validation. The results are presented in Table 3.

Our lexically-based model significantly outperforms both baselines. However, it is difficult to expect that the model whith F-scores between 40% and 50% for *probable* and *possible* classes can be put to use in real-world applications. The fact that precision is significantly higher than recall indicates that recognizing *possible* and *probable* events requires additional features.

Table 2: *Polarity prediction performance*

	Positive			Negative			Macro-average		
	P	R	F1	P	R	F1	P	R	F1
Baseline (majority)	95.52	**100.0**	97.72	–	–	–	47.76	50.00	48.85
Baseline (rule-based)	**98.75**	99.11	98.93	79.47	**73.30**	76.26	87.58	**86.21**	86.88
Supervised model	98.49	99.64	**99.06**	**89.67**	67.48	**77.22**	**94.08**	83.56	**88.51**

Table 3: *Certainty prediction performance*

	Certain			Possible			Probable			Macro-average		
	P	R	F1	P	R	F1	P	R	F1	P	R	F1
Baseline (majority)	81.44	**100.0**	89.77	–	–	–	–	–	–	27.15	33.33	29.92
Baseline (rule-based)	88.43	89.56	88.99	35.29	25.77	29.78	37.81	**46.76**	41.81	53.84	54.03	53.93
Supervised model	**88.45**	96.08	**91.95**	**54.29**	**36.20**	**43.44**	**61.82**	37.16	**46.41**	**68.19**	**56.48**	**61.79**

5 CONCLUSION

Assessing factuality of events in text is important for many NLP applications. Factuality of events can be defined in terms of their polarity and certainty. In this paper we presented a supervised machine learning approach to recognizing event factuality in Croatian texts. Our model uses lexically-based features, thus it is suitable for resource-poor languages. Our results indicate that while using a lexically-based model to predict the factual polarity of events is feasible and yields satisfactory results, the performance is not statisticaly signficiant when compared to a simple rule-based baseline. On the other hand, although it does outperform the baseline, the model still seems insufficient for capturing factual certainty of events, suggesting that this task mandates the use of syntactic (e.g., for capturing the long-distance dependencies) and semantic (e.g., semantic verb classes) features.

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COMPLEX EVENT PROCESSING AND DATA MINING FOR SMART CITIES

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ABSTRACT

Complex Event Processing (CEP) is emerging as a new paradigm for continuous processing of streaming data in order to detect relevant information and provide support for timely reactions. The main role of a CEP engine is to detect the occurrence of event patterns on the incoming streaming data. However, the problem of discovering the event patterns, although strongly related to the data mining field, has not been studied from the perspective of CEP applications.

This paper presents the first steps towards defining a framework that would allow seamless integration of CEP and data mining method. We present the smart cities scenarios as a good working-field for experimentation. A concrete use case is discussed and preliminary results are presented for real-live data that has been collected.

1 INTRODUCTION

The avalanche of data which information systems had to face in the last years influenced their evolution and characteristics. Continuous, on-time processing of incoming data streams imposed particular requirements [1], which traditional Database Management Systems (DBMS) were not able to fulfil. Consequently, due to the market needs, new tools have been developed, able to process multiple data sources, often streams, in a timely fashion in order to extract relevant information. Grouped under the domain of *event processing* (or, according to [2] information flow processing domain), two main types of such systems have emerged: Data Stream Management Systems (DSMS) and Complex Event Processing (CEP) systems.

The term *event processing* here refers to a broad study area. In [3] the term of *event processing* is coined to "any form of computing that performs operations on events". The key concept is that of an **event** which can represent anything that happens or is observed as happening (e.g. a mouse click, a sensor reading, water level increase, a river flood, spring coming, etc.). A common characteristic of event processing applications is to continuously receive such events from different **event sources** (e.g. sensors, software modules, blogs, etc.). The central module processing the events, called the CEP **engine**, detects **event patterns** from the incoming data streams and outputs the detected or predicted complex events which can be further used by other **event consumers**, or it can return as an input to the CEP engine. The event patter's role is to specify how the incoming events should be processed in order to extract relevant information. The language used to define these patterns should have the ability of specifying complex relationships among events flowing into the CEP engine.

The typical approach in defining patterns of events is to manually specify them. This is done either by domain experts, capable of providing the definition of event patters or by using other tools externally of the CEP systems in order to discover these patterns and then encode them in the event processing language (EPL). However, we see the integration of machine learning algorithms with the CEP system, as a solution for direct support in definition of event patterns. Although massive amount of research has been conducted in the areas such as pattern recognition and multisensor data fusion, the systems developed for many of the CEP applications do not provide a seamless integration with such techniques, but rather consider the human component responsible for defining the complex events patters that should be monitored and detected. Therefore, an important improvement for applying machine learning algorithms in event-based application is to develop a framework that would allow easy integration of existing algorithms with event processing techniques.

A first step in achieving such integration is choosing a scenario for running experiments. One example is the smart cities scenarios, as there can identified many data sources and use cases for data mining and CEP. In this paper we are proposing such a scenario, identify the data sources and run preliminary experiments for analysing the data. Future steps are discussed in the direction of using CEP engines with the patterns discovered and defining a framework for an easier integration of data mining and CEP.

The rest of the paper is structured as follows: Section 2 describes the smart cities scenario and introduces one use case considering the city of London. Data integration and preprocessing is presented in Section 3, while Section 4 discusses the result of data mining. Finally we conclude the paper and identify future directions.

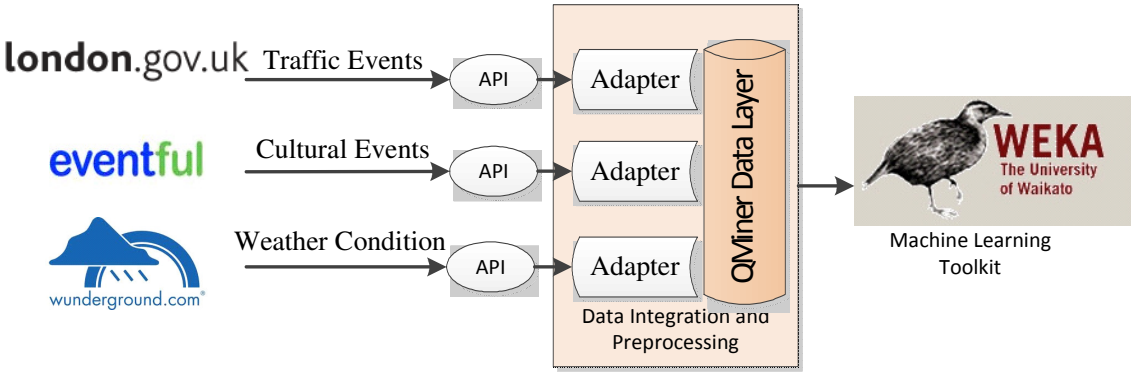

Figure 1. *Data Sources.*

2 SMART CITIES SCENARIO

The high level requirements for making a city smarter, as envisioned by IMB in the larger Smarter Planet[1] program, refer to collaboration and coordination between city agencies managing different domains (e.g. water management, transportation, buildings, etc.) in order to be able to optimize the limited resources and to efficiently and effectively deliver city services. Moreover, different technologies may enable smarter cities, such as: communication channels (e-mail, instant messaging, etc.), business rules, data sharing (data models, accessibility) and integration of different sources of data [4].

In another study [5], the classification of cities as smart is made based on 6 criteria: economy, people, governance, mobility, environment and living. Out of these, we focus on smart mobility, which refers to transport (accessibility, modern transport systems) and availability of ICT infrastructure.

2.1 London Use Case

The final goals for our experimental scenario will be to (1) find patters for appearance of traffic disruptions that could be then applied by a CEP engine for sending different alarms and (2) discover interesting correlations between cultural events happening in a city, social media and their influence on traffic.

The first step toward our goals is to identify data sources of potential useful information. Some specific sources are listed below:

- Traffic data (bus schedules and delays, congested roads, etc.). Sources: Bing Maps[2], Traffic for London[3] (Tfl).
- Weather conditions. Sources: Weather Underground[4], Yahoo! Weather[5], AccuWeather[6], etc.
- Events happening in the city: Live music, conferences, festivals, galleries, sports, etc. Sources: Eventful.com, upcoming.org, last.fm, zvents.com, socialevents.com.
- Social media about the events (microblogging and news). Sources: Twitter[7], IJS newsfeed[8].

2.2 Description of the Data Sources Used

After receiving the data through the data sources APIs, custom built adapters are used for storing data in a uniform data structure, which allows us to integrate all the sources for generating the input dataset for data mining. As illustrated in Figure 1, for the data storage functionality we have used the QMiner infrastructure which is based on tightly integrated and scalable custom software modules.

The data mining algorithm applied is for learning association-rules. The Weka toolkit [7] was used for running the experiments.

For our preliminary results we have used data only from the sources depicted in Figure 1, which have been crawled through several API made available by the source providers. Depending on the how often the sources were updated, different time intervals were used for crawling data as can be observed in **Error! Reference source not found.**; data was collected for a period of one month, between 16th of July to 16th of August 2012.

Table 1: *Time intervals for data collection*

Source	Update time interval
Tfl Road Disruptions	5 minutes
Current Weather Conditions[4]	30 minutes
Events (from Eventful.com)	Once per week

The road disruption events are identified with an unique id and have the following properties: start and end time, location details, time of last update, type, severity and category. The category property is described in **Table 2** , as it has predefined values which are used in the analysis of the results, while for the rest of properties more details can be found in [6]. The total number of road events registered is 3090. The type of the events indicates if the event has

[1] http://www.ibm.com/smarterplanet/us/en/
[2] http://www.bing.com/maps/
[3] http://www.tfl.gov.uk/
[4] http://www.wunderground.com/
[5] http://weather.yahoo.com
[6] http://www.accuweather.com/
[7] http://twitter.com/
[8] http://newsfeed.ijs.si/

Table 2: *Categories of road events and their frequency*

Category	**Interpretation**	**Percentage**
Works	planned and emergency road works	7%
Accident	road traffic accidents	30%
Signal Failure	automatic traffic signals failure	6%
Breakdown	vehicle breakdown	19%
Incident	emergency incident	4%
Event	cultural events	<1%
Hazard	dangerous structures, fire, flooding, ice and spillages	6%
Other Cause	abnormal loads, unexplained congestion, etc.	27%

happened during the period for which the data was crawled, or is it scheduled to happen in the future (caused by road works or other planned cultural events). Therefore, the number of road events analysed is 2305, and the percentage for each category is also presented in **Table 2**.

The weather conditions represent a report for the whole area of London city, and presents properties such as: temperature, wind speed and a short text description (e.g.: clear, partly cloudy, rainy, etc.). Unfortunately the precipitation information, which could presumably have an influence on traffic disruptions, was not available from this data source.

The cultural events are described by time, location, performers and can be of more categories (e.g. music, concert, arts, sports, etc.). The total number of events happening collected is 5931, in 1707 different locations. The top 10 most frequent categories of events are presented in **Table 3** (one event can have more categories).

3 DATA PREPROCESSING

The data preprocessing consisted of two main steps: (1) data integration and (2) generation of the set of instances. In the data integration step, the traffic events were correlated with cultural events and weather data based on time and location. We have also defined nearby events, as follows: if an event is situated at predefined maxim distance from the current event and starts with a predefined maximum time interval before or after the current event, than it is considered as nearby.

Table 3: *Frequent categories of cultural events*

Category	Freq.	Category	Freq.
Music	2652	Sales	215
Performing Arts	1138	Festivals-Parades	200
Other	887	Family-fun-kids	157
Singles social	279	Outdoors-recreation	124
Sports	351	attractions	100

Table 4: *Instance Attributes*

Attribute	Type	Distinct / [min-max]	Missing Values
category	Nominal	8	No
severity	Nominal	3	No
day	Nominal	7	No
time	Nominal	4	No
duration	Nominal	3	27%
traffic events nearby	Nominal	2	No
weather	Nominal	12	2%
Temperature (˚C)	Numeric	[10-30]	2%
wind speed (kph)	Numeric	[0-32]	2%
events nearby	Nominal	2	
cultural events categories (25)	Nominal	2	No

The maximum distance and time interval have been tested with different values, as it will be explained in the next section.

In the second step, we have created a set of instances around the road events, where each instance has 37 attributes, described in **Table 4**. As there can be more categories of cultural events, each is represented as an attribute which has value *t* if category is present and *f* otherwise. An example of an instance is illustrated in **Figure 2**. The total number of instances is equal to the number of road events analysed, which is 2305.

Hazard, Moderate, medium, Monday, Afternoon, 0, Mostly Cloudy, 16, 26, 1, f, f, t, f, t, f, f, f, f, f, f, f, f, f, f, f, f, f, f, f, f, f, f, f, f, f, f

Figure 2: *Example of an instance from the input dataset*

4 PRELIMINARY RESULTS

First, analysis was done on each attribute. The analysis with respect to day of the week and time of the day is illustrated in **Figure 3**, and presents the expected correlation.

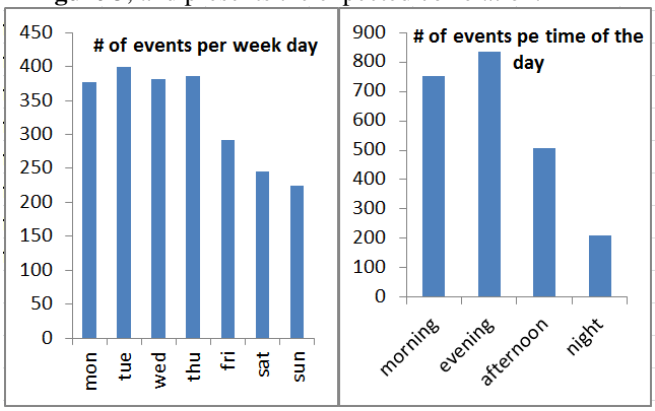

Figure 3: *Number of events per week day (left) and time of the day (right)*

Another aspect of importance is the presence of nearby events (road or cultural) for an instance of road event. This has been calculated for three sets of parameters, and the results in **Table 5** show the number of instances where nearby traffic events (#tfl), respectively cultural events (#evt) exist.

Table 5: *Number of instances that have nearby events for different constraints on distance and time difference*

Distance (m)	Time diff. (mins)	#tfl	#evt
500	60	9	104
1000	60	31	213
1000	240	96	487

Possible correlations between the attributes of our dataset have been studied using association rules. The algorithm used for discovering such rules is the Apriori algorithm, implemented in Weka. We choose the dataset with the constraints of 1000 meter in distance and 60 minutes time difference. As Weka crashed when running the algorithm on all the attributes we first try removing all the categories of cultural events from the attributes, reducing the number of attributes to 10. However no relevant rules were found.

As our interest was in the relation of different traffic events categories (listed in **Table 2**) with nearby cultural events, we have reduced the dataset to 213 instances (for which the constraints on distance and time where 1000 meters, respectively 60 minutes), which had at least one nearby cultural event. Although the rules obtained are not necessarily related to traffic events, they do illustrated normal relations, such as: cultural events are more often in the evening (rule 1) or that some cultural events categories are related (rule 2)

Rule 1: Weather = Clear, music = t, performing_arts = t (23) ==> Time=Evening (21) [conf:(0.91)]

Rule 2: singles_social = t. performing_arts = t (33) ==> music = t (28) [conf:(0.85)]

5 CONCLUSIONS AND FUTURE WORK

A number of conclusions can be drawn after our preliminary experiments as follows. Data must be collected for a longer time period, allowing thus generation of cleaner and more precise datasets. Although the 27% of missing values for the duration attribute (see **Table 4**) is not very high, it does influence the calculation of the nearby events. In our experiments we used an approximation of average duration, for being able to obtain other nearby events. A larger dataset would allow for extraction of data of better quality, which can then be used more successfully for association-rule learning.

Determining the nearby events may be done differently for different categories of cultural events; (e.g. a big music concert affects a larger area then a sales event) a more thoroughly study for determining the parameters involved is needed.

There is no clear evidence of the influence of cultural events over road events. However, common sense tells us that there should be. Therefore we shall continue our study once we gather more data.

As future steps we consider integration of more data sources, and first we will focus our attention on social media. Next we will also consider visualisation techniques that can provide a faster insight into the data, and then proceed with data mining methods.

Finally, once the event pattern obtained, we will research into connecting them to a CEP engine.

Acknoledgements

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NARRATOR: SYSTEM FOR REPORT GENERATION IN NATURAL LANGUAGE

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ABSTRACT

This paper presents NARRATOR, a system for report generation in natural language. The idea behind the developed system is based on merging statistical data with report templates predefined by the user. The user has a possibility to generate different kinds of reports with respect to various indicators, time periods and natural language statements.

1 INTRODUCTION

The aim of the narrative reporting is to analyze the data and to present them in a simple and understandable way to the user.

The motivation for automatic developing of stories in natural language can be different – to minimize human efforts and funding, to obtain interesting conclusions from the data, to create compelling entertaining content in short period of time etc.

For instance, the Quill technology of the Narrative Science [1] company allows to merge Artificial Intelligence with Big Data analytics and to transform data into stories, which are similar to stories authored by people.

Nichols [2] describes the method for creating machine-generated content and a system called "News at Seven" – an automatically generated news and entertainment show.

From the business prospective of view a lot of companies are interested in using technologies for automated reporting, since it allows systematically draw inferences from data.

The NARRATOR system, presented in this paper, is being developed for website performance analysis and following report generation in English. The system is based on statictical data coming from Google Analytics services [3]. The NARRATOR system works with general and user specific information – the users can adapt the system according to their needs. Furthermore, in this paper we describe the architecture, principles of work and provide a demonstration link to the NARRATOR system.

The paper is structured as follows: Section 2 provides the system architecture; Section 3 describes the system interface; in Section 4 we provide the inside on the data mining techniques employed in the system; and finally, Section 5 concludes the paper.

2 SYSTEM ARCHITECTURE

The NARRATOR system architecture includes several components.

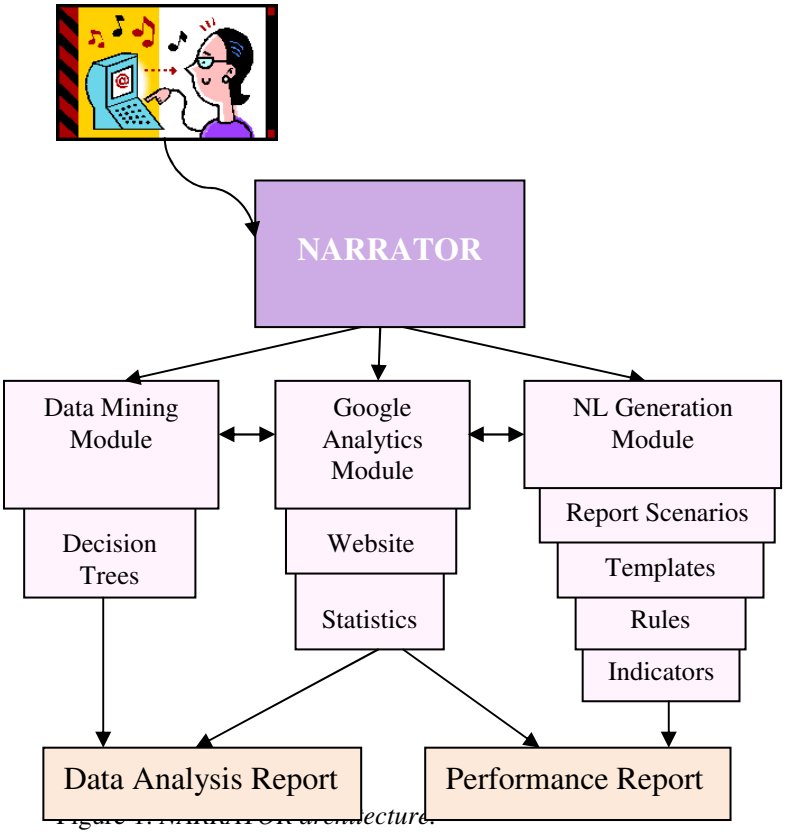

Figure 1: NARRATOR architecture.

As it is visible on Figure 1, the main NARRATOR modules are *Google Analytics Module*, *Natural Language (NL) Generation Module and Data Mining Module*.
The user connects to the NARRATOR system and selects the website she wants to work with in the processes of the performance and data analysis. The connection to the website is performed in the Google Analytics Module with a help of Google Analytics API [4]. The important note is that in the current settings of the NARRATOR system the user is assumed to have access to google analytics tools.
In addition, the user also selects the the report scenario she wants to get. The report scenario contains sets of templates, which connect natural language statements to rules and relevant indicators. The report scenarios, indicators, trules and templates are described below in this section.
Following that, the NARRATOR system obtains a set of statistical performance data for the particular website from the Google Analytics services. The reports are generated in the NL Generation Module based on the report scenario and statistical data. Finally, the user is provided with a natural language report for the selected website.
In addition, inside the NARRATOR system, we are developing a Data Mining Module, which allows to get more inside pictures of the website data. In this module the data mining techniques, such as decision tree generation algorithms, are used to analyze the website statistical data and to discover the rules hidden inside the data.

2.1 Google Analytics Tools

Google Analytics (GA) [3] is a free service from Google that provides detailed statistics about the visitors of the particular website. GA can be used to obtain the information on the mobile analysis, content analysis, conversion analysis, social analysis and advertising analysis. The Google Analytics API [4] can be used to develop custom applications, such as reporting tools.

2.2 Indicators

While automatically generating reports in natural language, it is necessary to connect the textual statements to the performace features. Indicators are the key performace features and the main building blocks for the narrative reports. Currently, inside the NARRATIVE system we have a list of 126 predefined indicators, which can combined together by the users as new indicators. The typical indicators are the following:

- *number of visits last week*
- *number of pageviews last week*
- *most popular keyword last week*
- *exit pages last week*
- *average time on site last week*
- *browsers used by visitors last week*
- *continents of visitors last week*
- *t-test visits last 4 weeks visits previous 4 weeks*
- *number of visits previous week*
- *top departures by visits last week*
- *visits bounce rare last week*
- *top paths by visits last week*
- *top arrivals by visits last week etc.*

2.3 Rules

Rules are used in the templates to trigger the natural language statement from the template to appear in the report. If all rules from the particular template validate, then the NL statement from the template is added to the report.
Rules contain indicators, numerical and logical operators. For instance, for the following rule to be validated, the indicator value *number of visits last week* should be larger than the indicator value *number of visits previous week*:

```
[number of visits last week] > [number of visits previous week]
```

or

```
[number of pageviews per visit last week] == [number of pageviews per visit previous week]
```

2.4 Templates

As stated above, templates combine together indicators, rules and statements in natural language:

```
<text>
        Traffic was down last week from the previous week
</text>
<rule>
        [number of visits last week]
        < [number of visits previous week]
</rule>
```

or

```
<text>
        The 4 week number of visits average is down significantly from the previous 4 week average.
</text>
<rule>
        [number of visits last 4 week average]
         < [number of visits previous 4 week average]
</rule>
<rule>
        [t-test visits last 4 weeks visits previous 4 weeks]
         < [5]
</rule>
```

Templates are merged into template sets. We assume that the text statement from no more than one template (from each template set) appears in the final report.

2.5 Report Scenarios

Finally, report scenarios contain the references to the specific template sets. If the user wants a template set to be included in the report, she should add it to the specific report scenario. For instance, a general weekly report can provide information about traffic (traffic was up, traffic was down, traffic stayed the same) in the last week with comparison to the previous week, about the most popular keyword last week, most popular browser last week etc.

3 SYSTEM INTERFACE

The NARRATOR system is accessible via web at:

http://narrator.ijs.si

Figure 2 presents a NARRATOR interface with connection to user's Google Analytics account. The user provides her Google Analytics username and password and, following that, gets the access to the websites suitable for analysis and report scenarios.

Figure 2: *NARRATOR interface – GA connection.*

Figure 3 demonstrates a performance report generated for the website **videolectures.net** [5] – a website that provides free and open access educational video lectures repository. The report includes the performance analysis of the visitos to the website in the last week versus previous week. From the report it can be seen that traffic was up last week, as well as the number of pageviews and the number of visitors.

Figure 3: *NARRATOR interface – generated report.*

The NARRATOR website provides the user with possibility to add and modify new indicators (based on the predefined indicators), rules, templates and report scenarios.

4 DATA MINING TECHNIQUES

In order to allow the users to get more insides on their data, the NARRATOR system provides a mechanisms to analyze the website statistical information with using data mining techniques, such as decision trees.

Decision tree learning [6] represents a method commonly used in data mining. As an input, a list of variables is provided and the model that predicts a value of the target variable is built.

The interior tree nodes correspond to the input variables; the edges connect tree nodes and each leaf represents a value of the target variable given the values of the input variables taking to the account the path from the root to the leaf.

We have selected C4.5 algorithm [7] by Quinlan, which is an extension of ID3 algorithm. C4.5 can be used for classification, which is a benefit for mining the website data.

The motivation for mining the website data comes from the idea that we can provide the user not only with website performance reports, but also with interconnections between data attributes and useful attribute characteristics, which would contribute to the decision making process of the user.

In our data mining experiment, we set a task to build an experimental decision tree for the website **videolectures.net** for the attribute *average time on site last week*, which would connect the statistical website performance data (such as *mobile visitors, visitor type, visitor continents, visit day of week* – for details, see Table 1).

Table 1: *Average Time On Site - decision tree attribute values.*

Attribute Name	**Attribute Values**
isMobile	YES, NO
continent	AFRICA, AMERICAS, ASIA, EUROPE, OCEANIA, NOT_SET
visitorType	NEW_VISITOR, RETURNING_VISITOR
dayOfWeek	0 (Sunday),1,2,3,4,5,6
avgTimeOnSite	0_10, 10_100, 100_500, 500_AND_MORE (seconds)

The built decision tree (with 12 leaves) is provided below:

isMobile = YES
| continent = AFRICA
| | dayOfWeek <= 3
| | | dayOfWeek <= 0: 100_TO_500
| | | dayOfWeek > 0: 0_TO_10
| | dayOfWeek > 3: 10_TO_100
| continent = AMERICAS: 10_TO_100
| continent = ASIA
| | dayOfWeek <= 4: 10_TO_100
| | dayOfWeek > 4: 100_TO_500
| continent = EUROPE: 100_TO_500
| continent = OCEANIA: 10_TO_100
| continent = NOT_SET
| | dayOfWeek <= 0: 100_TO_500
| | dayOfWeek > 0: 10_TO_100
isMobile = NO
| visitorType = NEW_VISITOR: 100_TO_500
| visitorType = RETURNING_VISITOR: 500_AND_MORE

From the experimental decision tree, for instance, it is noticeable that more non-mobile returning visitors tend to spend 500 and more seconds at the videolectures.net website, while more non-mobile new visitors tend to spend between 100 and 500 seconds at the website.
In the future work we plan to extend the data mining part of the NARRATOR system and to provide the users with more possibilities to analyze their data.

5 CONCLUSION

NARRATOR is a system providing the possibility to transform the numerical data from Google Analytics services into reports in natural language.
NARRATOR provides a set of report scenarios, based on numerical and textual indicators.
NARRATOR uses Google Analytics data for a specific periods of time.
In addition, inside the NARRATOR system, we are developing a functionalty, which allows to get more detailed analysis of the website data. The data mining techniques, such as decision tree generation algorithms, are used to analyze the website statistical data and to discover the rules hidden in the data.
For the future work we consider the further development of the NARRATOR data mining functionalities, as well as the technology adaptation for other data sources and data streams.

6 ACKNOWLEDGMENTS

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Visual divisive hierarchical clustering using k-means

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ABSTRACT

This paper presents a browser-based semi-automatic taxonomy construction tool Vd-chuck which is able to incorporate text and data mining algorithms into a user-friendly interface. The presented system is browser-based. Its unsupervised learning for concept suggestion and different visualization techniques assist the user with textual and numerical data analysis. We tested the Vd-chuck system on a real-world domain: a corpus of documents taken from Slovenian Language technologies conferences. The results show that with our system similar taxonomies as with other taxonomy editors can be constructed.

1 INTRODUCTION

Taxonomies and ontologies have been often considered as the most adequate knowledge representation formalisms for representing the relations between different domain objects. New directions for future ontology editors have been stimulated by the rapid growth in the need of textual and numerical data analysis, growth of the internet and also by the need for mobility and collaboration. All current major ontology editors (e.g. Protege [2], OntoStudio [13], Ontogen [1]) offer little support for user collaboration and mobility, while existing browser-based editors (e.g. Web-Protoge [12], Knoodl[1]) provide only basic ontology editing functionality with barely no tools for visualization.

Vd-chuck is a browser-based taxonomy editor, offering a similar functionality as the desktop topic ontology editor Ontogen [1]. Ontogen allows users construction of new topic ontologies, as well as visualization and exploration of the existing. Vd-chuck's main advantage over Ontogen is its accessibility. Since it is browser-based, it can be accessed from anywhere at any time. The Vd-chuck system combines several data mining and text mining techniques with an intuitive user interface. Different tasks require building taxonomies differently, so it is essential to include the user's knowledge as well. Vd-chuck is semi-automatic, which means that it is able to provide suggestions–such as concept naming, concept relations, assigning examples to concepts–during taxonomy construction. Although Vd-chuck supports simplified taxonomy and concept generation, it in the end still relies on the user's background knowledge to make appropriate corrections.

The paper is organized as follows. In Section 2 we present the main components of the Vd-chuck system. As Vd-chuck was inspired by Ontogen, we provide a comparison between the two in Section 3. In Section 4 we present a real-world use case of our system on a textual domain. Section 5 concludes the paper and gives some ideas for further development.

[1] http://knoodl.com

2 OVERVIEW OF THE VD-CHUCK SYSTEM

This section describes three major components of the Vd-chuck system: the concept hierarchy, concept management and finally concept visualization.

2.1 Concept hierarchy

One of the main components of the Vd-chuck system is the concept hierarchy tab, which is always present in the upper-left side of the screen (Figure 1). It shows the structure of the taxonomy in a tree-structured way, while giving the user an option of concept selection.

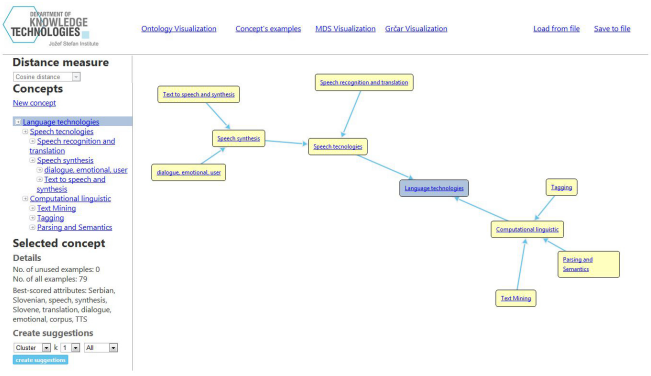

Figure 1: Vd-chuck's taxonomy visualization tab: taxonomy's concept hierarchy is displayed in the upper-left window; selected concept's details are listed on the bottom-left while the central part shows the taxonomy as a tree-structured directed graph, representing the concept hierarchy.

Under the concept hierarchy window various details of the currently selected concept are present: such as concept's name, example count, unused example count and the most informative attributes. Example count represents the number of all examples that are either part of the selected concept or in one of its descendants, while the number of unused example count represents the count of examples that are part of the selected concept but are not present in any of its descendants. The most informative attributes are the ten best scored attributes using attribute ranking method InfoGain [7], although when textual data is used ten words with the highest TF-IDF [8] values are selected.

As we can see from Figure 1, the main part of the screen presents an alternative visualization of the taxonomy—a directed graph with vertices representing the concepts and and edges representing relationship 'subconcept of'. Each concept can be selected, renamed, deleted or even moved as a subconcept to another concept by right clicking it and selecting the appropriate choice from the context menu.

The Vd-chuck system provides unsupervised learning for concept suggestion. The unsupervised learning is performed using the k-means clustering method [11], which uses one of the distance metrics available for selection with numerical data and cosine similarity [11] when using text data. Clustering can be done using the selected concept's all examples or only its unused examples. After clustering suggestions appear on the screen and the user can manually add appropriate ones to the taxonomy. Suggested concepts' initial names are generated as top three most informative features/words for that concept.

Another feature is creating concepts according to examples' classes. This feature is useful when an existing taxonomy or a dataset with a class variable needs to be altered or checked for outliers [4].

2.2 Concept management

The Vd-chuck's concept management tab is used to present all examples in correlation with the selected concept's centroid. The centroid of every concept is calculated with the k-means method as the average value for numerical attributes and most frequent value for discrete. The distance used to calculate the centroid depends on type of the data; when using textual datasets, cosine similarity is used. When working with numerical data, one of the following distances can be selected as the dissimilarity measure: Euclidean, Manhattan, Relieff, Hamming or PearsonR distance.

As shown in Figure 2.2, every example along with its unique identifier and distance from the selected concept's centroid is listed in the main window. Examples that belong to the selected concept (or one of its descendants) are marked with a different color. When clicked upon, each feature (or textual content for textual datasets) of the example is listed on the right side of the main window.

A similarity graph of all examples with selected concept's centroid is shown on the bottom of the main window. Each

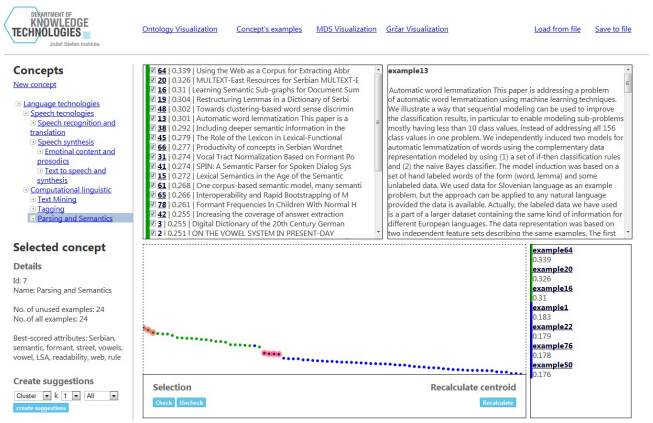

Figure 2: The concept management tab. Examples are listed in the top middle, while the selected example's content is shown on the right. Similarity graph of examples with concept's centroid is drawn on the bottom of the screen.

example is presented with a dot, colored according to its belonging to the selected concept. The similarity graph is very useful for outlier detection. The user can look at each example and decide upon moving it to another (more suitable) concept based on his own background knowledge. This can be done by simply dragging it to the desired concept's name on the always-present concept hierarchy on the left.

2.3 Concept visualization

The problem of projecting multidimensional data into two dimensional space has been investigated by different researchers due to its potential application to data analysis. As visualization is a useful tool for gaining insights into overwhelming amounts of data, the Vd-chuck system provides users with two different types of visualisation: multidimensional scaling MDS [6] and a MDS-like distance-preserving projection onto a 2D canvas, presented in [3].

MDS. MDS visualization uses dissimilarities between pairs of different examples. As mentioned, in the Vd-chuck system the user can choose between several similarity measures. Vd-chuck uses Sammon's projection [9] for mapping high-dimensional spaces to spaces of lower dimensionalities. Sammon's projection tries to preserve the structure of inter-point distances in high-dimensional spaces in the lower-dimension projections. This is done by minimizing the error function, which is often referred to as Sammon's stress:

$$E = \frac{1}{\sum_{i<j} d^*_{ij}} \sum_{i<j} \frac{(d^*_{ij} - d_{ij})^2}{d^*_{ij}}, \qquad (1)$$

where variable d^*_{ij} denotes the distance between i-th and j-th objects in the original space, while d_{ij} is the distance between their projections. The minimization of Equation 1 is a rather complex problem that cannot be solved in closed-form. Therefore, MDS algorithms use iterative numerical al-

gorithms to find a matrix that minimizes the stress function. Our implementation uses the SMACOF algorithm [5], which is based on iterative majorization.

Although Sammon's projection can unfold data belonging to manifolds of high-dimension, once large distances are taken into account in the optimization, it can fail for highly twisted spaces. As a result we see very similar cases projected far apart. A serious problem of Sammon's projection is also its relatively high computational complexity $O(n^2)$.

Document stream visualization. The method presented in [3] is a pipeline of different data mining techniques aimed at better mapping of higher-dimensional data onto a 2D canvas. First, the algorithm clusters examples in order to segment the data space. Using the k-means clustering method several (usually 100) centroids are obtained. These centroids are used as control points in the final stage of the visualization pipeline. Second, these representative instances are projected onto a planar canvas by using an iterative stress majorization method. Simultaneously, determining nearest neighbours for every point is required. Cosine similarity is used for computation of distances between examples. Finally, the least-squares solver is used to interpolate non-control points between the coordinates of control points. The basic idea how to construct the system of linear equations required by the interpolation process is that each (control or non-control) point can be described as the center of its nearest neighbors. The result of the solver is a n-dimensional vector which contains pairs of coordinates for every example.

Visualization tools. Vd-chuck's visualizations provide the user with different tools for easier interpretation of the visualized concept. Every instance can be selected by simply clicking on it (note that multiple area selection is possible too). Selected examples are listed on the right of the visualization window.

The 'Highlight selected on similarity graph' is used to check the similarity of all of the selected examples on the visualized concept's similarity graph. This is mostly useful for outlier detection and rearranging examples to other possibly more suited concepts. The 'Compare selected examples with concept's centroid' function gives the user a possibility to check how selected examples compare to the concept's average values, while the 'Calculate most influential attributes for selected examples' provides the user a list of attributes that best differentiate the selected examples against other examples of the visualized concept. The most influential attributes are obtained with the Relief measure.

3 COMPARISON WITH ONTOGEN

Vd-chuck was inspired by the desktop topic ontology editor Ontogen. In this section we provide a direct comparison between the two. The comparison is carried out according to four characteristics: browser-base, handling of numerical and textual data, active learning and visualization techniques.

Browser-based. As opposed to Ontogen, the Vd-chuck system is browser-based, so it can be accessed from anywhere. It does not need preinstalled software except for the web-browser. It is always up-to-date, so there is no need for local version upgrades. It is also possible to access it from mobile phones and tablets. Unlike in Ontogen, the user is not required to save and transfer files locally. Consequently, it enables easier collaboration as users can share their projects by simply sharing a link of the Vd-chuck's project web page.

Handling numerical or textual data. Vd-chuck offers taxonomy construction on either numerical or textual data, while Ontogen can deal only with textual data. When loading textual data in Vd-chuck, some basic text preprocessing (such as lemmatization and stop-word removal) and a TF-IDF transformation of all documents is done. TF-IDF features are then used in clustering and visualization algorithms.

Active learning. Vd-chuck system does not provide the supervised SVM active learning method [1] present in Ontogen. The user is therefore required to manually move each example that in his opinion does not suit the selected concept. When much example moving is required the absence of active learning can slow down the taxonomy construction process.

Visualization. Vd-chuck offers two visualization techniques: MDS and the document stream visualization. In contrast with Ontogen's, Vd-chuck's visualizations provide background colouring of examples according to their belonging concept. Meanwhile, Ontogen provides an option of mapping document keyword onto the 2D space. Furthermore, the density of documents in an area is used for generating the background relief in Ontogen.

4 TYPICAL VD-CHUCK USE-CASE

In this section we describe a real-life use case of Vd-chuck. We show how to build a topic ontology from textual data, in order to do so we repeated the experiment described in [10]. Construction of a topic ontology of a corpus of 79 English-written documents taken from Language technologies conferences, held in Ljubljana from 1998 to 2010, was performed. All documents were previously preprocessed—data transformations such as discarding authors' names, institutions, references, footnotes and page numbers were performed.

We used Vd-chuck's concept suggestion tool for every concept with different k values for the k-means clustering algorithm. The used k value was the one which splits the data to most sensible big-enough clusters, confirming the user's understanding of the area with its keywords. If a concept could not be split into reasonable subconcepts further concept division was not performed.

We decided to use a top-down approach of taxonomy generation. We started by dividing the root concept into two subconcepts. The Vd-chuck's suggested concepts' extracted keywords were very consistent with the general division of the field of language technologies which consists of computational linguistics and speech technology. Some additional hu-

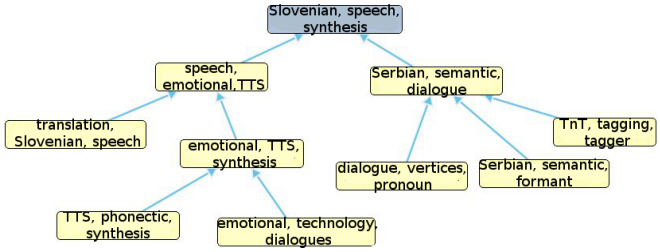

Figure 3: Taxonomy of documents from Language technologies documents before manual concept renaming. Concept names consist of most representative keywords.

man effort was also needed—some examples had to be moved to more suitable concepts.

Next, concepts of computational linguistics and speech technology where further divided. Again k-means suggestion tool was used. Inside the computational linguistics concept a general cluster (described by keywords such as 'serbian') was continually present. All examples from this cluster were manually moved according to user's knowledge and presentation of what other concepts are representing. After the sorting we could easily identify some other outliers using Vd-chuck's concept similarity graph.

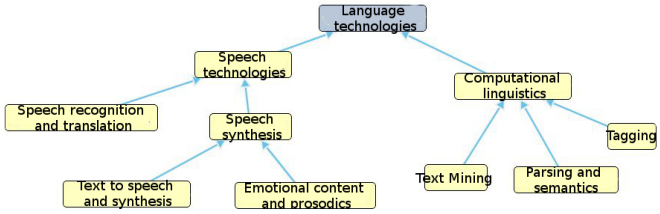

Figure 4: Updated taxonomy after manual moving of examples and concepts renaming.

Lastly, we renamed concepts in order to get a more comprehensible ontology. The result of our taxonomy generation can be seen in Figure 4. For the validation of a logical division, we checked the concepts' centroid similarity graphs. The results consistently showed that the examples in the concept were always very similar to the concept's centroid, while other examples were much further apart.

The presented topic ontology construction resulted in a similar topic ontology as described in [10]. The differences that we encounter, such as additional division of concept 'Speech recognition and translation', were mostly due to subjective judgment of the user.

5 CONCLUSION

This paper presented Vd-chuck, a browser-based semi-automatic taxonomy construction tool. We have provided a detailed comparison with the desktop ontology editor Ontogen. We have tested the Vd-chuck system on a real-life domain. The results show that with our system similar taxonomies as with other taxonomy editors can be constructed. The system is easy to use, although the lack of active learning makes taxonomy construction more time-consuming for the user. For further work we plan to construct more representative visualization, especially when dealing with smaller databases. Furthermore, work on adding active learning is planned.

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Evaluating photo aesthetics using machine learning

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ABSTRACT

In this paper we propose a method for automatic assessment of aesthetic appeal of photographs. We identify significant parameters that distinguish high quality photography from low quality snapshots. On the basis of these parameters, we defined calculable features for automatic assessment of photography aesthetics using machine learning methods. The calculation of features depends heavily on the identification of the subject in photographs. With the subject identified, we defined and implemented various features to analyze various aspects of a photograph. The features were tested on two datasets. First dataset was obtained from Flickr and manually labeled for evaluation. Second dataset was based on photographs from DPChallenge portal where subjects were identified with a face detection algorithm. Both experiments showed some promising results. In this article we specify the features which contribute to a successful classification of photographs, analyze their influence and discuss the results. In conclusion, we offer some suggestions for further research.

1 INTRODUCTION

With ever-decreasing cost of digital photography along with ease of their manipulation, the volume of photographs taken has increased exponentially. According to statistics quoted by the largest social network – Facebook, an average of 200 million photographs are uploaded daily by its users. Evidently, there is a need for an automatic system that rates and manages such content. Therefore, photo-quality evaluation is an area that has particularly attracted recent research attention.

Evaluating photo aesthetics proved to be challenging because of several reasons. The notion of a *high quality* photograph as perceived by a viewer is often an abstract concept. Even experienced photographers can disagree on the quality of a particular photo. However, there are some common rules that most of high quality photos follow. For instance, photos taken by experienced photographers usually adhere to one of the composition rules and color selection, which makes them more visually appealing than those taken by amateurs. Therefore, obtaining reliable evaluations of photo quality was an important motivation for our work.

We formalized abstract concepts of photographic quality into quality measures and designed features that can be efficiently determined by computers. Our method is also a top-down approach such as the one by Ke et al. [1] where high-level semantic features for photo quality assessment are constructed. Each constructed feature correlates to a concept established in professional photography.

The article is organized as follows: related work is presented in Sect. 2, parameters of high quality photographs in Sect. 3, followed by the proposed features in Sect. 4. Evaluation datasets and experimenal results are presented in Sect. 5 and 6, respectively. Sect. 7 concludes the paper with discussion and future work.

2 RELATED WORK

In recent research of automatic evaluation of photography aesthetics, Ke et al. [1] employed a top-down approach to construct high-level features for photo quality evaluation. Features are close to the concepts described by experienced photographers and were extracted from low level cues like noise, blur, color, brightness, contrast and spatial distribution of edges. In addition to the low level cues, the significance of complex features such as image similarity, region composition and depth of field indicator are presented in [2, 3]. Boutell and Luo [4] studied the impact of metadata recorded by a camera at image conception. The metadata consisted of camera settings such as ISO speed rating, F-number and shutter speed. But as it was shown later, metadata recorded by a camera is not

sufficient for reliable photo quality evaluation [5, 6].

Recent works are reseaching the influence of a good photo composition [7] with identification of a foreground object and analyzing its placement inside a photo frame. As foreground objects are usually people, their position can be automatically determined using face detection algorithms.

3 PARAMETERS OF HIGH QUALITY PHOTOGRAPHS

Before we can design computer-determined features that distinguish between high and low quality photos, we must identify the criteria used by people. Extensive research was made including photography books [8, 9], scientific papers [1] as well as various photography resources available online [10]. There are numerous characteristics that define a high quality photo and since it would be impossible to implement all of them, we selected only the three most influential parameters.

The most distinguishable characteristic of a high quality photo is its *simplicity*. To satisfy the simplicity criterion, a photo should have a clear center of interest which can be identified easily (Fig. 1). Images that do not meet the simplicity criterion often include unnecessary elements that clutter the scene and make the subject recognition difficult.

Figure 1: Simplicity parameter. Due to blurred background the subject clearly stands out.

The second significant parameter that we consider is *composition*. After we identify the subject of a photo, we need to consider the interaction with other objects. The composition is a process, where we establish a sense of order for the elements within a photo. Photos taken by experienced photographers usually follow one of the established rules of composition: Golden ratio (Fig. 2), Rule of Thirds or some other rule.

Figure 2: Composition parameter. A picture is divided into areas considering Golden ratio.

The third parameter is *color selection*. Experienced photographers often take photos in unusual lighting conditions to make the scene look appealing. Color selection of the scene is considered to be a design technique and high quality photos often contain colors that follow one of the established color schemes.

4 PROPOSED FEATURES

During our research we implemented 74 various features that analyze different aspects of a photo. Here we present only a selected few. Our approach relied heavily on identification of a photo's subject which characteristcs we compared with the rest of the photo and its background. Features that assess adherence to compositional rules such as golden ratio, rule-of-thirds and rabatment as well as the position of a subject relative to the image frame are defined. Distribution of image edges detected with an edge detector was also observed as well as photo's aspect ratio and its subject size. To assess the color palette, we calculate features that determine unique hues used in a photo along with its average hue, saturation and brightness. Simplicity of the photo was measured implicitly by comparing the color palette of the photo's subject and its background as well as with features that measure edge distribution. As a measure of visual complexity, compressed image file size is also considered.

5 DATASETS

Two different datasets were used to test our features. The first dataset was obtained by crawling recently uploaded photos on Flickr photo sharing portal. Due to the poor average quality of obtained photos, we also selected images from the Picks of the day category. The subjects of these photos were identified manually with the assistance of experienced photographers who also evaluated the composition and color balance of each photo. We obtained 258 photos, each evaluated by at least 3 different persons. For the purpose of the first experiment we used photo's overall rating which is a 3-class attribute with values: low, average and high. We excluded the photos rated as average which resulted in dataset size of 114 photos.

Obtaining a larger dataset proved to be challenging because of the time-consuming manual subject identification process. Therefore, for our second dataset we selected photos from DPChallenge portal [10] which were already evaluated. To determine also the subject automatically we decided to use only portraits so that the subjects were determined by a face detection algorithm. The photos were part of photographic contests and were rated with numerical range from 1 to 10. The average rating of a photo was 5.55 with a low standard deviation. Photos with a rating 4.5 or lower were labeled as low quality photos. Similarly, photos

Figure 3: An example of a high quality photo on the left and a low quality photo on the right. Both photos were rated by DPChallenge portal users where the photo on the left received the highest ratings in contrast to the right one which received the lowest ratings.

with a rating 6.5 or higher were labeled as high quality ones. The final dataset used in the second experiment consisted of photos previously labeled as low or high quality. It contained 1048 photos, each evaluated by at least 100 persons.

6 EXPERIMENTAL RESULTS

We evaluated the proposed features on both datasets described above. We used the Support vector machine (SVM) classifier with RBF kernel to automatically distinguish between high quality photos and low quality snapshots. We evaluate the classifier performance with a 10-fold cross validation technique and we use reliefF metric to determine feature quality [11].

In our first experiment, we calculated 73 features on 114 photos in Flickr dataset. The best classifier accuracy of 95% was achieved by using 28 best features ranked by reliefF metric. In Table 1 we show classification accuracy (in percents) which was achieved by using different number of best features (first row) ranked by reliefF metric.

Feat. used	5	10	20	28	73
CA [%]	80.2	91.3	94.7	95.3	95.3

Table 1: Flickr dataset results. Best classification accuracy of 95% was achieved using 28 automatically determined features.

In our second experiment, we calculated 71 features on 1048 photos in Flickr dataset. The best classification accuracy of 75% was achieved by using 41 best features ranked by reliefF metric. In the table below, we show classification accuracy (in per cents) which was achieved by using different number of best features (first row) ranked by reliefF metric.

Feat. used	5	10	20	30	41	71
CA [%]	69.8	71.1	72.1	72.4	74.8	73.4

Table 2: DP dataset results. Best classification accuracy of 75% was achieved using 41 features.

6.1 Feature performance

Although photos taken by experienced photographers look colorful and vibrant, the number of unique hues they contain is usually low. This was confirmed by both experiments. We observed that photos in DP dataset that contain less than 4 unique hues are preferred in comparison to more colorful ones.

Experienced photographers often crop photos to improve framing of selected subject. We observed that extreme aspect ratios are not desired. Results from DP dataset show that photos with aspect ratio from 0.81 to 1.2 are preferred.

High quality photos usually follow one of the established rules of composition. From both our datasets we observed the influence of the rule of thirds and the golden ratio. Both composition rules divide photos with two vertical and two horizontal lines. We observe that the subject center distance to nearest vertical line is the best predictor of a photo quality. Results obtained from DP dataset show that photos with a distance to nearest vertical line, defined by the rule of thirds of less than 11% of overall width are preferred (15% for golden rule). We used different templates to determine how much the photo follows the rule of thirds as well as the golden ratio rule. Application of the golden ratio rule template on a photo is shown in Figure 2.

It is not common for a subject to be placed near the photo edges. We observe that photos with the subject center distance from the left image edge of more than 38% of overall width are preferred. Similarly, distances from the bottom image edge in the interval from 23% to 86% are preferred.

We analyzed the spatial distribution of image edges detected by edge detector algorithm in order to capture the placement of distinct objects (subject). These features were ranked as the best features in DP dataset. We observe that high quality photos have the subject placed away from the image center. We also notice that the number of detected edge pixels has significant influence on perceived quality of a

photo. We argue that higher number of detected edges means more distinguishable subject and/or more visually complex photo.

Complex photos require more effort and skill in order to be produced. Consequently, they are more visually pleasing to the viewer's eye. Photo complexity should be understood in terms of complexity of a photo subject and should not be mistaken for low quality snapshots that introduce a lot of background clutter. A good and simple measure of visual complexity is the size of the compressed image in jpeg format [12]. We notice that high quality photos have a higher image file size.

7 CONCLUSION

In our work, we identified significant parameters that distinguish high quality photos from low quality snapshots. On the basis of these parameters, we defined calculable features for automatic assessment of photo aesthetics using machine learning methods. Proposed features were evaluated on two different datasets. Our system was able to achieve a 95% classification accuracy on the Flickr dataset. Second dataset proved to be more challenging, photos from DP dataset were part of various photography contests and were nearing artistic photography. Automatic assessment proved to be still feasible as our classifier achieved 75% accuracy on the described dataset. Both experiments showed results that are on par or even better than in comparable work [1, 7].

Future work should focus on distinguishing between different types of photos (landscape, portrait, etc.) and their specific features. Additional research could also address the problem of automatic identification of photo subject on common photos.

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Multilingual Document Retrieval through Hub Languages

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ABSTRACT

In this paper we extend previous work on document retrieval across multilingual corpora. In this setting it is often assumed that we have a certain alignment given based on which we can learn mapping between spaces. In true multilingual corpora however, we often do not have alignments between all languages. There are *hub* languages which have alignments with many other languages. We look at the effectiveness of leveraging these alignments to learn maps which may have small or no alignments given. We test several methods and investigate the performance of various approaches on the Wikipedia dataset.

1 INTRODUCTION

Document retrieval is a well-established problem in data mining. There have been a large number of different approaches put forward in the literature. In this paper we concentrate on a specific setting: multi-lingual corpora. As the availability of multi-lingual documents has exploded in the last few years, the need for automatic cross-lingual processing tools has become apparent. The prime example is Wikipedia - in 2001 the majority of pages were written in English, while by 2012 the percentage of English articles has dropped to 14%. In this context, we look at how to find similar documents across languages. In particular, we do not assume the availability of machine translators, but rather try to frame the problem such that we can use well-established machine learning tools designed for monolingual text-mining tasks.

This work represents the continuation of previous work [4, 2] where we explored representations of documents which were valid over multiple languages. The representations could be interpreted as multi-lingual topics, which were used as proxies to compute cross-lingual similarities between documents. We look at a specific aspect of this problem. The distribution of articles across languages in Wikipedia is not uniform. While the percentage English articles make up as a whole has fallen, in terms of absolute numbers, English is still the largest language. Indeed, there are a number of *hub* languages which have an order of magnitude more articles than other languages.

For document retrieval, if for example, we are looking for a German article comparable to an English article, there is a large alignment between the document corpora (given by the intersection in articles in the two languages) making the problem well-posed. If however we look for a relevant Slovenian article given a Hindi article, the intersection is small, making the problem much harder. However, almost all languages have a large intersection in articles with the *hub* languages, so the question we ask in this paper is: can we exploit hub languages to perform better document retrieval between non-hub languages?

A positive answer would improve cross-lingual analysis in particular between less represented languages. In the following section, we introduce our representation followed by our experiments, which also shed light on the structural properties of the multilingual Wikipedia corpus.

2 DATA MODEL

The key ingredient to our method is a language independent representation upon which we can compute similarities. To model documents we use the standard bag-of-words representation with TF-IDF (term frequency-inverse document frequency) weighting. This representation turns each language into a vector space and cosine similarity induces a metric. From this point on, we operate on languages as metric spaces denoted generically by L. Formally, each document is represented as a point in the metric space. Document comparison can therefore be done by applying the metric on two point $p, q \in L$. This is the starting point of monolingual document retrieval. We now extend this to the multilingual setting. The benefit of this linear representation is that maps between languages (metric spaces) are also linear and we can aim to find a simple (low dimensional/rank) map between the corpora. As input, we are given a partial map in the form of point-

Table 1: Slovenian-Hindi MAPR retrieval using different maps

	sl↦**hi**	hi↦**sl**	sl↦**en**↤hi	sl↦en↦**hi**	hi↦en↦**sl**
LSQ all	0.42	**0.49**	0.38	0.35	0.43
RCCA all	**0.55**	0.45	**0.38**	0.29	0.29
LSQ common	0.42	**0.48**	0.47	0.42	**0.49**
RCCA common	**0.55**	**0.46**	0.39	0.35	0.38
LSQ empty	N/A	N/A	0.27	0.28	**0.35**
RCCA empty	N/A	N/A	**0.32**	0.22	0.21

	sl↔hi	sl↦**en**↤ hi	sl↦en↦**hi**	hi↦en↦**sl**
CL-LSI all	**0.585**	0.35	**0.56**	0.54
CL-LSI common	**0.58**	0.47	**0.61**	**0.61**
CL-LSI empty	0	0.24	**0.48**	0.46

to-point correspondences and we must learn the map (usually through some regression). There are several different formulations of this problem depending on how we *learn* the map addressed in Section 4.2.

In the multilingual setting, for any two languages the number of correspondences may be too small to learn effectively. Therefore, we must go through the hub language (where the number of correspondence with each language may be large) and effectively compose the maps. There are numerous ways to do this which we discuss in the following section.

3 EXPERIMENTS

Experiments were performed using an alignment obtained by Wikipedia on several languages. Specifically we used Slovenian (sl, 91272 words), English (en, 344517 words) and Hindi (hi, 72063 words). The markup in brackets denotes language and number of words in each dictionary. As a preprocessing step, all stub documents with fewer than 20 different words were dropped to improve the quality of the data. The remaining alignment consists of 44426 Slovenian-English correspondences, 4034 Slovenian-Hindi correspondences, 14121 English-Hindi correspondences and 4017 joint Slovenian-English-Hindi correspondences. After stub removal we keep 614 of the initial 1000 test documents and remove them from the training data.

Retrieval can be done in five essentially different ways using our metric space approach:

1. $sl \mapsto \mathbf{hi}$,
2. $hi \mapsto \mathbf{sl}$.
3. $sl \mapsto \mathbf{en} = \mathbf{hub} = \mathbf{en} \leftarrow hi$,
4. $sl \mapsto en \mapsto \mathbf{hi}$
5. $hi \mapsto en \mapsto \mathbf{sl}$.

Bold denotes the space where retrieval is done. The first two represent a direct mapping $sl \leftrightarrow hi$, while the remaining methods map to a common hub space (in this case English), with retrieval occurring either in the target language or the hub language.

To see the amount of information present in the hub languages, we performed tests on three substantially different datasets

- *all* – we use all alignment information available,
- *common* – we use only alignment information consistent through all three languages
- *empty* – we remove all common alignment to simulate the case where we are forced to use hubs.

The evaluation criteria we use is the *mean average precision mate retrieval score* (MAPR). This enables us to compute a similarity between the documents and their translations in the common vector space induced by the latent model or mapping in the common space. Good models will map documents close to their translations – this indicates that some language independent (semantic) information was captured.

Let the individual language we are considering be denoted by L_1 and L_2. Each (latent) model is given by projection operators P_1 and P_2, where one can be identity. We evaluate each model by considering a pair of aligned test sets X and Y in L_1 and L_2. We select a query document $x \in X$ and denote the corresponding translated document $y \in Y$. We then compute the projections P_1x and P_2Y and rank the elements of P_2Y by their similarity to P_1x in the projection space (measured by cosine similarity). The mean average precision mate retrieval score is the inverse of the rank of P_2y. If only one score is displayed, then this is the average of the inverse of the rank of P_1x and the inverse of the rank of P_2y.

3.1 Methods used

In addition to studying the difference in performance depending on which space we perform the retrieval in, there is also the question of how we find the maps.

One approach is to learn the map from the aligned sets X and Y to use a least squares low rank approach.

Table 2: CL-LSI MAPR retrieval in common semantic space

	sl	**en**	**hi**
sl	0	0.77	**0.45**
en	0.73	0	0.64
hi	**0.38**	0.67	0

All

	sl	**en**	**hi**
sl	0	0.81	**0.6**
en	0.77	0	0.71
hi	**0.61**	0.76	0

Common

	sl	**en**	**hi**
sl	0	0.37	**0.22**
en	0.49	0	0.36
hi	**0.11**	0.29	0

Empty

Table 3: CL-LSI MAPR retrieval, full pairwise space

	sl	en	hi
sl	0	0.82	**0.57**
en	0.77	0	0.73
hi	**0.6**	0.78	0

All

	sl	en	hi
sl	0	0.81	**0.58**
en	0.77	0	0.71
hi	**0.58**	0.77	0

Common

	sl	en	hi
sl	0	0.78	0
en	0.7	0	0.71
hi	0	0.77	0

Empty

That is, we find W of rank k with which minimizes $\min ||WX - Y||_F$ where k is an input parameter. The solution can be obtained using a truncated SVD of the input X, $W = YX^+$, $X = U\Sigma V^*$, $X_k^+ = V_k\Sigma_k^{-1}U_k$, where $+$ denotes the pseudo inverse of matrix X. To speed up the computation, a low rank approximation of matrix Y is used. We always use truncated SVDs of size 1000. This approach is denoted as LSQ.

Another method that can be used to relate two aligned sets is regression canonical correlation analysis (RCCA) that is described in [3]. Essentially, this results in the map $q \mapsto (XX')^{-1}XY'q \approx U_k\Sigma_k^{-1}V_k^*Y'q$. Note that this must be used on (implicitly) centered data. Centering explicitly however, is not feasible due to the large number of words which would result in prohibitive RAM requirements. Again we use low rank approximations of implicitly centered Y's to reduce the time complexity and space complexity.

The third method we use is CL-LSI, latent semantic indexing. It is described in [1]. This method enables us to compare documents in the common semantic space. For the sake of clarity, we described this method only for two or three aligned document sets X_1, X_2, X_3. First, we do the SVD decomposition of the glued aligned documents, then we decouple the basis and map in the common subspace.

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} U_1 \\ U_2 \end{bmatrix} \Sigma V^*, \quad \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} = \begin{bmatrix} U_1 \\ U_2 \\ U_3 \end{bmatrix} \Sigma V^*,$$

The map to the common semantic space can be described as $x_i \mapsto V\Sigma^+U_i^+x_i$ for $i = 1, 2, 3$, where we overload symbols Σ and V.

To map to English (hub) using the full alignment, we first map Slovenian x_1 to the English word space as $x_1 \mapsto U_2^{12}(U_1^{12})^+x_1$ and Hindi x_3 to English word space as $x_3 \mapsto U_1^{23}(U_2^{23})^+x_3$. This can be done efficiently. Similary we map Slovenian x_1 to the Hindi-English semantic space through English as $x_1 \mapsto U_2^{12}(U_1^{12})^+x_1 = y_1 \mapsto (U_1^{23})^+y_1$ and Hindi x_3 to Hindi-English semantic space $x_3 \mapsto (U_2^{23})^+x_3$.

Mapping through the hub in CL-LSI case enables us to compare documents in the semantic space which as we will see seems to boost performance. In the *all* and *empty* datasets. we glue documents together all three languages despite the lack of an alignment to see how performance degrades in comparison with using the hub.

3.2 Results

As expected, the retrieval is dependent on the mapping used. It is important to note the lack of symmetry in retrieval for the computed RCCA and LSQ mappings. This is to be expected as we only use the information about the target(or alternatively the source) and no common information (as covariance). To illustrate this, RCCA mapping on the *all* dataset, $hi \mapsto \mathbf{sl}$, results in a retrieval score of 0.55, but RCCA mapping other way around on the same dataset, $sl \mapsto \mathbf{hi}$, results in a retrieval score of 0.45.

Better performance could be obtained by using canonical correlation analysis (CCA) although this is a more difficult computationally and has not yet been tested. A similar (dual) situation holds for LSQ mapping where we use only the information about the source space (rather than the target space).

From Table 1 it is not immediately clear which option of using the hub is the best. Using the hub does not improve performance even if we use the whole alignment information available. But is clearly the only option if there is no alignment information through all languages or this alignment is too small.

The CL-LSI method behaves more consistently and outperforms other methods. In this case, the better option is to go through the hub as we can then compare documents in the semantic space at the end. Further tests are

needed to better understand this behavior.

In Tables 2 and 3 we additionally display retrieval using mapping in the common semantic space and using full pairwise alignment, respectively. This gives us an idea about the quality of each mapping.

3.3 Ideal retrieval under misalignment

Consider the *empty* scenario described above: we wish to compare documents between languages L_1 and L_2, but we only have aligned sets for the two languages with a third language L_{hub}. Our aligned sets T_1 and T_2 correspond to $L_1 \mapsto L_{\text{hub}}$ and $L_2 \mapsto L_{\text{hub}}$ respectively.

We assume that no document is shared between T_1 and T_2. Since the alignments are disjoint it may follow that $rank(T_1 \oplus T_2) = rank(T_1) + rank(T_2)$. In such cases no nonzero document can be exactly represented in both bases. Let $f_1 : L_1 \to L_{\text{hub}}$ and $f_2 : L_2 \to L_{\text{hub}}$ represent the regression maps constructed using the alignment. By using the maps we can cast the information retrieval problem between documents in languages L_1 and L_2 as a monolingual information retrieval problem L_{hub}. Since $im(f_1) \subset span(T_1)$ and $im(f_2) \subset span(T_2)$, all inter-lingual similarities will be reduced due to the misalignment of the spaces $span(T_1)$ and $span(T_2)$ (rather than all of L_{hub}). Since the quality of retrieval typically degrades when no direct alignments are available(see Section 4.2), we investigate what is the best possible retrieval under the mis-aligned spaces. That is, what is the highest possible retrieval score on the test set, provided that the images of f_1, f_2 are restricted to $span(T_1)$ and $span(T_2)$ respectively. As in the previous section, the experiment is based on IR between Wikipedia pages written in Slovenian (sl), Hindi(hi) and English (en). The English language represents the hub language with the following document matrices: $T_1 \in \mathbb{R}^{406,044\times 41,529}, T_2 \in \mathbb{R}^{406,044\times 10,331}$, and $T_{\text{test}} \in \mathbb{R}^{406,044\times 604}$.

T_{test} is aligned to A_{test} and B_{test} and $rank([T_1 T_2]) = rank(T_1) + rank(T_2)$. In the ideal case A_{test} and B_{test} would be mapped to T_{test} under f_1 and f_2.

Let $P_X(\cdot)$ denote the orthogonal projection map to the column space of the matrix X. Since the images of f_1 and f_2 are spanned by T_1 and T_2, the test sets would ideally be mapped to $P_{T_1}(T_{\text{test}})$ (ideally projected Slovene test documents) and $P_{T_2}(T_{\text{test}})$ (ideally projected Hindi test documents).

The mean average precision mate retrieval scores we obtain are: 0.995 when A_{test} = query, B_{test} = target and 0.969 when A_{test} = target, B_{test} = query. High retrieval scores indicate that the space of possible maps admits good quality solutions. This result shows potential for improving the retrieval quality.

4 CONCLUSION

The experiments we ran serve two main purposes: the first is an investigation of the performance of using a hub language to enable us to compare languages where alignments may not exist using various different maps and approaches to learning the maps. The second is a structural study, which illustrates how much information is present in the maps. In principle this second part, illustrates that it is possible to find a linear representation in the hub space which yields very high retrieval score, even with no overlap in the alignment. This means that it should be possible to learn maps with very high retrieval rates.

The first set of experiments show that with the approprate preprocessing, going throuh hub languages work reasonably well. However, the lack of symmetry (whereas correspondences are symmetric) in the maps suggests that this may be degrading performance. A method which takes both structures into account may perform better at a higher computational cost. Further, with no alignment there are distribution issues which must be addressed (each language has a different distribution of documents in its monolingual metric space), suggesting that techniques based on transport distance may prove effective.

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Identifying good patterns for relation extraction

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ABSTRACT

In pattern based relation extraction, patterns that with high precision and recall produce semantically useful relations are preferred. We present a technique similar to n-gram extraction that extracts patterns from large text corpora and calculates statistics, like frequency, minimal token frequency and normalized expectation, which guide to preferred patterns. Patterns have named-instances and/or one variable length gap as arguments. We extracted patterns from a large news corpus and translated them to Cyc relations. We focused on four patterns, which we evaluate by asserting their translated relations to Cyc knowledge base.

1 INTRODUCTION

In this paper, we present an approach that identifies good patterns, which can be later used for domain-independent relation extraction. For instance, pattern "*[PERSON] was born in [LOCATION]*" might be used to extract relation *(placeOfBirth TigerWoods CityOfCypressCalifornia)* from unstructured text. We distinguish two types of relations. The first ones represent a fact. They consist of a predicate and arguments. The second ones represents a concept, which can be used as an argument to other relations. For instance *(StreetIntersectionFn PortageAvenue MainStreet)* represents the concept of the famous street corner in Canada. These relations consist of a function and arguments.

Mapping rule translates one match of the pattern to one, or several relations if any argument represents more than one argument. If word sense disambiguation is applied, we can reduce the result of translation to one relation. Relations are constructed in such a way that they can populate the target ontology. All relation's arguments must comply with semantic restrictions of the ontology in order for relation to be asserted in the ontology. For instance, a concept must be an instance of a person to become a valid argument of particular relation. Mapping rules are usually handcrafted. Our system helps human designers find patterns that are good enough to design mapping rules for them.

But, what is a good pattern? Good patterns give *high recall*, *precision* and *semantic usefulness* of the extracted relations. In our work, we built a system that optimizes this three metrics. We define recall of the pattern as the total number of unique matches of a pattern in the examined corpus. Precision is defined as the fraction of matches that produce a valid relation. Relation is valid if it complies with all the semantic restrictions, and if the extracted relation really reflects the meaning of the mention in the text. Semantic usefulness depends on how much do extracted relations contribute to the application that uses them. If the application is ontology population, semantically richer relations are favoured. While recall is very easy to measure, human evaluation needs to be done to measure the precision. Finally, semantic usefulness is almost unmeasurable because of its subjective nature.

Pattern based approach to relation extraction emerged in the early nineties, with the use of lexico-synctactic (Hearst) patterns to extract hypernym (is-a) relations [1]. In [2] similar approach was used to extract meronymy (part-of) relations. Next, semi-supervised approaches become widely used. They use a very small number of seed patterns or instances of relations to do bootstrap learning [3] [4] [5]. Recently, unsupervised (open) relation extraction techniques become very popular [6]. In these systems, relations are learned automatically from very large corpora. In contrary, our system does not learn relations neither pattern-relation pairs automatically. However, it can be used to find good patterns to extract relations in a domain-specific environment or to prepare seed patterns for the bootstrapping approach.

In Section 2, we present our system, which helps separate good patterns from the rest. In Section 3, we evaluate several patterns. We end with discussion and future work in Section 4.

2 IDENTIFIYING GOOD PATTERNS

We developed a scalable system that extracts patterns from a specially prepared corpus and calculates a few statistics that help identify good patterns. In this corpus, each sentence is an independent unit, disallowing patterns to be split across sentences. We replaced named instances with their types using a named entity recognizer [7]. We used the following types: person, location, organization, date, and money. These are later used as the arguments of the patterns. Each sentence is split on tokens where each token is defined as a part of text (usually words) that is tagged by a single part-of-speech tag, or an entity category.

Our system extracts two kinds of patterns. The first ones are fixed size n-grams. Each pattern is a sequence of n tokens, which contains at least one token that translates to an argument. Table 1 shows a pattern of the second type. These patterns have one variable length gap, which

Pattern	Frequency
[PERSON] , [__] of [ORGANIZATION]	9392
Gap filler	**Frequency**
president	878
director	818
chairman	560
head	549
one	449
executive director	438
a member	247
…	

Table 1: *Variable length gap n-gram representation*

becomes one of the arguments. Gaps are not allowed at the beginning or the end of the pattern. In this case, the length of the string that fills the gap, gap filler, is automatically defined. If the gap fillers are of the same type, the pattern has better chances of becoming a good pattern. The type of most of the gap fillers on Table 1 is "position in an organization". Therefore, one could make the mapping rule to the following relation template *(positionOfPersonInOrganization ?Person ?Organization ?Position).*

We extracted patterns from a corpus containing about half a million English news articles, which is about 14 million sentences. The extraction produced two sets of n-grams: a set of n-grams of length five tokens or less, and a set of n-grams that occurred at least twice and were of length ten tokens or less. From these n-grams, we generated all possible n-grams with one gap that had maximally five non-gap tokens.

The output of our system is a table of equally long patterns and their statistics. Table 2 shows part of the table for 6-grams patterns. We will present an example of how to manipulate the table to obtain good patterns. Patterns with very low pattern frequency (*Fq*) were filtered out to achieve good recall. We were only interested in patterns with two or three arguments (*Args*). Other patterns were filtered out. One could also order or filter the table according to the number of stop words (*StopW*). In our case, stop words are tokens from the standard stop-word list and non-alphabetical tokens. The table is sorted according to minimal token frequency (*MinTokFq*), which is the frequency of the token that appears the least. Patterns with high minimal token frequency are usually semantically poor, because they are too general. Similarly, patterns with higher normalized expectation (*NExp*) are usually semantically richer. As defined in [8], normalized expectation between n words is the average expectation of one word occurring in a given position knowing presence of other n-1 words also constrained by their positions.

$$NExp([w_1 w_2 \dots w_n]) = \frac{p([w_1 w_2 \dots w_n])}{\frac{1}{n}\sum_{i=1}^{n} p([w_1 w_2 \dots \widehat{w_i} \dots w_n])},$$

where $p([w_1 w_2 \dots w_n])$ denotes the probability of n-gram $[w_1 w_2 \dots w_n]$ occurring in the corpus. Term $\widehat{w_i}$ signifies that word w_i omitted from the n-gram, which becomes (n-1)-gram, which potentially has a gap. Authors in [8] have shown that normalized expectation multiplied with the frequency gives mutual expectation, which can be applied to find multiword units.

3 EVALUATION

In this section we present an experiment, where we selected several patterns with the process explained in Section 2, and translated them to relations, written in Cyc's language, CycL [8].

3.1 Pattern matching and translation algorithm

Our algorithm processes the corpus one sentence at the time. First, it finds all matches of the provided patterns in the sentence. Then, it first translates the patterns, which relations represent concepts. In the next step, it tries if any of these concepts fit as an argument in a pattern, which translates into a fact. These type of patterns are translated in the last step.

The translation of the pattern is done in the following way. First, each argument of the pattern (string) needs to be translated into one or more Cyc concepts. We inquired Cyc to obtain concepts that denote the argument and are instances of the argument's type. For example, we inquired the entity-type pair *("Boulder", Location).* The system accepts the first answer to the query, *(CityNamedFn "Boulder" Colorado-State)*, because it is a location, and rejects the second concept, Boulder, which represents the collection of all boulders (stones). If the query does not return and reject any concepts, we create a new concept. There are as many relations created, as there are combinations of concept assigned to each argument. At the end of the procedure, we assert all relations into Cyc's ontology.

3.2 Experiment

We used a test corpus of about 7500 news articles, published the same day, to test a few dozen rules. We will present evaluation of four different rules. One human evaluator examined all the match-assertions pairs. He was given the sentence containing the match and the translated relations to subjectively decide, whether the meaning of one of the assertions is also found in the sentence. Precision was calculated based on this number. Not having a system for word sense disambiguation integrated in our system, we considered the translation successful, even though the match had one valid assertion, but other assertions were not valid.

Pattern coachOfOrganization

This pattern connects sport coaches to sport organizations (Table 3). From pattern statistics table we expected a bigger recall for this pattern. However, many articles have talked about one NBA game. Most of the matches were connecting these two clubs to their coaches. Out of 70

Pattern	*Fq*	*Args*	*StopW*	*MinTokFq*	*NExp*
[PERSON] , executive director of *[ORGANIZATION]*	21	2	2	11699	0.484
's hospital in *[LOCATION]* , *[LOCATION]*	22	2	2	11917	0.571
to *[PERSON]* parents , *[PERSON]* was	40	2	3	12020	0.564
death by *[PERSON]* parents , *[PERSON]*	24	2	2	12020	0.282
[PERSON] parents , *[PERSON]* and *[PERSON]*	22	3	2	12020	0.506
[PERSON] have no idea what *[PERSON]*	20	2	3	12449	0.553
(*[ORGANIZATION]*) - *[PERSON]* scored	22	2	3	12514	0.735
victory over the *[ORGANIZATION]* on *[DATE]*	55	2	3	12626	0.653
, died *[DATE]* , at *[ORGANIZATION]*	61	2	3	12822	0.712
died *[DATE]* , at *[ORGANIZATION]* in	45	2	3	12822	0.732
[PERSON] was a member of *[ORGANIZATION]*	38	2	3	13399	0.623

Table 2 *Part of the table representing 6-gram patterns and their statistics*

matches, there were only 24 unique. There were less total assertions (19) than there were matches (24). Some matches were not transformed into assertions because of semantic constraints. While some matches had more than one assertion because one of its arguments had more than one denotation.

Pattern personPositionInOrganization

We present the second pattern on Table 3. The pattern expresses people's positions in organizations. The second argument is a variable length gap. Analysis from Table 1 has shown that most gap fillers are positions in organization. Out of 17 newly created "*POSITION*" concepts, eight were really representing position in organization. Majority of non-valid *"POSITION"* concepts were made out of very long gaps, which occupied almost the whole sentence. Seven "*POISTION*" concepts, like PresidentOfOrganization and CheifExecutiveOfficer, were already in the ontology.

Pattern personMadeAStatement

The analysis of the third pattern is also presented on Table 3. This pattern connects a person to the statement that he gave. The way pattern's CycL is structured, it connects them through the event of informing. This is one of the most frequent patterns in the news articles. It may be not be as semantically rich as the previous patterns. However, together with similar patterns, all the statements of the particular person can be quickly gathered. If the argument *STRING* had been further parsed, the pattern would have been semantically richer. The pattern has many more total assertions than matches. This is because a few matches have a big number of assertions. For instance, in one match LeBron James was mentioned as "James". There are 57 concepts denoting "James". Not even one of them is LeBron James.

Pattern personsFather

The result of the relation produced by this pattern is a concept denoting somebody's father. This pattern usually matches "his father" or "her father". Using the co-reference resolution, pronouns are connected to the name of the persons. This pattern had 147 matches. However, it was used in a fact relation only once. It was an argument in the personSaidAStatement relation.

4 DISCUSSION AND FUTURE WORK

Table 3 shows there were more cases when new term needed to be created than cases where the replacement for the arguments already existed in the ontology. Most of our arguments represented named-instances. It turns out that Cyc's ontology is not very well populated with named-entities. It would be reasonable to find named-instances in other ontologies like DBpedia or Freebase, and connect them to Cyc Ontology.

When constructing a system for relation extraction, the question is whether to create new concepts liberally or to allow only assertions that consist of arguments that are already in the ontology. Our system is in the middle of both extremes: high recall and high precision. New concepts are not created if there are recognized concepts, even if they all fail to meet the semantic requirements. If the system is self-supervised, it might be better to make it more biased towards precision.

One expansion of our system would be allowing variable length gaps at the beginning or the end of the pattern. When the gap is in the inner part, the length is defined by the pattern. However, if the gap is on either end of the pattern, it is hard to decide how many words to put in the argument. There are two approaches to deal this problem: for each of the first few lengths of n-grams check if there are any denoting concepts, or use a natural language parser to detect phrases.

In our case, arguments that represent named-entities have their type assigned from the beginning. On the other hand, types of arguments that represent variable length gaps must

Pattern	*[ORGANIZATION]* coach *[PERSON]*	
CycL template	*(#$hasCoach ?ORGANIZATION ?PERSON)*	
Recall		24
New terms		29
Recognized arguments		9
Total assertions		19
Matches with ambiguous assertions		0
Matches with a valid assertion		16
Precision		0.67

Pattern	*[PERSON] , [POSITION]* of *[ORGANIZATION]*	
CycL template	*(#$positionOfPersonInOrganization ?PERSON ?ORGANIZATION ?POSITION)*	
Recall		38
New terms		70
Recognized arguments		14
Total assertions		30
Matches with ambiguous assertions		2
Matches with a valid assertion		20
Precision		0.53

Pattern	*" [STRING] , " [PERSON] said*	
CycL template	*(#$thereExists ?INFORMING (#$and (#$isa ?INFORMING #$Informing) (#$senderOfInfo ?INFORMING ?PERSON) (#$infoTransferred-NLString ?INFORMING ?STRING)))*	
Recall		379
New terms		227
Recognized arguments		35
Total assertions		830
Matches with ambiguous assertions		37
Matches with a valid assertion[2]		337
Precision		0.89

Pattern	*[PERSON] father*	
CycL template	*($#FatherFn ?PERSON)*	
Matches		147
New terms		78
Recognized arguments		24
Valid assertions		1

Table 3 *Evaluation statistics of the selected patterns.* [2]*Expected number of valid assertions after evaluating 100 unique matches*

be manually assigned. We propose a method for finding the most common type of the gap filler. Each gap filler is assigned its type (node) in the hypernym (is-a) relation tree. The algorithm then searches for the lowest node that is the parent of the majority of nodes. Resulting nodes that appear very low in the hierarchy tree are more desirable.

Acknowledgements

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NewsSearch: Search and Dynamic Re-ranking over News Corpora

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ABSTRACT

NewsSearch proposed in this paper is a search engine interface, which allows users to visually re-rank search results. When a query is first made, the results are visualized using topic, concept and location widgets on the client side. The user is then able to filter and re-rank complete results by interacting with the visualization widgets. Filtering and re-ranking is performed on the server side, allowing the user to seamlessly browse through millions of results.

1 INTRODUCTION

Search engines emerged as useful tools for information seeking, allowing users to access relevant information quickly through simple keywords queries. Knowing how to use them can save time and get reliable results.

Search engines today have to display tens of thousands of ranked documents, which lead to user paralysis and poor choices. A typical query easily results in thousands or more results. However, on average less than 6% of users would click on a link from the second page of results [6]. This leaves a large unexplored space of results, which are hard to comprehend, since it requires manually iterating through results pages. NewsSearch [7] addresses this issue by visualizing the long tail of search results. The documents are grouped into related groups according to several criteria, allowing the user to filter and re-rank the documents based on the similarity to each group.

This paper improves upon the work from [7] in the following ways. First, re-ranking is performed on the server side, which increases the amount of results, which can be handled with this approach. Second, query expansion is made pare of re-ranking, further increasing the scalability of the approach. Finally, new visualization widget was introduced, allowing re-ranking and filtering according to geospatial information, associated with the document.

The paper is structured as follows. We start by giving an overview of news collection and indexing services, which are used in the paper. This is followed by introducing different types of visualization widgets, which are used to visualize the search results. We conclude by presenting the query extension based re-ranking approach and the system prototype.

2 NEWS COLLECTION AND INDEXING

NewsSearch uses news collection and indexing services developed at J. Stefan Institute (JSI) and available at http://newsfeed.ijs.si [1]. The services provide a real-time aggregated stream of news articles by crawling RSS-enabled news providers across the world. The crawler currently downloads 50,000-100,000 articles per day from about 100,000 RSS feeds. The current archive contains about 25 million articles and begins in May 2008. The stream of articles is serialized into XML and segmented by time into compressed files with several megabytes in size.

The news collection service collects articles from a multitude of languages, however in this work we only focused on a subset of English news sources. Each article is processed using text enrichment service Enrycher [8], which extracts topics and entities from the articles. Additionally, for all major news sources, additional meta data was collected, including their location.

For indexing and search the news collection we use News Miner, which is a system for processing and indexing news corpora and is entirely based on the code base developed at JSI. Each article is indexed across several dimensions (facets) using an inverted index. The system allows for retrieval of any Boolean combination of the facets.

Processing of a news feed contains the following steps each being executed by a separate process:

1. Retrieve the articles from the news feed (e.g. using News Collection service's Python script)
2. Parse the article and prepare the fields for indexing (e.g. tokenizing text)
3. Add the article to the index

Once the article is indexed, it can be accessed through keyword queries.

3 VISUALIZATION WIDGETS

NewsSearch interacts with the user through a series of widgets, which are designed to visualize different dimensions of the complete search results collection.

The user starts the search by entering a search query and the widgets are generated based on the resulting documents. The system starts by using default search engine ranking (e.g. BM25 [9]). The user can influence the ranking by moving the target with a mouse to different parts of widgets, which causes re-ranking of the results.

3.1 WORLD WIDGET

The world widget, shown in Figure 1, enables the user to reorder results based on the locations assigned to the document. This can be either the locations mentioned in the article, or the location of the news outlet, which produced the article. When the user moves the target, the coordinates are sent to the server and the results weighted and reordered based on the distance from the target coordinates.

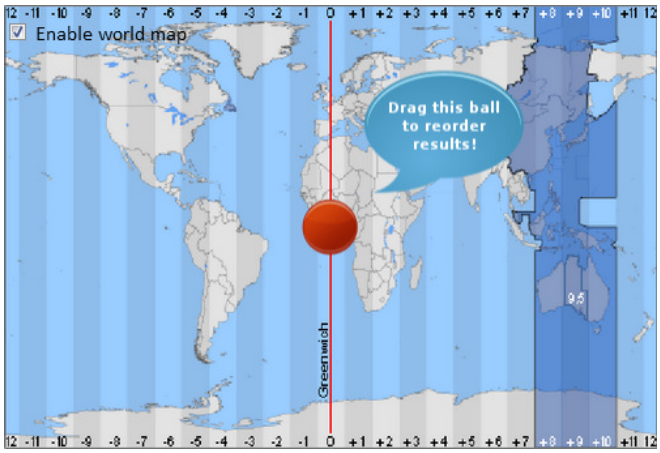

Figure 1. The world widget enables the user to re-rank results based on locations assigned to the documents.

3.2 TOPIC WIDGET

The topic widget, shown on the left in Figure 2, allows the user to filter and re-rank results based on the topics they want to view.

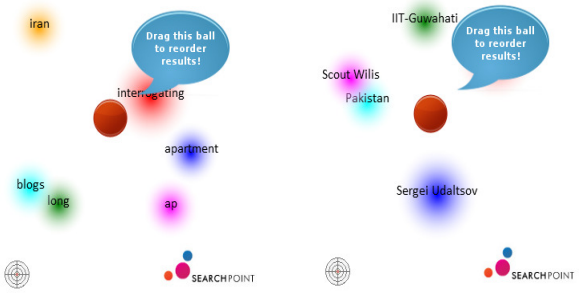

Figure 2. Topic and concept widgets enable the user to filter and re-rank results, based on keywords and concepts.

The widget displays clusters of articles represented by the most relevant keywords in each cluster. When the user moves the target, the new coordinates are sent to the server, which first computes the distance to each cluster and extracts the most representative keywords for particular coordinates. These keywords are then used to extend the query issued by the user, and sent to the search engine to filter non-relevant results and rank higher the remaining results using BM25 weights.

To construct the clusters, NewsSearch represents documents as vectors with the standard Bag-of-words representation where there is a dimension for each word. It then uses the K-Means++ [3, 4] algorithm, with cosine similarity, to cluster the documents into several clusters, which are displayed by the widget. Cluster centroid vectors are used to extract the most representative keywords for each cluster.

To visualize the clusters the keyword widget uses Multidimensional scaling (MDS [5]) to embed the centroids onto a two dimensional plane, similar as in [2].

3.3 CONCEPT WIDGET

The concept widget, shown on the right in Figure 2, allows the user to filter and reorder results based on the concepts contained in the articles. Concepts are extracted from the articles using the Enrycher service, and ranked using the News Miner service.

The widget displays clusters of articles represented by the most relevant concepts in each cluster. Like with the keyword widget, when the server receives new coordinates it computes the distance to each cluster and extracts the most representative concepts. It then constructs a new query using these concepts, to filter non-relevant ones and rank the remaining results using BM25 weights.

Unlike the topic widget, the concept widget clusters concepts and not documents. Each concept is represented as a "Bag-Of-Documents", where each document represents one dimension and a coordinate represents the number of times a concept appears in that document. The widget then uses the K-Means++ [3] algorithm, with cosine metrics.

Like the topic widget, the concept widget also uses MDS to visualize clusters on a plane.

3.4 DMOZ WIDGET

The DMOZ widget, shown in Figure 3, allows the user to reorder results based on their DMOZ categorization, provided by the Enrycher service.

The widget displays a tree of categories, extracted from the results, where the size of a category depends on the number of articles it contains.

When the server receives new coordinates, it reorders results based on the distance to their category.

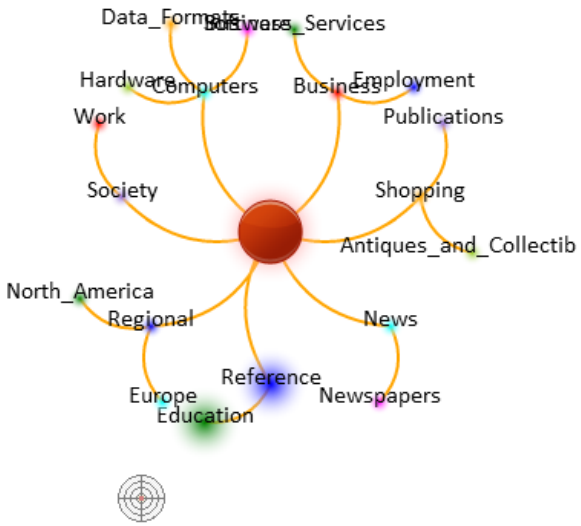

Figure 3. The DMOZ widget enables the user to reorder results based on their DMOZ category.

4 RE-RANKING

When re-ranking is performed, the server side is passed information about the position of all the targets in the widgets. The server constructs a new query by taking the user query, and extending it by weighting keywords and/or concepts contained in nearby clusters and selecting the top 5.

Keyword and/or concept weight is computed with the following formula:

$$w = w_c w_k.$$

The weight of the cluster w_c, is the same for all keywords and/or concepts in a cluster, and is computed using the Gaussian kernel

$$w_c(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}.$$

The weight w_k of a keyword and/or concept inside the cluster is computed using the position i of the keyword and/or concept in the cluster's centroid using following formula:

$$w_k(i) = e^{-\frac{i}{2}}$$

The new query is generated by conjucting a disjunction of the selected keywords/concepts. For example, let A be the original search term and let B, C, D be the keywords selected by the weighting procedure the new query Q will then be:

$$Q = A \wedge (B \vee C \vee D)$$

When the query results are obtained, they are weighted and ranked. The weight is computed using TF-IDF multiplied by the weight of the keyword/concept, so with the same TF-IDF keyword B will have a higher weight then keyword C. The world widget weight is computed using a Gaussian kernel. All three weights are multiplied and the results are sorted.

The results are then passed to the client side and displayed in a standard way.

5 EXAMPLE

In an example, we will create a query on a well-known Russian politician Vladimir Putin.

When the query is performed, the results are weighted using just the TF-IDF weight of keyword "putin". The results are shown in Figure 4.

(96144) Tens of Thousands Clog Moscow to Protest Putin
AP) - Police in Moscow have arrested top opposition figures along with demonstrators after a protest march on the eve of Vladimir Putin's inauguration as president tried to reach the Kremlin. The march by about 20,000 people to an island adjacent to ...
http://www.newser.com/story/147951/tens-of-thousands-clog-moscow-to-protest-putin.html

(39318) Putin's Extravagant $700000 Watch Collection
MOSCOW -- Russian President Vladimir Putin apparently has a soft spot for luxury watches, but some are wondering why the timepieces haven't been hard on his wallet. The Russian opposition group Solidarity has produced a slick video that begins with ...
http://abcnews.go.com/blogs/headlines/2012/06/putins-extravagant-700000-watch-collection/

(58708) Biggest anti-Putin rally
Tens of thousands of Russians flooded streets in Moscow to protest against President Vladimir Putin's rule in what appeared to be the biggest opposition rally yet. An estimated 100,000 demonstrators marched through downtown Moscow on Tuesday, which ...
http://www.thehindu.com/news/international/article3520402.ece

Figure 4. First three search results for query "putin".

(55038) Clinton's visit to the Caucasus
US Secretary of State Hillary Clinton made a whirlwind tour through the Caucasus, stopping in Armenia, Azerbaijan and Georgia on June 4-6. The visit focused international attention on the region, especially given the sudden spike in deadly armed clashes b...
http://www.todayszaman.com/columnistDetail_getNewsById.action?newsId=283293

(14973) For Obama, goal in Syria conflicts with goal in Iran
From one point of view, the connection between our troubles with Syria and Iran is straightforward. The Syrian regime of Bashar Assad is Iran's closest ally, and its link to the Arab Middle East. Without Syria, Iran's pretensions to regional heg...
http://www.palmbeachpost.com/news/news/for-obama-goal-in-syria-conflicts-with-goal-in-ira/nPQtY/

(14397) Obama's Iran and Syria muddle
So why are both the Obama administration and the government of Benjamin Netanyahu unethusiastic -- to say the least -- about even indirect military intervention to topple Assad? In part it's because of about what would follow the dictator. In Obama&a...
http://www.washingtonpost.com/opinions/obamas-iran-and-syria-muddle/2012/06/10/gJQAr6nITV_story.html

Figure 5. First three search results when the target is moved to topic "Iran".

When the target on the keyword widget is moved on to the "Iran" cluster, a new query is constructed on keywords "putin", "Iran", "Syria" and "Visit", and the results are weighted using TF-IDF giving keyword "Iran" the largest initial weight. The results are shown in Figure 5.

Then the target is moved to concept "Regional". A query is constructed on keywords "putin", "Iran", "Syria" and "Visit", and on concepts "Regional", "Syria", "Society and Culture", "Damascus" and "United States". The keywords are weighted same as before and the weight is multiplied by the weight of the concepts which are also weighted with TF-IDF, yielding results shown in Figure 6.

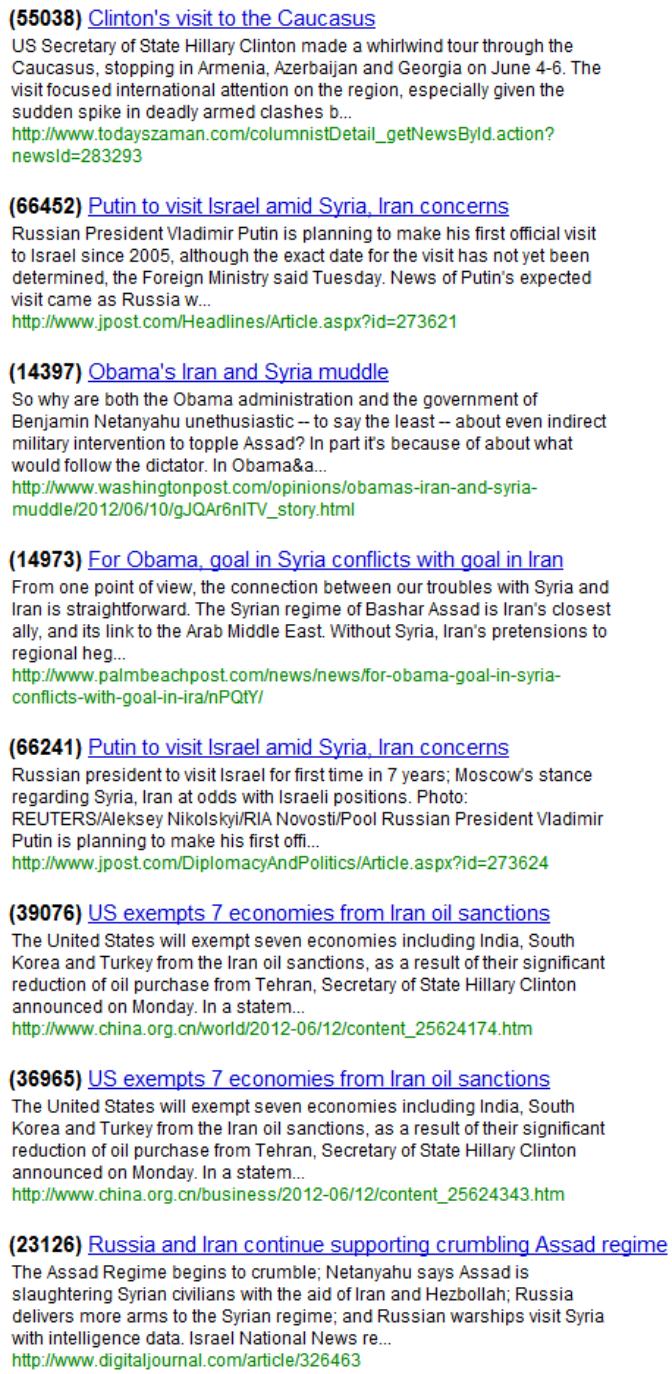

Figure 6. Search results when the topic widget is set to "Iran" and the concept widget is set to "Regional".

Finally when the target on the world widget is moved over New York, the previous weight is multiplied with the world position weight producing the final result.

6 CONCLUSIONS

NewsSearch aims to enable the user to more efficiently browse search results, which increases user productivity and the quality of information gathered. It can be used for search verticals or enterprise search, when one cannot invest a lot of money in tuning the ranking.

A demo can be found at http://searchpoint.ijs.si/ and where the data source used is Microsoft's search engine Bing.

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SEARCHING FOR INFORMATION IN SOFTWARE DEVELOPMENT PROJECTS USING THE ALERT SYSTEM

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ABSTRACT

Large open source projects use several communication channels to exchange information. Examples of these channels are bug tracking systems (BTS), source code management systems, mailing lists, forums and wikis. Since these information sources use different platforms there is no system which would allow users of these communication channels to find information appearing on any of these sources. Developing a system that will support such search functionality is the main goal of a European project called ALERT. In this paper we will introduce the project and describe the search features that can be used by the users of the ALERT system and highlight the advantages that they bring.

1 INTRODUCTION

Large open source projects commonly have their developers and users located all over the world. In order to exchange information such as questions, comments, requests and bugs reports, several information sources are employed. Each of these sources serves a particular purpose. Issue tracking systems such as Bugzilla[1], Mantis[2] and LaunchPad[3] are commonly used for reporting problems and feature requests. Mailing lists and forums allow users of the software to participate in open discussions about various topics related to the developed software. Wikis are often used as platforms for providing user support in the form of software documentation, user guides and tutorials. Source code management systems are used by software developers to commit modifications to source code and to describe the introduced changes.

Due to various information sources, a common problem affecting these communities is finding information. In order to find an answer to a question, the user has to open a separate web page for each of these sources and use different search interfaces to find information of interest. Because there is no integrated way of finding information, duplicates of the same questions can be found on different information sources. Display of search results is also quite limited. Results are only displayed as a list, frequently with a text snippet that matches the query. There is not additional summary of results that would allow discovery of useful and unexpected patterns.

Empowering the users by providing the missing functionalities of the current systems is the goal of the European project ALERT[4]. More specifically, ALERT system, which will be developed as the result of the project, aims to:

- Provide functionality to integrate information from issue tracking systems, source code management systems, forums, mailing lists and wikis.
- Extract information from structured (meta-data, source code commits) and unstructured sources (all text generated by users) and store it in a knowledge base
- Provide advanced search capabilities across all communication sources.
- Provide automatic methods for otherwise time consuming tasks such as finding bug duplicates and suggesting developers, who can fix an issue.
- Provide subscription mechanisms that allow users to specify their interests in order to be notified when something relevant is posted in some information source.

In this paper we will focus only on the ALERT's functionality related to search over all information sources. In the next section we will start by introduction the structure of the ALERT system. We will describe all main components of the system and the data flow. Then we will describe the search service and the visualization service – two main components responsible for enabling the user to find relevant information. Additionally we will also briefly describe more advanced search options such as finding potential bug duplicates and recommending developers who can fix an issue.

2 ALERT SYSTEM ARCHITECTURE

The ALERT system consists of several components, where each component is responsible for a particular task. The overview of the architecture is shown in Figure 1.

At the top of the figure we have a set of sensors that are responsible for detecting when new information is published in the information sources used by the community. Whenever new information is posted in these sources, the

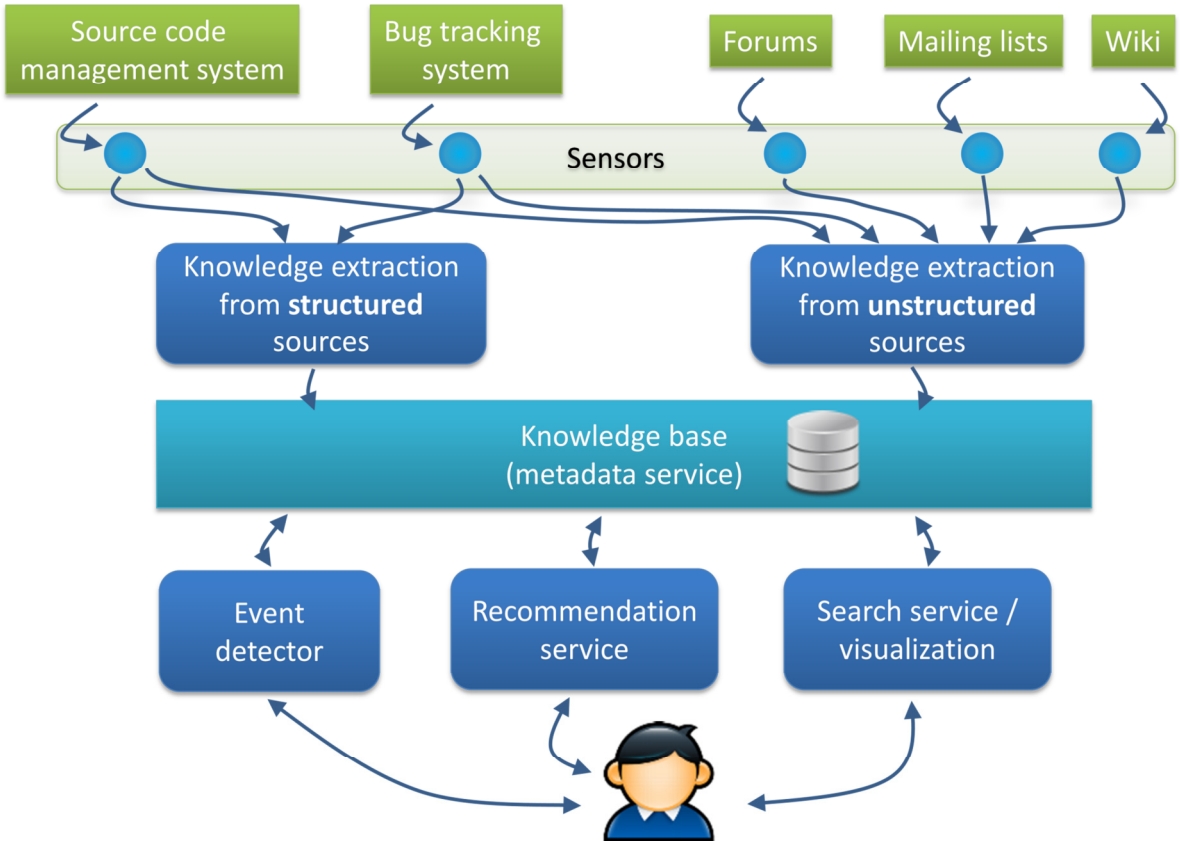

Figure 1. Architecture of the ALERT system.

sensors pass it forward to the components that are responsible for processing it.

Component "Knowledge extraction from structured sources" is able to process information on source code changes, such as what classes and methods were added or modified in a particular source code commit. The extracted information is then pushed to the Knowledge base where it can be accessed by other components.

The information generated in communication channels is mostly unstructured – it is plain text generated by the users. This type of data is processed by the component "Knowledge extraction from unstructured sources". One of the main tasks of the component is to annotate the text using the Annotation ontology [5]. The ontology contains relevant terminology for computer science and allows us to semantically enrich the text. The information extracted by the component is again stored in the Knowledge base.

After the data is stored in the Knowledge base it is ready to be consumed by other components. There are three main components that use the stored information to provide certain functionality for the user of the ALERT system. The Event detector enables the user to have control over what information he receives from the communication channels. The user can, for example, specify a set of topics he is interested in and as a result he will only be notified when posts on those topics are published in the communication channels.

The Recommendation service is responsible for recommending developers to fix an issue. Based on the activity of developers the service computes for each developer a set of scores that represents his/her expertise in different software development areas. When a new issue is created it can analyze what the issue is about (using the annotations from Annotation ontology) and identify the most appropriate developers to fix the issue.

The Search/Visualization service is responsible for providing to the user an integrated environment where he can search for information stored in the ALERT system. The details of the search service are described in the next section.

3 SEARCH SERVICE

The search interface provides the ability to search for information across all information sources. A screenshot of the interface is shown in Figure 2.

The top part of the interface contains a tab control offering four conceptually different search options. The first option is the general search. In the first text box it allows the user to enter plain search keywords. The second text box allows restricting the results based on the structured information available for the posts. When entering the text, the user is presented with a list of possibilities for the given text prefix. The possibilities are of the following types:

- People names. By specifying a person, the search results will be limited to posts where the person is the sender or recipient of the post.

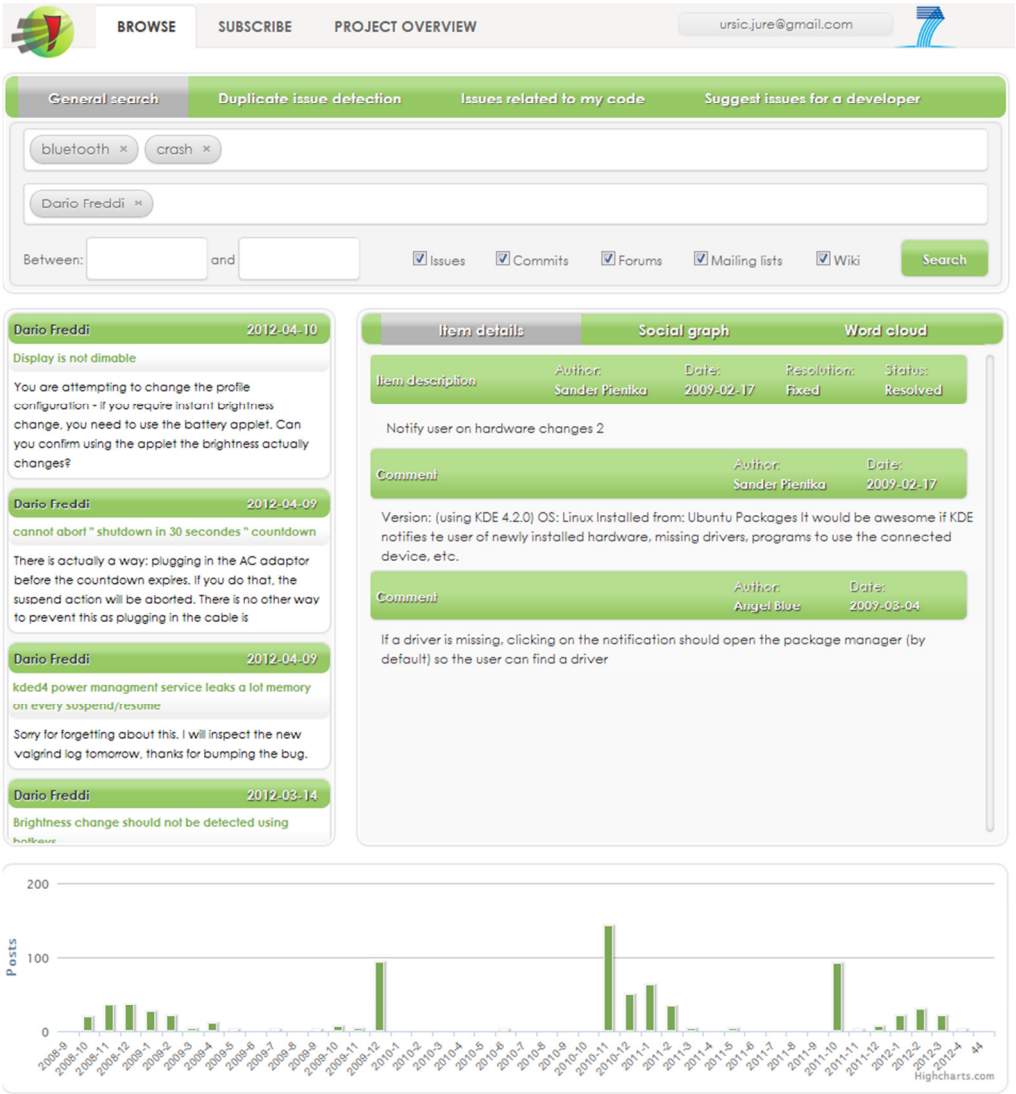

Figure 2. The search interface provided by the ALERT system

- Source code. By monitoring the source code management system we are aware of all the files, classes and methods developed in the project. By specifying the name of the file, class or method we can therefore limit the results to those posts that contain a reference to them.
- Project/component name. All issues on a bug tracking system are assigned to a particular product and component. By specifying a project or component we can limit results to a particular subset of issues.

The user can also specify a time constraint on the results by specifying a starting and ending date. Posts outside of the specified time window won't be considered in the query results. Additional constraint can also be the type of the posts. If the user would wish to ignore posts from a particular information source he can simply uncheck the appropriate checkbox.

Along with the general search, the user can also search for possible issue duplicates. On issue tracking systems the users often create duplicated reports of the same issue. Before starting to work on fixing the issue, a bug triager has to first determine if the issue is duplicate or not. Using our interface the bug triager can enter the id of the issue and the system will provide him with a list of most similar existing issues. For each existing issue the system even provides a score of the similarity. The similarity between issues is determined using an algorithm that takes into account the available meta information about the issue and the cosine similarity measure computed on the available text of the issue [6].

The third search option is to find issues related to my code. There are two crucial sources that ALERT has to monitor in order to support this functionality; the issue tracking system and the source code management system (SCMS). By monitoring SCMS we know for each developer which are the methods that he modified. By annotating the issues we also detect references to methods in the text. These references most often occur in stack traces that are provided

with the issue. By combining information from both sources we can suggest to the developer the issues that are possibly caused by his code.

The last search option is suggesting issues that a developer could solve. Although it seems similar to the previous one it is functionally different. In this case the user specifies the name of a developer. For each developer the ALERT system maintains an expertise profile that is created based on the topics that are mentioned in the posts created by the user. If the developer is, for example, in his posts frequently writing about Bluetooth, then he would be in a sense considered as an expert on this topic. The ALERT system can use the person's profile and match it to the existing open issues. Issues that are the best match are displayed to the developer and he can choose which ones he would like to fix.

4 VISUALIZATION SERVICE

After the user chooses the appropriate search option and specifies the search conditions, the search results are presented and summarized in different ways based on research done in [7].

The most ordinary display of the results is in a list. In Figure 2, this list is displayed in the middle left part. For each post in the list we show the author of the post, date, subject and a short content snippet. Clicking an item in the list shows its full content in the right part (Item details). If the clicked post is a part of a threaded message (such as an issue or email/forum discussion) the whole thread is displayed. The searched keywords are automatically highlighted in the text in order to more easily identify the information of interest. Depending on the post type, the item details tab also offers additional functionality. For issues, the user can also see a list of all posts that mention the issue and a list of most suitable developers to fix the issue. For source code commits, the shown information also contains a tree of files, classes and methods that were modified by the selected commit.

Together with the list of results, ALERT also provides three visualizations containing a summary of the search results. The first visualization is a timeline view and is displayed below the search results. It shows the distribution of search results over time. Using this visualization a user can spot times with high or low activity. Such patterns can be very helpful for gaining important insights. From our query in Figure 2 we can see that Dario Freddi was very active in December 2009 and then didn't participate again until December next year. When searching issues on a particular topic a spike on the timeline could identify when a bug was introduced in the code.

The second visualization is the social graph. By displaying a graph of people who are involved in the query results it shows a summary from the social perspective. There is a connection between two people in the graph if one is responding to the others post (for example, one person sends an email to the other). The size of the person's label depends on the number of times the person appears in the results. This visualization makes it easy to identify who are the most active/knowledgeable people on a particular topic. This information can be helpful if one would like find an expert on a particular topic in order to contact him directly.

The last visualization offered by the interface is the tag cloud. It offers a summary in a form of most relevant terms extracted from the results. The visualization can be helpful in different ways, depending on the entered search conditions. If a person is specified as a condition then the tag cloud can indicate what is the person's expertise or area of interest. In case the search is done using some keywords then the cloud can identify related topics that can be used to refine the query.

5 CONCLUSION

In this paper we presented an overview of the search functionality that is offered by the ALERT system. The system integrates information coming from several information sources – bug tracking systems, source code management systems, forums, mailing lists and wikis. We briefly described the architecture of the system and the way in which the information travels through individual components of the system. We described the search interface and the different search functionalities supported by the system. We also presented details of the visualization service which is responsible for displaying the results of the search queries. The service also provides different summaries of the results which enable the users to gain additional insights that would be otherwise hard to obtain.

6 ACKNOWLEDGMENTS

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Informal sentiment analysis in multiple domains for English and Spanish

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ABSTRACT

This paper addresses the problem of sentiment analysis in an informal setting in multiple domains and in two languages. We explore the influence of using background knowledge in the form of different sentiment lexicons, as well as the influence of various lexical surface features. We show that the improvement resulting from using a two-layer model, sentiment lexicons, surface features and feature scaling is most notable on social media datasets in both English and Spanish. For English, we are also able to demonstrate improvement on the news domain using sentiment lexicons and a large improvement on the social media domain. We also demonstrate that domain-specific lexicons bring comparable performance to general-purpose lexicons.

1 INTRODUCTION

Sentiment analysis is a natural language processing task which aims to predict the polarity (positive, negative or neutral) of users publishing sentiment data, in which they express their opinions. The task is traditionally tackled as a classification problem using supervised machine learning techniques. However, this approach requires additional effort in manual labeling of examples and often has difficulties in transferring to other domains.

One way to ameliorate this problem is to construct a lexicon of sentiment-bearing words, constructed from a wide variety of domains. While some sentiment-bearing cues are contextual, having different polarities in different contexts, the majority of words have unambiguous polarity. While this is a compromise, research shows that lexicon-based approaches can be an adequate solution if no training data is available. In practice, sentiment dictionaries or lexicons are lexical resources, which contain word associations with particular sentiment scores. Dictionaries are frequently used for sentiment analysis, since they allow in a fast and effective way to detect an opinion represented in text. While there exists a number of sentiment lexicons in English [1][2], the representation of sentiment resources in other lexicons is not as developed.

The second problem this paper focuses on is detecting sentiment in social media. Besides being domain-specific, it can also be grammatically less correct and contain other properties, such as mentions of other people hash-tags, smileys and URL, as opposed to traditional movie and product review datasets.

This paper explores various combinations of methods that can be used to incorporate out-of-domain training data, combined with lexicons in order to train a domain-specific sentiment classifier.

2 RELATED WORK

Sentiment classification is an important part of our information gathering behavior, giving us the answer to what other people think about a particular topic. It is also one of the natural language processing tasks which is well suited for machine learning, since it can be represented as a three-class classification problem (positive, neutral, negative). Earlier work applied sentiment classification to movie reviews [10], training a model for predicting whether a particular review rates a movie positively or negatively. While in the review domain all examples are inherently either positive or negative, other domains may also deal with non-subjective content which does not carry any sentiment. Furthermore, separating subjective from objective examples has proven to be an even more difficult problem than separating positive from negative examples [13]. Another difficult problem in this area is dealing with different topics and domains: models, trained on a particular domain do not always transfer well onto other domains. While the standard approach is to use one of widely used classification algorithms such as multinomial Naïve Bayes or SVM, explicit knowledge transfer approaches have been proven to improve performance in these scenarios, such as using sentiment lexicons [1] or modifying the learning algorithm to incorporate background knowledge [9]. Some challenges are also domain-specific. For instance, while a lot of sentiment is being expressed in social media, the language is often very informal, affecting the performance by increasing the sparsity of the feature space. On the other hand, the patterns arising in informal communication, such as misspellings and emoticons can be themselves used as signals [13]. It has also been shown that within social media, using different document sources, such as blogs, microblogs and reviews, can improve performance compared to using a single source. [12]

3 SENTIMENT LEXICONS

SentiWordNet [1] is the most known English-language sentiment dictionary, in which each WordNet [3] synset s is represented with three numerical scores – objective Obj(s), positive Pos(s) and negative Neg(s). However, SentiWordNet does not account for domain specificity of the input textual resources. In addition to addressing English

language, this paper also discusses applications of sentiment dictionaries in Spanish. For this purpose, we have used the sentiment dictionaries published by Perez-Rosas et al. [6].
Expressing sentiment and opinion varies for different domains and document types. In such way, sentiments carried in the news are not equivalent to the sentiments from the Twitter comments. For instance, the word "turtle" is neutral in a zoological text, but in informal Twitter comment "connection slow as a turtle", "turtle" has negative sentiment. This paper also evaluates a method for construction of dictionaries as domain specific lexical resources, which contain words, part of speech tags and the relevant sentiment scores. We have set the topic of telecommunications as the domain of primary interest, and the corpus, used for dictionaries development, was composed out of Twitter comments about telecommunication companies. We have started with a number of positive and negative seeds for different part-of-speech words (adjectives, nouns, verbs). These sentiment dictionaries are built in English and Spanish languages. As discussed in [3], there are a number of approaches to develop the sentiment dictionary. In our research on developing sentiment dictionaries we were following the work of Bizau et al. [4]. In the paper on expressing opinion diversity, the authors suggested a 4-step methodology for creating a domain specific sentiment lexicon. We have modified the methodology in order to generalize to other languages and provide sentiments for different parts of speech.
We have created dictionaries not only in English, but also in Spanish. Our dictionaries were built not only for adjectives as done in [4], but also for nous and verbs. For the English dictionary, we have additionally provided several extra features, such as the number of positive links and number of negative links for a particular word. The English sentiment dictionary for the Telecommunication domain is composed out of around 2000 adjectives, 1700 verbs and 8000 nouns, while the Spanish counterpart contains around 650 adjectives, 2000 verbs and 4100 nouns.

4 FEATURE CONSTRUCTION

We have used different feature sources to represent individual opinion data points. In news and review datasets, every data point is a sentence, while in social media datasets, every data point is a single microblog post. We preprocess the textual contents by replacing URLs, numerical expressions and the names of opinions' targets with respective placeholders. We then tokenize this text, lower-casing and normalizing characters onto an ASCII representation, filtering for stopwords and weigh the terms using TF-IDF weights. The words were stemmed using the Snowball stemmer for English and Spanish. The punctuation is preserved.

To accommodate social media, we have also used other text-derived features that can carry sentiment signal in informal settings:

- count of fully capitalized words
- count of question-indicating words
- count of words that start with a capital letter
- count of repeated exclamation marks
- count of repeated same vowel
- count of repeated same character
- proportion of capital letters
- proportion of vowels
- count of negation words
- count of contrast words
- count of positive emoticons
- count of negative emoticons
- count of punctuation
- count of profanity words[1]

We use lexicons in the form of features, where every word has assigned one or more scores. For instance, our dictionaries, described in Section 3, as well as SenticNet, provide a single real value in the range from -1 to 1, representing the scale from negative to positive. For these lexicons, we generate the sum of sentiment scores and the sum of absolute values of sentiment scores for every part of speech tag, as well as in total. SentiWordNet scores are represented as a triple of positive, negative and objective scores, having a total sum of 1.0. We have used a similar feature construction process as in [7]: providing sums of positive and negative scores, as well as the ratio of positive to negative score. These features were computed for each part of speech tag and in total. For Spanish, we have used the UNT sentiment lexicon [6]. Since each entry is labeled as positive or negative, we use the count of detected positive words and count of detected negative words as features.

5 MODELS

The data is composed of two modalities: bag-of-words features on one side, and having lexical and surface features, such as patterns and lexicon features on the other. In order to take differing distributions into account, we use two different approaches: either concatenating the features into a single features space, or using different models for each set of features. While this situation has been solved by extending the Naïve Bayes classifier with pooling multinomials [9], we chose to implement it with a two-step model. While they demonstrate that Multinomial Naïve Bayes performs well in sentiment analysis tasks, our results show that combining bag-of-words with lexical and surface feature reduces performance instead of improving it. We therefore experiment with modeling approaches that are better suited for integration of background knowledge.

[1] Obtained from http://svn.navi.cx/misc/abandoned/opencombat/misc/multilingualSwearList.txt

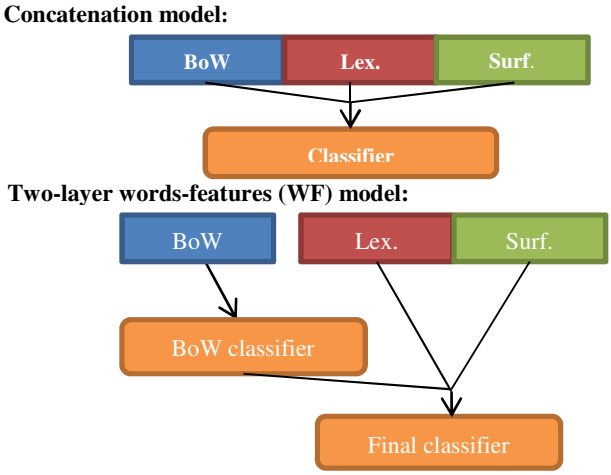

Figure 1: *Diagrams of the simple concatenation model and the two-layer words-features model which encodes the BoW model output as features for the final model.*

We therefore compare two modeling approaches, illustrated in Figure 1. We experiment by varying the training algorithm used: for the concatenating model, we vary the main algorithm, and for the two-layer model, we vary the second level algorithm, as we have fixed the BoW level classifier to Linear SVM, known to work well on BoW.

6 EXPERIMENTS

Furthermore, we focus our experiment onto performance on our target datasets. We use the following datasets:

- Pang & Lee review dataset, English [10]
- JRC news dataset, English [11]
- JRC news dataset, translated to Spanish using Microsoft Translator (JRC-ES)
- RenderEN, English. 134 Twitter posts about a telecommunications provider (48 Pos, 84 Neg)
- RenderES, Spanish, 891 Twitter posts about a telecommunications provider (388 Pos, 445 Neg, 58 Obj)

Besides our lexicons introduced in section 3 (denoted "RenLex" and "RenLexLinks"), we also evaluate performance of using the Spanish lexicons from Perez-Rosas et al [6] (denoted FullUNT and MedUNT for the full and medium variant respectively), as well as SenticNet [8] and SentiWordNet[1] for English. The label "Lex" indicates usage of all lexicons. Our key indicators are performance metrics on RenderEN and RenderES, as they represent our use case. We report F_1 scores for all of these datasets on various combinations of classifiers and features construction schemes. The experiments cover various learning algorithms, both modeling pipelines ("WF-" denotes the two-layer model), as well as the effect of feature scaling and centering (denoted with "WF-SVMSc"). We explore various combinations of feature sets: surface, bag-of-words, lexicons, as well as performance of individual lexicons.

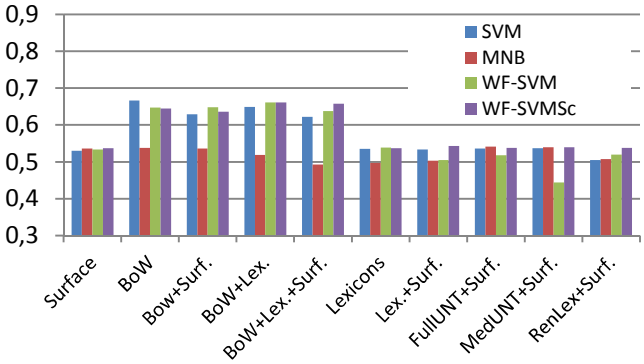

Table 1: Sentiment F_1 *scores on JRC-ES across settings.*

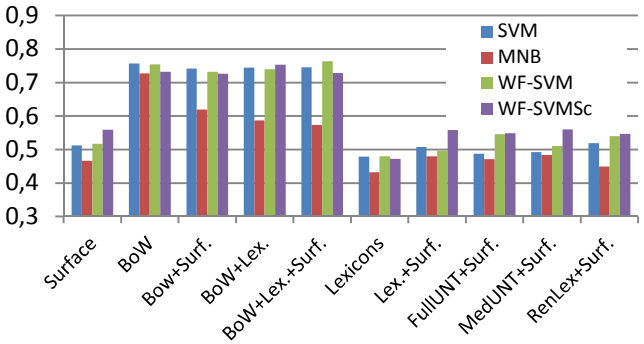

Table 2: Sentiment F_1 *scores on Render-ES across settings.*

Table 1 and 2 present the results on both Spanish datasets when combining different feature sets and learning approaches. We observe that on the news dataset, none of the additions improve over the bag-of-words baseline on an SVM model at 0.66 F_1 score. On Render-ES, the variant combining all additions and running on a two-layer SVM model improves over the bag-of-words model by a small margin, resulting in an F_1 score of 0.76. Looking at usage of various lexicons alone, it shows that the lexicons themselves only slightly improve over the surface features. In many cases, the difference is not significant, although we observe that the domain specific lexicon RenLex does not improve over a general domain lexicon neither in news nor in social media.

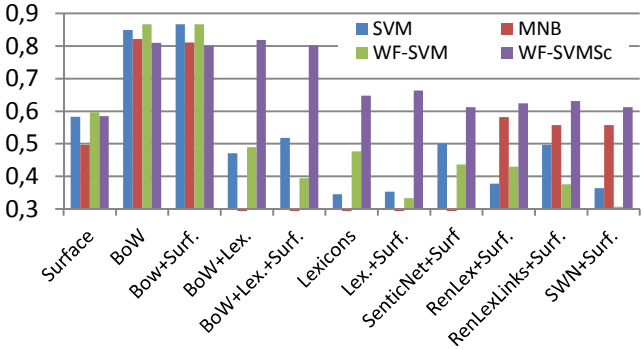

Table 3: Sentiment F_1 *score on PangLee across settings.*

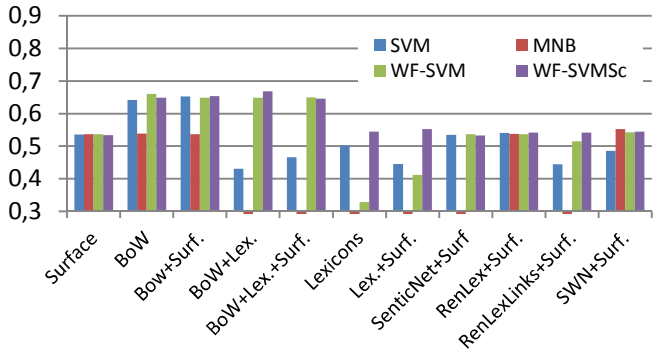

Table 4: Sentiment F_1 *scores on JRC-EN across settings.*

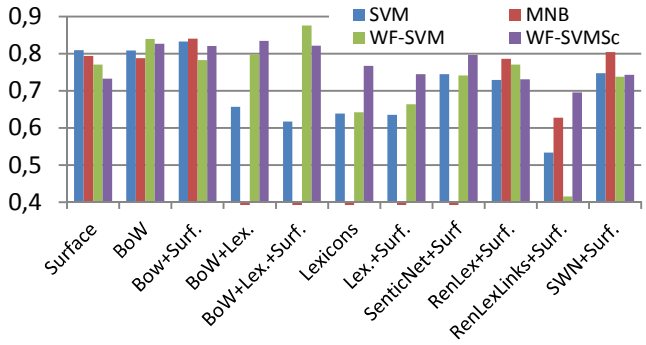

Table 5: Sentiment F_1 *scores on Render-EN across settings.*

Tables 3, 4 and 5 show the results on English reviews, news, and social media. While none of the additions beat the bag-of-words baselines on reviews, scoring at 0.86, it demonstrates that when combining bag of words and lexicon features, the two-step WF model is more robust than concatenation. It also demonstrates the importance of feature centering when combining lexicon features with outputs from the bag-of-words model. On news, while adding lexicons improves the performance from 0.66 to 0.67, surface features don't give any improvement, mostly due to the formal language used in reporting. On the final, social media dataset, we demonstrate the performance improvements in combining all three feature sets in a two-layer model along with feature scaling. The best performing model is able to obtain a F_1 score of 0.88. While the dataset is small, this demonstrates the feasibility of using external knowledge and surface features in a social media setting, especially with insufficient training data. Also, using the number of positive and negative links as features does not improve performance.

7 CONCLUSIONS

Results confirm that social media content is the domain which benefits the most from external knowledge. We show that topic-specific lexicons don't bring improvement over general purpose lexicons, likely because the ambiguity of certain words that a topic-specific lexicon would solve was not problematic. We have been able to show improvement on two English datasets, especially on social media, which benefited significantly from preprocessing, surface features, as well as lexicons. We also demonstrate feasibility of using machine translation to obtain a training corpus in another language. Evaluation shows that the performance for JRC-ES was comparable to JRC-EN. Other research shows [9] promising approaches to facilitate the knowledge transfer via lexicons using specifically tailored machine learning approaches. In future work we will explore cross-lingual learning, demonstrating approaches for training sentiment models using language resources from other languages.

7 ACKNOWLEDGMENTS

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INTERNALS OF AN AGGREGATED WEB NEWS FEED

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ABSTRACT

We present a pipeline for acquiring a clean, continuous, real-time aggregated stream of publically available news articles from web sites across the world.
The articles are stripped of the web page chrome and semantically enriched to include e.g. a list of entities appearing in each article. The results are cached and distributed in an efficient manner.

1 INTRODUCTION

The news aggregator is a piece of software developed at JSI which provides a real-time aggregated stream of textual news items provided by RSS-enabled news providers across the world. The pipeline performs the following main steps:

1) Periodically crawls a list of RSS feeds and a subset of Google News and obtains links to news articles
2) Downloads the articles, taking care not to overload any of the hosting servers
3) Parses each article to obtain
    a. Potential new RSS sources, to be used in step (1)
    b. Cleartext version of the article body
4) Process articles with Enrycher (see Section 0)
5) Expose two streams of news articles (cleartext and Enrycher-processed) to end users.

2 SYSTEM ARCHITECTURE

Refer to **Error! Reference source not found.** for a schematic overview of the architecture. The first part of the aggregator is based around a PostgreSQL database running on a Linux server. The database contains a list of RSS feeds which are periodically downloaded by the RSS monitoring component. RSS feeds contain a list of news article URLs and some associated metadata, such as tags, publication date, etc. Articles that are not already present in the database are added to a list of article URLs, and marked for

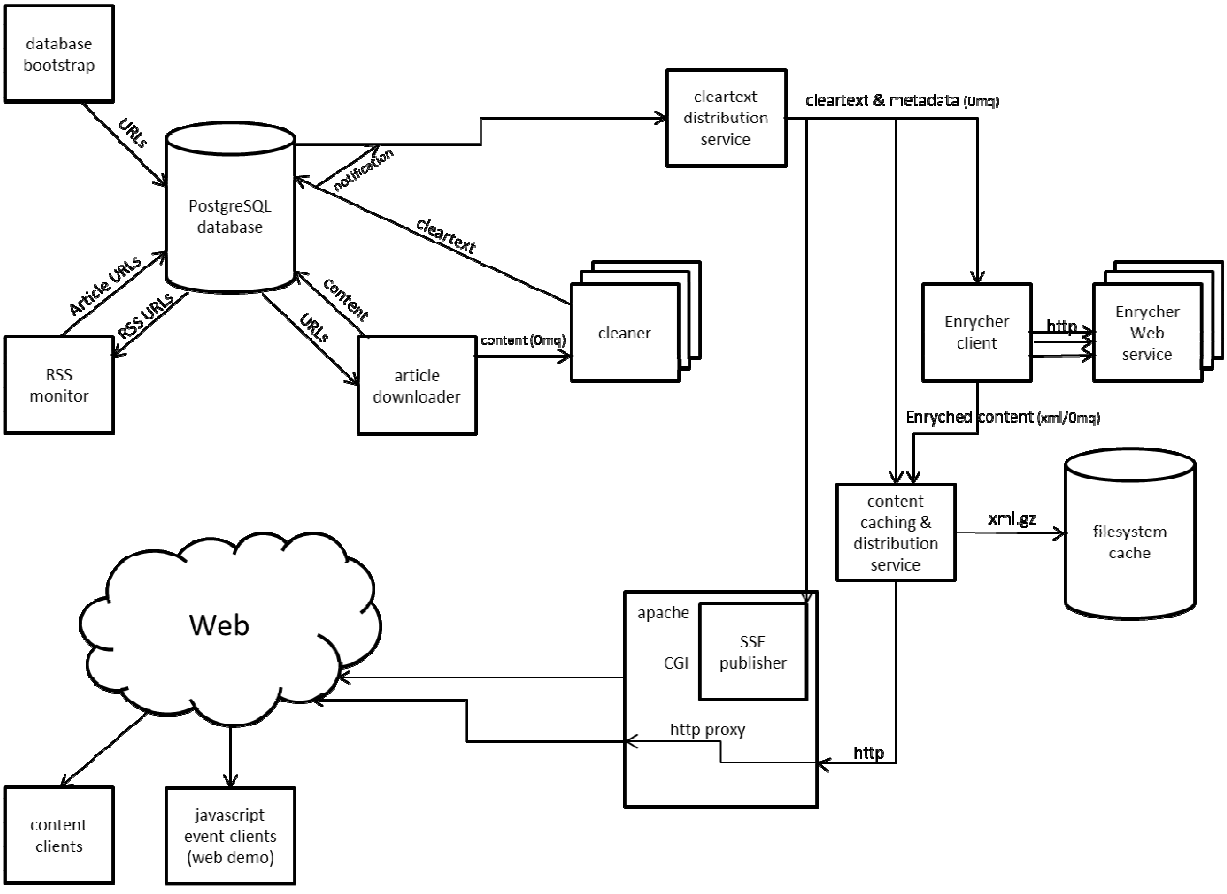

Figure 1: *The system architecture.*

download. Tags and publication date are also stored alongside, if found in the RSS.

A separate component periodically retrieves the list of new articles and fetches them from the web. The complete HTML is stored in the database, and simultaneously sent to a set of cleaning processes over a 0mq message queue.

The cleaning process converts the HTML into UTF-8 encoding, determines which part of the HTML contains the useful text, and discards the remainder and all of the tags. Finally, a classifier is used to determine the primary language.

The cleaned version of the text is stored back in the database, and sent over a message queue to consumers.

Documents in English language are sent to the Enrycher web service, where named entities are extracted and resolved, and the entire document is categorized into a DMOZ topic hierarchy.

Both the cleartext and the enriched versions of documents are fed to a filesystem cache, which stores a sequence of compressed xml files, each containing a series of documents in the order they have arrived through the processing pipeline. The caching service exposes an HTTP interface to the world through an Apache transparent proxy, serving those compressed xml files on user request.

The Apache server also hosts a CGI process capable of generating HTML5 server-side events, which contains the article metadata and cleartext as payload. These events can be consumed using Javascripts EventSource object in a web browser.

3 DATA PREPROCESSING

Data preprocessing is an important part of the pipeline, both in terms of the added value provides and in terms of challenges posed by the data volume. The articles themselves are certainly useful, but almost any automated task dealing with them first needs to transform the raw HTML into a form more suitable for further processing. We therefore perform the preprocessing ourselves; this is much like the practice followed by professional data aggregation services like Spinn3r or Gnip.

In terms of data volume, preprocessing is the most interesting stage and the one at which the most tradeoff can be made. The present data download rate of about one article per second is nothing extreme, especially if we consider scaling to multiple processing nodes; however, it is nontrivial in that adding complex preprocessing steps (e.g. full syntactic parsing of text) or drastically increasing data load (e.g. including a 10% sample of the Twitter feed) would turn preprocessing into a bottleneck and require us to scale the architecture.

3.1 Extracting article body from web pages

Extracting meaningful content from the HTML is the most obviously needed preprocessing step. As this is a pervasive problem, a lot has been published on the topic; see e.g. Pasternack (2009), Arias (2009), and Kohlschütter (2010). We initially implemented the algorithm by Pasternack because of its simplicity and reported state-of-the-art performance. The algorithm scores each token (a word or a tag) in the document based on how probable it is to comprise the final result (the scores are trained); then it extracts the maximum token subsequence.

Datasets

We tested the initial algorithm on three manually developed datasets. Each of the three consists of 50 articles, each from a different web site.

- **english** – English articles only.
- **alphabet** – Non-English articles using an alphabet, i.e. one glyph per sound. This includes e.g. Arabic.
- **syllabary** – Non-English articles using a syllabary, i.e. one glyph per syllable. This boils down to Asian languages. They lack word boundaries and have generally shorter articles in terms of glyphs. Also, the design of Asian pages tends to be slightly different.

Some of the input pages (about 5%), realistically, also do not include meaningful content. This is different from other data sets but very relevant to our scenario. Examples are paywall pages and pages with a picture bearing a single-sentence caption.

The fact that each of the 150 articles comes from a different site is crucial – most of the papers on this topic evaluate on a dataset from a small number of sites, which leads to overfitting and poor performance in the general case. This was also the case with Pasternack's algorithm. As the performance was unsatisfactory, we developed three new algorithms.

Algorithms

- **WWW** – an improved version of Pasternack, it extracts *two* most promising contiguous chunks of text from the article to account for the fact that the first paragraph is often placed separately from the main article body.
- **WWW++** – a combination of WWW and heuristic pre- and post-processing to account for the most obvious errors of WWW. For instance, preprocessing tries to remove comments.
- **DOM** – a completely heuristics-based approach which requires the DOM tree to be computed. With the fast libxml package, this is not a limiting factor. The core of the heuristic is to take the first large enough DOM element that contains enough promising <p> elements. Failing that, take the first <td> or element which contains enough promising text. The heuristics for the definition of "promising" rely on metrics found in other papers as well; most importantly, the amount of markup within a node. Importantly, none of the heuristics are site-specific.

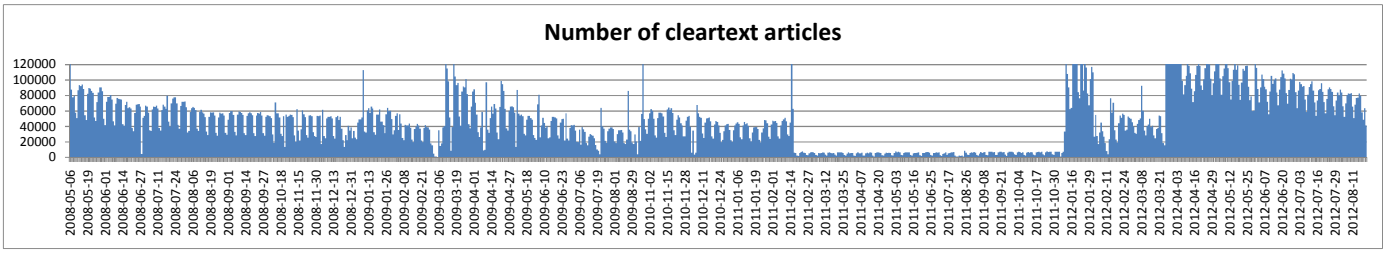

Figure 2: *The daily number of downloaded articles. A weekly pattern is nicely observable. Through most of 2011, only Google News was used as an article source, hence the significantly lower volume in that period.*

In all three algorithms, all pages are first normalized to the UTF-8 character set using the BeautifulSoup package (which in turn uses a combination of http headers, meta tags and the chardet tool).

Evaluation

We evaluated two of the three pairs of algorithms by comparing per-article performance. We did compare WWW and DOM; based on informal inspection of outputs, DOM would be certain to perform better.

Algo / Dataset	WWW vs WWW++ number of articles where one of the algorithms performs better			WWW++ vs DOM number of articles where one of the algorithms performs better		
	WWW	**tie**	**WWW++**	**WWW++**	**tie**	**DOM**
English	2	43	4	7	34	8
alphabet	4	37	8	6	36	7
syllabary	0	44	6	2	12	32

Table 1. Performance comparison of webpage chrome removal algorithms

The differences between the algorithms are statistically significant with a 5% confidence interval only on the syllabary dataset; it is however clear from the data that overall, WWW++ performs better than WWW and DOM performs better still. DOM is therefore our algorithm of choice.

For DOM, we additionally performed an analysis of errors on all three datasets. As the performance did not vary much across datasets, we present the aggregated results. For each article, we manually graded the algorithm output as one of the following:

- **Perfect [66.3%]** – The output deviates from the golden standard by less than one sentence or not at all: a missing section title or a superfluous link are the biggest errors allowed. This also includes cases where the input contains no meaningful content and the algorithm correctly returns an empty string.
- **Good [22.1%]** – The output contains a subset or a superset of the golden standard. In vast majority of the cases, this means a single missing paragraph (usually the first one which is often styled and positioned on the page separately) or a single extraneous one (short author bio or an invitation to comment on the article). A typical serious but much rarer error is the inclusion of visitors' comments in the output.
- **Garbage [5.8%]** – The output contains mostly or exclusively text that is not in the golden standard. These are almost always articles with a very short body and a long copyright disclaimer that gets picked up instead.
- **Missed [5.8%]** – Although the article contains meaningful content, the output is an empty string, i.e. the algorithm fails to find any content.

If we combine "Perfect" and "Good" (where the outcome is most often only a sentence away from the perfect match) into a "Positive" score, both precision and recall for DOM are 94%. This (article-based) metric is arguably comparable with the word- or character-based metrics employed in some other papers on state of the art methods (Kohlschütter 2010); those also report precision and accuracy of at most 95%.

3.2 Extracting semantic information from clear text

For most of semantic processing, we rely on Enrycher (Štajner 2009) running as a service. In order to increase error resiliency, improve the utilization of the service and avoid undue delays in the preprocessing pipeline, we access the service in a multithreaded fashion. For performance evaluation and other information, please refer to the paper by Štajner.

Enrycher annotates each article with named entities appearing in the text (resolved to Wikipedia when possible), discerns its sentiment and categorizes the document into the general-purpose DMOZ category hierarchy.

We also annotate articles with a language; detection is provided by a combination of Google's open-source Compact Language Detector library for mainstream languages and a separate Bayesian classifier. The latter is trained on character trigram frequency distributions in a large public corpus of over a hundred languages. We use CLD first; for the rare cases where the article's language is not supported by CLD, we fall back to the Bayesian classifier. The error introduced by automatic detection is below 1% (McCandless, 2011).

4 DATA PROPERTIES

In no particular order, we list some statistics of the data provided by the news aggregator.

4.1 Sources

The crawler actively monitors about 75000 feeds from 1900 sites. The list of sources is constantly being changed – stale sources get removed automatically, new sources get added from crawled articles. In addition, we occasionally manually

prune the list of sources using simple heuristics as not all of them are active, relevant or of sufficient quality. The feed crawler has inspected about 350000 RSS feeds in its lifetime. The list was bootstrapped from publically available RSS compilations.

Besides the RSS feeds, we use Google News (news.google.com) as another source of articles. We periodically crawl the US English edition and a few other language editions, randomly chosen at each crawl. As news articles are later parsed for links to RSS feeds, this helps diversify our list of feeds while keeping the quality high.

We also support additional custom news sources, provided by payable services and/or project partners in various projects.

The sources are not limited to any particular geography or language.

4.2 Language distribution

We cover 37 languages at an average daily volume of 100 articles or more. English is the most frequent with an estimated 54% of articles. German, Spanish and French are represented by 3 to 10 percent of the articles. Other languages reaching at least 1% of the corpus are Chinese, Slovenian, Portugese, Korean, Italian and Arabic.

4.3 Data volume

The crawler currently downloads 50000 to 100000 articles per day which amounts to roughly one article per second. The current archive contains about 40 million articles and begins in May 2008. See Figure 2.

The median and average article body length is 1750 and 2400 bytes, respectively.

4.4 Responsiveness

We poll the RSS feeds at varying time intervals from 5 minutes to 12 hours depending on the feed's past activity. Google News is crawled every two hours. All crawling is currently performed from a single machine; precautions are taken not to overload any news source with overly frequent requests.

Based on articles with known time of publication, we estimate 70% of articles are fully processed by our pipeline within 3 hours of being published, and 90% are processed within 12 hours.

5 DATA DISSEMINATION

Upon completing the preprocessing pipeline, contiguous groups of articles are batched and each batch is stored as a gzipped file on a separate distribution server. Files get created when the corresponding batch is large enough (to avoid huge files) or contains old enough articles. End users poll the distribution server for changes using HTTP. Such a mechanism introduces some additional latency, but is very robust, scalable, simple to maintain and universally accessible.

Independent of this server-side, filesystem-based cache, a complete copy of the data is still kept in the traditional structured database (see Section 2). This is the only copy guaranteed to be consistent and contain all the data; from it, the XML files can be regenerated at any time. This is particularly useful in case of XML format changes and/or improvements to the preprocessing pipeline.

Figure 3: A real-time preview of the stream demonstrating some of the semantic annotations. See http://newsfeed.ijs.si/visual_demo/

6 CONCLUSION

We presented a news crawling and processing engine that is scalable, responsive and achieves state of the art performance in most of the processing stages.

The data provided by the pipeline is being successfully used in several multilateral projects with expected applications in cross-lingual text mining, opinion mining and recommender systems.

Acknoledgements

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PREFACE

The transition to an information and knowledge society is being accompanied by a redefinition of business processes and a renewal of information solutions, networks and services. The main challenge remains unchanged – i.e. how to successfully manage and control the complexity of processes, software and services in order to improve collaboration between individuals, organizations and/or systems. This year's contributions address different aspects of software and service engineering, however the main focus is on Service-Oriented Architecture including design patterns, software metrics used in automated assessment, architecture for intelligent mobile applications, development and collaboration work in virtual environment, as well as project evaluations with monitoring quality, process models and business processes.

We hope that these proceedings will be beneficial for your reference and that the information in this volume will be useful for further advancements in research and industry.

Our special thanks goes to the members of the Program Committee as well as to the authors who have contributed to the success of this sub-conference.

Marjan Heričko

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V sodelovanju z / In collaboration with

DEVELOPMENT OF A LIGHT-WEIGHT PROCESS MODEL FOR OPEN INNOVATION – A PRACTICAL APPROACH

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ABSTRACT

In this paper the results of the development of light-weight process model in the field of open innovation are presented. Due to the fact that most literature and project reports come from large companies the specific requirements of especially small and medium-sized enterprises are not always taken into consideration.
With this light-weight process model especially small and medium-sized enterprises, located in the European Union should be addressed. Furthermore this process model should also be used for pilot or initial projects by SMEs.
The results are based on two central sources. Firstly, on a comprehensive literature review and secondly, experts have been integrated in this research project that have the practical experience in the establishment of open innovation projects in SMEs in Europe.

1 INTRODUCTION

Open innovation is the new paradigm that is being promoted as the future pathway for innovation in the globalized, knowledge and service dominated economy of the 21st century [1, 2]. As research into this paradigm is intensified by several authors [3, 4] and policymakers in the European Union [5] as well as the United States of America [6] have taken the concept on their agendas. Companies of all sizes and industries start looking into the concept and attempt to implement it for their own purposes [7].
The original arguments for open innovation are usually based on cases from Xerox, IBM, Intel and Procter & Gamble, mainly large manufacturing companies [2, 8].
Subsequent research has also been highly focused on large and/or manufacturing companies [9, 10] in which the innovation is focused on products.
Chesbrough's [1] concept of open services innovation is a combination of a service approach to business combined with open innovation and a customer-focused perspective, so that every effort of an enterprise precisely meets the needs of customers. The only way to achieve such a customer-centric operation "is to create a feedback loop that incorporates the customer into the services creation process".
Open innovation in SMEs is a rather new and upcoming research field. However specific research on how to implement open innovation in small and medium-sized service enterprises is currently in an early stage. The purpose of this research work was to develop a suitable process model.

2 INNOVATION AND SMES

Innovation can occur in three ways: "how they are provided, the addition of new functions or characteristics to existing services, or the introduction of entirely new services" [11]. Due to the nature of services – their intangibility, heterogeneity, perishability, and customer relationship and involvement in the process – innovation in services is a more complex and variant process than goods innovation.
SMEs have been identified and declared as the prime drivers of the European economy. They represent 99 per cent of all enterprises, provide around 90 million jobs, which include two-thirds of the jobs in the non-financial business sector, and are the prime generators of entrepreneurship and innovation in the European Union [12–14].
The following definition of open innovation, coined by Chesbrough in 2006, is used for this research work:
"Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology" [15].
The concept of open innovation has been put into several models and frameworks. One of the most important is the 'Three Core Process Archetypes of Open Innovation' which are:
"(1) The outside-in process: Enriching the company's own knowledge base through the integration of suppliers, customers and external knowledge sourcing can increase a company's innovativeness. (2) The inside-out process: earning profits by bringing ideas to market, selling IP and multiplying technology by transferring ideas to the outside environment. (3) The coupled process: coupling the outside-in and inside-out processes by working in alliances with complementary partners in which give and take is crucial for success." [16]

These processes are also applicable for SMEs, however the suitability and capability for implementation might be hindered by the disadvantages of the firm, e.g. lack of resources. Thus the benefits of open innovation in SMEs emerge in the roles these companies can fulfill much easier due to their advantages like speed and flexibility.
Implementing all three core processes is the key for SMEs in leveraging all of the opportunities of open innovation [1, 17–19].

3 INTEGRATION OF EXPERTS AND PRACTITIONERS

The second source used to achieve the goal was to invite practitioners and researchers to derive an adequate process model suitable for SMEs in the service industry. A total of ten experts have been interviewed. managing research and development activities. The person has been doing this for at least more than one year and is located or acts within the European Union.
The experts have received the interview guideline in decent time before the interview and have been asked to prepare themselves. This was done in order to enable the experts to answer the very specific questions with as much detail as possible and structure their responses.
After the first interviews and the preparation of the preliminary results a second round of interviews have been conducted in order to gain further results and deeper insights.

3.1 Initial Process Model

Based on preliminary talks with the experts the Model 'Want, Find, Get, Manage' was proposed by one expert. This model contains a majority of the mentioned characteristics as a common denominator, is applicable to companies of all sizes and industries, and has already been examined and documented in past research [20, 21].
Therefore this model, as shown in figure 1, is being used as the foundation and will be modified and expanded with additional detail and other models.

Want	What are our resource needs? Which ones should we internally develop? Which should be find externally?
Find	How do we find and evalute the external sources of technology and capabilities that will fulfill our needs?
Get	What processes will we use to plan, structure and negotiate an agreement to access external resources?
Manage	What tools and metrics we use to implement and manage ongoing collaborative relationships?

Figure 1: *The Want, Find, Get, Manage Model [20]*

3.2 Refinement and Adjustment of the Initial Model by the Experts and Practitioners

At the very beginning there has to be a phase of self-diagnosis, even before the company can concern itself with the 'Want' for its open innovation implementation.
In this phase an in-depth investigation of the company itself has to take place, which starts at identifying the corporate vision, mission and strategy, next the existing innovation strategy and innovation processes and finally look in more detail into the key assets, key capabilities and core business. In combination with this, the readiness for open innovation of the entire company has to be assessed to a nicety.
Based on this diagnosis, the company can enter a phase of planning, in which it has to establish a new innovation strategy with very precise and clear goals on what to achieve with open innovation, i.e. open innovation strategy. This open innovation strategy already is a form of project planning, and should include at least the following details: budget allotment, human resource allocation, the prospective idea generation, implementation, commercialization process, the locus and direction of each of these three processes, the closeness/openness of each of these processes, the intellectual property governance and key performance indicators.
Next comes the 'Want' phase, which is being renamed into 'Prepare' phase, because it is being expanded into the preparation for the open innovation. This means that based on the exact areas and types of innovation and search from the plan phase, i.e. in-bound, out-bound or coupled approach and the corresponding method or tool, a specific preparation in form of a sub project planning and realization is performed.
The sub preparation project shall take place in form of an iterative model with the phases 'Concept, Validation, Pilot and Ramp-Up'.
This means that after the conceptualization of the method or tool it should be validated, if possible from an external expert or an external network of experts, otherwise internally. Then in the pilot phase the selected approach, method or tool is being tested, i.e. a trial run with small group of people, to make sure that it is working as intended.
Finally there is the 'Ramp-Up', which means finalizing the preparation and arranging for the live run, which also has to involve a lot of communication and marketing about open innovation throughout the company in order to promote and enable the cultural change from closed to open innovation.
The 'Find' phase, in which the selected approach is being performed, takes place after the 'Prepare' has been completed. This conduction depends on the selected approach.
The next phase contains the realization of the innovation and the beginning of the value creation. While in the original model this phase is called 'Get', it is being renamed to 'Create' for improved clarification and removal

of the in-bound process connotation. In this phase the internal innovation processes and structures are either being modified to match the selected approach if existing, or created a new if not existing and then start operating. This means that, e.g. the selected new ideas are being fed into the internal innovation process, or the collaboration partner starts his work on the desired innovation with support of an internal project management. At the end of this phase there is a new product, service or any other kind of innovation ready for introduction to the market or firm.

The 'Manage' phase then deals with bringing the results from the 'Create' phase to market or into the firm through existing or new routes, as well as the necessary administration of this process based upon the necessary key performance indicators, for example management of the partnership relation or the crowdsourcing platform. At this point in the project the decision is being made, whether the pilot project remains a one-off or is being permanently integrated into the enterprise as an innovation process, which means the transformation into and subsequent administration of the 'Find' and 'Create' phase as a continuous innovation process.

The 'Review' comes next and should go hand in hand with the 'Manage'. In this phase the lessons learned are identified, like what has worked, what has not worked, how we can improve the system for on-going open innovation process.

The project and processes are thoroughly examined in accordance with the key performance indicators and reflected towards the set goals, in order to make sure to identify the value the open innovation project with its processes creates or has created for the company.

The entire model is similar to the sequence plan for implementing open innovation by Ili [22] and also covers all steps as suggested by Rufat-Latre, Muller & Jones [23].

As knowledge about innovation management is increasing and the strategy and processes become more mature, this stage-gate process should transform into an iterative cycle in which the phases 'Plan, Prepare, Find-Create-Manage, Review' are linked as a continuous cycle of innovation [24–27]

4 DISCUSSION

For small and medium-sized enterprises special ramifications according the field of application (product, process or services) apply to this model. SMEs might be unaware of open innovation and therefore need to learn more about it before they can perform the 'Plan' phase, some experts mentioned.

Due to their lack of resources SMEs have to be more thoughtful about resource allotment being made in the planning for all the following processes, especially for the 'Find' and 'Create' phase, e.g. acquisition and administration of ideas as well as their realization and be very clear about their goals, because they cannot afford to implement open innovation just as an experiment and waste resources

On the other hand, due to the smallness, decisions can be made faster, easier and be less formal and the penetration of open innovation into the culture can occur faster and with more intensity due to less opposition.

For services the company has to be particularly considerate about intellectual property, because services are much harder to secure through patenting or trademarks and assess their value, which is needed for proper management of the process.

A very important remark is that this entire model assumes a top down approach for the implementation of open innovation in an enterprise. One of the experts suggested that this concept is evolving, into a hybrid model for implementation, which means that the implementation occurs top down and bottom up simultaneously, i.e. while the top management starts off with this pilot stage-gate implementation model, employees come up with success stories of open innovation and push the implementation of open innovation through from the bottom. [21].

5 LIMITATIONS AND FUTURE WORK

The empirical findings contain the insights of ten experts and therefore cannot be considered as complete. But first of all it is necessary to test the developed process model in different projects in order to proof its eligibility and to identify its shortages and possible improvements.

The research stems from a European perspective and thus cannot be considered to be applicable for companies in other regions, such as America or Asian Regions.

Another possibility would be to perform more detailed research on best practices in open innovation for specific sectors, for example finance or education, on a local, national or European level. Based upon these case studies the current progress and state of open innovation could be re-examined, maybe even with a very specific focus on a particular dimension, e.g. strategy, processes, corporate IT, organizational structure and culture, market environment, company partner network.

Further research could also be to explore the successful implementation and application of open innovation in the government system or the educational system, e.g. establishing a better feedback loop.

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ENGINEERING INSTANCE-MIGRATABLE BPEL BUSINESS PROCESSES

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ABSTRACT

Business processes are the backbone of business logic in a Service Oriented Architecture. Most software vendors provide BPEL engines to host and execute business processes. A BPEL engine usually stores the states of business process instances in a database; however, the schema of this database may change between engine versions and is most certainly varying between different vendors' engines. Usually, vendors do not provide means to migrate the states of running business process instances to other engine versions or to other vendors' products. This paper proposes a non-intrusive framework and a design pattern for BPEL processes to make their instances migratable by replaying previously recorded SOAP messages.

1 INTRODUCTION

Many business processes are long running processes, since they usually require human activities. Such processes may run for days or even weeks in e-Governmental environments. When a new version of the underlying process execution engine is published, it is usually desirable to migrate the running process instances to the new version; however, the engine's software vendor usually does not provide any support to do this. An even greater risk of using a specific process engine is vendor lock-in. There are no converters that could migrate process instance states between different vendors' engines; hence, it is nearly impossible to move running process instances to another engine.

The direct migration of the product-specific inner-state representation of BPEL processes would indeed be a very complicated and unmaintainable task, since all the desired process engines would have to be examined and even all their different versions would have to be taken into account.

Therefore, our proposition is that the process state should be restored from the "outside". At first, the calls made by the original process and the responses to those calls sent by the outer world should be recorded. When the instance migration of the processes is required, the processes should be deployed to the new process engine, and a new process instance should be started for each of the original process instances. However, the new process instances are not communicating with the outside world until they reached the same state as the original process instance already had. Instead, the calls made by them are captured, and the original replies are replayed to them. This way, the new processes behave exactly as the original ones and can easily reach the same state.

This method works between different versions of the same process engine and even between products of different vendors. It is also a non-intrusive solution, since the modification of the process engines is not required.

The only requirement for this solution to work is that the process should be carefully engineered. In this paper we propose a design pattern for such processes and also a framework that supports recording and replaying SOAP messages.

The rest of the paper is structured as follows. The second section sums up the related work in the subject area. The third section elaborates our proposition for creating instance-migratable business processes. The fourth section defines a framework that provides instance migration for processes built on the proposed design pattern. The fifth section evaluates our proposition, and, finally, the sixth section concludes the paper.

2 RELATED WORK

There are some other approaches for process instance migration, too, however, they cannot be used as generally as our proposition.

Some suggest that processes should be split up at design time, and their parts should be distributed [1-5]. These solutions change the processes too much, making them harder to maintain, although, their parts can be changed individually without affecting the other parts.

Zaplata et. al. [6] proposed that the processes should be split up at runtime, preserving the original process description. Their solution is very useful and extensive; however, it is intrusive regarding the process engine: their migration manager must be customized for each engine.

Liske et al. [7] introduced jumper transitions to check whether instance migration does not result in behavioral problems with other running partners. The not too strict limitation of their solution is that they only consider asynchronous (one-way) communication between services.

3 ENGINEERING INSTANCE-MIGRATABLE PROCESSES

If a process is carefully engineered, its state can be migrated between different process engine versions or even between engines of different vendors. This section describes how this can be achieved.

3.1 Instance-migratable processes

BPEL processes are web services by themselves and are communicating with the outside world via SOAP messages. One-way messages find their way back to the process instance through so called correlations, i.e. there are specific parts of the message that are matched against the internal state of the process instance. This mechanism can also be used for instance migration.

A BPEL process can be described as the following tuple:

$$B = (P, V, M, C, F, E, A)$$

where:

- P is the set of partnerLinks
- V is the set of variables
- M is the set of messageExchanges
- C is the set of correlations
- F is the set of faultHandlers
- E is the set of eventHandlers
- A is the set of activities

In order to make a BPEL process instance-migratable, its instances must be uniquely identifiable through the *process instance identifier* (PIID). This means that every SOAP message should contain the PIID of the process. Most process engines do not allow processing SOAP headers in the BPEL process code; therefore, this identifier should be included in the SOAP body. In case of the most commonly used document-wrapped SOAP message style this is easily achievable.

There may be a more complex system of BPEL processes, where these processes work in collaboration, and it is also required to migrate the state of the whole collaboration, too. In this case, the caller and the callee processes have to be identified separately. This means, that the following identifiers should be included in all SOAP messages travelling to or from the BPEL process:

- source instance identifier (SIID): PIID of the caller
- target instance identifier (TIID): PIID of the callee

When a new process instance is created by a call, the caller must assign a unique identifier to the new process through the TIID. If a process has a process instance identifier (PIID), then from the viewpoint of the process the following must be true:

- for the *invoke* and *reply* activities: SIID=PIID
- for the *receive*, *onEvent* and *onMessage* activities: TIID=PIID

From these requirements it is easy to build an instance-migratable BPEL process. Only the following conditions must be met:

$$PIID \in V \; ; \; C = \{CPIID\}$$

This means that the *process instance identifier (PIID)* should be among the variables used by the process, and the process should have a single correlation set *CPIID* defined for the incoming calls. This correlation set should be initialized by the TIID in the first *receive* or *pick* activity that creates the process instance, and it should be also matched with the TIID in every other *receive*, *onEvent* or *onMessage* activity.

In addition, on every *invoke* and *reply* activity, the process should assign its PIID to the SIID. On *reply* activities, the TIID must also match the SIID of the initiating *receive*, *onEvent* or *onMessage* activity. On *invoke* activities, the TIID must either be newly generated (if it starts a new process), or it should contain a SIID received from a *receive*, *onEvent* or *onMessage* activity earlier.

Any process following this design pattern is instance-migratable, i.e. all its running instances can be migrated to another process engine, if the appropriate framework is recording and replaying the messages exchanged by the process instances.

3.2 Converting an existing BPEL process to an instance-migratable process

The design pattern defined in the previous subsection is easily applicable if a new process is designed. Already existing process descriptions can also be converted to match this design pattern, however, only those instances of this process can be migrated which already follow the new design pattern.

Let's take the following general BPEL process:

$$B = (P, V, M, C, F, E, A)$$

It can be made instance-migratable as

$$B' = (P', V', M', C', F', E', A')$$

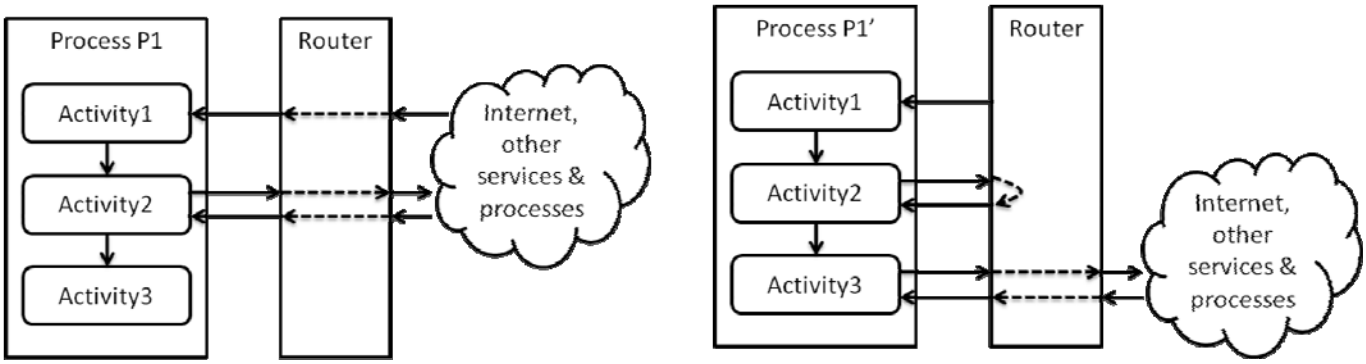
with the following assignments:

$$P' = P \; ; \; V' = V \cup \{PIID\} \; ; \; M' = M \; ; \; C' = \{CPIID\} \; ; \; F' = F$$

The original *C* correlation sets must either be outsourced to the framework that records and replays the messages, or they have to be entirely replaced, by always correlating to the PIID. The latter is recommended, if possible.

The set of events *E* and the set of activities *A* remain the same, but some of them (*invoke*, *receive*, *reply*, *onEvent* and *onMessage*) also have to be modified to include the new *CPIID* correlation set as described in the previous subsection.

The transformation described here can be easily automated. This includes two steps. In the first step, assuming the most common document-wrapped SOAP encoding style, the appropriate XSD types in the types section of the WSDL have to be transformed to include the SIID and TIID. In the second step, the BPEL process has to be transformed by the mappings defined above. This step can also be easily automated. The only place where manual override may be required is when an *invoke* activity should send out a TIID assigned from a SIID received earlier. All other transformations can be made fully automatic.



Execution of the instance-migratable process P1: the router records its SOAP messages

Migrating the process P1 to P1': replaying SOAP messages, then continuing the execution of P1' normally

Figure 1: *Illustration of the process instance migration*

4 RUNTIME FRAMEWORK FOR BPEL PROCESS INSTANCE MIGRATION

Instance migration of BPEL processes requires a runtime framework that can record and replay SOAP messages. For this, a "clever" proxy component, the *router* has to be set up. All SOAP messages must go through this router so that it can have control over them. This, obviously, introduces an overhead, but with a high performance cluster under the router this overhead can be minimized. In fact, the router may even speed up the execution of process instances on migration, since the replayed SOAP messages are only fetched from the router's logs instead of travelling around in the outside world.

When the router receives a SOAP message, it stores it in its message log, and decides whether this message is part of a real execution, or it participates in a migration process. In the former case, the message is forwarded to the target service. In the latter case the router checks its log, whether it should send a previously stored reply for the received message.

Figure 1 illustrates the system's behavior: P1 is the original instance-migratable process; its messages are recorded, and are forwarded to the target services. After the execution of Activity2, P1 is migrated to P1', which is started by the router, and the recorded messages are replayed to this process. After P1' reaches the same state as the original P1 process, its calls are also forwarded to the outside world.

When forwarding a message, the router also has to decide where to forward it. An obvious solution is that the router listens on many URLs, each of them corresponding to a service (processes are also services). In this case, each service has a unique *service identifier* (SID) assigned to it, and this identifier is included in the listening URL of the router. If the service has multiple ports, or a process has multiple partnerLinks, the name or identifier of this port or partnerlink can also be appended to the URL, e.g. *http://router/SID/portName*. These kinds of URLs can be easily processed by RESTful web services, so the easiest way to implement the router is using REST. The local part of the URL (*SID/portName*) can be considered as a *virtual address*, and the real service URL behind it can be dynamically modified. This enhances the flexibility of the whole system.

The router's the database consists of three tables. The first table stores service information:

- SID: the service identifier
- Port: a port name or partnerLink name of the service
- URL: the actual URL of the service's respective port or partnerLink

The second table stores message information:

- TSID: target service identifier
- TPort: the target port name of partnerLink name of the service
- TIID: target instance identifier
- SIID: source instance identifier
- Sequence: the sequence number of the message sent towards the target process instance
- Direction: request/reply/oneway
- Message: the stored message

The sequence number is necessary to preserve the original order of the messages. The direction is for deciding whether to send the reply back in the HTTP response (request-reply), or in a separate HTTP request (oneway).

The third table stores migration information:

- SID: the service identifier
- PIID: the process instance identifier
- State: active/updating/inactive
- NewSID: the new service identifier
- NewPIID: the new process instance identifier

The State indicates whether the process is active (i.e. it is accepting messages from the outside as a normal process does), is being updated (i.e. the router is replaying messages to it), or it is inactive (i.e. it is no longer accepting messages, because it has a new instance that is activated or being updated). The NewSID and NewPIID are empty, when the process is in the active or updating state. If

a process instance is inactive, these two fields point to the new service and its new instance respectively.

Based on the data stored in the tables defined above, the router can perform the migration as described earlier. When a process is to be migrated, its state is changed to *inactive*, its new instance is started with an *updating* state. Then, the router sends and also stores the first, initiating message to the new process instance using a newly generated instance identifier as TIID. The router also marks this information in the migration table. From now on, the router is performing its normal behavior.

The router's normal behavior is determined by the following algorithm:

1. A SOAP message is received at the URL *http://router/SID/portName*
2. The TIID and SIID are extracted from the message.
3. The SIID is looked up in the migration table. Based on the state of the process, the following cases can occur:
   a. active: go to step 4.
   b. updating: the next reply or oneway message is looked up in the message table and is sent back to the process, but the TIID is replaced by the new identifier. The new message is also stored with the new parameters. If there are no more messages to replay, set the process state to active. Then, go to step 6.
   c. inactive: cannot occur, since the process is no longer running
4. The TIID is looked up in the migration table. Based on the state of the process, the following cases can occur:
   a. active: look up the actual URL of the service from the service table, and send the message to the service
   b. updating: do not forward the message yet, it will be automatically forwarded later
   c. inactive: find the parameters of the new instance in the migration table, update the message content accordingly, and go back to step 4.
5. If a reply is received through the HTTP channel, store it as a reply message, and store the updated incoming message as a request. Otherwise, store only the updated incoming message as a oneway message.
6. Finished processing the message.

5 EVALUATION

In the previous sections we proposed a solution for migrating instances of BPEL business processes. We tested the framework with some real-life processes, and successfully migrated process instances between IBM WebSphere and ActiveVOS. The router was implemented as a RESTful web service in Apache CXF running on a JBoss server.

Due to space limitations, the solution presented in this paper only describes the basic behavior of the framework, which has some limitations. For example, timed messages, parallel execution and non-deterministic order of SOAP messages may cause problems in the migration process. However, with a more advanced algorithm in the router, this shortcoming can be eliminated.

It is also common, that the interface of the process cannot be changed, i.e. the outside world cannot handle the SIID and TIID values in the message body. In this case the router may transform these values into SOAP headers, or use the MessageID and RelatesTo headers of WS-Addressing to match requests and replies. The router with a more advanced correlation strategy may even handle more complicated cases. It is also possible to secure messages towards the outside world, while communicating with the processes behind the router through non-secured messages.

If necessary, the router can even put SOAP headers into the SOAP body when communicating with the process, allowing processes to access SOAP headers indirectly, even if the process engine does not allow managing them directly.

The framework may also be used to migrate process instances when their BPEL code changes (e.g. some errors are corrected in them), if the router is made clever enough to transform the old messages into the new ones.

6 CONCLUSION

In this paper we proposed a design pattern for BPEL business processes to make their instances migratable between process engines. We also sketched the basic behavior of a framework capable of migrating process instances. We have successfully tested the framework on some real-life processes. As it can be seen from the previous section, there can be many other advantages of having this framework, and our future work will be directed towards these possibilities. (The results discussed above are supported by the grant TÁMOP -4.2.2.B-10/1--2010-0009.)

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ANALYSIS OF COLLABORATIVE WORK BASED ON DESKTOP AND CLOUD SOLUTIONS

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ABSTRACT

In this article, we present an analysis of performing collaborative work in virtual environments by using desktop and cloud (web-based) solutions. The first part of the analysis, which is based on 3C-model of collaboration, presents the conceptual differences of collaborative work based on desktop and cloud environments. The second part of the analysis is based on literature review and investigates both types of tools in light of software product quality characteristics. Finally, the results of both analyses are summarized.

1 INTRODUCTION

Collaborative work or collaboration represents one of three main types of human to human interaction (other types are conversational interaction and transactional interaction) (1). It is commonly defined as "a mutually beneficial relationship between at least two people, groups or organizations, who jointly design ways to work together to achieve related or common goals and who learn with and from each other, sharing responsibility, authority and accountability for achieving results" (2).

Collaborative work is an ubiquitous presence in our lives and a constant feature of modern society (3). It is important because it has a critical impact on the success of any type of community (4). From a conceptual point of view, collaborating participants alter a collaboration entity (i.e. a common tangible or intangible asset). So, the collaboration entity is in a relatively unstable form and changes with participants' interactions (1). For example, employees might represent collaborating participants where the common documents, which are constantly evolved by employees, might represent instable collaborating entities.

The efficiency and effectiveness of collaborative work can be increased with computer supported collaborative work (CSCW) or gropware, which stands for *"computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment"* (5).

Several types od groupware exist where the most common model of classifying groupware is based on two dimensions: time and space (table 1). The time dimension is divided into same time (synchronous) and different time (asynchronous), where the spaces dimension is divided into same place (collocated) and different place (remote).

Table 1: Collaborative work types and supporting groupware (6)

	Same time (synchronous)	**Different time (asynchronous)**
Same place (collocated)	**Face to Face Interactions** - decision rooms, - single display groupware, - shared table, - wall displays, - roomware.	**Continuous tasks** - team rooms, - group displays, - shift work groupware, - project management.
Different place (virtual, remote)	**Remote Interactions** - video conferencing, - instant messaging, - shared screens, - multi-user editors.	**Communication and Coordination** - e-mail, - bulletin boards, - blogs, - group calendars, - workflow, - version control, - wikis, - blogs.

In the early stages, groupware mainly supported collaborative activities in collocated environments. However, nowadays, many teams or entire organizations require tools which enable effective and efficient collaboration in distributed environments. Instead of meeting face-to-face with colleagues in offices, these tools support collaborating activities in dislocated environments, which is commonly defined as e-collaboration (7).

When discussing e-collaboration and the technology to support it, we cannot ignore virtual teams. A virtual team is actually a way of collaborating, when the team members are in different places or just a way to make collaboration more efficient. Virtual teams are therefore used to help members

and companies by connecting them to each other, regardless of their demographic.

This article further focuses on e-collaboration which is common in virtual teams and is organized as follows. In the second section, the collaborative work and supporting software is represented in an theoretical way. The third section presents analysis of collaborative work based on desktop and cloud architectures. The fourth and final section summarizes the article and presents the conclusion.

2 THEORETICAL REPRESENTATION OF COLLABORATIVE WORK

Collaborative work is commonly represented in 3C-model of collaboration (8). 3C-model defines collaborative work as the combination of communication, coordination and cooperation activities. Communication is related to the exchange of messages and information among people. Coordination is related to the management of people, their activities and resources. Cooperation is the production which takes place in a shared space.

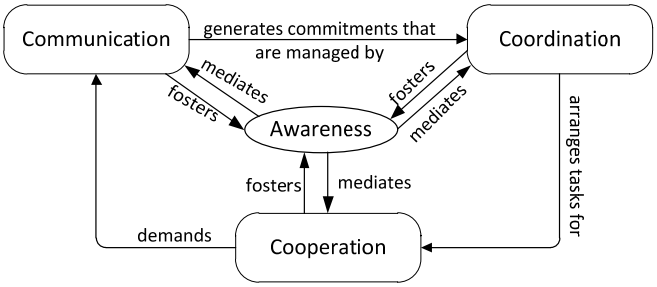

Figure 1: 3C model instantiated for collaborative work (9)

As evident from Figure 1, the 3C-model activities are interrelated and organized into a cycle, starting with communicating activities in which team members negotiate, discuss and make decisions. The out-coming commitments are defined in the coordinating type of activities, where team members organize tasks focusing on effectiveness and efficiency. These planned tasks are performed in cooperative type of activities in which common artifacts are changing and improving. New challenges and ideas, which arrive when cooperating, are discussed in a new collaborative cycle, staring with new communicating activities. This shows the iterative nature of the collaboration. The participants obtain feedbacks from their actions and "feedthrough" from the actions of their companions by means of awareness information (shared workspace) related to the interaction among participants (10).

3C-model can also be used to classify collaborative software based on the type of collaborative activity it is primary supporting (figure 2).

Figure 2: Classification of collaborative software based on 3C model (9)

In addition to Figure 3, these three types of collaborative activities form a hierarchy. For example, coordination of group activities involves communication and collaboration on joint objects requires coordinating access to this objects (9).

Independent of the collaborative work types (table 1) and types of collaborative activities *(figure 1), the supporting software can be desktop or cloud* based, each having their strengts and weaknesses.

3 ANALYSIS OF E-COLLABORATION BASED ON DESKTOP AND CLOUD GROUPWARE

Independen of previously presented classifications of groupware, we can divide groupware according to two most common software types or architectures: desktop and cloud.

Traditional or **desktop computing** is commonly defined as *"an end-user environment, defined by a profile consisting of applications, documents and configuration data"* (11). In general it is presumed that desktop computing lacks of collaboration capabilities (12). On the other side, it is still assumed that desktop-based applications have richer functionality than their web-based counterparts (12). Groupware, which is desktop based, is further defined as **desktop groupware.**

Cloud computing emerged in 2007 (13) as a new computing paradigm, which represents an alternative deployment strategy for web applications (14). Besides

changing the way that web applications need to be designed, it has also a lot in common with collaboration. Both, cloud computing and collaboration (15): cross the boundaries of an organization, are relevant to the relation between business and IT and can have a major impact on the efficiency of organizations and IT. Also, both have been identified as a key business technology trends that will reshape enterprises worldwide (16). Thus, adopting cloud computing, enterprise collaboration can happen at a much broader scale, since the cloud provides a collaborative environment (16).

Groupware, which is cloud based, is further defined as **cloud groupware.**

3.2 Conceptual comparison

From the conceptual view, there are significant differences between performing collaborating work with desktop and cloud-based solutions (figure 3).

In case of using dektop groupware, participants do not own a common collaboration entity. Instead, each of participants owns their own local entity (i.e. localy stored document). The common entity is evolved by mearging individual entities.

In case of using cloud groupware, a common entity exists (i.e. web document) and participants can evolve it in a collaborative manner.

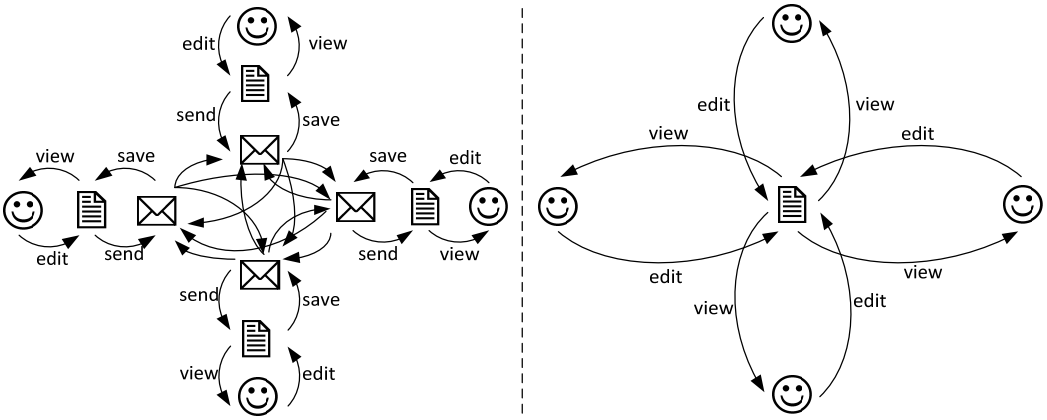

Figure 3: Conceptual differences by using dektop (left) and cloud-based solutions (right), based on Maider (17)

Table 3 presents characteristinc of desktop and cloud groupware in respect to 3C-model type of activities.

Table 3:Conceptual comparison of desktop and cloud grpware.

	Desktop solutions	Cloud solutions
Communication activities	- Requires explicit communication tools. - Requires sharing of entities.	- Implicit and less communication. - No sharing necessary, since a common entity exists.
Coordination activities	- Requires coordination between participants and local entities. - Requires locking of a shared entity or merging of local entities. - Possibility of overriding other participants's work.	- Less coordination between participants necessary. - Risks only in case of writing/editing the same section of common entity.
Cooperation activities	- No common entity. - Capable of performing independet work on local entities.	- A common entity exists. - Capable of performing synchronous (simultaneous) work.
Number of interactions	- The number of interactions increases quadraticaly to the number of particip.	- The number of interactions increases lineary to the number of participants.

3.3 Related work comparison

Several authors already investigated different aspects of desktop and cloud solutions. Table 4 represents a comparison between the desktop and cloud solutions, based on ISO/IEC 9126 Software product quality model's characteristics (18).

Table 4: Comparison of desktop applications and SaaS

Quality characteristics	Desktop solutions	Cloud solutions
Functionality	Assumed, that desktop-based applications have richer functionality than their web-based counterparts (12).	The "Rich Internet Applications – RIA" are able to approach the experience of their desktop counterparts in terms of functionality (15).
Reliability	Some of the reliability issues can be associated with different operating systems, which may or may not support a specific application. Also, users have to be in direct contact with the computer to use the installed application (19).	Potential system outages or Internet network instability are considered as major risks in the field of SaaS (20). SaaS users are also dependent on the reliability of the vendor, to have the application online and running. Usually, if the application goes offline, users cannot proceed with their work until the service is restored (19).
Usability	Desktop applications allow user customization with the use of customizable toolbars and menu bars, which enable them to have the most common functions just a mouse click away. Many desktop applications also have a selection of themes, which are sets of coordinated backgrounds, button and cursor styles (21).	SaaS should be easy to use, capable of providing faster and reliable services. User Experience driven design aims to maximize the usability, desirability and productivity of the application (16).
Efficiency	Performance is supposedly quicker on a desktop, because the screen is drawn only once and data is usually not transferred from the server, which additionally increases the time to display data (22).	The computing resources are used more efficiently. The computers can also be physically located in geographical areas that have access to cheap electricity while their computing power can be accessed over the Internet (12).
Maintainability	According to Benlian and Hess (20), two-thirds of the average corporate IT staffing budget goes towards routine support and maintenance activities. Also, user application has to be usually deployed manually to hundreds or thousands of users (22).	SaaS shifts the responsibility for developing, testing, and maintaining the software application to the vendor (20).
Portability	Software is licensed on company's own information technology (IT) infrastructure (23). Moving from one workstation to another we have to worry about whether or not the application is installed (22).	With the lack of standards in the fields of cloud computing, a customer might risk the possibility of vendor locking them into using their technology (also known as vendor lock-in) (12).

4. CONSLUSIONS

Considering characteristics and conceptual differences between desktop and cloud solutions, we can conclude the following.

From the conceptual point of view, cloud groupware outperforms desktop-based in following ways: (1) it requires less communication and collaborating activities, (2) it enables synchronous work and (3) the interactions between participants scale lineary. On the other side, researchers report that desktop solutions still outperform cloud based on following characteristics: (1) richer user interface, (2) user-interface customization, (3) offline work and (4) interoperability between file formats and vendors. In addition, cloud solution offer less control over the tool and its upgrades (20) and rise security and privacy concerns.

However, the characteristics of cloud computing are continuously evolving towards desktop ones. For example, with the introduction of standards and technologies, which provide client-side programmability (e.g. Java-Script DHTML, Flash and Silverlight), cloud solutions started to approach the experience of their desktop counterparts (15).

The question which remais is if and how much cloud solutions outperform desktop ones in lignt of end-user productivity. We will try to empiricaly answer this question in our future investigations.

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DEVELOPMENT OF A 3D MULTIUSER VIRTUAL ENVIRONMENT FOR OLDER ADULTS

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ABSTRACT

This paper presents the concept and applied methodology in developing a 3D multiuser virtual environment intended to improve the quality of life of older adults. The User Centered Design was utilized as the development approach for the implementation of the first prototype and the final system as well as for their evaluations. User Centered Design ensures user involvement throughout the development process, to maximize the usability of a product and the usefulness of a service. The project cycle is divided in three main phases consisting of the user requirements analysis, the user input for the design phase and the evaluation of the developed system. The evaluation had provided invaluable information which helped us enhance and improve the final system.

1 INTRODUCTION

On account of the demographic changes in modern society, there is an increasing number of aging adults lacking social support and experiencing social isolation. Social integration and participation of older adults in society are frequently seen as indicators of productive and healthy aging. It is widely accepted that social support has a strong protective effect on health [1]. Some of the current tools specifically designed for meeting new people and maintaining contact with friends and family members, like social networking websites, are becoming increasingly popular with older generations. However, they do not offer an immersive, intuitive and realistic experience, made possible by a 3D virtual environment.

The main aim of the 3rD-LIFE project is to develop a 3D virtual environment providing a tool for entertainment, education, communication and other functionalities to improve the quality of life of older adults (aged 60-75 years).

2 MULTIUSER 3D VIRTUAL ENVIRONMENT

There are many definitions of a virtual world, but possibly the most accurate would be a synchronous, persistent network of people, represented by avatars and facilitated by networked computers. Virtual worlds offer an awareness of space and distance along with co-existence of other participants, giving a sense of environment. A virtual world is considered synchronous in the sense of a common time, which allows for mass group activities and other coordinated social activities, while the term persistent refers to the fact that the virtual world continues to exist and function after the user has left it [2]. When compared to the conventional 2D Web, virtual worlds offer many advantages, such as multi-media content navigation, playing multi-player games, social skills development, etc. The term virtual world has become largely synonymous with interactive 3D virtual environments, where the users take the form of avatars.

3 METHODOLOGY

Within the 3rD-LIFE project the consortium has chosen to apply a User Centered Design (UCD) process, which is a development approach that focuses on the end users that will use the product or service created [3]. The aim of UCD is that the product/service developed should suit the user, rather than making the user suit the product/service. This is accomplished by employing techniques, processes, and methods throughout the life cycle of the product/service, that maintain the focus on the user from the very beginning until the end. The following are three key principles of UCD regarding [3] that we apply throughout the project.

3.1 An Early Focus on Users and Tasks

The first principle focuses on the systematic and structured collection of users´ requirements. By involving the user in the development from the beginning, the usability of a product and the usefulness of a service are maximized. It is also an effective procedure since the

sooner the end user is involved in the process, the earlier useful input is known and makes it possible to avoid developing in a direction that must be altered after the

3.4 Application of the User Centered Design for development of the 3D Multiuser Virtual Environment

The project cycle is divided in three phases; the first is the

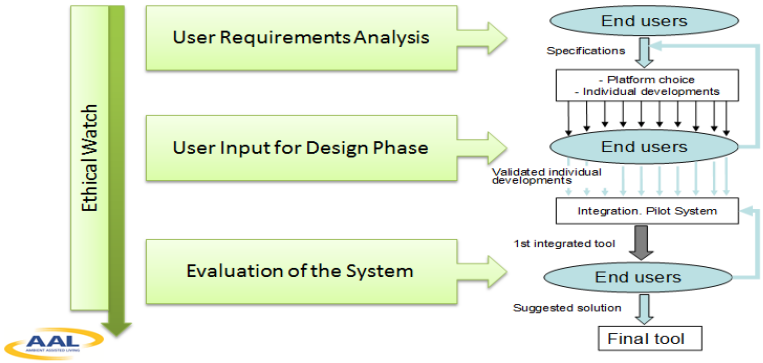

Figure 1: *Application of the User Centered Design*

user evaluation phase. The first step realized in 3rD-LIFE project was to gather these user requirements with individual interviews and focus groups with primary users (60-75 years old) and secondary users (relatives of the primary users that were younger than 60 years old). This helped us get an understanding of what the user really wants and needs, which activities they participate in or would like to perform. This information proves to be invaluable when creating a superior product.

3.2 Empirical Measurements of Product/Service Usage

The focus of this principle is on the ease of learning and effective, error-free use. This can be assessed early in the life cycle via usability evaluations of prototypes/models. A usability evaluation was planned and implemented in a later phase of the project where the users interacted with a prototype and were asked to complete a variety of tasks Different metrics such as errors, assists, and task completion rates predict the usability and are analyzed so that changes are made to improve the product/service before the final version is developed.

3.3 Iterative Design

This is the final principle, that recommends the requirements are collected and the product/service is designed, modified, and tested repeatedly. The development cycle is continuously iterated and fine-tuned with each following cycle. It is impossible to acquire all the needed information in the first iteration, no matter how expertly the usability activity is executed. This means that there will several iterations of the user evaluations throughout the project's life-time.

user requirements analysis, followed by the user input for the design phase and finally the evaluation of the developed system.

Throughout the project development, an iterative design will be followed. In the initial phase of the project – user requirements analysis – the requirements, needs and wishes of the end users were collected. There were two groups of users that took part in the analysis, one in Spain and the other in Austria. The objective was to have a bottom-up approach where end users were involved in the design process from the very beginning. Participants are required to participate in another two phases which constitutes three separate occasions within the whole project: the initial design phase (ideas generation & design input), first and final trials.

4 DESIGN AND FEATURES OF THE FIRST PROTOTYPE

In the initial phase of the project, there was a decision made to use Second Life [4] as the development platform. When compared to other similar platforms (e.g. Open Simulator or Open Wonderland), it provides better scalability and operational stability. Furthermore, Second Life is arguably the most popular virtual world platform, with an important emphasis on social interaction.

Second Life also supports advanced, realistic voice chat featuring 3D mapped voice with audio focusing capabilities and speech gestures. This means that when an avatar walks around while someone is speaking, it will hear the voice relative to its location. If the avatar moves closer, the sound will get louder [5].

When Second Life users require in-world storage of the content they have created or own, they can buy virtual real-estate. They can choose between a variety of land types, located on the mainland or on an estate. Since there

was a need for a private region within the 3rD-LIFE project, an island was acquired.

Following the user requirements analysis conducted with two groups of users, special consideration was put into developing applications that would be useful and interesting to the intended users. Different factors were taken into account, especially simplicity of use and making the applications appear as realistic as possible.

As can be seen in Figure 2, the island is divided in three main areas, the *Residences* (A), the *Exhibition* area (B) and the *Café* (C).

Figure 2: *Map of the island*

Each section of the island has its own set of applications and functionalities pertaining to that specific area. The *Café* area will offer a range of activities, from watching movies and concerts, to playing multi-player games. It is the main area for social interaction between the users.

The *Exhibition* area allows users to exhibit their own photographs and also allows other users to vote and post comments on the exhibited pictures.

Figure 3: *Photograph display with repositionable notes and a like counter*

During the user requirements analysis, the users expressed a desire for a private area, they could retreat to. In light of this, we created the *Residences* with a locking door mechanism, which allows the door to respond only to the owner and any additional added user. This provides the users with the desired private personal space.

The three principal areas are interconnected with roads and there are also a few scenic areas the users can visit. There is a lighthouse with a pier and boats on the water (D) as well as a scenic view point on the mountain, with views of the whole island. The different places can be visited using the teleport function or simply by walking.

5 EVALUATION OF THE DEVELOPED SYSTEM

The objective of the first trials was to evaluate the usability of the features that were developed thus far, as a step of the iterative circle, to involve the users in the design of the 3D virtual world. The questions were taken from the Computer System Usability Questionnaire [2] and were adapted to fit our project. They are expected to provide the outcome in form of the data we are interested in collecting. The objective was to measure the users' opinion regarding the prototype's usability, attractiveness, usefulness, accessibility and reliability.

The first part of the evaluation is the training phase, where users are instructed to navigate and interact with various objects. The navigation and communication evaluation is transversal during the whole trial as the user continues moving around and communicating while performing the assigned tasks. The user has a 5-10 minutes test period once entering the island to learn how to move the avatar from one place to another using the teleports, walking and flying functions. One researcher is assisting the user in order to use the correct keys on the keyboard to make the avatar walk, jump, turn around, grasp objects, fly, land etc. The concept of using the teleports is explained and tried out with the user. Another researcher is present as an avatar inside the 3rD-LIFE island to communicate with the user, using the chat and voice functions.

After the training phase is concluded, the user is instructed to visit the *Residences*, verify the lockable door at one of the residences and enter their house. While in the house, they test the email functionality and after completing the task, they are instructed to leave the house. Throughout the entire exercise a researcher observes and evaluates the users' capability to perform the tasks. After the user leaves the house, they use the teleport function to visit the *Café* and *Exhibition* area, where they have to perform similar tasks.

5.1 Enhancements of the first prototype

The evaluation highlighted some aspects of the system that could be improved in order to enhance the user experience. The first step was to identify the usability problems and positive aspects of the product that users experienced. Based on these results, there will be some changes made to the island topology itself as well as some changes to the developed applications. The main topology enhancements are comprised of two new areas on the island, one for learning and the other for gaming activities. One of the most important aspects of the 3D virtual environments is the social interaction. For this reason, we

have decided to add two more areas, one for playing multiplayer games and the other for various learning activities, such as language courses.

While the gaming area is meant mainly for entertainment and socializing, it will also include games for improving the cognitive skills of the user. The learning area will serve as a Collaborative Virtual Environment (CVE). CVEs can be used for educational applications, such as collaborative e-learning. Collaborative e-learning is defined as any kind of learning process performed by more than one person that takes place mainly in a virtual environment [6]. In contrast to conventional 2D web e-learning applications, the shared sense of space and presence is a big asset of 3D virtual environments due to the real time communication features.

There will also be some usability enhancements, for example removing walls and making the furniture in the residences smaller, as the users have had problems navigating the interior of the residences. Other changes include simplifying the use of the liking and commenting mechanisms in the *Exhibition* area, as well as rearranging the *Café* layout. All of these changes will bring added value to the developed system and make the 3D virtual environment easier to use.

5.2 Effect of input devices on end-user experience

During the evaluation of the first prototype, the users used a keyboard and mouse combination as their input devices for navigating and interacting with the system. This combination was primarily used because it was the most familiar to the intended users. However, they found this method difficult, even with prior experience with the before mentioned devices. This means, there must be further research and analysis of possible alternative solutions, to improve the interaction between the users and the 3D virtual environment.

There are many possible input devices that could be utilized, but the main focus must be on the simplicity of use. To ensure intuitive simplicity, the amount of devices need for navigation and interaction should be limited. The users must find the interaction with the system intuitive and simple, as this is a vital part of the system's usability and it might hinder the success of the application.

6 CONCLUSION

The evaluation of the developed 3D Multiuser Virtual Environment and its applications provided a valuable insight into possible usability related issues and helped us define enhancements for the final version of the system. For the most part, the user opinions and the evaluation of the prototype were positive. There will be minor changes made to the island topology and applications that will contribute to a better user experience. The first user trials emphasized the importance of having more areas specifically focused on social interaction. The significance of the multiuser aspect was made apparent during the first trials, while the users were only testing the applications, and possibly not enough focus was placed on interaction between the users. For this reason, we are developing the additional areas, which will greatly enhance the user experience.

There will also be special consideration of the means of interaction between the users and the developed 3D virtual environment, as this has presented itself as one of the key issues in developing a useful and functional system.

7 ACKNOWLEDGEMENTS

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PROJECT EVALUATION THROUGH MONITORING QUALITY INDICATORS WITH PROJECT MANAGEMENT TOOL

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ABSTRACT

Rapid progress in technology and global competition is emphasizing the importance of quality on a daily level. Therefore enterprises evaluate their projects to ensure continuous improvement as to meet quality standards. This paper presents a project quality evaluation model used and integrated into application for project management (BuyITC Tasks). We outline basic project evaluation methods and different models used by enterprises.

The described model uses qualitative methods of evaluation in combination with semiautomatic measuring of defined indicators. We conclude with highlighting the importance of measured data visualization, which encourages positive attitude of employees towards evaluating.

1 PROJECT EVALUATION

The notion of evaluation was most comprehensively defined in year 1994 as "systematic investigation of the worth or merit of an object" by Joint Committee on Standards for Educational Evaluation [1]. Usually we evaluate projects, programs, politics, learning and other processes. Reasons for conducting an evaluation are different, but often executed with objectives for continuous improvement and learning. Evaluation serves for better planning, success recording or evaluating achievement of defined objectives.

Evaluation is associated with the term monitoring, which represents continuous or periodical observation and analysis of a project: use of sources, realization of activities and achieving objectives and results. It is also often associated with the term assessment, which relates to evaluation in a comparative manner. Impact assessment determines "*whether project interventions have contributed to longer-term impact.*" [2]

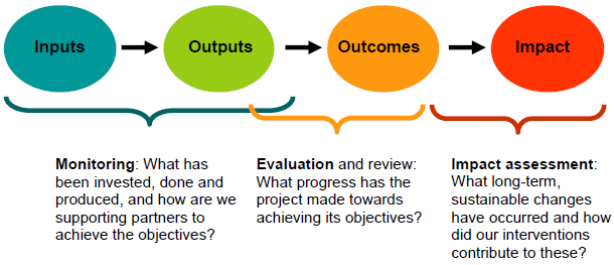

Figure 1: *Monitoring, evaluation and impact assessment* [2]

Frechtling [1] describes two types of project evaluation (Figure 2). Formative evaluation begins in early stages of a project lifecycle and intents to assess initial and ongoing project activities, while the purpose of summative evaluation is to assess the quality and impact of a fully implemented project. Vrčon [3] indicates a third type, a perspective evaluation, which intents to assess the potential results and impact of suggested projects.

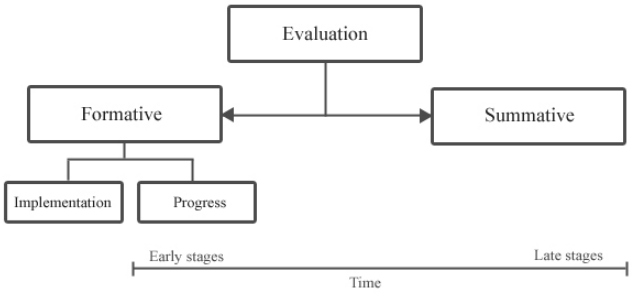

Figure 2: *Evaluation types* [1]

1.1 What to evaluate?

Projects can be evaluated from different, usually interconnected points of view: financial, time and quality perspective. The concept is summarized in so-called project triangle, which represents constraints of project management and traditionally consists from three components: scope, resources and schedule. When one of the components changes, it almost always affects other components. [4] Quality, often seen as the fourth component, is also strongly connected and affects other components.

While traditionally all components are equally important when evaluating a project, quality is one of growing importance. With globalization and advances in technology users can choose from a wider range of products and services, therefore importance of quality is increasing.
Financial data is not sufficient for evaluating success or progress of a project, therefore measures of successfulness, efficiency and quality need to be undertaken.
Since perceptions of quality can significantly differentiate, there were many models and standards, which define quality, developed. Hereafter we outline models related to quality of software development projects, which usually define quality characteristics and their relations.

2 EVALUATING SOFTWARE QUALITY

Companies use different criteria, standards, models or combination of all, for evaluating and ensuring quality. We outline a few often enforced models for evaluating software development projects.

2.1 McCall's quality model

One of the earliest and renowned models was presented by Jim McCall in 1977. Model focuses on software quality factors, which represent user's views as developers' priorities. It uses three major perspectives for defining and identifying the quality of a software product: product revision (ability to undergo changes), transition (adaptability to new environments) and operations (characteristics). Contents of McCall's model are further divided to 11 quality factors (such as maintainability, flexibility, testability etc.) and 23 quality criteria (such as simplicity, conciseness, modularity etc.). [5] [6]

2.2 Boehm's quality model

Another important hierarchical model of software quality characteristics was presented in 1978 by Barry M. Boehm. Model underlines the importance of usability, represented by "as-is" utility, maintainability and portability, which all contribute to comprehensive usability. [7] [8]

2.3 Dromey's quality model

Model from 1995 represented by R. Geoff Dromey recognizes the need for more dynamic modeling, since quality evaluation differs for each product. [9] Dromey focuses on relationships between quality attributes (such as functionality, reliability, usability, efficiency, maintainability etc.) and also tries to connect product properties with those quality attributes. [6]

2.4 ISO 9126 quality model

ISO/IEC 9126 "Software engineering - Product quality" is an international standard for the evaluation of quality, defined by International Organization for Standardization and International Electrotechnical Commision. The standard is divided into quality model, external, internal and quality in use metrics. Quality model is structured set of 6 characteristics (such as functionality, reliability, efficiency etc.) and sub-characteristics (such as suitability, accuracy, security etc.). [10]

2.5 Models comparison

Models cover different quality characteristics (Table 1), of which are common efficiency, reliability and maintainability. Quality model described in ISO/IEC 9126 is most comprehensive and also describes quality in software life cycle.

Table 1: *Quality characteristics in Boehm's, McCall's, Dromey's and ISO 9126 quality model* [11]

Quality characteristics	Boehm	McCall	Dromey	ISO 9126
Testability	X	X		X
Correctness		X		
Efficiency	X	X	X	X
Understandability	X			X
Reliability	X	X	X	X
Flexibility		X		
Functionality			X	X
Human engineering	X			
Integrity		X		X (security)
Interoperability		X		X (functionality)
Process maturity			X	
Maintainability	X	X	X	X
Changeability	X			
Portability	X	X	X	X
Reusability		X	X	

3 CASE STUDY: SEMIAUTOMATIC MONITORING AND EVALUATING SOFTWARE DEVELOPMENT PROJECTS

Hereafter we describe the case of designing an application BuyITC Tasks[1] as a tool for quality management. Application was initially designed and developed for internal project management purposes in a small company, which main business is design of advanced information solutions. BuyITC is developing business applications, intranets, e-commerce portals and other applications serving specific customer needs. Application BuyITC Tasks serves as at tool for project management from scope, time and financial point of view. Application provides tasks and workflow overview. Before integrating quality indicators in the application, project quality had to be defined. Hence every project is specific, there was an own model, based on combination of different models described before, for quality evaluating designed. The model was designed mainly for information technology development purposes,

[1] BuyITC Tasks is an project management tool, developed by BuyITC d.o.o., http://www.buyitc.si/resitev/3170/Organizator-dela

but is open enough to be customizable for different project-specific needs.

The model was integrated in existing application for project management BuyITC Tasks. As a result, application enables semiautomatic quality evaluation through implementation phase and at the end of every project. Automatic part of evaluation is enabled by integrating quality indicators.

Company uses combination of different quality measures and indicators. Quality is company- and project-wide managed mainly by leadership and project managers, but implied in tasks of every employee.

The model consists of two layers of ensuring quality: ensuring achievement of quality characteristics of a product (what mainly covers ISO 9126 model for external and internal quality) and ensuring quality of a development process as whole environment in which a product is developed. As also standard ISO/IEC 9126 emphasizes, quality in use (quality as users see it) is dependent of process quality.

In BuyITC Tasks every project is divided to main phases, such as analysis and planning, implementation and training, however there could be several iterations within main phases. Therefore we could define the operating methodology as combination of traditional and agile development. This methodology is implemented in project management tool. Every phase of a project is further divided into tasks. The implementation phase consists of several tasks, which represent defined functionalities of a product. Every task has a status: "open", "in execution", "confirmed" or "rejected". The latter status means, the task (functionality) did not meet determined criteria (suitability, accuracy, time behavior etc.) while testing it and has to be improved or corrected. At the end of a project, every task has to be confirmed. This covers ensuring quality characteristics of a product.

For ensuring and monitoring quality of the development process, there are also other quality indicators defined. Project managers take care of quantitative monitoring and evaluation through and at the end of the project as also monitor and handle problems that cannot be automatically detected. Metrics and indicators that can be automatically measured are represented in a dashboard in BuyITC Tasks. The latter are mostly connected to implementation activities.

Most of the indicators are visually presented, since visualization contributes to more efficient analysis of measures. Indicators are visualized in form of histograms, pareto, pie charts etc. Project manager as other employees, who work on a project, can monitor progress and quality on a dashboard (Figure 3). Alerts are also sent via email in case of any critical values.

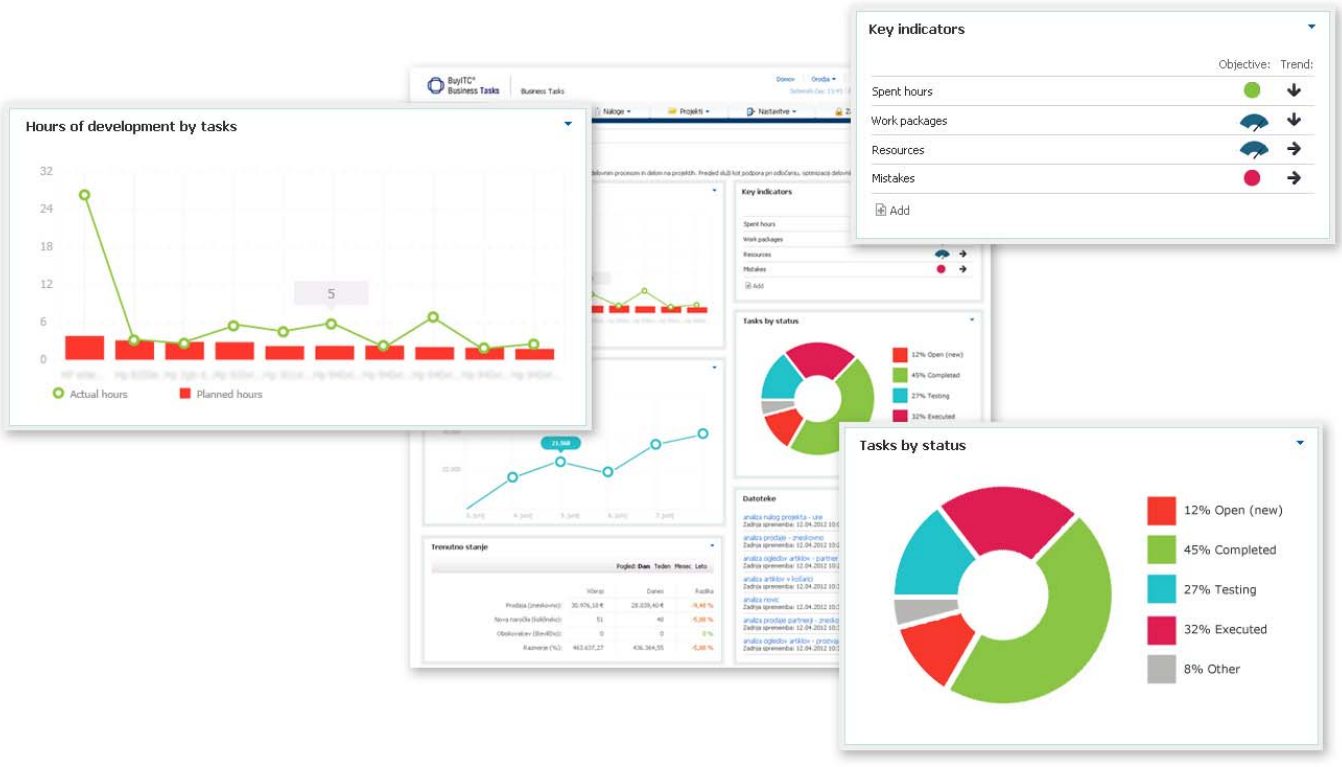

Figure 3: *Dashboard in BuyITC Tasks*

Hereafter we indicate some examples of automatically measured indicators of process quality integrated in application:

- planned vs. actual spent hours for graphic design,
- planned vs. actual spent hours of development (usually broken into structure of tasks or functionality of software),tasks
- planned vs. actual spent hours of development per employee,
- ratios between total number of mistakes made and individual type of mistakes (mistake made due to later adjustment of definition, mistake or slip made by developer etc.),
- percent of work packages adhering to the schedule,
- number of assigned resources versus planned resources,
- ratio between total number of tasks by status of the tasks,
- percent of work packages adhering to the budget,
- etc.

At the end of every project there is comprehensive evaluation of quality made. It takes into account early measurement and evaluation, such as engagement measurement (customer involvement, user testing), as automatically reported evaluations in BuyITC Tasks as also final evaluations (customer satisfaction survey).
To date, BuyITC Tasks was mostly used with software development projects, as also with some smaller projects in services sector. Project managers report BuyITC Tasks as useful and as efficient tool for monitoring and also evaluating projects. They indicate advantages such as good progress overview, which is consequently also advantage for employees who work on a project, since they do not have negative feelings of someone always monitoring them. Alerts or quick review of the dashboard, for example, indicate when a project manager needs to personally approach an employee. Also they can easily monitor spent hours, resources or budget. Project managers indicate the tool does not meet the needs for personal communication between employees entirely. They stress precise planning, especially in agile projects, is still the hardest part, whereas for effective automatic evaluation in BuyITC Tasks this is necessary. For comprehensive evaluation of project quality there are also some subjective, manual assessments (such as of customer involvement) needed.

4 CONCLUSION

Competition on global market indicates the need for higher quality standards; therefore the importance of quality perspective in projects is also growing. To ensure quality, companies often use different models, standards or technologies for measurement and evaluation.
The paper presents a case study, where quality evaluation is made semiautomatic with use of project management tool with integrated measurement of quality indicators.
We see visualization of indicators as particularly important part of application, since it encourages every individual to self-assess and evaluate the project.
We also suggest the research of potential integration of other quality indicators that to date could not be measured automatically, such as assessment of customer involvement, results from user testing, customer satisfaction survey etc.

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FIRST EXPERIENCES IN USING SOFTWARE METRICS IN AUTOMATED ASSESSMENT

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ABSTRACT

Automated assessment systems are very helpful in reducing the amount of repetitive work done by instructors on computer science courses with a lot of practical exercises. These systems can also help students by providing objective grading and quicker feedback. In this paper we explore the usage of software metrics in automated assessment. The metrics are utilized to assess algorithm complexity among other aspects that currently demand instructor attention. Additional value of our approach is programming language independency of the used tools: SMIILE for software metrics calculation and Testovid for automated assessment.

1 INTRODUCTION

Assessing student programming knowledge and grading their solutions of programming assignments can be very tedious. Even with a small number of students attending the course, the number of programming assignment solutions that an instructor must grade during a semester can be overwhelming. With the constant increase in the number of enrolled students, and with continual assessment on courses with programming exercises, this problem becomes even more pronounced.

Automated assessment systems can help alleviate the effort of grading large amounts of similar student solutions. Most of this workload can be transferred from the humans to the machine freeing instructors for more cost-effective activities in the learning process. These systems also provide instant feedback to the students improving their learning experience.

Unfortunately the aspects of student programming solutions that automatic assessment systems can check are somewhat limited. They are usually constrained to black-box (input-output) tests, unit tests and lately code style checks. However software metrics as means for assessment of student programs are often under looked. Also, many testing systems provide only information about success or failure. They also fail to provide students with details on what exactly is not working correctly within their solution and how to fix it.

Our motivation is described in section 2. An overall description of the work related to usage of automated assessment tools and application of software metrics in automated assessment is provided in sections 3, with our proposed approach to a solution introduced in section 4. Section 5 presents an application of our approach with a case study. The paper concludes and describes directions for the future work in section 6.

2 MOTIVATION

Automated and semi-automated assessment systems are effective way to alleviate overburdened instructors and transfer most of repetitive and cumbersome work to the machine. As such, these systems have been utilized almost from the start.

Software metrics are a widely accepted way to measure the program quality. Although software metrics can tell a lot about a program they have highly diverse methodologies and objectives. It is also difficult to define or measure program quality for many various programs in a uniform way. Hence, the main source of difficulty is in determining the meaning of metrics which matter the most for a student solution of a particular programming assignment.

Software metrics, even when used in automated assessment, are utilized only by plagiarism detection subsystem and grading process rather than to provide valuable feedback to the student and help him improve his programming solution and programming knowledge in general.

Our goal is to provide a program analysis framework that uses software engineering metrics and tools evaluate the quality of student programs. The framework is programming language independent and performs the analysis based on XML representation of program by the special type of concrete syntax trees; for static analysis using metrics and also incorporates dynamic analysis to provide detailed feedback to students.

3 RELATED WORK

Automatic assessment and testing of student programs written in programming languages dates all the way back to 60's of the last century. Among the first authors were Hollingsworth [10] and Wirth [7] and systems were designed for assembler and Algol. During time many systems were developed [1, 12] and they usually followed

modern concepts introduced by new operating systems and new programming languages.
There were also successful contemporary efforts to address problems of electronic submission and assessment. Unfortunately, many such ventures focus on a specific programming language or a specific platform.
The only truly programming language independent testing system is [14], a system built for UNIX platform, also based on command scripts, but a little outdated and without network support.
The systems like [4, 6, 8, 11] focus on Java programming language, and the system [9], focus on Scheme with a possibility of linking to some other programming languages. There were some attempts to create a system for testing that will encompass wider spectrum of programming languages developed in python [2].
The main advantage of our automatic assessment tool - Testovid [3], in comparison to mentioned systems is that it is built on Apache Ant and thus it is modern and not dependent on programming language or specific building and compilation logic. Also, the system can be used in a wide variety of situations and environments, and is very extensible, modular, and can quickly adapt to new trends.
Furthermore, Testovid system incorporates hints and advices into the testing reports, enabling graders to give students comprehendible feedback about their programming solutions. This feature of the system fits naturally into our idea of using software metrics to provide students with rich information about fallacies of their solutions.
Despite that software metrics are well known way to measure the quality of programs; existing automated assessment systems that have adopted them are rare [13]. Leach and Mengel claims that Halstead metrics, McCabe cyclomatic complexity and some other NDepend metrics are common and useful static metrics for computer science education applications [16]. However, they are often used only for plagiarism detection purposes rather than for providing students with feedback for writing good quality programs.
One contemporary attempt in usage of software metrics to improve automated testing is described in [15]. This is a very inspiring approach, but focuses exclusively on Java programming language. The framework utilizes static analysis to give students feedback about how solutions might be improved and help instructors in grading. The system uses software metrics and relative comparison to mark the quality of student programs. As we are using multiple programming languages in teaching, in our case it cannot be applied on all courses.

4. FRAMWORK FOR AUTOMATED ASSESMENT

Framework for automatic assessment of students' program consists of two components:

- SMIILE – input language independent tool for calculating software metrics
- Testovid – tool for automatic assessment

Both components are already in use. Also, both systems are based on modern technologies with utilization of xml as data representation and are platform and programming language independent.
The only obstacle during integration of these two systems was adaption of an xml file holding output values of calculated software metrics to the format that can be easily manipulated from inside the testing system.
The Testovid testing system is implemented as a framework for running domain specific testers. These domain specific testers are written as Apache Ant scripts. When using software metrics in automated assessment, the script runs SMIILE tool which generates xml file with metrics values for a student program (figure 1, steps 1 and 2). This xml file is then slightly transformed using XSLT and the values of calculated software metrics are then loaded (figure 1, step 3).
With values of software metrics for student solution loaded, Ant script can freely use them in the assessment process for grading, generation of intelligent advices or other calculations (figure 1, step 4). These advices along with the success/failure information are presented to the student on the final testing report.

4.1. Testovid

Testovid [3] is the testing system implemented by using Apache Ant that allows students to test their assignments in a controlled manner. The system allows instructor to run the same tests on a set of student assignments. Results of tests are recorded in a log file and are available to students and the instructor. The system accepts any type of files as assignment and the instructor has a great flexibility in specifying how and what is to be tested. The system is independent of underlying platform and programming language used for solutions.

4.2 SMIILE

The SMIILE tool [5] is software metrics tool in the development phase independent of input programming language. This independency is based on enriched Concrete Syntax Tree (eCST) – specific internal representation of source code (CSS ref).
eCST is a slightly modified Concrete Syntax Tree enriched with universal nodes. These nodes are unique for all languages and serve as marker for specific element in source code. Examples of these elements are: unit (class, module, etc.), loop_statement (for, while, repeat, etc.), branch_statement (if, case, switch…), branch (single branch in branch statement), condition, etc. This enriched Concrete Syntax Tree is completely independent of programming language and is a basis for calculation of software metrics.
The SMIILE tool consists of eCST generator and metrics calculator. The eCST generator recognizes input programming language based on input file extension and calls the appropriate scanner and parser to generate an eCST

representation of provided source code. This eCST representation is then exported in XML format. Metrics calculator takes eCST from generated XML file, parses it, calculates software metrics and exports results in XML format. The final result from SMIILE is one XML file containing values of all calculated metrics for the given source code.

Current prototype of SMIILE tool supports several software metrics such are Lines of Code (LOC) and Cyclomatic Complexity (CC). Some design metrics are moved to space of language independency. Therefore we propose general Number of Units (NOU) instead of object-oriented Number of Classes (NOC) and Number of Functions (NOF) instead of Number of Methods (NOM).

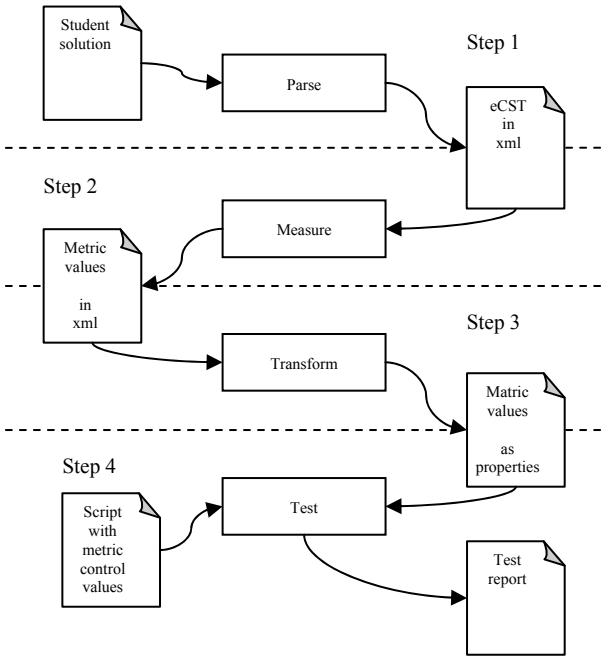

Figure 1: *Assessment process*

5 CASE STUDY

In this section, the applicability of the proposed solution is illustrated using a case study.

One student assignment from Data structures and algorithms course on our Department is taken as a case study to show that it is possible to use metrics for assessment of student solutions. In this case we are testing efficiency of the student program written in Modula 2.

The assignment that we selected asks the student to write a program which finds and prints Pythagoras triplets, positive integer numbers x, y and z for which $x^2+y^2=z^2$.

In testing this assignment we use cyclomatic complexity metric which can detect loop and branch statements. Using these metric values we created a domain specific tester for Testovid that can differentiate between typical student solutions and award points accordingly.

The first, naive, approach to solving the chosen assignment that comes into mind and which the majority of students implement, is to generate all possible pairs of x and y, to calculate z as square root of x^2+y^2 and to check if z is integer. One such typical solution is shown on figure 2.

```
1.  MODULE Triplets1;
2.  ...
3.  VAR x, y, z: INTEGER; zreal: REAL;
4.  BEGIN
5.    FOR x := 1 TO Gr DO
6.      FOR y := 1 TO Gr DO
7.        zreal := REAL(Sqrt(LONGREAL(x*x + y*y)));
8.        z := TRUNC(zreal);
9.        IF zreal = FLOAT(z) THEN
10.         WriteString('x = '); WriteCard(x,2);
11.         WriteString(', y = '); WriteCard(y,2);
12.         WriteString(', z = '); WriteCard(z,2) WriteLn;
13.       END
14.     END
15.   END
16. END Triplets1.
```

Figure 2: *Naive student solution*

Although such solution is not optimal, students often come up with even worst solution similar to one on figure 3. They try to generate all possible triplets (x, y, z) and to check if $x^2+y^2=z^2$. Such solution has an extra inner loop that drastically reduces efficiency.

```
1.  MODULE Triplets2;
2.  ...
3.  VAR x, y, z: INTEGER;
4.  BEGIN
5.    FOR x := 1 TO Gr DO
6.      FOR y := 1 TO Gr DO
7.        FOR z := 1 TO Gr DO
8.          IF x*x + y*y = z*z THEN
9.            WriteString('x = '); WriteCard(x,2);
10.           WriteString(', y = '); WriteCard(y,2);
11.           WriteString(', z = '); WriteCard(z,2) WriteLn;
12.         END
13.       END
14.     END
15.   END
16. END Triplets2.
```

Figure 3: *Worst solution*

A better solution could be devised by not generating all possible numbers but only the ones that will give a Pythagoras triplet. A theorem exists that states that for any integer numbers n and m, where m is less than n, the numbers n^2-m^2, $2 \cdot n \cdot m$ and n^2+m^2 are Pythagoras triplets. Figure 4 shows a solution that makes use of this theorem. Here the checking is completely eliminated and only two loops are left.

```
1.  MODULE Triplets;
2.  ...
3.  VAR x, y, z, m, n: CARDINAL;
4.  BEGIN
5.    FOR m := 1 TO Gr DO
6.      FOR n := 1 TO m-1 DO
7.        x := m*m - n*n;
8.        y := 2*m*n;
9.        z := m*m + n*n;
10.       WriteString('x = '); WriteCard(x,2);
11.       WriteString(', y = '); WriteCard(y,2);
12.       WriteString(', z = '); WriteCard(z,2) WriteLn;
13.     END
14.   END
15. END Triplets.
```

Figure 4: *Better solution*

After calculating cyclomatic complexity for each one of the three typical student solutions we can analyze the values and devise a formula for allocation of points to students.
This first naive solution has two nested for loops and uses one branch statement to checks if the calculated z is integer. Such solution has cyclomatic complexity of 3. The brute force solution, which is considered to be worse, has three nested for loops and a branch statement giving the cyclomatic complexity of 4. A better solution that utilizes the theorem has cyclomatic complexity of 2.
Analysis of calculated values shows that the greater the cyclomatic complexity the worst the solution efficiency as it containes more loops. The amount of points awarded to the student should, thus, be reverse proportional to the cyclomatic complexity.
One grading model could be to award inefficient solutions with no points, average solutions with half the maximum amount of points and more efficient solutions with all the points.
The calculated values and amount of points to be awarded are summarized on figure 5.

Solution	Efficiency	Metric value	Awarded points
Triplets1	Average	3	50%
Triplets2	Bad	4	0%
Triplets3	Good	2	100%

Figure 5: *Cyclomatic complexity and point distribution*

The instructor should use his knowledge and experience to choose the metrics to be used for the assignment in question, which was McCabe cyclomatic complexity in out case. By defining minimum and maximum values for metrics and the amount of points to award for those cases, testing system can automatically classify student solutions using our script and grade them accordingly.

6 CONCLUSIONS

Our approach was to utilize software metrics in the assessment process of the student solutions to programming assignments. Software metrics are used to increase the scope of student solution aspects that can be covered by automatic tests.
By using automated testing system that is platform and programming language independent and provides hints and advices to students we also added intelligent assistance and improved student learning experience on various programming courses. Furthermore, utilizing a software metrics tool that is also platform and programming language independent and support a wide range of metrics we left great flexibility in selecting interesting metrics to the instructor.

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AN ANALYSIS OF SOA-RAF WITH REGARD TO SOA DESIGN PATTERNS

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ABSTRACT

In this paper we aim to explore ways of realizing SOA best practices and guidelines, as expressed by architectural implications using suitable design patterns. Our exploratory research was focused on discovering correlations between OASIS SOA-RAF architectural implications and SOA design patterns.
OASIS is in the process of developing a Reference Architecture, which represents an abstract view. Even though it is still in the development phase, it offers sufficient data for this research work.

1 INTRODUCTION

Service-Oriented Architecture (SOA) is an architectural style for building agile, cost efficient enterprise solutions based on business aligned processes. Companies around the world have been adopting the principles and techniques associated with SOA for different types of projects in different industries. The usage of SOA Reference Architecture is a key enabler for achieving the value propositions of SOA [1].
Although creating and maintaining a reference architecture is one of the more difficult best practices for SOA, it is an important and critical success factor in achieving SOA goals [2]. Many organizations have therefore been developing their own reference architectures, from the most abstract to the most detailed.
The OASIS SOA Reference Architecture Foundation (RAF), upon which this research is based, is positioned at the more abstract end of the spectrum of reference architectures and constitutes what is described as a "foundation architecture." The foundation architecture is what TOGAF v9.1, an Open Group framework for developing an enterprise architecture, describes as an architecture of generic services and functions, which provides a foundation upon which more specific architectures and architectural components can be built [3]. It is nonetheless a reference architecture as it remains solution independent. However, since it takes a first principles approach to the architectural modeling of SOA-based systems, it is characterized as a Reference Architecture Foundation.

The goal of this research is the identification of SOA design patterns that can be used to realize SOA-RAF architectural implications for every viewpoint of a SOA Ecosystem.

Our research consists of individual and group work. (1) We started by performing an individual overview of existing literature with a focus on SOA Reference Architecture, OASIS SOA-RAF and SOA Design patterns that also provided the basis for our research. (2) The research continued with an overview of individual architectural implications from the OASIS SOA-RAF document. (3) On the basis of each architectural implication we performed research based on a summary of the individual design pattern. (4) After the completion of the preliminary comparison research we conducted group work, where we examined the preliminary results, exchanged the information of our separate research and decided upon further steps for research. (5) This group work was followed by more comparison research, based on a detailed description of the design patterns, which provided more accurate results. (6) Based on this, we concluded another group work, where we examined and presented our final results.

2 OASIS SOA-RAF

OASIS SOA-RAF represents an abstract realization of SOA, with an emphasis on the elements and their connections necessary to enable the use, implementation and ownership of systems based on SOA, without relying on specific technologies. It shows how SOA fits into the life of users and stakeholders, how SOA-based systems may be realized effectively and what is involved in owning and managing them.

It takes the Reference Model as its starting point, in particular the vocabulary and definition of important terms and concepts. The SOA-RAF goes further in that it shows

how SOA-based systems can be realized in an abstract way. Therefore it is intended to provide foundational models on which to build other reference architectures and eventually concrete architectures [4].

Viewpoint Element	Participation in a SOA Ecosystem	Realization of a SOA Ecosystem	Ownership in a SOA Ecosystem
Main concepts covered	Captures what is meant for people to participate in a SOA ecosystem	Captures what is meant to realize a SOA-based system in a SOA ecosystem	Captures what is meant to own a SOA-based system in a SOA ecosystem
Stakeholders addressed	All participants in the SOA ecosystem	Those involved in the design, development and deployment of SOA-based systems	Those involved in governing, managing, securing and testing SOA-based systems
Concerns addressed	Understanding ecosystem constraints and contexts in which business can be conducted predictably and effectively	The effective construction of SOA-based systems	Processes to ensure governance, management, security and testing of SOA-based systems.
Modeling Techniques used	UML class diagrams	UML class, sequence, component, activity, communication and composite structure diagrams	UML class and communication diagrams

Table 1: *Viewpoint specifications for the OASIS Reference Architecture Foundation for SOA* [4].

The reference architecture foundation views the SOA architectural paradigm from an ecosystems perspective, where a system will be a capability developed to fulfill a defined set of needs. It specifies three viewpoints on SOA [4]:

- Participation in a SOA Ecosystem,
- Realization of a SOA Ecosystem and
- Ownership in a SOA Ecosystem.

Participation in a SOA Ecosystem viewpoint captures a SOA Ecosystem as an environment for people to conduct business. It therefore includes all the stakeholders of the ecosystem. Its goal is to ensure that all the stakeholders can conduct their business effectively and safely in accordance with the SOA paradigm.

The realization of a SOA ecosystem viewpoint focuses on the infrastructure elements needed to support the construction of SOA-based systems. It includes all the stakeholders that are involved in the design, development and deployment of a SOA-based system. Therefore, its main concern is the effective construction of SOA-based systems.

Ownership in a SOA ecosystem addresses what is meant to own a SOA-based system in a SOA ecosystem. It therefore includes all stakeholders that are involved in governing, managing, securing and testing SOA-based systems [4].

As mentioned in the previous chapter, SOA-RAF presents three viewpoints on a SOA ecosystem. Every viewpoint conforms to models that further explain every viewpoint. Participation in a SOA ecosystem viewpoint provides two main models: Social structures in a SOA Ecosystem, and Action in a SOA Ecosystem Model. These together further provide the following models: (1) Social Structures, (2) Resource and Ownership, (3) Policies and Contracts, (4) Communications as a Means of Mediating Action, (5) Semantics, (6) Trust and Risk, (7) Needs, Requirements and Capabilities and (8) The Importance of Action.

The realization of a SOA ecosystem conforms to the (1) Service Description Model, (2) Service Visibility Model, (3) Interacting with Service Model and (4) Policies and Contracts Model.

Ownership in a SOA Ecosystem divides into the (1) Governance Model, (2) Security Model, (3) Management Model and (4) Testing Model [4].

OASIS SOA-RAF provides each model with individual architectural implications, which further offer guidelines on how to successfully implement each viewpoint of the SOA ecosystem. These constitute the basis for our research. Therefore, the focus of these article will be on architectural implications provided by OASIS SOA-RAF.

3 SOA DESIGN PATTERNS

Service developers are frequently faced with many design and architectural challenges when attempting to apply the design principles of SOA. An important software engineering tool that can help to overcome these

challenges are design patterns. They provide a description and understanding of common architectural, design or implementation problems and offer their corresponding solutions. Solutions of a Problem captured as design patterns are generic, which means that design patterns are applicable to a number of different contexts while guiding developers from a problem in a given context to a proven solution with predictable consequences [5]. Each design pattern is usually specified by a [6]:

- **problem:** describe the domain of problems that the pattern aims to solve and their impacts.
- **solution:** describes the design solution proposed by the pattern to solve the problem.
- **application instruction:** provides generic guidance on how to change the design in order to apply the pattern.

Design patterns are, according to the domain they cover, usually gathered in a catalogue. For the purpose of this research we used one of the most influential catalogues in the domain of design principles of Service-Oriented Architecture: Thomas Erl's SOA Design Patterns. Design patterns collected in the previously mentioned catalogue are also available on the web site www.soapatterns.org, [7][8].

The design pattern catalogue used in our research contains a range of design patterns that tackle a vast spectrum of design problems and can be incorporated into a variety of SOA based solutions. In general, design patterns in the catalogue address architectural and design problems related to different stages of a service development lifecycle. The most important groups of design patterns cover the domain of the establishment and governance of a service inventory. Some of them are also associated with the important realm of good practices and principles of service design, the establishment of security mechanisms and service messaging.

4 RESEARCH RESULTS

Through our exploratory research we discovered that in most cases it is difficult to identify a direct correlation between an individual architectural implication and a SOA design pattern. We therefore developed a system for recording correlations on more than one level. On that basis we divided the results of our research into three categories:

- **direct correlation** - in this category we classified the design patterns that directly meet the demands of the architectural implication;
- **indirect correlation** - in this category we classified the design patterns that only partly meet the demands;
- **general correlation** - in this category we classified the design patterns that were related by their definition, but otherwise did not meet the demands that were listed in the OASIS SOA-RAF document.

At the moment, the OASIS SOA-RAF document is still under development, therefore is lacks some content, which in the final document could reflect in the changes of research results.

4.1 RESULTS SUMMARY

Our research showed that suitable design patterns exist for most of the models of the OASIS SOA-RAF, except in the case of Social Structures and Testing Model. We believe that the reason for this is because design patterns primarily cover the patterns in which we can realize SOA. However, it does not provide patterns that support social structures that use SOA or the testing model, which is useful for testing an already existing SOA solution. In addition to the previously mentioned exceptions where we could not find a suitable corresponding design pattern, we also could not search for a comparison in the case of the Management Model, as it was not yet described in the current version of the OASIS SOA-RAF document. Detailed results are presented in Table 2.

Architectural Implication	Direct corr.	Indirect corr.	General corr.
Participation in a SOA Ecosystem			
Social structures	0	0	0
Resource and Ownership	1	1	0
Policies and Contracts	2	5	0
Communication as a Means of Mediating Action	3	2	3
Semantics	3	0	0
Trust and Risk	1	0	0
Needs, Requirements and Capabilities	4	2	1
The Importance of Action	0	1	1
Realization of a SOA Ecosystem			
Service Description Model	4	0	0
Service Visibility Model	6	2	0
Interacting with Services Model	0	7	2
Policies and Contracts Model	2	5	0
Ownership in a SOA Ecosystem			
Governance Model	2	0	6
Security Model	10	0	6
Management Model	/	/	/
Testing Model	0	0	0

Table 2: *Results summary.*

4.2 EXAMPLE

As an example, we will present the correlation between the architectural implication Needs, Requirements and Capabilites and suitable design patterns from the SOA design patterns catalogue [8]. The model itself specifies that in the process of capturing need as requirements and the subsequent requirements, decomposition and allocation processes need to be informed by capabilities that already exist. Therefore, the architecture needs to take into account existing capabilities available as services [4]. The results of our comparison analysis are presented in Table 3.

DIRECT
Inventory Governance Patterns
Metadata Centralization
Capability Composition Patterns
Capability Composition Capability Recomposition
Composition Implementation Patterns
Agnostic Sub-Controller

INDIRECT	**GENERAL**
Composition Implementation Patterns	**Logical Inventory Layer Patterns**
Composition Autonomy	Utility Abstraction
Service Messaging Patterns	
Service Agent	

Table 3: *Example of correlation results.*

As can be seen in Table 3, we could find at least one suitable design pattern for each of the categories. Patterns that directly correlated to the architectural implication were: Metadata Centralization, Capability Composition, Capability Recomposition and Agnostic Sub-Controller. On the other hand, Composition Autonomy and Service Agent represent patterns that indirectly correlate. The Utility Abstraction pattern, however, only generally correlates.

5 CONCLUSION

In our exploratory research we came to the conclusion that it was possible to reach the goal of realizing SOA with the use of specific design patterns following the guidelines and best practices provided by SOA-RAF architectural implications.

Based on the degree of correlation match, we divided the identified correlations into three different categories. Although the research showed that we could find a suitable design pattern for most of the models, we discovered that in most cases it is difficult to find direct correlations between an individual architectural implication and a SOA design pattern.

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CONTEXT-SENSITIVE ARCHITECTURE FOR INTELLIGENT MOBILE APPLICATIONS

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ABSTRACT

Although the amount of sensors on mobile devices and web services online is rapidly increasing, mobile applications are still not exploiting all the potentially available contextual data. For instance, they do not generally integrate different kinds of data available to infer more complex context, or make extensive use of a user's context history. This is difficult to achieve, however, without a context-sensitive system which provides a context server that can take much of the load off both the applications and the devices, without making itself indispensable. In this paper, we propose a context-sensitive architecture to resolve this problem.

1. INTRODUCTION

Over the last few decades, increasing mobility has been arguably the most significant continuous development in software applications. Client-server architecture made it possible to physically separate the machines storing and running applications from the ones gathering and displaying their results. Later, the Internet allowed people to access a given application from all over the world, as long as they accessed it from a desktop computer connected to the Internet. The subsequent invention of wireless technologies and infrastructure made it possible to move with a laptop and run the same Internet applications from different places, as long as a wireless network was available. And finally, the most recent major development along this path has been that of small mobile devices, increasingly equipped with full operating systems, Internet capacities and mobile applications. Obviously, software is as mobile as it has ever been.

There has been rapid growth in the number and sophistication of mobile applications. Increasingly, they are designed to take into account the user's context, such as his current location, native language, and screen resolution. Nevertheless, the variety and quantity of information available to mobile applications is still expanding much faster than the applications' exploitation of that information, so there is still a lot of untapped potential. However, the problem lies less in the mobile applications themselves, than in the lack of a context-sensitive architecture in which they can be conveniently developed and effectively deployed.

2. MOBILE APPLICATIONS

Mobile applications are applications which operate on a mobile device. However, mobile applications should not just be mobile versions of non-mobile (e.g., desktop) applications, adapted to the smaller screens and and power of mobile devices and providing the same functionality and services to the extent possible. Mobile applications should be viewed as a different type of application and with different criteria. Indeed, mobility and immediate access to data compensate for the relatively inconvenient aspects of using mobile applications deriving from mobile device limitations.

The fundamental problem of the typical (especially, business) mobile user is the need to optimise on their use of time. In order to address this, we propose that mobile applications should be designed and deployed with the following points in mind:

- A mobile user does not generally have the time to input large amounts of data manually, and manual input of data via mobile devices is especially inconvenient
- Mobile users generally only need a basic set of essential services
- Useful applications include those which the user invokes himself; however, even more useful are applications which activate automatically when a set of predefined conditions is met which accurately identifies the mobile user's informational needs.
- Mobile applications must be sensitive to context, meaning that their behaviour must depend on the context of the user's situation and informational needs.

Of course, mobile applications already exist which take these points into consideration. However, as we will see, the full richness and potential of context has yet to be exploited.

3. EXAMPLE

Consider Odpiralni Časi, a Slovenian mobile application which shows the opening hours of different shops and institutions around Slovenia. The application lists places that are in the vicinity of the user and that still have not closed for the night. As such, it exploits two kinds of pieces of context coming from different sources: the user's position obtained from his mobile device, and the date and time from their own system clock. However, the application could potentially use and calculate several other pieces of context to help it predict what kinds of places the user might be most interested in and provide him with a small default list. Here are a few examples how:

- Using the device's location, it could check the local weather conditions with a web service and forecast to help it decide whether to list certain outdoor places such as tennis courts.
- Regularly sampling the device's location, it could track its route and stop pattern, and then guess whether the user was traveling by car, bus, train, bicycle or foot. Accordingly, it could then prioritise bus stops, parking lots, etc, as appropriate.
- It could identify the user's device, and list places depending on patterns it discovered based on the user's history. For instance, if the user went to supermarkets every Monday after work, then it might first list supermarkets on Monday evenings (and then stop showing them once the shopping was done).

These three cases exemplify three different general methods: reliance on other web services which also use context (the weather service), deriving complex context from raw context (the user's mode of transport from its location changes) and the analysis of a user's history to make guesses (Monday evening shopping).

However, at present, there is no suitable system in place to make the development of such mobile applications straight-forward or efficient. Every mobile application which needs to guess the user's current mode of transport would have to track and store the user's position, interface with road and bus route maps, and implement its own algorithm for making the inferences. In other words, each application only has access to basic context from users' devices, and has to calculate derived context itself. It would be much better if the mobile devices could already provide such enriched context to the applications as input. Given the relatively limited capacity of mobile devices, this would require an external server, which would be responsible for gathering context data from users' mobile devices, making certain calculations and inferences with the help of whatever web services were appropriate, and feeding these back to the devices as enriched context. In effect, the mobile device's data "sensors" would be enriched. In our example, the mobile device could now provide "mode of transport" as well as location to different applications as input.

4. CONTEXT

Before we get more specific, a definition of context is needed. We define context as all information concerning:

- the user's current situation (**situational context**)
- the user's informational needs (**informational context**)
- the technological capabilities and properties of the user's device (**technological context**).

Situational context thus refers to data from any sensors to which the user's device has access. The sensors can be either on the device itself, or provided by intelligent devices attached to the user or found nearby. Situational context also includes the user's social situation, such as which of his friends or colleagues are in his vicinity.

Informational context refers to the user's current informational needs. From a conceptual point of view, here we are concerned with attributes and relations between them which identify the information, services and applications the user is most likely to need. These may derive from the user's profile (e.g., business or personal), his history of activity and device usage in similar situations, and his current activity and input.
Technological context determines which services and applications are available to the user and to what extent. This is derived from the technological capabilities and status of his own mobile device as well as of any other devices in his vicinity which his device can connect to and obtain data from.

The user's overall context consists of his situational, informational and technological context. We should emphasise, however, that these three context types are not independent of each other but rather have complex relationships. For instance, the technological context partly determines what kind of situational context is available, while the situational context largely determines the informational context. Moreover, the source of the context might vary substantially, ranging from simple direct sensors on the device to complex web services mediated through an appropriate server on the Internet.

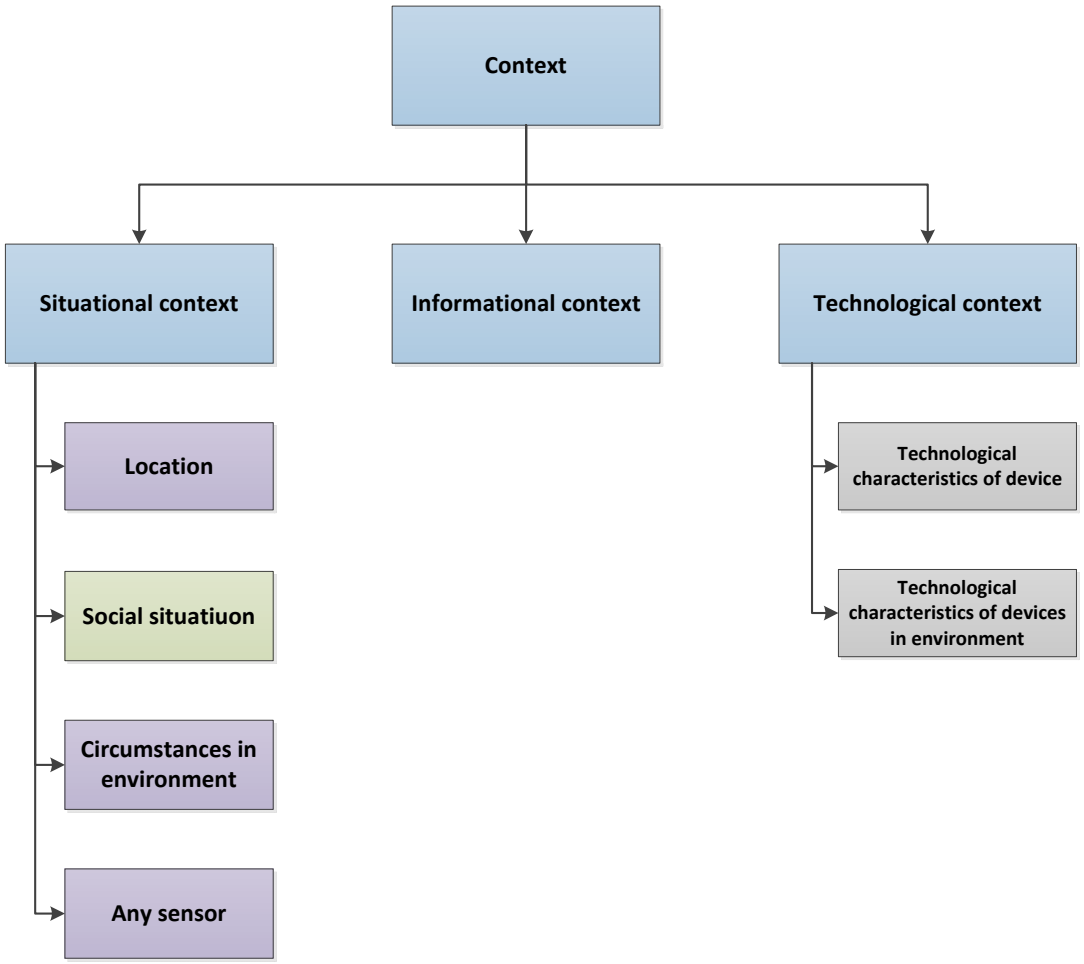

Figure 1: Model of context structure

To demonstrate this, let's imagine that a mobile phone user, Sebastian, is driving with some friends along the road, and that his phone is equipped with an application which makes suggestions of nearby interesting places. However, determining what comprise interesting places depends on the context, such as, for example, temperature (e.g., consider ski resorts, parks and beaches). But how does a mobile device determine the current temperature?

A priori, there are many possibilities. First, Sebastian's phone might have a built-in thermometer itself. Second, his car may have a thermometer, with the possibility of connecting it to the device. Third, one or more of Sebastian's friends may have a thermometer on their phone, and the two phones could make a Bluetooth connection. Fourth, assuming that the mobile phone knows its own location and has access to the Internet, it could use a web service to determine the approximate local temperature based on the user's current location. Fifth, if there is no local access to temperature or location, then the phone could guess the temperature based on the current date, time of day, recent weather trends, and the driver's recent driving history. And the list goes on. Of course, another thing to consider is that some of these methods give us the outdoor temperature outside the car while others the indoor temperature in the car.

5. A CONTEXT-SENSITIVE ARCHITECTURE

There have been previous proposals addressing the issue of context. However, the systems proposed suffered from one of two contrasting general problems: either they placed too heavy a burden on the mobile device (e.g., Hydrogen), or they made it too dependent on a server (e.g., SOCAM) (Miraoui et al, 2008). In the first case, the mobile device must use up too many of its limited processor, memory and storage resources dedicated to storing and processing context data. In the second case,

mobile applications running on the mobile device are rendered virtually useless if the server is temporarily unavailable. In this section, we outline a context-sensitive architecture which aims to walk the line between these two pitfalls.

In our view, a context-sensitive architecture consists of three main loci and the interactions between them: a context server, the user's device, and the web. The context server defines the context types and relationships, maintains a context database, and provides a means of adding and querying context data. The device registers sensor data, submits it to the context server, requests complex context data back from the server, and provides context back to context-sensitive applications. And the web provides web services, which help the context server generate more complex context from simpler context as well as providing other tools and components for applications. Figure 2 shows a diagram of the basic architecture.

The context server is a complex system of components and modules which takes care of the most demanding tasks of the entire context-sensitive system. It includes the following functional components:

- Components for communicating with the sources of context data and transforming the data into a single selected format suitable for integration and reuse
- Components which process context data, identify potential inconsistencies and conflicts, and draw appropriate inferences from context information on the basis of reasoning algorithms
- Components which store the context data and context history in a suitable format in the context data database
- Context data database
- Components, which provide context-sensitive services access to required context information

It is important to note that while the context server is integral to the system and does a lot of work, the system does not collapse without it. If the server is unavailable, the mobile applications can still access the basic context data from the mobile device directly, and invoke appropriate web services without going through the context server, as long as they are designed robustly themselves. The applications could still run effectively, but would simply be less context-sensitive.

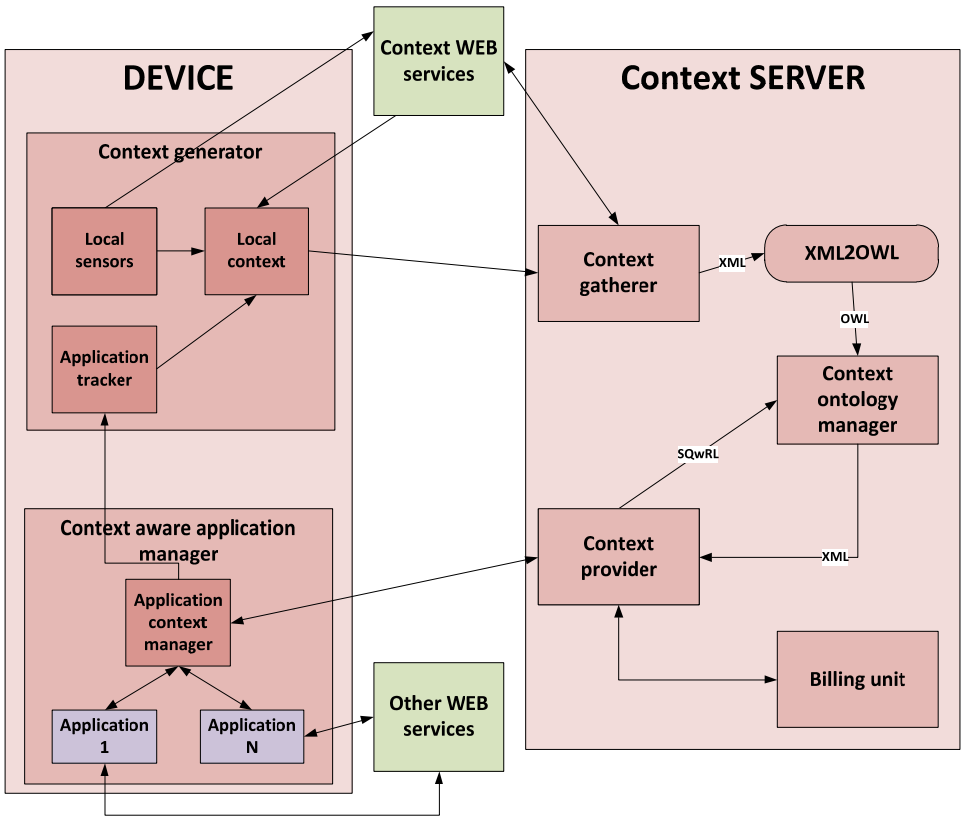

Figure 2: Context-sensitive architecture

6. IMPLEMENTATION TECHNOLOGIES

There are many ways the context-sensitive architecture we have proposed could be implemented. However, we suggest that two particularly suitable technological components are ontologies and rule engines, together with a powerful programming language like Java.

Ontologies are formal descriptions of conceptual domains. They specify the key concepts in a domain, how they are related to each other, what properties they have, and which concepts individual items belong to. As such, they go beyond merely structuring XML data, as they also give it semantic content, which both humans and machines can understand. Ontologies are becoming increasingly prevalent in semantic web development, and in particular the Web Ontology Language (OWL), which is a W3C recommendation, Defining a context ontology and storing context data in this format would allow for a high degree of integration and data reuse.

Rule engines are systems which execute logical business rules in a runtime environment. Importantly, the rules are separated from the program code, so that the rules can be changed at will without changing the underlying software. This also allows business users to maintain and update the logic of the system without any technical programming expertise. For the context-sensitive system, business rules would be defined and updated to specify how complex context derives from simpler context (e.g., on-train-track(person) and going-fast(person) → traveling-by-train(person)) or what to do when a certain condition is achieved (e.g., warm(weather) and near-beach(person) → show-details(beach)). Many rule engine systems exist for different programming languages, such as Drools for Java.

7. CONCLUSION

There is a wealth of information potentially available to mobile applications which could help them cater more to the changing needs of individual users. Moreover, it is bound to continue growing as mobile devices and web services become more and more sophisticated. However, this makes it crucial to establish an infrastructure in which a specialised component helps enrich the context and mediates between mobile devices and applications. In particular, we have proposed a context-sensitive architecture centered on a context server which is equipped with a context ontology database, manages logical rules for making inferences and triggering actions, and provides interfaces between mobile applications, web services, and mobile devices. Importantly, however, the system does not rely excessively on the server, as applications and devices can still communicate should the server become inaccessible, albeit with less information available.

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PREFACE

COGNITIVE SCIENCES – FROM WATCHING TO SEEING

Cognitive science is an interdisciplinary project involving different scientific fields as well as technology, and the humanities. Its main task is research of the phenomena of cognition - perception, reasoning, thinking, consciousness and behaviour - from an interdisciplinary perspective. It grew out of the cybernetics movement in the 1950s and has seen a number of paradigm changes since. Anthropology, Artificial intelligence, Biology, Linguistics, Neuroscience, Philosophy, and Psychology have emerged as core disciplines. It takes a fresh approach in looking at the phenomena from different angles, taking up a question, which is deeply philosophical and looking at it in an interdisciplinary manner through the eyes of different disciplines and scientific methods. The basic assumption of cognitive science as a research field is that by integrating insides form all contribuiting disciplines we can gain better and more integrated knowledge about cognitive phenomena. This is why the principal question of cognitive science was (and still is) how to integrate these diverse approaches, for each scientific discipline deals with cognitive phenomena from its own perspective and uses its own technical language and specific methods.

This years' conference is dedicated to a cognitive phenomenon, the research of which stretches across the wide range of perspectives: from basic neurophysiological level, all the way to psychological, phenomenological and philosophical considerations. The title of the conference: *From Watching to Seeing*, is meant to encapsulate the attempt of cognitive science to breach the so called explanatory gap, i.e. the divide between third-person descriptions (events in neurological system) and first-person perspectives (reports on lived human experience).

The selection of participants reflects the variety of angles from which the visual processing can be researched as well as variety of levels on which related cognitive phenomena occur. Our key invited contributors are covering two distinct angles:

- The contribution of dr. David Križaj, renowned neurophysiologist from University of Utah, overviews the path of the visual stimuli on its way from a simple electromagnetic signal to formation of a visual representation. In the spirit of cognitive science, he attempts to integrate Greek phenomenology, modern neuroscience and medicine, with help of the recently discovered retinal mechanosensitive ion channels.
- The second invited contributor, dr. Liliana Albertazzi, philosopher and phenomenologist from University of Trento, presents a study of the morphology of nature, art and cognition. Her contribution also attempts integration of different disciplinary fields – in this case: the geometry of nature, the organic stereometry, the categorization of natural shapes and their patterns, and the aesthetics of nature.

The themes and presenters of this years' conference are covering the whole spectrum of perspectives, bracketed by the plenary contributors: neurophysiology (Hawlina), cognitive neuroscience (Pirtošek, Ravnik, Palmović, Bon, Brezovar, Levstek, Bregant), artificial intelligence and computer vision (Gams, Tkalčič), psychiatry,

psychology, phenomenology, philosophy and consciousness research (Škodlar, Smrdu, Albertazzi, Kordeš, Markič, Peruš).

Besides being able to bring together this exceptional group of contributors, our conference also succeeded building a bridge betweens Slovenian society for Cognitive sciences, University Medical Centre's Department of Neurology (which also contributed the conference workshop) and Institute Jožef Stefan.

We hope that the whole selection of topics and contributions as a unit, is greater than the sum of separate papers. If that is so, and if going through the proceedings at hand will enable the reader to understand the entire path *From Watching to Seeing* more coherently, than we believe that we reached our goal.

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Matjaž Gams
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POLYMODAL SENSORY INTEGRATION IN THE VISUAL SYSTEM

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ABSTRACT

In many, perhaps most, vertebrate species, vision represents a dominant sensory modality that is essential for orientation and communication with the outside world. An animal's ability to perceive the external world is conditioned by its capacity to extract and encode specific features of the visual image. Thus, the output of the vertebrate retina is not a simple representation of the 2D visual map generated by photon absorptions in the photoreceptor layer but rather is transmitted as an abstract representation that emphasizes species-specific behavioral needs. The output is sculpted by complex analog-to-digital transformations at the bipolar- retinal ganglion cell (RGC) synapse and by state-dependent inhibitory, disinhibitory and facilitatory synaptic feedbacks that drive RGC spiking. RGC output is distributed in the form of (at least) 21 parallel channels that mediate the spatial, temporal and color "dimensions" of the original image and must eventually be recombined in the cortex. Another layer of complexity is associated with modulation of light-evoked responses by the local ion microenvironment, gliotransmission and systemic parameters such as intraocular pressure, temperature and immune activation. We propose that the visual information transmitted to the brain is necessarily polymodal, because it includes light-independent inputs that reflect the functional states of the retina, anterior eye and the body. If this is the case, then percepts that appear to us as unified representations of the visual universe are instead biological constructs that include the embodied context within which vision takes place. As an example of a light-independent stimulus that can affect retinal output we use modulation of retinal output by mechanical stimuli. Mechanical impact gives rise to light percepts known as "pressure phosphenes" but also underlies debilitating eye diseases such as diabetic retinopathy and glaucoma. Ancient Greeks used pressure phosphenes as a key explanatory principle that guided their theories of sensory function. We use the recently discovered retinal mechanosensitive ion channels as an example through which molecular physiology could unify Greek phenomenology, modern neuroscience and medicine.

1 INTRODUCTION. Vision is a complex process.

Life took advantage of light early on in the evolutionary process as photons were harnessed to drive the cells' energy metabolism through early photosystems and antenna complexes. Because light is also the fastest possible way of transmitting information about the physical environment, early on (~600 million years ago) cells began to employ additional rhodopsin-like photopigments linked to G-protein cascades as a means for providing sensory information about potential food, mates and predators. Vision turned out to be so advantageous that natural selection tinkered with numerous designs of light detecting pigments, cells and organs which eventually included the arthropod compound eye and camera-styled eyes and layered retinas of jawed vertebrates (9, 18). Vertebrate retinas can extract information about photon absorptions in the external world from a wide variety of ambient illuminations that span the range from starlight to bright sunlight (~12 log units). Photoreceptors can be extraordinarily efficient detectors of photons, as illustrated by our ability to detect 5-7 photons over an area covering several hundred rods (14, 26) or by the capacity of toad rods to reliably guide the animal during prey-catching at light levels which produce only 1-2 photons/100 rods (1). At higher illuminations, retinal circuits employ sophisticated molecular protocols to subtract background luminance signals from changes in ambient light and to separate weak signals from noise (6).

The standard view of retinal function comprises four stages (6, 22). First, photons are

intercepted by visual pigments (rhodopsin, cone opsin, melanopsin) within rod, cone and ganglion cells. At this stage, contrast and brightness of the visual signal are normalized and the background intensity signal is subtracted through phototransduction adaptation and outer retinal synaptic feedback. The second stage consists of dividing the 2D map generated by photoreceptors into (at least) 11 parallel bipolar channels. At this stage, daylight (cone) channels are separated from starlight (rod) channels; color information is generated through color-opponency; spatial contrast is formed through the receptive field center-surround mechanisms; transient vs. sustained responses are generated through intrinsic (ion channel) & extrinsic (inhibitory feedback) mechanisms, and input noise is discarded through nonlinear filters involving the newly discovered TRPM1 channel. Third, the output of bipolar cells is modified by more than 50 types of amacrine interneurons which extract additional spatial and temporal contrast information through local and long distance, sequential and crossover feedback loops involving GABAergic, glycinergic, catecholaminergic and peptidergic mechanisms. Finally, retinal output is encoded into spikes by >20 types of RGCs that create their own, often independent, representations of the visual world within the brain. At each stage of visual signal transmission, information percolating through retinal circuits appears in the form of increasingly refined aspects of the primary photoreceptor 'bitmap' that tend to inhabit the space, time, color, direction "dimensions". In addition, light-induced signals may acquire additional circadian feedback inputs and light-independent contributions from intraocular pressure (17) and systemic effects (2).

2 EARLY THEORIES OF VISION are based on mechanically induced percepts of light

The phenomenological experience of visual percepts triggered by mechanical indentation of the eye may have inspired the very earliest forms of human art (19) and laid the foundation for the earliest known theories of vision and physiology/medicine (11-13, 29). The *physiologos* (writer on nature) Alcmaeon of Croton (~450 B.C.E.) described the optic nerves, proposed they represented the "light-bearing paths" to the brain, identified the brain as the central sensory organ and the seat of understanding, and suggested that sensation allows humans to make reasonable judgments about the external world (*tekmairesthai*) [15]. Alcmaeon was the first to report that application of physical pressure to the eye induces perception of light, and used the mechanically induced visual phenomena ("pressure phosphenes") to conclude that vision is based on the transmission of light (fire) within the eye. [Phosphenes, also called "the prisoner's cinema", are also perceived by people deprived of visible light for prolonged periods of time, meditators, patients with migraine headaches and are used to diagnose the inflamed optic nerve (optic neuritis) (30, 31). Their molecular mechanism is not understood].

Another Pythagorean, Empedocles (419-430 B.C.), hypothesized that the 'fire' in the eye described by Alcmaeon illuminates the external world, that this light is reflected into the eye from objects in the external world and that the eye has two channels (of water and fire) that conduct dark and pale impressions towards the brain (29, 33) (i.e., phenomenological analogs of retinal ON and OFF channels). The visual extramission theory was refined by Plato (427-347 B.C.), whose theory involved complicated interactions between external light and projected light, and dominated Western views on vision well into the 18th century.

More clarity arrived with Enlightenment (11, 13). While Kepler still believed that sparks of light produced by deformation of the eye stimulate the retina, Descartes proposed that a blow on the eye produces vision by moving the "small fibers of the optic nerve". Newton showed that that pressure does not produce light but rather mimics the action of light on the retina, whereas Helmholtz suggested that mechanical stimulation of the eye gives rise to visual rather than other (tactile) sensations because of hard-wired connections that are committed to a particular sense independent of the origin of the carried excitation. Subsequently, visual psychophysics moved to greener pastures, and the physiological mechanism underlying phosphene generation while relevant to a restricted clinician niche has remained largely unknown (12). Phosphenes have become increasingly relevant as a phenomenon that could share common signaling elements with a devastating blinding disease, glaucoma.

3 INTRAOCULAR PRESSURE, MECHANICAL OVERSTIMULATION AND HUMAN VISION

Retina regularly experiences mechanical forces and strains such as intraocular pressure (IOP), activity-dependent and pathological cell swelling or detachment that follows traumatic mechanical impact to the eye (28). For example, IOP reflects the balanced

production and drainage of aqueous humor within the anterior chamber of the eye. Continuous secretion of the aqueous is essential for providing lens epithelial cells with nutrients, however, the resulting hydrostatic pressure is an emergent phenomenon that in itself regulates proper eye growth, maintains permanent eye shape, prevents the inflow of blood from systemic circulation and protects the eye from deformations caused by the ocular muscles. While in most people IOP levels fluctuate between 10-15 mm Hg, a sizeable population (>3 millions of Americans; >80 million humans worldwide) experience elevated IOP levels (>20 mm Hg) due to excessive aqueous production or blocked outflow (5, 24). While increases in IOP typically do not damage the anterior eye, they turned out to represent a primary risk factor for developing glaucoma, a devastating blinding disease that is characterized by selective degeneration of RGCs. Because these neurons represent the sole communication channel to higher order visual centers, their loss results in permanent blindness (24). It is clear that mechanical forces associated with the IOP in the anterior part of the eye must impinge on the physiology of the RGCs in the posterior eye (28) and therefore their targets represent a prime target for potential neuroprotection strategies. The identification of mechanotransduction mechanism(s) within RGCs remains one of the great challenges of the contemporary vision research.

4 MECHANICAL STIMULI SELECTIVELY DRIVE RGC PHYSIOLOGY THROUGH MECHANOSENSITIVE TRPV4 CHANNELS

Recent studies have identified many mechanosensitive ion channels, permeable to Ca^{2+}, K^+ and Na^+ ions, in mechanotransduction in the liver, kidney, cardiovascular system, brain and ear (3, 16). Intriguingly, many of these channels also transduce vertebrate, invertebrate and prokaryote sensation (3, 8). Our search for the presence of such channels revealed that the retina expresses the transcripts for most of the known mechanosensitive TRP, piezo, TWIIK and TRAAK channel isoforms. We next employed a combination of biophysical, molecular, histochemical, electrophysiological and optical approaches to focus on mechanosensitive responses in RGCs. Application of pressure steps to RGCs through the "high-speed pressure clamp" technique revealed fast inward currents, suggesting that RGCs directly respond to mechanical stimuli through one or more types of cation-permeable plasma membrane channels. This hypothesis was confirmed by optical measurements from RGCs loaded with calcium indicator dyes which established the dose-dependent relationship between experimental stretching of the plasma membrane, Ca^{2+} entry and pathological consequences for RGCs. For example, mechanical overstimulation induced apoptotic cell death of RGCs but not photoreceptors, bipolar cells or amacrine cells (25). This result is consistent with the etiology of glaucoma, which selectively targets RGCs (24). Our data also suggest a potential mechanism that could account for previous observations of chronically elevated baseline $[Ca2+]_{RGC}$ and activated calcium-dependent phosphatases/proteases in rodent experimental glaucoma models (7, 22) as well as with clinical trials which showed that high doses of daily calcium supplements increase the risk for developing glaucoma [38].

What channel isoform confers pressure sensitivity to RGCs? Stretch-induced responses in RGCs were antagonized by nonselective antagonists of the transient receptor potential (TRP) channel superfamily such as Gd^{3+} and Ruthenium Red (25). Analysis of retinal expression of mechanosensitive TRPs identified one isoform, TRPV4, as selectively localized to RGCs and absent from other classes of retinal neuron. Specific TRPV4 antagonists antagonized mechanically induced calcium elevations in RGCs and were also able to prevent RGC degeneration induced by TRPV4 overactivation. Intriguingly, calcium overloads mediated by gain-of-function V4 mutations underlie severe human neuropathies (16, 20, 23, 36) and overexpression of TRPV4 was shown to compromise the development of the zebrafish eye (32). In collaboration with Rene Rentería lab at UT San Antonio we used multielectrode arrays to observe that temperature (an activator of TRPV4) and selective agonists of TRPV4 channels elicited >100-fold increase in RGC spiking (25), indicating that TRPV4-mediated cation influx is sufficient to bias the firing threshold of RGCs. Thus, transient activation of mechanosensitive TRPV4 channels is sufficient to modulate RGC excitability, whereas sustained stimulation of TRPV4 channels compromises RGC survival by overactivating intracellular 2^{nd} messenger cascades. Our data strongly suggest that we have identified a sensitive mechanotransduction pathway in mammalian RGCs.

5 CONCLUSION

In the 1980s, Sidney Brenner and his colleagues heroically reconstructed the entire nervous system of the nematode *Caenorhabditis elegans* with

the expectation that the collage of several thousands series EM will help explain the behavior of the humble worm (34). It turned out that this painstaking work failed to illuminate the biology of *C. elegans* behavior, which is dependent on higher-order interactions between neuronal circuits that mediate sensation, appetitive behavior, locomotion etc. We argue that, likewise, vertebrate vision involves complex physiological operations that deconstruct the original visual map and merge light-induced signals with systemic information. Apart from the clinically relevant consequences of pathological mechanical and immune stimulation that reveal themselves in diseases such as age-related macular degeneration, diabetic retinopathy and glaucoma, the significance of such non-visual inputs for daily visual function in diurnal vertebrates is unclear. Are they epiphenomena such as pressure phosphenes? Do they contribute to perception? We know that the vertebrate retina is not like a camera that translates images into 2D negatives, nor is it like Adobe Photoshop that performs a myriad filtering operations regardless of the machine that powers it. What then **is** "seeing? Can seeing be considered as independent of the organism's environment, individual and social context? Is there a single biological computation (percept) that is subserved by the multiplicity of neuronal responses or are the parallel and equivalent processors that mediate the visual data streams accessible to the perceiver under specific context-dependent circumstances? Our own view of vision is that of an emergent process that rapidly defeats simplistic quests for mathematic tractability and that is possessed of an intrinsic sensitivity to the present moment, like a sail talking to the gust of wind.

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MORPHOLOGY IN NATURE, ART, AND COGNITION

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The context

Morphology is the study of outward appearances like shape, structure, and patterns of visual objects, which are of a huge visual complexity and overall spread in nature. To quote D'Arcy Thompson, for example: "The waves of the sea, the little ripples on the shore, the sweeping curve of the sandy bay between the headlands, the outline of the hills, the shape of the clouds, all these are so many riddles of form, so many problems of morphology, and all of them the physicist can more or less easily read and adequately solve … They have also, doubtless, their *immanent* teleological significance; but it is on another plane of thought from the physicist's that we contemplate their intrinsic *harmony* and perfection, and 'see that they are good'" (1, p. 7).

Shape morphology played also a relevant role in some important episodes in the interaction between science and art (2). It has been observed that: "According to this approach, the "goodness" and hence the aesthetic value, of certain natural forms is such because it fulfills a perceptual principle of naturalness and belongingness of the various parts of the visual object's dynamic appearance" (1; see also 3; 4; 5).

From this viewpoint, the study of morphology involves a series of different disciplinary fields like the geometry of nature, exemplified in the art works of Leonardo and Dürer, the organic stereometry of Haeckel (6, 1904/2004), the categorization of natural shapes and their patterns (1), and the aesthetics of nature, of Art Nouveau in particular, exemplified in the works of Binet, Bonvallet, Endell, Obrist, Olbrich, and Tiffany (7). Particularly interesting is the relationship between science and art. There is a letter written by Binet to Haeckel, for example, in which he writes: "At present, I am busy realizing the monumental entrance gate for the exhibition in the year 1900 and everything about it, from the general composition to the smallest details, has been inspired by your studies" (1899, see (8)).

And indeed, there is a strict similarity between the frame of the gate that Binet constructed for the 1900 Paris World Exposition and, for example, the *Alacorys Bismarckii*, one of the radiolarians drawn by Haeckel himself in Art forms in nature (9, 1904/2004).

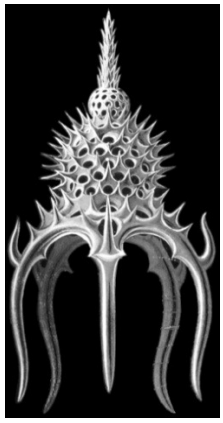

Fig. 1: *Alacorys Bismarckii (9)*

Fig.2*: Binet, Entrance gate, Paris World Exposition 1900 (http://www.squidoo.com/ernest_haeckel).*

The colour of natural shapes

We performed an experiment on the relation between the two dimensions of shape and colour of the same modality (vision) to analyse in detail the correlations between patterns of nature and specific hues. The experiment and its results are already published (10).

Besides Goethe's idea of the existence of a pattern uniformity in nature (11), we started from two guiding hypotheses. The first concerns the idea of a generalized synesthesia, i.e. that there is a common synesthetic relation in perceiving which individuals analyze by focusing on shape qualities like those concerning the "good" and "bad" points in vision. These pertain to the tertiary qualities of appearances, analysed at length by Gestalt psychologists (12; 13; 14. See also 15; 16; 17; 18). The second, of the existence

of naturally biased associations between shapes and colours, that we proved also in another study with geometric shapes (19. See also 20; 21).

The experiment

60 undergraduate and post-graduate university students (overall mean age 25.8 yr. (*SD* = 4.8; range = 18–36), with similar education levels participated in the experiment. Although it was not a cross cultural study, students were from Italy (29), Germany (12), Brazil (9), Turkey (2), Argentina (1), South Korea (1), Kenya (1), India (1), Romania (1), Russia (1), Thailand (1), and Vietnam (1).
The experiment was carried out in a laboratory with constant and controlled lighting conditions (less than 10 lux on the table). Participants were seated at a desk, at a distance of about 60 centimeters from a calibrated Monitor CRT 19-in. View Sonic G90fB Graphics Series with a 1,280 × 1,024 resolution, controlled by a DELL Latitude D630 (Intel Core 2 Duo T7500, 2.2 GHz, RAM 2GB, Windows XP Professional Service Pack 3), on which the stimuli were presented.

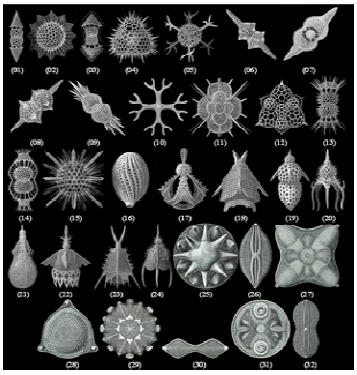

Fig. 3: *Stimuli used in the experiment (9)*

Because of the complexity of these natural shapes, we grouped them according to *Shape* (elongated vs. rounded), *Margins* (spicules vs. non spicules), *Texture* (porous vs. non-porous) and *Dimensionality* (thick vs. flat). Each shape was presented in grey, internal to the Hue circle of 40 hues, and participants had to decide, for each shape, what colour fitted best. No reaction times were recorded.
For what concerns the relationship between *Shape and colour*, round shapes are matched by reddish colours (In the orange-red interval of the Hue Circle), while elongated shapes are matched by bluish colour (In the blue-green interval of the Hue Circle).
For what concerns the relationship between *Texture and colour*, holed figures showed positive associations with Green-Yellow, and negative associations with Yellow-Red and Mainly Red groups.
For what concerns the relationship between *Dimensionality and colour*, flat shapes showed positive associations with Mainly Red and Mainly Green groups (and slightly with Yellow-Red), and Thick shapes positive associations with Blue-Green (and slightly with Mainly Yellow).

Conclusions

Direct choices of observers matched Rounded figures with the Yellow-Red and Mainly Red groups, and Elongated figures with the Blue-Green group. This result is very clear, and it also matches the findings of other research conducted by our group, in which the circle was matched by Red and Yellow, and negatively associated with Blue-Green (19).

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EVOLUTION OF THE HUMAN VISUAL BRAIN

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ABSTRACT

Apart from having big brain primates are also distinctly visual animals. For better visual perception the eyes of the mammals project forwards thus enabling binocular vision, two physiologically distinct pathways, (parvocellular attending to the detail and colour, and magnocellular involved in movement) within the layered subcortical lateral geniculate nucleus, an excellent binocular integration, and high visual acuity have developed and, later in evolution, higher nonV1 visual regions have emerged with a numerous cortical regions interacting in a complex arrangement of progressively more elaborate and more focused analysis of visual information. Relatively recently, in early Paleolithic, these hierarchically organized visual cortices start interacting with the now mature prefrontal cortex and - while remaining predominantly visual - Homo sapiens sapiens was now able to fully express his human creativity, arts, symbolism, religion, science and plan more coherent and formally organized social life.

1 INTRODUCTION

Mammals and primates have large brains and the latter are distinctly visual animals. It seems that large brains have evolve at least partly through selection on specific types of visual mechanisms.

Several distinctive features of the visual system occur in mammals, such as frontally directed eyes, the existence of two physiologically distinct pathways within the layered subcortical lateral geniculate nucleus, a high degree of binocular integration, and high visual acuity (1). In primates, and particularly hominids, complex arrangement of interconnected and numerous cortical visual areas additionally emerged in already large brains.

Complex eyes probably first evolved about 540 million years ago in the rapid burst of evolution dubbed as the Cambrian explosion. Much later, approximately before 400.000 years, a primitive optical sense organ incorporating efficient photopigments evolved into a more sophisticated human-like eye (2). But vision is more than just an eye. The ocular and brain visual systems of mammals consists of the eye, especially the retina, and the brain. From the retina, the optic nerve leads to the optic chiasma. At the optic chiasma, the visual information from both eyes is combined, but immediately after the chiasma it splits according to the visual field. The right half of the field is sent to the left hemisphere and the left field to the right halves of the brain, to be processed via the optic tract in the lateral geniculate body. Here, it is possible to identify two distinct layers, the parvocellular and magnocellular. The parvocellular system directs attention to the detail and colour, whereas the magnocellular system is primarily involved in movement detection and processing of dynamic forms (3). The neurons of the lateral geniculate body then relay the visual image via the optic radiation to the primary visual cortex (also called V1) which is located in the occipital lobe close to the calcarine sulcus (4). Visual information then flows through higher and higher associative cortical areas involved with more and more focused tasks (perception of colours, recognition of faces…) designated as 'nonV1' areas (V2, V3, V4 and area V5/MT). The V1 neurons in the primary cortex respond selectively to a line of a particular orientation in a particular retinotopic location and they efficiently process information about static and moving objects and enable an excellent pattern recognition. More laterally (hierarchically higher in visual association cortices) neurons respond selectively to complex visual and multimodal stimuli, such as objects and human faces. Visual processing activates two distinct pathways: the dorsal stream and the ventral stream (5). The dorsal stream ("where" or "how" stream) directs covert and overt spatial attention, and modulates regions that control eye and hand movements in guiding behaviors to spatial locations. The ventral stream ("what" stream) participates in the recognition, identification and categorization of visual stimuli.

In mammals and primates, visual inputs have been modified. To start with, the eyes of the mammals project forwards thus enabling binocular vision, two physiologically distinct pathways, (parvocellular attending to the detail and colour, and magnocellular involving in movement) within the layered subcortical lateral geniculate

nucleus, an excellent binocular integration, and high visual acuity have developed (1). But for the Homo species important changes occured, later in evolution, particularly in higher nonV1 regions with the emergence of a numerous cortical regions with a complex arrangement. Primary visual cortex in Homo sapiens sapiens occupies a much smaller area (4%) than in monkey (16%), but more and more processing of visual information is carried out in higher nonV1 areas and adjacent temporo-parietal regions. This is the emergence of new abilities, multi-modality-cognitive and largely visual, located in cortical visually based associative posterior brain systems. These visual cortices represent the largest system in the human neocortex. They reflect a rapid development of the brain and a fast evolution, unique to the hominids. There must have been a noticeable evolutionary selection pressure so that the brain evolved into a larger, more complex and more efficient organ which created a more advanced civilization and culture where the advantage of a larger brain became more pronounced and the evolutionary process accelerated, resulting in a quick progression to modern Homo sapiens. Interestingly, for the time being, Homo sapiens remains a predominantly visual animal.

As the hominids emerged from the dawn of the evolution they were already equipped with the full visual pathways from the retina via the lateral geniculate body to the primary cortex. They were eqipped with excellent motion, mastering the visual space, starting with the upright gait, constructing more and more complex tools, from wood to stone and, much later, metals. There was a rounded fullness of the superior parietal lobe in Homo habilis, possibly already in australopitecines, related to motion and to visual space, which is particularly important in bipedalism. Visuoconstructive abilities, located particularly in the inferior parietal area of the right hemisphere clearly improved from the times of Australopitecines to the times when Homo sapiens emerged as judged indirectly, e.g. from production and the use of tools. Australopithecines had a well developed tool culture in wood but they did not master stone. Later, slow advance with occasional evolutionary stasis in stone tool culture persisted in the form of Oldovan (chopped stones of Homo habilis), Acheulian (hand axes of Homo erectus) and Mousterian (flaking techniques of Homo neanderthalensis) cultures for over 1 million years, from Homo habilis to Homo sapiens.
In the same period social bonding salso lowly progressed It is interesting that there seems to be a positive correlation between the overall size of the neocortex and social group size (6,7) and Barton (7) believes that visually based social information, such as facial expressions and gaze direction are the crucial aspects of socio-cognitive information processing contributing to this cortical expansion. Correlation between the size of neocortex and social size is not general, it differs in various parts of the visual system. For example, V1 cortex shows smaller correlation than hierarchically nonV1 cortical areas raising the possibility that visual cortex is not involved in the maintenance of social group size directly but through the development of associative nonV1 areas. Evolutionary changes in the number of neurons in parvocellular layers of the lateral geniculate nucleus correlate more than the number of neurons in the magnocellular layers suggesting an important role of colour (relatively large brains of frugivorous species may be products of selection of the ability to perceive and select fruits using specifc visual cues such as colour).

When Homo sapiens sapiens occurred, around 150.000 to 200.000 years ago, somewhere on the East African plains, something was still missing, in spite of the fully evolved visual system and emerging nonV1 areas which enabled good vision, good perception and excellent visuomotor coordination. Early Homo sapiens had no creative creative technical skills, there was no artistic expressions and structured social institutions. First signs of change occurred very late, around 40.000 years ago, in the early Paleolithic; then, around 40.000 years ago, in a relatively short period a very fine tool kits appeared (the blade culture of Cro Magnon), a need for artistic expression and new improved social bonds emerged. What really happened? From the neurological point of view, slow progression in earlier ages was possibly due to the immaturity of the prefrontal lobes which are related to motivation, initiation, concept formation, working memory and executive coordination with planning for future. It seems that there is a rapid and widespread activation of these prefrontal cognitive functions in the early Paleolithic with the emergence of arts, symbolism, religion and more coherent and formally organized society. Thus, it seems that an interplay between the hierarchically organized posterior visual cotices and the newly arrived prefrontal cortex is needed for the full expression of man as a rational, artistic, philosophical but still largely visual being.

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Correlation between Macular Morphology and Sensitivity in Patients with Retinitis Pigmentosa and Hyperautofluorescent Ring

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Purpose. To assess the correlation between retinal morphology and function in patients with retinitis pigmentosa (RP) using spectral domain optical coherence tomography (SD-OCT), fundus autofluorescence imaging (FAF), and fundus-related perimetry and to use coregistration of data sets to achieve high-resolution structure-function correlation of human macula.

Methods. Twelve patients with RP and hyperautofluorescent parafoveal ring in FAF imaging were tested. Ophthalmological examination, static and kinetic fundus-related perimetry, and SD-OCT were performed. Custom software allowed coregistration of fundus-related perimetry, SD-OCT, and FAF data sets.

Results. A high correlation between retinal sensitivity and outer retinal thickness was observed ($\rho = 0.72$, $P < 0.0001$). The median retinal sensitivity over the central circular area of normal autofluorescence was significantly higher when compared with the area over the surrounding hyperautofluorescent ring and to the area outside the ring ($H = 34.2$, $P < 0.0001$). The outer retina at the site where kinetic stimuli were perceived was better preserved and had higher retinal thickness, corresponding to higher sensitivity ($H = 289$, $P < 0.0001$). The site of the hyperautofluorescent ring correlated in SD-OCT scans with a zone of impaired integrity of the photoreceptor layer ($\rho = 0.67$, $P = 0.0003$).

Conclusions. Retinal sensitivity to static and kinetic stimuli correlates better with outer than with overall retinal thickness. The hyperautofluorescent ring in FAF represents a transition zone from relatively well-preserved to abnormal retinal morphology and function, rendering FAF imaging a clinically significant tool for assessing the severity and progression of dysfunction in RP patients. Accurate coregistration of different modalities drastically increases the power of structure-function correlation studies and allows consistent associations to be drawn. (*Invest Ophthalmol Vis Sci.* 2012;53:47–52) DOI: 10.1167/iovs.11-8048

Retinitis pigmentosa (RP [MIM 268000]) denotes a group of genetically determined retinal dystrophies exhibiting immense clinical and genetic heterogeneity and is characterized by night blindness and progressive visual field loss. Forms of this condition differ in severity, natural history, and mode of inheritance.

Ophthalmic imaging and perimetry testing have long played an important role in the documentation and diagnosis of conditions such as RP. In the past decade, noninvasive retinal imaging technologies such as optical coherence tomography have significantly increased our understanding of structural changes in retinal disease; specifically, spectral domain optical coherence tomography (SD-OCT) has enabled high-resolution, 3-dimensional (3D), in vivo visualization of retinal morphology.[1] Additionally, imaging techniques such as fundus autofluorescence (FAF) have allowed characterization of the spatial distribution and intensity of lipofuscin-derived autofluorescence. By marking the accumulation of lipofuscin granules in retinal pigment epithelium (RPE), FAF provides a molecular marker of RPE health.[2] Fundus-controlled perimetry allows functional assessment of the central retina with high spatial resolution. Along with FAF and SD-OCT, they provide a basic toolset with which to analyze the structure, molecular composition, and function of the central retina in vivo.

Understanding how function, structure, and molecular footprint are interconnected enables accurate assessment of disease progression and is pivotal for clinical trials.[3] Coregistration of different modalities enables precise alignment of data sets, thus allowing for the statistical analysis of relationship and the study of correlation. Both custom-made image registration software overlaying different data sets[4–7] and instruments automatically combining structural and functional modalities (OPKO SLO/SD-OCT microperimeter; OPKO, Miami, FL)[8] have been used for this purpose.

Previous studies have reported abnormal FAF in the form of a parafoveal ring of increased signal in RP patients.[9–12] This distinctive autofluorescence phenotype has been reported in more than 50% of subjects with RP.[13] Similar ring or ringlike structures have been described in other inherited retinal dystrophies.[14,15] Although it is a nonspecific finding, the ring seems to be of prognostic value and is useful in assessing the degree of macular dysfunction in patients with RP.[9,11,14,16,17] When SD-OCT was performed, loss of the hyperreflective band corresponding to the photoreceptor inner and outer segment (IS/OS) junction was observed at the transitional zone of the hyperautofluorescent ring.[17–20]

The structural and functional significance of the hyperautofluorescent ring as well as its prognostic and monitoring value have been well established.[9–12,14,17,21–23] However, there is still a need for a more robust correlation between structural abnormalities and functional deficits. In the present study, we have evaluated 12 patients with RP who had parafoveal ring of hyperautofluorescence. The purpose of this study was to assess the correlation of visual function measured by both static and kinetic fundus-related perimetry with structural changes in the

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inner and outer retina evaluated with SD-OCT and with molecular changes in the RPE visualized with FAF.

Subjects and Methods

Study Subjects

Twelve patients from 11 families with clinically and electrophysiologically confirmed diagnoses of RP, hyperautofluorescent ring on FAF, retained central vision, and stable fixation were included in this cross-sectional study. Six patients had nonsyndromic autosomal recessive RP, three had autosomal dominant RP and three had Usher syndrome type 2. Median age was 40 years (range, 23–72 years). Median best-corrected visual acuity was 1.0 (range, 0.3–1.0). The study was approved by the National Medical Ethics Committee of the Republic of Slovenia and adhered to the tenets of the Declaration of Helsinki.

FAF imaging (Heidelberg Retina Angiograph; Heidelberg Engineering, Heidelberg, Germany) and SD-OCT (3D OCT-1000; Topcon, Tokyo, Japan) were performed in all subjects. Our SD-OCT protocol included a volume scan covering a 6 mm (horizontal) × 6 mm (vertical) × 1.7 mm (axial) block of the macular region, centered on the fovea. Fundus-controlled static and kinetic perimetry (MP1 Microperimeter; Nidek Technologies, Padova, Italy) were performed in 8 and 11 patients, respectively. For static perimetry (Humphrey 10–2), we tested 56 retinal locations in the central 20°, with 2° resolution at threshold sensitivities from 0 to 20 dB; the test spot size was Goldmann III. For kinetic perimetry (Goldmann III), stimuli with five luminance levels (0, 4, 8, 12, 16 dB) were used. The stimuli were moving centripetally from 20° to the starting point in the center of the macula with an automated algorithm in eight directions and a velocity of 2.4°/s. All patients had previously undergone static and kinetic visual field testing and were familiar with the testing procedure.

Coregistration of Functional Testing, Autofluorescence Imaging, and Retinal Thickness Profiles

A custom-made software tool, MultiModalMapper 1.1, was used to accurately align FAF, MP1, and SD-OCT data sets using anatomic landmarks. The MultiModalMapper 1.1 software is not a commercial product. The software was developed as WPF application (Microsoft Windows Presentation Foundation; Microsoft, Redmond, WA) using the Microsoft NET framework 3.5 sp1.[24] To map FAF and MP1 on SD-OCT data, we manually selected at least three landmarks on related fundus images. The result of the coregistration process was visualized immediately as an overlaid image to allow for adjustment by moving or adding additional landmarks. After coregistration and alignment, the SD-OCT data set was rendered as a 3D model, with the FAF image and the MP1 color-coded data layers displayed as textured planes.

Although a number of automatic segmentation algorithms have been developed,[25–27] their accuracy in pathologic eyes remains to be demonstrated; in this study, manual segmentation by an expert grader was performed. Markers for the inner limiting membrane, the inner border of the outer plexiform layer (OPL), and the outer border of RPE were manually positioned in MultiModalMapper with an accuracy of 4 μm or better (depending on the chosen zoom level during segmentation). Subsequently, these markers were used to define borderlines and create thickness maps for total (from the vitreoretinal interface to the outer border of the RPE), inner (from the vitreoretinal interface to the inner border of the OPL), and outer (from the inner border of the OPL to the outer border of the RPE, including the axons of the photoreceptors[28,29]) retina. Total, inner, and outer retinal thicknesses were determined for each MP1 data point and for each of the three distinct FAF regions (the hyperautofluorescent ring, the area enclosed by the hyperautofluorescent ring, and the area outside the hyperautofluorescent ring).

On the site of kinetic perimetry data points, qualitative analysis of the structural integrity of the IS/OS junction line was performed. The IS/OS junction line was characterized as absent (complete disappearance of the IS/OS junction line), disrupted (disorganization of the IS/OS junction line), or preserved (intact IS/OS junction line).

Statistical Analysis

Statistical analysis was performed with statistical software (Prism 4.0; GraphPad Software, San Diego, CA). Data are reported as median with corresponding interquartile ranges. Spearman rank correlation coefficient (ρ) was used to measure the association between static perimetry values and retinal thickness; a nonparametric (distribution-free) test was chosen because the calculated parameters were not distributed normally. We plotted retinal thickness as a function of retinal sensitivity in linear units because it was previously shown that a simple linear model accurately relates SD-OCT to retinal sensitivity parameters.[5,30,31] For kinetic perimetry, results were ordered into five groups (0, 4, 8, 12, and 16 dB). Inner, outer, and total retinal thicknesses were evaluated at each data point, and a nonparametric test (Kruskal-Wallis one-way ANOVA) was used to compare the five independent groups of sampled data. Statistic H was compared with a χ^2 distribution with 4 *df*, and *P* was computed. Based on fundus autofluorescence imaging, the retina was split into three groups: the area within the ring of high density, the area over the ring, and the area peripheral to the ring. Kruskal-Wallis one-way ANOVA was used to compare retinal thickness or sensitivity in those three groups; 2 *df* was used to compute *P*. The alternative hypothesis for Kruskal-Wallis states that at least one median is different from the rest. Therefore, when the result was significant, Dunn posttest (multiple, pairwise, stepdown comparisons) was used to identify those groups that caused the Kruskal-Wallis test to reject the null hypothesis. $P < 0.05$ was considered significant.

Results

Correlation between Fundus-Related Perimetry and SD-OCT

Thickness of the segmented layers was assessed at the spots corresponding to the static perimetry data points. Both total and outer retinal point thickness correlated with retinal sensitivity, with a positive correlation coefficient indicating that when thickness increases, sensitivity increases ($\rho = 0.54$ and 0.72; $P < 0.0001$ and $P < 0.0001$). Correlation for outer retinal thickness and sensitivity was the highest in magnitude; these data are presented in Figure 1.

Structural integrity and thickness of the outer retina were evaluated at the kinetic perimetry data points. Perimetry results were ordered into five groups (0, 4, 8, 12, and 16 dB), and median thickness across groups was compared (Fig. 1). There was strong evidence that outer retinal thickness was different in at least one sensitivity group ($H = 288.6$; 4 *df*; $P < 0.0001$). Multiple comparisons of each pair of groups gave $P < 0.05$ for all (Dunn posttest). Qualitative structural integrity of the IS/OS junction line for kinetic MP1 data points is presented in Figure 2. There was no statistically significant difference in retinal thickness and presence of IS/OS on the site of recognition of 0 dB between kinetic and static perimetry ($P = 0.574$, Mann-Whitney *U* test).

Comparison between FAF and SD-OCT

The thickness profile was assessed inside, over, and outside the hyperautofluorescent ring in each eye. H values were 17.0 ($P = 0.0002$), 61.5 ($P < 0.0001$), and 41.3 ($P < 0.0001$) for inner, outer, and total retinal thickness, respectively, rejecting the null hypotheses (no difference among groups). Multiple pairwise comparisons between groups to locate the source of significance found critically different outer and total retinal thickness between the three areas (Dunn posttests after two Kruskal-Wallis tests for outer and total retina). For the inner

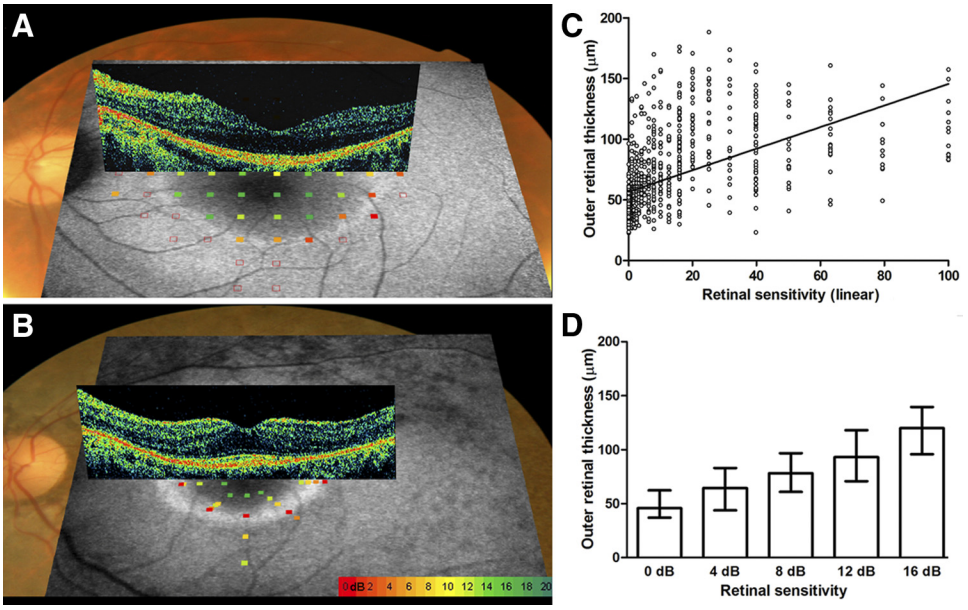

FIGURE 1. Structure-function correlation in patients with retinitis pigmentosa and hyperautofluorescent ring. Static (**A**) and kinetic (**B**) fundus-related perimetry results superimposed on a fundus autofluorescence image and an SD-OCT scan. Comparison of outer retinal thickness with retinal sensitivity assessed by static (**C**; 20, 40, 60, 80, 100 in linear scale correspond to 13, 16, 18, 19, 20 dB) and kinetic (**D**) fundus-related perimetry.

retinal thickness, the pairwise comparisons revealed differences between the area inside and over as well as inside and outside the ring but not between the area over and outside the ring (Dunn posttests). Results are summarized in Figure 3. A high correlation between the diameter of the inner border of the hyperautofluorescent ring and the IS/OS junction line on the OCT was observed ($\rho = 0.67$, $P = 0.0003$; Fig. 4).

Comparison between FAF and Fundus-Related Perimetry

Static perimetry data points were grouped into those inside, those over, and those outside the ring of high density (Fig. 3). Sensitivity values were collected for each spot. The results of a Kruskal-Wallis test were significant ($H = 34.2$, 2 *df*, $P < 0.0001$), and the mean ranks of retinal sensitivity were significantly different among the three areas (Dunn posttest).

DISCUSSION

SD-OCT, static, and kinetic fundus-related perimetry were performed in patients with RP and parafoveal ring of increased signal on FAF imaging. Custom-made software was used to coregister the three different modalities, representing retinotopic maps of structure, molecular composition, and function of the central retina. To more accurately assess morphologic alterations and their functional consequences, manual segmentation was performed. We have shown that retinal sensitivity correlates better with outer as opposed to total retinal thickness. Additionally, the inner retina was relatively preserved, which is critical for novel therapeutic approaches such as retinal prostheses.[32–34]

The ring of hyperautofluorescence can encircle either preserved (RP) or diseased retina (cone dystrophies, maculopathies), representing an accumulation of lipofuscin in a transition zone.[15,16] Understanding this transition zone has implications for treatment strategies and helps delineate the nature of disease progression.[18,30] In our cohort of RP patients, SD-OCT imaging revealed the preserved IS/OS junction line inside the ring, confirming the results of previous studies.[13,17,19–21,23] At the inner border of the hyperautofluorescent ring, outer retinal thickness sharply decreased; this was not the case with inner retinal thickness, which was relatively preserved. On static perimetry, inside the hyperautofluorescent ring, retinal sensitivity was relatively preserved. On the

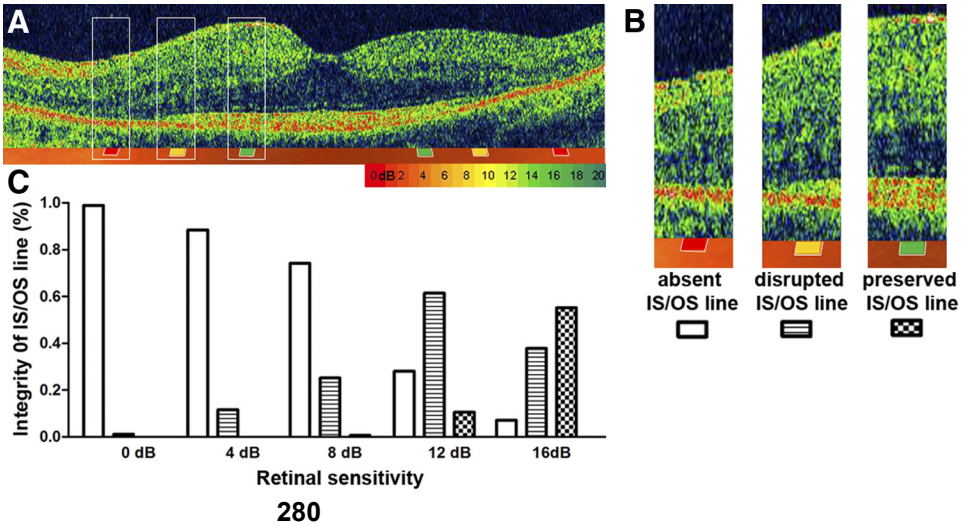

FIGURE 2. (**A**) Kinetic fundus-related perimetry superimposed on an SD-OCT image. (**B**) Higher magnification of images presenting absent, disrupted, or preserved IS/OS junction line. (**C**) Qualitative structural integrity of the IS/OS junction line as a function of retinal sensitivity derived from kinetic fundus-related perimetry.

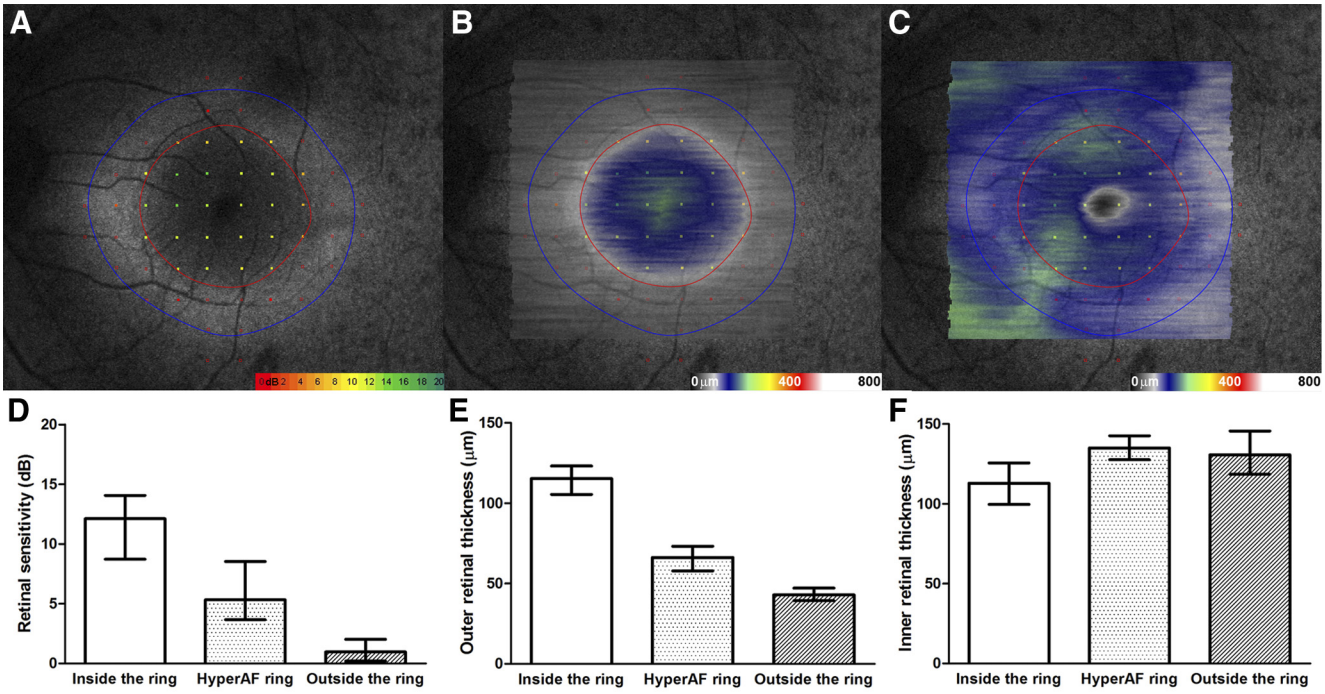

FIGURE 3. Static fundus-related perimetry (**A**), outer (**B**), and inner (**C**) retinal thickness maps superimposed on a fundus autofluorescence image. *Red lines*: inner border of the hyperautofluorescent ring; *blue lines*: outer border of the hyperautofluorescent ring. Median retinal sensitivity (**D**), outer (**E**), and inner (**F**) retinal thickness with interquartile range inside, over, and outside the hyperautofluorescent ring is shown.

site of the ring sensitivity decreased, and outside the ring an absolute scotoma was observed. In agreement with a recent study by Greenstein et al.,[17] statistically significant differences in retinal sensitivity among these three groups were observed. These results are in accordance with the notion that the hyperautofluorescent ring represents the transition zone between functional and dysfunctional retina.[9–11,16,17,21,23] Notably, recent evidence suggests that structural and functional changes may also occur inside the ring.[14,17]

Kinetic perimetry is superior to static perimetry for evaluating peripheral visual fields and delineating scotomata but is less sensitive in detecting small central visual field defects.[35] Fundus-related kinetic perimetry enables observation of fixation and allows precise delineation of scotomata at the posterior pole.[36–39] In this study, we have evaluated outer retinal structural integrity and thickness at specific kinetic perimetry data points. Low-intensity (16 dB) stimuli were seen only where the IS/OS line was preserved, whereas high-intensity (0 dB) stimuli could be seen despite complete loss of the IS/OS line. Similar results have been reported in a study[40] in which Goldmann perimetry (in which patient fixation cannot be carefully monitored) and time-domain OCT were used; this was attributed to poor patient compliance and low OCT resolution. Reaction time is expected to induce displacement of the isopter toward the direction of the stimulus movement. In RP patients, reaction time is prolonged and is estimated to be 702 ms.[41] The velocity of the stimulus movement in this study was 2.4°/s; hence, a shift of 1.68° would be expected. This would mean that the signal was recognized at 1.68° or approximately 0.4 mm before the location at which the retinal structure was evaluated. Therefore, we feel that the recognition of kinetic perimetry stimuli despite the IS/OS line loss is not artifactual. This is in agreement with results of a previous study using static perimetry and showing that the IS/OS line had essentially disappeared when sensitivity was reduced by 10 dB or more[5] and highlights that increased photoreceptor density is critical for the recognition of low-intensity but not of high-intensity perimetry stimuli. Further studies with cellular resolution in vivo retinal imaging using adaptive optics will allow visualization of residual outer segment material (below resolution

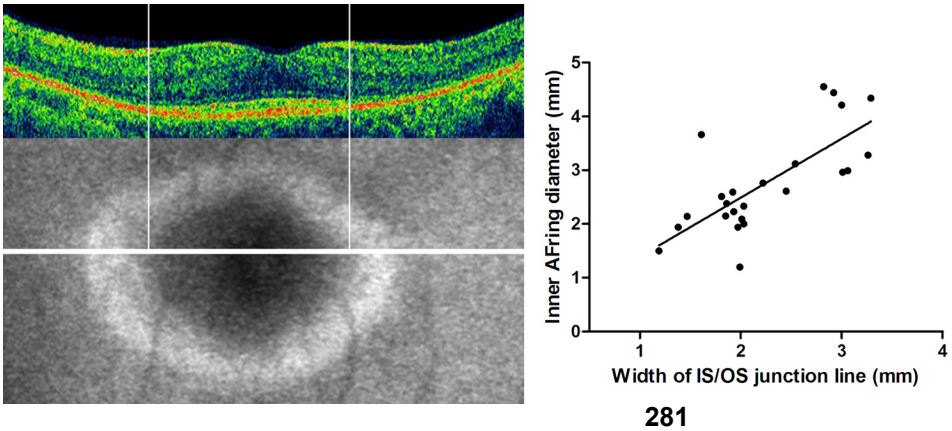

FIGURE 4. Comparison between the diameter of the inner border of the hyperautofluorescent ring and the length of inner and outer segment junction line on OCT ($\rho = 0.67$, $P = 0.0003$).

threshold of standard SD-OCT) and will facilitate more accurate assessment.

By performing both static and kinetic fundus-related perimetry, we were able to demonstrate reduced sensitivity to a static stimulus as opposed to the identical kinetic stimulus at certain field locations of some patients. This phenomenon is known as statokinetic dissociation and was first reported in 1917 by George Riddoch in patients with occipital lobe lesions.[42] Since then it was described in many other conditions, including RP.[43,44] Wood et al.[43] showed that the kinetic nature of the stimulus is more effective in detecting small degrees of residual field in RP. In this study we compared retinal structure on the site of recognition of 0 dB between kinetic and static perimetry, and no statistically significant difference in either retinal thickness or presence of IS/OS was identified. Therefore, it can be speculated that the dissociation of static and kinetic perimetry is unlikely to be due to outer retinal contribution.

Our study has some limitations that must be addressed. Both retinal sensitivity and thickness vary between individuals and with eccentricity from the foveal center. Nevertheless, a large data set of normative MP1 data (n = 190 eyes) has revealed only a small difference in retinal sensitivity between peripheral and central areas (18.7 ± 1.2 dB vs. 19.4 ± 0.8 dB).[45] Additionally, in our protocol, most MP1 data points (54/56) fell within the inner and outer ETDRS subfields, where observed variation in retinal thickness is small.[46,47] Therefore, a significant confounding effect is not expected. Additionally, accurately measuring the photoreceptor nuclei thickness remains a challenge, and higher resolution SD-OCT will provide further insight.

In patients with RP, a hyperautofluorescent ring on FAF imaging separates areas with different structural and functional characteristics. We have used a variety of methods to show that these differences are statistically significant, highlighting the clinical usefulness of FAF in RP. The importance of structure-function correlation studies is difficult to understate. The segmentation of OCT volume scans, the combination of static and kinetic perimetric methods, and the accurate coregistration of different modalities drastically increases the power of these studies and allows consistent associations to be drawn.

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WHEN IT COMES FROM THE POSTERIOR BRAIN IN CHILDREN: EPILEPSY, MIGRAINE OR OTHER BUSINESS RELATED TO PERCEPTION, NOT NECESSARILY VISUAL

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Parietal and occipital brain lobes are capable of producing a rich repertoire of paroxysmal phenomena often but not necessarily epileptic and often but not necessarily involving visual perception. In children, these are rather difficult to study due to age, subjective nature and fleeting occurrence, as a rule hard to observe or even document (video, home or lab, EEG), except for those induced by specific stimuli.

Some are epileptic and/or more or less associated with epilepsy (ictal, post-ictal or release - related), associated or not with photoparoxysmal response or other types of photosensitivity. A variety of pathophysiological mechanisms may be involved, generating other less tangible phenomena, incompletely understood and quite often not allowing more than a tentative diagnosis. Most of them rare, yet making differential diagnosis of epilepsy considerably more puzzling. Focal seizures can occur in a relatively benign »idiopathic« syndromic context or as a consequence of clear-cut lesional abnormalities. Also, in combinations with non-epileptic phenomena, hard to explain by common denominator mechanism/s put together by chance or blended by some underlying laws that escape our understanding of dys/function in these brain regions. There are cases on the record of double or even triple pathology co-existing in the same person (migraine, epilepsy, paroxysmal disorder of perception related to infection). One has to be aware of this before appropriate treatment is administered, if at all.

Some of the epileptic syndromes specifically originate from these two lobes. Relative paucity of objectively observable phenomena at the focal origin of seizures in parietal lobes and fast involvement of wider neural networks in epileptic processes favor clinical expressions that are »borrowed« or expressed »at distance«. The electrical signal – a very important diagnostic element – may be lacking or does not reliably point to the source of origin and to explanation of the anatomo - electro – clinical correlations.

Multiple spread patterns (to temporal, to motor regions) are frequently observed in seizures originating from occipital lobe. Ictal spread my depend on the location of the epileptogenic zone. Seizures beginning in different regions of the brain surrounding the lesion may vary in the same patient. A phenomenon related to visual function during an epileptic seizure does not necessarily locate the origin of the disorder into occipital regions but may have spread there from neighbour regions to involve functionally related networks; even more, this is true about eye movements.
When epilepsy occurs in the posterior brain, aetiological search has to be applied very carefully. A few of the more obvious pathologies that affect these regions and may underlie the appearance of focal symptomatic occipital lobe epilepsy include perinatal brain injury, pial angiomatosis, coeliac disease, mitochondrial disorder (MELAS), Lafora's disease, together with any of the other lesional factors (trauma, tumour, dysplasia, vascular lesion, history of meningitis, encephalitis). Thorough elucidation of eventual neurological deficits is mandatory, since a child (and an adult patient too) may not be aware of the visual field defect associated with the lesion.

The presentation will introduce main elements of the clinical realm of paediatric epilepsy from posterior brain, excluding psychiatric phenomenology, to remind of the well accepted epileptic syndromes originating from posterior brain lobes. In addition, some other clinically relevant nonepileptic paroxysmal events will be described occurring by virtue of neuro- vascular mechanisms (migraine and related equivalents), sleep disorders, putative neuro-immune mechanisms related to pos/infectious state, release phenomena, episodes related to psycho-emotional development also found in non-clinical populations. Last, but not least important, the fits and faints occurring from the very posterior brain, the cerebellum, shall be mentioned with features not necessarily classically indicating their origin, yet able to compromise vital autonomic functions

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VISUAL HALLUCINATIONS – A PHENOMENOLOGICAL PERSPECTIVE

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ABSTRACT

Hallucinations and visual hallucinations among them accompany human mankind since time immemorial. They provoked all sorts of explanations in the course of history: from messages and prophecies to organic brain disorders. Phenomenologically speaking, we try to thoroughly describe the phenomenon of visual hallucinations and to search the essential features constituting them. In this vein, we can follow two lines of (re)search: (1) describing the experiential dimension of visual hallucinations per se and (2) looking for a primary alterations of one's being-in-the-world (existential a prioris), of which hallucinations are considered as secondary phenomena. Both lines of research, which walk hand-in-hand can be informative for a clinical and neuroscientific understanding of visual hallucinations.

INTRODUCTION

Hallucinations are part of the baggage humanity carries with itself since its beginnings and throughout its history. They were and are understood very differently. On the one side, they were seen – and still continue to be so – as messages, parts of revelations or prophecies. On the other side, they were during the eighteenth century 'medicalized' and are since then mostly considered as manifestations or symptoms of illnesses (1).

Visual hallucinations are together with auditory hallucinations the paradigmatic forms of hallucinations and at the same time the most common forms of hallucinations. They are defined as seeing things which are not present for other people or visual perception which is not reconciled with the outside, consensual and common-sense reality. They are part of the normal human experience, especially as part of the peripheral vision or in connection with sleep (as hypnagogic and hypnopompic hallucinations), and they are part of numerous disorders, like psychotic disorders, dementia, delirium, migraine, epilepsy, use of substances, especially hallucinogenic drugs etc. They are not very typical for a paradigmatic psychiatric disorder connected with hallucinations, i.e. schizophrenia.

EXPERIENTIAL DIMENSION OF VISUAL HALLUCINATIONS

Visual hallucinations are experienced as vivid and clear visual perceptions as persuasive as other visual experiences. At least at the first "sight" they are so. They are namely almost always part of pervasively changed consciousness in which usual monitoring, reflection or mentalization are missing. So a person is in a changed experiential world with a touch of confusion, which prevents him/her to properly analyze the perceptual datum and its characteristics. Retrospectively speaking, many patients report some specificities about the quality of visual perception in visual hallucinations. What they report are features of a certain factor of subjectivity as Sass pointed it out in the case of delusions (2).

They say for example that they can discern between the factual and the hallucinatory visual experience (this is reported by patients who experience visual hallucinations on a repetitive or continuous basis). Even if they claim that they learned to discern between the two only a posteriori, there still must be an experiential basis for the possibility of discernment.

PRIMARY ALTERATIONS OF BEING-IN-THE-WORLD AND SECONDARY HALLUCINATIONS

Most of the phenomenological accounts of hallucinations (and delusions) conceptualize the overall transformation of one's being-in-the-world as an experiential basis for the development of hallucinations.

Visual perception – as well as any other perception – is not a passive intake of information, a sort of a mechanistic processing or a neuronal state, activated by sensory input. Rather, it is part of the action of the whole organism while exploring the world (3).

As such, it is always contextualized and enacted within one's being-in-the-world with all its existential a prioris, such as temporalization, spatialization, body, 'being-with' others etc. The alterations of these existential a prioris result in an alterations in the whole structure of experience (4). Hallucinations are in this perspective seen as manifestations of such an altered structure of experience.

More specifically, we can identify several elements of a changed basic anthropological context in a hallucination formation. These elements are weakening of the automatic

and active syntheses, excessive world-openness, and subsequent reduction of complexity of experience (5). Weakening of the automatic syntheses in perception prevent the ability to combine stimulus into coherent perception of objects, which is according to phenomenological tradition related to the overall self-experience (6).

Even though these findings stem from schizophrenia research, they may well represent the essential structures of other forms of hallucinations – visual hallucinations in our case – in other disorders too. A good and relatively well-researched example is Kafka, who suffered from dreamlike hypnagogic hallucinations during his sleep-deprived writing periods. In his spontaneous hallucinations he was experiencing the imaginary double, so called autoscopy (7).

CONCLUSION

We can conclude that research of visual hallucinations, as well as other hallucinations, needs a strong descriptive phenomenological input. We need to know, what it is like to experience visual hallucinations in the first place. Then we need to understand how these hallucinations are embedded in one's pervasive structures of being-in-the-world. And with this whole armamentarium at hand we can be good dialogue partners to other streams of research of these intriguing phenomena.

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EYE MOVEMENT CORRELATES FOR COMPLEX SUBTRACTION IN HEALTHY ADOLESCENTS

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ABSTRACT

With our research we wanted to determine the added value of eye-movement data in investigating arithmetic processing, more specifically complex subtraction. We tried to understand how adolescents, who have finished their elementary schooling some time ago and are not using complex arithmetic in everyday life, subtract two digit numbers with borrow and no borrow problem. One of the most frequent problem features is problem size (small vs. large numbers). We investigated how the size of a difference, i.e. the distance between the first and the second operand, affects subtraction. Our study offered some insights into adolescents' strategies of complex subtraction and their practicability.

1 INTRODUCTION

Numbers are integrated in our everyday life. With numbers we count, measure, sort, mark…, in short, we are using them (un)consciously all the time. Basic sense of arithmetic is inherited in humans and in animals (Dehaene, 1997), because the representation of quantity is important for the existence and survival of species in the new, unknown environment. In humans, it was discovered that even newborns have an intuition for numbers and in the first year of life babies already add and subtract up to the number three (Feigenson et al., 2004; Dehaene, 1997). The calculation ability is developing very fast during childhood and with the acquisition of language children acquire symbolic numbers and arithmetic. In the first school years they tackle the strategies of arithmetic and learn how to calculate single- and multi-digit numbers. The strategy use differs due to the different school systems and cultures and its practicability has been studied for many years.

Lemaire et al. (2007) investigated strategies used in solving two-digit addition problems and two-digit subtraction problems in adults and in children. Participants used the full decomposition strategy, i.e. they decomposed both operands to tens and units (e.g. 43 + 25 = (40 + 3) + (20 + 5) = 60 + 8 = 68), and the partial decomposition strategy, i.e. they decomposed the second operand only (e.g. 43 + 25 = 43 + (20 + 5) = 63 + 5 = 68) in choice and no-choice conditions. They used full decomposition more often than the partial decomposition strategy to solve addition problems. To solve subtraction problems both strategies were used equally often.

Participants' performance is grossly affected by arithmetic problem characteristics and strategy use, such as size of the operands and whether problems involve carryover or borrow. With relation to problem size, participants show a better performance on smaller numbers such as 3·4; 12+23 than on larger numbers such as 6·7; 38+53 (Zbrodoff & Logan, 2005; in Green et al., 2007). With larger numbers the problem of an arithmetic carry appears. Green et al. (2007) showed that execution of carries is an elementary process in arithmetic. They found that carries become reliably faster with practice whereas time to encode a single digit or to retrieve addition facts does not change with the amount of practice.

Subtraction is harder than addition because children deduce differences from their knowledge of sums rather than by using a retrieval of subtraction facts from the memory (Kamii et al., 2001).

Investigation of the arithmetic processes usually relies on the evaluation of performance in different tasks or on participants' self-reports. A rather new method for investigating arithmetic and calculation strategies is the study of eye movements. Visual perception is an important cognitive process and eye movements subserve it. Eye fixations, saccadic movements, total viewing time and fixations in areas of interest are the measures which may be used in vision research to study cognitive processes and

help us understand characteristics of their development and also different cognitive disabilities.

Neural activity that results in a saccadic movement is shaped in the brainstem (Liversedge et al., 2000). Two principal descending input pathways to the superior colliculus come from the frontal eye field (FEF) region and posterior parietal cortex. Brainstem organization shows a separation between cells encoding the spatial characteristics of the saccadic movement ('where') and those for triggering the movement ('when'). Liversedge et al. (2000) suggested that the number of saccades prior to a target presence or absence decision is an increasing linear function of display size. They also suggested that fixation durations are affected by low-level visual factors (e.g. contrast) and high-level semantic properties.

A normal eye-movement comprises of a series of fixations and saccades. During fixations, the eye shows only small drift movements. Saccades are fast ballistic movements of the eyes that re-locate the point of fixation (Liversedge et al., 2000).

Little is known about the eye movements as a measure of mathematical thinking processes. Only a few studies (e.g. Green et al., 2007; Schneider et al., 2008) have demonstrated the results of eye tracking data. Green et al. (2007) investigated eye movement correlates of younger and older adults' strategies for complex addition. When studying how people process carries in addition tasks they discovered that young adults more successfully distinguished between different strategies. They also determined the usefulness of eye-movement data to study strategies in arithmetic processing and in cognitive aging. Schneider et al. (2008) investigated to what extent eye movements recorded during task solution reflected children's use of the number line when solving number line estimation tasks. They expected that both manual responses and eye movements would show improvement in the number estimation with increasing grade level. Indeed, the results suggested that eye-tracking data collected with the number line estimation task are a valid, detailed and sensitive indicator of children's developing number sense.

Previous studies therefore showed that eye movements are related to arithmetic strategies, are sensitive to problem features and are thus a useful method for further investigation.

To study subtraction characteristics in more detail, we decided to investigate eye movement correlates for complex subtraction of two digit numbers with/without borrow and with small/large difference between operands. We hypothesized that borrow trials will take longer to calculate and will lead to higher number of errors and more fixations. We also hypothesized that the size of the difference between operands will have an impact on calculating.

2 METHODS

2.1 Subjects

Thirteen adolescents (9 males and 4 females) voluntarily participated in our study. Their age was between 18 and 24 years (M = 22 years). One of them was employed, eight were university students and four still had to finish the secondary school.

2.2 Measurements

Participants were tested on the subtracting tasks with the eye-tracker device EyeLink 1000 DeskTop Mount, supported with the EyeLink SR Research Experiment Builder program. Recording was monocular, calibration HV9, camera 500 Hz, head stabile. The tasks were separated into four groups of 10 calculations, with each group representing a different combination of numbers' distance (small distance was between 15 and 35 and large distance was between 42 and 62) and borrow-no borrow problem. All task groups had the same standard deviation of differences and both borrow and no borrow groups were matched in mean difference value. In all tasks, digits were not equal to zero and the unit numbers of the first and the second number were not the same. The subtraction was presented horizontally with the suggested answer. Half of the answers were true.

We defined different areas of interest (AI): AI 1 – ten of the first number, AI 2 – unit of the first number, AI 3 – ten of the second number, AI 4 – unit of the second number, AI 5 – the suggested answer (Figure 1). Participants pressed the key on the Cedrus box when they calculated the difference between two operands; with this we measured the reaction time. Then the question was displayed on the monitor whether the suggested result was correct or not, and participants responded with 'Yes' or 'No' using the Cedrus box. Fifteen additional tasks of addition have been added as disruptions, 3 to 4 in each group. The trials were randomly intermixed. Subjects also reported their strategy of subtraction verbally at the end of experiment.

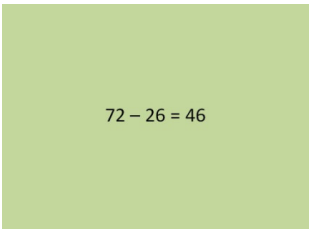

Figure 1: An example of subtraction

With the eye-tracker device we investigated the reaction time, i.e. the time spent for calculation, the first gaze (the first area of interest in the trial), eye fixations in general and in AI, blinks and saccadic movements. We also analyzed the accuracy of the answers. Data were analyzed with SPSS Statistics 17.0 software. We calculated descriptive statistic (frequencies, means and standard deviations) of different measures in different conditions. To compare experimental conditions, we used χ^2 tests for categorical data and non-parametric Mann-Whitney *U* tests for ordinal and interval data. All hypotheses were tested at .05 alpha error rate.

3 RESULTS

3.1 Response accuracy

Adolescents solved 88.4% of tasks correctly. The accuracy in the borrow trials (83.4%) was lower than the accuracy in the no borrow trials (93.5%), $\chi^2(1) = 12.85$, $p < .001$. Small or large difference between operands did not significantly affect the accuracy. Detailed data on accuracy is shown in Table 1.

Table 1: Percent numbers of incorrect (0) and correct (1) answers for four groups of tasks

Note: S = small difference, L = large difference, B = borrow, nB = no borrow.

3.2 Reaction times (RT)

On average, adolescents needed 8372 ms for a task (*SD* = 4551 ms). The average RT for the borrow problem (*M* = 9109 ms, *SD* = 4745 ms) was larger than the average RT for the no-borrow problem (*M* = 7547 ms, *SD* = 4216 ms), Mann Whitney *U* = 26182.50, *Z* = −4.38, *p* < .001, whereas the size of a difference was not statistically significant (for the small difference, *M* = 8448 ms, *SD* = 4761 ms; for the large difference, *M* = 8208 ms, *SD* = 4337 ms; Mann Whitney *U* = 33223, *Z* = −0.26, *p* = .794).

3.3 Fixations

The average number of fixations in a trial was 22 (*SD* = 14). In the borrow problem, the number of fixation (*M* = 23, *SD* = 16) was larger than in the no borrow problem (*M* = 20, *SD* = 13), Mann Whitney *U* = 28795, *Z* =−2.86, *p* = .004. Although the participants did not know the results of calculations, we found a significant difference in the number of fixations between correct (*M* = 21, *SD* = 14) and incorrect answers (*M* = 25, *SD* = 13), Mann Whitney *U* = 10666, *Z* = −2.84, *p* = .004. Analyzing blinks' number in a trial we found that on average participants had 1.52 blinks (*SD*=1.8). Neither the borrow problem (Mann Whitney *U* = 30788, *Z* = −1.75, *p* = .081) nor the correctness of response (Mann Whitney *U* = 13620, *Z* = −0.14, *p* = .887) affected the number of blinks (see Table 2).

Correctness	S/nB (%)	S/B (%)	L/nB (%)	L/B (%)
0	7.7	16.2	5.4	17.1
1	92.3	83.8	94.6	82.9

Table 2: Average number (M) and standard deviation (SD) of blinks for incorrect (0) and correct (1) answers with regard to the borrow problem

	0 (M)	0(SD)	1(M)	1(SD)
nB	1,29	1,40	1,38	1,65
B	1,56	1,72	1,69	2,00

3.4 Areas of interest (AI)

We defined five areas of interest (AI): the digits of both numbers (sequentially from left to right AI1, AI2, AI3 and AI4) and the suggested result AI5. First, we analyzed interest area dwell time (Table 3). Participants spent the minimum time on AI4, i.e. on the units of second number (with regard to the digits of numbers), and they had distributed the time approximately evenly among the first three digits. The dwell time on AI5, i.e. on the result of the equation, was much shorter, because they were initially informed that the result was not relevant for our experiment and it should be used only at the end of calculation to collect correctness data. We should also mention a huge deviation of dwell time.

Table 3: Average interest area dwell time M and standard deviation SD (ms)

	AI1	AI2	AI3	AI4	AI5
M	1529	1590	1593	1000	595
SD	1696	1261	1307	1745	613

Second, we investigated the first three fixations on AI (Figure 2). The first fixation in a trial was mostly made outside AI (on the so-called A0), but among digits, tens of the first operand got the maximum number of the first fixations (22%), followed by units of the first and the second operands and at the end tens of the second operands. Noticeable share of first fixations was also observed on the result AI5 (12%). Maximum percentage of the second fixation was found on units of first operands (31%), whereas tens of both operands got an equal share (17%). It is also interesting that the third fixation was approximately equally distributed among the first three digits, whereas units of second operands received gaze less frequently.

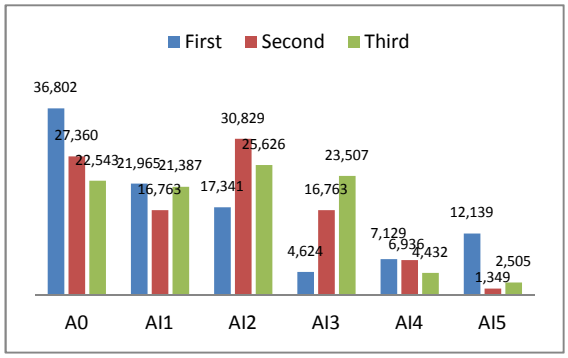

Figure 2: Percentage of the first, second and third fixations received by different AIs

3.5 Calculation strategies

Participants reported their strategy of calculation verbally at the end of the experiment with the help of a questionnaire, where four tasks (one from each group) were presented. As they do not use arithmetic in everyday life, the findings are very interesting. The strategies used varied a lot and we could divide them into four groups. If, for example, a participant should solve an equation 73-46, then the four strategies would be the following:

S1: first tens 70 – 40 = 30 or 7 – 4 = 3, then units 3 – 6 = -3, 30 – 3 = 27 or 33 – 6 = 27;

S2: first 73 – 40 = 33, then 33 – 6 = 27;

S3: first tens 70 – 40 – 10 = 20, then units 13 – 6 = 7, together 20 + 7 = 27;

S4: participants used a mixed strategy, e.g. 73 – 46 = 73 - 50 + 4 or (46) + 4 + 20 + 3 (= 73).

S1 and S3 are full decomposition strategies (decomposition of both operands) and S2 is a partial decomposition strategy (decomposition of second operand only). The first three strategies had an equal number of users (three each) and four participants used strategy S4. Participant using strategy S4 were most accurate and participants with S1 were the least accurate (see Figure 3).

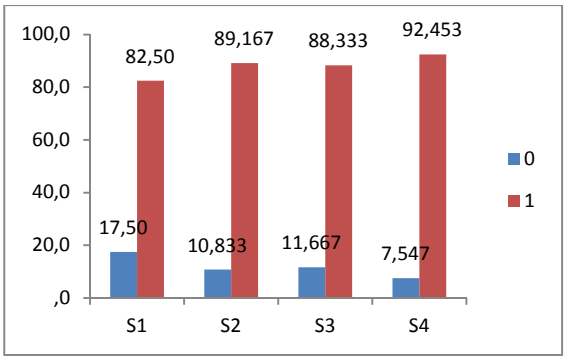

Figure 3: Percentage of incorrect (0) and correct (1) answers with regard to strategies

With regard to the borrow problem in no-borrow trials the accuracy was approximately the same for all strategies (Figure 4), whereas in the borrow trials there were some differences among strategies. Strategy S4 led to the highest accuracy and S1 to the worst one.

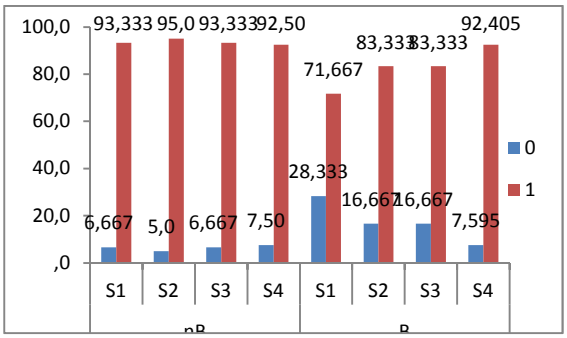

Figure 4: Percentage of incorrect (0) and correct (1) answers with regard to strategies and to borrow problem

Using strategy S1, participants needed much more time for calculations in comparison to other strategies (Table 4). This result is congruent with the number of fixations—participants using strategy S1 made the highest number of fixations (M = 28, SD = 9) and those using S2 made the smallest number of fixations (M = 13, SD = 5).

Table 4: Average M and standard deviation SD of RT (ms) with regard to strategies

	S1	S2	S3	S4
M	11496	5644	8064	8158
SD	4722	2311	4108	4606

4 DISCUSSION

Many analyses of strategies in arithmetic have been done in the past. With our research we tried to find some new aspects of the subtracting. As expected, with regard to the borrow problem, there were significant differences between the borrow and no-borrow tasks in response accuracy (the no-borrow tasks had higher accuracy), in RTs (the borrow tasks took more time to calculate) and in the number of fixations (the borrow tasks had more fixations). Surprisingly, there was no significant difference in blinks with regard to the borrow problem. We may say that the borrow problem has a large impact on response accuracy and RTs, but a somewhat smaller impact on eye movements.

We also hypothesized that trials with large and small differences between operands will result in different measures. Surprisingly, our results did not show any significant differences between these two levels (neither in RT nor in response accuracy or in eye movements). The so called 'problem size' may be evident only in manipulating with the size of digits and operands, but the distance between operands seems to have no impact on the calculations. Zorzi et al. (2011) claimed that numerical representations are rooted in cortical networks and also subserve spatial cognition, i.e., numerical cues can orient attention in visual space. But our results suggest that mental calculation with large numbers is not based on mental representations of operands and shifts of attention along an internal 'number line'.

We tried to define the eye movement paths in subtracting tasks by analyzing AI dwell time and the area of the first, second and third gaze. The dwell times on the first three digits were approximately the same; the least time was spent on gazing at units of the second operand. But standard deviations were large; we can assume that there are big differences among individuals with regard to eye movements during calculation. It was also interesting to observe eye movements at the beginning of calculations, analyzing the first gazes. Mostly participants' first gaze was directed outside the defined AIs, but the second most frequent option was to fixate at the first tens (22%). The second operand received the first fixations less frequently (only 12% by both digits), and the same was true for the second and third fixation as well.

At the end we analyzed the strategies of calculating. The participants were adolescents (aged between 18 and 24 years) who finished their elementary education (where such arithmetic operations are heavily practiced) quite some time ago. They were not instructed how to make the calculations, they just reported their way of calculating at the end of the experiment. They mostly did not report new strategies, almost 70% of adolescents were using full/part decomposition strategies and only four of them tried new ways of calculating, using both strategies and also an intuitive approach for closeness of operands or decade numbers. So we can speculate that strategy is stored in a long-term memory like other arithmetic facts and it is used by retrieval. The analyses showed that different strategies lead to different response accuracy, RTs and number of fixations. We can emphasize that with strategy S4 participants made the minimum amount of errors and with the full decomposition strategy S1 the maximum. This holds true for borrow trials as well, while in no-borrow tasks the response accuracy was approximately the same for all strategies. With regard to RT, strategy S2 was the fastest and strategy S1 the slowest. We can conclude that strategy S2 (part decomposition) is the most convenient manner of subtracting, with small amount of errors and fast calculations.

5 CONCLUSIONS

With our study we tried to examine characteristics of subtraction in healthy adolescents and find some correlation between eye movements and complex subtraction. Eye movement data has demonstrated its usefulness for investigating spatio-temporal distribution of attention during arithmetic tasks regarding problem features (borrow and size problem) and strategies one more time. Although we found a lot of interesting results, the field of eye movement correlates for complex arithmetic is wide and it is waiting for new research projects, e.g. about the differences between groups with regard to age or gender of participants, and about the differences between healthy individuals and individuals with dyscalculia.

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ALPHA ACTIVITY IN YOUNG ADULTS AFTER PERINATAL MILD-MODERATE HYPOXIA

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ABSTRACT

We studied the cohort of 13 young adults (mean age of 21.7 years), who experienced mild (69.2%) to moderate(30.8%) hypoxic-ischaemic encephalopathy (HIE) in neonatal period. They were clinicaly examined; we examined their health status and performed regular EEG with additional spectral analysis - principal component analysis (PCA) of EEG in young adults who did not have epilepsy and their regular EEG was normal.

Epilepsy evolved in 15.4% adolescents with perinatal HIE. PCA analysis showed a hyperbolic decline curve in otherwise normal EEG. The first component, located symmetrically occipitally, originating in visual cortex, comprised majority (50%) of the total EEG variability and increased during stroboscopic light stimulation. Rebound of the spectrum in alpha range was observed except in adolescents with specific learning disorder.

1 INTRODUCTION

HIE is often reported to be the most frequent cause of neonatal seizures, which usually occur 12-24 hours after birth and are difficult to control with anticonvulsants. In addition, they can be subtle and difficult to detect clinically. These types of seizures are best detected by conventional or amplitude-integrated EEG. Some studies suggest that seizures, including asymptomatic electrographic seizures, contribute to brain injury and increase the risk of subsequent epilepsy [1-3]. In HIE, seizures are independently associated with poor outcome [4]. However, a recent study suggests that clinical seizures in neonatal HIE have no additional, direct impact on neurodevelopmental outcome [5].

Brain damage accounts for a growing number of childhood visual impairment [6]. At least 60% of children with neonatal HIE have cerebral visual impairment [7]. These children usually exhibit a slow, ineffeicient , and highly variable visual performance, which is usually better when they are relaxed, well rested and familiar with situation [8,9]. If their visual acuity is spared, vision processing can still be affected.

Since our studied group was comprised of young adults after perinatal HIE, we decided to use a regular EEG after sleep deprivation and PCA analysis as a report from the American Academy of Neurology and the American Clinical Neurophysiology Society concluded that quantitative EEG remains investigational for clinical use in post-concussion syndrome, mild-to-moderate head injury, learning disability, attention disorders, schizophrenia, depression, alcoholism, and drug abuse [10, 11]. We have used regular as well as a quantitative EEG as a method of analyzing the electrical activity of the brain to derive quantitative patterns that may contribute to diagnostic information and give some insight into long-term changes in brain functioning after hypoxia in a critical brain developmental period.

2 METHODS

2.1 Subjects

Thirteen (13) young adults, mean age 21.7 years (SD=±0.9), agreed to participate in the late follow-up of HIE. They were born near term between 1988-1990, and admitted to the PICU, University Medical Centre Ljubljana, due to mild to moderate HIE. They were introduced to the study and provided written informed consent. They agreed upon EEG monitoring after sleep deprivation. All the participants were volunteers and did not receive any payment.

2.2 Measurements

Young adults were neurologically examined and interviewed. Regular EEG after sleep deprivation was recorded. PCA analysis was performed.

2.3 EEG recording and PCA analysis

EEG recording after sleep deprivation was performed in all with Nicolet One, version 5.7.1. with NicVue 2.9.1 reader. Standard international 10-20 system of electrode placement was used. We used a set of recording conditions after whole night sleep deprivation using: eye movements and alpha blocking followed by eyes closed resting; eyes open resting; hyperventilation; and photic stimulation. Data were exported and further analysed. An average reference was used for the signals, and the signals were filtered with the 50Hz notch filter and band-pass filter between 0.1Hz and 70Hz. Numerical analysis was performed in Matlab 2009b (The mathworks inc., Natick, Massachusetts, USA).

3 RESULTS

3.1 Spectral EEG analysis

Principal component analysis (PCA) and spectral EEG analysis were performed in 11 HIE adolescents (84,6%) who had normal EEG after sleep deprivation. PCA showed two distinctive components. The first component, located symetrically occipitally, comprised 50% of the total EEG variability and increased during stroboscopic light stimulation. Its eigenvector is oriented from frontal to occipital electrodes, suggesting that it originates in the occipital region. The assumption is backed up by the fact that the significance of the first component raises up to 80% during photic (light) stimulation. The second component, located over the motor area, either symetrically or lateralized, comprised 15% of the total EEG variability and increased during hyperventilation.

No.	No. of spectrum rebounds (4Hz – 40Hz interval)	Frequencies of the spectrum local maxima (Hz)	spectrum rebounds (%)*	learning disorder
1	1	9	105	no
2	2	10, 21	113, 4	no
3	1	10	43	no
4	0	-	-	yes
5	2	11, 22	221, 48	yes
6	0	-	-	yes
7	1	10	123	no
8	1	9	3	yes
9	1	10	21	no
10	0	-	-	yes
11	1	11	29	no

*Calculated as the difference between the specific spectrum maximum and directly preceeding minum, then divided by the preceeding minimum.

Figure 1: *Analysis of the spectrum of the first principal component charateristics.*

Spectral analysis of raw EEG signals showed no significant pattern. The spectral power density showed the usual high power-density values for low frequency signals and approximately exponential decay toward higher frequencies for all subjects. However, spectral analysis of the prinicipal component divided our patients into two group. Rebound of the spectrum in the alpha range was observed in some while in the others, no visible local maximum in the alpha range was observed. The absence of the "alpha peak" was observed in adolescents with learning disorder.

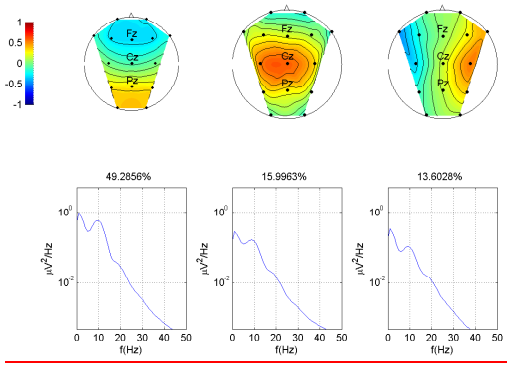

Figure 2: *Spectral analysis of regular EEG after sleep deprivation in young adults, who had perinatal HIE (the 1st PC – the first principal component, the 2nd PC and the 3 rd PC).*

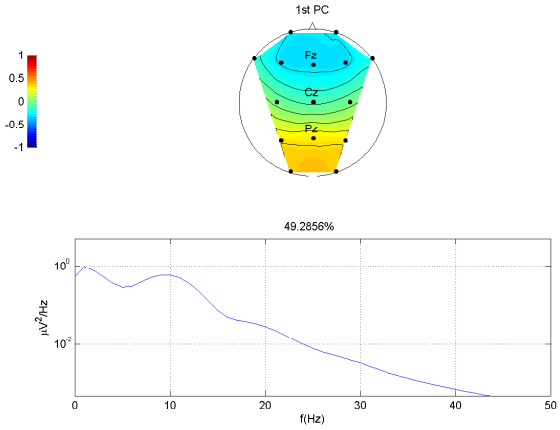

Figure 3a: *A power spectra and principal component composition in patient No. 1 who is very successful at school. He studies Forestry at the Biotechnical faculty. An obvious local maximum of the power spectrum in the alpha range is noted.*

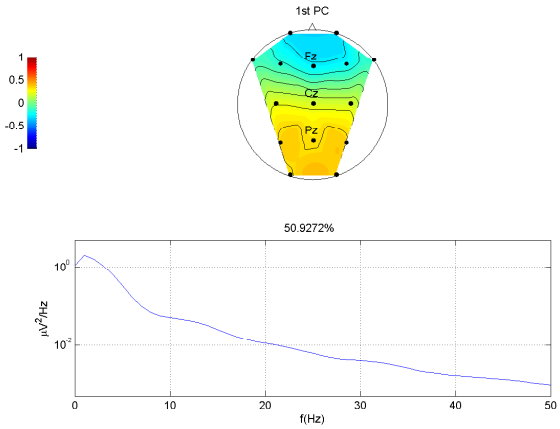

Figure 3b: *A power spectra and principal component composition in patient No.4 who has learning disorder. He is finishing the secondary school and receives extra help from psychologist as well as the teachers. He puts a lot of efforts in mathematics. Alpha range rebound in the spectrum is absent.*

4 DISCUSSION

HIE is still one of the major causes of neonatal epilepsy [12, 13]. In our cohort we observed epilepsy in 15% of adult survivors of perinatal hypoxia. Animal evidences suggest that seizures in the neonatal period can alter brain development per se which leads to long-term deficits in learning, memory and behaviour [14-16]. Some studies suggest that seizure severity in infants with perinatal asphyxia is associated with brain injury and impaired metabolism independent of the severity of hypoxic-ischemic brain injury [17, 18]. Some studies claim that clinical seizures in neonatal HIE have no additional, direct impact on neurodevelopmental outcome [5]. Our cohort was a part of the previous study, where with MRI we have shown the white matter changes in the group [19]. The contribution of isolated white matter changes on brain development is hard to interpret. It has been reported that white matter lesions seen on neonatal scans carry increased risk for motor and cognitive problems even in their early teens [20]. The recent study of infants with HIE and selective white matter injury shows a low prevalence of cerebral palsy but a wide-range of other problems in affected children, where vision can be affected in almost two thirds of patients with HIE [21].

We have decided to take a closer look at EEG findings. We speculated that regular EEG reading may not be sensitive enough for some subtle changes. Hence we performed a quantitative EEG with PCA analysis as it offers an insight into brain functioning [22, 23]. PCA of the EEG recordings of the patients enrolled in the present study shows that there are three distinguished principal components that describe more than 80% of the total EEG variability. Two of the components can be physiologically interpreted as the inactivity of the visual area with the closure of the eyes and the activity of the motor area while breathing. Higher principal components carry insignificant amount of information and their composition varies between the patients, therefore, they were omitted from the results.

Most interesting result is a correlation between charateristics of the power spectrum of the first principal component and learning disorder. As the first component is so clearly located above the occipital area, its signal can be interpreted as the signal at the source of the visual area. Its spectral analysis would indicate the frequency transmission/generation properties of the underlying network. As lower frequencies are associated with wide-area network synchronisations, we can speculate that in people with learning disorder the long-range connectivity of the occipital area was disturbed in a manner that prevents wide-area synchronisation. Hence, alpha rhythms are disturbed, which is clealry seen from the results presented in Figure 1, 2a and 2b. One can speculate that the observed alpha rhythms that originate from the occipital area might have a role in organising and storing the collected data into a long-term memory during resting. The disturbance of the rhythms would thus cause learning problems. Only the patient No.5 does not fit the pattern, however, its spectrum is an outlier as well, as it has amost twice the amplitude of the rebound in alpha range than all the rest, and it also has a strong rebound in beta range, suggesting some other reasons that prevent successful learning. Interestingly, the identified pattern is only visible when principal components are analysed while the analysis of the raw EEG signals shows no such pattern, regardless of the choice of the source electrode. PCA takes into account whole EEG recording at once, therefore, it provides more detailed insight into processes of the most active brain areas, especially, because the conductivity specifics of the head and its geometry can spread the signal from its origin over the whole head.

Spontaneous alpha rhytms appear during wakefulness and are best seen with eyes closed and under relaxation, hence regarded as “idle” rhytms. As alpha related oscillations are realted to the stimulus, e.g.: visual stimulus, they can also be interpreted as a manifestation of thalamo or cortico-cortical circuits [24]. Visual and cognitive development are closely related. As our patients were lacking substantial visual acuity problems, one can speculate their changed alpha acitivity as a result of disturbed vision processing which can importantly contribute to the learning problems, they had.

Our research has limitations. Technologies have evolved enormously since our patients were enrolled in the study. MRI has become a standard investigation in neonates. We have now a portable EEG machinery, which allows us to record EEG by the bed-side. The number of patients is small, but as HIE is a relatively rare entity, the number of patients in Slovenia with approx. 18.000 live births/year is also small. Retrospective methodology limits the accuracy of analysis of clinical characteristics of neonates with HIE. As PCA analysis separated our patients into two groups, one with learning problems and one without them, we also plan to perform PCA analysis in adolescents who have no significant health history and are depicted as completely healthy. Electrophysiological studies, including VEP, is warranted.

5 CONCLUSIONS

In the absence of clinical signs that can be detected by the regular screening and pertinent changes seen on MRI, we propose the use of quantitative EEG (qEEG) as a method of detecting specific electrical activity pattern which may contribute to diagnostic information. We can speculate from normal EEG reading and subtle, via qEEG detected changes, that in children with milder forms of HIE and isolated white matter injury, plasticity of the brain can sometimes overcome the reduced volume of brain structures by using alternative network connections to restore network functions, as long as some critical mass of the connections is still available and as long as the key network structure is not damaged. As long as the white matter injury is isolated and not profound, the

motor problems and severe cognitive impairment may be absent. More subtle changes, including the higher order skills, which can include different stimuli, e.g.: vision processing, can clinically manifest as learning problems. Better diagnostic tools, including a detailed EEG analysis, are needed.

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COGNITIVE AND ELECTROPHYSIOLOGICAL ASPECTS OF VISUAL ATTENTION DURING A HIGH-ALTITUDE EXPEDITION

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ABSTRACT

The relationship between prolonged high altitude exposure and cognitive functions was first studied in beginning of the 20th century by Ross A. McFarland. Although the majority of studies conclude that living at extremely high altitudes (more then 5000 meters) leads to significant impairment in cognitve functioning a number of questions still remain open. For example very few studies have attempted to precisely specify how high altitude exposure selectively impairs different cognitive functions (e. g. attention, memory, executive functions). Even a basic mechanism of potential cognitive impairment is currently lacking. In this paper we present the behavioral and electrophysiological data of our experiment which address the relationship between high altitude exposure and visual attention impariment. Six participants who summited Mt. Elbrus (5642 m) were included in the experiment. They performed a visual attention task on three occasions: before the expedition, one week after the expedition and one month after the expedition. Moreover participants also performed a standard clinical visual evoked potential (VEP) task [CITAT] aimed at tracking possible changes in earlier stages of visual information processing. VEPs were additonally measured at a basecamp on the mountain itself (3800 m). During both tasks subjects' EEGs were recorded. The raw EEGs were averaged according to standard ERP (event related potential) protocols to investigae possible mechanisms of high altitude related cognitive changes. Firstly our results showned that latencies of early ERP components (VEP) were significantly affected by high altitude. Specifically the latencies of the N100 and P100 were increased at high altitude and these changes were consistent across all six subjects. One week after descent these latencies returned to pre-expedition levels. Our results also indicate that processing of more complex visual stimuli is affected to a greater degree than the processing of simpler stimuli. Secondly we compared the P300 cognitive ERP component evoked by a visual attention task before and afther the expedition. The results of these measurements have shown that the post-expediton P300 amplitude is decreased in some participants but increased in others . Although it is difficult to draw reliable conclusions about the nature of these diverging changes our results might reflect different individual responses to hypoxic condtions. We provisionally concluded that prolonged high altitude exposure (i) can influence early stages of visual processing, especially processing of complex visual stimuli and it (ii) might also affect higher cognitive processes such as visual attention, selection and inhibition. Additonal studies involving more subjects are however needed to verify these conclusions. Future work might also benefit from increasing the subjects' exposure to hypoxia either by studying them at a higher altitude or prolonging their stay there. Moreover the visual attention task should also be performed during the expedition itself, which was impossible on Mt. Elbrus due to logistical problems. Finally independent experiments controlling for possible confounding variables such as hypothermia and fatique are needed to more precisely assess the isolated contribution of high altitude conditions.

1 HIGH ALTITUDE PHYSIOLOGY

While the fraction of oxygen in the atmosphere remains fairly constant up to the outer troposphere limit (cca. 15.000 m), the partial O_2 pressure drops exponentially with altitude. This leads to a reduction of inspired and alveolar oxygen pressure, associated with a decreased oxygen concentration in the blood (hypoxaemia). Hyperventilation may then occur causing a drop in carbon dioxide levels (hypocapnia)

(Virues-Ortega et al., 2006). These physiological changes can lead to acute mountain sickness and in severe cases also to high altitude pulmonary and/or brain edema. Climbers and travelers who are exposed to high altitude environments report numerous cognitive deficits which can persist for more than a year. Problems with memory, word recall, attention, decision making, problem solving were reported in literature (Virues-Ortega et al., 2004). Although anecdotal evidence on cognitive changes due to high altitude exposure is common, actual experimental data are quite rare.

2 HIGH ALTITUDE AND VISUAL ATTENTION

A number of clinical and non-clinical studies suggest that lower levels of oxygen (hypoxia) can impair visual attention. For example Fletcher (1945) reported about 8 cases of anoxia from nitrous oxide poisoning. Fletcher noted persisting defects of judgement, loss of insight, apathy, indifference, and restlessness, in addition to deficits in attention and memory in all 8 patients. Auerbach and Hodnett (1990) also observed gross impairments in visual processing in patients after hypoxia, involving Balint's syndrome with disturbed visual scanning, poor eye–hand coordination and an inability to integrate visual input. Also cases of patients with ischemic strokes especially in parietal and occipital lobe show us that lack of oxygen coulg substantially impair visual attention.

While clinical trials studying the influence of hypoxia on visual attention are quite numerous, impacts of high altitude exposure on visual attention have rarely been described. Evans and Witt (1966) found that their subjects obtained significantly lower scores on Digit symbol test from the Weschler Adult Intelligence Scale at 4,200 m compared to normoxia. Berry et al. (1989) also report the finding of impairment in the Digit symbol test after exposure to simulated altitudes between 3,000 m and 5,000 m. Stivalet et al. (2000) noted that the results in a task of visual search (detecting a target among a group of distractors) were reduced after 8 hours of moderate hypoxia. Specifically, the authors concluded that hypoxia delayed the serial-attentional processing while the parallel-preattentional remained unaffected. In a field research, Bonnon et al. (2000) monitored the attention performance of one expedition that remained 16 days between 2,000 m and 5,600 m and took 2 more days to climb to 6,440 m and another that stayed 21 days at 6,542 m. They employed a modified version of the Fort Test with two levels of complexity. Attention impairment was only observed in the second expedition. The more difficult the task was, the greater the differences with the control group.

A thorough review of all (clinical and non-clinical) studies revealed that the concept of visual attention originates from very different theoretical frameworks. Some studies even lack any explanation of their presumed theoreteical framework, while the cognitive tasks they applied reflect more than one cognitive processes. From such heterogeneous work it is hard to produce reliable conclusions about the influence of hypoxia on one specific cognitive system – visual attention in our case. Another problem is that the methodology employed in previous studies didn't permit investigation into the underlying neural mechanisms of high altitude related cognitive changes. In an effort to contribute to the already voluminous work in this field from both a theoretical and methodological perspective we decided to use a contemporary model of visual attention and to also try and find correlates to collected behavioral results in neuronal oscillations recorded with the EEG. The chosen theoretical framework postulates two different mechanisms of visual attention: a bottom-up and a top-down process. Top-down control regulates the relative signal strength of different information channels based on immediate goals and past experience. Bottom-up control acts automatically to enhance responses to biologically salient stimuli. While bottom-up attention seems reflexive and automatic, top-down attention appears effortful, slow, and dependent on context (e.g. the number of distractors) (Li et al., 2010).

A number of different tasks derive from that model and our study design enabled us to not just obtain behavioral data but also electrophysiological data. In this way we are able to record participants brain activity during task performance to gain insight into the underlying mechanisms of these cognitive processes.

3 PARTICIPANTS, VISUAL ATTENTION TASK, AND PROCEDURE

PARTICIPANTS

Seven healthy participants (one female) were included in the present study. They were recruited via advertisements as they applied for a mountain expedition and subsequently informed about the nature of our high altitude research. One participants was excluded from the sample since he was not able to be present at all recordings. All participants signed informed written consent before the first experiment.

VISUAL ATTENTION TASK

In each set (repetition) of the task participants were first shown a sample triangle, followed by an array of four triangles among which one (the target) was identical (in color and orientation) to the previous sample triangle. They were then asked to decide as quickly as possible which side of the screen the target triangle was on, Figure 1 *(Visual attention task)*. In the bottom-up (pop-out) condition, the color and orientation of the three distractors differed from that of the target. In the top-down (search) condition, however, only the orientation of the distractors differed from that of the target (Figure 1).

In addition to the visual attention task we also performed a standard checker-board pattern-reversal visual evoked potential (PRVEP) task to elucidate the effects of hypoxia on earlier stages of visual processing.

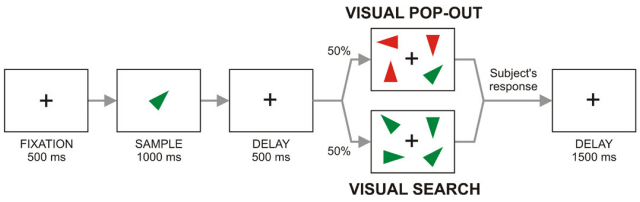

Figure. 1: *Visual attention task*

PROCEDURE

Measurments before and after the expedition were performed at the Laboratory for Cognitive Neuroscience, Department of Neurology, University Medical Centre Ljubljana using a 32 channel digital EEG (BrainAmp, Brain Products GmbH) The first series of measurements took place one week before the expedition. Participants performed the visual attention task first, followed by the VEP task. The procedure was the same on subsequent measurements after the expedition (one week and one month after the expedition). During the expedition we were forced to merely conduct the VEP task due to logistical issues that severely limited the electrical power needed to run our equipment. The measurements on the expedition were performed at the »Barrel huts camp« located at 3900 m which was our unofficial basecamp (Figure 2). Those measurements were performed 3 days after arrival to this altitude. Before these measurements participants had already undertaken two days of acclimatization at altitudes higher than 4400 meters.

Figure. 2: *A participating climber before EEG recording*

4 RESULTS AND DISCUSSION

VEP ANALYSIS

All EEG analyses were performed post-recording (“offline”) with BrainVision Analyzer 2. First we addressed the question of whether PRVEP latencies and amplitudes were affected by high altitude exposure and whether they returned to their initial values after the expedition.While PRVEP amplitudes were not significantly influenced by the climb the latencies of some components, especially the N1 (N100) and P1 (P100) were increased at high altitude, Figure 3 *(PRVEP results)*. The N1 component peaked some 10 ms (8 ms – 14 ms) later compared to baseline. The P1 peak was prolonged for about 8 ms (6 ms – 12 ms). These differences were consistent across all subjects and highly significant ($p<0.01$) even with our small sample of 6 subjects. In both cases the peak latencies returned to their initial states one week after descent. These findings were independent of electrode position but more pronounced with smaller checker-board squares (15 arc minutes) than with large ones (1 arc degree) which could indicate that the processing of more complex visual stimuli is affected to a greater degree than the processing of simpler stimuli.

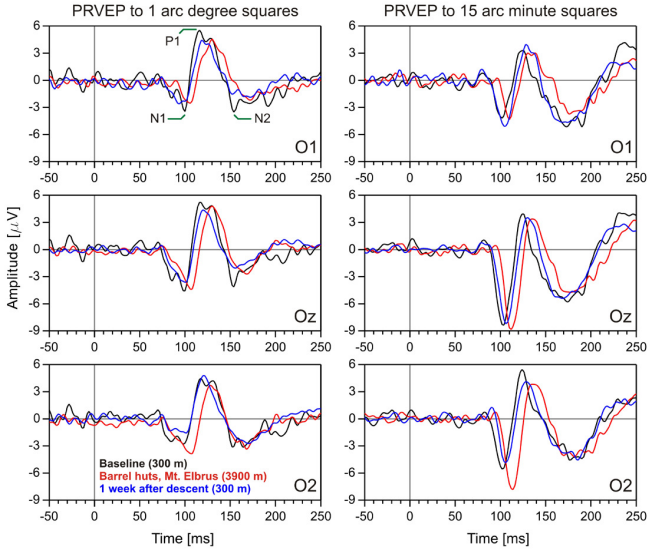

Figure. 3: *Pattern-reversal visual evoked potential (PR*VEP) results

P300 ANALYSIS

Figure 4 *(Visual attention task results, topographies show times of individual peak P3 amplitudes, time in ms after display of triangle array is indicated)* shows peak topographiesof the P3 (P300) ERP for the visual search and pop-out condition for each individual. In 4 individuals (Subjects 1-4) the P3 is, somewhat counter-intuitively, increased after the expedition. In Subjects 5 and 6 the P3 was reduced after descent.These results are individually consistent across both task variants (pop-out and search). Due to the small number of subjects it is difficult to deduce reliable conclusions about the nature of these differential P3 changes under hypoxic conditions but they may point to different coping mechanisms present in each individual and/or different “reserve” capacities for visual attention processing in conditions of hypoxic stress.

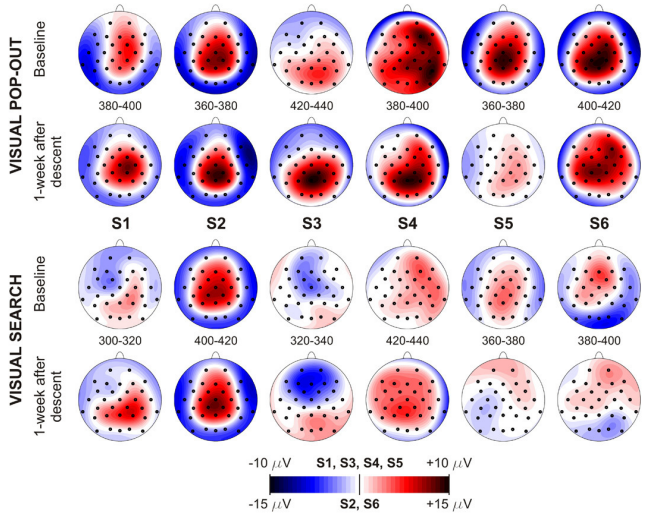

Figure. *4: Visual attention task results*

5. CONCLUSIONS

We concluded that prolonged high altitude exposure (i) can influence early stages of visual processing, especially processing of complex visual stimuli and it (ii) might also affect higher cognitive processes such as visual attention, selection and inhibition. More studies should be performed to confirm our findings. In future work it would be informative to obtain such measurements also at higher altitudes. Moreover the visual attention task should be also applied during the actual expedition, which was impossible on Mt. Elbrus due technical problems. Finally independent experiments controlling for specific variables (hypothermia, fatique) are needed to assess the individual contribution of a single variable.

We will be able to expand on these preliminary findings after our next expedition to Muztagh Ata (7546 m) which will take place between 3rd and 27th of August 2012. Our goal is to connect individual ERPresults with other psychological or physiological variables to try and better understand the dynamics of the P3 response to hypoxic conditions.

6. ACKNOWLEDMENTS

We hereby thank the administrative and technical staff of Brain Products GmbH which gave us access to their EEG equipment (BrainAmp 32 channel EEG amplifier, ActiCap active electrode system and the MOVE wireless add-on) to perform these measurements. This study would not have been possible withouth the versatility and ease of EEG recording that this equipment offered.

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CONTRALATERAL DELAY ACTIVITY IN VISUAL WORKING MEMORY RESEARCH

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ABSTRACT

Working memory (WM) refers to a cognitive ability of maintaining and manipulating information over brief periods of time. WM is thought to be comprised of different subcomponents and subserved by dynamic interactions between different brain regions. Some of the possible subcomponents like goal maintenance, content updating and interference control are both critical for optimal performance and likely compromised in normal aging, patients with schizophrenia and neurodegenerative diseases. Due to its temporal resolution, electroencephalograhy (EEG) seems to be well suited for observing the temporal dynamics of activity during working memory processes. An ERP component, contralateral delay activity (CDA) is a sustained contralateral negativity present during retention period of working memory task, which both depends on the overall goal maintenance capacities of the individual and closely follows temporary changes in task conditions, like updating of material maintained or presence of distracting stimuli. In research that will be presented at the meeting we used a visual working memory task to study CDA during different kinds of changing working memory conditions and to explore how changes in CDA relate to pharmacological manipulations of the dopamine system.

1 INTRODUCTION

Working memory (WM) is a cognitive concept that refers to the short term storage of information and the set of processes that keep this information active and usable (1). Defined in this way, it represents a basic cognitive system, important for numerous other cognitive functions like comprehension, reasoning, planning, spatial processing etc. Present view on this matter has evolved from research in cognitive psychology, using behavioral studies in healthy volunteers, while first data on the neuroanatomical correlates came from animal studies, which identified the activity of neurons in prefrontal cortex as related to working memory processes. Later on a number of functional neuroimaging and electrophysiological studies were done in healthy and ill subjects.

WM is thought to be comprised of different subcomponents and subserved by dynamic interactions between different brain regions. One of the best known theoretical models of working memory is Baddeley's model (Figure 1), which was developed based on observations from a number of behavioral studies in healthy subjects (2). This model is meant to account for different working memory functions, from temporary maintenance of one stimulus to manipulation of multiple types of information.

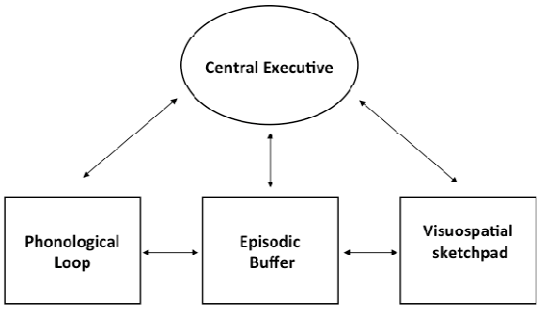

Figure 1. Baddeley's working memory model.

Baddeley proposes that there are capacity limited subsystems for processing and integration of different kinds of information, like verbal, visual and spatial. Subsystems have a double function, pasive storage and active maintenance. Information is thought to enter memory store, where it is subject to rapid decay if it is not actively maintained. Central executive functions as a kind of a multipurpose modul, which coordinates the maintenance of information in subsystems and performs different other executive processes like goal maintenance, content updating or interference control, which are all critical for optimal performance and likely compromised in normal aging, patients with schizophrenia and neurodegenerative diseases

(3). Goal maintenance and updating refer to active maintenance and manipulation of information in WM, which includes task goals in addition to the specific momentary information represented in WM stores. Conversely, interference control represents mechanisms important for preserving the maintained set from other distracting stimuli, which may be irrelevant for the task.

2 FUNCTIONAL NEUROIMAGING OF WORKING MEMORY

Functional neuroimaging studies consistently show a number of different brain regions activated in working memory tasks (Figure 2). It is likely that these regions represent a functional network, which is activated to different levels according to the complexity of specific working memory task in question.

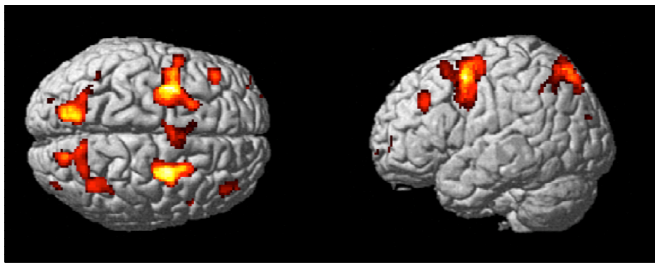

Figure 2. Some of the brain areas active in working memory tasks.

Regions usually found active are parietal, premotor and prefrontal areas together with subcortical regions and cerebellum (4). In relation to Baddeley's model, posterior regions are probably more involved in pasive storage processes, which make part of active rehearsal loops. Left parietal cortex is usually involved in verbal tasks, right parietal cortex in spatial. With higher memory load, activity in parietal areas becomes bilateral, which was proposed to signify the overflow of processing or employment of additional strategies or processes. Activity in prefrontal cortex has been observed either in left or right hemisfere or bilaterally and is related to active maintenance and other executive processes. This prefrontal acitivity was shown to be specific, not just a consequence of task difficulty, but there is less agreement regarding the specific functions of different prefrontal areas. There is some evidence that left hemisfere is preferentially involved in verbal and object tasks and right hemisfere in spatial tasks (5).

3 ELECTROPHYSIOLOGICAL RESEARCH OF WORKING MEMORY

Electrophysiological methods are relatively better suited to explore questions on overall network dynamics because of their higher temporal and lower spatial resolution in comparison with functional neuroimaging. Different major methods in cognitive electrophysiology, like event-related potentials, oscillatory dynamics and connectivity in functional networks have been used in working memory research. In recent years important discovery was made in the area of visual working memory. Contralateral delay activity (CDA) is an ERP component, sustained contralateral negativity which is present during retention periods of working memory tasks (6, 7). It depends on the overall maintenance capacities of the individual and closely follows temporary changes in task conditions, like updating of material maintained or presence of distracting stimuli. During an individual trial of working memory task subjects direct their attention to only one half of the visual field and try to retain only visual stimuli shown there. In this manner the brain activity in the contralateral parietal and temporal areas is larger then ipsilateral activity and the difference between them in the retention period of the task is labeled as contralateral delay activity (Figure 3).

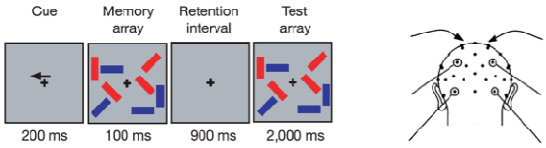

Figure 3. Example of a visual working memory task used to obtain contralateral delay activity.

As mentioned, this ERP component was shown to be very sensitive to maintenance capacities of the individual and temporal changes in working memory task conditions and is thus well suited to explore many unanswered questions on working memory processes on the level of the brain activity. The example in Figure 4 shows a normal ability of a healthy individual to filter distracting stimuli during a visual working memory task.

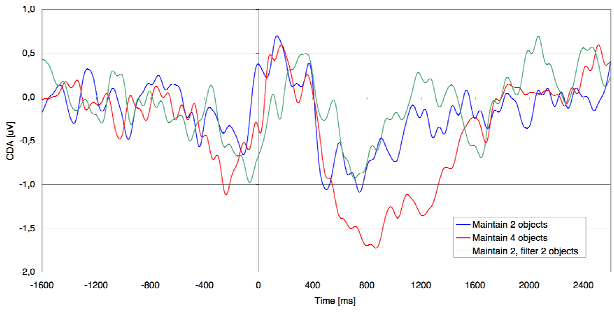

Figure 4. Contralateral delay activity time course in a healthy subject in three different experimental conditions.

4 RELEVANCE OF CDA FOR WORKING MEMORY IMPAIRMENTS IN BRAIN DISEASES

Working memory performance depends on the activity in network of brain areas mentioned above. Dorsolateral prefrontal cortex, its connections to basal ganglia and the modulatory influence of dopamine play an important mediating role in the network. Brain disorders like Parkinson's disease or schizophrenia, which affect different parts of this network, provide pathological models to study working memory processes. Better understanding of working memory impairments in these and other disorders can on the other hand lead to major improvements in their treatment, because it was shown that deficits in working memory and related cognitive abilities can represent the main determinants of overall functioning of the patients.

In schizophrenia, cognitive impairments are present together with other more obvious psychopathological symptoms. They are probably related to basic disturbances in brain function and could be causally related to other symptoms of this disorder (8). Specifically impaired are executive functions, attention, working memory and verbal memory (9). Pathophysiological mechanisms of schizophrenia have not been adequately explained so far. Neurobiological theories propose a disturbance in function of a large brain network, comprised of frontal, temporal, parietal, subcortical and cerebellar structures, while the primary cause could be a diffuse structural impairment on the level of synapses. (10, 11). Cognitive impairments are in this view seen as a signature of this malfunction and also as the primary reason for pervasive problems in everyday functioning of the patients (9).

Main pathophysiological cause of Parkinson's disease is a degeneration in cortico-subcortical connections between basal ganglia and different parts of the cortex which lead to lowering of dopamine levels and changes in dopaminergic modulation of motor, cognitive and affective functions.
Charateristic symptoms of the disease are tremor, bradykinesia, rigidity and disturbed postural reflexes. In recent years research has shown the presence of disturbances in different cognitive functions, which can be subtle at the beginning of the disease but progress in later stages . These cognitive abilities are dependent on intact functioning of cortico-subcortical connections outside the motor system, like dorsolateral prefrontal, lateral orbitofrontal and anterior cingulate loops. Studies show impairments in working memory and executive functions, especially planning, inhibition and regulation of goal oriented activity. (12, 13, 14). Impairments in memory functions have been observed too, which probably reflect deficient prefrontal functions like use of strategies and organization of free recall, temporal and visuospatial dimensions of tasks (14).

Similarly useful to understand brain influences on working memory are pharmacological modulations of dopamine activity. Studies in healthy volunteers have confirmed the influence of dopamine on executive functions, attention and working memory (15, 16, 17). Some of the data points to important role of D1 receptors for visual working memory. Application of pergolide, a D1/D2 agonist shows beneficial influence on visual working memory performance, while bromocriptine, a selective D2 agonist, has no effect (18). Pergolide improves reaction times in subjects with high working memory capacity, which is related to higher activity in prefrontal and parietal cortex. Direct stimulation with l-dopa also shows benefical effect on learning ability (19), while depletion of dopamine levels in young healthy volunteers impairs their executive functions (20). Similar to these findings amisulpride and haloperidol, both antipsychotics and D receptor antagonists, impair executive functions and speed of processing in a dose dependent fashion (17, 21).

5 CONCLUSION

Contralateral delay activity is a relatively novel ERP component, related to working memory performance in healthy and ill subjects (7, 22). At the meeting we will present results from some of our ongoing studies exploring how CDA relates to changing working memory conditions and pharmacological manipulations of the dopamine system.

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QUANTUM–NEURAL BACKGROUND OF CONSCIOUS VISUAL PERCEPTION

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The lecture will present an integrated model of conscious image- and object-perception, based mainly on the Holonomic Brain Theory by Karl H. Pribram (1991). The new aspect of this comprehensive model is, roughly, that *visual mind is neural, but experiencing its "mental images" consciously involves quantum processing*. Visual brain is thus presented as quantum –neural: brain acts as a neural pre-processor for ultimate quantum image processing, i.e. *neurally pre-processed visual data enter as inputs into a quantum network core-process similar to holography*. Conscious visual experience will be discussed. Why quantum substrate is hypothetically needed for becoming conscious of an image will be emphasized (e.g., binding problem, efficiency). Because of model's complexity, the lecture will focus on cognitive-neuroscientific aspects of vision, but this abstract describes some further details which are fully presented in a book (Peruš & Loo, 2011).

Founded on extensive studies of experimental and computational literature, and on authors' experience with neural-net simulations, the model is partly descriptive and partly computer-implementable (a set of "algorithms" emulating information processing at various stages), and model's "quantum" core itself which has been successfully computer-simulated (Peruš at al., 2005). Image processing is presented as largely spectral, holography-like, parallel-distributed processing, mainly along the retino-geniculo-striate pathway and in the striate cortex (V1), which provides representations for subsequent object perception in extrastiate cortices. Tay et al. (2010) and others have henceforth computationally realized appearance-based object perception, not always being able to fully follow the biologically-plausible model of Peruš & Loo (2011). However, the efficient quantum–neural collaboration has been nicely demonstrated in real-life visual tasks. Although the *biological* interaction of neural nets and quantum fields is not clear yet (e.g., in microtubules, presynaptic vesicular grids?), these efficient neural-plus-quantum net simulations indicate that brain may also use similar ways.

Trying to explain how we become conscious of the results of image processing, quantum and subcellular micro-processes are presented, but also essentials of macro neural processing in the extrastriate and infero-temporal cortices. In the context of conscious image processing, data on the following processes of visual perception are considered in the model: sensation, figure/ground segmentation, object perception / recognition, visual memory (and retinotopic mapping onto cortex), perceptual binding, a sketch of color processing, visual attention and conscious experience.

Gestalt formation is implemented, in the model, in the attractor dynamics of brain networks like the neural, dendritic and quantum nets. Attractors can migrate between different areas and scale-levels. Special attention is devoted to the holonomic dynamics of slow wave potentials of the electric polarization fields inside the webs of criss-crossed dendrites and their membranes, because they are considered as the neural correlates of conscious experience by the holonomic theory. Since the holonomic theory proposes perceptual convolutions using the Gabor-wavelet-like receptive-field profiles, which maximally preserve information ("infomax") along the visual pathway, the "infomax" phase-processing of higher-order statistics is discussed as essential. It is also shown to be necessary for detection of edges.

The following relevant parallel-distributed processing models are considered, compared and roughly integrated (where possible): the Holonomic Brain Theory, "infomax"-models like Independent Component Analysis and the sparseness-maximization network (by Bell, Sejnowski, Olshausen, Field, and others), MacLennan's dendritic field computing, quantum neurodynamics by Jibu & Yasue, Holographic Neural Technology by J. Sutherland, and quantum associative network by Peruš. Biologically plausible elements of these models are

extracted in order to achieve plausible integration into our comprehensive bio-vision model.

Three sorts of image representation are proposed to be used in the cortex: 1. the Gabor wavelets, rooted in dendritic webs, seem to be used for associative processes underlying visual cognition; 2. their Gabor coefficients represent neural-net's sparse codes which serve for automatic processing; 3. the spatial image, reconstructed in the extrastriate area, is those which is then consciously perceived "with shapes and colors". Because the third image representation is even *perceptually projected back into external space, so that it coincides precisely with the original object*, we propose that *quantum holographic process is necessary*, since neural nets cannot realize that alone.

As the core of image processing in V1, essentially modulated by various (sub)neuronal processes, holography-like implementation of pattern recognition and content-addressable associative memory in an original model called Quantum Associative Network is presented. The quantum interfering waves are Gabor wavelets. The so-called Hebb rule is generalized into a form named the phase-Hebb rule, since it mediates oscillatory (phase) coupling or coherence phenomena. The Green-function propagator, which has a phase-Hebb structure, is harnessed for the quantum memory-storage and associations. The quantum wave-function "collapse" is proposed as the dynamic correlate of image recognition, based on selective recall of the most similar memory "traces", which results in pictorial conscious experience.

In sum, our computational model has realized brain-like visual processing using quantum-implementable Gabor-wavelet encoding of images. Although the qualia problem remains open, we have made a step forward, showing new possibilities for neuroscience.

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SUPPRESSION OF μ-RHYTHM AS A TRACE OF MIRROR NEURON SYSTEM

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ABSTRACT

In an EEG experiment we measured μ-rhythm suppression in subjects that performed a motor action or just viewed it. In both conditions μ-rhythm has been observed. However, hemispheric differences proved not to be statistically significant in viewing condition (left vs. right hand). This corroborates the claim that mirror neurons do not encode just imitation, but the meaning, purpose or concept of the action.

1. INTRODUCTION

Mirror neurons are usually defined as a particular class of visuomotor neurons or as a class of multimodal association neurons in premotor and posterior parietal cortex that increase activity not only during action execution, but also while observing or hearing another individual performing the same or similar action. They were discovered by accident in macaques, in the F5 region considered to be monkey's analogue of Broca's region (1). They have a considerable role in understanding the action of others and are therefore vital for social organization (2). Recently, the mirror-neurons have been related to theory of mind and language (3). The role of mirror-neurons in language has been discussed due to the fact that mirror-neurons seem not to encode simple imitation of movement without the access to the meaning of the movement (e.g. grasping a cup of tea on a table would trigger a different neural reaction to exactly the same movement, but without the cup, (4). In short, it seems that mirror-neurons turn a sequence of movements into a concept or a sequence of movements into a sequence of concepts (or, roughly, syntax). This is, in a nutshell, what the action theory of language claims.

2. SUPPRESSION OF THE μ-RHYTHM

The μ-rhythm is an EEG rhythm with typical oscillations at 8-13 Hz. It can be recorded over human sensorimotor cortex and its duration is usually brief (from 0,5 to 2 seconds). It is similar to α-rhythm, but with more anterior focus. It was discovered in the 1959 (5) and was also known as "central", "Rolandic" or "wicket" (for an overview, v. (6)). Similarly to α-rhythm it is considered to be a sign of the idling state of the cortex. Therefore, desynchronization, of μ-rhythm, i.e. its suppression is functionally related to the activation of the cortical network, as its synchronization is a correlate of its deactivation. Since the suppression of μ-rhythm occurs both when the subject performs an action and when (s)he looks at it, it is considered that μ-rhythm is a signature of the mirror neuron system.

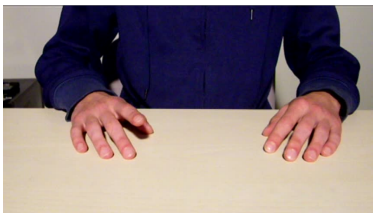
In this study we used a design similar to Oberman et al. (7) where suppression of μ-rhythm was measured for grasping observation. Grasping was performed either by robot or by human hand. While the same robot movement occurred twice, grasping an object and without an object, human hand acted "volitionally" (grasping an object) and "nonvolitionally", attached to a string like a marionette. Power density was measured; each condition was compared to the "rest" condition (white noise screen) as a $\log\frac{condition}{rest}$; for statistical significance of the suppression the log ratio (expected to be a negative number if μ-rhythm is stronger at rest) was compared to 0.

Volitional movement showed stronger μ-suppression than nonvolitional, while robot grasping an object elicited stronger μ-rhythm suppression if the object was present.

Generally, this research group focus on the differences between understanding human and robot behavior, as well as the role of mirror neurons in autistic persons (8). In our study we used the same kind of analysis (t-test performed on log ratios in different conditions), but with a slightly different question: can we find hemispheric differences in viewing an action or in imitating it; if imitation elicits lateralized brain activity (i.e. larger suppression over the side contralateral to the movement), does the same apply to viewing?

3. MATERIALS AND METHODS

EEG signal has been recorded in 23 participants, University of Zagreb students, age 20-23. All of them were right-handed with no history of neurological problems. They were put in front of a computer screen and told to watch a movie showing a person tapping with his index finger (Picture 1) or, when indicated, to perform the same action as in the movie with the hand indicated by an arrow.

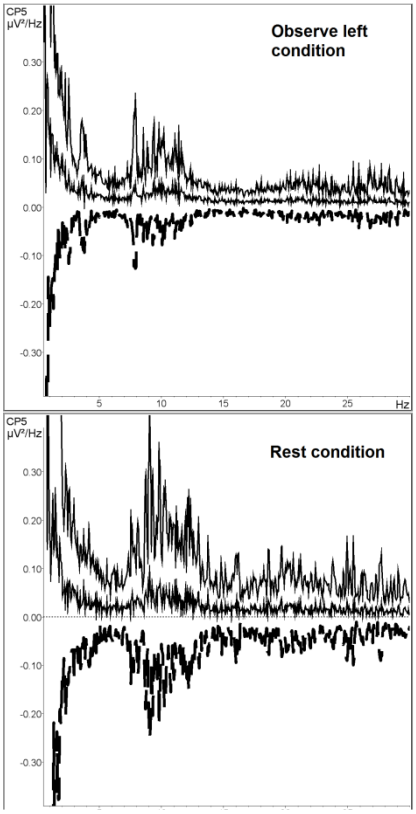


Picture 1. A snapshot from the video (right hand tapping)

Each video lasted for 15 seconds and was repeated 10 times, as well as the arrows and the rest video. The "rest" conditions the "observe-the-tapping" condition and the "tapping" condition were presented in random order. The EEG signal was recorded with the Brain Products QuickAmp128 amplifier and a 32-channel active electrode cap with a standard 10-10 electrode positions. The signal was recorded with the average reference and the impedance was kept under 10 kΩ. Upon recording the signal was filtered with the low-pass filter set at 30 Hz and the FFT was performed for each condition. Power density in the 8-13 Hz was calculated and the values exported to a statistical program. T-tests were performed on the log ratios, as mentioned above.

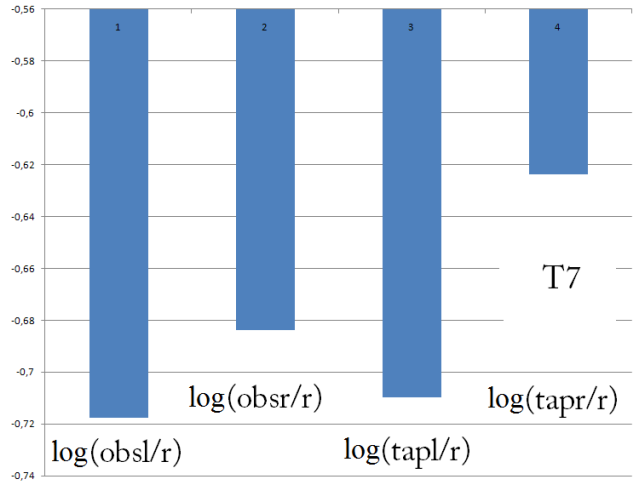
4. **RESULTS**

The results showed the greatest μ-rhythm suppression over central, centro-parietal and temporal electrodes (left: C3, C7, Cp5, T7, and right: C4, C8, Cp6 and T8). The example of the raw data is given for the "observe" and the "rest" condition on Picture 2.



Picture 2. *Power density in "observe" and "rest" conditions. In this case the action was performed by the left hand of the actor, therefore, it appeared on the right side of the screen; The Cp5 (left) electrode is, therefore, contralateral.*

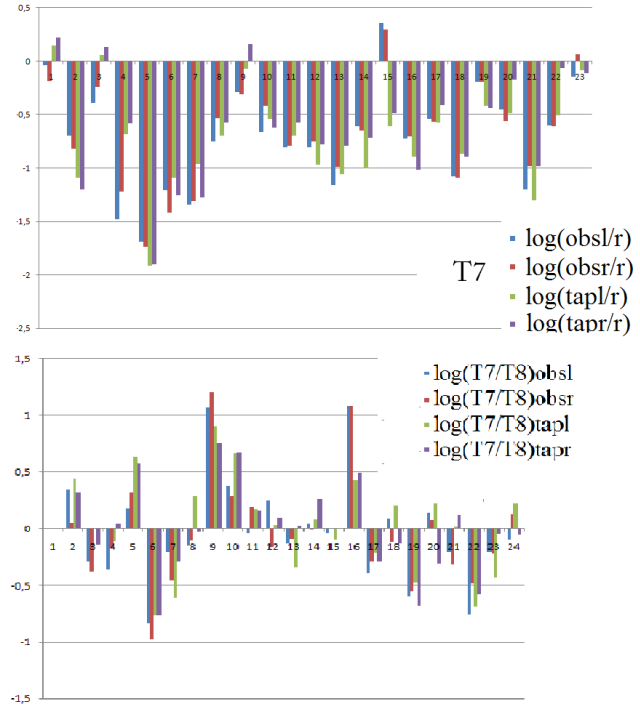
The amount of suppression was statistically significant both for "tapping" condition and for "observe-the-tapping" condition, as well as ipsilaterally and contralaterally with the p<0,001). The results are graphically shown on Picture 3. Similar results were obtained on all relevant electrodes.



Picture 3. *Suppression of the μ-rythm, as obtained on T7. Obsl - observing the left hand tapping, Obsr - observing the right hand tapping; tapr - tapping with the right hand, tapl - tapping with the left hand; r - rest*

It can be noticed that the suppression is, oddly, stronger if the activity is ipsilateral - T7 is the left temporal electrode. However, the observed left handed tapping is presented on the right side of the screen, therefore, if the suppression is larger on the left, it seems that the participants are looking at the screen as if they are looking their own mirror reflection, i.e. the larger left suppression corresponds to the observing the right hand on the left side of the screen. This is in accordance with other findings (9).

In order to analyze the lateralization of the μ-rhythm suppression a log ratios between ipsi- and contralateral sides were calculated. Namely, if the mirror neuron activity is lateralized with respect to the observed or performed action, the ipsilateral side electrodes should show activity similar to the rest condition. However, for both "observe-the-tapping" and "tapping" condition when left side and right side electrodes are compared in the same condition (and not when the same electrode is compared with its value in the rest condition) the results are far from significant (for e.g. C3/C4 electrodes, tapping with the left hand cond. $t(22)=0,28$, $p=0,78$, for observing left hand tapping cond. $t(22)=-0,32$, $p=0,75$). This is mainly due to huge individual differences when contralateral electrodes are compared. Individual data for all conditions/rest are shown on Picture 4.



Picture 4. *Individual results for ratios between conditions (observe or tap/rest, upper graph) and between left and right electrodes in the same condition (lower graph).*

5. DISCUSSION

To a large extent the experiment replicates the results obtained in many similar experiments. Usually, these experiments include object grasping and, interestingly, the results are not affected by a change in distance, angle or the choice of object, but with the meaning or intention of the action (9). In this experiment the intention was to obtain as much hemispheric differences as possible; the choice of left and right index finger tapping was based on the representation of hand on the somatosensory and motor cortex. However, hemispheric differences have not been obtained, i.e. the μ-rhythm suppression occurred over both hemispheres regardless of the condition side as shown on the upper graph on Picture 4 where all conditions, left and right tapping and observing elicited μ-rhythm suppression in the majority of subjects. In addition, individual differences are large when contralateral electrodes are compared (lower graph); in nearly a half of the participants the suppression is larger over the "wrong" hemisphere (namely, one could expect that log (T7/T8) is negative for the left hand tapping or observing (on the right side of the screen) and positive for the right hand tapping or observing in the same individual. This was not obtained. These results can be interpreted in line with the claim that mirror neurons do not encode mechanical imitation of an action, as well as the action itself, but encode more abstract aspect of it, a sort of concept of tapping. If so, the absence of clear hemispheric differences is not odd, a concept of grasping or tapping seems quite natural if a meaning or intention of the action is to be encoded, a concept of left-hand-grasping would be odd as a concept required for understanding the same action since a different concept would be required for righ-hand-grasping and no generalization would be possible.

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AUTOMATIC DETECTION OF EMOTION

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ABSTRACT

In this paper we present an overview of emotion detection methods with different modalities (input sources). We then present a method, developed in our group, for detecting emotions from videos of facial expressions.

1 INTRODUCTION

This paper addresses the automatic acquisition of users' emotion for various applications, such as labeling content in recommender systems as presented in (Tkalčič, 2012). A review of related literature (Picard, 2005, Zeng, 2009, Vinciarelli, 2009) reveals that several modalities (e.g. video, audio, physiology etc.) can be used to effectively detect the emotive state of a user. However, in the concrete case of a multimedia content based recommender (CBR) system (i.e. the detection of emotion during the user's consumption of a content item) the most appropriate modality is video.

The problem of automatic detection of emotive responses using video streams of users' faces has been addressed several times in the past years (see the survey (Zeng2009)). These attempts focused on the detection of emotions from databases of video clips of users acquired in controlled environments with deliberately displayed and exaggerated face expressions (e.g. the Kanade-Cohn database (Cohn, 2000)) and usually yielded high detection accuracy. For example, (Wang, 2008) achieved accuracy values up tp 90\%. However, although it appears that emotion detection from face videos can be performed with high accuracy, recent research performed on spontaneous facial expressions (as surveyed by (Zeng, 2009) report lower accuracy. For example, (Bartlett, 2006), report a drop of the average accuracy from 86 \% to 65 \% when detecting face expressions in posed and spontaneous datasets.

In this paper we present the results of the comparison of an emotion detection technique on a posed database (the Kanade-Cohn database (Cohn, 2000) and on a spontaneous database (the LDOS-PerAff-1 database (Tkalčič, 2012, LDOS))

2 MODELS OF EMOTIONS

In order to be able to detect emotions automatically using computers, we first need to be able to describe emotions in a suitable way. For computer processing we have two options: (i) numerical or (ii) discrete-class characterization of emotions. Hence, among several models of emotions developed, the universal emotion model and the valence-arousal-dominance model are the most suitable for the purpose of automatic detection.

Figure 1 The six basic emotions as proposed by (Ekman, 1999)

The universal emotions model is the consolidation of the work started by (Darwin, 1872) and is based on the observable features of the face. It describes each emotive state as a distinct state or a combination of distinct universal emotions. There is no unanimity as to which are the universal emotions. We will use the emotions proposed by (Ekman, 1999), who defined a list of seven universal emotions, which have different observable facial features (neutral, anger, disgust, fear, happiness, sadness and surprise) and eleven additional universal emotions that do not exhibit facial-muscle changes.

On the other hand, the dimensional model, which was introduced by (Mehrabian, 1996) as the pleasure-arousal-dominance (PAD) space, describes each emotive state as a point in a three-dimensional space. In this paper we will refer to the dimensional model as the valence-arousal-dominance (VAD) space because our work relies on the

dataset provided by (Lang, 2005), which uses that terminology. The dimensions of the space are valence (accounts for the pleasantness of the emotion), arousal (accounts for the strength of the emotion) and dominance (describes whether we are in control of our emotions or not).

3 OVERVIEW OF EMOTION DETECTION TECHNIQUES

Generally the approach taken in related work in automatic detection of emotions from video clips of users' faces is composed of three stages: (i) a preprocessing stage, (ii) the low level features extraction stage and (iii) the classification stage. Related work differ mostly in the last two stages.

In the works of (Bartlett, 2006, Wang, 2008, Zhi, 2008) , the authors used Gabor wavelets based features for emotion detection. Beside these, which are mostly used, (Zhi, 2008) report the usage of other facial features in related work: active appearance models (AAM), action units, various facial points and motion units, Haar based features and textures.

Various classification schemes were used successfully in video emotion detection. In (Bartlett, 2006), the authors employed both the Support Vector Machine (SVM) and AdaBoost classifiers. In (Zhi, 2008), the authors used the k-nearest neighbours (k-NN) algorithm. Before using the classifier they performed a dimensionality reduction step using the locality preserving projection (LPP) technique. In their work (Wang, 2008) compared four classifiers: the Gaussian Mixture Model (GMM), the k-NN, neural networks (NN) and Fisher's Linear Discriminant Analysis (FLDA). The latter turned out to yield the best performance. The survey (Zeng, 2009) reports the use of other classifiers like the C4.5, Bayes Net and rule based classifiers.

4 EMOTION DETECTION FROM VIDEOS OF FACIAL EXPRESSIONS

The emotion detection procedure involved three stages: (i) pre processing, (ii) low level feature extraction and (iii) emotion detection.

4.1 Datasets

We performed emotion detection on two different datasets: the Kanade Cohn database (Cohn, 2000) and the LDOS-PerAff-1 database (Tkalčič, 2012, LDOS).

The Kanade Cohn database is a set of videoclips of posed emotions. All the subjects are shot frontally with good illumination and central position. Each videoclip represents a user performing the transition from a neutral face expression to the full face expression of the posed emotion. The videoclips are annotated with action units (AU see (Ekman, 1996)) which we mapped into 7 basic emotions (joy, fear, anger, surprise, disgust, sadness and unknown). In total we used a subset of the database composed of 1116 different frames from 186 videoclips of 50 users posing the 7 emotions.

The LDOS-PerAff-1 database is a set of videoclips representing users having spontaneous emotions elicited by visual stimuli. The videoclips show a continuous shifting among different emotions of a single user. The emotions are annotated with the average and standard deviations of the VAD values of the emotions induced by the visual stimuli. We mapped the average VAD values into 8 quadrants by discriminating the single VAD values into positive/negative. As two of these quadrants did not have any items the total number of different emotions was 6.

4.2 Preprocessing stage

In the pre processing stage we extracted and registered the faces from the video frames to allow precise low level feature extraction. This procedure was repeated for all the frame. We used the eye tracker developed by (Valenti, 2009) to extract the locations of the eyes. Based on the locations of the eyes we registered the face by rotating the image to the horizontal position and scaling the image to fixed interocular distance.

4.3 Low level feature extraction

The detection of emotions from frames in a video stream was performed by comparing the current video frame of the user's face to a neutral face expression. The calculation of the neutral face expression frame was performed separately for the two databases.

The Kanade Cohn database is composed of distinct video clips of posed emotive expressions. Each video clip is a sequence of frames depicting the user's face from a neutral emotive state (first frame of the sequence) to the extreme expression (last frame). For each user and emotion we took the first frame as the neutral face frame.

The LDOS-PerAff-1 database is an ongoing video stream of users consuming different images. Each image is the emotion elicitation stimulus and the content item at the same time. As the stimuli images are displayed without interruption, the video streams of the users depict continuous changes in the users' emotive responses. In most cases the transitions from one emotion to another do not pass through a neutral emotion. Since we can not know which face frame to take as a neutral we had to derive it from all the frames available. All the frames of the observed user, after being registrated, were averaged to yield the neutral frame. This method is applicable when we have a non supervised video stream of a user with different face expressions. In contrast with the Kanade Cohn dataset where we had a neutral frame for each

user and emotion in the LDOS-PerAff-1 database the neutral frame is linked only to the observed user.

The low level features used in the proposed method were drawn from the images filtered by a Gabor filter bank. Gabor filtering involves a set of spatially and frequency tuned filters that decompose the frame into a set of filtered images. We used a bank of Gabor filters of 6 different orientation and 4 different spatial sub-bands which yielded a total of 24 Gabor filtered images per frame. At this point both the neutral expression frame and the observed frame were decomposed to Gabor images. For each Gabor filtered image we calculated the first two statistical moments (average and standard deviation) of the luminance across the whole Gabor image. This yielded two feature vectors. Both feature vectors were combined in the final feature vector by calculating the differences and quotients of both frames' features, which has the total length of 240 elements.The vector division was done on a per element basis.

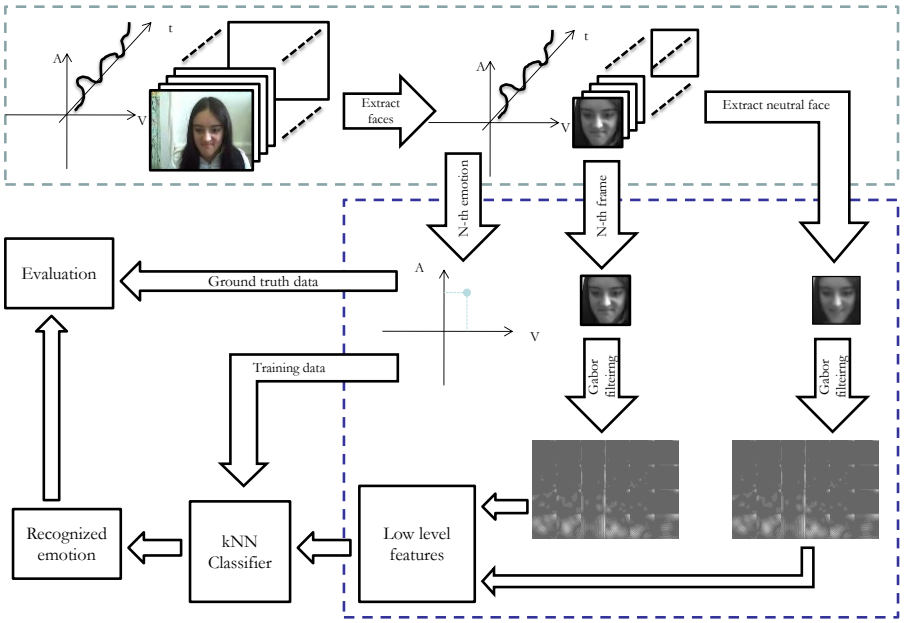

Figure 2 Overview of the emotion detection algorithm

4.4 Emotion detection

The emotion detection was done by a k-NN algorithm after performing dimensionality reduction using the principal component analysis (PCA). For each feature vector the reduction was done from the initial 240 features to 72 features for the Kanade Cohn dataset and to 80 features for the LDOS-PerAff-1 dataset that described 95% of the variance of the raw feature vectors. Following the approach of (Zhi, 2008), who took the last eight frames in a video sequence, we took the last five frames of each video sequence corresponding to the response of a user to a specific emotion stimulus under the assumption that these represent the most extreme facial expressions.

Each frame from the LDOS-PerAff-1 dataset was labeled with a six tuple of the induced emotion. The six tuple was composed of scalar values representing the first two statistical moments in the VAD space. However, for our purposes we opted for a coarser set of emotional classes. We divided the whole VAD space into 8 subspaces by thresholding each of the three mean values *v*, *a* and *d*. We thus gained 8 rough classes. Among these only 6 classes actually contained any items at all so we reduced the emotion detection problem to a classification into 6 distinct classes problem.

4.5 Evaluation methodology

In both cases (posed and spontaneous dataset) we were detecting distinct emotion classes. Thus we used the confusion matrix as the base for assessing the performance of emotion detection. From the confusion matrix we further derived four scalar performance measures: precision, recall, F-measure and accuracy as defined by (Herlocker, 2004).

The feature vectors were randomly divided into the training and test set where the training set represented 70 % and the test set represented 30 % of all feature vectors. We used 1115 frames from the Kanade Cohn dataset (780 for training) and 7787 frames from the LDOS-PerAff-1 dataset (5450 for training).

5 Results and Discussion

We achieved an overall accuracy of 92% on the Kanade Cohn database and 62% on the LDOS PerAff-1 database which is in line with the results reported by (Bartlett, 2006), who achieved 86% and 65% detection accuracy of rough face expressions in posed and spontaneous datasets respectively. The confusion matrices for the posed (Kanade Cohn) and spontaneous (LDOS-PerAff-1) datasets are reported in the tables below.

classified as	fear	surprise	sadness	anger	disgust	happyness	unknown
fear	115	7	1	0	5	13	1
surprise	6	165	4	0	4	2	2
sadness	0	0	159	3	3	0	0
anger	1	0	8	101	8	3	1
disgust	0	0	1	2	103	2	4
happyness	2	2	1	0	0	196	0
unknown	0	0	2	2	1	0	75

Figure 3 Confusion matrix for the Cohn-Kanade dataset

classified as	1	2	3	4	5	6
1	15	3	0	4	5	6
2	4	456	18	19	107	48
3	0	57	98	10	51	29
4	2	42	3	156	41	13
5	2	101	19	28	477	64
6	1	82	11	21	104	240

Figure 4 confusion matrix for the LDOS-PerAff-1 dataset

We identified three main reasons why the accuracy of emotion detection drops so dramatically in spontaneous expressions: (i) weak supervision in learning, (ii) non optimal video acquisition and (iii) non extreme facial expressions.

6 CONCLUSION

In this paper we have given an overview of existing methods for the detection of emotions from different modalities. We also presented a method, developed in our group, for the detection of emotions from videos of facial expressions. The results have shown that the presented method works best on posed than on spontaneous videos.

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THE VISUAL TURING TEST

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ABSTRACT

In the year of Turing's centenary, achievements of Alan Mathison Turing are presented through his cognitive legacy, and in particular through computer vision. In terms of computer science and informatics, Turing's achievements resemble those of Albert Einstein in physics. Since several of his major discoveries deal with artificial and human intelligence, many already correspond to cognitive science since one of the essential areas of cognitive science is strongly related to artificial intelligence. Several AI and human-intelligence related concepts are analyzed. An important part of the presentation is devoted to computer vision, in particular to the vision version of the Turing test. An appeal for Turing's full recognition is proposed also to the cognitive society.

1 INTRODUCTION TO TURING

2012 denotes Turing's centenary, and all over the world there were or are proposed events related to Alan Mathison Turing. Examples include: ACM Turing Centenary Celebration, Alan Turing Centenary Conference, ECAI Turing centennial, and several new books. A large majority of them is related to computer science and computing. In Slovenia, there have already been lectures and publications about Turing, e.g. (Gams 2012).

Today, Turing is considered to be the father of computer science, artificial intelligence and computational biology. The later refers to the way mathematical patterns appear in animals and plants, e.g. in leaves, and is not strongly related to cognitive sciences. However, both computer science – computability issues and artificial intelligence are related to cognitive intelligence. Both are also related to computer vision, in particular through the visual version of the Turing test.

In Figure 1 one can see an example of a book about Turing and in Figure 2 one can see an example of a book, related to Turing and cognitive sciences. It is titled: Rethinking Cognitive Computation: Turing and the Science of the Mind. The book provides a detailed understanding of the computational foundations of cognitive science. In a typical book of this type, the author provides a critical evaluation of the symbol processing and offers a new computational framework for cognitive science.

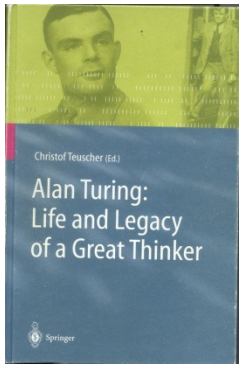

Figure 1*: What is the legacy of Turing in cognitive science?*

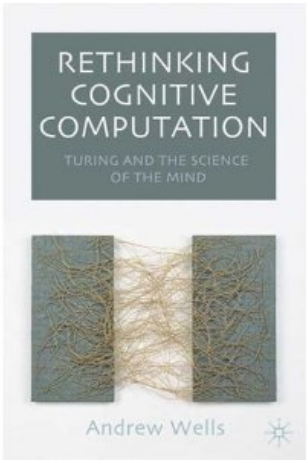

Figure 2: *A "typical" book analyzing Turing's viewpoint on cognitive computing.*

2 COMPUTER VISION

In the intersection of human and computer vision (Broek 2011) is the study of pictures and videos in order to achieve results similar to those as by men. In one way, human vision acts as a lower bound on ambitions with regard to computational image analysis and is close to the Turing Test for computer vision. On the other hand, there have been some remarkable applications where computers already outperformed humans also in vision tasks (ECAI 2012). The field of computer vision has inspired a large number of researchers in computer science, engineering, mathematics and even though we are still far from achieving the ultimate goal of passing the visual Turing

text, the field has gathered a great amount of work and knowledge in the process. Several commercial real-world applications of computer vision already exist, e.g. medical imaging, video surveillance, computer graphics, video compression etc. Some of them use methods of artificial intelligence and a couple of them use also cognitive models.

David Marr (1979) was conducting research in the areas of psychology, artificial intelligence, and neurophysiology, introducing new models of visual processing. To him, vision is the process of discovering from images what is present in the world, and where it is. Marr described vision as solving the "ill-posed problems" of reverse by adding assumptions about the world into the process of vision. Marr is in particular important since he unlike some other researchers strongly believed in the Turing computational theory of the mind.

For decades researchers have wondered whether computers can be programmed to imitate human cognitive processes (visual perception, natural language processing, and deductive reasoning). The problem was assumed to be easier in the beginning and only processing power and limited storage was regarded as the problem. Yet, decades have passed and in spite some major successes of computer vision the Turing vision test is not close to passing.

In certain respects, Marr's account of vision resembles the art by Adolf Hildebrand. He introduces two different modes of seeing, the kinesthetic "close vision", in which the eye constantly scans from a close vantage point, transforming perception into a temporal sequence of images; and the calm coherence of the distant view, which alone yields the image of the "three-dimensional complex," with its pure surface and implied depth.

One of the established researchers with new vision theories of the mind is **Karl Pribram**. He invented the holonomic brain model of cognitive function and other neurological discoveries related to memory, emotion, motivation and consciousness. Pribram's holonomic model of brain processing is based on two types of information processing: a) those of the circuitry accomplished by the large fiber tracts in the brain, and b) processing in webs of fine fiber branches, e.g. dendrites, performing multiple computing from multiple sources in the web. This type of processing is based on the Gabor quanta of information, wavelets that are used in quantum holography. Gabor wavelets are Fourier transforms that convert complex spatial/temporal patterns into component waves whose amplitudes at their intersections become reinforced or diminished, forming the basis of holography, the visual way of presenting information, either stored or thinking processes. Holograms correspond to 3D images and can correlate and store a huge amount of information. The similarity with the human memory is that holograms through inverse transform return the results of correlation into the spatial and temporal patterns.

In the following, we will present analyzes of the computability issues, the Turing test and in particular the vision version of the Turing test.

3 COMPUTABILITY AND THE TURING MACHINE

Turing was interested in the problem of decidability (Reiter 2012), i.e. whether any algorithm will be decidable or not. In other words – will any algorithm produce a decision or not in a reasonable time. He designed and in 1936 published his solution which introduced two novel contributions: the Turing machine and the halting problem (Turing 1936). The universal and the Turing machine are simple formal models of execution: they execute a program on a tape of symbols by changing one symbol at a time. This model not only executes any program or algorithm on a set of symbols, it can also simulate any other Turing machine.

In this way, Turing created a universal computing model, i.e. a universal computing machine, and then connected two such machines that the result was a logical contradiction: if one machine stops, the other does not, and if the second one stops, the first one does not. Since it is possible to design another machine encapsulating the performance of any two machines, this machine will not be able to ever decide, therefore is undecidable. Of course, most of programs and problems are decidable, but Turing showed with this counterexample, that some of them are not. Gödel published his incompleteness theorems (Raguni 2012) proving something similar to two theorems, related to provability and truth. In both cases, in a formal system there are statements that are true and cannot be proven, even though there are sentences (algorithms, programs, theories), that cannot be proven regardless of their truth value (Bojadzijev 1999). While Gödel showed these dilemmas in mathematical terms, Turing showed them in the executional form, proving that these issues are true for any computer.

Another consequence of the halting problem is the Church-Turing thesis (Wikipedia 2011). It states that any function that is algorithmically computable can be computed by a Turing machine. There are publications indicating that no physical machine can be designed to surpass the Turing machines, and that it is not possible to construct a counterproof neither in terms of actual machine nor in terms of computers performing symbol manipulations.

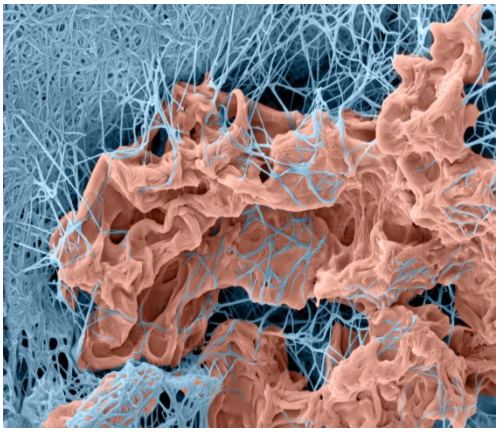

Figure 3: *Are neural networks, connectionism and embodiment stronger than Turing machines?*

But if one looks at the books related to cognitive sciences and Alan Turing, a typical book challenges the Turing machine and introduces some other solution, often based on neural networks and connectionism as indicated in Figure 3. In terms of computability, this seems a pretty vague idea. Neural networks, for one, are proven to be as strong as Turing machines and nothing more. The same holds for connectionism, quantum computers or any existing known device humans have designed.

The essence is that the Turing-machine concept represents such a basic concept or a computing principle that it can be compared to the Einsteins' relativity principles. But before one disregards all non-computational theories, it should be noted that according to Penrose (2002), there are several types of computing models and their consequences:

- Digital computers resembling Turing machines
- Humans that can be of the same computational power than Turing machines, but are performing significantly different compared to computers in real life
- Stronger mechanisms, be it hypercomputers of humans.

In light of this, new theories can be just Turing computable; Turing computable, but different in practical terms, or they can be in principle stronger than the Turing machines.

4 TURING TEST, TURING VISUAL TEST

In 1950 Turing published a paper describing the Turing test and a debate about artificial intelligence. The Turing test (Turing 1950) is the best known and discussed test of all times. It proposes comparing behaviors of two computing mechanisms (originally one human and one computer) and identifying the computing type of each of them in a limited time and through typing only. There are tens of different versions of the Turing test, e.g. a Total Turing Test including physical tasks, and a Total Total Turing test, examining populations of subjects.

The interrogator can also test the perceptual abilities of the subject thus requiring computer vision and in a consequence transforming the test into the Turing vision test. In this case, the interrogator need not necessary communicate with the subject in other ways than only graphically, e.g. demanding only y/n button pressed for a typical IQ vision test. On the other hand, mixed communication is also allowed.

The most practical version of the Turing test is the visual version called CAPTCHA. A CAPTCHA is a program that according to Google can generate and grade tests that humans can pass but current computer programs cannot. Typically, humans can read a distorted text (an example presented in Figure 4), but current computer programs can't, and therefore only humans are alowed to enter some web application.

The term CAPTCHA (for Completely Automated Public Turing Test To Tell Computers and Humans Apart) was coined in 2000 by Luis von Ahn, Manuel Blum, Nicholas Hopper and John Langford of Carnegie Mellon University. Today, these programs are open source and are widely used. An example of its use is our computer dictionary http://dis-slovarcek.ijs.si/, which soon fell prey of e-commerce net agents introducing commercials until the introduction of CAPTCHA.

In practical terms, the computers have improved their performance by a factor of 100.000 in the last 20 years, yet human interrogators decipher computers from humans in a couple of questions or with one CAPTCHA as before two decades. The reason is that current computers lack any human-level understanding, and vision is strongly connected to cognition. This is the empirical argument of weak AI, claiming that computers need major improvements in order to approach human-level intelligence and computing (Gams 2001).

Figure 4: *A Google example of CAPTCHA, the practical example of the Turing visual test.*

5 DISCUSSION

Vision is one of the essential cognitive processes. Humans not only see pictures, they comprehend visual images as the world consisting of objects, models and meaning. Even though Turing did not directly do much research in vision, his research poses such essential principles that the connection is worth discussing.

The Turing Award is generally regarded as the Nobel prize of computer science and Turing himself as »Einstein of computer science« by many scientists, including the authors of this paper. Turing introduced several basic concepts of computing, artificial intelligence and cognitive science. One of the versions of the Turing test is the vision Turing test. Just by decoding the Enigma, the German coding machine, the Second World War shortened by months by some reports, saving hundreds of thousands of lives.

But to what avail is that Turing is widely recognized in computer science and informatics, if an average European does know him while everybody knows for example Einstein or Mozart? The fact that Turing was neglected 60 years ago does not discard the fact that he is still neglected now as for example internet hits show.

It should not be only on us, computer science community, but on all scientists to revive the fallen acknowledgement of an extraordinary scientist, demolished by intolerant bureaucrats because of his sexual preferences. It should be only fair for the world to fully accept Turing as one of the most important people ever. If anybody for a second doubts about that, just look around and count the Turing machines embedded in the near-by machines. We should also remember Donald Michie as the Turing companion, in a list of computer geniuses that changed the world as hardly anybody did.

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VISION: RETHINKING PHILOSOPHICAL ASSUMPTIONS

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ABSTRACT

The author discusses the shift that embodied cognition provoked in the understanding and shaping research in vision. Instead of a typical view that visual processing is best understood as computational processes in the brain, embodied cognition approach stresses the active involvement of the agent with the environment.

1 INTRODUCTION

Visual consciousness is nowadays typically understood as a process within the brain. There is a long history of philosophers and scientists that were contributing to better understanding of brain processes involved in visual experiences, from the early Egiptian Imhotep to the Nobel laureates David Hubel and Torsten Wiessel. Alcmaeon of Croton (ca. 450), who came from one of three major centers of Greek medical science, was the first writer to champion the bran as the site of sensation and cognition and is considered as a first neuroscientist. Andreas Vesalius of Padua (1514 – 1564) was the greatest of the Renaissance anatomists and contributed drawings of different dissections of the brain (Fig. 1) [1].

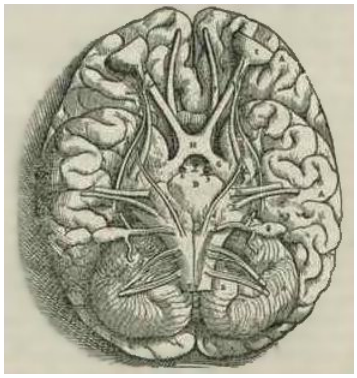

Figure 1. The base of the brain, including optic nerve (http://en.wikipedia.org/wiki/File:1543,AndreasVesalius%27Fabrica,BaseOfTheBrain.jpg)

For the better understanding of the current debates about the philosophical assumptions let me mention philosopher Rene Descartes' theory of sensory processing.

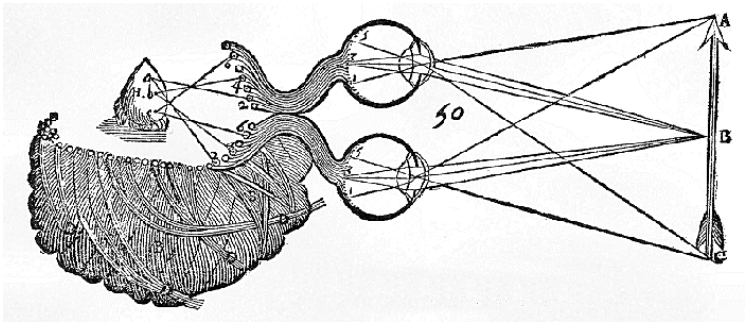

Figure 2
Diagram from Descartes' T*reatise of a Man (1664)* showing the formation of inverted retinal images in the eyes, and the transmission of these images, via nerves so as to form a single, re-inverted image (an idea) on the surface of the pinal gland (taken from [2]).

Descartes was ontological dualist and distinguished two different kinds of things, *res extensa* and *res cogitans.* According to his theory visual experiences belong to the latter and the brain alone is not enough to explain them. Contemporary scientists mostly reject such an ontological dualistic position and accept brain as the „seat“ of consciousness. But, as Dennett argues in his book *Consciousness explained* [3] they are usually accepting an important part of Descartes' legacy. They follow what he describes as Cartesian theater and Cartesian materialism, a view that there is a central place in the brain, a theater, where everything come together. As he said, almost all researcher in cognitive science - neuroscientists, psychologists or artificial intelligence researchers, “tend to postpone questions about consciousness by restricting their attention to the “peripheral” and “subordinate” systems of the mind/ brain, which are deemed to feed and service some dimly imagined “center” where “conscious thought” and “experience” take place” [3, p. 39].

2 THE INFORMATION PROCESSING MODEL OF THE MIND

Cognitive science developed a theory of mind on the assumption that mind is brain in the middle of last century. The fundamental hypothesis on which the research was based was the idea that the mind and the brain are information processing systems. There were different approaches that differ in the understanding of the notion of information processing. The classical symbolic approach takes it as symbol manipulation while connectionist and neural network approaches take it as parallel distributed system that propagate information. David Marr in his landmark book *Vision* (1982) explicitly stated that vision is an information-analysis process carried out in the brain. As Alva Noë argues, the idea is quite common and takes vision as a process of discovering how things in the scene form the images in the eyes. "It is a process of extracting a representation of what is where in the scene from information about the character of light arrayed across the skin of receptors in the eyes. [...] That process is inferential in the sense that the brain constructs and tests hypotheses about what sort of events in the world are producing these impressions" [4]. Hubel and Wiesel's as well as Marr's research was based on the idea that the visual system, more precisely the parts of the brain dedicated to vision, perform an information processing task. This is still the dominant view among the scientists. According to it seeing is extracting information about the environment from the retinal image and constructing an internal representation of it.

The skeptical challenge that such theories of perception are facing was already presented in Descartes' *Meditations.* It questions whether we can know that things are as we experience them as being. consequence of this approach is traditional skepticism. The new wave skepticism, based on new research in psychology and neuroscience questions whether we even have the perceptual experience we think we have because it seems we have radical false beliefs about what our perceptual experience is like. As Noë phrase it: The visual world is a grand illusion" [5, p.1]. He thinks that the worries are based on the false account of perceptual phenomenology that he calls "the snapshot conception of experience" [5]. The empirical research based on this conception is faced with a puzzle how to explain detailed, continuous and complex visual experience when the information on the retina is limited. The traditional approach assumes that the brain integrates information into a stable representation that is underlying the actual visual experience. Scientists need to find out how this is possible and solve the so called "binding problem". Daniel Dennett, the most famous proponent of new skepticism argues that we are mislead by the appearances and that consciousness is really discontinuous. We are victims of an illusion about the character of our own consciousness. More recently two other experimentaly-generated phenomena seem to support the new skepticism, change blindness and innatentional blindness [4], [6].

3 THE EMBODIED MIND APPROACH

The view of the mind that takes an information system approach is internalistic. The mind is restricted to the internal states of individuals. But the question is if the shift from understanding the mind as something supernatural to understanding the mind as brain is enough to answer the puzzle of visual consciousness. There are problems that seem to be deeper then just technical problems about how the brain is functioning.

One possible way is to go back to the basic assumptions. The embodied mind approach rejects the internalistic assumption that brain alone is sufficient for producing consciousness. An alternative to traditional cognitive science is presented by embodied cognitive science. The basic ideas were presented in the book *The Embodied Mind* by Varela, Thompson and Roch in 1991 [7]. They "introduced the concept of *enaction* to present and develop a framework that places strong emphasis on the idea that the experienced world is portrayed and determined by mutual interactions between the physiology of the organism, its sensorimotor circuit and the environment" [8]. They stressed the view that only creatures with certain features (e.g. legs, hands, eyes) can possess certain kinds of cognitive capacities and that knowledge emerges through the agent's bodily engagement with the environment. Similarly, Noë describes his position as follows: "to understand consciousness - the fact that we think and feel and that a world shows up for us – we need to look at the larger system of which the brain is only one element. Consciousness is not something the brain achieves on its own. Consciousness requires the joint operation of brain, body, and world." [4]. He argues that embodied approach to visual experience can better explain the puzzling phenomena that have lead to new skepticism.

Wilson and Fogilia stress two important points that motivated a shift to an embodied approach to vision:
(1) Vision is not a mere brain process devoted to constructing mental models, but rather a skill of the whole situated, embodied agent, one whose movements are crucial to visual agency (cf. Gibson 1979)
(2) Visual processing should be recognized as a temporally extended activity, where such activity is guided in part by the agent itself [8].

Scientists have designed a series of interesting experiments, known as change blindness and innatentional blindness where they demonstrate that we fail to notice quite a lot what is going on around us, unless we are directly attentive to the details that change. One can try by herself some of these interesting videos [9].

The proponents of embodied approach stress that what one may learn from these experiments is the fact that "visual conscious experience is a skillful engagement with the world

and heavily depends on what we *do* with our eyes, head and body to bring something into visual consciousness" [8].

4 CONCLUSION

Two alternative approaches to understand and explain conscious visual experience are based on different philosophical assumptions. The one that takes mind/brain as an informational processing system is internalistic and owes much to the Descartes' legacy. Embodied cognition approach is more holistic and takes into account the relations between the brain, body and environment. It seems that it is in a better position to explain some puzzling phenomena in a vision research although it is not without challenges [10].

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VISUAL HALLUCINATIONS – IMPORTANCE OF EXPERIENCE AND (EMOTIONAL) INTERPRETATION

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ABSTRACT

In the past (already from the time of Socrates – in 4th century) visual hallucinations were mostly considered as mystical experiences important for society. However at the end of 19th century that changed and since then visual hallucinations are getting more and more medical and psychopathological interpretation. Similar discrepancy doesn't stand just in regard to historical time aspects but as well as cultural one. In many countries (specially in Africa and Middle East) visual hallucinations are part of rituals and even when present outside of them, considered important and often positively evaluated, meanwhile in West countries the case is opposite. Beside that, the importance of experience of visual hallucinations and about all emotional connotation and their interpretation will be described in two cases.

1 Main approaches

The word *hallucination* has its roots in the Latin *hallucinere or allucinere*, meaning "to wander in mind" or "idle talk". The first usage of the word hallucination in the English language as in the 1572 translation of a work by Lewes Lavater, to refer "ghosts and spirits walking by night" (1). However, it was Esquirol who introduced the concept of hallucination, as currently understood, into psychiatry. In his book Mental Maladies: A Treatise on Insanity, Esquirol (1845/1965;1) described a person experiencing hallucinations to have "thorough conviction of the perception of a sensation, when no external object, suited to excite this sensation, has impressed the senses."

Brierre de Boismont (in 1861) maintained that not all hallucinations should be tied to madness (2). Instead he distinguished between physiological and pathological hallucinations. The first ones can occur in healthy people: they are compatible with reason and can be voluntary (as was the case with Goethe, according to Brriere). Thus hallucinations of thinkers like Socrates or religious visionaries like Joan of Arc would be regarded as physiological hallucinations. And "the madness of hallucinations is in their involuntariness, delirious content, its falsity, childish terror of the hallucinator; in other words, nothing specific to hallucinating" (2, p.12) . The way of viewing hallucinations profoundly affected the way hallucinatory experiences were interpreted and this doesn't stand just for historical and cultural aspect but for individual as well.

From the very beginning of conceptual thinking about hallucinations, two different approaches can be distinguished: psychological and medical. In general the former considers the hallucinatory experience as continuous with normal experience, whereas the latter regards it as discontinuous with normal experience. For instance, F. Galton (1883/1943; 1), argued that there is a continuity between all forms of visual imagination, from an almost absence of pictorial thought to images so vivid that they are indistinguishable from full percepts, thereby ending in complete hallucination. In contrast, Arnold (1806) and Esquirol (1832) considered hallucinations to be pathological and categorically distinct from normal mental events. According to Arnold, hallucinations only arise after a defect to bodily organs whereby incorrect information is transmitted to the brain. Although the medical model has been dominant over the past centuries, the controversy about pathological versus normal continues and even increases in present day. A consensus seems to emerge that pathological and nonpathological forms of hallucinations exist, whereby aspects such as attributions, loudness, frequency, degree of distress that they elicit, and negative and emotionally threatening content seem to be decisive factors (3).

Although visual hallucinations can occur in a number of populations, they are frequently observed in people with brain disorders (4) and are prominent feature of late onset schizophrenia (5) and major neurodegenerative disorders (6). Surveys of the general population

(7) also find visual hallucinations to be the most common type of hallucinations.

It is difficult to find an unambiguous definition of hallucinations, however I hereby incline to David's (8, p. 108) definition: "Hallucination is a sensory experience which occurs in the absence of corresponding external stimulation of the relevant sensory organ, has a sufficient sense of reality to resemble a veridical perception, over which the subject does not feel he/she has direct and voluntary control, and which occurs in the awake state."
Phenomena ranging from spots, rays and plays of color, through human figures, to panoramic or apocalyptic scenes, were considered by Kraepelin (1913) to be common enough, if rather inconspicuous in schizophrenia. Bleuler (1922, 1926) described visual hallucinations as being frequent and lively in acute states, but otherwise rare. Subsequently, nowadays visual hallucinations came to be regarded as rare. Certain psychotic patients describe hallucination-like visual experiences. These are mostly fairly vague experiences that have a visual character and represent extreme misinterpretations of ordinary impressions and can have a mystical or frightening aspect (1).
Delespaul et al. (9) carried out an experience-sampling study that showed that during a week's duration, patients with schizophrenia experienced more visual hallucinations (62,5%) than auditory hallucinations (49,1%). These relatively high prevalence rates suggest that visual hallucinations are probably more common in schizophrenia than traditionally thought.

2 Historical aspects
Ancient texts describe the phenomenon of hallucinations, showing that their authors regarded hallucinations as a culturally integrated aspect of human experience that conveyed a meaningful message. (1). Not until the 18th century, however, were hallucinations systematically described as a separate entity and considered to be "fallacies of the senses" (Dufor, 4) or even as a "disease" (4). Before 19th century, hallucinations were termed apparitions and were generally not seen as erroneous perceptions but as mystical and spiritual experiences.

3 Cultural aspects
Western rational-scientific societies strive to clarify and distinguish whether a given experience is real or imaginary, and when individuals are not able to make such a distinction between percepts and images, they are likely to be labeled as out of contact with reality and therefore pathological (i.e. having hallucinations). In contrast, many non-Western (or less rational-scientific) societies do not make such a rigid distinction between reality and fantasy even tending to encourage individuals to fantasize, and therefore the possibility of misclassifying an imaginary event as real is less important. Al-Issa (10) went on to show how these contrasting attitudes may affect the emotional reaction to hallucinatory experiences, with a predominance of negative reaction and negative attitudes toward hallucinations in Western societies, in contrast to more open and positive attitudes to such experiences in non-Western societies.
Bourgouignon (11) found evidence that hallucinations play a role in ritual practices in 62% of cultures studied. The presence of hallucinations was not associated with the intake of psychoactive chemicals, hallucinations were positively valued, and they could be understood in the context of local beliefs and practices.

There is evidence of cultural variation in the frequency of different kinds of hallucinations between cultures. Auditory hallucinations seem to be the most frequently reported by schizophrenic patients in the West, with visual hallucinations only appearing in the more deteriorated patients (12). In contrast, a number of studies have found that visual hallucinations are more common type of hallucinations in African and Asian countries compared with the West (10, 13). Similarly, Al-Issa found visual hallucinations to be more common in developing countries than in the developed world.

4 Emotional aspects
Gauntlett-Gilbert and Kuipers (14) examined various characteristics of visual hallucinations. In 45% patients claimed that psychological factors triggered hallucinations, and for all patients the trigger was affect. Visual hallucinations were associated with conditions of low sensory and social stimulation. In particular, 75% of visual hallucinations occurred when participants were alone, 65% when they were in a quiet place, and 55% in dim light conditions. In terms of affective responses, a large majority of patients (80%) reported fear (i.e. feeling anxious, frightened or helpless), whereas a relatively smaller number (60%) reported misery (i.e. feeling depressed, sad or hopeless), and 45% reported more positive emotional reactions (i.e. feeling reassured, happy or inspired). In addition majority (55%) perceived the visual

hallucination as a supernatural event rather than as a concrete physical presence. Although the results revealed that few of the visual hallucinations were chronic and persistent (with nearly half occurring in less than 2 weeks), they nonetheless had an impact on patients long after their offset. For example, more than half of the participants reported that visual hallucinations affected their beliefs and in 55% of cases they helped underpin a delusion.

5 Introduction to case studies

A man, age 48, hospitalized in Psychiatric hospital for 6th time, has a repetitively occurring visual hallucination of a funeral. He sees several men carrying a coffin, they are going towards him and finally through him. With that he gets unpleasant sensations in his body and deep anxiety, even anxiety attacks. He knows he is not in any danger at moments of hallucination, however he is constantly pondering what does it mean, if is not a vision of his future funeral. This hallucination occurs without any predictions, it may happen several times a day or once in a three months. However when it happens, it leaves him in a great distress so he can't function at least several days after that and more it repeats, longer are his periods of unfunctioning and more profound becomes depression and anxiety he feels. When hallucination occurred for the first time, it was when he was walking in the woods, he thought it was a real thing, and he hid behind a tree. He thought it was extremely strange but quite quickly stopped thinking about it. However when it kept occurring in different environment, contextually incongruent to funeral, he recognized it as a hallucination and later even saw that it has more grayish colors.

A man, age 28, at his 1st hospitalization in Psychiatric hospital, describes a repetitive visual hallucination of his grandfather with whom he lives. When it happened for the first time (2 years ago) he started to talk with it and was wondering how come he didn't hear his grandfather enter his room. The conversation was continuing for at least ten minutes, so his real grandfather, from another room, asked him who is he talking with. With that he realized that is a hallucination. The hallucination keeps occurring unpredictably, mostly once per week, but it can also be more or less frequent. He doesn't think much about it and it doesn't bother him and doesn't have any emotional relation towards it. He learned to recognize it since its colors are less vivid and sometimes he ignores it and other time he speaks with it. He is currently unemployed but has continuous, regular and trustful relations with several people.

6 Conclusion

If we consider hallucinations to be personal experiences or the expressions of personal concerns and ideas, then it is not difficult to suggest that hallucinations will be shaped by the person's immediate environment. Affective component is an integral part of one's experience and therefore of great importance for one's functioning. With understanding of the first person experience of patient's visual hallucinations experts can help him/her to cope and function in everyday life.

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VISUAL THINKING?

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Abstract

In this short overview, I will try to show the vagueness of our present knowledge about thinking, especially as an experiential modality. I intend to focus to one of surprising types of thinking: visual thinking, which will be investigated mostly through the first-person reports by Temple Grandin.

1 INTRODUCTION

Thinking is among the most common modalities of human experience. We are intimately acquainted with it and yet (or perhaps, because of it), the phenomenon seems to be surprisingly poorly defined. In everyday conversation we use the term for a wide variety of experiences: from remembering something to trying to solve a problem. The situation is not much more precise even within the scientific framework – modern cognitive neuroscience, for example, is quite broadminded in the use of the term *thinking*: one can find it in connection with abstract problem solving (1), argumentation (2), bringing forth memories of past events, associative processes, sense-making and meaning (3), appearance of intrusive mental images (4) etc.

Recent "discovery" of default mode networks, has focused scientific attention to the area of mind wandering (5), and via that, the rekindled some questions concerning thinking. To be able to extract some research value from the concept, it is (again) becoming necessary to narrow down its definition. In this respect, most authors agree that thinking is some sort of symbolical mental process, associated with processing of content – may it be connected to a concrete object or event, or to an abstract idea.

Further, despite the ages old philosophical argument about the relationship between thoughts and language, mostly everybody agrees that thinking is *somehow* connected to language. Most authors don't doubt the common intuition that thinking is inner talking, most prominently George H. Mead (6) who stated that thought is nothing but internalised conversation. This view has not changed a lot within the last century. A prominent cognitive scientist Bernard Baars confirms it: "Human beings talk to themselves every moment of the waking day. Most readers of this sentence are doing it now. It becomes a little clearer with difficult-to-say words, like infundibulum' or methylparabine'. In fact, we talk to ourselves during dreams, and there is even evidence for inner speech during deep sleep, the most unconscious state we normally encounter. Overt speech takes up perhaps a tenth of the waking day; but inner speech goes on all the time." (7, p. 106).

Leaning on this assumption, Matthew Botvinick from Princeton University summarises "the long-term goal" of thoughts related cognitive neuroscientific research: "to translate [that] brain-activity pattern into the words that likely describe the original mental 'subject matter" (8).

It is interesting though, that Baars' and Botvinick view is not universally accepted. A prominent linguist John McWhorter is sure that we are not so much talking, but *reading* in our mind: "When we utter a word, we cannot help but mentally see an image of its written version. In our heads, what we have said is that sequence of written symbols. When we say 'dog,' a little picture of that word flashes through our minds, Sesame Street-style. Imagine saying 'dog' and only thinking of a canine, but not thinking of the written word. If you're reading this book, it follows that you couldn't pull this off even at gunpoint " (9, p.3).

So, is thinking inner *talking* or is it inner *reading?* It is really hard to assume that one's own way of experiencing thinking might not be universal. This is probably one of the reasons why nobody thought of empirically testing the assumptions in the area of thoughts and thinking for quite a long time[1]. The young field of phenomenological inquiry is attempting to bracket intuitions concerning our mind's workings and instead gather empirical data about lived human experience. Let's see what it has to say about thinking.

2 PHENOMENOLOGY OF THINKING

Russell Hurlburt, one of the prominent figures in contemporary empirical phenomenology, comments on above-mentioned descriptions:

"I'm pretty sure that Baars and McWhorter are entirely mistaken. Maybe Baars talks to himself all the time, and

[1] With the fine exemption of physicit Richar Feynman, who describes an interesting first-person experiment, which helped him realize that behind a seemingly well coordinated communicational behaviour, a multitude of very different modalities of experience is hiding (11).

maybe McWhorter himself sees images of written words while he talks (there's reason to be sceptical of both claims), but I've investigated such things as carefully as I know how and become convinced that most people (let alone all people) do not do such things" (10).

Hurlburt is mostly known for his invention of descriptive experience sampling method – one of the oldest (more 35 years now) and most effective methods of collecting phenomenal (experiential or first-person) data. In recent years, research of experience is gaining momentum. Many new methods are being developed, all having one thing in common: asking not *what it is about*, but *how* a particular modality (thought, feeling, sensory experience ...) is experienced.

Bracketing the content (the *what* of experience) is the hardest in the area of thinking: content is the very essence of thoughts. The predilection of our everyday experience (what Husserl would call a *natural attitude*) makes us pay all our attention to *t*he content of thoughts and none to its structure. We can easily remember *what* we were thinking, on the other hand, *how* this was experienced is rarely observed. Therefore, beside a well designed research method, a lot of exercise, determination and mindfulness is needed to explore experience, and especially the *how* of thinking.

Results though, are pretty surprising. In the area of thinking, Hurlburt et all. showed that the experiential modality of inner speech occurs in 26% of all samples, with "large individual differences: some subjects never experienced inner speech; other subjects experienced inner speech in as many as 75% of their samples. The median percentage across subjects was 20%" (10).

Inner speech has shown to be a robust phenomenon, but far from being the only way of how people think: "...some people talk to themselves a lot, some never, some occasionally" (10). Furthermore, it seems that – behind the interface of well coordinated external communication – there is a vast variety of experiences, all called "thinking". Hurlburt reports on different other modalities of thought, one of which is for example so called *unsymbolised thinking,* which is quite interesting in light of old philosophical debates on possibility of such way of thinking.

Many other modalities of thinking were detected. I intend to dedicate the rest of this paper to one of them: *visual thinking*.

3 VISUAL THINKING

Most clearly and convincingly, this modality of experience is reported in the works of Temple Grandin – publicist, academic and a well known spokeswoman for people with disorder of autistic spectrum. At some point in her struggle to co-exist and communicate in "normal" social surrounding, she discovered to her surprise that a great deal of her troubles originates in the fact, that – in order to be able to communicate – she has to constantly translate her way of experiencing the world. She found out that this seems to be a common problem of many people with autistic disorders. Following this observation, she started an inquiry that resulted in articulation of three different specialized autistic/Asperger cognitive types: "(i) visual thinkers such as I who are often poor at algebra, (ii) pattern thinkers such as Daniel Tammet who excel in math and music but may have problems with reading or writing composition, and (iii) verbal specialists who are good at talking and writing but they lack visual skills." (12)

In her reports, Grandin offers a unique insight into the experience of a full-fledged visual thinker. She doesn't experience thinking as a linear (or consequential) affair. And she certainly doesn't think by talking to herself. Most of her experience consists of browsing through vivid recollections of pictures of (concrete) things.

The simplest example is her report on deciphering words, describing generalized entities: "If you say the word 'butterfly', the first picture I see is butterflies in my childhood backyard. The next image is metal decorative butterflies that people decorate the outside of their houses with and the third image is some butterflies I painted on a piece of plywood when I was in graduate school. Then my mind gets off the subject and I see a butterfly cut of chicken that was served at a fancy restaurant approximately 3 days ago." (12)

It seems that she is not utterly unfamiliar with inner speech. But it only plays a role of narrator, without having any power of abstraction or leading the argumentative process. Her experience handles what we know as logic and abstraction "with high-speed handling of hundreds of 'graphics' files".

Grandin reports about her struggle to grasp the idea of abstraction: at first, whenever the certain non-concrete thing was mentioned, a series of all pictures pertaining to it rushed through her experience. It took her decades to invent a way of dealing with this flood of concrete memories. Today, she normally just chooses a couple of the last (or most prominent) images, as described in the "butterfly" example, using it as a sort of representation of the whole class.

Still, she is unfamiliar with the experience of concept as something containing information about all the members. Her way of forming a concept is to sort into categories, the many specific photo-realistic pictures she have stored in her memory. To form concepts "I sort pictures into categories similar to computer files. To form the concept of orange, I see many different orange objects, such as oranges, pumpkins, orange juice and marmalade"

"When I was a child, I categorized dogs from cats by sorting the animals by size. All the dogs in our neighbourhood were large until our neighbours got a Dachshund. I remember looking at the small dog and trying to figure out why she was not a cat. I had to find a visual feature that she shared with big dogs. I had to create a new category in my mind to differentiate. All dogs, no matter how big or small, have the same nose shape. My concept is sensory based, not word based. Other ways of sensory-based categorization would be sound (barking or meowing) or smell."[2] (12)

4 CONCLUSION

This venue doesn't allow exploring visual thinking in more detail. I hope this short introduction managed to point at the vast and mostly unexplored territory of human experience. It seems that some of the assumptions about human experience that most of cognitive scientists (as well as philosophers) have been taking for granted, will have to be re-evaluated. One of them being the supposition that smoothly coordinated dance of human communication means that actor's are sharing (not only behaviour but also) experiences.

Could it be, for example, that there are different types of thinkers? And furthermore – is it possible that there are some cognitive processes that are: a) experienced differently and b) therefore produce a different pattern of neurophysiologic correlates?

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[2] Please note prof. Grandin's use of first person singular, narrowing her description only to her personal experience (comparing to Baars' and McWorther's use of third person plural, assuming that their personal experience – or perhaps only a personal belief – is reflecting universal truth).

Zbornik 15. mednarodne multikonference

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Robotika

Robotics

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Jadran Lenarčič, Leon Žlajpah, Andrej Gams

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PREDGOVOR

Pod okriljem multikonference »Informacijska družba« četrtič zapored organiziramo tudi konferenco Robotika, s katero nadaljujemo tradicijo raziskovalne robotike v Sloveniji. Kljub finančno in raziskovalno zahtevnem področju se je v Sloveniji uveljavilo več raziskovalnih skupin, ki ne samo, da sledijo trendom sodobne robotike, temveč jih soustvarjajo.

Robotika se je v zadnjih desetletjih utrdila v zavesti ljudi kot nepogrešljiv del moderne tehnologije. Brez robotskih manipulatorjev si ne znamo več predstavljati sodobnih industrijskih procesov, npr. varjenja avtomobilskih ohišij, vstavljanja obdelovancev v stiskalnice, razpršilnega barvanja ter izdelovanja drugih visokotehnoloških produktov. Ne presenečajo nas kirurški roboti ali servisni mobilni roboti, ki bodo kmalu čistili naša stanovanja. Znanstvena fantastika in pa zabavna industrija pa silita ideje še naprej. Na nekaterih področjih je raziskovalna robotika pravzaprav že ujela ideje znanstvene fantastike. Tudi vse večje število kvalitetnih mednarodnih robotskih strokovnih revij dokazuje, da postaja robotika priznana tudi kot samostojna znanost.

V zborniku so zbrani prispevki raziskovalcev iz več raziskovalnih skupin v Sloveniji in tudi tujini. Veseli, da je med avtorji velik del mladih raziskovalcev, ki so še dokaj na začetku svoje raziskovalne poti, kljub temu pa so njihovi prispevki svetovno primerljiva konferenčna dela.

Tako kot je raznoliko raziskovanje v robotiki, so raznoliki prispevki na letošnji konferenci. Razdelimo jih lahko v več sklopov.

Prvi prispevek obravnava didaktiko v robotiki ter področje avtonomnih mobilnih robotov. Prispevek je vsebinsko povezan z vabljenim predavanjem. Avtonomni roboti morajo nekako zaznavati okolje, zato drugi prispevek obravnava robotski vid.

Drugi sklop obravnava prispevke s področja učenja v robotiki. Pri tem ne gre samo za učenje gibanj robotskih manipulatorjev temveč tudi za napredne metode izboljšanj učenja z vključitvijo človeka v zanko, genetske algoritme ter sklapljanje trajektorij za koordinirano gibanje.

Temu sledi drugi sklop prispevkov, kjer je tematika vezana na bolj klasično robotsko generiranje trajektorij, kar je lahko uporabno v industriji. V industriji pa roboti prodirajo tudi v vse manjše procese, zato ta sklop začenja prispevek o nano-manipulaciji.

Posebne pozornosti so v zadnjem času deležni eksoskeletni mehanizmi, ki obetajo, da bodo v prihodnosti pomagali ljudem pri premikanju. Razvoj na tem področju je precej napredoval, kljub temu pa takih mehanizmov še ni v splošni uporabi, prav tako pa ni povsem preučen njihov vpliv na metabolno porabo ljudi.

Eden izmed namenov te robotske konference je, da vzpodbudi interdisciplinarno debato med znanstveniki, ki se ukvarjajo z različnimi področji robotike. Letošnji prispevki predstavljajo različne inovativne raziskave sodelavcev treh skupin na katerih temelji prihodnost raziskovalnega dela na področju robotike v Sloveniji in svetu.

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ROBOTI ZA REŠEVANJE PO POTRESU

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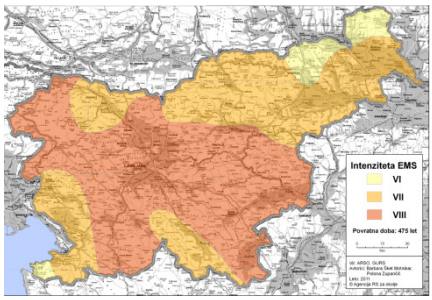
ABSTRACT/POVZETEK

In this article the foreseen seismic effects as a base for preparation of exercises for rescuers in Slovenia are presented. The described RoboCup Rescue Robot competition is important for the modern technology development. The detailed description of the Sl-AT joint rescue robot team TEDUSAR is given along with the first experiences gained at the RoboCup Rescue competition. A need for cooperation with the rescuers is exposed in order to develop better rescue technologies./ *V* članku so predstavljeni predvideni potresni učinki na osnovi katerih URSZR Slovenije usposablja reševalce. Nato je opisano tekmovanje RoboCup Reševanje, ki spodbuja razvoj sodobnih tehnologij za reševanje po potresu. Podrobneje je predstavljen robot za reševanje skupne slovensko avstrijske ekipe TEDUSAR in izkušnje pridobljene s sodelovanjem na *tekmovanju. Izpostavljena je potreba po sodelovanju z reševalci pri razvoju tehnologij za reševanje.*

1 UVOD

Potresi spadajo med naravne nesreče, ki jih ni mogoče napovedati, zato vedno udarijo nenadno. Vendar lahko potrese z instrumenti zaznavamo, merimo njihovo moč in zbiramo podatke o njihovi moči ter pogostosti. Statistika nam govori, da na svetu v enem letu v povprečju nastane en potres z magnitudo 8 ali več, 15 potresov z magnitudo 7 do 7.9, 134 potresov z magnitudo 6 do 6.9 in 1319 potresov z magnitudo 5 do 5.9, itd. Potresi z manjšo magnitudo so kar precej pogosti. V letu 2012 je našo pozornost pritegnilo kar nekaj potresov. Eden takšnih je bil potres z magnitudo 6.3, ki je nastal marca 2012 v bližini severovzhodne obale otoka Honšu na Japonskem in zaradi katerega je bila poškodovana jedrska elektrarna v Fukušimi. Drugi potresi pa so pritegnili našo pozornost zaradi tega, ker so nastali v naši neposredni bližini. Od 20.maja 2012 do 3.junija 2012 so nastajali potresi z magnitudo od 5 do 6 na območju Severne Italije. Nekatere izmed potresnih sunkov pa smo občutili tudi pri nas. V Italiji so se zaradi posledic potresa rušile stavbe, potres je terjal več človeških življenj, mnogi ljudje so morali zapustiti svoje domove. V Sloveniji skrbi za beleženje in obveščanje o potresih Agencija Republike Slovenije za okolje, ki na svojih spletnih straneh objavlja podatke o potresih nastalih v Sloveniji in izdeluje karte potresne ogroženosti Slovenije na osnovi zbranih podatkov. Karte, ki jih izdela agencija so namenjene gradbenikom, ki na njihovi osnovi načrtujejo in gradijo zgradbe z ustrezno potresno varnostjo, pa tudi Upravi Republike Slovenije za zaščito in reševanje (URSZR)(Slika 1), ki skrbi za reševanje po potresu.



Slika 1: *Zemljevid s podatki o intenziteti potresov (vir:Agencija Republike Slovenije za okolje)*

Karta za reševalce prikazuje intenziteto potresov po 12 stopenjski evropski lestvici EMS, ki jo v Sloveniji uporabljamo od leta 1995. Intenziteta potresov opisuje učinke potresa na predmete, ljudi in zgradbe. Največja intenziteta, t.j. intenziteta VIII, ki je označena na karti za reševalce na območju osrednje Slovenije (Slika 1) tako pomeni naslednje učinke: Mnogi ljudje s težavo lovijo ravnotežje. Pojavijo se velike razpoke na stenah mnogih stavb. Pri posameznih dobro grajenih navadnih stavbah se porušijo stene, slabo grajene stavbe se lahko porušijo.
Na osnovi napovedane potresne ogroženosti URSZR organizira vaje za reševalce (civilna zaščita, gasilci, rdeči križ, reševalni psi) iz reševanja po potresu. V letu 2012 se osrednja vaja iz reševanja po potresu imenuje Potres 2012 in bo predvidoma v septembru, v preteklem letu pa je URSZR organizirala mednarodno vajo iz reševanja po potresu IPA-SI QUAKE 2011. Ob potresih, še posebej ob večjih potresih se pogosto pojavi vprašanje, kako bi lahko z uporabo sodobnih tehnologij povečali hitrost in učinkovitost reševanja in tako zmanjšali število žrtev potresa? Kakor tudi, kako bi lahko povečali varnost reševalcev med reševanjem? Prvi, ki so začeli usmerjeno iskati odgovore na zastavljena vprašanja so bili Japonci. Povod za tako razmišljanje jim je dal potres velikih

razsežnosti, ki je leta 1995 prizadel širše mestno področje milijonskega mesta Kobe (4600 mrtvih v mestu). Na njihovo pobudo je bil v okviru tekmovanja RoboCup, ki je dotlej pokrivalo le tekmovanja v robotskem nogometu, ustanovljen nov razred tekmovanja v robotskem reševanju, imenovan RoboCup Reševanje (RoboCup Rescue Robot League). Namen tekmovanja v reševanju je spodbujanje razvoja sodobnih tehnologij za potrebe reševanja po potresu.

V drugem poglavju bomo predstavili robotsko tekmovanje RoboCup Reševanje, v tretjem poglavju bomo predstavili projekt SI-AT TEDUSAR in robota za reševanje, ki smo ga zgradili za potrebe sodelovanja na tekmovanju, ter primerjali njegovo zgradbo in lastnosti z roboti drugih ekip. V zadnjem poglavju bomo ovrednotili stanje razvoja robotov za reševanje in skušali odgovoriti na vprašanje, kako bi lahko sodelovanje z URSZR, oziroma reševalci na splošno, prispevalo k razvoju robotov za reševanje, da bi lahko le-ti sodelovali v pravih reševalnih akcijah.

2 ROBOCUP REŠEVANJE

Na tekmovanju RoboCup Reševanje je mogoče tekmovati v simulaciji reševanja in v reševanju z roboti (Rescue Robot League – RRL). Slednje tekmovanje bomo opisali v tem prispevku. Prvo RoboCup tekmovanje v reševanju z roboti (RRL) je bilo leta 2002 izvedeno v Fukuoki na Japonskem. Razen svetovnega tekmovanja RoboCup v reševanju obstajajo še regijska tekmovanja v reševanju v Nemčiji (RoboCup German Open), v Iranu (RoboCup Iran Open) in na Japonskem (RoboCup Japan Open). V nekaterih državah, denimo na Tajskem, pa na državnem tekmovanju robotov v reševanju sodeluje tudi po 100 ekip s svojimi roboti. Naloga robotov na tekmovanju v reševanju z roboti je iskanje žrtev potresa med vožnjo po tekmovalni areni. Pri tem pod izrazom žrtev potresa razumemo vse ljudi, ki so ujeti pod ruševinami nastalimi zaradi potresa in jih je potrebno izpod njih čimprej rešiti. Da bi lahko reševalci žrtve, ki jih je robot našel, rešili, robot hkrati z iskanjem žrtev izdeluje tudi načrt prostora po katerem se premika in vsako najdeno žrtev v ta načrt označi. Roboti vsake na tekmovanju sodelujoče ekipe imajo za iskanje žrtev v areni na voljo več poskusov, pri čemer vsak poskus traja 20 minut. Več žrtev kot najde robot, več točk pridobi. Zmaga ekipa, ki najde največje število žrtev (zbere največje število točk). Tekmovalna arena, ki predstavlja simulirano okolje po potresu, je velika približno 10m x 6m in je razdeljena na področja. Področja znotraj arene so namenjena različnim izzivom tekmovanja in so barvno označena. Z rumeno barvo je označeno področje namenjeno avtonomnemu iskanju žrtev z roboti, ki ima najmanj razgibana tla s 15^o nakloni tal (slika 2 levo zgoraj). Z rdečo barvo je označeno območje namenjeno preizkusu ali se lahko robot premika preko zelo razgibanih tal (mobilnost robotov). Osrednji del rdečega področja je polje stopnic (slika 2 desno zgoraj), poseben del področja pa so stopnice in 45^o naklon (slika 2 desno spodaj). Na rdeče označenem področju so lahko roboti daljinsko vodeni. Trenutno avtonomnost in velika mobilnost predstavljata dve nasprotujoči si skrajnosti znotraj tekmovanja. Praviloma se roboti z visoko stopnjo avtonomnosti ne morejo premikati preko zelo razgibanih tal in obratno. Znotraj arene je zato predvideno med rumenim in rdečim področjem vmesno oranžno področje, znotraj katerega so tla bolj razgibana (z 22^o nakloni tal), kot v rumenem, a dosti manj kot v rdečem področju. Tudi znotraj oranžnega področja so lahko roboti daljinsko vodeni. Znotraj vsakega področja se nahaja 5 simuliranih žrtev (lutk)(Slika 2 levo spodaj), ki se največkrat nahajajo na stenah arene v treh možnih nivojih in so vidne skozi majhne odprtine v steni. Zraven lutk se nahajajo električne grelne blazine ogrevane na temperaturo malo višjo od 37^oC , tako da jih lahko robot zazna s toplotnimi tipali.

Slika 2 prikazuje dele tekmovalne arene s tekmovanj RoboCup German Open 2012, oziroma 2011. Na sliki 2 so levo zgoraj prikazana tla in stene rumenega področja, desno zgoraj je rdeče področje s poljem stopnic, spodaj desno so stopnice in 45^o naklon (rdeče področje), levo spodaj pa je prikazana lutka – žrtev v areni.

Slika 2: Tekmovalna arena (German Open 2012/2011)

Na tekmovanju lahko daljinsko vodi robota le en član ekipe, ki se nahaja v posebnem ograjenem prostoru, tako da le-ta vidi kje in kako se robot premika le preko kamer in senzorjev ter načrta, ki ga izdela robotu. V letu 2009 so areni dodali še rumeno-črno področje, na katerem roboti ne smejo biti daljinsko vodeni, saj so tam radijske zveze prekinjene (radio dropout) in modro področje namenjeno razvoju rokovanja s predmeti.

V okviru tekmovanja RoboCup Reševanje se izvajata tudi podtekmovanji v avtonomnosti in mobilnosti robotov. Na podtekmovanju v avtonomnosti zmaga ekipa katere roboti v določenem času med avtonomno vožnjo po areni pravilno izdelajo največji načrt arene. Na podtekmovanju v mobilnosti pa zmaga ekipa katere robot v določenem času prevozi najdaljšo razdaljo na polju stopnic.

3 ROBOTI ZA REŠEVANJE

V okviru programa čezmejnega sodelovanja med Slovenijo in Avstrijo smo v okviru projekta TEDUSAR (Technology

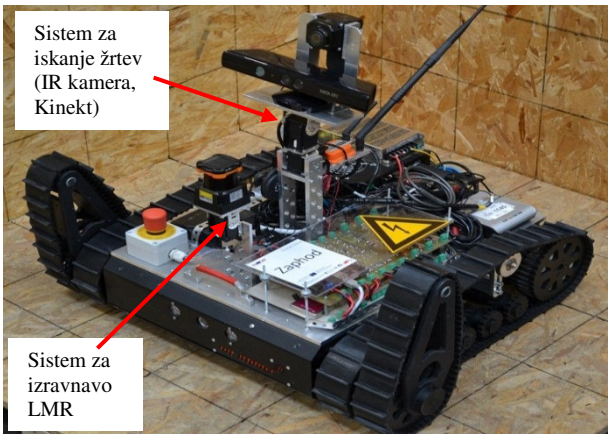
Education and Search and Rescue Robots) ustanovili skupno slovensko avstrijsko univerzitetno ekipo TEDUSAR za sodelovanje na mednarodnih robotskih tekmovanjih RoboCup v reševanju (RRL). Ekipo TEDUSAR sestavlja osem članov, t.j. štirje člani iz Fakultete za elektrotehniko, računalništvo in informatiko, Univerze v Mariboru in štirje člani iz Inštituta za programske tehnologije, Tehniške univerze v Gradcu. Na slovenski, kakor tudi na avstrijski strani, je ekipa sestavljena iz mentorja, doktorskega študenta - vodje SI/AT dela ekipe in dveh dodiplomskih študentov. Člani ekipe TEDUSAR smo zgradili robota za reševanje, opisnega v nadaljevanju, in z njim prvič sodelovali na tekmovanju RoboCup German Open 2012.

3.1 Robot za reševanje

Podvozje robota za reševanje je mobilna platform Jaguar z gosenicami in dvema neodvisno premičnim ročicama z gosenicami spredaj. Platforma ima dimezije 176×700×830 mm in tehta 25 kg. Premika se lahko z največjo hitrostjo 5.5 km/h, lahko vozi po 45° naklonu in stopnicah ter prevaža 15 kg breme. S pomočjo premičnih ročic z gosenicami lahko robot pelje preko do 20 cm visokih ovir ali se reši iz pasti. Ohišje platforme je odporno na padce z višine 1.5 m, vendar ni ognjevarno. Platforma ima vgrajeno kamero, sistem senzorjev (kompas, pospeškometer, žiroskop) za določanje lege v prostoru (IMU) in komunikacijska vrata za Ethernet povezavo s krmilnim računalnikom s pomočjo katere lahko robota krmilimo. Na robota smo prigradili krmilni računalnik (PC), na katerem teče programska oprema, ki omogoča iskanje žrtev in izdelavo ter prikaz načrta arene po kateri se robot premika. Na sprednji strani robota smo prigradili sistem za izravnavo laserskega merilnika razdalje (LMR), malo za njim pa še sistem za iskanje žrtev na osnovi infra rdeče (IR) kamere in Kinekt senzorja. Robot za reševanje z vsemi prigrajenimi sistemi je prikazan na sliki 3.

3.2 Robotski operacijski sistem (ROS)

Programska oprema robota je zasnovana na robotskem operacijskem sistemu (ROS). ROS je meta-operacijski sistem, ki temelji na Linux Ubunto operacijskem sistemu. Uporaba ROS-a omogoča hitro gradnjo robota, saj ROS ponuja velik nabor gonilnikov za različne mobilne platforme in senzorje, kakor tudi mnogo uporabnih knjižnic in programov, npr. knjižnico za računalniški vid, programe za navigacijo in izdelavo načrtov, ipd. Uporabniki ROS-a lahko izmenjujejo programe in izkušnje, ker je ROS odprto koden. Skupnost sodelujočih na tekmovanjih RoboCup Reševanje na osnovi ROS-a gradi skupno programsko ogrodje, ki bo omogočalo hitrejši napredek sodelujočih



Slika 3: Robot za reševanje

ekip, lažjo vključitev novih ekip in razmah raziskav na področju reševanja. V ta namen prirejajo tudi poletne šole.

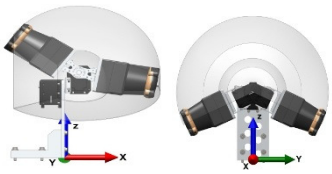
3.3 Izravnava laserskega merilnika in izdelava načrta

Autonomno delovanje robotov za reševanje razbremenjuje reševalce in s tem omogoča hitrejše in učinkovitejše iskanje žrtev potresa, zato je v reševalnih akcijah zelo zaželeno. Roboti za reševanje iščejo žrtve v neznanem okolju, saj ni mogoče predvideti katere ulice in zgradbe ter kako bodo poškodovane. Pa tudi sicer praviloma načrti poškodovanih zgradb reševalcem niso dostopni. Zato potrebujejo avtonomni roboti programe, ki omogočajo hkratno lokalizacijo in izdelavo načrta (SLAM, ang.). Pri tem lokalizacija pomeni, da robot "ve" kje na načrtu, ki ga izdeluje, se nahaja. Zato lahko na osnovi tega načrta načrtuje svoje gibanje, tako da se izogiba oviram in luknjam ter hkrati išče žrtve. Današnji programi za lokalizacijo in izdelavo načrtov (2D SLAM) temeljijo na LMR (in merilnikih zasuka koles robota) ter zanesljivo delujejo, če se roboti premikajo na ravnih tleh (pisarne, stanovanja – 2D ravnina). Roboti za reševanje zato predstavljajo nov izziv za razvoj programov za hkratno lokalizacijo in izdelavo načrtov, saj lahko pričakujemo, da bodo tla kjer bo vozil reševalni robot neravna in močno razgibana zaradi mnogih ruševin. Iz tega razloga so tla v tekmovalni areni tudi v področju avtonomnega delovanja neravna (Slika 2). 3D algoritmi za hkratno lokalizacijo in izdelavo načrtov so še v fazi razvoja, zato RoboCup ekipe za reševanje uporabljajo programe za hkratno lokalizacijo in izdelavo načrtov na osnovi 2D SLAM, problem razgibanih tal pa rešijo s pomočjo mehanizma za izravnavo LMR. Mehanizem za izravnavo LMR (Slika 4) ima vsaj dve prostostni stopnji, tako da lahko med vožnjo robota po neravnem terenu na osnovi meritev IMU vzdržuje vodoravno orientacijo LMR, oziroma njegove merilne ravnine. Tako na meritve LMR in program za hkratno lokalizacijo in izdelavo načrta ne vpliva razgibanost tal.

3.4 Sistem za iskanje žrtev

Sistem za iskanje žrtev je mehanizem z dvema prostostnima stopnjama (sukanje in nagib), ki služi premikanju t.i. senzorske glave. Senzorsko glavo predstavljata IR kamera

(FLIR PathFinder) in senzor Kinekt. IR kamera daje termično sliko in omogoča zaznavanje žrtev na osnovi oblike in telesne temperature. Senzor Kinekt daje poleg RGB slike še globinsko sliko, zato omogoča zanesljivejšo razpoznavo obraza in drugih delov telesa žrtev. Senzorska glava je lahko težka največ 1,5 kg. Med iskanjem žrtev deluje sistem za iskanje žrtev neodvisno od premikanja robota.

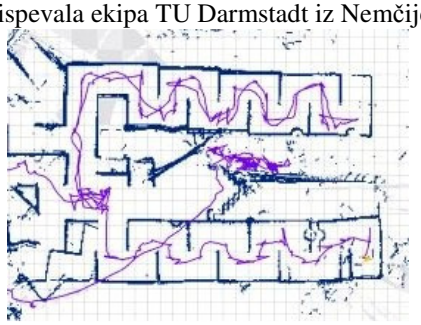


a) b)

Slika 4: Mehanizem za izravnavo LMR
(a) pitch–55/+100 stopinj (b) roll+/- 115 stopinj

4 IZKUŠNJE IN NAJUSPEŠNEJŠI ROBOTI

Gradnja robota za reševanje, ki deluje avtonomno, je neprimerno zahtevnejša od gradnje daljinsko vodenega robota. V to smo se prepričali tudi sami, saj tudi nam na tekmovanju RoboCup German Open 2012 ni uspelo vzpostaviti avtonomnega delovanja našega robota. Zato smo našega robota vodili daljinsko. Sistem izravnave laserskega merilnika in sistem za iskanje žrtev sta delovala dobro. Na tekmovanju smo našli 6 žrtev in uspešno izrisali načrt arene (Slika 5). Za izdelavo načrta smo uporabili program Hector-SLAM, ki ga je v skupno programsko ogrodje prispevala ekipa TU Darmstadt iz Nemčije.



Slika 5: Načrt arene, kot ga je izdelal naš robot

Na tekmovanju RoboCup German Open 2012 je prvo mesto v iskanju žrtev in na podtekmovanju v avtonomnosti zasedla ekipa TU Darmstadt z robotom Hector (slika 6). Od desetih ekip, ki so sodelovale na tekmovanju, sta le robota dveh ekip iskala žrtve v areni avtonomno! Ekipa TU Darmstadt je v letu 2012 osvojila drugo mesto v iskanju žrtev na svetovnem tekmovanju RoboCup Reševanje v Mehiki in prvo mesto na podtekmovanju v avtonomnosti. V preteklem letu je ekipa TU Darmstadt zasedla drugo mesto na podtekmovanju v avtonomiji na svetovnem tekmovanju RoboCup 2011 v Turčiji. V avtonomiji jo je premagala le ekipa CASuality iz Avstralije (slika 6).

Slika 6: Robot ekipe TU Darmstadt, Nemčija (levo) in robota ekipe CASuality (desno).

Slika 6 kaže, da imata svetovno najuspešnejša robota v podtekmovanju avtonomija zelo različno podvozje, vendar imata oba sistem za izravnavo LMR in senzorsko glavo, ki vključuje IR kamero za iskanje žrtev.

5 SODELOVANJE Z REŠEVALCI

Tekmovanje RoboCup Reševanje prav gotovo spodbuja raziskave in uporabo sodobnih tehnologij pri reševanju. Tekmovalna arena je standardizirana in za vse tekmovalne ekipe enaka, zato omogoča dobro primerjavo med rešitvami različnih ekip. Kljub temu tekmovalna arena ne more povsem nadomestiti pravega okolja v katerem delujejo reševalci. Iz tega razloga je potrebno tudi dobro sodelovanje z reševalci, ki lahko s pomočjo povratnih informacij prispevajo k uspešnemu razvoju sodobnih tehnologij za reševanje. Zavedamo se, da trenutno tehnologija še ni dovolj razvita za ocenjevanje na pravih reševalnih akcijah. Želeli pa bi si postopnega vključevanja v praktične vaje reševalcev.

6 ZAKLJUČEK

V okviru projekta SI-AT TEDUSAR je predvideno še sodelovanje naše ekipe na tekmovanju RoboCup German Open 2013 in na svetovnem RoboCup tekmovanju leta 2014. Cilj, ki ga želimo doseči v letu 2013, je avtonomno delovanje našega robota na tekmovanju in vzpostavitev uspešnega sodelovanja z reševalci.

ZAHVALA

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A STEREO-SYSTEM BASED TRAJECTORY RECOVERY OF A MOVING OBJECT

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ABSTRACT

In this paper we present a system for estimation of a trajectory of a tennis ball using a pair of cameras. Our goal is to detect the ball accurately and reliably and also describe its spatial trajectory. We captured video using inexpensive cameras and calculated their intrinsic, extrinsic and radial distortion model parameters. The ball is detected using an Adaboost classifier. A cascade classifying system and a nearly constant velocity dynamic model is used to reduce the computational complexity by cutting down the number of ball candidates. The algorithm computes a strong classifier from a number of weak classifiers using Haar features. We test the resulting classifier and describe its accuracy and detection rate. Epipolar constraints are applied to prune detections and triangulation is applied to recover the trajectory. We experimentally evaluate our system by controlled experiments.

1 INTRODUCTION

Tracking a moving object is an essential part of many tasks in measuring systems [2], surveillance [3], control [4], different cognitive systems [5] and many more. The challenge is to provide an accurate, reliable method that meets the needs of a particular task. One possible solution is using machine vision systems. The advantage of these systems is that they do not interfere with the action by requiring any modification of the observed object, they can be price sufficient and versatile.

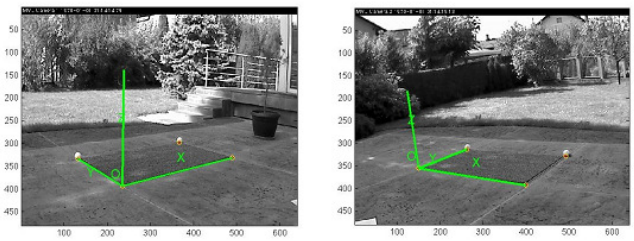
There are numerous ball tracking methods based on edge detection. D'Orazio and Guaragnella [1] use a Circle Hough Transform to detect circles. They first detect edges using a Canny filter and try to extract circles of different diameters. This method is sensitive to noisy images and takes a lot of processing time. Scaramuzza [6] uses a faster version of the circle transform, Coath and Musumeci [7] use an arc detection which also allows finding occluded balls. Ancona et al. [8] uses a Support Vector Machine (SVM) to classify footballs. Given a set of labeled data points belonging to one of two classes, the SVM finds the hyper plane that best separates the two classes. It does this by maximizing the margin between the two classes. Osorio [9] uses the Adaboost algorithm with cascades and finds it superior to SVM. The Adaboost algorithm combined with cascades is recommended by Viola and Jones [10] for face recognition. They show that the method is acceptable for real time implementation. They also recommend using Haar features. Mitri et al [11] use a version of the algorithm proposed by Viola and Jones and train it using output from a Sobel filter.

In this paper we present a method of an accurate and reliable recognition of a moving tennis ball using two inexpensive of-the-shelf cameras. We imposed several constrains to the experiment to focus on the algorithm effectiveness and not on the implementation. The maximum number of moving balls is limited to one, while we can have still tennis balls in the frame to provide possible false positives. The maximum speed of the ball is limited to make sure the ball is not smudged in individual frames and the ball moves mainly across both images to provide a fairly constant size of the ball on the image. At a distance of 2-3 meters the ball has an approximate diameter of 18 pixels on the image, thus we use a constant search window of that size.

In Section 2 we mention the basic camera theory and describe the necessary calibration. In section 3 we explain the background of the Adaboost Algorithm, describe Haar features, the advantages of a cascade system and our motion model. In Section 4 we describe pairing of objects using epipolar constrains and the triangulation process. In section 5 we validate our system and provide the accuracy results. In Section 6 we conclude our method and recommend feature work.

2 CALIBRATION

Projective geometry uses an idealized pinhole model camera to describe relations between points and their projections [13]. Intrinsic and extrinsic properties of the cameras must be found to apply this theory. However this model does not suffice in real world applications, thus we must extend our system to compensate for lens distortion. A radial distortion model is introduced and all parameters of our system are calculated with help of a calibration tool using a checkerboard [15]. We marked the corners of our checkerboard by hand and provided the checker and pattern size. We used several images with checkerboard at different positions and orientations. In Figure 1 we see the chosen world coordinate system that defines the extrinsic transformation matrices, in individual cameras.



(a) (b)

Figure 1: *World coordinate system in the left (a) and right (b) camera defining the extrinsic parameters of our system.*

3 CREATING A CLASSIFIER

Finding an object on a picture requires searching for it at all positions where the object might occur. To label every candidate as a correct or incorrect object we need to build a classifier that separates the candidates between the two mentioned groups.

3.1 Adaboost Algorithm

Adaboost is an algorithm that creates a strong classifier *H(x)* from a number of weak classifiers as seen in Eq. 1.

$$H(x) = \sum_{t=1}^{T} \alpha_t h_t(x) \quad (1)$$

Weak classifiers $h_t(x)$ are simple classifiers, with only slightly better hit rate than chance, but combined in a linear combination produce very good results. A candidate x is classified as an object or non-object {+1, -1} by $h_t(x)$. The factor α_t is calculated by the algorithm. T is the number of iterations used in the final classifier. If the sum returned by $H(x)$ is greater than zero the candidate is recognized as an object {+1} and if the sum is smaller than zero the contrary {-1}. Adaboost algorithm requires m labeled learning examples with n properties or features. The labels are represented by $y = \{1, -1\}$ for objects and non-objects respectively. The algorithm minimizes the cost function$E(H) = \sum_{i=1}^{m} e^{(-y_i H(x_i))}$, which represents the classifier error. The algorithm finds the best threshold for each single property n among learning examples. It minimizes the function $\varepsilon_n = \sum_{i=1}^{m} D(i) * [y_i \neq h_n(x_i)]$ for every property and compares the results representing the error of each weak classifier. The best weak classifier, the one with the lowest error $\varepsilon_t = \min(\varepsilon_n)$, is chosen for the t-th iteration $h_t(x)$ in the final classifier. $D(i)$ represents the weight factor of i-th example, initialized at $D_1(i) = 1/m$. After every iteration step $D_t(i)$ changes for individual learning examples. The weight of misclassified examples increases. This ensures that they are correctly classified in later iterations of weak classification.

In the following iteration steps we find the best weak classifiers as described before using updated weight factors according to (2) and (3).

$$\alpha_t = \frac{1}{2}\ln\left(\frac{\varepsilon_t - 1}{\varepsilon_t}\right) \quad (2)$$

$$D_{t+1}(i) = D_t(i)\exp(-\alpha_t y_i h_t(x_i))/Z_t \quad (3)$$

Z_t is the normalization factor, making sure the sum of all weights equals one.

The α_t returned in the process and the weak classifiers chosen represent the linear combination of the final powerful classifier build by Adaboost algorithm.

3.2 Features

Features or properties are descriptions by which we can separate objects from one another. There is a vast choice of possible object descriptions and it is very important to include some that offer good differentiation between objects and non-objects. Usually it is difficult to predict which feature is suitable to achieve that, but our algorithm automatically chooses the one that offers best differentiation. That is why we can provide a wide variety of descriptions and let the algorithm do the rest.

Haar features are descriptions commonly used in face recognition. These features are simple and fast to calculate, but offer more insight to objects than just comparing pixel values. These features capture the change in pixel values behaving similar to gradients. They are invariant to scale and mean differences. A mask is applied to a part of an image, where the value of the pixels in the white rectangle is subtracted from the value of the pixels in the black rectangle. The resulting difference is the feature response. In Figure 2 we can see some examples of the Haar features used in our work. One can choose many different sizes and positions of different features arbitrarily to provide as detailed description of the object as possible.

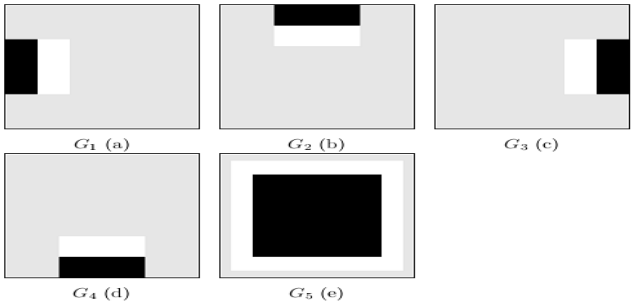


Figure 2: *Example of Haar features used to describe objects.*

3.3 Cascade System

Searching for objects represents a computationally demanding task, so reducing computation time is an important aspect. By creating a cascade of several strong classifiers from simple to complex it is possible to improve performance. The early stages discard the obvious non-objects, which are not evaluated in later stages. Only the actual object goes through all the stages requiring further processing in later stages that require more computational time due to higher complexity. That is a rare event, since most of the picture consists of the background and other non-objects that are discarded earlier.

Every stage requires a high hit rate, since they need to make sure every object arrives to the next stage, but we are not bothered by a high false positive rate. For example five

independent stages with a hit rate of 95 % and a false positive rate of 40 % combine to a final strong classifier with a 77 % hit rate ($0.95^5 = 0.77$) and a false positive rate of 1 % ($0.4^5 = 0.01$). In the learning procedure we use the false positives from the current cascade stage as the non-object learning examples for the next cascade stage. This procedure, called "Bootstrapping", helps to eliminate misclassifications of our previous stage sufficiently.

3.4 Motion Model

When tracking a ball we can expect a continuous movement trajectory. The object candidates can therefore be limited to an area where we expect the ball to be found considering its speed and direction. This further decreases computational demand and speeds up our process.

In our work we used a nearly constant velocity dynamic model (4), which assumes that the speed of the ball will not change much between successive picture frames.

$$\dot{\boldsymbol{x}}(t) = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \boldsymbol{x}(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} w(t), \boldsymbol{x} = \begin{bmatrix} x(t) \\ v(t) \end{bmatrix} \quad (4)$$

The change in speed *w(t)* is modeled by a Gaussian noise with a standard deviation equal to a third of the current ball speed. Considering the change in speed we can also track accelerating objects, like a ball influenced by gravity.

To enable tracking a ball after a bounce as well, we have to include the possibility of a change in direction in our velocity model. This broadens the area for ball candidates to a circle all around the previous positive hit.

3.5 Classifier Learning

To teach our classifier we used a learning set of 160 non-objects and 116 objects. We decided to create a two stage cascade. The non-object learning set for the second stage consisted out of 2372 false positives from the first stage classifier tested on a slightly changed background set. The object learning set remained the same. The resulting first stage classifier used $T = 5$ itterations and the second used $T = 21$. They both successfully classified all learning objects, achieving an error of 0.

3.6 Classifier Testing

To test the classifier we used a set acquired at the same location but at different lighting conditions. The ball is successfully classified when the error is smaller than a third of the ball width. With a fairly constant ball size on the image and a fixed search window size of $18 * 18$, the error must be smaller than 5.4 pixels. The resulting hit rate on a set size of 338 examples was 96.7 % with a false positive rate of 1.2 %. Every ball was hand labeled to test the accuracy of the classification. The average error was 1.64 pixels with a maximum of error 4,82 pixels. The average error represented approximately 10 % of the ball width.

4 CAPTURE SYSTEM

To capture video, we used 2 Axis 207W Ethernet cameras and placed them parallel approximately 80 cm high and 440 cm apart turned slightly towards one another. The cameras had a resolution of 640x480 pixels, captured 30 frames per second and had a sticker price under 200 euros. It is very important that we got frames from both cameras at the same moment. We needed to make sure the cameras were synchronized and had a constant frame rate. Pairing objects from images with a delay between them leads to bad triangulation results.

4.1 The Epipolar Constraint

Epipolar geometry describes characteristics specific for stereo images. Using the pinhole camera model the notions of epipole, epipolar line, plane and the fundamental matrix are defined [14]. They represent relations between 3-D points and their projections onto 2-D images. As seen in Figure 3 a point P is projected through the two optical centers O_L and O_R to the corresponding points p_L and p_R on the images. The line connecting the optical centers defines the epipoles E_L and E_R on each image. All mentioned points lie on the epipolar plane that defines the sections on individual images called epipolar lines. This plane can be defined by just one projected point and the optical centers, which enables us to calculate the epipolar line on the opposite image. The epipolar constraint requires that the projection of the same point on the opposite image must appear somewhere on that epipolar line.

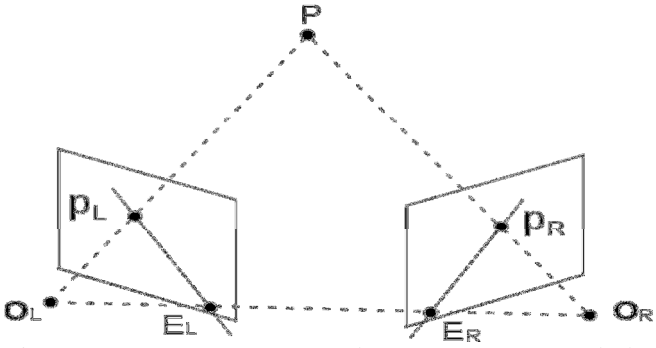


Figure 3: *A point P projected on two images and the constrains defined by epipolar geometry. [12]*

We used this characteristic to select viable pairs from individual image objects returned by our classifier. In this step we eliminated false positives, since they do not bear the epipolar constraint.

4.2 Triangulation

The process of determining 3-D coordinates of a point from its projection to two or more planes is called triangulation. To solve this problem we used the pair of objects confirmed by epipolar constraint and the extrinsic camera parameters that represent the transformation from each camera coordinate system to the world coordinate system. The projected object to a picture frame represents a straight line on which the object is located. The intersection of the lines from the two projections is the point where the object is actually located. Since there are some errors that occur due to lens distortion, inaccurate camera parameters and

approximate object projection position the lines do not actually intersect. The problem then becomes finding the point that best corresponds to the data using a least mean square error method.

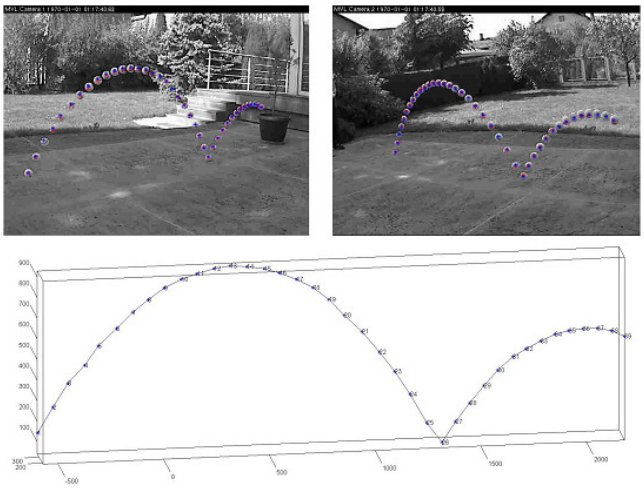


Figure 4: *Motion sequence images from the left and right camera with red crosses representing found objects and blue representing the triangulation reprojection (top) and the resulting trajectory (bottom).*

5 EXPERIMENTAL SYSTEM VALIDATION

To test the system accuracy we performed controlled trajectories and compared the results with the trajectory returned by our system.

An accurate trajectory was achieved by creating a fixed sledge where we slid the ball. We performed the sled test at different positions and orientations in the work area to get a representative set of results. In Figure 5 you can see the resulting trajectory of one example. The errors in the Y axis are in magnitude of 20 millimeters.

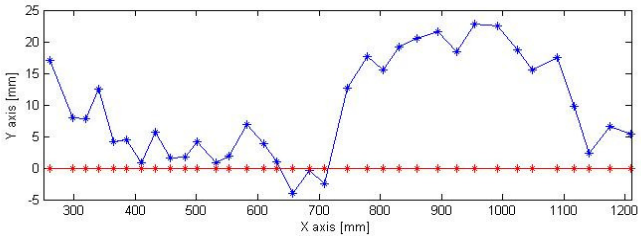


Figure 5: *A projection of a controlled trajectory on the X axis in red and the system's result in blue.*

The validated performance of our system has the following characteristics:

axis	mean error	std. deviation	max. abs. error
X	-0.5 mm	9.0 mm	18.6 mm
Y	15.2 mm	11.1 mm	33.6 mm
Z	-5.1 mm	8.1 mm	16.4 mm

6 CONCLUSION

Our system showed promising results that make it applicable to different tasks of moving object detection. The system could easily be extended to use more than two cameras and track more objects simultaneously at different scales. Possible implementations are in robotics research, sports tracking, measuring and safety systems and similar tasks, where an accuracy of a few centimeters is acceptable. We expect additional improvements by upgrading cameras, extending the learning set and the number of features and applying a more accurate motion model.

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USING GAUSSIAN PROCESS REGRESSION WITH REINFORCEMENT LEARNING TO MAKE ROBOT LEARNING MORE AUTONOMOUS

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ABSTRACT

In this paper we present a new methodology for robot learning that combines learning by demonstration and reinforcement learning. The idea is to provide as few training data as needed, so the robot can learn more autonomously. First we obtain a few training movements that solves the given task in some specific situations. Then we apply statistical generalization to compute relatively good initial approximation of new situation inside learning space. As the next step the reinforcement learning is used to refine the approximation in few steps so the robot can accomplish the task correctly. Every learned movement is then stored in the training base, so that additional approximations of different situations can be estimated more accurately and that reinforcement learning can get faster results. We compared how fast the learning space is fairly revealed by using Gaussian process regression (GPR) or simple linear interpolation (SLI) as a generalization method. Both approaches were tested by learning of pouring action with 7 DOF KUKA Light-Weight Robot arm.

1 INTRODUCTION

Autonomy is one of the main unresolved issues in contemporary robotics. In order to create fully autonomous robots, efficient and robust learning algorithms are indispensable. This is especially true for humanoid robots with many degrees of freedom. Among the most promising paradigms are learning by demonstration [1] and reinforcement learning [2].

Both learning approaches have their strengths and weaknesses. Learning by demonstration requires large amount of examples at the beginning, which takes up a lot of time. But once examples are collected, the task can be performed appropriately for all situations inside the learning space with desirable accuracy. On the other hand reinforcement learning requires little help from the teacher and can start performing the task right away, but takes up a lot of time to perfect the learning behavior. If we for instance combine this two learning approaches, then the learning experience would take less time and become more autonomous.

Robot actions are often encoded using parametric representations with a large number of parameters, thus the search space that reinforcement learning algorithms need to explore is normally very large. Recently, new probabilistic algorithms such as PI2 [3] and PoWER [4] were developed to deal with sensorimotor learning in high dimensional spaces. Despite of these advances a good initial approximation can boost the learning process.

The goal of this paper is to show that the generalization function can provide a good initial guess for the most promising search direction. We evaluate this idea on an upper-body humanoid robot, where the robot has to learn how to pour a given quantity of liquid into a glass from bottles containing different amounts of liquid.

As in our previous work [5], we use nonlinear dynamic systems (Dynamic Movement Primitives - DMPs) to encode the learned actions. Every generalized movement, represented by a DMP, is guaranteed to converge towards the desired target point [6].

2 APPROXIMATION OF MOVEMENTS WITH GAUSSIAN PROCESS REGRESSION

Lets assume that we have a set of robot movements $\mathbf{M}_i,\ i = 1,\ldots,NumEx$, which all result in a successful execution of a given task in different situations. We denote the parameters characterizing the task by $\mathbf{q}_i \in \mathbb{R}^m,\ i = 1,\ldots,NumEx$, m being the dimensionality of these parameters, which we also call query points and $NumEx$ the number of example movements. Every movement $\mathbf{M}_i$ is encoded by a sequence of trajectory points $\{\mathbf{y}_{ij}, \dot{\mathbf{y}}_{ij}, \ddot{\mathbf{y}}_{ij} \in \mathbb{R}^{dof}\}$, measured at times $t_{ij},\ j = 1,\ldots,n_i,\ t_{i1} = 0$. Here n_i denotes the number of samples on trajectory $\mathbf{M}_i$, while dof denotes the number of degrees of freedom encoded by the example trajectories. We have experimented with robot joint trajectories (in this case $\mathbf{y}_{ij}$ are the joint angles stemming from the active degrees of freedom). The problem is to compute a trajectory for any given query point $\mathbf{q}$. For example, in case of pouring, a query point is given by the desired liquid quantity in the bottle and we need to compute the associated pouring trajectory $\mathbf{M}$. Example movements $\mathbf{M}_i$ can be acquired either by kinesthetic guiding [1] or by imitation [7].

To become able to accomplish a task in any situation, the robot needs to learn a function that maps the parameters describing the task $\mathbf{q}$ into the parameters describing the desired

trajectory $\mathbf{M}$, i. e.

$$\mathbf{G} : \mathbf{q} \longmapsto \mathbf{M}. \tag{1}$$

In general, $\mathbf{G}$ is not a function. For example, in the case of reaching movements, there are many different ways to reach towards a desired destination. However, we can impose an additional constraint that synthetic reaching trajectories should be similar to the example reaching trajectories. The closer the desired query point $\mathbf{q}$ is to the example query point $\mathbf{q}_j$, the more similar the generated trajectory $\mathbf{M}$ should be to the trajectory $\mathbf{M}_j$ associated with query point $\mathbf{q}_j$. With this additional constraint, $\mathbf{G}(\mathbf{q}; \{\mathbf{M}_1, \ldots, \mathbf{M}_{NumEx}\})$ becomes a function that can be learned.

To reduce the amount of data that we need to process for action generalization, we first encode each of the example movements $\mathbf{M}_i$ as a dynamic movement primitive (DMP), i. e. $\mathbf{M}_i \longmapsto (\mathbf{w}_i, \mathbf{g}_i, \tau_i)$, where $\mathbf{w}_i \in \mathbb{R}^{N \times dof}$ are the weights of DMPs for all degrees of freedom, $\mathbf{g}_i \in \mathbb{R}^{dof}$ are the final configurations on the example trajectories, i. e. $\mathbf{g}_i = \mathbf{y}_{in_i}$, and $\tau_i \in \mathbb{R}$ are the time durations of example trajectories, i. e. $\tau_i = t_{in_i}$. In this case function (1) becomes

$$\mathbf{G}\left(\{\mathbf{w}_i, \mathbf{g}_i, \tau_i; \mathbf{q}_i\}_{i=1}^{NumEx}\right) : \mathbf{q} \longmapsto (\mathbf{w}, \mathbf{g}, \tau). \tag{2}$$

GPR can be applied to estimate function (2). Gaussian processes are based on Bayesian probability modeling [8]. GPR exhibits good generalization performance and the predictive distribution can be used to measure the uncertainty of the estimated function. It has been demonstrated that this technique outperforms other regression methods on problems such as estimating inverse dynamics of a seven degrees of freedom robot arm [9].

Technically, a Gaussian process is defined as

$$g(\mathbf{q}) \sim \mathcal{GP}\left(m(\mathbf{q}), k(\mathbf{q}, \mathbf{q}')\right), \tag{3}$$

where $m(\mathbf{q}) = \mathbb{E}[g(\mathbf{q})]$ is the mean function and $k(\mathbf{q}, \mathbf{q}') = \mathbb{E}[(g(\mathbf{q}) - m(\mathbf{q}))(g(\mathbf{q}') - m(\mathbf{q}'))]$ the covariance function of the process. Lets assume that we have – as when estimating function (2) – a set of noisy observations $\{(\mathbf{q}_i, y_i)|i = 1, \ldots, NumEx\}$, $y_i = g(\mathbf{q}_i) + \epsilon$, $\epsilon \sim \mathcal{N}(0, \sigma_n^2)$. Subtracting the mean from the training data, we can further assume that $m(\mathbf{q}) = 0$. Given a set of query points $g(\mathbf{q}^*)$, the joint distribution of all outputs is estimated by

$$\begin{bmatrix} \mathbf{y} \\ \mathbf{y}^* \end{bmatrix} \sim \mathcal{N}\left(\mathbf{0}, \begin{bmatrix} \mathbf{K}(\mathbf{Q}, \mathbf{Q}) + \sigma_n^2 \mathbf{I} & \mathbf{K}(\mathbf{Q}, \mathbf{Q}^*) \\ \mathbf{K}(\mathbf{Q}^*, \mathbf{Q}) & \mathbf{K}(\mathbf{Q}^*, \mathbf{Q}^*) \end{bmatrix}\right), \tag{4}$$

where $\mathbf{Q}$, $\mathbf{Q}^*$, $\mathbf{y}$, $\mathbf{y}^*$ respectively combine all inputs and outputs and $\mathbf{K}(\cdot, \cdot)$ are the associated joint covariance matrices calculated according to Eq. (3). It can be shown [8] that the expected value $\bar{\mathbf{y}}^*$ associated with the new query points $\mathbf{q}^*$ is given by

$$\bar{\mathbf{y}}^* = \mathbb{E}[\mathbf{y}^*|\mathbf{Q}, \mathbf{y}, \mathbf{Q}^*] = \mathbf{K}(\mathbf{Q}^*, \mathbf{Q})[\mathbf{K}(\mathbf{Q}, \mathbf{Q}) + \sigma_n^2 \mathbf{I}]^{-1}\mathbf{y}, \tag{5}$$

with the following estimate for the covariance of the prediction

$$\begin{aligned} \mathrm{cov}(\mathbf{y}^*) = \; & \mathbf{K}(\mathbf{Q}^*, \mathbf{Q}^*) - \\ & \mathbf{K}(\mathbf{Q}^*, \mathbf{Q})[\mathbf{K}(\mathbf{Q}, \mathbf{Q}) + \sigma_n^2 \mathbf{I}]^{-1}\mathbf{K}(\mathbf{Q}, \mathbf{Q}^*). \end{aligned}$$

One commonly used covariance function is

$$k(\mathbf{q}, \mathbf{q}') = \sigma_f^2 \sum_{i=1}^{m} \exp\left(-\frac{1}{2}\frac{(q_i - q_i')^2}{l_i^2}\right), \tag{6}$$

which results in a Bayesian regression model with an infinite number of basis functions. m denotes the dimension of the query point space. See [5] and [8] for more details.

3 REFINING MOVEMENTS WITH POWER LEARNING

Lets assume the following process model

$$\theta = \mathbf{G}^*(\mathbf{q}^*; \{\mathbf{M}_1, \ldots, \mathbf{M}_{NumEx}\}) + \Delta\theta, \tag{7}$$

where θ are the parameters describing the selected movement representation, e. g. DMPs. In all interesting cases, the dimensionality n of the policy parameter space θ is significantly larger than the dimensionality m of query points $\mathbf{q}^*$. Our goal is to learn such $\mathbf{q}^*$ and $\Delta\theta$, which will maximize the reward r. For that, we define an extended parameter set in the form

$$\theta^* = [\mathbf{q}^*, \Delta\theta]^T. \tag{8}$$

Recently, efficient methods which combine the well-developed methods from statistical learning and empirical inference with classical reinforcement learning approaches were proposed [3, 4]. Such algorithms can scale to significantly more complex learning systems. For our experiments we selected PoWER [4], which is a policy improvement method derived from an expectation-maximization algorithm using probability matching [10]. The parameter update in PoWER follows the rule

$$\theta_{m+1}^* = \theta_m^* + \frac{\langle(\theta_i^* - \theta_m^*)r(\tau_i)\rangle_{w(\tau_i)}}{\langle r(\tau_i)\rangle_{w(\tau_i)}} \tag{9}$$

where i denotes the i-th roll-out, $r(\tau_i)$ is the positive reward accumulated from the trajectory τ in i-th roll-out and $\langle\rangle_{w(\tau_i)}$ denotes the importance sampling. Extended parameters θ_i^* used in roll-outs are selected according stochastic exploration policy

$$\theta_i^* = \theta_m^* + \epsilon_i, \qquad \epsilon_i \sim [\mathcal{N}(0, \sigma_1^2), \mathcal{N}(0, \sigma_2^2)]. \tag{10}$$

Noise variance σ^2 is the only tuning parameter of the PoWER algorithm, which has to be carefully selected to obtain the good learning results. The value is highly dependent on the process parameters θ^*. Generally, higher values of σ^2 speed up the learning and lower values of σ^2 lead to more accurate results. Physical units of $\mathbf{q}$ are also considerably different from the policy parameters $\Delta\theta$, therefore we propose to use one noise variance for the query estimation and a different one for the general movement parameters.

Noise variation is difficult to guess if we start learning from scratch. However, in our system we have a few training trajectories available, hence the appropriate σ^2 can be calculated as $\sigma^2 = s \max_{i,j}\{\|\theta_i - \theta_j\|\}$, where s is a suitably chosen constant, which defines the span of parameter exploration. It is good idea to decay the noise variation σ_1^2 with time, since the

learning of $\mathbf{q}^*$ is generally much faster than learning of $\Delta\theta$ due to the considerably different dimensions.

The update rule is the sum of parameter exploration in each roll-out weighted by its reward. The role of the importance sampling is to minimize the number of roll-outs, which are needed to estimate new policy parameters. Additionally, it automatically rejects unsuccessful roll-outs, which can be caused for example by false sensor readings. It allows the reinforcement learning algorithm to re-use previous most successful roll-outs τ_i during the estimation of the new policy parameters θ_{m+1}. Importance sampler sorts all past parameters update by descending order of their return and rejects less successful ones and re-weights past explorations according to the θ_m [11]. In general, shorter importance sampler results in faster learning and longer importance sampler in better disturbance rejection.

4 EXPERIMENTAL RESULTS

The goal of our experiment was to find out, which method, GPR or SLI, cooperates better with reinforcement learning PoWER, in other words, which algorithm combination performs faster learning with some desired accuracy. Both learning approaches were evaluated on KUKA LWR arm with 7 degrees of freedom and Barrett hand. We tested them for learning of a bartender skill, where the task is to pour the same quantity of liquid into a glass from bottles containing different volumes of liquid. We wanted to provide as few learning examples as possible and we decided to provided two demonstration pouring movements (at the border of the workspace), which poured 0.2 *l* of liquid into the glass from a bottle containing 0.3 *l* and 1.0 *l* of liquid. Demonstration trajectories were obtained using kinesthetic guiding (Figure 1) and were captured in joint coordinates. The quantity of liquid in the glass was measured with a precision scale after the execution of the pouring movement.

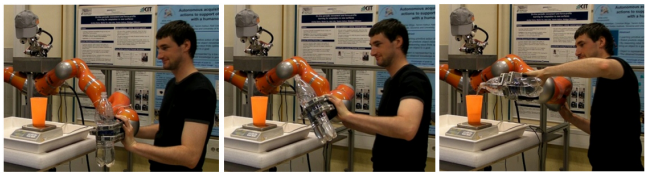

Figure 1: Image sequence showing the acquisition of one pouring movement with KUKA LWR 7 DOF arm using kinesthetic guiding.

The demonstrated trajectories in joint space were encoded as DMPs with 20 radial basis functions for each joint trajectory. It turned out that 20 is the optimal number of radial basis functions depending on the complexity and length of the pouring movements. From given query points (which were the estimated liquid quantities in the bottle) the statistical generalization with both methods were performed over the redial basis functions of all movements in the database (which define the shape of the robot movement) and over the goals of pouring movements (which were the joint positions at the end of each pouring movement). Time duration of pouring movements was fixed to 5.15 seconds. The task for the robot was to learn how to pour 0.2 *l* of liquid into the glass from a bottle with different quantities of liquid in sequence: 0.7, 0.5, 0.8, 0.4, 0.9, 0.6, 0.35, 0.45, 0.55, 0.65, 0.75, 0.85 and 0.95 *l*. Liquid quantities were organized in such a way that they were evenly distributed throughout the learning process.

Each method gave the first approximation movement and adjusted the parameters inside the learning loop with cooperation of PoWER learning. The reward function for this case was $r = 1 - 5\|v_d - v_m\| - 5v_s$, where r is the reward, v_d is the desired volume of the liquid in the glass, v_m is the measured poured volume and v_s is the volume of the spilled liquid defined just in case, but there was no spilling in that experiment. The constants in reward function were selected in such a way that the reward was always positive. We used three roll-outs for each parameter update and set the importance sampler length to 3. Every learned movement was instantly stored in the database so that the next pouring action would be easier to learn.

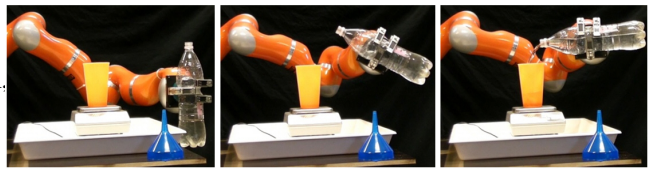

Figure 2: Image sequence showing one of the pouring movements in the learning experience with KUKA LWR 7 DOF arm.

The learning of pouring experiment was done first with GPR and then with SLI method as demonstrated in Figure 2 with image sequence of one of the pouring movements. Table 1 shows the number of parameter updates at each liquid quantity in which the robot has learned the pouring move with accuracy of 0.01 *l*. The results shows that learning with GPR method needed only 18 parameter updates all together to learn all the pouring movements, where learning with SLI needed 25 parameter updates in the same learning experience. The same results are represented on Figure 3a as well, along with bold smoothing line for each method for better interpretation of results. It turns out that learning with help of our proposed method GPR is faster than learning experience with SLI method. The smoothing line shows that learning with GPR becomes faster after sixth learned movement, since the parameter workspace is fairly revealed at that point.

As mentioned above GPR defines first approximation movement with statistical generalization as SLI on the other hand uses the nearest learned movement as a basis for new learning movement. Figure 3b shows, that SLI in general estimates the first approximation movements a bit better, but at the end of learning experience GPR performs better results. Figure 3c demonstrates the convergence for learning of pouring movements from a bottle containing different volumes of liquid. Here we can see that GPR sometimes makes a bit worse first approximation, but in general converge faster. Figure 3d represents the adaptation of liquid quantity in bottle throughout the learning experience of all the pouring movements for both methods. As we can see form Figure 2 the seventh joint (the final joint) changes the most during pouring action. On Figures 3e and 3f the seventh joint trajectories of all learned pouring movements (GPR - green curves, SLI - red curves) are

quantity	0.7	0.5	0.8	0.4	0.9	0.6	0.35	0.45	0.55	0.65	0.75	0.85	0.95	SUM
GPR	0	5	1	3	3	0	0	2	1	0	1	0	2	18
SLI	1	2	4	4	2	0	0	0	2	5	0	0	5	25

Table 1: The table shows the number of parameter updates at each liquid quantity in which the robot has learned the pouring move with accuracy of 0.01 *l*. The sum of overall parameter updates goes in favour of GPR method.

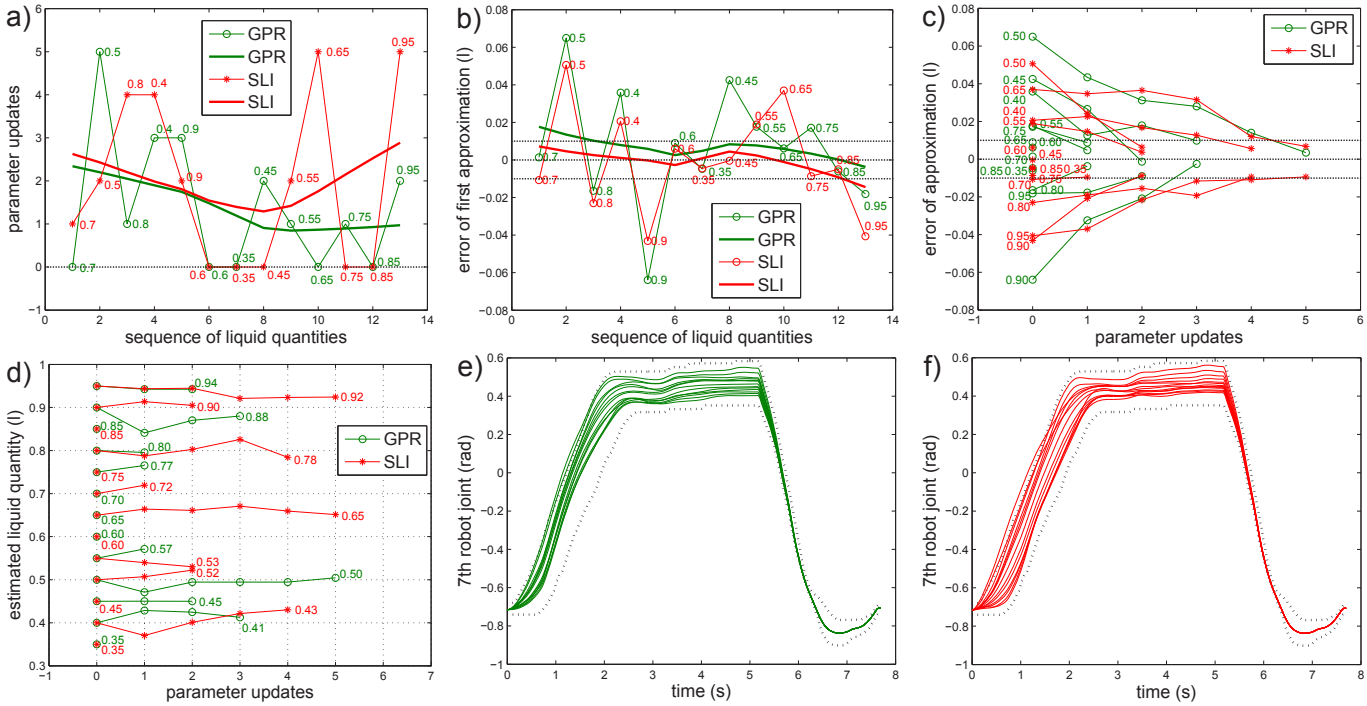

Figure 3: Graphs represent results of pouring action with 7 DOF KUKA LWR arm.

presented along with both initial example movements (black dotted curves).

5 CONCLUSION

In this paper we presented a novel approach to reinforcement learning in robotics. It combines ideas from statistical generalization and standard reinforcement learning. In the first stage we generalize the available training data to compute a control policy suitable for the current situation. This initial approximation is further improved using learning on the manifold defined by the training data. The proposed approach was verified on the real robot for the task where we had to learn how to pour from a bottle containing different volumes of liquid. Experimental results demonstrate that reinforcement learning with our proposed generalization method, Gaussian process regression, performs faster learning, than cooperation with simple linear interpolation method, after few learned movements, when the learning space is a bit revealed.

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ZAGOTAVLJANJE RAVNOTEŽJA ROBOTA S POMOČJO HAPTIČNEGA VMESNIKA

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ABSTRACT

Humanoidna robotika je v zadnjem času ena izmed bolj popularnih področji robotike. Humanoidni roboti čim bolje poskušajo posnemati človeka, človekove lastnosti in obnašanje. Vodenje humanoidnih robotov je kompleksen in večdimenzionalni problem. Na drugi strani je človek izredno prilagodljiv in se je sposoben naučiti različnih stvari. V tem članku smo izkoristili človekove sposobnosti prilagajanja, za učenje humanoidnega robota zagotavljanja stabilnosti. Pri tem smo zasnovali poseben haptični vmesnik, ki je nudil človeku določeno povratno informacijo o stanju robota. Haptični vmesnik je deloval s silo na človekovo težišče glede na položaj robotovega težišča. Človek se je odzval na to povratno informacijo s premikom telesa v stabilen položaj. Odzive človeka smo nato prenesli na robota. Med izvajanjem te naloge, smo zajemali podatke o robotovem težišču in pripadajočimi odzivi človeka, katere smo uporabili za učenje nevronske mreže. Nevronsko mrežo smo nato uporabili za samostojno vodenje robota.

1 UVOD

Ena izmed osnovnih nalog humanoidnega robota je zagotavljanje svojega ravnotežja. Za razliko od mnogih industrijskih robot, ki so pritrjeni na različne podlage, humanoidni robot stoji oziroma hodi po dveh nogah. Tak sistem je dinamično nestabilen, zato je potrebno imeti algoritem, ki skrbi za to, da robot ne pade.

Ker smo navdih za humanoidne robote dobili pri človeku, si želimo, da bi robot posnemal človeka in deloval na podoben način. Človek pri zagotavljanju svojega ravnotežja uporablja svoja čutila, da zazna spremembe povezane s stabilnostjo in nanje reagira s premiki svojega telesa. Raziskave, ki so jih izvedli Lockhart in drugi so pokazale, da je ključna informacija za aktivacijo mišic pri zagotavljanju ravnotežja sesalcev, informacija od pospešku težišča [1].

Človek ima izredno sposobnost prilagajanja na različne stvari in se je sposoben, skozi svoje življenje naučiti vrsto različnih nalog. V zgodnji fazi življenja se naučimo zagotavljanja ravnotežja, ki am omogoči stojo in hojo po dveh nogah. Poleg tega pa se naučimo uporabe raznih orodij in vožnje vozil. Te sposobnosti imenujemo senzorično-motorične sposobnosti učenja. Bistvo senzorično-motoričnega učenja je učenje povezave med dano informacijo iz človekovih čutil in primernimi motoričnimi odzivi.

Vodenje humanoidnih robotov je zapletena naloga, ki zahteva strokovna znanja iz robotike in programiranja. Ker želimo robote vključiti v vsakdanje življenje, kjer uporabniki ne bodo imeli omenjenih znanj, je ključno, da je učenje robotov kar se da preprosto in intuitivno. Enostavnejše vodenje ponuja izkoriščanje človekovih senzorično-motoričnih sposobnosti. Robota lahko vidimo kot orodje, katerega se mora človek nauči upravljati. Ta pristop je podoben teleoperaciji, kjer se človek najprej nauči uporabljati povratno informacijo s haptičnega vmesnika, preden lahko uspešno upravlja robota. Razlika med omenjenim pristopom in teleoperacijo je v tem, da mi želimo znanje, ki ga človek pridobi, prenesti na robota in ga uporabiti za samostojno vodenje robota. Ta pristop sloni tudi na učenju robotov z demonstracijo (ang. Programming by Demonstration) [2], [3], [4], [5].

Predhodno je bilo že nekaj raziskav na tem področju. Oztop in drugi so uporabili vizualno povratno informacijo za učenje naloge z robotskimi prsti [6]. Babič in drugi so učili robota zagotavljanja ravnotežja s pomočjo vestibularne in proprioceptivne povratne informacije, saj se je pokazalo, da je vizualna informacija neprimerna za dano nalogo [7]. Vizualna povratna informacija je v primerjavi z vestibularno in proprioceptivno povratno informacijo nekoliko počasnejša [8]. Pri omenjenem eksperimentu so človeku nudili povratno informacijo s pomočjo Stewartove ploščadi, na kateri je ta stal.

Stewartova ploščad ima določene pomanjkljivosti. Ker mora človek stati na ploščadi, je njegov delovni prostor omejen z dimenzijami ploščadi. Poleg tega je nagibanje nekoliko nenaravno za človeka. Da bi odpravili te pomanjkljivosti smo zasnovali poseben haptični vmesnik, ki daje človeku taktilno, propriceptivno in vestibularno povratno informacijo. Ta vmesnik deluje s silami na človekovo težišče s pomočjo vlečnih mehanizmov.

V eksperimentu smo uporabili omenjen haptični vmesnik za zagotavljanje povratne informacije o robotovi dinamiki, na

podlagi katere je človek zagotavljal robotovo ravnotežje. Med demonstracijo smo zajemali senzorične podatke in pripadajoče motorične odzive, na podlagi katerih smo kasneje zgradili algoritem za avtonomno zagotavljanje robotovega ravnotežja. Ta algoritem smo zgradili s pomočjo nevronskih mrež [9], [10].

2 HAPTIČNI VMESNIK

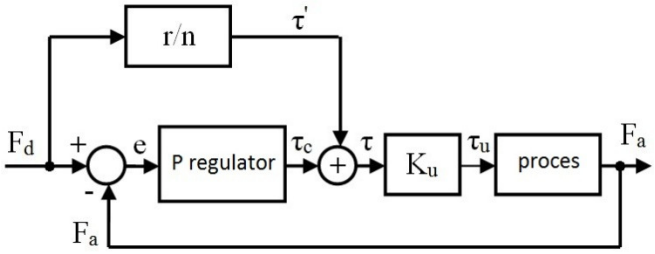
Glavna naloga omenjenega haptičnega vmesnika ja primerna povezava med človekom (demonstratorjem) in robotom. Ta vmesnik mora reproducirati enake pospeške na človekovo težišče, kot jih je deležen robot na svojo težišče. Ideja tega je, da človek čuti enake pogoje, kot robot.

Slika 1. Haptični vmesnik uporabljen za zagotavljanje povratne informacije o robotovi dinamiki.

Izdelan haptični vmesnik je prikazan na sliki 1. Osnovan je okoli dveh aluminijastih podpornih stebrov, na katerih sta pritrjena dva električna motorja. Podporna stebra sta bila postavljena nekaj metrov eden od drugega in med njima je stal človek. Naloga motorjev je vrtenje vitla, ki vleče jekleno žico navito okoli bobna. Žica je bila povezana s človekom preko posebnega pasu, ki je bil pripet okoli človekovega pasu na približnem položaju težišča človekovega telesa [11]. Med pasom in žico je bil postavljen senzor sile, ki je meril silo, s katero je vmesnik deloval na človeka.
Motorja smo krmilili v navorovnem načinu, pri čemer smo omejili hitrost vrtenja. Silo, ki jo izvaja vlečni mehanizem na žico lahko izračunamo po enačbi 2.1.

$$F = \tau \frac{n}{r} \tag{2.1}$$

kjer je F sila na vrhu bobna vitla, τ je navor motorja, n je prestavno razmerje reduktorja in r je premer bobna. Da smo zagotovili želeno silo na povezovalni žici, ki vleče človeka, smo uporabili regulacijski algoritem prikazan na sliki 2. Želeno silo $F_{d,}$ katero narekuje vmesnik, dosežemo z regulacijo napake e med želeno in dejansko silo na žici. Korekcijski navor, ki je odvisen od napake e, seštejemo z navorom τ', ki ga dobimo po enačbi 2.1. Če je dejanska sila F_a enaka želeni F_d, bo krmilni navor motorja kar enak navoru τ'. Če je dejanska sila na žici F_a večja od želene, potem bo korekcijski navor zmanjšal krmilni navor motorja, kar bo povzročilo postopno zmanjševanje dejanske sile na žici. Obratno velja v primeru ko je dejanska sila manjša od želene. V tem primeru bo korekcijski navor povečal krmilni navor motorja, kar bo povzročilo postopno povečanje sile na žici. Ker regulacijski algoritm na sliki 2 teži k temu, da motorja vlečeta z želeno silo v vsakem trenutko, ta odpravi tudi nezaželena vpliva lepenja in trenja mehanizma.



Slika 2. Regulacija sile na večni vrvi.

Ker imamo po en motor na vsaki strani, je bilo potrebno izvesti določeno koordinacijo med njima. Vhodni parameter haptičnega vmesnika je želena sila F_d. Če je želena sila enaka nič, potem oba motorja vlečeta le z minimalno silo F_t, ki drži žico napeto. Če je želena sila večja od nič, potem vleče motor, ki je postavljen v smeri, ki smo jo določili kot pozitivno smer (motor 2). Če pa je želena sila manjša od nič, pa vleče motor, ki je postavljen v smeri, ki smo jo določili kot negativno smer (motor 1). Ta postopek opisujeta enačbi 2.2 in 2.3.

$$F_1 = \begin{cases} -F_t & F_d \geq 0 \\ -F_t - F_d & F_d < 0 \end{cases} \tag{2.2}$$

$$F_2 = \begin{cases} F_t & F_d \leq 0 \\ F_t + F_d & F_d > 0 \end{cases} \tag{2.3}$$

kjer je F_1 sila, ki jo generira prvi motor, F_2 sila, ki jo generira drugi motor in F_t majhna sila, ki drži žico napeto.

3 NEVRONSKE MREŽE

Umetne nevronske mreže so eno izmed orodij strojnega učenja in so poenostavljen model človekovih možganov. Najpogosteje so uporabljene pri iskanju in učenju povezave med danimi vhodnimi in izhodnimi podatki. Naučena nevronska mreža podaja funkcijo, ki ustreza tem povezavam. Sestavljene so iz več osnovnih elementov, imenovanih nevroni, ki so razdeljeni v nivoje. Posamezni nevroni so povezani med seboj preko uteženih povezav. Prvi nivo imenujemo vhodni nivo. Vhodi tega nivoja predstavljajo vhode celotne nevronske mreže. Zadnji nivo imenujemo izhodni nivo in izhodi tega nivoja so izhodi nevronske mreže. Vmesne nivoje imenujemo skriti nivoji. Nevron je sestavljen iz sumarnega elementa in izhodne prenosne funkcije. Sumarni element sešteje vse vhode v

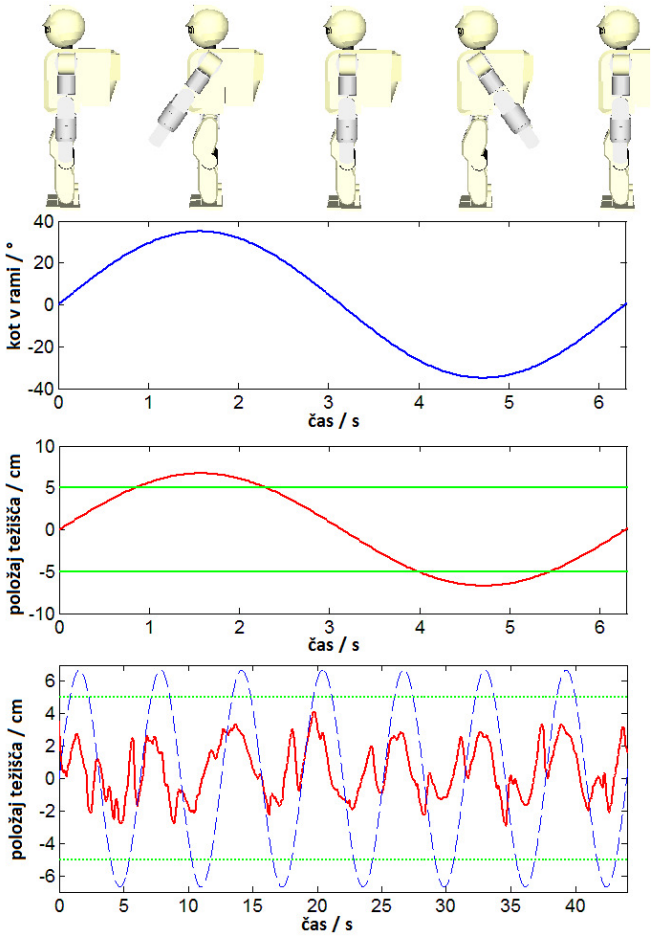
nevron in poda signal aktivacije, ki gre preko prenosne funkcije, katerega izhod je enak izhodu nevrona. Za prenosno funkcijo se največkrat uporablja pragovna funkcija ali Gaussova funkcija.
Pri eksperimentu smo uporabili usmerjeno nevronsko mrežo (ang. feed-forward neural network). Pri tej vrsti nevronske mreže gredo podatki le v smeri od vhodnega nivoja k izhodnemu nivoju. Torej ne vsebuje nobenih povratnih zank med nivoji.

3 EKSPERIMENT

Glavni cilj eksperimenta je bil, da človek nauči robota, kako zagotavljati svojo ravnotežje ob prisotnosti določenih motenj. Pri tem so bili uporabljeni trije glavni elementi. Prvi element je bil haptični vmesnik, ki je človeku nudil povratno informacijo o robotovi dinamiki. Drugi element je bil vmesnik, ki je zajel gibanje človeka in ga prenesel na robota. V ta namen smo uporabili sistem za zajem gibanja (ang. motion capture system). Ta sistem je sestavljen iz markerjev, ki jih pritrdimo na človekove sklepe, in kamer, ki optično zaznavajo položaje teh markerjev. Na podlagi položajev zaznanih markerjev smo izračunali kote v človekovih sklepih. Zaradi podobnosti konstrukcije človekovega in robotovega telesa smo kote v človekovih sklepih direktno prenašali na motorje v robotovih sklepih. Eventualne razlike med sklepi robota in človeka pa je človek kompenziral s prilagodljivostjo in sposobnostjo senzorično-motoričnega učenja. Zadnji element pa je bilo orodje strojnega učenja, s pomočjo katerega smo zgradili avtonomni krmilnik. V našem primeru je bila to umetna nevronska mreža.

3.1 Demonstracija

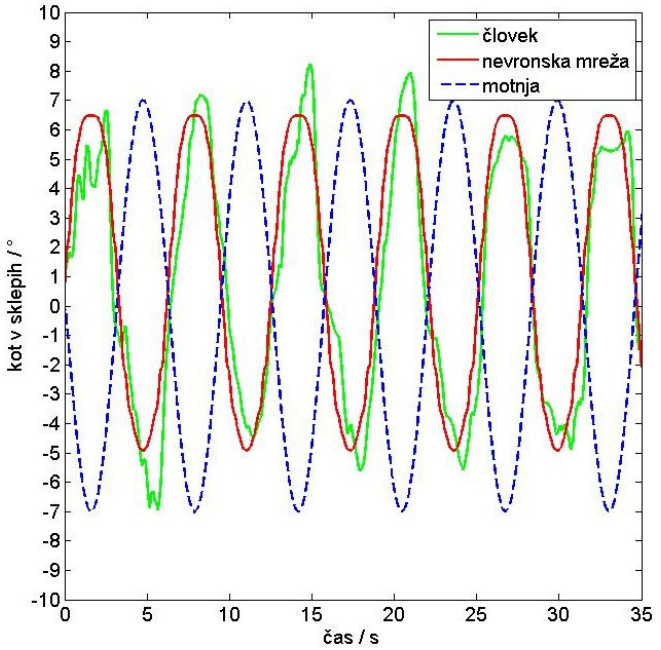
Eksperiment je potekal v več fazah. V prvi fazi se je človek priučil uporabe povratne informacije iz haptičnega vmesnika. Sledil je glavni del, kjer je človek robotu demonstriral, kako zagotavljati svoje ravnotežje ob prisotnosti motenj. Zadnja faza pa je bila učenje nevronske mreže na podlagi pridobljenih učnih podatkov. Eksperiment je bil opravljen v simulacijskem okolju MATLAB Simulink. Robota smo simulirali s pomočjo inverznega nihala. Robot je držal v rokah nek predmet z določeno maso. Ta predmet je premikal iz položaja pred svojim telesom, v položaj za svojim telesom. Te premiki so predstavljali motnjo robotovemu ravnotežju in so bili izvedeni s pomočjo rotacije v ramenskih sklepih. Zaradi mas rok in mase predmeta, se je spreminjal položaj robotovega težišča. Te spremembe je zaznal človek preko haptičnega vmesnika, na podlagi katerih se je moral primerno odzvati z rotacijo c gležnju.
Slika 3 prikazuje premike rok ter posledične spremembe položaja težišča. Zgornja ilustracija prikazuje položaje robotovih rok v določenih trenutkih. Premike rok iz točke pred robotovim telesom, v točko za robotovim telesom smo izvajali periodično po sinusni funkciji. Posledica premika rok je premik težišča robota (prvi graf). V primeru, da ne pride do reakcije na to spremembo, gre robotovo težišče izvem stabilnega področja (drugi graf). Stabilno območje smo definirali z dimenzijami podpornega poligona oziroma dolžino robotovih podplatov. Da robotovo težišče ostane znotraj stabilnega območja, je potrebna primerna reakcija človeka. Iz zadnjega grafa vidimo, da je bil človek sposoben držati težišče robota znotraj stabilnega območja skozi celoten potek demonstracije.



Slika 3. Na prvi sliki vidimo položaje rok robota ob različnih trenutkih. Prvi graf prikazuje spremembo kota robotovega ramenskega sklepa (modra črta). Drugi graf prikazuje posledično spremembo robotovega težišča v primeru, ko človek ni vodil robota (rdeča črta). Vidimo da gre težišče izven stabilnega območja (zeleni črti). Tretji graf pa prikazuje robotovo težišče skozi demonstracijo (rdeča črta).

3.2 Strojno učenje

Skozi človekovo demonstracijo smo zbirali podatke za učno množico, katero smo v naslednji fazi eksperimenta uporabili za učenje robota. Avtonomni robotski krmilnik smo zgradili s pomočjo umetne nevronske mreže. Pri tem smo, kot vhodni podatek v nevronsko mrežo, uporabili informacijo o težišču robota. Izhod nevronske mreže pa je bil kot v sklepu gležnja, potreben za kompenzacijo spremembe težišča, ki predstavlja motnjo robotovega ravnotežja.



Slika 4. Primerjava človekove reakcije (zelen graf) na motnjo robotovega ravnotežja (moder graf) in odziva naučene nevronske mreže (rdeč graf).

Na sliki 4 je prikazana primerjava med odzivom človeka na motnjo ravnotežja in odzivom nevronske mreže, ki sedaj avtonomno krmili robota. Modra prekinjena črta predstavlja premik robotovega težišča, zaradi premika rok. Želena črta je sprememba kota v gležnju, ki je bil posledica človekovega odziva na omenjeno motnjo. Ta dva podatka sta predstavljala primer oziroma učno množico za učenje nevronske mreže. Rdeča črta pa je kot v gležnju robota, krmiljen s strani naučene nevronske mreže. Vidimo, da nevronska mreža uspešno imitira nalogo, ki je bila predhodno pokazana s strani človeka.

4 ZAKLJUČEK

V članku smo predstavili poseben haptični vmesnik, namenjen učenju robotov. Ta vmesnik smo preskusili z eksperimentom, kjer je človek moral zagotavljati ravnotežje robota ob prisotnosti motenj, s premiki telesa v gležnju. Ker se je ta eksperiment osredotočal na preskus učinkovitosti povratne informacije, ki jo človeku nudi omenjeni hpatični vmesnik, smo izbrali relativno enostavno nalogo. Eksperiment smo nadgradili z učenjem robota zagotavljanja lastne stabilnosti. Podatke o reakcijah človeka na motnje robotovega ravnotežja smo uporabili za učenje nevronske mreže, ki je v naslednji fazi zamenjala človeka pri vodenju robota.

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MINIMUM TIME TRAJECTORY PLANNING USING GENATIC ALGORITHMS AND DMPS PRESENTATION FOR INDUSTRIAL ROBOTS

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ABSTRACT

This paper presents a Steady State Genetic Algorithm (SSGA) to obtaine minimum time trajectories with Dynamic Movement Primitives (DMPs) presentation. The algorithm is fed in first place by a sequence of configurations then, cubic spline functions are used for the construction of joint trajectories for industrial robots. Consequently, these polynomials are used to to learn the weights w_i in the nonlinear function f that characterize the spatiotemporal path of a DMP. In this manner, many of DMPs charecteristics like phase stopping can be achieved online during the robot operation. The algorithm has been tested with kinmeatic constraints on Puma 560 robot.

1 INTRODUCTION

In the last decades, industrial robots have been used widely in automatic production lines. They are, in general, highly nonlinear, coupled, multivariable systems with nonlinear constraints. For this reason, the indirect method for trajectory planning is often used. Indirect method is divided into two stages: path planning and then trajectory adjustment. Path planning concerns of the obtainment of the free collision path between initial and final configurations of the manipulator considering kinematic and geometric constraints. A trajectory can be adjusted to a given path by optimizing the temporal evolution of the robot configurations.

In order to maximize the speed of operation that affects the productivity in industrial situations, it is necessary to minimize the total traveling time of the robot. More research works have been carried out to get minimum time trajectories [1]-[5]. The early trajectory planning models [6]-[7] used a nonlinear programming approach to solve the trajectory planning problem in either gripper or joint space.

Algebraic splines are widely employed for path planning, cubic splines [7], quartic splines [8], and quintic splines [9]. The first formalization of finding the optimal curve by interpolating a sequence of nodes in the joint space can be found in [7].

The methods that are used in the literatures such as sequential unconstrained minimization technique (SUMT) [1]-[5], sequential quadratic programming (SQP) [10], interval analysis [11], [9] and numerical iterative procedure [12] to deal with the complex instances (obstacles environment) have some notable drawbacks: (1) they may fail to find the optimal path , (2) they have limited capabilities when handling cases where the limits of maximum acceleration and maximum deceleration along the solution curve are no longer met and (3) singular points or critical points of robot configuration may exist. To overcome the above drawbacks, the evolutionary algorithms can be used [13]. The advantages of evolutionary techniques are (1) Population based search, so more lucky to avoid local minima. (2) No need of any auxiliary information like gradients, derivatives, etc. (3) Complex and multimodal problems can be solved for global optimality. (4) Problem independent nature. In the last two decades, evolutionary algorithms such as Niched Pareto Genetic Algorithm [14], Multi-Objective Genetic Algorithms [15], Elitist Non-dominated Sorting Genetic Algorithm [16], Multi-Objective Differential Evolution [17], SSGA and parallel populations GA [18]-[22], evolutionary algorithm using B-splines [23], among many others, have been applied in the fields of robotics, planning, control, system identification, etc..

In this paper, SSGA is used to find and optimize the sum of the time intervals $[t_j, t_{j+1}]$ needed to move the robot from initial to final configuration through a via points. The via points are connected in first place by cubic polynomials. These polynomials are then used to estimate the DMPs weights w_i. The summation of time intervals will be the temporal scaling factor τ for DMPs. During the DMP integration, the velocities and accelerations constraints are validated for a certain amount of intermediate points between each two via points.

Discrete DMPs have been used in this work, which can encode control policies for discrete point to point movements. DMPs are based on systems of second-order differential equations, which encode the properties of the desired motion [24]. Periodic and discrete movements

formulation have been developed [25]. One of the most important advantages of DMPs is the ability to take into account perturbations and to include feedback terms.

2 CUBIC POLYNOMIAL FORMULATION

The initial expression for the robot trajectory between via points is done using cubic polynomials. Let Q be the set of m viapoints the compose the path. $Q_j(q_i, j)$ and $Q_{j+1}(q_i, j+1)$ two via points belonging to Q.

$$q_{ij} = a_{ij} + b_{ij}t + c_{ij}t^2 + d_{ij}t^3 \quad (1)$$

where t is the minimum time needed to move the robot between two via points. i = 1, 2,…, DOF, is the robot degrees of freedom. j = 1, 2,…, m-1, m is nuber of via points. The smoothness of the trajectory can be guaranteed by imposing the following conditions::

1) Position:
   For each interval j the initial and final position must fit Q_j and Q_{j+1}, obtaining $(2 \cdot \mathrm{DOF} \cdot (m-1))$ equations.
2) Velocity:
   The velocities at the ends of the path must be zeros. This will contribute $(2 \cdot \mathrm{DOF})$ equations. On the other hand, between intermediate configurations, the velocities at the end of an interval must be the same as the initial velocities of the following interval. This will contribute $(\mathrm{DOF} \cdot (m-2))$ equations.
   $$\dot{q}_{ij} = \left(t = \sum_{j=1}^{n} t_j\right) = \dot{q}_{i,j+1}(0) \quad (2)$$
3) Acceleration:
   In the intermediate configurations, the acceleration at the end of an interval must be the same as the one at the beginning of the next interval. This will contribute $(\mathrm{DOF} \cdot (m-2))$ equations.
   $$\ddot{q}_{ij} = \left(t = \sum_{j=1}^{n} t_j\right) = \ddot{q}_{i,j+1}(0) \quad (3)$$

The previous conditions define a $(4 \cdot \mathrm{DOF} \cdot (m-1))$ linear independent system of equations when the time between successive configurations of the sequence Q is known.
In next step, the previous polynomials will be used to learn DMPs. A SSGA procedure has been implemented to optimize the time intervals which will be used as a temporal scaling for DMPs.

3 DMPs FORMULATION

The most current formulation as outlined in [26] is used. For a single degree of freedom denoted by y, which can either be one of the internal joint angles or one of the external task-space coordinates, the following system of linear differential equations with constant coefficients has been proposed as a basis for motion specification:

$$\tau\dot{z} = \alpha_z(\beta_z(g - y) - z) \quad (4)$$

$$\tau\dot{z} = z \quad (5)$$

where α_z and β_z are selected appropriately, e.g., $\alpha_z = 4\beta_z$ and $\tau > 0$, this system has a unique attractor point $y = g, z = 0$.

Differential Eq. (4)–(5) ensure that y converges to g and can therefore be used to realize discrete point-to-point movements. To increase a rather limited set of trajectories that can be encoded by Eq. (4) and Eq. (5) and thus enable the approximation of general point-to-point movements, Eq. (4) needs to be modified. In the case of discrete movements, one can add a linear combination of radial-basis functions to Eq. (4), [27].

$$f(x) = \frac{\sum_{i=1}^{N} w_i \Psi_i(x)}{\sum_{i=1}^{N} \Psi_i(x)} x, \quad \Psi_i(x) = e^{-h_i(x-c_i)^2} \quad (6)$$

where c_i are the centers of radial basis function distributed along the trajectory, and $h_i > 0$. [26] scaled f by $(g - y_0)$; $y_0 = y(0)$. Thus, when the attractor point g changes, the encoded movement gets scaled. In this paper, [27] method is used where the scaling factor is omitted because we are not interested in automatic scaling. A phase variable x is used in (6) instead of time to make the dependency of f on time more implicit. Its dynamics can be defined by

$$\tau\dot{x} = -\alpha_x x \quad (7)$$

with initial value $x(0) = 1$. A solution to (7) is given by:

$$x(t) = e^{-\alpha_x t/\tau} \quad (8)$$

thus x tends to 0 as time increases. As shown in [26], the appealing property of using the phase variable x instead of explicit time is that by appropriately modifying (7), we can, for example, stop the evolution of time to account for perturbations during trajectory execution. This results in the following system of differential equations:

$$\tau\dot{z} = \alpha_z(\beta_z(g - y) - z) + f(x) \quad (9)$$

$$\tau\dot{y} = z \quad (10)$$

The trajectory of any smooth movement can be approximated by adapting the parameters w_i of Eq. (6). The system of two first-order liner equations Eq. (9) and Eq. (10) can be rewritten into one second-order equation by replacing z with $\tau\dot{y}$ in Eq. (9)

$$\tau\ddot{y} + \alpha_z\tau\dot{y} - \alpha_z\beta_z(g - y) = f \quad (11)$$

with f defined as in Eq. (6). Note that time constant τ must be the same for all degrees of freedom. A possible choice is $\tau = t_T$; where t_T is the duration of the training movement. On the other hand, the attractor points g vary across the degrees of freedom. They can be extracted directly from the data: $g = y_d(t_T)$.

$$F_d(t_j) = \tau^2\ddot{y}_d(t_j) + \alpha_z\tau\dot{y}_d(t_j) - \alpha_z\beta_z\left(g - y_d(t_j)\right) \quad (12)$$

$$f = \begin{bmatrix} F_d(t_1) \\ \cdots \\ F_d(t_T) \end{bmatrix}, \quad W = \begin{bmatrix} w_1 \\ \cdots \\ w_N \end{bmatrix} \quad (13)$$

This leads to the following system of linear equations:

$$Xw = f \quad (14)$$

which needs to be solved to estimate the weights of a DMP encoding the desired motion. The system matrix X is given by:

$$X = \begin{bmatrix} \frac{\sum_{i=1}^{N} \Psi_1(x_1)}{\sum_{i=1}^{N} \Psi_i(x_1)} x_1 & \cdots & \frac{\sum_{i=1}^{N} \Psi_N(x_1)}{\sum_{i=1}^{N} \Psi_i(x_1)} x_1 \\ \vdots & \ddots & \vdots \\ \frac{\sum_{i=1}^{N} \Psi_1(x_T)}{\sum_{i=1}^{N} \Psi_i(x_T)} x_T & \cdots & \frac{\sum_{i=1}^{N} \Psi_N(x_T)}{\sum_{i=1}^{N} \Psi_i(x_T)} x_T \end{bmatrix} \quad (15)$$

The phase sampling points x_i are obtained from Eq. (8). The parameters w can be calculated by solving the above system of linear equations in a least-squares sense. The resulting DMP ensures that the robot (approximately)

reaches the attractor point g at time t_T. Since discrete DMPs have been designed to represent discrete point-to-point movements, the training movement must come to a full stop at the end of the demonstration if the robot is to stay at the attractor point after t_T. If any other type of motion is approximated by a DMP, the robot will overshoot the attractor point and returned back to it after the dynamics of the second-order system of differential equations starts dominating the motion. At least theoretically, the velocity does not need to be zero at the beginning of movement.

In the equations above, α_x, α_z, and β_z are constants. They are set so that the convergence of the underlying dynamic system is ensured, which is for example the case used in this paper; $\alpha_x = 2$, $\beta_z = 3$, $\alpha_z = 4\beta_z = 12$. Note that unlike [24]-[28], who suggested to estimate the parameters w_i independently of each other using locally weighted regression, we apply a full linear system (14) to estimate w. In this way we can approximate trajectories more accurately because we can take into account the interplay between the neighbouring basis functions Ψ_i of Eq. (6). Note that the separate estimation of $\{w_i\}$ has its advantages, especially in the presence of noise when overfitting can become a problem [25]. The local approach is especially useful in the context of reinforcement learning, where the initial trajectories do not need to be estimated accurately because they are updated in later steps anyway.

4 SSGA PROCEDURE

Steady State Genetic Algorithm (SSGA) uses overlapping populations. This means, the ability to specify how much of the population should be replaced in each generation. Newly generated offspring are added to the population, and then the worst individuals are destroyed [29].

The objective in this optimization procedure is to determine a set of optimum values of time intervals $t_1, t_2, \dots, t_{n-1}$. The $\sum_{i=1}^{n-1} t_i$ will be used as a temporal scaling in the DMPs that represent the whole trajectory.

GA Objective Function: $\sum_{i=1}^{n-1} t_i$, subject to velocities and accelerations limits.

5 RESULTS

The introduced procedure has been applied to a Puma 560 robot using a computer with Intel(R) Core™ i7 CPU 920 @ 2.67GHz, 4GB RAM. For GA, the MIT GALib [29] is used and adapted to the problem.

Joint	Via-points (deg)					
	1	2	3	4	5	6
1	-10	virtual	60	20	virtual	55
2	20		50	120		35
3	15		100	-10		30
4	150		100	40		10
5	30		110	90		70
6	120		60	100		25

Table 1: Sequence of configurations

A path with 6 configurations including the initial and final one has been used for testing, Table 1. The algorithm succeeds to solve the problem and obtains a path that passes through the via points in 8.5627 seconds. Moreover, it succeeds to represent the path using DMPs,. Like this we can utilize the DMPs parameters, e.g. phase stopping online while the robot is operating and, as a consequence, preventing any unanticipated situation in the offline planning.

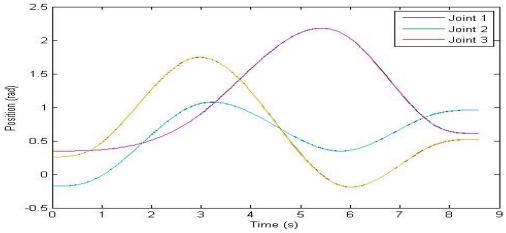

Figure 1: *Position for joints 1, 2, 3.*

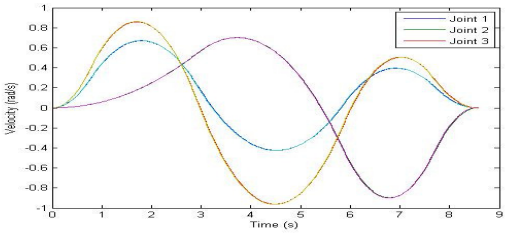

Figure 2: *Velocity for joints 1, 2, 3.*

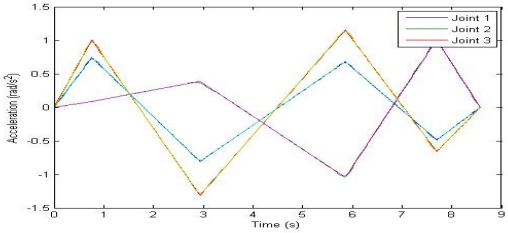

Figure 3: *Aceleration for joints 1, 2, 3.*

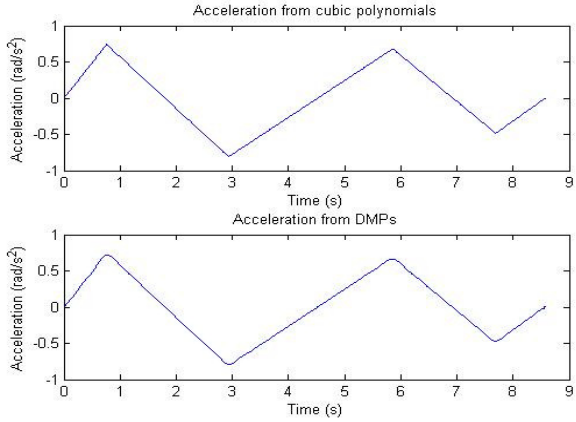

Figure 4: *Aceleration for first joints.*

6 CONCLUSION

In this paper SSGA is used to optimize the time trajectory intervals for a given sequence of configuration and then presenting the trajectory using DMPs. The use of DMPs will provide many advantages: (1) achiving smooth movement and acceleration, see Fig (1-4), (2) the appility to execute the

path online and utilize the DMPs parameters, e.g. phase stopping.

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SKLAPLJANJE TRAJEKTORIJ ZA IZVAJANJE DVOROČNIH NALOG

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ABSTRACT

The framework of dynamic movement primitives allows the generation of discrete and periodic trajectories, which can be modulated in various aspects. In this paper we propose and evaluate a modulation approach which extends the framework to allow coupling of independently executed robotic trajectories and thus simplifies the execution of bimanual and cooperative asks. In a few iterations the proposed algorithm learns the necessary coupling term to modify the trajectory in accordance to the desired position or external force. The strengths of the algorithm, which fits in the scope of the iterative learning control algorithms, are shown in bimanual or two-agent tasks, where no higher level cognitive reasoning or planning are required. Results of simulated experiments are presented.

1 UVOD

Vse večji del robotskih raziskav se direktno ali indirektno nanaša na kompleksna vsakodneva okolja ljudi [1]. Taka okolja so nestrukturirana in se spreminjajo, zato potrebujejo roboti sposobnost prilagajanja in učenja, da lahko delujejo tudi ob nepredvidenih situacijah in to brez prisotnosti eksperta [2]. Sinteza trajektorij zato ostaja eden od ključnih raziskovalnih problemov robotike [3]. V prispevku opisujemo nov pristop prilagodljivega učenja robotskih gibanj. Taka gibanja omogočajo varno interakcijo z okoljem ter izvedbo dvoročnih nalog. V prispevku se osredotočamo predvsem na dvoročne naloge. Algoritem je osnovan na modulaciji dinamičnih primitivov gibanja (*ang.* dynamic movement primitive – DMP), ki izhajajo iz demonstracije giba. Mi vnesemo dodaten sklopitveni člen, s katerim spremenimo trajektorijo v nekaj poskusih oz. epohih učenja. Pradlagani algoritem učenja sodi med iterativno učenje vodenja (*ang.* Iterative Learning Control – ILC).

Različni načini zapisa trajektorij omogočajo razne vrste modulacije, interpolacij ter celo kategorizacije trajektorij [3]. Med različne zapise spadajo npr. zlepki (*ang.* spline) [4], Gausova Regresija (Gaussian Mixture Regression) [5] ter skriti markovski modeli [6]. Mi gradimo na dinamičnih primitivih gibanja, ki so jih uvedli Ijspeert et al. [7]. Ta metoda omogoča zapis trajektorije z naborom diferencialnih enačb, njeno spreminjanje pa z majhnim številom parametrov. Slednje je uporabno za učenje z okrepitvijo [8, 9, 10, 11], statistično generalizacijo [12, 13] ter kombiniranje trajektorij [14, 15].

Struktura DMP zapisa omogoča vključitev senzorskih informacij, kar se je pokazalo npr. pri izogibanju oviram [16],[17] ali pa pri izvajanju periodičnih nalog [18]. V prispevku predlagamo uporabo senzorskih informacij za moduliranje DMP trajektorij, kjer prvič izvedemo neko trajektorijo, drugič pa uporabimo informacije s prvega poskusa za spremembo gibanja. Pri tem ne spreminjamo originalne demonstracije ampak se učimo oblike in amplitude sklopitvenega člena. Sklopitveni člen lahko predstavlja merjeno silo med dvema manipulatorjema / agentoma ali pa virtualno silo. Pri metodi se zgledujemo tudi po ljudeh, ki ponavadi potrebujejo nekaj poskusov gibanja, preden lahko nalogo uspešno izvedejo [19].

Povratno informacijo o sili za učenje in popravljanje trajektorij gibanj v obliki DMP so že uporabili za brisanje ravnih in kompleksnih površin [2]. V nasprotju s predlaganim pristopom so modificirali celoten zapis trajektorije. Podobno so Pastor et al. [1] demonstrirali metodo, ki zahteva nekaj ponovitev končne (diskretne) naloge, s čimer modificirajo trajektorijo z uporabo senzorskih informacij. Implementirali so nizko-nivojska pozicijski regulator ter regulator sile, ki se integrira z DMP trajektorijo na nivoju pospeškov. Njihova ideja je, da se po motnji uporabi senzorske informacije v naslednjem poskusu izvedbe.

V prispevku najprej podamo osnovne informacije o primitivih gibanja oz. DMPjih. Sledi razlaga sklopitve ter algoritma učenja. Rezultati so prikazani v petem poglavju. Na koncu sledijo zaključki.

2 PRIMITIVI GIBANJ

Zapis trajektorije s primitivi gibanj oz DMPji je podrobno opisan v literaturi [7, 20]. V tem poglavju podamo osnovno formulacijo, na kateri je v nadaljevanju izpeljana modulacija za dvoročne naloge. Formulacija v tem članku je bila uporabljena tudi v [20, 12]. Za eno stopnjo prostosti (DOF), ki jo označimo z y, v našem primeru je to ena od prostostnih stopenj prostora naloge, je DMP definiran z naslednjim sistemom nelinearnih diferencialnih enačb

$$\tau \dot{z} = \alpha_z(\beta_z(g - y) - z) + f(x), \quad (1)$$

$$\tau \dot{y} = z. \quad (2)$$

$f(x)$ je podan kot linearna kombinacija baznih funkcij

$$f(x) = \frac{\sum_{i=1}^{N} w_i \Psi_i(x)}{\sum_{i=1}^{N} \Psi_i(x)} x, \tag{3}$$

$$\Psi_i(x) = \exp\left(-h_i \left(x - c_i\right)^2\right), \tag{4}$$

kjer so c_i centri baznih funkcij, razporejenih po trajektoriji in $h_i > 0$. Če so parametri $\alpha_z,\ \beta_z,\ \tau > 0$ in $\alpha_z = 4\beta_z$, je sistem (1) – (2) kritično dušen in $y = g,\ z = 0$. Fazna spremenljivka x, iz enačb (1), (3) in (4) omogoča izogibanje neposredni odvisnosti f od časa . Njeno dinamiko podaja

$$\tau \dot{x} = -\alpha_x x, \tag{5}$$

z začetno vrednostjo $x(0) = 1$. α_x je pozitivna konstanta.

Vektor uteži $\mathbf{w}$, sestavljen iz w_i, določa obliko trajektorije. [7] in [12] opisujeta učenje uteži. Več stopenj prostosti izvedemo s seti enačb (1) – (4), en sam kanoničen sistem, podan z enačbo (5), pa jih sinhronizira.

3 SKLAPLJANJE TRAJEKTORIJ

Dve trajektoriji, zapisani z DMPji, sta podani z utežmi $\mathbf{w}_j$ in $\mathbf{w}_{j-1}$ ter ciljema g_j in g_{j-1}. Za sklopitev trajektorij oz. za njuno kooperativno delovanje, primer tega bi bil dvoročno prenašanje objekta, med trajektoriji vnesemo vitrualno vzmet. To si lahko predstavljamo tudi kot realno vzmet med vrhoma dveh manipulatorjev, ker sta trajektoriji zapisani v prostoru naloge. Virtualna vzmet deluje na vsako od trajektorij s silo (v eni od prostostnih stopenj)

$$F_{1,2} = k(d - l), \tag{6}$$

kjer je d želena razdalja med vrhoma robotov in l dejanska razdalja, k pa konstanta vzmeti. Ker je vzmet med robotoma, deluje sila na DMP_1 v drugo smer kot pri DMP_2

$$F_{1,2} = -F_{2,1}. \tag{7}$$

Te sile vnesemo v enačbo(2). Enačbe dveh kooperativnih DMP trajektorij so sedaj:

$$\tau \dot{z_1} = \alpha_z(\beta_z(g_1 - y_1) - z_1) + f_1(x), \tag{8}$$

$$\tau \dot{y_1} = z + F_{1,2} \cdot l_f, \tag{9}$$

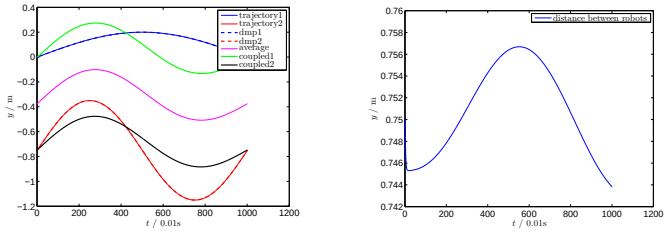
$$\tau \dot{z_2} = \alpha_z(\beta_z(g_2 - y_2) - z_2) + f_2(x), \tag{10}$$

$$\tau \dot{y_2} = z - F_{1,2} \cdot l_f. \tag{11}$$

Spremenljivka l_f določa razmerje vodilni/sledilni robot. Za sedaj je $l_f = 1$.

Obnašanje koopeerativnih DMPjev, kot sta npr. DMP_1 in DMP_2, je odvisno od konstante vzmeti k. V splošnem je z večjo konstano vzmeti večji tudi vpliv na trajektorijo.

Za primer vzemimo, da DMP_1 zapiše trajektorijo $x_1 = \sin(1/10 * \pi * t) * 0.2$ in DMP_2 trajektorijo $x_2 = 0.4 * \sin(2/10 * \pi * t) - 0.75$. Trajektoriji sklopimo po enačbah (8 – 11) z virtualno vzmetjo s kontanto $k = 100$ N/m. V rezultatih lahko vidimo, da se trajektoriji prilagodita ena drugi, vendar razdalja med njima ni konstantna. Želena razdalja med robotoma je v tem primeru $d = 0.75$ m.



Slika 1: Spremenjeni trajektoriji zaradi sklopitve DMPjev (levo) ter razdalja med robotoma (desno).

4 UČENJE

Za kooperativne trajektorije, kjer želimo, da ni napake v razdalji med robotoma, oz. da je napaka minimalna, predlagamo algoritem učenja, ki deluje na principu iterativnega učenja vodenja (ILC) [21]. Algoritem zahteva nekaj ponovitev gibanja, da se s tem nauči oblike in amplitude sklopitvene sile, ki jo prištejemo izmerjeni (virtualni) sili. Konstanta vzmeti je konstantno na k=100 N/m.

Enačbo (6) spremenimo v

$$F_{1,2} = F_{meas} + F_l, \tag{12}$$

kjer je F_{meas} izmerjena (virtualna) sila po enačbi 6 in F_l naučena sila, ki jo vnaprej prištejemo DMP trajektoriji. Nekaj ponovitev giba oz. epohov je potrebnih, da se naučimo F_l. V prvem poskusu je $F_l = 0$. V nadaljnih uporabimo, v i-tem epohu

$$F_{l,i} = F_{l,i-1} + F_{meas,i-1}. \tag{13}$$

Sklopitveni člen oziroma silo nadalje zapišemo v enaki obliki kot enačbo (3). Utežne parametre v i-tem epohu izračunamo po

$$F(t_j) = F_{l,i}(t_j), \tag{14}$$

$$\mathbf{f} = \begin{bmatrix} F(t_1) \\ \dots \\ F(t_T) \end{bmatrix},\ \mathbf{w} = \begin{bmatrix} w_1 \\ \dots \\ w_N \end{bmatrix}.$$

Dobimo set linearnih enačb

$$\mathbf{X}\mathbf{w} = \mathbf{f}, \tag{15}$$

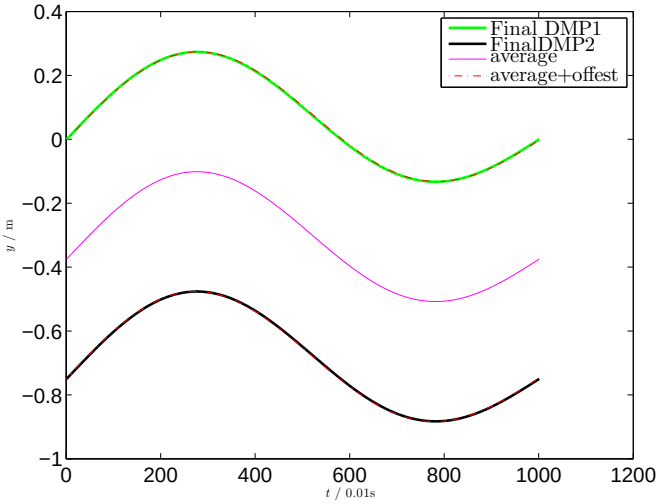
ki jih moramo rešiti, torej

$$\mathbf{X} = \begin{bmatrix} \frac{\Psi_1(x_1)}{\sum_{i=1}^{N} \Psi_i(x_1)} x_1 & \dots & \frac{\Psi_N(x_1)}{\sum_{i=1}^{N} \Psi_i(x_1)} x_1 \\ \dots & \dots & \dots \\ \frac{\Psi_1(x_T)}{\sum_{i=1}^{N} \Psi_i(x_T)} x_T & \dots & \frac{\Psi_N(x_T)}{\sum_{i=1}^{N} \Psi_i(x_T)} x_T \end{bmatrix}$$

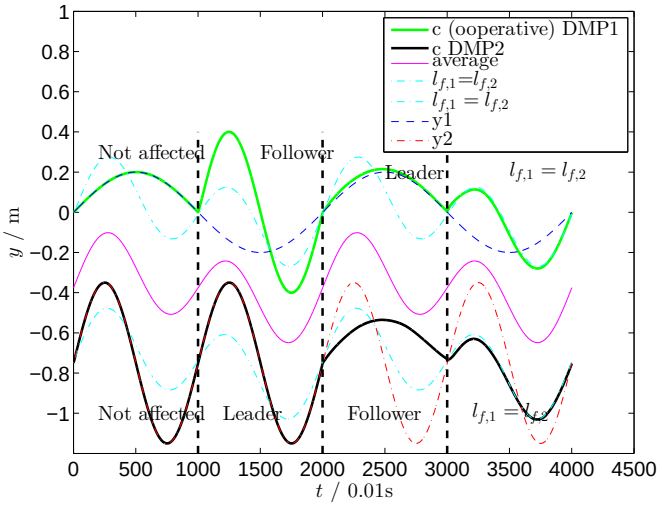
Utežne parametre $\mathbf{w}$ izračunamo z rešitvijo zgornjega sistema linearnih enačb v smislu najmanjših kvadratov.

5 REZULTATI

V simulaciji smo preizkusili sklopitev trajektorij dveh robotov. Slike 2 - 4 prikazujejo rezultate.



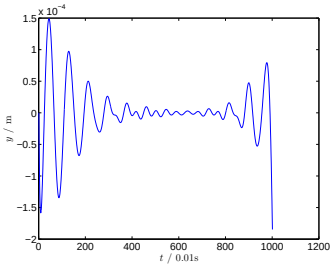
Slika 2: Kooperativne trajektorije v črni in zeleni barvi. Trajektorije so enako oddaljene od roza trajektorije, ki predstavlja povprečje obeh ttrajektorij.



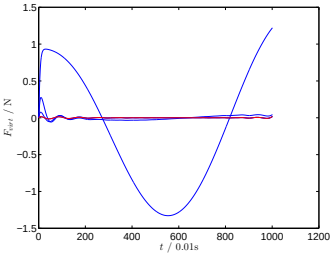
Slika 5: Kooperativne trajektorije (zelena in črna) ob spreminjanju odnosa vodilni – sledilni robot.

5.1 VODILNI–SLEDILNI ROBOT

Razmerje vodilni–sledilni robot je pomembno, če se mora, npr. en od robotov umakniti oviri. Slika 2 prikazuje rezultate, kjer se obe trajektoriji prilagajata in rezultat je povprečna trajektorija med njima. Če se mora prilagoditi samo en od robotov, medtem ko mu mora drugi enostavno slediti, to spremeni enačbi (9, 11). Spremenljivka l_f v (9, 11) določa kateri je vodilni robot in kateri sledi. Če je l_f v enem DMPju $l_f = 0$, ta robot ne bo spremenil svoje trajektorije (v smislu kooperacije) in bo to vodilni robot. l_f v drugem DMPju je $l_f = 1$. Če je $l_{f,1} = l_{f,2} = 0$, DMPja nista kooperativna. Če je $l_{f,1} = l_{f,2} = 1$, se oba DMPja prilagodita na želeno razdaljo od povprečne trajektorije. Če je $l_{f,1} = 0$ in $l_{f,2} = 1$, je DMP_1 vodilni. Če je $l_{f,1} = 1$ in $l_{f,2} = 0$, je DMP_2 vodilni. Odnos vodilni – sledilni robot se lahko sproti spreminja. Slike 5 – 6 prikazujejo rezultate spreminjanja razmerja vodilni – sledilni robot.



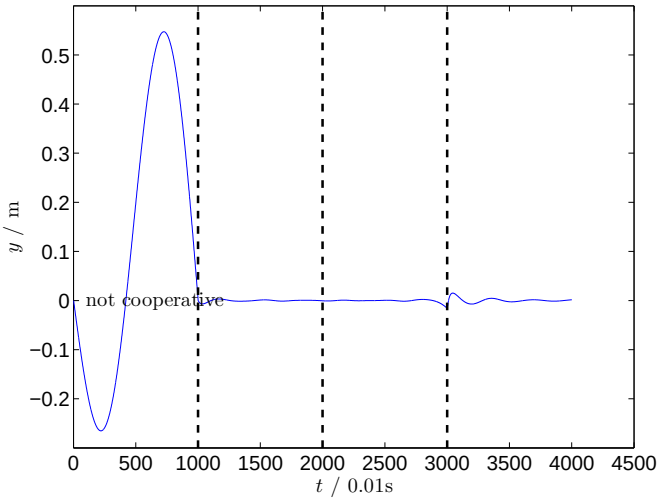
Slika 3: razdalja med vrhoma robotov po 4 epohih.



Slika 4: Virtualna sila med eksperimenti, po zadnjem (4-tem) eksperimentu označena z rdečo.

6 ZAKLJUČEK

V prispevku smo predstavili metodo modulacije DMP trajektorij za izvajanje dvoročnih kooperativnih nalog. Metodo se lahko uporabi tudi za prilagajanje robotov ob kontaktu z okoljem. Metodo lahko uporabimo tudi z realno silo, kar bomo preizkusili v nadaljnjih eksperimentih.



Slika 6: Razdalja med robotoma po 10 epohih.

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3 DOF NANO-PRECISION ROBOT MANIPULATION

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ABSTRACT

The paper describes the development of a nano-precision robot manipulator for micro assembling techniques with micro-sized objects. The experimental set up and its components are described, together with the three types of micro grippers: a two-finger griper, a one-finger pneumatic gripper and a one-finger ice-gripper. It has been shown that this types of a grippers are capable of gripping, moving and releasing objects of tens of micrometers in size. The one-finger ice-gripper has been found particulary useful for micro assembling techniques.

1 INTRODUCTION

Building micro-mechatronic structures or assembling micro parts are promising research topics, and will certainly result in the development of a new branch within modern industry. The possibility of producing systems in micro or even in nano scale opens new frontiers in various industries, because micro devices and machines with completely unpredictive features and properties could be built. All this is possible with extensive minituarization of components, which can already be seen in modern products. Of course, massive micro machine production with micro positioning, micro-machining, and especially micro-assembling tasks for micro-components within a micro world require new dedicated nano-precision robot-manipulators that must have submicron resolution and precision, must be reliable, and compact. An often used term for such a handling is nanohandling, due to nano scale positioning accuracy, or repeatability.

Several techniques for nanohandling are used for moving micro/nano objects:

-A top-down approach performs nanohandling using robotic systems with nano precision accuracy. The main goal of this approach is the miniaturization of robots, their end-effectors and other supporting robotic technology (sensing, gripping, control, *etc*.) to fulfill the demands of micro system technology and nanotechnology [1].

-A bottom-up approach or self-assembly performs massive parallel nanohandling by the autonomous organization of micro- and nano objects into patterns or structures by positioning parts onto a substrate (2D self-assembly) or the creation of 3D microstructures without human intervention [1], [2], [3].

Several other approaches have been reported, the use of optical tweezers [4], or dielectrophoresis [5] are also suitable for automated nanohandling.

The main part of this paper presents the experiments where different grippers are used for gripping the micro-scale objects. The most important physical effect for such objects is the so called van der Waals force. This force is a dominant force for objects smaller than 100 μm and is greater than the gravitational force of the same object. There is no problem when gripping the object and moving it to the other places with two or more finger gripper. The huge problem occurs when the gripper would like to release the micro-sized object. In this case, the adhesive force (van der Waals force) doesn't allow the object to be released from the gripper, so the object remains glued to one of the gripper's fingers. The so-called ice-gripping technique which overcomes previously mentioned problems is presented in the paper.

2 NANO-PRECISION 3 DOF ROBOT MANIPULATOR

The nanorobotic system is divided into two parts (see Fig. 1). The upper part of the figure consists of a real-time target application with a nanorobotic cell: a development computer machine marked as 1, a real-time controller computer card marked as 2, and a target computer application marked as 3.

The usual notebook computer marked as 1 is used as the development computer for control algorithms and user interfaces with an installed Windows XP operating system and a LabView 8.5 software package.

The PC computer, marked as 2, executes real time control algorithms using so-called Real Time Desktop Target software. This PC runs a LabView Real Time operating system, which is independent of all the other operating systems already installed on the PC. Our real-time target PC is supported by a 7356 PCI motion-controller card from the National Instruments Company. This card is used as an interface between the control algorithm and the piezoelectric motor-power drivers. Its output has a separate reference signal for piezoelectric motor drive in regard to each axis of the controlled system for all 5 axes and is calculated by signals from the position of feedback and desired position inputs using the control algorithm. The execution time of the control algorithm is about 3 μs. The micro/nanorobotic cell, presented as 3 (Fig. 2), is actuated by five linear piezo-motors produced by the PiezoMotor Upsala AB Company,

where the motor movement steps can have lengths from 4 nm to 8 µm and can achieve speeds of up to 12.5 mm/s using factory-delivered demo-drive electronics [6]. The construction of the nanorobotic cell is done in such a way that two of the piezo-motors act as X/Y manipulators, and the other three are used as motion drivers for three separate serving tables within the Z axis. Positional feedback values for all axes are achieved using electro-magnetic linear encoders produced by the NANOS Instruments Company. Each encoder-set's electronics are built using magnetic scale and sensor electronics. The linear position instrument has a resolution of 61 nm with precision of +/- 0.15% [7].

The second part of the application, as presented in the lower part of Fig. 2, shows a man-machine interface. It consists of a "remote computer" marked as 4, where a virtual model of the micro/nanorobotic cell, marked as 5 and a haptic-device, marked as 6, have been installed. The "remote computer" is a notebook, based on the Windows XP operating system, supported by a Microsoft Visual C++ software package and OpenHaptics software package from the Sensable Technologies Company. Both packages with the PC hardware are used for developing and executing the micro/nanorobot application. A UDP protocol, marked as 7, is used to ensure the fastest and reliable enough communication between the user and the machine.

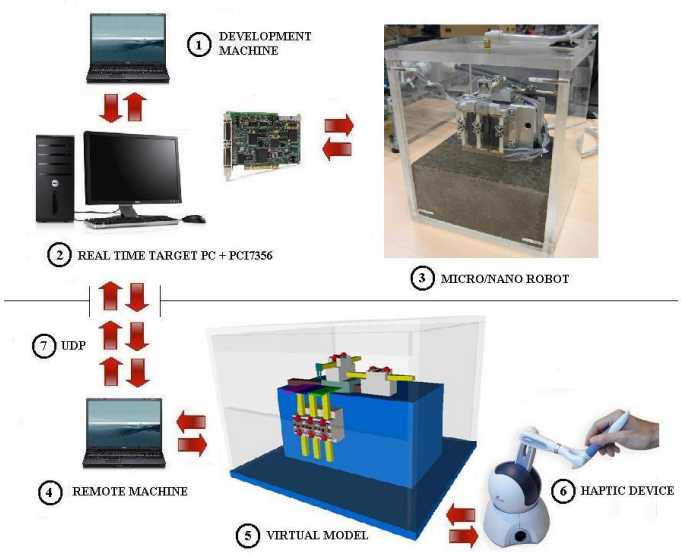

Figure 1: The nanoprecision robot workcell system

A virtual VRML model of the micro/nanorobotic cell, marked as 5, is also included in the application, because the user does not see the target application - manipulation of the micro sized objects on all three serving tables with the naked eyes. The user doesn't have a real feeling of what is exactly happening within the target application.

The fuzzy position controller system is established on the 7356 PCI motion-controller card [8] and was also succesfully tested on the 3 DOF nano precision robot.

3 GRIPPERS FOR MICRO OBJECTS

3.1. Two-finger gripper

The nano-precision robotic cell allows implementation of different micro-robotic tip tools. A special two finger gripper (Fig. 2) is used for gripping objects of micro-scale sizes (60 µm to 200 µm). It is placed at the top of the Y axis. It is made of so called structural glass, driven by a piezoelectric motor, which is situated horizontally to the vertical fingers of the gripper. The piezoelectric actuator allows the fingers to be moved approximately 140 µm. So, the gripping distance between fingers is between 60 µm and 200 µm. It was specially designed to grip and move optic fibre glass-cables with diameters between 100 µm and 125 µm.

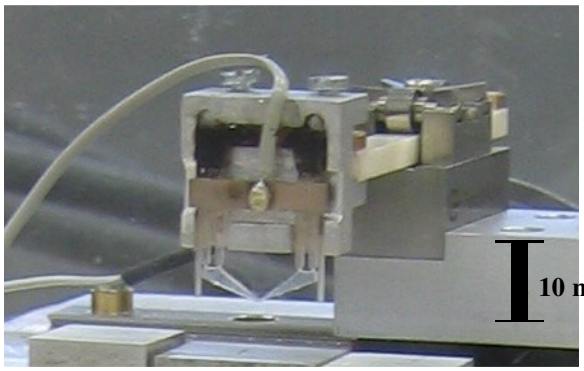

Figure 2. Close look of a micro -robot two-finger gripper

3.2 One-finger pneumatic gripper

Fig. 3 shows the scheme of a one-finger pneumatic gripper mounted on the tip of a nano-precision robot. Fig. 4 shows the tips of a one-finger pneumatic gripper, when it grips the micro-object (left part of the figure) and holds the micro-object (the right part of the figure). It consists of a glass tube with an inner diameter of approx. 70 µm. So, the gripper is appropriate for the gripping and releasing of micro-objects that are greater than the mentioned 70 µm.

This type of a gripper is able to annihilate the adhesive force between the gripper and the micro-object by simple airflow pressure on the tip of the tube. The tube is 0.8 cm long and needs a pressure of more than 8 bar to produce enough pneumatic force for the micro-object to be released. The problem is that if is deserable to decrease the inner diameter of the tube (to grip smaller micro-objects) then the needed pressure would increase remarkably. The other problem is that it is difficult to retain the airflow in the tube to be laminar. In case where the airflow becomes turbulent, then the reliability for a controlled releasing of the micro-object from the tube tip, decreases dramatically. This method has the success-rate of releasing the micro object at lower than 10 %, and in our opinion is unusable for massive industrial usage. Perhaps this method would be more successful if, instead of the pressurized air, some other gas with lower viscosity is needed.

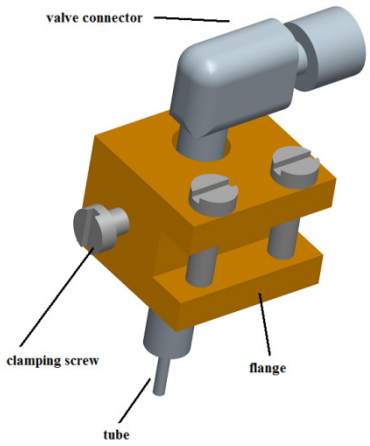

Figure 3: The scheme of a one-finger pneumatic gripper

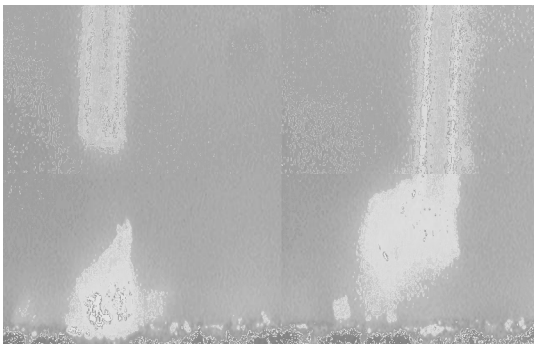

Figure 4: A one-finger pneumatic gripper in action

The idea of an ice-gripper is to move the robot metal tip close to the object and freeze the tip rapidly. The ice formed on the tip and eventually around the object is formed from water vapour surrounding the tip within a vacuum chamber. This ice encloses the object to be moved, than simply heat the tip, melt the ice and release the object after the movement.

Here, another problem is encountered. All the three phases of water have to be crossed: vapour, liquid, solid, and vice versa when cooling and heating the tip within a normal atmosphere. It is known that liquid water possesses enormous surface tension on its droplets, which is even more critical when treating it on a micro-scale. This great surface tension prevents the objects from being released even more because they are 'glued' to the surface of the tip or even get lost within the relatively large volume of droplets. For this reason it is necessary to eliminate the liquid phase of the water. In the phase diagram of the water (see Fig. 5), it can be clearly seen, that under the so- called 'triple point of water' (cca. 0 °C; cca. 6 mbar) there is no longer any liquid phase, but it is possible to move from vapour to solid (deposition) or solid to vapour (sublimation) phases directly.

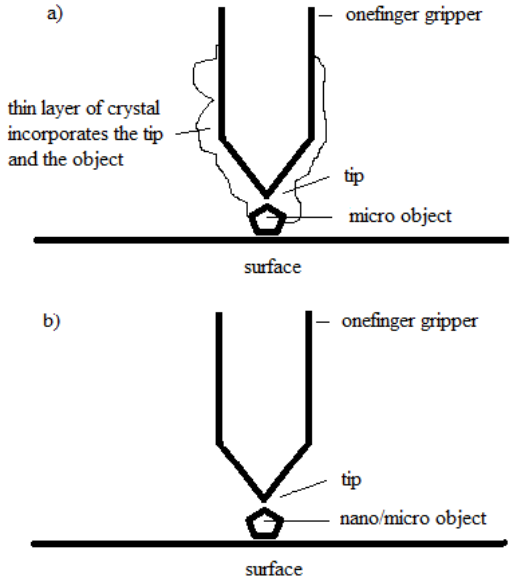

Figure 5: Gripping (a) and releasing (b) the object

Due to this reason, it is necessary to build a vacuum chamber with the cooling system for the ice-gripper (Fig. 6) with supporting systems (a feedback controled cooling system based on Peltier elements, an optical microscope, a feedback controled pressure sysytem) that can guarantee the conditions needed for operating of such an ice gripper. The overall mass, energy and information flow-summary of the whole ice-gripper system is presented in Fig. 7.

3.4 Comparison of grippers

Although all the presented micro-grippers have shown some level of usability, significant differences occurred between all the three principles. The two-finger gripper principle is the most intuitive solution, showing good gripping but poor releasing reliability. It is very limited when trying to build a gripper that would diminish the adhesion force between the finger and the object.

The one-finger pneumatic gripper is another solution, as it works well with objects that are greater than the inner diameter of the tube. In the presented case, this limit is about 70 µm and cannot be significantly reduced due to gas viscosity. Another usability limit is the uncontrolled release of the object, which happens very often.

The one-finger ice-gripper is the latest presented principle and has the greatest usability. The succes rate of gripping and releasing of objects' size between 1 - 60 µm is practically 100%. Futhermore, the mentioned principle allows to use micro assembling techniques, as shown in Fig.

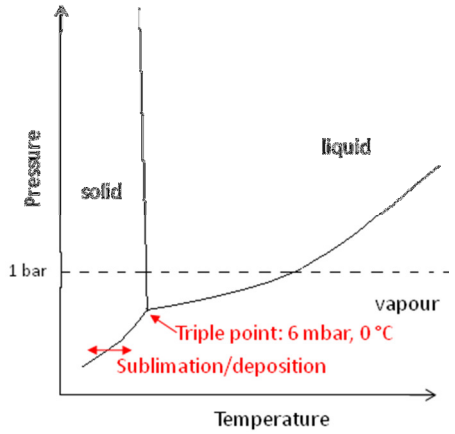

Figure 5: Water phase diagram [9]

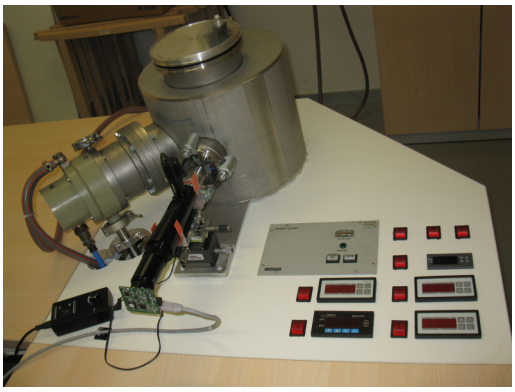

Figure 6: Vacuum chamber with an optical microscope

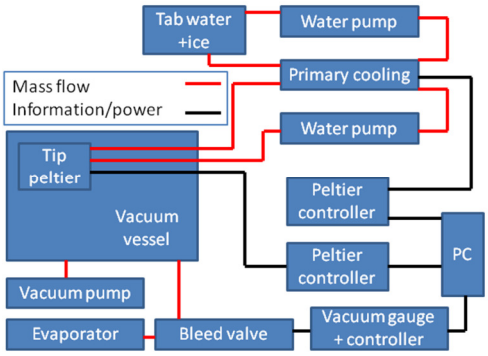

Figure 7: An ice-gripper system mass information and power-flow scheme

8, where a L-shape micro-sculpture was built with objects'size between 20-40 µm. The force that makes the sculpture standing upright is the Van der Waals force.

Figure 8: The upright standing construction made by glass microspheres sized between 20 and 40 µm

4 CONCLUSIONS

The paper presented the research development of a 3 DOF nano-precision robot manipulator with ultra-precise manipulating (repeatability: 4 nm to 61 nm) for emerging technologies of micro machine building. Then three grippers' techniques and their comparision were presented: a two-finger gripper, a one-finger pneumatic gripper and a one-finger ice-gripper. The most suitable gripping/releasing technique (a one-finger ice-gripper.) was used for micro assembling task.

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IZOGIBANJE OVIRAM NA NIVOJU KINEMATIČNEGA VODENJA

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ABSTRACT

Common approaches for kinematically redundant robot consist of a definition of several tasks properly combined in priority. However, in some cases the task priority needs to be changed in order to successfully perform the desired task without changing the initial strategy. One of such tasks is also obstacle or self-collision avoidance. The obstacle avoidance problem is usually defined as how to control the robot to track the desired end-effector trajectory, while ensuring that no part of the robot collides with any obstacle or itself. Without changing the trajectory of the end-effector, the reconfiguration of the robot can only be done if the obstacle is not in the end-effector path and if the manipulator has redundant degrees-of-freedom (DOF). If the obstacle appears on the end-effector path, methods which change the initial strategy and path need to be applied. In this paper we propose a novel method for obstacle avoidance of kinematically redundant robots, where we focus on a smooth, continuous transition between fully tracking the desired end-effector trajectory and moving away from the obstacles. The effectiveness of the proposed method is demonstrated on a robotic system with two Kuka LWR robots.

1 UVOD

Ena od pomembnih lastnosti, ki jo imajo nove generacije servisnih in humanoidnih robot je kinematična redundanca [1]. Kinematična redundanca je karakterizirana kot dodatna prostostna stopnja, ki se ne potrebuje za izvedbo določene naloge. Večina robotskih rok pritrjenih na mobilne platforme, kot tudi humanoidni roboti so kinematično redundantni. Kinematično redundantni roboti lahko premikajo vrh po isti trajektoriji vsakič z drugačno konfiguracijsko strukturo. Ta lastnost omogoča reševanje zapletenih nalog, kot je na primer izogibanje oviram, izogibanje singularnosti, optimizacija manimpulabilnosti, minimizacija navorov itd [2]. Posledično se gibljivost sistema precej izboljša, kar omogoča izvedbo kompleksnih nalog [1].

Splošen pristop za vodenje redundantnih robotov, ki se je uveljavil v zadnjem desetletju, je uporaba algoritmov, ki generirajo primerne pospeške v posameznih oseh tako, da se zagotovi izvajanje primarne naloge, sekundarne pa v ničelnem prostoru primarne naloge[1,3]. Preslikava hitrosti v ničelni prostor je naslednji primeren način vodenja redundantnih robotov. Vendar je pri teh metodah znano, da izkazujejo v določenih primerih nestabilno obnašanje [4]. Alternativni pristop tem metodam je uporaba razširjenega Jacobija [5], kjer se druga naloga doda primerni nalogi tako, da se dobi kvadratna Jacobijeva matrika, katero lahko invertiramo. Glavna pomanjkljivost tega pristopa so singularnosti algoritma. Te se pojavijo takrat, kadar je sekundarna naloga v konfliktu s primarno nalogo. Veliko napora je vodenje v kinematičnih robotov vložil tudi Khatib, ki je raziskoval uporabo kinematičnega inverza drugega reda na nivoju navorov in pospeškov. Njegove raziskave se nanašajo na vodenje redundantnih manipulatorjev [6], kot tudi na aplikacije na humanoidnih robotih [7,8].

V splošnem velja za algoritme, ki imajo naloge razvrščene po prioritetah, da ti ne omogočajo enostavnega spreminjanja prioritet posameznih nalog [2,9]. Na primer, če je naloga robota, da premika vrh po neki trajektoriji od točke A do točke B in če se na tej poti pojavi ovira, potem mora robot trajektorijo primerno popraviti, da bo uspešno izvedel zadano nalogo (se izognil oviri in prišel do točke B). To lahko stori tako, da spremeni trajektorijo [10,11], kar v splošnem pomeni tudi, da spremeni strategijo izvajanja naloge. Takšen pristop je na primer bil uporabljen v [12], kjer so uporabili potencialna polja.

V tem prispevku je predlagan nov algoritem vodenja redundantnih robotov, ki omogoča gladko prehajanje med posameznimi prioritetami posameznih nalog. Primarna naloga je v našem primeru aktivna le takrat, kadar dosežemo vnaprej določen prag. Dokler je robot daleč od praga, naš pristop omogoča direktno vodenje posameznih sklepov. V primeru, da se robot približa izbranemu pragu, primarna naloga postane aktivna, sekundarna pa se preslika v njem ničelni prostor. Predlagani pristop vodenja omogoča gladko prehajanje v obe smeri, aktivno primarno nalogo in preslikavo sekundarne naloge v ničelni prostor primarne, ali samo aktivno sekundarno nalogo. To omogoča neomejeno premikanje posameznih sklepov, kadar je robot daleč stran od določenega praga. Uporabnost predlagane metode je predstavljena na različnih scenarijih, ki vključujejo uporabo dveh KUKA LWR robotov.

V drugem poglavju je opisana predlaga metoda za izogibanje oviram. V tretjem poglavju so podani

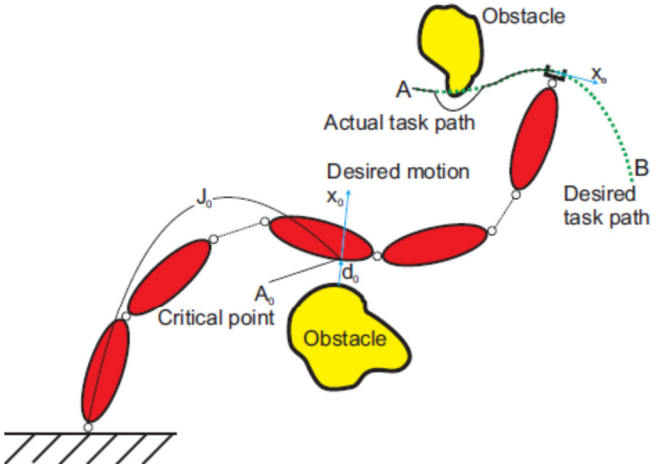
eksperimentalni rezultati. Zaključki in diskusija so v četrtem poglavju.

2 KINEMATIČNO VODENJE

Predlagani pristop vodenja je lahko uporabljen kot del najnižjega nivoja vodenja za različne robotske naloge, kot so na primer izogibanje oviram, omejevanje gibanja posameznih sklepov, refleksna obnašanja, zagotavljanje stabilnosti itd. V tem prispevku pa se osredotočimo na uporabo predlaganega pristopa pri medsebojnemu izogibanju dveh robotov.

V splošnem mora robot pri izogibanju oviram najprej identificirati točko na robotskem mehanizmu, ki je najbližje oviri in določiti gibanje, ki to točko potisne stran od ovire. Pre-konfiguracija robota se izvede, če je vsaj ena od ovir v kritični bližini robota. Kritična bližina se določi z pragom. To oviro označimo z izrazom "aktivna ovira" (glej sliko 1).

Za naš predlagani pristop vodenja predpostavimo, da se lahko ovira pojavi tudi na poti vrha robota, kar pa ni bilo v primeru [1]. Če se je pojavila takšna situacija, je bilo potrebo nalogo prekinit in določit novo trajektorijo, ki pelje vrh robota mimo ovire. Vendar, če sledenje trajektoriji ni pomembno, na primer kadar želimo da vrh robota pride iz točke A v točko B, lahko uporabimo naš predlagani pristop, kjer ni potrebno ponovno izračunati trajektorije. Predlagani pristop vodenja omogoča gladko prehajanje med nalogo sledenja in nalogo izogibanja oviram. To omogoča da se robot izogiba oviram tudi če se ovira pojavi na poti vrha.



Slika 1: Robot ob prisotnosti ovir

Strategija izogibanja oviram v splošnem zahteva gibanje robota v smeri premice ki povezuje kritično točko na robotu z najbližjo oviro. To je v eno dimenzionalna omejitev in zahteva le eno prostostno stopnjo redundance. Naj bo $\boldsymbol{d}_0$, vektor ki povezuje najbližje točke med robotom in oviro in naj bo A_0 definiran kot eno-dimenzionalen prostor v smeri vektorja $\boldsymbol{d}_0$ [1]. Jacobi, ki povezuje hitrosti v sklepih in hitrosti v smeri $\boldsymbol{d}_0$, je definiran kot

$$\mathbf{J}_{d_0} = \boldsymbol{n}_0^T \mathbf{J}_0,$$

kjer je $\mathbf{J}_0$ Jacobi definiran v kartezičnem prostoru in $\boldsymbol{n}_0$ je enotski vektor v smeri $\boldsymbol{d}_0$, podan z

$$\boldsymbol{n}_0 = \frac{\boldsymbol{d}\_0}{||\boldsymbol{d}_0||}.$$

Sedaj je dimenzija matrike $\mathbf{J}_{d_0}$ enaka $1xn$. To pomeni, da je samo ena prostostna stopnja redundance potrebna za izogibanje oviram. Hkrati je velikost hitrost x_0 skalar.

Naj bo sedaj primarna naloga izogibanje oviram definirana z Jacobijem $\mathbf{J}_{d_0}$, ki povezuje gibanje robota v smeri $\boldsymbol{d}_0$. Sekundarna naloga pa je gibanje vrha robota v kartezičnem prostoru. Jacobi $\mathbf{J}$ definira povezavo med kartezičnimi hitrostmi in hitrostmi v sklepih.

Nato, naj bo $\dot{x}_{d_0}$ hitrost izogibanja oviram definirana z

$$\dot{x}_{d_0} = \lambda(\boldsymbol{d}_0) v_0,$$

Kjer je v_0 nominalna hitrost in $\lambda(\boldsymbol{d}_0)$ je definirana z

$$\lambda(\boldsymbol{d}_0) = \begin{cases} \left(\frac{\boldsymbol{d}_m}{||\boldsymbol{d}_m||}\right)^2, n = 1,2,3 & ||\boldsymbol{d}_0|| \geq \boldsymbol{d}_m \\ 1 & ||\boldsymbol{d}_0|| \geq \boldsymbol{d}_m \end{cases}$$

kjer je $n = 1,2,3$ in $\boldsymbol{d}_m$ je kritična dolžina med med oviro in robotom. Enačbo kinematičnega vodenja lahko sedaj zapišemo z

$$\dot{\boldsymbol{q}} = \mathbf{J}_{d_0}^{\dagger} \lambda(\boldsymbol{d}_0) v_0 + \mathbf{N}_0' \mathbf{J}^{\dagger} \dot{\boldsymbol{x}}_c,$$

kjer je $\dot{\boldsymbol{x}}_c$ hitrost v kartezičnem prostori za sledenje vrha robota in $\mathbf{N}_0'$ je podana z

$$\mathbf{N}_0' = \mathbf{I} - \lambda(\boldsymbol{d}_0) \mathbf{J}_{d_0}^{\dagger} \mathbf{J}_{d_0},$$

Ta zapis ničelnega prostora omogoča neomejeno premikanje posameznih sklepov dokler je $\lambda(\boldsymbol{d}_0)$ enaka nič. To tudi pomeni, da bo sedaj vrh robota popolnoma sledil trajektoriji sekundarne naloge. Po drugi strani pa bo, takrat kadar je $\lambda(\boldsymbol{d}_0)$ enaka 1, zapis te enačbe dobil znano obliko

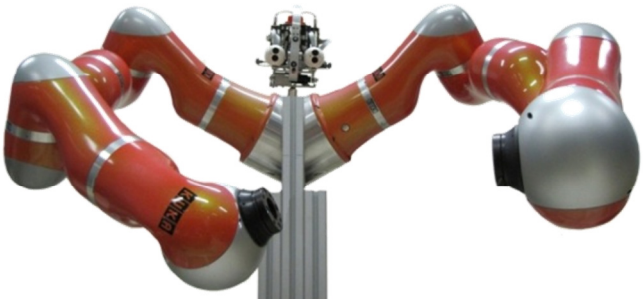
$$\mathbf{N}_0' = \mathbf{I} - \mathbf{J}_{d_0}^{\dagger} \mathbf{J}_{d_0}.$$

Če sedaj slikamo sekundarno nalogo v ta ničelni prostor, bo robot gibanje sekundarne naloge izvedel le če to gibanje nebo vplivalo na primarno nalogo. Če je primarna naloga izogibanje oviram in sekundarna sledenje v kartezičnem prostoru, se bo robot za vsako ceno izogibal oviram, tudi če pri tem nebo sledil trajektoriji sekundarne naloge.

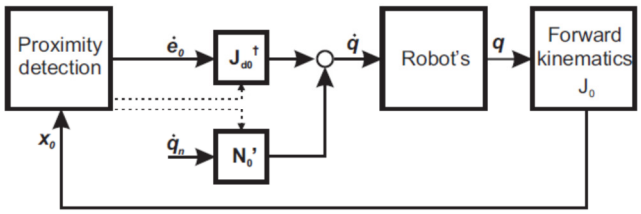
3 EKSPERIMENTALNI REZULTATI

Predlagani pristop vodenja smo implementirali za medsebojno izogibanje dveh Kuka LWR robotov, prikazanih na sliki 2. Algoritem vodenja je uporabljen kot najnižji nivo vodenja za preprečevanje medsebojnih trkov. V prvem scenariju pokažemo izogibanje levega robota, katerega naloga je definirana v kartezičnem prostoru, od desnega, katerega ročno vodi človek. V drugem scenariju je demonstrirana uporaba master-slave konfiguracije med robotoma. V tretjem scenariju je prikazana uporaba kinestetičnega vodenja z uporabo Microsoft Kinect senzorja.

Poenostavljena shema vodenja je podana na sliki 3. Kot smo že omenili predlagani pristop vodenja spremeni formulacijo zapisa primarne in sekundarne naloge, tako da je želeno gibanje robota dejansko sekundarna naloga. Primarna naloga pa je aktiva le takrat, kadar se mora robot izogniti oviri.

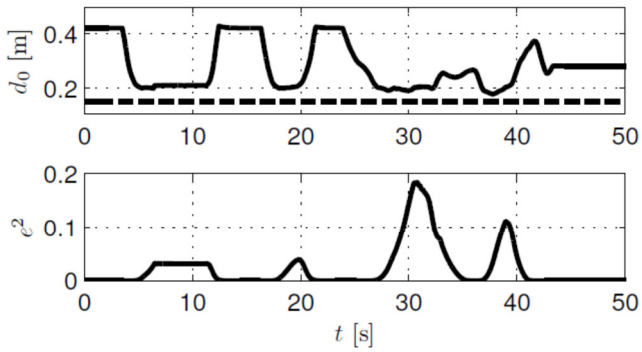


Slika 2: Eksperimentalni sestav



Slika 3: Blokovna shema vodenja

Slika 4 prikazuje rezultate vodenja prvega scenarija, kjer je naloga levega robota, da vrh ostne na želeni poziciji v kartezičnem prostoru. Desni robot je bil voden ročno, posledično je bilo njegovo gibanje popolnoma naključno.



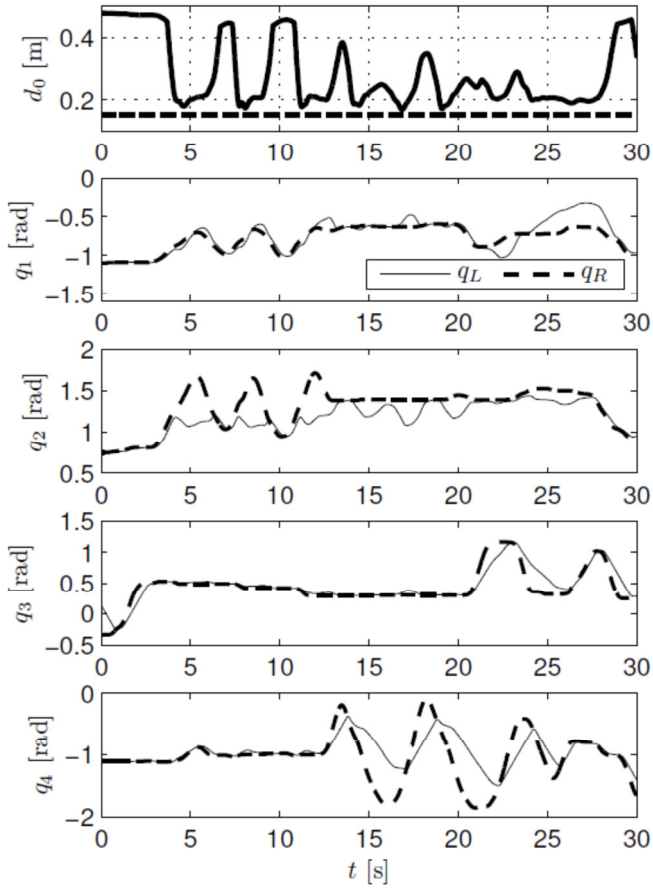
Slika 4: Minimalna razdalja med robotoma na zgornjem grafu in kvadrat napake sledenja trajektoriji v kartezičnem prostoru levega robota.

Na zgornjem grafu na sliki 4 lahko vidimo, da najmanjša razdalja med robotoma ne preseže želenega praga (d_m=0.15 m). Hkrati vidimo na spodnjem grafu, da kvadrat napake sledenja levega robota na delih, kjer se minimalna razlika približuje pragu, velik. Razlog za to je, da se levi robot odmika desnemu, da prepreči trk, ne glede na to, da ne bo mogel slediti želeni trajektoriji v kartezičnem prostoru. Trajektoriji bo torej sledil le, če bosta oba robota medsebojno dovolj oddaljena.

Drugi scenarij prikazuje obnašanje medsebojnega izogibanja, ko sta robota v master-slave konfiguraciji. Rezultat eksperimenta je prikazan na sliki 5, kjer na zgornjem grafu vidimo da je najmanjša razdalja med robotoma zopet nad definiranim pragom. Ostali grafi na sliki 5 prikazujejo trenutne položaje posameznih osi za prve štiri sklepe obeh robotov. Zopet lahko vidimo, da levi robot uspešno sledi desnega, če je minimalna razdalja med robotoma dovolj velika.

V tretjem scenariju je prikazana imitacija človeškega gibanja v realnem času. Gibanje človeka je zajeto s pomočjo Microsoft Kinect senzorja. Microsoft Kinect senzor je zasnovan na osnovi PrimeSense kamere globinskega zaznavanja, ki deluje na osnovi projekcije strukturirane infrardeče svetlobe. S procesiranjem globinske slike omogoča programska oprema PrimeSensa sledenje uporabnikovih kretenj v realnem času.

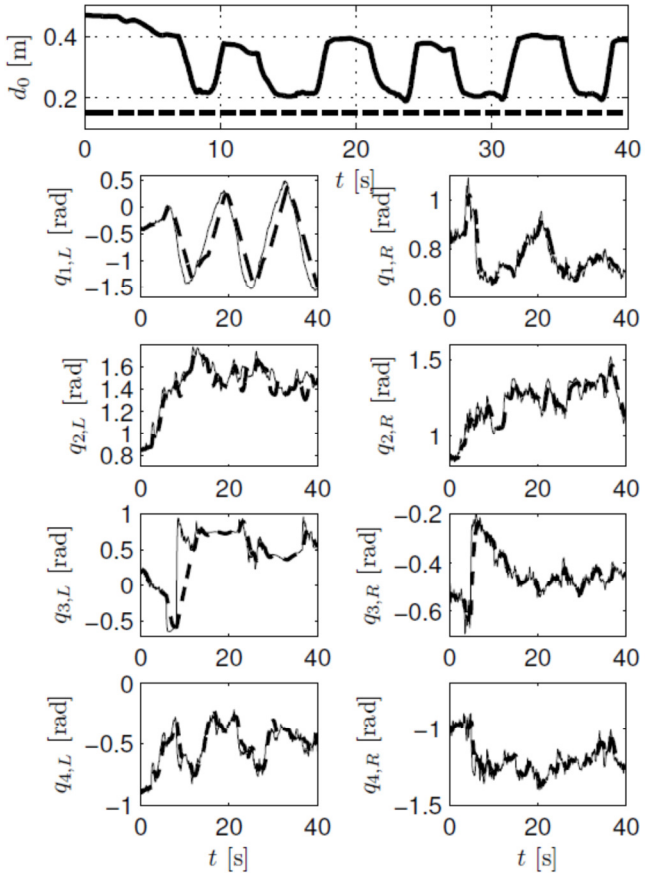
Imitacija gibanja uporabnikovih rok zahteva poleg sledenja tudi osnove človeške fiziologije. Pozo roke lahko v groben zapišemo z kombinacijo štirih kotov: treh v rami in enega v komolcu [15]. Ti koti si izračunani na podlagi podatkov pridobljenih s senzorjem Microsoft Kinect.



Slika 5: Minimalna razdalja med robotoma v master-slave konfiguraciji na zgornjem grafu. Ostali grafi prikazujejo dejanske kote v sklepih. Črtkana črta predstavlja master robota in polna črta predstavlja slave robota.

Slika 6 prikazuje eksperimentalne rezultate, kjer robota posnemata gibe demonstratorja v realnem času. Ponovno lahko vidimo na zgornjem grafu, da je minimalna razdalja med obema robotoma nad določenim pragom. Ostali grafi prikazujejo želene in dejanske kote obeh robotov. Vidimo lahko, da je sledenje želenim kotov dobro, kadar sta robot dovolj medsebojno oddaljena. Če sta robota v bližini eden

drugemu, se njuno gibanje primerno prilagodi, tako da se izogneta medsebojnemu trku.



Slika 6: Minimalna razdalja med robotoma na zgornjem grafu Robota posnemata gibe demonstratorja v realnem času. Ostali grafi prikazujejo želene in dejanske kote v sklepih.

4 ZAKLJUČEK

V tem prispevku smo predstavili modificiran pristop vodenja redundantnih robotov, ki omogoča zvezno prehajanje med posameznimi nalogami. Naloge z višjo prioriteto so aktivne le takrat, kadar so potrebne. Na primer, ko robot doseže nek definiran prag, postane naloga z višjo prioriteto aktivna. Vklapljanje in izklapljanje posameznih nalog je zvezno. Predlagani pristop vodenja smo demonstrirali na medsebojnem izogibanju dveh KUKA LWR robotov.

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BALANSIRANJE PLADNJA Z DVOROČNIM ROBOTOM: PRISTOP Z UPORABO VIRTUALNEGA MEHANIZMA

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ABSTRACT

We propose a novel control approach for cooperative dual-arm object manipulation. Our scheme has three typical features: (1) the two arms with the object together form a new kinematic chain, where the base of the second arm is the end-effector of the new robot; (2) the object between the robots is defined as a virtual mechanism, therefore manipulating the object is accomplished by controlling the virtual mechanism; (3) the proposed scheme allows cooperative dual-arm systems performing a task while moving on mobile platforms. The proposed algorithm is verified with simulations on dual-arm planar robot system and experiments on a dual-arm system with Kuka LWR robots, performing a task of balancing the plate.

1 UVOD

Dvoročni roboti v primerjavi z enim robotom nudijo večjo fleksibilnost in vsestranskost izvajanja nalog. Z dvoročnimi roboti je mogoča manipulacija večjih in težjih predmetov, povečan pa je tudi delovni prostor.

Načini vodenja dvoročnih robotov so razdeljeni v dva razreda: simetrična formulacija in formulacija glede na nalogo. Prva temelji na preslikavi med silami in hitrostmi vrhov robota in navideznimi vektorji v predmetu [1]. Druga formulacija [2, 3] opisuje skupen prostor naloge obeh robotov in omogoča opis naloge s pozicijskimi in orientacijskimi spremenljivkami.

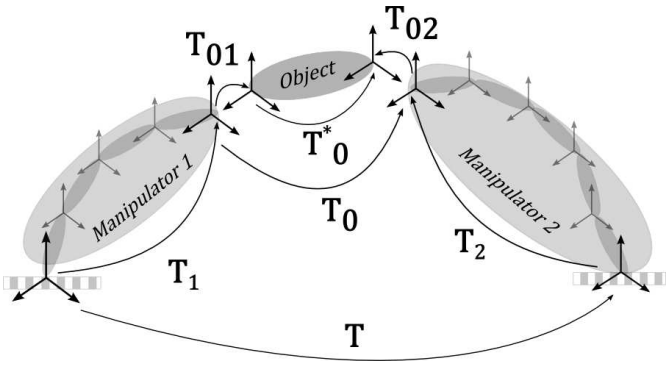
V obeh formulacijah je prostor naloge definiran z absolutno pozicijo in orientacijo predmeta, ter z relativno pozicijo in orientacijo med vrhoma obeh robotov. Vendar pa je večina nalog, ki so lahko opravljene z dvoročnim robotom, neodvisna od absolutne pozicije in orientacije predmeta. Primer takih nalog je igranje harmonike, zapiranje steklenice,...

V industriji so roboti pogosto pritrjeni na tekoče trakove ali na mobilne ploščadi. Vodenje takih robotov ob premikajoči bazi je lahko zahtevno. Članek opisuje drugačen pristop vodenja dvoročnih mehanizmov. Robota, ki držita predmet, tvorita novo kinematično verigo. Bazni koordinatni sistem te nove verige se nahaja v bazi prvega robota, medtem ko se vrh nahaja v baznem koordinatnem sistemu drugega robota. Predmet, ki ga držita robota pa predstavlja virtualni mehanizem. Naloga je opisana z vodenjem virtualnega mehanizma s poljubnim številom prostosnih stopenj [4].

Predlagani algoritem omogoča preprosto hitrostno vodenje dvoročnih mehanizmov tudi v primerih, ko je njihova baza pritrjena na mobilno ploščad oziroma tekoči trak. Vodenje takih dvoročnih mehanizmov je rešeno z vodenjem navideznega robota, z referenco v bazi drugega robota.

2 VIRTUALNI MEHANIZEM

Predpostavimo dvoročni robotski sistem, ki drži tog predmet. Kontakt med robotom in predmetom je nespremenljiv. Naj bo n_i število sklepov i-tega robota (i=1,2), $\boldsymbol{q}_i$ pa $(n_i \times 1)$ vektor kotov v sklepih, homogena transformacija $\mathbf{T}_i$ ki vsebuje pozicijo vrha i-tega robota $\boldsymbol{x}_i$ in $\mathbf{R}_i$ rotacijsko matriko vrha robota. Vektor hitrosti vrha robota $\dot{\boldsymbol{x}}_i$ in vektor hitrosti v sklepih $\dot{\boldsymbol{q}}_i$ povezuje Jakobijeva matrika $\mathbf{J}_i(\boldsymbol{q}_i)$. Sistem dvoročnega robota je predstavljen na (slika 1).



Slika 1: Dvoročni robot s predmetom tvori novo kinematično verigo.

$\mathbf{T}_0$ je homogena transformacija virtualnega mehanizma, $\mathbf{J}_0$ pa je Jakobijeva matrika virtualnega mehanizma, ki preslika vektor sklepnih hitrosti $\dot{\boldsymbol{q}}_0$ v vektor hitrosti vrha $\dot{\boldsymbol{x}}_0$ virtualnega mehanizma z n_0 prostostnimi stopnjami (DOF). Velja homogena transformacija celotnega sistema z baznim koordinatnim sistemom v bazi prvega robota in koordinatnim sistemom vrha v bazi drugega robota.

$$\mathbf{T} = \mathbf{T}_1 \mathbf{T}_0 \mathbf{T}_2^{-1} \tag{1}$$

oziroma

$$\mathbf{T} = \begin{bmatrix} \mathbf{R}_1 \mathbf{R}_0 \mathbf{R}_2^T & \boldsymbol{p}_1 + \mathbf{R}_1 \boldsymbol{p}_0 - \mathbf{R}_1 \mathbf{R}_0 \mathbf{R}_2^T \boldsymbol{p}_2 \\ \mathbf{0} & 1 \end{bmatrix} \tag{2}$$

Dvoročni robot skupaj s predmetom, tvori novo kinematično verigo. Imenujmo to verigo navidezni robot. Naj $\dot{\boldsymbol{x}}_r$ predstavlja hitrost vrha, $\dot{\boldsymbol{q}}_r$ pa vektor hitrosti v sklepih. Preslikava med njima je določena z zakonom direktne kinematike.

$$\dot{\boldsymbol{x}}_r = \mathbf{J}_r \dot{\boldsymbol{q}}_r \tag{3}$$

Kjer je

$$\dot{\boldsymbol{q}}_r = \begin{bmatrix} \dot{\boldsymbol{q}}_1 \\ \dot{\boldsymbol{q}}_0 \\ \dot{\boldsymbol{q}}_2 \end{bmatrix} \tag{4}$$

Za vodenje navideznega robota je potrebno poznati Jakobijevo matriko $\mathbf{J}_r$.

2.1 Izpeljava Jakobijeve matrike $\mathbf{J}_r$

Jakobijeva matrika je izpeljana s pomočjo časovnega odvoda homogene transformacije (2) navideznega robota. V splošnem, Jakobijevo matriko sestavlja pozicijski del $\mathbf{J}_v$ in orientacijski del $\mathbf{J}_\omega$.

$$\mathbf{J}_r = \begin{bmatrix} \mathbf{J}_v \\ \mathbf{J}_\omega \end{bmatrix} \tag{5}$$

Če upoštevamo lastnost Jakobijeve matrike, da predstavlja preslikavo hitrosti v sklepih v translacijske in kotne hitrosti vrha robota, lahko izpeljemo $\mathbf{J}_v$ s časovnim odvodom pozicijskega vektorja $\boldsymbol{p}$ v homogeni transformaciji (2).

$$\begin{aligned} \dot{\boldsymbol{p}} &= \dot{\boldsymbol{p}}_1 + \dot{\mathbf{R}}_1 \boldsymbol{p}_0 + \mathbf{R}_1 \dot{\boldsymbol{p}}_0 - \dot{\mathbf{R}}_1 \mathbf{R}_0 \mathbf{R}_2^T \boldsymbol{p}_2 \\ &- \mathbf{R}_1 \dot{\mathbf{R}}_0 \mathbf{R}_2^T \boldsymbol{p}_2 - \mathbf{R}_1 \mathbf{R}_0 \dot{\mathbf{R}}_2^T \boldsymbol{p}_2 - \mathbf{R}_1 \mathbf{R}_0 \mathbf{R}_2^T \dot{\boldsymbol{p}}_2 \end{aligned} \tag{6}$$

In dobimo:

$$\mathbf{J}_v = \begin{bmatrix} \mathbf{J}_{1,v} + \mathbf{A}\mathbf{J}_{\mathbf{1},\omega} \\ \mathbf{R}_1(\mathbf{J}_{0,v} - \mathbf{B}\mathbf{J}_{\mathbf{0},\omega}) \\ \mathbf{C}\mathbf{J}_{\mathbf{2},\omega} - \mathbf{D}\mathbf{J}_{\mathbf{2},\mathbf{v}} \end{bmatrix}^T \tag{7}$$

kjer je

$$\begin{aligned} \mathbf{A} &= \mathbf{S}(\mathbf{R}_1 \mathbf{x_0})^\mathbf{T} - \mathbf{S}(\mathbf{R_1 R_0 R_2^T x_2})^\mathbf{T} \\ \mathbf{B} &= \mathbf{S}(\mathbf{R}_0 \mathbf{R}_2^T \mathbf{x_2})^\mathbf{T} \\ \mathbf{C} &= \mathbf{R}_1 \mathbf{R}_0 \mathbf{R}_2^T \mathbf{S}(\mathbf{x_2})^\mathbf{T} \\ \mathbf{D} &= \mathbf{R}_1 \mathbf{R}_0 \mathbf{R}_2^T \end{aligned} \tag{8}$$

$\mathbf{J}_{i,v}$ ter $\mathbf{J}_{i,\omega}$ sta pozicijski in orientacijski del Jakobijeve matrike virtualnega mehanizma ter obeh robotov.
Podobno, s časovnim odvodom rotacijske matrike $\mathbf{R}$ v homogeni transformaciji (2)

$$\dot{\mathbf{R}} = \dot{\mathbf{R}}_1 \mathbf{R}_0 \mathbf{R}_2^T + \mathbf{R}_1 \dot{\mathbf{R}}_0 \mathbf{R}_2^T + \mathbf{R}_1 \mathbf{R}_0 \dot{\mathbf{R}}_2^T \tag{9}$$

dobimo orientacijski del

$$\mathbf{J}_\omega = \begin{bmatrix} \mathbf{J}_{1,\omega} \\ \mathbf{R}_1 \mathbf{J}_{0,\omega} \\ -\mathbf{R}_1 \mathbf{R}_0 \mathbf{R}_2^T \mathbf{J}_{2,\omega} \end{bmatrix}^T \tag{10}$$

Če sedaj združimo enačbi (7) in (10) dobimo Jakobijevo matriko navideznega robota

$$\mathbf{J}_r = \begin{bmatrix} \mathbf{J}_{1,v} + \mathbf{A}\mathbf{J}_{\mathbf{1},\omega} & \mathbf{J}_{1,\omega} \\ \mathbf{R}_1(\mathbf{J}_{0,v} - \mathbf{B}\mathbf{J}_{\mathbf{0},\omega}) & \mathbf{R}_1 \mathbf{J}_{0,\omega} \\ \mathbf{C}\mathbf{J}_{\mathbf{2},\omega} - \mathbf{D}\mathbf{J}_{\mathbf{2},\mathbf{v}} & bfD\mathbf{J}_{2,\omega} \end{bmatrix}^T \tag{11}$$

dimenzij $(6 \times p)$, kjer je $p = n_1 + n_0 + n_2$. Podrobna izpeljava je opisana v [5].

3 ZAPRTOZANČNO VODENJE

Trajektorija izvajanja naloge je preračunana v gibanje v sklepih redundantnega robota s pomočjo inverzne kinematike.

$$\dot{\boldsymbol{q}}_r = \mathbf{J}_r^{\#} \dot{\boldsymbol{x}}_r + \mathbf{N}\xi \tag{12}$$

kjer je

$$\mathbf{J}_r^{\#} = \mathbf{W}^{-1} \mathbf{J}_r^T (\mathbf{J}\mathbf{W}^{-1} \mathbf{J}_r^T)^{-1} \tag{13}$$

utežena generalizirana inverzna Jakobijeva matrika $\mathbf{J}_r$. $\mathbf{W}$ je matrika uteži dimenzij $(p \times p)$. $\mathbf{N} = (\boldsymbol{I} - \mathbf{J}_r^{\#} \mathbf{J}_r)$ je $(p \times p)$ matrika, ki predstavlja projekcijo v ničelni prostor $\mathbf{J}_r$, in ξ je p dimenzionalen vektor hitrosti v sklepih robota[6].
Referenca za izračun hitrosti vrha robota $\dot{\boldsymbol{x}}_r$ je pozicija in orientacija baze drugega robota, ki predstavlja vrh navideznega robota v koordinatnem sistemu $\mathbf{T}$. Ko je baza drugega robota pritrjena, se napaka kaže kot napaka med vrhoma obeh robotov. Naloga je opisana z gibanjem virtualnega mehanizma. Hkratno vodenje navideznega robota in izvajanje naloge z virtualnim mehanizmom je doseženo z uporabo razširjenega prostora naloge in razširjene Jakobijeve matrike.

$$\mathbf{J}_e = \begin{bmatrix} \mathbf{J}_0^* \\ \mathbf{J}_r \end{bmatrix} \tag{14}$$

kjer je

$$\mathbf{J}_0^* = \begin{bmatrix} \mathbf{0} & \mathbf{J}_0 & \mathbf{0} \end{bmatrix} \tag{15}$$

in

$$\dot{\boldsymbol{x}}_e = \begin{bmatrix} \dot{\boldsymbol{x}}_0 \\ \dot{\boldsymbol{x}}_r \end{bmatrix} \tag{16}$$

kjer je $\dot{\boldsymbol{x}}_0$ hitrost vrha virtualnega mehanizma. Inverzna kinematika (12), z razširjeno Jakobijevo matriko

$$\dot{\boldsymbol{q}}_r = \mathbf{J}_e^{\#} \dot{\boldsymbol{x}}_e + \mathbf{N}_e \xi \tag{17}$$

V simulacijah in eksperimentih tega prispevka je uporabljen preprost P-člen, ki služi kompenzaciji pozicijske napake $\dot{\boldsymbol{x}}_t$ in $\dot{\boldsymbol{x}}_r$ v En. (16).

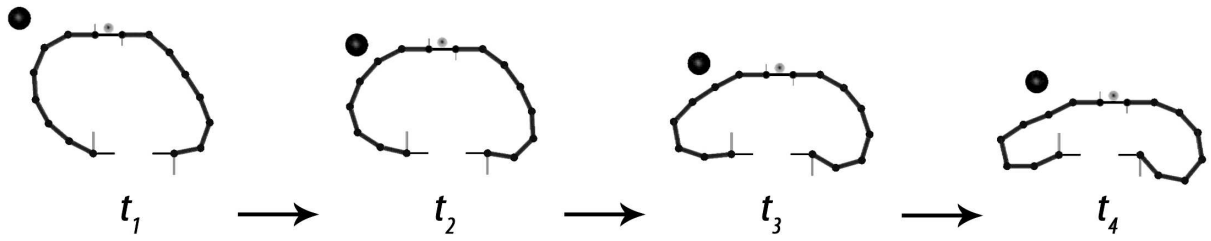
$$\dot{\boldsymbol{p}} = \dot{\boldsymbol{p}}_{ref} + K_p(\boldsymbol{p}_{ref} - \boldsymbol{p}) \tag{18}$$

Za regulacijo kotnih hitrosti $\dot{\boldsymbol{x}}_t$ in $\dot{\boldsymbol{x}}_r$ je bil uporabljen regulator kvaternionov.

$$\dot{\boldsymbol{\phi}} = \dot{\boldsymbol{\phi}}_{\boldsymbol{ref}} + K_q(\boldsymbol{q}_{ref} - \boldsymbol{q}) \tag{19}$$

4 REZULTATI SIMULACIJ

Predlagani algoritem je bil testiran s simulacijo na sistemu dveh robotov, ki sta opravljala skupno nalogo. Planarna robota, ki sta bila pritrjena na statični platformi sta imela po 7 prostostnih stopenj. Sistem je bil modeliran s skupno kinematično verigo, kjer je bazni koordinatni sistem prvega robota, sovpadal s baznim koordinatnim sistemom navideznega robota. Baza drugega robota pa je sovpadala s koordinatnim sistemom



Slika 2: Naloga balansiranja pladnja z dvoročnim planarnim robotom in hkratno izogibanje oviram.

vrha navideznega robota. Naloga je bila izogibanje oviri in balansiranje pladnja. Za opis naloge sta potrebni dve spremenljivki; translacijsko gibanje v x smeri (držanje pladnja) in rotacija okrog vertikalne z osi glavnega koordinatnega sistema (balansiranje pladnja). Naloga držanja pladnja je izvedena z vodenjem virtualnega mehanizma. Virtualni mehanizem je bil za to nalogo definiran kot 1 DOF robot s translacijsko stopnjo.

$$\boldsymbol{x}_{t1} = \begin{bmatrix} x \end{bmatrix} \tag{20}$$

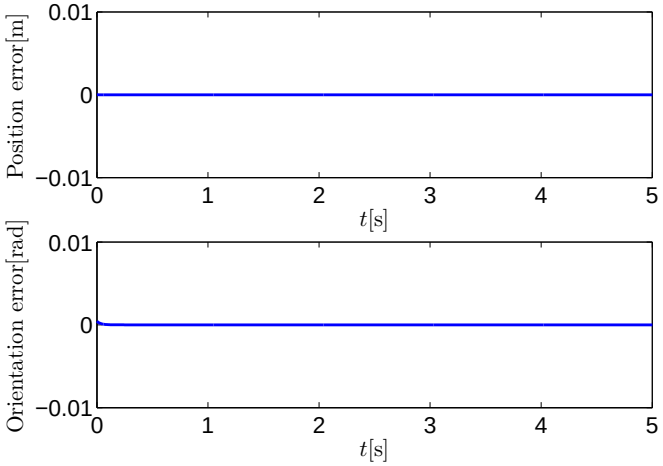
Naloga balansiranja pladnja je bila izvedena z vodenjem orientacije vrha prvega robota.

$$\boldsymbol{x}_{t2} = \begin{bmatrix} \phi \end{bmatrix} \tag{21}$$

Ob uporabi pravila (16) razširjenjega prostora naloge, velja:

$$\dot{\boldsymbol{x}}_e = \begin{bmatrix} \dot{\boldsymbol{x}}_{t1} \\ \dot{\boldsymbol{x}}_{t2} \\ \dot{\boldsymbol{x}}_r \end{bmatrix} \tag{22}$$

V delovnem prostoru dvoročnega planarnega robota se je gi-



Slika 3: Zgoraj: napaka naloge držanja pladnja (razdalja med vrhoma robotov). Spodaj: napaka naloge balansiranja pladnja (odstopanje od horizontalne lege).

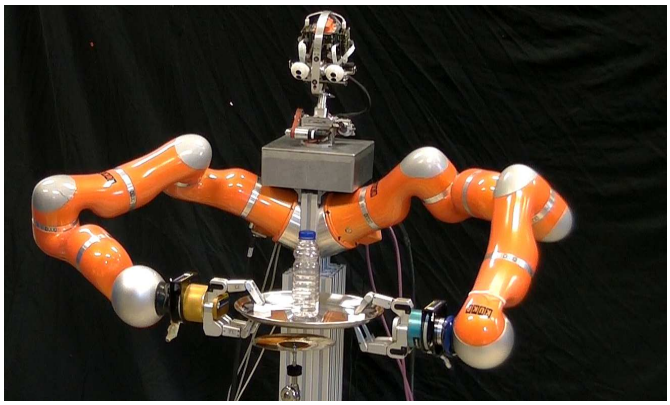
bala ovira, katere se je moral robot izogibati in hkrati balansirati pladenj. Hitrosti (23), ki so bile izračunane z algoritmom izogibanja oviram [7], so bile uporabljene za vodenje dvoročnega robota v ničelnem prostoru (12).

$$\xi = [\xi_1 \;\; \xi_0 \;\; \xi_2]^T \tag{23}$$

Matrika ničelnega prostora je bila izbrana tako, da je bila ohranjena konzervativnost sistema [6]. Rezultati simulacije so prikazani na sliki (slika 3). Zaporedje slik prikazuje izvajanje naloge balansiranja pladnja (slika 2).

5 REZULTATI EKSPERIMENTOV

Naloga balansiranja pladnja je bila izvedena na realnem sistemu dveh robotov Kuka LWR prikazanem na sliki (4). Robota



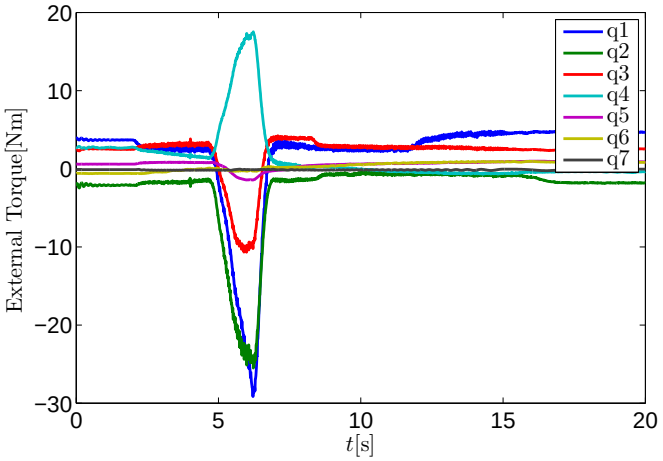
Slika 4: Dvoročni sistem z dvema Kuka LWR robotoma.

sta bila krmiljena preko vmesnika Fast Research Interface (FRI) v načinu podajnosti v sklepih [8]. Krmilnik robota (KRC) je omogočal hitrostno vodenje v sklepih (17). Utežnostna matrika je bila izbrana $\boldsymbol{W} = \boldsymbol{I}$. Podobno kot pri simulaciji, naloga je bila definirana s pomočjo razširjenega prostora naloge in razširjene Jakobijeve matrike. Držanje pladnja je bilo doseženo z vodenjem virtualnega mehanizma, ki je imel eno linearno prostostno stopnjo (20). Balansiranje pladnja je bilo doseženo z vodenjem orientacije vrha prvega robota:

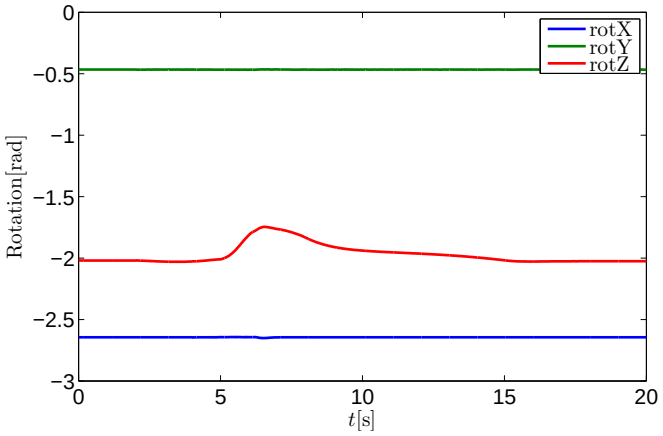
$$\boldsymbol{x}_{t2} = \begin{bmatrix} \psi \\ \theta \end{bmatrix} \tag{24}$$

kjer je ψ rotacija okrog x-osi in θ je rotacija okrog y-osi globalnega koordinatnega sistema z z-osjo pravokotno na tla. Med balansiranjem pladnja je en izmed robotov občutil zunanjo motnjo ob času $t = 5s$. Slika 5 prikazuje navore v sklepih robota.

Algoritem je kljub motnji uspel obdržati horizontalno orientacijo in balansiran pladenj. Slika (6) prikazuje orientacijo pladnja v globalnem koordinatnem sistemu. Za uspešno balansiran pladenj, samo rotacija okrog z-osi je dovoljena.



Slika 5: Izmerjeni navori v sklepih, ki jih povzroči zunanja motnja.



Slika 6: Orientacija pladnja okrog treh osi globalnega koordinatnega sistema.

6 ZAKLJUČEK

V tem članku je bila predlagan nov način vodenja dvoročnih robotov. Predlagan pristop obravnava robota, ki držita predmet, kot novo kinematično verigo. Predmet predstavlja nalogo, ki je opravljena s gibanjem virtualnega mehanizma z toliko prostostnimi stopnjami kolikor stopenj ima zahtevana naloga.

Predlagani algoritem vodenja je uporaben tudi v dvoročnih sistemih, kjer je en izmed robotov pritrjen na mobilno ploščad ali tekoči trak. Rezultati simulacij in eksperimentov prikazujejo uporabnost algoritma z uporabo enostavnih hitrostnih regulatorjev. Napaka vodenja navideznega robota se kaže v napaki med vrhoma robotov, ker je vrh navideznega robota (baza drugega robota) pritrjen. Zaradi te napake nastanejo sile na predmet. To pa rešuje uporaba aktivne podajnosti robota oziroma pasivne podajnosti predmeta.

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SENZORSKI SISTEM ZA ESTIMACIJO INTERAKCIJE MED UPORABNIKOM IN EKSOSKELETOM

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ABSTRACT

This paper presents a system for measuring the human kinematics, interaction between the user and a wearable robot and intention detection. First the system measures user's kinematics and interaction with the wearable robot. From this data the algorithms can establish the current phase of the gait and detects the user's intention when he or she wants to start or stop walking. Hardware part of the system comprises of inertial measurement units positioned on the user body segments and pressure sensitive insoles, while software part comprises of algorithms for estimating human kinematics, interaction and intention detection. The information from the system can be used by the main controller of the wearable robot to appripriatelly change the control mode of the wearable robot .

1 UVOD

Eksoskeletni roboti (ang. exoskeleton wearable robots) se uporabljajo kot pomoč uporabnikom pri gibanju, bodisi kot podpora uporabnikovemu gibanju pri rehabilitaciji ali kot dodaten vir mehanske moči uporabniku pri opravljanju fizično napornih opravil [1,2]. Takšni robotski sistemi običajno težijo k optimalnem razmerju med učinkovitostjo v smislu pomoči, ki jo nudijo uporabniku, ter ključnimi zahtevami, kot je minimalna teža in velikost, nizka poraba energije in številnimi drugimi dejavniki, ki lahko vplivajo na učinkovitost robotskega sistema.

Zaradi kompleksne interakcije robota tako z okoljem kot z uporabnikom, je vodenje nosljivih robotov razdeljeno na več nivojev, od vodenja motorjev na najnižjem nivoju, do odločanja na podlagi uporabnikove aktivnosti [3]. Ta kompleksnost zato narekuje uporabo večjega števila senzorjev in različnih vrst algoritmov, od preprostih PD algoritmov do uporabe algoritmov umetne inteligence.

Prispevek bo predstavil senzorski sistem za interakcijo robot-uporabnik (SHRI). Naloga sistema je prepoznavanje faz hoje, ki jih izvaja uporabnik, in vnaprejšnje prepoznavanje spremembe faze hoje (vnaprejšnje zaznavanje začetka hoje ter vnaprejšnje zaznavanje ustavljanja). Sistem je namenjen za uporabo pri vodenju nosljivega robota, ki je bil razvit v sklopu projekta Evryon.

2 ARHITEKTURA VODENJA EKSOSKELETA

Vodenje robota Evryon je razdeljeno na dva dela: nizko-nivojsko vodenje in visoko-nivojsko vodenje. Nizko-nivojsko vodenje poteka na nivoju posameznih sklepov robota, uporabljajo se senzorji v sklepih robota: enkoderji motorjev in senzorji navorov. Visoko-nivojsko vodenje skrbi za vodenje celotnega robotskega sistema in za pravilno izvajanje posameznih faz hoje, ter na izhodu podaja reference za nizko-nivojsko vodenje. Pri visoko-nivojskem vodenju se uporabljajo trije sklopi senzorjev:

- Senzorji, ki se nahajajo na samem robotu in so isti senzorji, ki se uporabljajo na nivoju nizko-nivojskega vodenja.
- Senzorji, ki se nahajajo med robotom in uporabnikom in omogočajo določanje interakcije med robotom in uporabnikom. V ta sklop štejemo merilne vložke, ki se nahajajo v čevljih.
- Senzorji, ki se nahajajo na uporabniku in se uporabljajo za ugotavljanje stanja uporabnika. V ta sklop štejemo inercijske merilne enote.

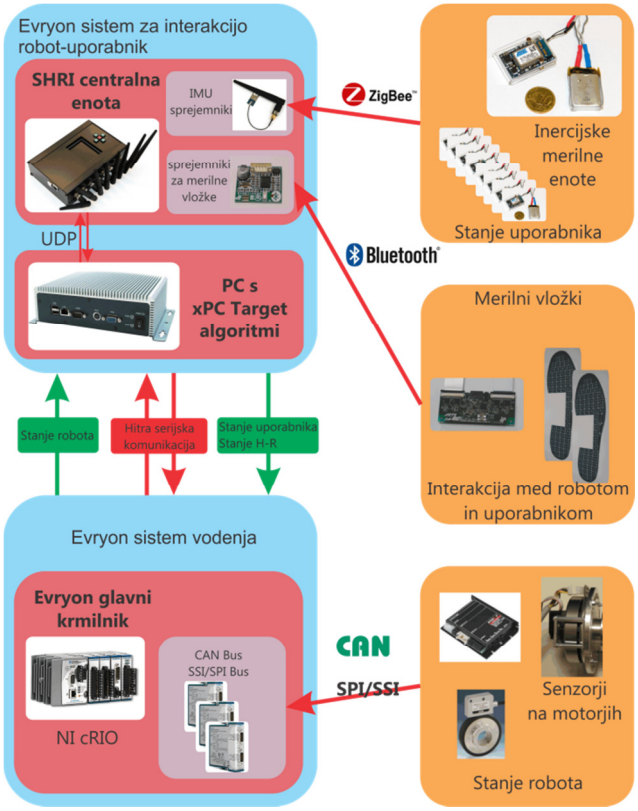
2.1 Sistem za interakcijo robot-uporabnik

Sistem za interakcijo robot-uporabnik (SHRI) je sestavljen iz treh delov: senzorjev (inercijske merilne enote in merilni vložki), SHRI centralne enote in osebnega računalnik na katerem tečejo algoritmi v realnem času.

Inercijske merilne enote se uporabljajo za ugotavljanje stanja uporabnika. Sestavljene so iz treh 3-osnih senzorjev (pospeškometra, magnetometra in žiroskopa), ki skupaj omogočajo estimacijo orientacije. Enote so nameščene na telo, roke in noge uporabnika in so brezžično povezane preko ZigBee protokola na SHRI centralno enoto. Bolj podorobno so inercijski senzorji predstavljeni v [4]. Merilni vložki, ki se nahajajo v čevljih se uporabljajo za ugotavljanje interakcije med uporabnikom in eksoskeletom. Merilni

vložki so sestavljeni iz 64 pritiskovnih senzorjev in so brezžično povezani preko Bluetooth protokola na SHRI centralno enoto. Bolj podorobno so merilni vložki predstavljeni v [5].

SHRI centralna enota vsebuje brezžične sprejemnike za senzorje in ARM Cortex procesor, ki skrbi za brezžično komunikacijo med centralno enoto in senzorji ter UDP komunikacijo med centralno enoto in osebnim računalnikom. Na osebnem računalniku teče xPC Target operacijski sistem, njegova naloga je obdelava podatkov iz senzorjev in določanje stanja uporabnika iz izmerjenih signalov v realnem času s frekvenco 100 Hz. Na računalniku se izvajajo tudi algoritmi za detekcijo namena. Slika 1 prikazuje celotno shemo sistema, ki izvaja estimacijo interakcije med uporabnikom in robotom, s poudarkom na prenosu podatkov med sistemi.



Slika 1. Arhitektura vodenja nosljivega robotskega sistema

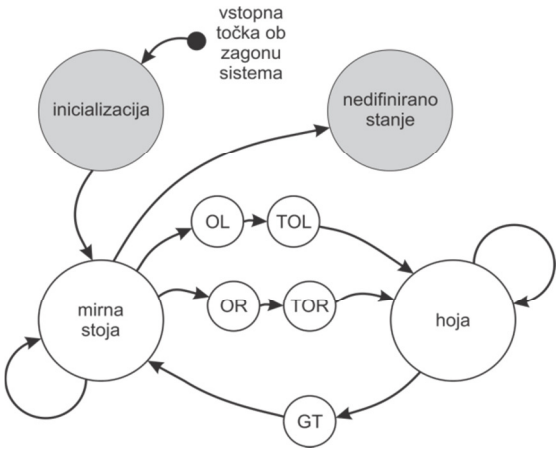
2.2 Algoritmi za estimacijo interakcije robot-uporabnik

Centralna enota sprejme neobdelane signale iz senzorjev in preverja napake pri brezžičnem prenosu signalov. Signale centralna enota nato pošlje prek Ethernet mrežne povezave (UDP protokol) na osebni računalnik na katerem se izvaja xPC Target operacijski sistem. Na osebnem računalniku poteka obdelava signalov in določanje stanja uporabnika. Obdelava neobdelanih signalov poteka na sledeč način:

- Preverjanje napak pri prenosu podatkov.
- Pretvorba vrednosti signalov v SI enote.
- Pretvorba iz nekalibriranih v kalibrirane signale.
- Senzorno združevanje na nivoju senzorjev:
  - Inercijske merilne enote – kalibrirani podatki so vhod v Kalmanov filter, ki vrača na svojem izhodu orientacijo posameznih inercijskih merilnih enot.
  - Merilni vložki – iz izhodov posameznih senzorjev pritiska se določi celoten pritisk na merilni vložek in center pritiska.
- Izračun kinematike uporabnika – iz orientacije inercijskih merilnih enot se določi orientacija posameznih segmentov in koti v sklepih.
- Detekcija namena uporabnika – najvišji nivo senzorne fuzije, ki ugotavlja trenutno stanje uporabnika in fazo hoje. Stanje uporabnika je posredovano glavnemu krmilniku robota, ki ustrezno prilagodi kontrolni algoritem.

2.3 Detekcija namena uporabnika

Cilj detekcija namena uporabnika je zgodnje zaznavanje začetka ali konca hoje uporabnika. Cilj je zaznati namen prehoda v novo stanje, tako da ima glavni krmilnik dovolj časa, da preide v fazi primeren način delovanja.



Slika 2. Diagram prehajanja stanj pri hoji.

Ob zagonu SHRI se najprej zažene inicializacija sistema. Ob inicializaciji sistema mora uporabnik stati v fazi mirne stoje. Ob inicializaciji se najprej določijo začetne orientacije inercijskih merilnih enot, ter transformacija med segmenti uporabnika in inercijskimi merilnimi enotami. Po inicializaciji sistem preide v stanje uporabnika *mirna stoja*. Cilj algoritma za detekcije namena je ugotoviti ali želi oseba začeti s hojo oziroma se ustavit, še preden oseba dokončno izvede prehod iz ene faze v drugo. V primeru, da algoritem zazna gibanje (absolutna vrednost vsaj enega od žiroskopov je večja od 5-sigma vrednosti šuma), ni pa bil zaznan začetek hoje, stanje uporabnika preide v *nedifinirano stanje*. SHRI je v tem primeru potrebno ponovno zagnati. Nedifinirano stanje lahko signilizira tako slabo detekcijo namena uporabnika kot tudi nepravilno delovanje sistema (npr. nepravilno delovanje kakšnega od senzorjev).

Začetek hoje

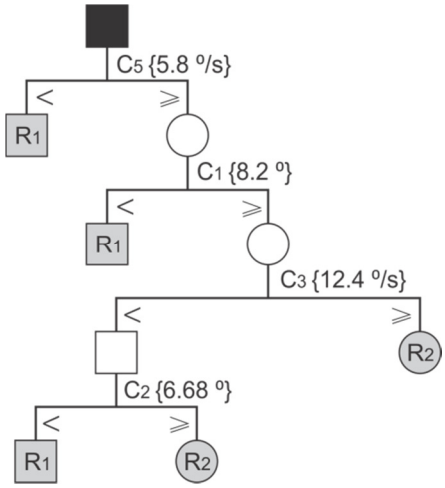
Med mirno stojo ima oseba obe stopali na tleh in vzrdžuje ravnotežje. Ob namenu začetka hoje oseba spremeni strategijo iz vzdrževanja statičnega ravnotežja v izvajanje dinamičnega ravnotežja potrebnega za hojo. Preden oseba dvigne stopalo s tal, premakne center mase na drugo nogo. Nato začne dvigovati stopalo, najprej dvigne peto, nato pa celotno stopalo s tal. Sledi druga noga in oseba začne hoditi. Prve spremembe pri prehodu iz mirne stoje v hojo se začnejo že pol sekunde preden oseba dvigne stopalo s tal [6].

Algoritem za detekcijo namena začetka hoje je bil zato načrtan tako, da detektira dva dogodka ob začetku hoje. Prvi dogodek je detekcija prvega gibanja (*Gait Onset*), ki presega gibanje ob vzdrževanju statičnega ravnovesja med mirno stojo. Detekcija prvega značilnega gibanja omogoča zgodnjo detekcijo začetka hoje, vendar pa lahko potencialno vodi tudi do napačne detekcije začetka hoje. Zato je bil izbran še dogodek dviga stopala s tal (*Toe-off*), ki ga je precej lažje detektirati točno, vendar pa je zadnji dogodek, ki še omogoča pravočasno detekcijo začetka hoje. Ker oseba lahko začne hojo s tako levo kot desno nogo, je algoritem za detekcijo začetka hoje podvojen in preverja signale iz leve in desne noge.

Konec hoje

Ob koncu hoje oseba preide iz stabilne hoje v fazo mirne stoje. Ob tem oseba zmanjša odriv pri predzadnjem koraku, ob zadnjem koraku ustavi vodilno nogo in nazadnje priključi še drugo nogo in preide v vzdrževanje statičnega ravnovesja. Pri tem je zadnji korak značilno drugačen od korakov med stabilno hojo. Cilj je torej čimprej ugotoviti ali je trenutni korak zadnji, še preden se korak popolnoma konča in se oseba ustavi.

Za detekcijo dogodkov se uporabljajo odločitvena drevesa. Iz signalov kotov in kotnih hitrosti v sklepih, ter sile in centra pritiska na podplatih se določijo cenilke, ki so vhod v algoritem za določanje faze hoje in prehodov med fazami. V primeru začetka hoje so cenilke vrednosti signalov. V fazi mirne stoje algoritem klasificira ali vrednosti signalov pripadajo fazi mirne stoje ali fazi med dogokom *Onset* in dogodkom *Toe-off*. Trenutek, ko algoritem ugotovi, da pripada vzorec fazi med dogokoma *Onset* in *Toe-off*, je označen kot dogodek *Onset.* Algoritem v naslednjem koraku preverja ali pripada vzorec k trenutni fazi (faza med dogokoma *Onset* in *Toe-off*) ali že pripada fazi stabilne hoje. Trenutek, ko algoritem ugotovi, da pripada vzorec fazi stabilne hoje, je označen kot dogodek *Toe-off.* Slika 3 prikazuje poenostavljen primer odločitvenega drevesa za detekcijo *Onset* dogodka. V odločitveno drevo so vključeni signali zapisani v Tabeli 1.



Slika 3. Primer odločitvenega drevesa za detekcijo dogodka *Onset*.

C1	Kot v kolenu φ_k v sagitalni ravnini
C2	Kot v kolku φ_h v sagitalni ravnini
C3	Kotna hitrost v kolenu $d\varphi_k/dt$ v sagitalni ravnini
C4	Kotna hitrost v kolku $d\varphi_h/dt$ v sagitalni ravnini
C5	Vsota kotnih hitrosti v kolenu in kolku $\lvert d\varphi_k/dt \rvert + \lvert d\varphi_h/dt \rvert$

Tabela 1. Cenilke, ki se uporabljajo v odločitvenem drevesu za detekcijo dogodka *Onset*.

Klasifikacija se začne s cenilko C5 (vsota kotnih hitrosti v kolenu in kolku $|d\varphi_k/dt|+|d\varphi_h/dt|$). Če je vrednost vsote kotnih hitrosti v kolenu in kolku v sagitalni ravnini manjša od 5.8^0/s potem je oseba v fazi mirne stoje. Če je hitrost večja ali enaka se odločitveno drevo nadaljuje na desno stran. Naslednji korak vsebuje preverjanje vrednosti sagitalnega kota v kolenu. Če je kot manjši od 8.2^0, potem je oseba v fazi mirne stoje. Vzdrževanje stabilne stoje v fazi mirne stoje povzroča gibanje v sklepih, ki je po vsotu absolutnih vrednosti manjše od 5.8^0/s. V nekaterih primerih vzdrževanje stabilnosti privede do višjih vrednosti vsote hitrosti, vendar je kot v kolenu vedno manjši od 8.2^0. Če je kot v kolenu večji, potem se drevo nadaljuje. Naslednja cenilka, ki se preverja, je kotna histrost v kolenu. Če je vrednost večja od 12.4^0/s, potem je oseba prešla v fazo med dogodkom *Onset* in dogodkom *Toe-off*. Prišlo je torej do dogodka *Onset*. V primeru, da je vrednost kotne histrost v kolenu manjša od 12.4^0/s, se drevo nadaljuje v levo. V naslednjem koraku se preverja kot v kolku. Če je vrednost manjša od 6.7^0, potem je oseba še vedno v fazi mirne stoje, če pa je večja ali enaka pa je prišlo do dogodka *Onset*.

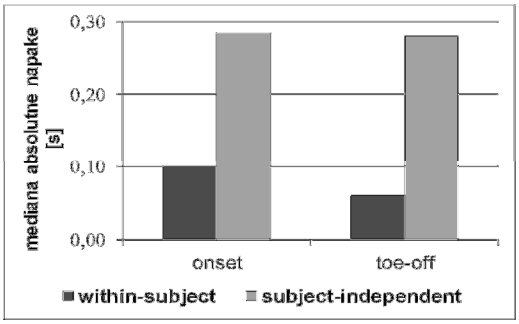
Za detekcijo namena konca hoje se med hojo ob vsakem začetku koraka signali shranjujejo v spomin določen čas, ki je krajši od dolžine koraka, nato pa se iz shranjenih vrednosti določije cenilke, ki so vhod v odločitveno drevo. Odločitveno drevo nato klasficira trenutni korak v dva razreda: razred 1 - korak, ki pripada stabilni hoji ali v razred 2 – zadnji korak. Dolžina spomina je lahko različna, vendar je smiselno, da je krajša od trajanja koraka. Korak je tako mogoče klasificirati, še preden se konča.

3 REZULTATI

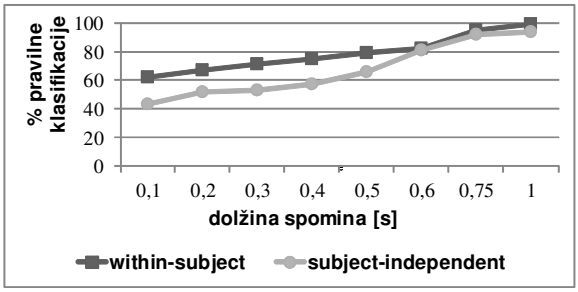
Algoritem za detekcijo začetka in konca hoje je bil validiran z eksperimenti na 10 osebah. Učenje algoritma je potekalo s pomočjo učne množice primerov začetka in konca hoje, ki so bili pridobljeni z meritvami na testnih osebah. Pri vsaki osebi pa je bilo posnetih 40 začetkov in koncev hoje. Del nabora segnalov je bil uporabljen za učenje algoritma, drugi del pa za validacijo. Testirana sta bila dva tipa algoritmov:

- *Subject-independent* – splošni algoritem, ki upošteva učne množice vseh oseb razen ene od oseb, ki je nato uporabljena za validacijo.
- *Within-subject* – algoritem, ki je naučen za določeno osebo. Za učenje so uporabljeni vsi primeri začetka in konca hoje, razen enega, ki je uporabljen za validacijo.

Slika 4 prikazuje rezultate detekcije dogodkov *Onset* in *Toe-off*. Rezultati za *Within-subject* algoritem so precej boljši kot rezultati za *Subject-independent* algoritem. Pri *Within-subject* algoritmu je napaka za dogodka *Onset* in *Toe-off* okoli 0.1 s, pri *Subject-independent* algoritmu pa okoli 0.3 s.



Slika 4. Mediana absolutne napake pri detekciji dogodkov *Onset* in *Toe-off*.



Slika 5. Točnost pravilne klasifikacije koraka.

Slika 5 prikazuje točnost klasifikacije korakov v odvisnosti od dolžine spomina. Z večjo dolžino spomina se točnost klasifikacije izboljšuje. Trajanje enega koraka je okoli 0.5 s, pri tej dolžini spomina je točnost klasifikacije za *Subject-independent* algoritem 66%, za *Within-subject* algoritem pa 79%. *Within-subject* algoritem je torej ponovno boljši od *Subject-independent* algoritma. Bolj podrobno so rezultati predstavljeni v [7].

4 ZAKLJUČEK

V prispevku je predstavljena arhitektura sistema za interakcijo robot-uporabnik. Algoritma za detekcijo namena začetka hoje in konca hoje sta se izkazala kot primerna za uporabo detekcije namena.

Testirana sta bila dva algoritma: *Subject-independent* in *Within-subject* algoritem, od katerih se je *Within-subject* algoritem izkazal precej bolje. Za človeško hojo je značilno, da je zelo ponovljiva, kar se odraža v natančni detekciji obeh dogodkov v primeru *Within-subject* algoritma, saj na rezultate vpliva samo variabilnost hoje pri posamezniku, ki je majhna. Se pa hoja med različnimi osebami lahko precej razlikuje, kar se odraža v natančnosti *Subject-independent* algoritma, ki je precej manj natančen, saj na natančnost vpliva variabilnost med posameznimi osebami. Priporočilo bi torej bilo, da se za vsako posamezno osebo pripravi algoritem, ki je naučen na primerih posnetih na tej osebi. Kadar je priprava učne množice preveč zamudna ali pa nemogoča, je potrebno uporabiti *Subject-independent* algoritem, saj ta ne potrebuje priprave učne množice, temveč je naučen na že prej zbrani učni množici.

ZAHVALA

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EVALVACIJA NOSLJIVEGA SENZORNEGA SISTEMA ZA VSTAJANJE

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ABSTRACT

The paper presents a wearable sensory system for measuring sit-to-stand movement. The system consists of 8 inertial measurement units and 2 measuring instrumented shoes. Experimental evaluation of wearable system was accomplished by comparison to reference data acquired by reference measuring system consisted of Optotrak Certus and two force plates. Experiment evaluated standing up from a chair at three different speeds: normal, slow and fast. Differences between data acquired by reference and wearable measuring systems were below 4 degrees for joint angles and around 20-50 N for ground reaction forces. Results demonstrate that the presented wearable sensory system can be utilized for tracking and analysis of sit-to-stand movements.

1 UVOD

Vstajanje je manever, ki ga človek pogosto izvaja preko celega dneva. Predstavlja tudi začetno gibanje za druge aktivnosti. Z biomehanskega vidika je vstajanje zahtevno opravilo, ki zahteva dobro koordinacijo ob precejšnjih navorih v sklepih.

S klasifikacijo faz pri vstajanju se je v preteklosti ukvarjalo več raziskovalcev. Kralj s sodelavci je razdelil vstajanje na šest faz, pri čemer je za zagotavljanje senzorne informacije uporabil reflektivne markerje, goniometre ter pritiskovne plošče [1]. Entyre in Thomas sta razdelila vstajanje glede na potek signalov reakcijskih sil pod podplati [2]. Nuzik in sodelavci so preučevali vstajanje na podlagi filmskih posnetkov, pri čemer so spremljali trajektorije gibanja delov telesa [3]. Z analizo razlik biomehanike vstajanja zdravih in bolnih so se ukvarjali [4, 5].

Pričujoče delo preverja možnost merjenja kinematike gibanja in detekcijo faz pri vstajanju s pomočjo nosljivih senzorjev. Tovrsten sistem je zaradi prijaznosti do uporabnika primeren za merjenje kinematike vstajanja zdravih kot tudi bolnih. Namenjen je kot senzorni sistem za vodenje robotskih protez kot tudi eksoskeletov [6].

2 METODOLOGIJA

Za preverjanje kvalitete informacije smo izvedli eksperimentalne primerjalne meritve manevra vstajanja. Pri eksperimentu je sodelovala ena oseba, ki je bila opremljena z dvema merilnima sistemoma: nosljivim in referenčnim. Podatke z dveh merilnih sistemov smo primerjali v času vstajanja od trenutka pričetka vstajanja do trenutka stoje.

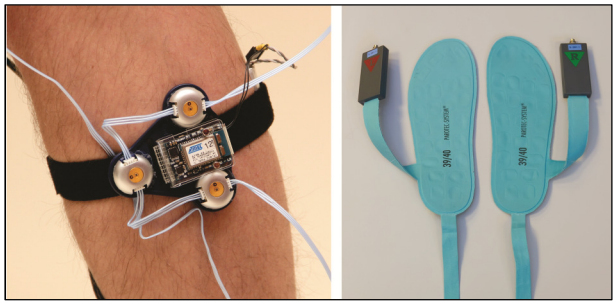
2.1 Nosljivi merilni sistem

Nosljiv senzorni sistem je bil sestavljen iz osmih inercijskih merilnih enot (IME) razvitih v Laboratoriju za robotiko, Fakultete za elektrotehniko, UL, ter dveh merilnih podplatov (MP) podjetja Parotec System.

Vsako enoto IME (slika 1 levo) sestavljajo triosni žiroskop, triosni pospeškometer in triosni magnetometer [6]. Poleg senzorjev je v vezje integriran čip Atmel ZigBit, ki skrbi za brezžično povezavo s centralno enoto. Ta prejete podatke iz vseh enot posreduje naprej po UDP povezavi.

Posamezni merilni podplat (slika 1 desno) je sestavljen iz 24 s silikonom napolnjenih merilnih celic s pripadajočim senzorjem tlaka. Analogni izhodni signali senzorjev tlaka so zajeti s pomočjo ciljnega računalnika preko vhodno-izhodne kartice DAS 1002 podjetja Measurement Computing.

Merilni sistem sestavlja tudi ciljni računalnik, na katerem teče operacijski sistem xPC Target kot del razvojnega okolja Matlab/Simulik. Ciljni računalnik sprejema podatke poslane iz centralne enote in zajema vrednosti merilnih podplatov, obenem pa generira tudi sinhronizacijski signal za sinhronizacijo obeh merilnih sistemov.



Slika 1: *Merilna ploščica z IR oddajniki in IME enoto na goleni (levo) in merilni podplati (desno).*

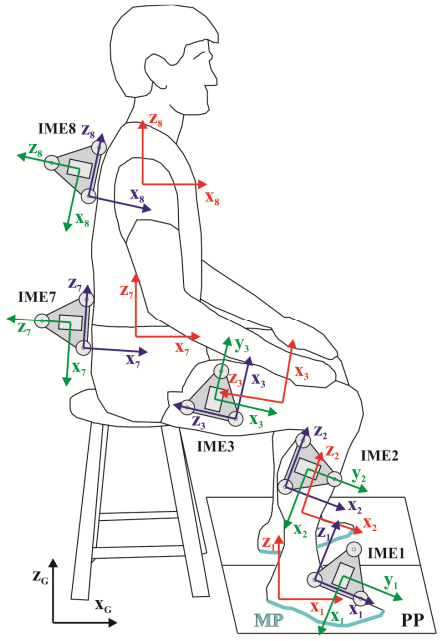
2.2 Referenčni merilni sistem

Referenčni merilni sistem je bil sestavljen iz optoelektronskega merilnega sistema Optotrak Certus, 24

merilnih IR svetlečih diod *Smart Marker* in dveh pritiskovnih plošč (PP). Trije IR oddajniki so bili skupaj z inercijsko merilno enoto pritrjeni na merilno ploščico, le-ta pa je bila nameščena na posamezen segment merilnega subjekta (slika 1 levo).
Optoelektronski sistem je zajemal pozicijo v prostoru posamezne IR svetleče diode ter jo skupaj z zajeto silo iz pritiskovnih plošč pošiljal po UDP povezavi na ciljni računalnik, na katerem je tekel operacijski sistem xPC Target. Tako kot nosljiv senzorni sistem je tudi referenčni zajemal sinhronizacijski signal.

2.3 Protokol

V eksperimentu je sodelovala ena oseba, moški, star 24 let, visok 173 cm in težak 80 kg. Merjena oseba je imela nameščenih osem merilnih ploščic; tri na vsaki nogi (stopalo, golen in stegno) ter dve na trupu (predel ledvenih in prsnih vretenc). Merjena oseba je imela v čevljih nameščene merilne podplate številka 42, hkrati pa je z vsako nogo posebej stala na pritiskovnih ploščah. Razporeditev merilnih sistemov je predstavljen na sliki 2.
Eksperiment je bil sestavljen iz treh delov. Vsak del je zajemal pet ponovitev izvedbe vstajanja z višine stola, ki je ustrezala 90% višine merjenčevega kolena. Pri prvem delu je merjena oseba dobila ustna navodila, naj vstane tako, kot vstaja v vsakodnevnem življenju (normalna hitrost), v drugem delu, da naj vstaja počasi, v tretjem delu pa da naj vstaja hitro.
Za validacijo so bili uporabljeni podatki zajeti od trenutka pričetka vstajanja do trenutka stoje. Začetek vstajanja smo zaznali kot gibanje trupa naprej, konec vstajanja pa kot dosežena končna reakcijska sila.



Slika 2: *Postavitev merilnih ploščic na telesu. Postavitev na levi nogi je zrcalna postavitvi na desni. Označeni so koordinatni sistemi IME enot (zelena), merilnih ploščic (modra) in segmentov telesa (rdeča).*

2.4 Analiza izmerjenih podatkov

Z merilnima sistemoma smo hkrati izmerili kote v sklepih in sicer levega/desnega gležnja (GL/GD), levega/desnega kolena (KL/KD), levega/desnega kolka (KoL/KoD) ter naklonski kot spodnjega in zgornjega dela trupa (ST in ZT). Podatke senzorjev na IME smo preko Kalmanovega filtra preračunali v orientacijo segmenta, na katerega je bila IME pritrjena [6]. Pri določitvi orientacije smo uporabili transformacije kvaternion med globalnim koordinatnim sistemom (KS) in IME $\boldsymbol{q}_{GI}$, kvaternion med IME in koordinatnim sistemom segmenta $\boldsymbol{q}_{IS}$, ter kvaternion med globalnim koordinatnim sistemom in segmentom $\boldsymbol{q}_{GS}$. Kot med dvema segmentoma smo določili kot je opisano v [6].
Izračun kota med dvema sklepoma z uporabo referenčnega merilnega sistema je prikazan na sliki 3. Vsaka merilna ploščica je sestavljena iz 3 IR oddajnikov, ki definirajo koordinatni sistem merilne ploščice. Orientacijo tega KS nam podaja kvaternion $\boldsymbol{q}_{GO}$. V prvem koraku je potrebno pridobiti relacijo med KS merilne ploščice ter KS segmenta, ki jo opisuje kvaternion $\boldsymbol{q}_{OS}$. Določimo ga v začetnem položaju ob predpostavki, da sta kota v kolenu in kolku enaka 90°. Ob znanima začetnima orientacijama segmenta in merilne ploščice v globalnem KS (kvaterniona $\boldsymbol{q}_{GS0}$ in $\boldsymbol{q}_{GO0}$), lahko določimo

$$\boldsymbol{q}_{OS} = \boldsymbol{q}_{GO0}^{*} \cdot \boldsymbol{q}_{GS0} \,. \tag{1}$$

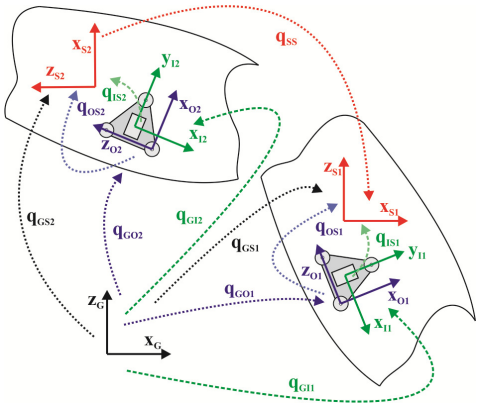
Z uporabo izmerjene orientacije merilne ploščice ($\boldsymbol{q}_{GO}$) in znanega $\boldsymbol{q}_{OS}$ določimo orientacijo segmenta

$$\boldsymbol{q}_{GS} = \boldsymbol{q}_{GO} \cdot \boldsymbol{q}_{OS} \,. \tag{2}$$

Iz znanih kvaternionov dveh sosednjih segmentov določimo kvaternion med tema segmentoma

$$\boldsymbol{q}_{SS} = \boldsymbol{q}_{GS2}^{*} \cdot \boldsymbol{q}_{GS1} \,. \tag{3}$$

Iz dobljenega kvaterniona $\boldsymbol{q}_{SS}$ pa je možno s trivialnimi postopki določiti kote okoli posameznih osi. V našem primeru so nas zanimali koti v sagitalni ravnini, se pravi koti okoli y osi koordinatnega sistema segmenta.



Slika 3: *Grafični prikaz določitve kvaterniona med dvema segmentoma* $\boldsymbol{q}_{SS}$.

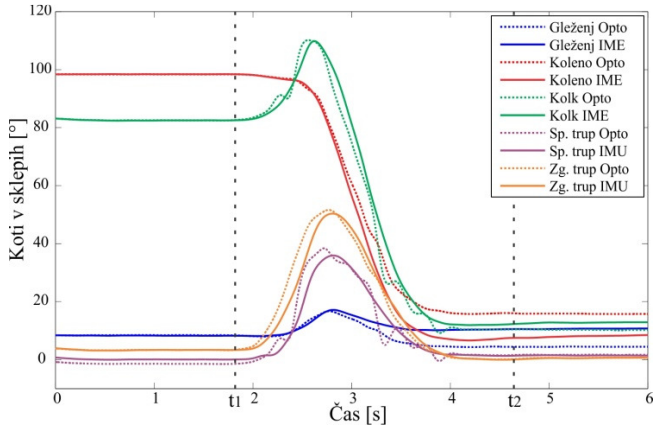
Merilne celice merilnih podplatov delujejo na principu merjenja tlaka. Da lahko izmerimo silo, je bilo potrebo celice najprej umeriti ter določiti njihovo F(U) karakteristiko. Predpostavili smo, da celice merijo le vertikalno silo na celice, saj zaradi njihove ploščate zasnove horizontalne sile ne doprinesejo veliko k skupni sili. Reakcijska sila posameznega merilnega podplata F_{MP} je določena kot vsota sil posameznih celic F_{Ci}

$$F_{MP} = \sum_{i=1}^{24} F_{Ci} \,. \qquad (4)$$

Ker merilne celice pokrivajo le okoli 45% površine merilnih podplatov, je tudi končna rezultančna sila premosorazmerno manjša od sile, izmerjene s pritiskovnimi ploščami.

3 REZULTATI

Na sliki 4 je prikazan primer izmerjenih kotov v sklepih (gleženj, koleno in kolk leve noge ter spodnji in zgornji del trupa) pridobljenih z IME (polna črta) in kotov dobljenih s pomočjo optoelektronskega sistema (črtkana črta) pri normalni hitrosti vstajanja. Povprečna absolutna napaka (razlika med koti iz IME in koti iz Optotraka) pri petih ponovitvah meritev vseh kotov pri različnih hitrostih vstajanja je prikazana v tabeli 1. Na sliki 5 pa so prikazani škatlasti diagrami absolutne napake kotov v sklepih, kjer je označena mediana, prvi in tretji kvartil ter največja in najmanjša vrednost znotraj 1.5 IQR (ang. *inter quartil range*).

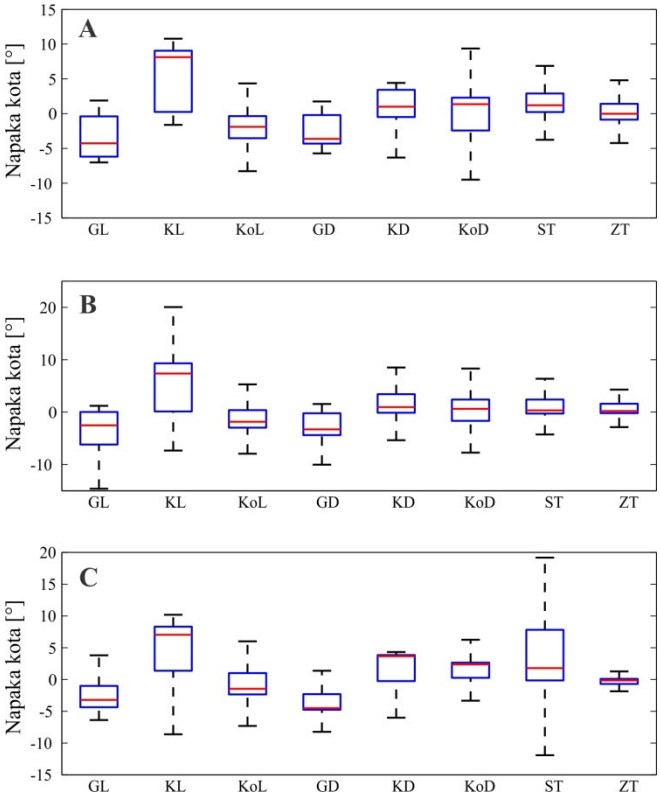


Slika 4: *Primerjava kotov v sklepih dobljenih z IME (polna črta) in dobljenih iz merilnih ploščic (črtkana črta). S časoma t_1 in t_2 sta označena začetek in konec vstajanja.*

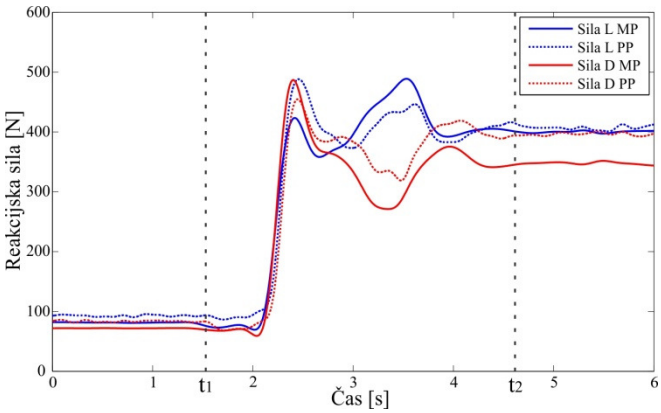
Način	*Normalno*		*Počasi*		*Hitro*	
Kot	$\bar{\theta}$ [°]	$\tilde{\theta}$ [°]	$\bar{\theta}$ [°]	$\tilde{\theta}$ [°]	$\bar{\theta}$ [°]	$\tilde{\theta}$ [°]
L. gleženj	– 3,54	– 4,27	– 3,78	– 2,51	– 2,70	– 3,23
L. koleno	4,69	7,12	5,35	6,37	5,13	7,02
L. kolk	– 2,39	– 1,89	– 4,01	– 1,83	– 2,64	– 1,47
D. gleženj	– 2,73	– 3,63	– 3,22	– 3,29	– 3,40	– 4,52
D. koleno	1,10	0,99	4,32	0,96	1,59	3,65
D. kolk	– 0,41	1,36	3,35	0,62	– 0,30	2,36
Sp. trup	1,64	1,21	0,32	0,34	3,48	1,77
Zg. trup	0,74	– 0,01	0,71	0,20	0,26	– 0,16

Tabela 1: *Absolutna napaka kotov v sklepih v sagitalni ravnini predstavljena kot povprečna napaka $\bar{\theta}$ in mediana $\tilde{\theta}$.*

Na sliki 6 je prikazan primer poteka reakcijske sile izmerjene z merilnimi podplati (polna črta) in pritiskovnimi ploščami (črtkana črta). Povprečna relativna napaka reakcijske sile v sedečem položaju znaša okoli 20% tako za levo kot za desno nogo in je posledica nelinearnosti senzorjev v merilnih podplatih pri majhnih silah. Povprečna relativna napaka reakcijske sile v stoječem položaju pa znaša 2,3% za levo nogo ter 12,8% za desno nogo. Večja napaka desnega merilnega podplata je posledica nedelovanja ene merilne celice na omenjenem podplatu.



Slika 5: *Napaka kotov v sklepih, kjer rdeča črta predstavlja mediano pri treh različnih hitrostih vstajanja: normalno (A), počasi (B) in hitro (C).*

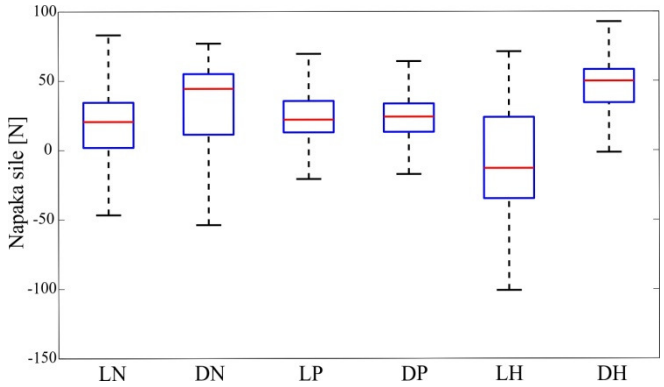


Slika 6: *Primerjava reakcijske sile za levo (modra črta) in desno (rdeča črta) nogo izmerjene z merilnimi podplati (polna črta) in pritiskovnimi ploščami (črtkana črta). S časoma t_1 in t_2 sta označena začetek in konec vstajanja.*

Absolutne napake med reakcijsko silo izmerjeno s pritiskovnimi ploščami in reakcijsko silo izmerjeno z merilnimi podplati so predstavljene v tabeli 2. Na sliki 6 pa so s škatlastim diagramom prikazane absolutne napake reakcijske sile pri treh različnih hitrostih vstajanja posebej za levo in desno nogo.

Način	***Normalno***		***Počasi***		***Hitro***	
Stran	$\bar{F}$ [N]	$\tilde{F}$ [N]	$\bar{F}$ [N]	$\tilde{F}$ [N]	$\bar{F}$ [N]	$\tilde{F}$ [N]
Leva	18,72	20,63	23,92	22,10	–7,57	– 12,88
Desna	28,14	44,38	21,33	24,16	33,31	49,96

Tabela 2: *Absolutna napaka reakcijske sile predstavljena kot povprečna napaka $\bar{F}$ in mediana $\tilde{F}$.*



Slika 7: *Napaka reakcijske sile leve in desne noge pri treh različnih hitrostih vstajanja, kjer rdeča črta predstavlja mediano (L – leva noga, D – desna noga; N – normalno vstajanje, P – počasno vstajanje, H – hitro vstajanje).*

4 ZAKLJUČEK

Evalvacijski rezultati merjenja kinematike človeka pri vstajanju kažejo, da so IME z meadiano napake od 1 do 3 stopinj v primerjavi z Optotrak referenčnim sistemom primerni za merjenje kotov v sklepih. Odstopa edino merjenje kota v kolenu leve noge (mediana od 6 do 7 stopinj), kar se lahko pripiše slabi predhodni kalibraciji inercijske merilne enote. Kot možen vzrok večje napake pri kotu leve noge in kotu spodnjega dela trupa je tudi slaba pritrjenost IR svetlečih diod na merilne ploščice. Rezultati kažejo, da sama hitrost vstajanja ni korelirana z natančnostjo meritve.

Pri inercijskih merilnih enotah je potrebno izpostaviti tudi lezenje pri dolgotrajnih meritvah, kar se da rešiti s ponastavitvijo kotov IME, ko je osebek v stacionarnem stanju (npr. ko mirno sedi oziroma stoji). Problem pri uporabi IME je tudi vpliv bližine feromagnetnih materialov na magnetometer. Ta problem se da omiliti z nastavitvijo zmanjšane stopnje zaupanja magnetometru pri Kalmanovem filtru.

Posebej se je potrebno posvetiti tudi določanju začetnih parametrov – orientaciji segmentov ($\boldsymbol{q}_{GS}$). Primerna rešitev pri vstajanju je določanje teh parametrov pri mirnem sedenju, ko so koti v kolenu in kolku 90°, koti v gležnju in nagib spodnjega in zgornjega dela trupa pa 0°.

Evalvacijski rezultati merjenja reakcijske sile kažejo, da signali merilnih podplatov zadovoljivo sledijo obliki signalov pridobljenih iz pritiskovnih plošč. Vzrok za mediano napake od 20 do 30 N lahko iščemo v sami zasnovi merilnih podplatov, saj je zaradi delno pokritega podplata s senzorji potrebno silo ustrezno skalirati. Lahko pa se pojavijo tudi slabe merilne celice v podplatu, kar še dodatno poslabša merilni rezultat. Rezultati kažejo, da je sama natančnost meritve boljša pri počasnem vstajanju kot pa pri hitrem.

Uspešna evalvacija nosljivega senzornega merilnega sistema je pokazala, da je nosljiv merilni sistem primeren za merjenje kinematike in reakcijskih sil, seveda ob pogoju ustrezne kalibracije in pravilno nastavljenih začetnih parametrih. Nosljiv merilni sistem je kot tak primeren kot sistem za analizo kinematike vstajanja, kot sistem za detekcijo faz ali pa tudi kot senzorni sistem za potrebe vodenje robotskih protez oziroma eksoskeletov, pri katerih igra kinematika pomembno vlogo v samem vodenju proteze.

ZAHVALA

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KNEE EXOSKELETON CONTROL APPROACHES: DIFFERENT EFFECTS ON ENERGY EXPENDITURE?

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ABSTRACT

Several studies to date have examined different design and control mechanisms of the exoskeletons yet very few address the resulting changes in the users energy expenditure. We investigated the effects of a knee exoskeleton application on the energy expenditure and physiological responses during periodic squatting in humans. Oxygen consumption, minute ventilation, heart rate and EMG signals were measured during four squatting series (5 minutes @ squat/2 s). One series was performed without the exoskeleton and served as a control trial. The knee exoskeleton was during the subsequent squatting series controlled using three different control methods: gravity compensation approach, oscillator based approach and position based approach. Significant differences in all measured physiological responses were observed when using the knee exoskeleton under gravity compensation and oscillator based control. On the other hand, the effects of position based control were not significant in all parameters although all approaches significantly reduced the energy expenditure during squatting.

1 INTRODUCTION

Exoskeleton mechanisms using different designs and control approaches have been the subject of research for many years (Dollar and Herr, 2008). However, very few experiments focused on the qualitative evaluation of the exoskeleton effectiveness. As noted by Dollar & Herr (2008), a comparison of the metabolic power between performing a task with or without an exoskeleton is good determinant as to whether there is any energetic advantage of using the device. Thus measuring different physiological and kinematical parameters can serve as a method of assessing the exoskeleton efficiency.

In particular, Walsh et al. (2007) estimated the metabolic cost of a quasi-passive leg exoskeleton for load carrying augmentation. Interestingly, they reported a 10% increase in the energy cost of transport compared to a conventional loaded backpack, even though the exoskeleton largely supported the payload during single support phase of walking. They reasoned that the added mass and kinematic constraints imposed on the wearer are the causes of this increase. Moreover a study by Krewer et al. (2007) investigating energy expenditure during walking on a treadmill, using the Locomat for assistance has also shown an increase in oxygen consumption, one of the main physiological parameters associated with the metabolic cost. Electromyography of active muscles (EMG) has also been suggested as a criterion of exoskeleton efficiency (Banala et al., 2006). It was also used for the control of the HAL-5 exoskeleton device (Fleischer et al., 2005).

This paper presents the physiological effects of using a knee exoskeleton device during periodic squatting with three different control methods. The squatting movement was used as it effectively mimics common everyday tasks (i.e. walking up or down the stairs; getting up from and back to a chair).

2 METHODS

We performed a randomized crossover designed study that compared the effects of different control approaches of the knee exoskeleton on physiological parameters during periodic squatting. Participants performed 4 series of squatting for 5 minutes. Each participant first performed a series without the exoskeleton (Free) as a referential series. Subsequently, they performed the other three series with different control methods (gravity compensation, oscillator based, position based) in a randomized order. Participants rested for at least 1.5 hrs following the Free series and at least an hour after each of the following series.

2.1 Participants

Seven healthy, young, male participants (Age 28.6(2.7); Body mass 79.3(3.7), Stature 182.9(3.7)) volunteered to participate in the study. Before the experiments, the participants were informed about the experimental procedure and gave their free informed consent.

2.2 Knee exoskeleton

The used exoskeleton mechanism was designed for both legs. Each exoskeleton leg has one active rotational degree of freedom in the knee and a passive hinge joint in the ankle. The ankle joint is relatively loose and allows the device to rotate with the leg of the user. Each exoskeleton leg is attached to the supporting frame, so the user does not have to carry it. The user attaches each leg to the mechanism with 4 Velcro straps. The coupling between the user and the device is thus not completely rigid. Additional crossbars

behind the thigh, in front of the knee, and behind the calf ensure a more rigid connection. Each leg of the device is actuated with a 200W, 36V DC electrical motor (Maxon RE50, 370955) with a gear ration of 113. Theoretically this allows a maximal continuous torque of 47.23Nm.

Three different control methods were tested in the study. We termed the control methods with gravity compensation approach, position control approach and oscillator based approach. The gravity compensation approach tries to compensate the weight of the user. Because the mechanism cannot output enough torque, only a part of the weight of the user is compensated. The torque t in the knee of the device is calculated with the following equation:

$$t = K \sin q/2$$

Where K is a positive constant and q is the current joint angle. This way the device is always trying to extend the knee, even when the user is trying to perform a squat. Since the mechanism is back drivable, it reacts to external torque, i.e. if external torque is greater that the output torque of the motor, the mechanism will comply. The position control approach, as the name suggests, uses a positional feedback loop to ensure the desired joint angle. The mechanism tries to follow a referential sinusoidal position. Since the maximal torque if the motor is limited, the device acts in a compliant way. This also helps prevent injuries of the user. The control loop is set so that the motor outputs the maximal torque if the error of the knee joint position reaches 10°. The oscillator based approach relies on an adaptive frequency oscillator (Righetti et al., 2006; Gams et al., 2009) to determine the frequency of the squatting movement and produce an assisting torque. The approach is based on an adaptive frequency oscillator combined with an adaptive Fourier series, as described in (Petrič et al., 2011). This method estimates and predicts the knee joint angle, and outputs a torque value, which was anchored to the estimated position. The anchored torque values were determined in advance. This allows the device to help both extend and flex the knees when necessary. In all control methods the output torque was limited with regard to the weight of the participant in the study.

2.3 Physiological and kinematic measures

Heart rate (HR), oxygen consumption (VO_2), minute ventilation (V_E), blood oxygen saturation (SpO_2) and electromyography (EMG) of the vastus lateralis muscle were measured throughout all squatting series. VO_2 and V_E were measured using a portable metabolic cart (K4-b2, Cosmed, Italy) while HR was measured using the WristOx 3100 Pulse Oximeter (Nonin Medical, USA). The EMG of muscles was measured using surface EMG electrodes with a pre-amplifier (Biometrics Ltd. UK).

2.4 Experimental procedure

Before the start of the protocol the participants were asked to stand erect and completely still for 10 seconds. The resulting measurements were used as the resting EMG. Each squatting protocols began with a 2-minute rest period. The participants were then asked to perform squatting, ranging from an extended knee (0° in the knee), to a low yet still comfortable squat (at least slightly over 90°), for 5 minutes. The squatting frequency was kept at one squat per 2 seconds, where either a metronome or the movement of the knee exoskeleton was used for the reference. The participant held to a rail during the squatting to prevent possible injuries from falling on the back (the device was attached to the frame), but did not use it for assistance. Two minutes following the squatting were used to measure recovery phase responses.

2.4 Data analysis

The data is reported as mean (SD) unless otherwise indicated. One-way repeated measures analysis of variance was used to examine the differences in responses to different squatting series. Multiple comparisons using the Tukey-Kramer criterion were performed to examine possible differences in the power consumption of the device. Significance level α was set *a priori* at $P < 0.05$.

3 RESULTS

Metabolic rate as expressed in MET was significantly lower ($P < 0.05$) during the second part of the squatting series when using the exoskeleton compared to Free (Fig. 1.). No differences in metabolic rate were observed between the different control approaches.

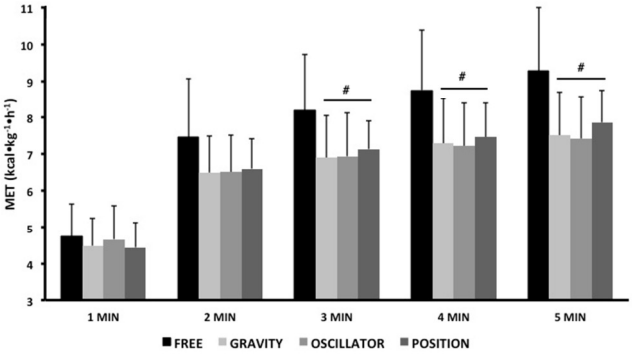

Figure 1: *Metabolic rate of the participants (MET; mean (SD)) during the squatting series without (FREE) and with using the knee exoskeleton under three different control approaches (GRAVITY, OSCILLATOR & POSITION). # Denotes significant differences between FREE and all three control approaches (P < 0.05).*

As can be seen in Fig. 2. V_E was during the last part of the squatting significantly decreased compared to Free only when using Gravity and Oscillator control approaches ($P < 0.01$). No differences were observed in V_E between Free series and Position control or between the different control approaches.

VO_2 was lower during all series using the exoskeleton as compared to free series (Fig. 3.). Significant differences were observed during the last three minutes of the series as well as during the recovery period ($P < 0.05$). No differences in VO_2 were observed between different control approaches (Fig. 3.).

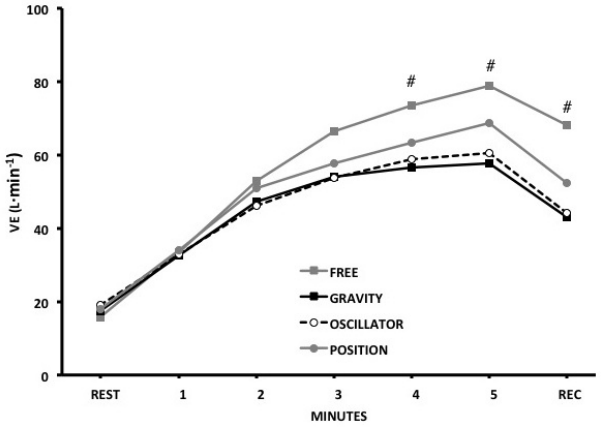

Figure 2: *Minute ventilation of the participants (V_E; mean) during the squatting series without (FREE) and with using the knee exoskeleton under three different control approaches (GRAVITY, OSCILLATOR & POSITION). # Denotes significant differences between FREE and both GRAVITY and OSCILLATOR control approaches (P < 0.01). For clarity purposes the SD's are not presented.*

HR was significantly different between Free and both gravity and oscillator control approaches (Fig. 4.) from the second minute onward (P < 0.01). No significant differences were found between the Free and position methods as well as between all three control approaches.

Collectively, the physiological responses to Free were significantly higher than in series when using the knee exoskeleton regardless of the control method (Figs. 1-4)

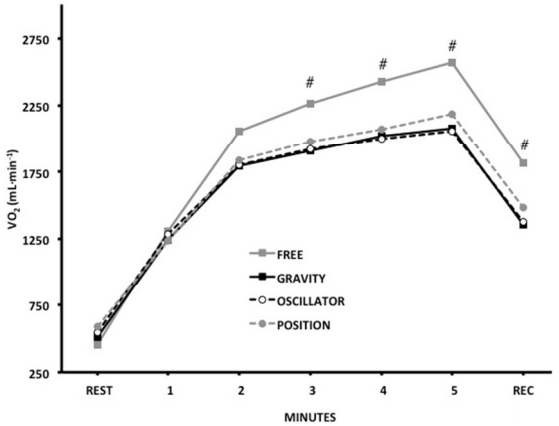

Figure 3: *Oxygen consumption of the participants (VO_2; mean) during the squatting series without (FREE) and with using the knee exoskeleton under three different control approaches (GRAVITY, OSCILLATOR & POSITION). # Denotes significant differences between FREE and all three control approaches (P < 0.05). For clarity purposes the SD's are not presented.*

Differences in the shapes of the EMG envelopes for different methods were observed (Fig. 5.). Two peaks of muscle activity are observed in all 4 cases, especially when using the oscillator based control method (Fig. 5.).

A comparison of the average system power/weight ratio between the control approaches shows that position method is significantly different from the oscillator and gravity methods (Fig. 6.). No significant differences were observed between the oscillator and the gravity method.

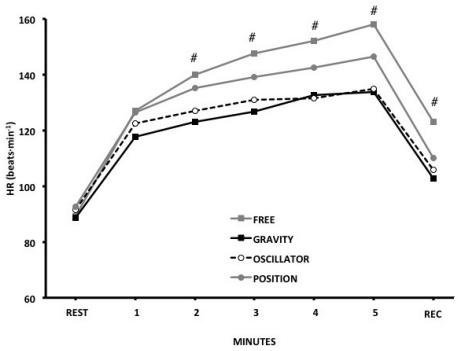

Figure 4: *Heart rate of the participants (HR; mean) during the squatting series without (FREE) and with using the knee exoskeleton under three different control approaches (GRAVITY, OSCILLATOR & POSITION). # Denotes significant differences between FREE and both GRAVITY and OSCILLATOR control approaches (P < 0.01). For clarity purposes the SD's are not presented.*

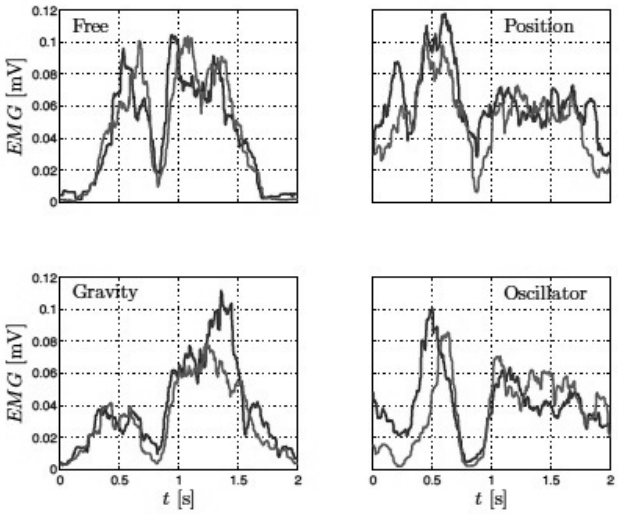

Figure 5: *EMG signal envelopes measured during an average squat halfway through the exercise, for all 4 squatting series. Plots show results for both legs.*

4 DISCUSSION

The main finding of this study is that the calculated energy expenditure (as expressed in MET) was significantly reduced in all series when exoskeleton was applied as compared to the control series (Free). Although no differences were observed between different control approaches in MET and VO_2, only oscillator and gravity based approaches induced significantly decreases in HR and V_E compared to the control series (Free).

Even though previous studies investigating the metabolic cost when applying an exoskeleton mechanism for carrying loads (Walsh et al., 2007), or stationary walking (Ronsse et al., 2011), have shown an increase in energy expenditure while using the exoskeleton, we have noted a different effect

when applying a fixed knee exoskeleton for squatting. The main reason for the disparity in the outcome might be the different studies and/or exoskeletons design. A major impact on the differences can be attributed to the fact that our participants did not have to carry the exoskeleton mass, as squatting does not demand lifting of the legs. Secondly, the movement used in our study was not as complex as bipedal walking. Therefore the assisting torque exerted by the device was more easily targeted to produce the optimal effect.

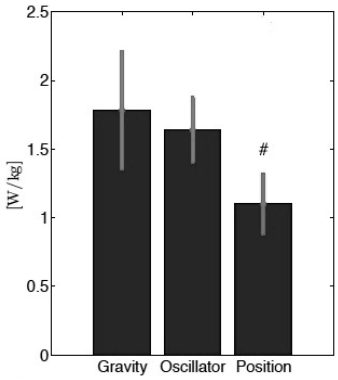

Figure 6: *System Power/Weight ratio for Gravity, Oscillator and Position control methods (mean (SD)).*

Our data obtained from using different control methods show that even when using a squatting movement the changes in the physiological responses and/or energy expenditure greatly depends on the type of knee exoskeleton control. As noted in the results section, significantly different physiological responses occur when the device is controled by gravity compensation and oscillator based method. On the other hand, the use of the knee exoskeleton with the position control method, as defined in this paper, does not statistically significantly reduce all the measured physiological parameters. Similarly to the different outcomes in the physiological parameters with different control approaches, reductions were also noted in the energy consumption of the exoskeleton device. This is important especially in terms of a possible reduction of the device power consumption, a possible crucial point with wearable devices. In particular, when using a wearable device, prolonged autonomous operation of the device can be more beneficial than slightly reduced metabolic costs. Calculation of the device power consumption under different control approaches roughly coincides with the measured physiological responses. In particular, both results showed that gravity compensation and oscillator based methods provoked similar responses, while the position based method was slightly different.

5 CONCLUSION AND PERSPECTIVE

In conclusion, our data shows that by using a fixed knee exoskeleton a significant reduction in the metabolic cost and selected physiological responses can be observed during squatting. Different tested approaches, that allow for natural interaction between the user and the device, have shown that a correct control method is important. In the future we would like to further develop our mechanism and evaluate the effects of such a mechanism as well as different control approaches during bipedal walking.

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PREDGOVOR

Če menimo, da je računalnik računalništvu in informatiki v napoto v procesih vzgoje in izobraževanja, potem je jasno, da je nekaj hudo narobe tako v šolah pa tudi v stroki sami. Kaj nas pri stvari moti? V čem in kako računalnik ovira računalništvo?

Računalnik je lahko prijetna igrača. Z njim delamo razne stvari, tudi take, ki jih do sedaj nismo. Pri tem ni nujno, da vemo, zakaj delamo, tako kot delamo in ne drugače. »Igračkanje« nas lahko zavede tako pri osebni rabi računalnika pa tudi pri rabi v šoli in še kje drugje. Motivacija, ki jo prinaša stroj in za uporabo potrebna funkcionalna znanja, nas lahko odvrnejo od kritičnega razmišljanja o konceptih in novih rešitvah. Splošni koncepti kot so npr. koncepti komunikacij, obravnave podatkov in reševanja problemov lahko utonejo v »rokodelskih« spretnostih uporabe trenutno razpoložljive tehnologije. Zakaj to ni dobro? Zato, ker ti koncepti niso koncepti »motoroznastva«, ki jih voznik ne potrebuje za vožnjo avtomobila, ampak koncepti, iz katerih izhajajo ne le nove tehnološke kreacije, ampak tudi novi odnosi med ljudmi, v gospodarstvu in družbi na sploh.

Zato moramo eksplicitno izpostaviti splošne koncepte računalništva in informatike, a ne le teh. Menimo, da v okvir informatike sodijo tudi nekateri drugi koncepti kot so npr. koncepti organizacije, odločanja in sistemske dinamike. Lahko rečemo, da prav pomanjkanje slednje vodi v številne ne dovolj premišljene rešitve. Z dinamičnim opazovanjem pozitivnih in negativnih vplivov, med dejavniki sistema se lahko izognemo marsikateri slabi odločitvi in poiščemo boljšo. Če vzamemo za primer vročo temo ločenega zbiranja odpadkov, lahko rečemo, da smo v evforiji koristi povsem pozabili na nekatere stranske negativne vplive kot je npr. higiena, ki je eden od temeljev varovanja zdravja.

Seveda pa se more in mora koncepte učiti tudi ob računalniku. Saj je nesmiselno učiti plavanje brez stika z vodo. Računalnik je univerzalni stroj za modeliranje in vizualizacijo podatkov, ki je v pomoč našim miselnim procesom. Tudi pri sistemski dinamiki lahko uporabljamo svinčnik in papir. Če pa uporabimo še računalniške simulacijske programe, zadeve oživijo in dodatno stimulirajo našo kreativnost.

In kaj naj naši učenci, dijaki, študentje ustvarjajo? V splošnem nove rešitve, ki pa se ne nanašajo le na nove računalniške in informacijske rešitve, ampak tudi na nove poslovne modele na različnih področjih človekove dejavnosti. Z upoštevanjem sodobnih tehnoloških možnosti lahko z novimi modeli pridemo do rešitev, ki jih od nas zahteva sedanjost in se njihova dodana vrednost ne meri le v denarju. Tudi šola na vseh ravneh potrebuje nove modele in rešitve. O tem bo tekla beseda na 15. konferenci »Vzgoja in izobraževanje v informacijski družbi«, ki poteka v okviru multikonference »Informacijska družba«.

Vladislav Rajkovič, Mojca Bernik, Tanja Urbančič

PREFACE

If we perceive a computer as an obstacle to educational processes in computer and information sciences then it is clear that there is something fundamentally wrong with the state of affairs in schools as well as in the discipline itself. But where is the problem? How and why is a computer an obstacle to computer science?

A computer can be a nice toy. It can be used in different ways, even in ways we haven't used it before. But that doesn't mean we know why we use it the way we do and not in a different way. "Toying" can also be misleading and this goes for the personal use of the computer as well as for its use in schools. The motivation that the machine brings and the functional skills needed to work with it can lead us away from critical thinking about concepts and new solutions. The craftsmanship of the use of currently available technology can easily drown the basic concepts such as the concepts of communication, data analysis and problem solving. Why is this a bad thing? It's bad because – to give an example – in this case we are not dealing with concepts of how a motor works, which is not something a driver needs to understand in order to drive a car, but instead with concepts that not only give rise to new creations in technology but also to new relations between people, in economy and in society in general.

That is why it is necessary to explicitly highlight the general concepts of computer and information sciences, and not only these. We believe that concepts such as the concepts of organization, decision-making and system dynamics are also a part of the information science framework. The lack of system dynamics, especially, is in our view the main reason for solutions that are not thought through as thoroughly as they should be. Through dynamic observation of both positive and negative impacts on system factors we can avoid bad solutions and find better ones. If we take a look at the heated debate of separate collection of waste, we can say that in the euphoria of its benefits we have completely disregarded some of its negative impacts such as hygiene which is one of the foundations of health protection.

But of course one can and should teach concepts with the help of a computer as well. For it is foolish to try to learn how to swim without jumping in the water. A computer is a universal machine for data modeling and visualization and an aid to our mental processes. In system dynamics, we can help ourselves with pen and paper. But if we use computer simulation programs, everything comes to life and stimulates our creativity in a much more profound way.

And what should our pupils and students create? Generally speaking – new solutions. But not only new solutions in the field of computer and information sciences but also solutions for new business models in different areas of human activity. By taking into consideration the new technological possibilities and through new models, we can come up with a solution that the present demands from us and the added value of which is not measured solely in terms of money. New models and solutions on all levels are also needed in schools. And this is the topic of discussion of the 15th conference titled "Education in information society" that will take place as a part of the "Information society" multiconference.

Vladislav Rajkovič, Mojca Bernik, Tanja Urbančič

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Izdelajmo svoja e-gradiva za pouk tujih jezikov – hitro in preprosto!

Create your own E-learning Materials for your Foreign Language Lessons - In a Simple Way!

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Povzetek
V prispevku želim predstaviti prednosti uporabe e-gradiv pri poučevanju tujega jezika, še posebej če le-ta izdelamo sami. Uporaba e-gradiv pri pouku se mi zdi smiselna kot dodaten izobraževalni vir, ki olajša individualizacijo in diferenciacijo pouka, predvsem pa bistveno pripomore k višji motiviranosti učencev. Opisujem nekaj primerov preproste izdelave e-gradiv, ki so moje ure opazno popestrila in zagotovila večjo dinamičnost in kakovost pouka.

Ključne besede: e-gradiva, individualizacija, diferenciacija pouka

Abstract
My intention is to show some advantages of teaching foreign languages by using e-learning materials, especially when teachers create them by themselves. E-learning materials facilitate successful classroom learning by enabling the individualisation of the students' learning process. They provide some suggestions for dealing with mixed-ability classes and most importantly, they guarantee a higher grade of students' motivation to learn. Teachers can download some free programmes from the Internet and create their own e-learning materials in a simple way. Using interactive language activities and games created with these programmes is an engaging way for students to practice their language skills and it provides a variety of challenging and fun lessons.

Keywords: e-learning materials, individualisation, mixed ability classes

Spodbujanje branja z računalniško podprtim projektnim učnim delom pri učencih z bralnimi težavami

Stimulating Reading with Computer-Supported Learning Project Work with Students with Reading Difficulties

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Povzetek
Izobraževalna tehnologija je danes pomemben del učnega procesa, zato jo je potrebno vključevati med vse učence, tudi med tiste, ki imajo bralne težave. Rezultati vsebinske analize rabe računalniško podprtega projektnega učnega dela, ki sem ga vnesla v učni proces pri učencih z bralnimi težavami, so pokazali, da ta učna metoda omogoča uspešnejši kognitivni in socialni razvoj učencev in da bralne težave nikakor ne morejo biti razlog za to, da sodobne računalniške podprte učne metode uporabljamo le pri učno uspešnejših učenci.

Ključne besede: računalniško podprto projektno učno delo, bralne težave, kognitivni in socialni razvoj

Abstarct
Educational technology is now an important part of the learning process, therefore it is necessary to include all students, even among those who have reading difficulties. The results of content analysis of the use of computer-supported learning project, which I entered in the learning process for students with reading difficulties, has shown that this learning method enables effective cognitive and social development of pupils' reading difficulties and that can not possibly be the reason for that modern computer-based learning methods are used only for teaching students more successful.

Keywords: computer-supported learning project work, reading difficulties, cognitive and social development

Vodenje kakovosti: kaj imata skupnega Moodle in kakovost? In kakovostno komuniciranje?

Quality Management: What do Moodle and Quality have in Common? What about a Quality Communication?

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Povzetek
Sistem vodenja kakovosti različnih organizacij se dokumentira v poslovniku kakovosti in drugih dokumentih, oblika dokumentiranja pa največkrat ni predpisana. V primeru vodenja kakovosti v terciarnem izobraževanju, konkretno vodenja Komisije za spremljanje in zagotavljanje kakovosti na višji strokovni šoli, avtorica (in hkrati predsednica tovrstne komisije) v prispevku predstavi način arhiviranja dokumentov v spletnem okolju Moodle. Takšen način predstavlja podporo in v nekem smislu tudi nadgradnjo klasičnemu načinu dokumentiranja sistema vodenja kakovosti; dostop do bistvenih dokumentov (dostop je omogočen le preko dodeljenega gesla oz. ključa) od kjerkoli in kadarkoli tako članom komisije za kakovost omogoča lažje in hitrejše odzivanje, sodelovanje in izvajanje potrebnih aktivnosti. Na ta način se lahko zmanjša tudi število formalnih sestankov, komunikacija med člani komisije pa je kljub temu enako ali celo (ob dopolnjevanju z drugimi vrstami komunikacij) še bolj kakovostna. Orodje Moodle pa omogoča tudi komunikacijo z drugimi (registriranimi) udeleženci.

Ključne besede: vodenje, kakovost, Moodle, komunikacija, komisija za spremljanje in zagotavljanje kakovosti, terciarno izobraževanje

Abstract
The quality management system is documented within the rules of procedure of the quality and other documents, but the form of the documentation is mostly not prescribed. In the case of a quality management within the tertiary education, more specifically, the management of the Commission for the Monitoring and Ensuring of Quality at a vocational college, the author, being at the same time the president of such a commission, introduces a way of documents filing within the Mooodle web environment. Such a way represents a support and in a certain sense also an upgrading of the classical way of the documenting of the quality management system: the access to essential documents (authorized only with an assigned password and/or "key") from anywhere and anytime enables to the members of the Commission of the Quality an easier and faster reaction, cooperation and performance of the necessary activities. Thus, the number of formal meetings is decreased, whereas the communication among the commission members remains at the same level or (if supplemented with other ways of communication) is even improved. Besides, Moodle application ensures a communication with other (registered) participants, as well.

Keywords: management, quality, Moodle, Commission for the Monitoring and Ensuring of Quality, tertiary education

Razvojni model e-učenja za plavanje distrofikov

E-learning Development Model for Disabled People Swimming

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Povzetek
E-učenje za mnoge distrofike in ostale gibalno specifične osebe, odpira nove, bolj prilagodljive in dostopne poti. Ko govorimo o plavanju je tem osebam potrebno pomagati z veliko mero strokovnosti. V vodi se sila, ki je potrebna za premik telesnih segmentov, močno zmanjša. Zmanjšanje je lahko tolikšno, da distrofik ali ostale gibalno specifične osebe sami s svojimi oslabelimi mišicami uspejo premagovati upor proti gibanju telesa v vodi. Plavanje je tako ključno za ohranjanje večje stopnje gibljivosti omenjenih oseb.
Zaradi zagotavljanja varnosti gibanja v vodi, mora distrofika v vodi vedno spremljati asistent. Skrb za distrofika zahteva visoko stopnjo učinkovitosti komunikacije med distrofikom in asistentom. Poudarek je na njuni medsebojni komunikaciji in pomoči. Teoretična interaktivnost preide v učenje z delom. Če hočemo čim bolj nazorno predstaviti problematiko pravilnega plavanja, potem si lahko pomagamo tudi s predpripravo, kjer uporabimo multimedijske vsebine.
Pripravili smo klasični izobraževalni material, dopolnjen z e-vsebinami, ki lahko tvorijo celoto v obliki priročnika. Posamezne elemente lahko uporabimo ločeno – klasično ali z multimedijsko podporo. Razvoj obeh delov usmerjamo v smeri interaktivnosti.
Učenje se prenaša v vodno okolje, kjer je namen najti točko najvišje komunikacijske motivacije pri distrofiku in mu na ustrezen način posredovati ključno informacijo, ki bo vsekakor izboljšala razumevanje zakonitosti obnašanja teles v tekočinah.

Ključne besede: plavanje, distrofiki, e-učenje, multimedija, interaktivnost

Abstract
New more adaptable and accessible ways for disabled people and other motion specific persons are enabled by e-learning. Professional approach should be applied when swimming is considered. Force needed for human body segments movement is significantly reduced in water. Force reduction can be high enough to enable disabled people and other motion specific persons with weakened muscles overcome resistance against body movements. Swimming is crucial for maintaining higher level of mobility of restricted person.
For safety assurance reasons disabled people in water need to be always accompanied by assistant. Attention for disabled people requires high level of effective communication between disabled people and assistant. Emphasis is on their communication and assistance. Theoretical interactivity is transferred to learning by work. Multimedia preparation can be used for vivid illustration of correct swimming challenges.
Classical educational content with additional e-content was prepared which generate comprehensive manual. Individual elements can be used separately-classical or with multimedia support. Development of both elements is targeted towards interactivity.

Learning is transferred to water environment where the main purpose is finding highest communication motivation with disabled people. Crucial information should be transferred and consequently enhance disabled people understanding of body behavior laws in fluids.

Keywords: swimming, disabled people, e-learning, multimedia, interactivity

Holistični pristop k zmanjševanju vodnega odtisa v izobraževalnih organizacijah

Holistic Approach to Reducing the Water Footprint in Educational Organizations

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Povzetek
Cilj raziskave je najti ustrezen pristop pri ozaveščanju porabnikov vode v izobraževalnih organizacijah. Porabniki vode običajno vodo le porabijo in pri tem redko razmišljajo na kakšen način je voda prispela do porabnika in kam se po uporabi umika.

Pri celovitem oz. holističnem pristopu k ozaveščanju porabnikov smo uporabili formulacijo vodnega odtisa. Osnovna orientacija v raziskavi je analiza izpiskov plačil izobraževalne organizacije za vodo v nekajletnem obdobju. V prvi fazi ocenjujemo količino puščanja vode, nato nadaljujemo z učinkovitim preprečevanjem teh izgub in končno želimo kampanjsko vplivati na zmanjšanje porabe vode s predstavitvijo aktualnega vodnega odtisa.

Holistični pristop se začne z ozaveščanjem o dejansko porabljeni vodi in o virtualni vodi. V raziskavi so bili najprej popisani porabniki, zabeležene napake in izvedene meritve količine porabljene in zavržene vode. Na konkretnem primeru smo oblikovali osnove kampanije za zmanjševanje vodnega odtisa.

Na podlagi priporočil za porabo vode, ki veljajo v svetu, smo skušali oblikovati program holističnega pristopa k zmanjševanju vodnega odtisa. Zavedamo se, da je delo z mladostniki zelo specifično, zato je izziv določanja vodnega odtisa logičen, zanimiv in izzivalen.

Ključne besede: vodni odtis, poraba vode, varčevanje, izobraževanje

Abstract
Research objective is to find appropriate approach for enhancing water awareness among educational institutions. Water consumers usually use water without consciousness of how water is distributed and where it is discharged afterwards.

Water footprint term was used for comprehensive approach to raise water usage awareness. Basic information used in study is derived from educational institution water expenses over past few years. In first part water leakage amount is assessed followed by effective prevention of water losses. Finally we want to influence water usage reduction by presentation of current water footprint.

Comprehensive approach starts with water usage awareness together with virtual water. First water users and errors were identified followed by measurements of used and waste water amounts. Water footprint reduction campaign was based on specific example.

Based on generally accepted world recommendations we tried to form complete approach to water footprint reduction. We are aware that working with young people is very specific and water footprint determination is logic, interesting and challenging.

Keywords: water footprint, water consumption, water saving, education

Optimizacija organizacije dela v izobraževanju s pomočjo ekspertnih sistemov

Optimising the Organisation of Educational Work through Expert Systems

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Povzetek
Uvedba sodobno zasnovane integralne informacijske podpore v poslovne procese prinaša številne prednosti v smislu optimiziranja dela zaposlenih, razpoložljivosti pravočasnih in točnih informacij na pravem mestu in s tem zniževanje stroškov ob povečanju učinkov dela. Predlog izboljšave procesa dela v izobraževalni inštituciji se nanaša na računalniško podporo izdelavi elektronskih urnikov, zasnovani na podlagi zmožnosti evolucijskih algoritmov umetne inteligence oziroma ekspertnih sistemov. V prvem delu prispevka so opisane osnovne značilnosti in prednosti ekspertnih sistemov, v drugem delu pa je podan primer rešitve, ki je izdelana na osnovi uporabe evolucijskih algoritmov ekspertnega sistema in že uvedena v številnih izobraževalnih inštitucijah. V prispevku so v nadaljevanju opredeljeni bistveni pozitivni učinki uporabe aplikacije iUrnik, opredeljeni s strani uporabnikov te rešitve. Integralnost in povezljivost sistema z drugimi računalniško podprtimi sistemi nam omogočata vso potrebno osnovo za nadgradnjo informacijskega sistema za podporo odločanju, ki ga kot pomoč pri sprejemanju pravilnih in pravočasnih odločitev potrebuje management v šolstvu.

Ključne besede: racionalno upravljanje z zaposlenimi, umetna inteligenca, ekspertni sistemi, elektronski urnik

Abstract of the Paper
The introduction of state-of-the-art integral IT support into business processes brings several advantages such as optimising the work of employees and ensuring greater availability of timely and accurate data; it also in falling costs while at the same time allows work output to be increased. The proposed improvements to the work processes in educational institutions refer to introducing IT support to generating electronic schedules based on the capability of artificial intelligence evolution algorithms, namely expert systems. In the first part of the paper, we describe the basic characteristics and advantages of using expert systems, while in the second part we provide an example of a solution based on using evolution algorithms of an expert system, which has already been introduced in several educational institutions. In the paper, we describe the main positive effects of using the iSchedule application cited by its users. The fact that the integral system can be connected to other IT systems provides all necessary bases to upgrade the IT system and enable it to support decision-making in education management with a view of providing assistance to taking correct and timely decisions.

Keywords: rational employee management, Artificial Intelligence, Expert Systems, electronic schedule

Poštevanka in računalnik

Multiplication and the Computer

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Povzetek
Poštevanka sodi med temeljne standarde znanja v 3. razredu. Učenci jo morajo usvojiti do avtomatizma. Za nekatere učence pa to predstavlja velik problem. Učitelji kaj kmalu ugotovimo, da smo uporabili že večino naših metod za utrjevanje znanja in se kaj kmalu začnemo ponavljati. Tak način dela lahko pripelje do monotonega pouka, zato želim v prispevku predstaviti spletne strani, ki učenje poštevanke zelo popestrijo. Sama sem jih preizkusila v razredu, zato lahko rečem, da so bili učenci zelo motivirani za delo, saj so se učili skozi igro. Poštevanko so lahko vadili tudi doma, brez pomoči staršev.

Ključne besede: poštevanka, spletna stran, utrjevanje, zanimiv pouk

Abstract
Knowing your multiplication table is one of the foundations of syllabus of the 3rd grade of primary schools. The pupils not only need to learn it but also use it automatically and this presents a huge problem to some of them. Teachers soon discover that we have exhausted all our methods for revising and that we start to repeat ourselves, which might lead to monotony of lessons. Therefore, I would like to present you some web sites which bring dynamics back to the learning of multiplications. They have all been tested in real school environment, the pupils were highly motivated as they were learning through playing and they were able to practise multiplication at home as well without any help of their parents.

Keywords: multiplication, computer, revision, www

Jaz in drugi

Others and I

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Povzetek
Učitelji in starši stremimo k temu, da bi otroci znali reševati konflikte in komunicirati na nenasilen način. Žal se konfliktom v medčloveških odnosih ne moremo izogniti, zato je prav, da otroke naučimo pravilnega reševanja le-teh. S tem začnemo že v vrtcu ali takoj v prvem razredu. V predstavitvi želim predstaviti dejavnosti, ki jih skoraj vsakodnevno vključujem v pouk in s katerimi razvijam različne socialne veščine in tako otroke navajam na nenasilno reševanje konfliktov. Pri tem mi je v pomoč tudi i-tabla.

Ključne besede: nenasilna komunikacija, socialne veščine, i-tabla

Abstract
Teachers and parents together strive to teach children to solve their problems and deal with conflicts through non-violent communication. Unfortunately, we cannot avoid conflicts therefore it is necessary to teach children the right way of solving them. The learning process starts in the first grade or if possible also in the preschool years. The presentation will show you different activities which are almost daily used on the classroom, often with the help of the interactive board, to help develop different social skills and through them children learn how to solve the conflicts in calm, non-violent way.

Keywords: non-violent communication, social skills, interactive whiteboard

Sodelovanje v oblaku za kakovostnejše vzgojno-izobraževalno delo

Cooperation in a Cloud for Better Quality in Educational Work

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Povzetek
V zadnjih letih smo priča intenzivnemu razvoju računalniške tehnologije, še zlasti računalništva v oblaku, ki predstavlja velik premik v razvoju IKT tehnologije. Ima pa oblak tudi didaktično vrednost, saj omogoča udejanjanje novega razumevanja učenja. Govorimo o sodelovalnem učenju in poučevanju, ki postavlja temelje za razvijanje partnerskega odnosa med učenci kot tudi med učenci in učiteljem. Prispevek prikazuje primere uporabe dokumentov v oblaku v spletni učilnici Moodle pri pouku slovenščine v osnovni šoli.

Ključne besede: računalništvo v oblaku, delo v oblaku, učno okolje Moodle, osnovna šola, slovenščina, sodelovalno delo, partnerski odnos

Abstract
In the last few years we have witnessed a tremendous development in computer science, especially the cloud computing, which represents a big step in the development of educational technology. The cloud also has didaktical value, because it enables the realisation of a new understanding of learning. We are specifically talking about the cooperation of learning and teaching which sets the building blocks for developing a relationship between students, as well as students and teachers. The article discusses some examples of using documents in a cloud in a Moodle interactive classroom for teaching Slovene in primary school.

Keywords: cloud computing, working with cloud, Moodle, primary school, slovene, cooperative work, relationships

Projektno delo z vidika kemije pri podajanju smernic zdravega in učinkovitega prehranjevanja mladostnikov

Project Work from the Viewpoint of Chemistry at Passing Guidelines of a Healthy and Efficient Nutrition of Young People

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Povzetek

Projektno delo s prehransko vsebino ima namen ozaveščanja in izobraževanja dijakov o zdravem in učinkovitem prehranjevanju mladostnikov. Hkrati omogoča poglobljeno razumevanje kemije temeljne ravni ter nadgradnjo in pridobitev posebnih znanj in spretnosti iz kemije.

Projekt je v osnovi zasnovan interdisciplinarno z naslednjimi vključenimi predmeti: kemija, slovenščina, angleščina, nemščina, ruščina in psihologija ob podpori IKT.

V kemijske dejavnosti, ki so od dijakov zahtevale precejšnjo aktivnost, so bili vključeni še dijaki dveh slovenskih gimnazij, različni gostje in prehranski strokovnjaki. Nekateri med njimi so v projektu delovali v živo, drugi na daljavo (videokonferenčno povezovanje).

Dijaki so spoznali najpomembnejša hranila in živila, eksperimentalno so dokazali delovanje antioksidantov in vitaminov, s kromatografsko metodo so določali barvila v rdeči papriki. Prepoznavali so strukturo pesticidov in umetnih barvil ter razpravljali o njihovi varni rabi v hrani. S pomočjo gosta iz tujine so pripravili nekaj tradicionalnih indijskih in slovenskih jedi, čemur je sledila degustacija. Obiskali so sejem Narava – Zdravje, kjer so posneli reportažo. Na glavni ljubljanski tržnici so spoznali razlike med ekološkim, integriranim in tradicionalnim kmetijstvom ter pridobili informacije o avtohtonih vrstah sadja in zelenjave na Slovenskem. Srečali so se tudi z nekaterimi funkcionalnimi živili, ki imajo varovalen učinek pred določenimi civilizacijskimi boleznimi. Informirali so se tudi o aditivih v hrani in spoznali novo prehransko vejo – nutrigenomiko. Ta pri načrtovanju prehrane upošteva človeški genom. Kemijski del projekta se je zaključil s pregledom dvanajstih korakov zdravega in učinkovitega prehranjevanja mladostnikov, ki so jih napisali nutricionisti s celega sveta.

Ključne besede: projektno delo, zdravo prehranjevanje, mladostniki, medpredmetno povezovanje, videokonferenca, digitalna tehnologija

Abstract

The project work with nutrition contents carries the purpose of informing and educating secondary school students about healthy and efficient ways of eating of young people. Simultaneously, it enables an in-depth understanding of chemistry on a basic level, its proficiency, as well as obtaining special knowledge and skills in the field of chemistry.

The project is interdisciplinary based and includes the following subjects: chemistry, Slovenian, English, German, Russian and psychology supported by ICT (information and communication technologies).

Included in the activities pertaining to chemistry, which demanded extensive student activity, were students from two other Slovenian grammar schools, various guests and nutrition experts. Some of the participants were active on site and some contributed from distance (videoconferencing).

The students got to know the most important foods and nutrients, experimentally they proved the workings of antioxidants and vitamins, and determined the pigment in red capsicum by using chromatographic method. They determined the structure of pesticides and artificial colourings as well as debated their safe use in foods. With the help of a guest from abroad they prepared several traditional Indian and Slovene dishes which was followed by a degustation. They visited the fair Narava – Zdravlje (Nature – Health) where they made a video report. At the Central Ljubljana Market they got to know the differences between ecological, integrated and traditional farming and obtained information on authentic fruit and vegetable sorts in Slovenia. They were acquainted with some functional nutrients which have a protective effect on certain civilisation diseases. They were informed about food additives and got to know a new branch of nutrition – nutrigenomics, which takes into consideration the human genome while planning nutrition. The chemical part of the project ended with an overview of the twelve steps of a healthy and effective nutrition of young people, which was written by nutritionists from all over the world.

Keywords: project work, healthy nutrition, young people, interdisciplinary learning, videoconference, digital technology

Hrana kot vezni člen medpredmetnega sodelovanja in uporabe IKT

Food as a Link between Interdisciplinary Learning and the Usage of ICT

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Povzetek
S projektom smo želeli poudariti pomen zdravega prehranjevanja v sodobni družbi, ne le v šolskem prostoru, ampak tudi na vseh področjih človekovega življenja, pri čemer smo povezali teoretična izhodišča sestave hrane s sporazumevalno, digitalno in medkulturno kompetenco. To pomeni, da je imel project za izhodišče tako medpredmetno povezovanje kot tudi uporabo IKT.
Delo je vključevalo spoznavanje kemijske strukture hranil, sestave živil, predavanja prehranskih strokovnjakov, stik s tujimi kuhinjami s pomočjo ljudi iz drugih kultur in reflektirano dojemanje lastnega doživljanja okusov. Pri izvedbi smo uporabili videokonferenco, spletno učilnico, forum, spletno klepetalnico, predavanja strokovnjakov, srečanja in intervjuje s tujci, snemanje intervjujev, uživanje hrane iz različnih kultur, pisanje komentarjev v tujem jeziku, izdelavo slovensko-angleško-nemško-ruskega slovarčka s prehranskimi pojmi in refleksijo lastnega doživljanja hrane oz. njenih okusov.

Ključne besede: kemijska analiza hrane, IKT, medpredmetno povezovanje, mladostniki

Abstract
With this project, we tried to emphasise the importance of healthy nutrition in modern societies, not only in schools but on every level of a human life. Hereby we joined theoretical knowledge of food with communicative, digital and intercultural competences. In other words, the project was based on both interdisciplinary learning and the usage of ICT.
Students studied the chemical structure of nutrients and their composition, and got an insight by listening to various experts, also from other cultures, and tried to understand thier own taste. We used a video conference, an on-line classroom, forums, interviews, tried various foreign dishes, commented

upon it all in foreign languages, made a dictionary and reflected upon our own idea of a taste.

Keywords: chemical analysis of food, ICT, interdisciplinary learning, adolescents

Programsko orodje za podporo projektnemu delu študentov

A Software Tool to Support Student Project Work

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Povzetek

Na Fakulteti za računalništvo in informatiko Univerze v Ljubljani že vrsto let poučujemo metodo Scrum kot eno najbolj priljubljenih agilnih metod za razvoj programske opreme. Učni načrt obsega skupinsko delo na zaključnem projektu (angl. capstone project), kjer se študenti spoznajo z metodo ob delu na (skoraj) realnem projektu. Za uspešno izvedbo predmeta je nujna uporaba ustreznega programskega orodja, ki podpira skupinsko delo po metodi Scrum. Tovrstno orodje namreč študentom olajša delo, učnemu osebju nudi sproten vpogled v delo študentskih skupin, zbrani podatki pa lahko služijo tudi za raziskovalne namene. Zaradi neprimernosti komercialnih rešitev smo se odločili za lastno realizacijo orodja. Pri tem smo realizirali podporo vsem postopkom in dokumentom, ki jih zahteva metoda Scrum, hkrati pa smo dodali tudi nekaj unikatnih funkcionalnosti, ki so namenjene tako razvijalcem kot tudi učnemu osebju. Naše orodje smo že uporabili tudi v praksi pri izvedbi prej omenjenega predmeta, rezultati pa so zelo spodbudni.

Ključne besede: Scrum, agilne metode, projektno delo, programsko orodje

Abstract

At the Faculty of Computer and Information Science of University of Ljubljana we introduced Scrum as one of the most popular agile software development methods to the curriculum. The class is organized as a capstone course, where students learn to use Scrum while working on the development of a (nearly) real-life project. To successfully conduct such a class, it is necessary to use a software tool that supports Scrum development. Such a tool presents a great benefit for students and teachers as well as researchers, who can use the collected data for scientific purposes. Since most of the commercially available tools are not appropriate for use in an academic environment, we decided to develop our own solution that supports all of the procedures and documents that are required by Scrum and also comprises some additional features that benefit the development team as well as teaching staff. We are already using the tool in practice to execute our classes with very positive results.

Keywords: Scrum, agile methods, capstone project, software tool

Uporaba različnih računalniških programov pri načrtovanju projekta

Use of the Different Computers Program at Planning Project

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Povzetek
Načrtovanje konkretnih projektov, s pomočjo katerih se dijaki učijo projektnega dela, je v pedagoškem procesu dokaj zahtevno opravilo. Posebno, če je pri tem potrebno uporabljati različne računalniške programe, npr. Googlove dokumente, MS Project, MS Word, MS Excel, spletno učilnico Moodle ipd. Pri tem pouku prevladuje samostojno delo dijakov. Pri reševanju nalog si pomagajo z video-vodiči, povezavami, pripombami v Excelu ipd. Učitelj na začetku reševanja naloge okvirno predstavi nalogo in način reševanja le-te. Med reševanjem naloge dijakom pomaga samo v primeru, če ga dijaki zaprosijo. Ves čas pa kontrolira delo dijakov.

Dijaki izvedejo naslednje faze v pedagoškem procesu, ko načrtujejo konkreten projekt. Nalogo za reševanje dobijo v spletni učilnici Moodle. Sledi možganska nevihta za zbiranje idej o projektnih dejavnostih. Na koncu pa načrtujejo projekt s pomočjo različnih računalniških programov, npr. z MS Projectom, MS Excelom, MS Wordom in MS Slikarjem.

Ko uspešno izvedejo celoten proces s pomočjo različnih računalniških programov, pridejo do rezultatov načrtovanje projekta: časovnega diagrama in načrtovanih stroškov projekta.

Ključne besede: načrtovanje projekta, MS Project, video-vodiči, samostojno delo dijakov

Abstract
Planning of specific projects to help students learn project work, is in the teaching process a hard task. Especially if we have to use the different computer programs, such as Google documents, MS Project, MS Word, MS Excel, Moodle webclass. By this way of teaching dominates the individual work of students. Students help by solving the tasks with the video guides, web links, comments in Excel etc. Teacher at the beginning of solving the tasks presents the tasks and how they can solve the tasks. Teacher help to students at solve the tasks only if students ask him or her. Teacher all the time control the work of students.

Students carry out the following steps in the teaching process when planning a concrete project. They get the task in webclass Moodle. Next step is a brainstorming for collect the ideas for project activities. At the end they plan their project activities with the various computer programs, for example. MS Project, MS Excel, MS Word and MS Painter.

When they successfully made the entire process with a variety of computer programs, they got the results of project planning: Gantt chart and the planning project costs.

Keywords: planning of project, MS Project, video-guides, individual work of students

Mobilni telefoni v šoli

Mobile Phones at School

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Povzetek
Uporaba mobilnih telefonov je v večini osnovnih in srednjih šol prepovedana, saj se mobilni telefon dojema kot moteč pripomoček. Razvoj na tem področju postavlja mobilne telefone na mesto zelo uporabnega didatkičnega pripomočka. Pri razmišljanju o uvajanju mobilnih telefonov v učni proces si lahko pomagamo s pripravljeno spletno anketo. Razprave o uvajanju naj vključujejo obravnavo pravnih vidikov, varnostne vidike, socialne momente, razpravo o upravljanju mobilnih telefonov in končno največji poudarek na izvedbi posameznih učnih enot s podporo mobilnih telefonov. Uvajanje mora biti načrtno, vključevati mora vzgojo za varno rabo interneta, spremembo pravilnikov in usposabljanje učiteljev.

Ključne besede: mobilni telefoni, varnost, načrt uvajanja, primeri rabe

Abstract
Usage of mobile phones in elementary and secondary schools is mostly forbiden as mobile phones is perceived as annoying devices. Development in this area promotes mobile phones as very useful didactic tool. In preparation phases of thinking about posibilities of introduction of mobile phones to the learning process teachers can use the prepeared online survey. Discussions on the introduction should include consideration of legal aspects, security aspects, social moments, the discussion on the management of mobile phones and finally implementation of teaching units that include mobile phones. Deployment must be well planned and must include education on subjects of safe Internet use, change of school policies and teacher training.

Keywords: mobile phones, security, deployment plan, use cases

V šole bi bilo potrebno uvesti pouk računalništva

Slovenian Schools should Teach Computing

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Povzetek
Slovenske šole ne poučujejo računalništva (čeprav se večini zdi, da ga), vendar bi ga bilo potrebno uvesti (čeprav se nekaterim zdi, da ga je potrebno ukiniti). Številni dejavniki, kot sta odlična opremljenost šol z računalniško opremo in zavedanje države o pomenu računalništva za prihodnost, so privedli do tega, da slovenske šole ne nudijo ustreznega računalniškega znanja in ne zaostajamo več le za svetovnim, temveč celo za evropskim in ameriškim poprečjem. Rešitev, ki jo pripravlja računalniška stroka, je preprosta in poceni, zato bo pot do njenega sprejema dolga in težka.

Ključne besede: izobraževanje, računalništvo

Abstract
Slovenian schools do not offer courses in computer science (although most think they do), so we need to introduce them (although some think they need to be abolished). Most schools are well equiped with computers and the state recognizes the importance of the field. These factors affected the computer courses in such a way that international surveys estimate our knowledge to be not only below the world average but even below that of EU and USA. The solution proposed by computer scientists is simple and inexpensive, therefore the road to its implementation will be long and difficult.

Keywords: education, computing

IKT in otroci in mladostniki s posebnimi potrebami

ICT and Children and Youth with Special Needs

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Povzetek

V današnjem svetu hitrega tehnološkega razvoja se nam je nemogoče izogniti uporabi informacijsko komunikacijske tehnologije (v nadaljevanju IKT). Komunikacija igra ključno vlogo tudi pri otrocih in mladostnikih s posebnimi potrebami (v nadaljevanju OMsPP), zato je pomembno, da spoznajo, kaj jim lahko omenjena tehnologija ponudi, še pomembneje pa je, da se naučijo, kako jo s pridom, vendar varno uporabljati.

Za mnoge je to ena od pomembnejših ali celo edina oblika komuniciranja s t. i. »normalnim« svetom, je pa lahko tudi eden ne tako pogostih načinov kompenziranja primanjkljajev.

V prispevku predstavljam nekaj primerov dobre prakse s področja uporabe IKT pri delu z otroki in mladostniki z raznovrstnimi posebnimi potrebami[1], ki so na eni strani izjemno enostavni, na drugi strani pa zelo učinkoviti. Tudi s pomočjo IKT so OMsPP postali bolj samostojni, samozavestni, v nekaterih primerih pa jim je računalnik pokazal tudi pot do samozagovorništva.

Učitelji oziroma vzgojitelji OMsPP nosimo veliko odgovornost, da jim te možnosti predstavimo in jim pomagamo najti tiste, preko katerih bodo lahko pokazali svoje zmožnosti in sposobnosti.

Ključne besede: informacijsko komunikacijska tehnologija, otroci in mladostniki s posebnimi potrebami

Abstract

It's impossible to avoid the use of information and communication technology (ICT) in today's world of fast technological development. When it comes to children and youth with special needs, communication plays a significant part. Therefore it's important for them to get to know this technology, and more importantly, to learn how to use it safely.

For many children and youth with special needs computer is one of the most important, sometimes even the only form of communication with so called "normal world". It can also be a way to compensate learning deficiencies.

The paper presents several examples of good practice in the use of ICT in work with children and youth with different special needs[2] that turned out to be both extremely simple and very effective. Using it, students became more independent and self-confident, in some cases even found a way to self-advocacy.

Teachers and educators of children and youth with special needs bear huge responsibility to present them the options they have using ICT and to help find them those that will help them show their full potential.

Keywords: information and communication technology, children and youth with special needs

[1] Opomba: Imena nekaterih OMsPP so izmišljena.

[2] Note: The names of some children and youth with special needs are fictitious.

Opismenjevanje v 1. razredu s pomočjo e-gradiv, interaktivne table in spletne učilnice

Literacy of First Class Pupils by Using E-learning Materials, Interactive Whiteboard and Virtual Classroom

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Povzetek
V prispevku želimo prikazati prednosti opismenjevanja z e-gradivi, in i-tablo pred klasično tablo v 1. razredu.
Z opismenjevanjem, ki je eden izmed temeljnih ciljev osnovnošolskega izobraževanja, pričnemo s posodobljenim učnim načrtom že v 1. razredu. Med šestletniki, ki pridejo v šolo, so velike individualne razlike v predznanju, sposobnostih, motivaciji … Učitelj mora zato uporabljati raznovrstne didaktične pristope in učne metode, graditi mora na otrokovem predznaju.
I-tabla je izvrsten pripomoček, ki z izbiro različnih metod poučevanja omogoča poleg frontalnega tudi individualizirano delo, z izbranimi nalogami, ki jih imamo v spletni učilnici in na spletu, pa omogočimo individualni napredek vsakemu učencu.

Ključne besede: opismenjevanje, šestletnik, i-tabla, spletna učilnica, e-gradiva

Abstract
In this article we would like to present advantages of literacy by using e-learning materials and interactive whiteboard over classical board.
The literacy is one of the basic aims of primary school education and according to the new curriculum we start with it already in the first class. There are many individual differences in knowledge, abilities, motivation among six year old children. A teacher has to use various didactic approaches and teaching methods, and he/she has to work on child's prior knowledge.
Interactive whiteboard is an excellent tool, which enables frontal and individualized work if different teaching methods are used. Progress of every individual pupil is enabled by chosen exercises which can be found in the virtual classroom.

Keywords: literacy, six year old child, interactive whiteboard, virtual classroom, e-learning materials

Kako se informatiziramo – pogled arnesa ob 20-letnici delovanja

Progress of Informatisation - A View of Arnes on Its 20th Anniversary

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Povzetek

Prispevek predstavlja pogled na informatizacijo – predvsem izobraževanja – skozi izkušnjo sodelovanja v tem procesu. Arnes, ki letos praznuje 20-letnico ustanovitve, je sicer infrastrukturni zavod, a je njegova vloga pri informatizaciji večplastna. V 20 letih se je skozi tesna sodelovanja v tem procesu nabralo precej izkušenj s sistemskimi izzivi uvajanja IKT. Želja prispevka je pokazati na soodvisnost različnih komponent tega procesa in na opaženih primerih dobre prakse spodbuditi nadaljnji razvoj.

Ključne besede: Informatizacija, raziskovalno in izobraževalno omrežje, prenos znanja, dobre prakse, omrežna skupnost, Arnes

Abstract

The paper presents an overview of informatisation – particularly of education – through the experience of participation in this process. Arnes, which this year celebrates its 20th anniversary, is an infrastructure institution, but its role in informatisation is multi-faceted. Over the last 20 years, through close involvement in this process it has accumulated considerable experience of systems challenges in the introduction of ICT. The paper is intended to show the co-dependence of various components of this process and to foster further development based on observed examples of good practice.

Keywords: Informatization, research and education network, knowledge transfer, best practice, network community, Arnes

Približajmo učencem šolsko knjižnico s pomočjo lastne spletne strani

Getting Closer Students and School Library with own School Library Website

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Povzetek
Šolske knjižnice običajno nimajo svojih spletnih strani kljub temu, da se v njih vedno dogaja veliko stvari in se v njih zvrsti veliko uporabnikov. Eden od dobrih načinov, da povečamo obisk šolske knjižnice in se približamo mladim bralcem je samostojna spletna stran, neodvisna od spletne strani šole. Danes so učenci vajeni drugačnega komuniciranja kot pred desetimi leti. Eden od enostavnih programov, ki nam omogoča izdelavo takšne strani je program Weebly. Pri izdelavi spletne strani je potrebno upoštevati smernice, ki naredijo spletno stran boljšo in atraktivno, zato je dobro upoštevati nekaj osnovnih oblikovalskih napotkov.

Ključne besede: šolska knjižnica, komuniciranje mladih, program Weebly, oblika spletne strani, izdelava spletne strani, spletna stran šolske knjižnice OŠ Polje

Abstract
School libraries do not usually have their own websites, although they are a lot of things going on in them and they have many different kinds of users. One of the best ways to increase visit in the school library and to get closer to young readers is an independent website, independent of the school site. Today, students are accustomed to a different communication than ten years ago. One of the simple software that enables us to make such website is a program cold Weebly. When making a website it is required to follow the guidelines that make the site better and more attractive, so it's good to follow some basic design guidelines.

Keywords: school library, teenage communication, program Weebly, website design, web development, web site of the school library OŠ Polje

Bolonjska prenova uvodnega programerskega predmeta na Fakulteti za računalništvo in informatiko Univerze v Ljubljani

Bologna-Induced Restructuring of the Introductory Programming Course at University of Ljubljana, Faculty of Computer and Information Science

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Povzetek
V pričujočem prispevku predstavljamo nedavno prenovo uvodnega programerskega predmeta na univerzitetnem študiju na Fakulteti za računalništvo in informatiko Univerze v Ljubljani. Prenovo je vzpodbudila bolonjska reforma, ki jo je omenjena fakulteta uvedla v študijskem letu 2009/10. V okviru prenove smo povečali težo sprotnega in samostojnega dela študentov. Za aktivnejšo udeležbo (boljših) študentov pri pedagoškem procesu smo uvedli vsakoletno tekmovanje v programiranju namiznih iger in natečaj za pripravo nalog na temo dedovanja pri objektnem programiranju. Poleg tega smo s pomočjo lastne tehnološke rešitve izboljšali učinkovitost izvajanja vaj. Ocenjujemo, da je prenova predmeta skladna z glavnimi cilji bolonjske reforme.

Ključne besede: univerzitetno poučevanje programiranja, bolonjska reforma, aktivno čenje

Abstract
In this paper, we present our recent restructuring of the introductory programming course at University of Ljubljana, Faculty of Computer and Information Science. The restructuring was induced by the Bologna reform, which Faculty of Computer and Information Science adopted in the academic year 2009/10. As part of this restructuring, we increased the significance of ongoing and independent student work. To achieve a more active involvement of (better) students in the pedagogic process, we introduced the annual board game programming competition and the annual contest of student problems on the theme of inheritance in object-oriented programming. Using our own technological solution, we improved the way in which laboratory sessions are conducted. We estimate that our restructuring of the introductory programming course conforms to the main goals of the Bologna reform.

Keywords: university-level programming education, Bologna reform, active learning

Turistična vzgoja z informacijsko-komunikacijsko tehnologijo

Tourism Education with Information and Communication Technology

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Povzetek
Učenci se pri izbirnem predmetu Turistična vzgoja seznanijo z osnovami turizma. Poleg tega spoznajo tudi načine pridobivanja in posredovanja informacij v turizmu in o turizmu. V današnjem času ljudje potujejo več kot kadarkoli prej v preteklosti. Potovanja ponujajo turistične agencije, vse več pa jih potuje v lastni režiji. Kar zahteva dobro organiziranost in informiranost. Informacije so dostopne na spletu. Posamezniki imajo dostop do informacij lahko vedno pri roki – s pametnimi telefoni. Da bi učenci kot bodoči turisti lažje načrtovali svoj izlet ali potovanje v svoji prihodnosti, so se pri pouku seznanili z uporabo informacijske pismenosti in multimedije na področju turizma. Pri pouku so pisali načrt za ekskurzijo, in sicer od prevoznika, nastanitve, do hrane in znamenitosti … Informacije so iskali na spletnih straneh. Le-te zapisali z uporabo digitalne tehnologije. Mnogi učenci namreč še niso bili na potovanju (v tujini). Tako so se seznanili s širokim naborom informacij o potovanjih in z uporabo svetovnega spleta. Njihovo znanje je bilo poglobljeno: tako na vsebinski kot multimedijski ravni.

Ključne besede: informacijsko opismenjevanje, turistična vzgoja, digitalna tehnologija, spletne strani

Abstract
In class, students of the optional subject Tourism Education learn about basics of tourism. They also learn about ways of getting and transmitting information in and on tourism.
Nowadays, people travel more than ever. Travels can be organized either by tourist agencies or by travellers themselves. The latter requires good organising and at hand access to information on the internet, which is enabled by the so called smart phones.
In order to teach them how to plan a trip or a journey in the future, information and communication technology in tourism was presented and explained to students. Moreover, they made up a plan for a school excursion, including transport, accomodation, food, drink and sightseeing ... Students sought information on the above on various websites.
As a result, they learnt a lot about travelling and seeking necessary information on the internet since many students have never been abroad so far. What is more, students have built up their knowledge on travelling and using ICT.

Keywords: information and communication technology, tourism education, digital technology, websites

Uporaba e-gradiva v 1. triletju, pri matematiki

Using E-learning Materials in the First School Triad in Mathematics

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Povzetek
Učitelj v 1. triletju uporablja raznovrstne in sodobne didaktične in metodične pristope, oblike in metode dela z učenci tudi pri matematiki. To pa zato, da že na začetku izobraževanja zagotavlja visoko raven aktivnosti učencev pri pouku. Z vključevanjem različnih iger in poučevanjem s sodobno učno tehnologijo, z e-gradivi, omogoča učencem aktivno vlogo pri oblikovanju lastnega znanja. Z uporabo informacijsko-komunikacijske tehnologije učitelj pomembno pripomore k vseživljenjskemu učenju. Z vpeljevanjem bolj raznovrstnih poti učenja z novimi prijemi postajajo učni proces in vsebine zanimivejše.
Umeščanje IKT v izobraževanje je ena od ključnih kompetenc za učenje matematike v 1. triletju. Učitelj in učenci morajo za uspeh in znanje matematike učinkovito uporabljati tehnologijo. Uvedba IKT v učilnice vpliva na učenje matematike tako, da učencem pomaga razviti spretnosti, ki so potrebne za uspešno življenje. Spodbuja učitelje k izboljšanju načina učenja v razredu z interaktivnimi in dinamičnimi viri, ki jih nudi IKT. Zagotavlja več motivacije in bogatejšo izkušnjo učenja za učence.

Ključne besede: 1. triletje, matematika, e-gradiva, učitelj, učenci, uporaba IKT-ja pri pouku

Abstract
In the first triad of the primary school a teacher systematically uses a variety of modern didactic and methodical approaches which enable him/her to ensure a high level of pupils' activities and their involvment in the learning process. By including different didactic games and presenting learning materials through modern learning methods and e-learning, the teacher enables the pupils to be creative in acquiring their skills and knowledge. The use of the information and communication technology (IKT technology) contributes significantly to the life-long learning. By introducing more varied methods and ways of learning through new approaches, the learning process and the subjects are becoming more interesting.

The use of IKT technology in the learning process is one of the basic competences in learning mathematics in the first triad of the primary school. The teacher and his/her pupils have to use technology to reach the desired results and aimed knowledge of the subject. The introduction of the IKT technology in the classrooms has improved learning maths in such a way that it helps them to understand life and develop skills for their success in life. It encourages teachers to improve their ways and methods of distributing knowledge in class with interactive and dynamic sources which IKT technology offers. This approach increases the level of motivation in class and gives a pupil new experiences in learning.

Keywords: first school triad, mathematics, e-learning materials, teacher, children, ICT use in teaching

Stanje na področju e-učbenikov v Sloveniji

Current Situation in the Area of E-textbooks in Slovenia

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Povzetek
Informacijsko-komunikacijska tehnologija (IKT) nas spremlja na vsakem koraku. Prisotna je na vseh področjih, še posebej v šolstvu. V izobraževanju se računalnik in drugi informacijski in komunikacijski tehnološki pripomočki uporabljajo na različne načine, tako pri sami pripravi kot pri izvedbi pedagoškega procesa. Hkrati pa se tehnologija sunkovito razvija in ponuja vedno več različnih možnosti uporabe.
E-učbeniki so eden izmed novih učnih pripomočkov in se v našem prostoru šele uveljavljajo. Prispevek opisuje stanje na področju e-učbenikov v Sloveniji, in sicer obstoječe e-učbenike, ki so na voljo, in uporabo le-teh v osnovnošolskem izobraževanju.
V raziskavo je bilo vključenih 105 učiteljev in učiteljic, ki so rešili anketni vprašalnik, katerega rezultati so predstavljeni v prispevku.

Ključne besede: e-učbenik, IKT, poučevanje

Abstract
Information and communication technology (ICT) is everywhere around us. It is present in every area, especially in education. In education the computer and other ICT products are used in different manners, at planning and preparing and also at carrying out the pedagogical process. At the same time the technology is developing rapidly and offers more and more possibilities of its usage.
E-textbooks are one of the new teaching accesories and are not widely used in Slovenia yet. This article is describing the current situation in the area of e-textbooks in Slovenia, namely the existing e-textbooks that are available and the use of them in primary education.
105 teachers from five primary schools answered the questionnaire, the results of which are presented in the article.

Keywords: e-textbook, ICT, education

Raziskovalna naloga »Kdo špara, prišpara« ob podpori sodobnih informacijskih tehnologij

Research Work: »Who puts by that Saves« with the Support of Modern Informational Technology

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Povzetek
V prispevku je predstavljen primer nastanka raziskovalne naloge iz zgodovine z naslovom »Kdo špara, prišpara« (Raziskovalna naloga, 2012). Naloga je nastala pod pokroviteljstvom ZPMS, osrednja uporabljena IKT tehnologija pa so spletna učilnica in Googlovih dokumenti, besedilni dokumenti v oblaku. Raziskovalno delo je oblika dela, ki je za učence in mentorje velik izziv. Prav uporaba sodobnih informacijskih tehnologij omogoča posodobitev dela in večjo organiziranost vseh akterjev. Pri učencih kot tudi mentorjih spodbuja sodelovalno učenje in predvsem partnerski odnos. Izdelava raziskovalne naloge je primer projektnega dela, in sicer konstruktivnega projekta, kjer je aktivnost usmerjena h končnemu cilju, to je k sami raziskovalni nalogi. Delo poteka izven rednega pouka, to pa pomeni veliko dodatnega dela za vse sodelujoče, ob uporabi sodobnih tehnologij pa je delo bolj zanimivo, in kreativno ter je hkrati nova izkušnja tako za učence kot tudi za mentorje.

Ključne besede: raziskovalna naloga, spletna učilnica, Googlovi dokumenti, besedilni dokumenti v oblaku, projektno delo

Abstract
In the article is introduced the beginning of research work from history » Who puts by that saves«. With sponzorship of ZPMS with online classroom and Google.doc, that is a text document in a cloud. Research work is for pupils and mentors a very big chalenge, that is why use of modern informational technology enables modernisation of work, and bigger organisation of all included. It offers co-operational learning to pupils and mentors. Research work is an example of a project work with constructive project where is an activity headed toward the main goal. It proceeds out of school lessons which means a lot of extra work for all included. With the use of modern technology the work is more interesting, creative and it is a new experience as for pupils as for us mentors.

Keywords: research work, online classroom, Goggle.doc – a text document in a cloud, project work

Nemogoča naloga - s pametno tablo skoraj ne več ?

»Mission Impossible« - With a Smart Board Hardly Anymore?

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Povzetek
Pametna i-tabla s podporno IKT s svojo sugestivnostjo poveča avtentičnost učnih situacij, s svojo demonstrativno močjo podpira potrebno nazornost, dinamična raznovrstnost uporabljenih virov navaja dijake k samostojnosti aktivnosti, z možnostjo takojšne povratnega informiranja pa omogoča zadostno utrjevanje učne snovi. Z njimi torej učitelj lahko kljub določenim zadržkom in težavam veliko bolj kot kdajkoli prej doseže, da postane poučevanje celo najkompleksnejših jezikovnih struktur učinkoviteje ,poleg tega pa ponuja tudi neslutene možnosti nadaljnje nadgradnje uporabe .

Ključne besede: I-tabla,IKT, učinkoviteje, nadgradnja

Abstract
The Smart interactive board enhanced by accessory IT , with its suggestiveness contributes to the authenticity of the learning situations, its demonstrative force supports the required explanatory features, the dynamic variety of exploited sources encourages students to independent activity, whereas the on-spot feed-back possibilities ensure a sufficient consolidation of the teaching material. Despite certain reservations and problems it makes it possible for a teacher more than ever before to become even the teaching of the most complex structures more effective. Besides it offers unimagined further possibilities of usage upgrading.

Keywords: I-board, IT, more effective, upgrading

Učiteljeva priprava na pouk z informacijsko komunikacijsko tehnologijo

An Example of good Praxis in Teaching Slovene Language in the First Three Year Period with ICT

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Povzetek
Hiter tehnološki napredek, množična raba svetovnega spleta, informiranost družbe vplivajo na številna področja v človekovem življenju, to se odraža tudi v vzgoji in izobraževanju. Kakovost izobraževanja je v današnjem času tesno povezana z metodami poučevanja. Spremembe so vedno hitrejše in kompleksnejše, to pa od učitelja zahteva fleksibilnost, sposobnost predvidevanja ter hitrega in ustreznega odzivanja na spremembe že uveljavljenih poučevalnih načinov, ter vpeljavo novih načinov poučevanja s pomočjo IKT. Učitelj, ki se nenehno uči in razvija, je sposoben prilagajanja spremembam, fleksibilnosti, ustvarjalnosti in podajanja znanja na način, primeren razvojni stopnji učencev. V prispevku je predstavljen primer dobre prakse pri poučevanju slovenščine v 1. triletju, in sicer učiteljeva priprava na pouk s pomočjo IKT.

Ključne besede: tehnološki napredek, informacijsko komunikacijska tehnologija, svetovni splet, kakovost izobraževanja, prilagajanje spremembam, fleksibilnost, ustvarjalnost

Abstract
Fast technological development, common use of the internet and people who are more and more informed have had an impact on numerous domains in our lives including on education. The quality of education is nowadays closely linked to educational methods. Changes are fast and more complex thus demanding from the teacher s to be more flexible, able to predict and fast and correct when changes of some old teaching methods are needed. A modern teacher has to be able to use contemporary teaching methods with the help of ICT. Only a teacher who constantly teaches and is open to progress is capable of adapting to changes, to flexibility, creativity, and is also able to educate in a way that is appropriate for pupils of certain age. This article presents an example of good praxis in teaching Slovene language in the first three year period with the help of ICT.

Keywords: technological development, ICT, internet, quality of education, adapting to change, flexibility, creativity, lesson plan

Interaktivnost pri pouku matematike

Mathematics Class with Interactivity Elements

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Povzetek
V sodobnem času razvoj izobraževalne tehnologije omogoča vrsto novih možnosti za popestritev in dopolnitev pouka matematike. V celotnem učnem procesu lahko povečuje nazornost pouka, motiviranost učencev in aktivnost učencev pri pouku. Elektronska interaktivna tabla je v slovenskih učilnicah že uveljavljen del izobraževalne tehnologije. Učenci ob pravilni uporabi i-table niso samo opazovalci dogajanja na tabli ampak tudi njegovi soustvarjalci. Delo z i-tablo je zasnovano tako, da zahteva tako od učitelja kot od učencev aktivno vlogo.
Izvedli smo primerjalno raziskavo, da bi preverili učinkovitost uporabe i-table, in sicer z vidika znanja učencev. Vključeni so bili učenci dveh osnovnih šol 9. razreda (N = 30). Ob tem nas je zanimalo, ali so učni rezultati učencev pri pouku z uporabo i-table boljši kot pri učencih z običajnim pristopom. Rezultati so pokazali, da je z vidika osvajanja znanja, uporaba i-table učinkovitejša kot pouk, kjer učenci niso bili deležni uporabe i-table.

Ključne besede: interaktivna tabla, matematika, učni proces, znanje

Abstract
Nowadays the development of computer technology and media enables various opportunities for enrichment and variability of the subject of mathematic. In the whole process of education the ICT – technology clarifies the lessons and has an important role in pupil's motivation and their activation. The interactive whiteboard is now a standard piece of learning technology in Slovenian schools. Pupils who correctly use the interactive whiteboard are not just observers of the lesson development, but also its co-creator. Working with the interactive whiteboard is designed in the way that requires both the teacher's and the pupil's active role.
A didactic lesson was executed in order to verify the effectiveness of interactive whiteboard from pupil's knowledge point of view. Involved were pupils from two different primary schools of the ninth grade (N = 30). Upon this a question was defined; whether the learning results of pupils, according to the lesson with the interactive whiteboard, are better than by pupils with usual accession. The results have shown that the acquired knowledge was more effective when using an interactive whiteboard instead of the usual lesson without the interactive whiteboard.

Keywords: interactive whiteboard, mathematics, process of education, knowledge

Blog kot učilnica in časopis

Blog as a Classroom and Nawspaper

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Povzetek
V prispevku je predstavljena uporaba bloga pri izbirnem predmetu šolsko novinarstvo. Z blogom kot sodobnim učnim okoljem so se učenci srečali prvič, a so ga povsem prevzeli kot način aktivnega sodelovanja pri ustvarjanju spletnega časopisa. S študijo tega primera sem skušala ugotoviti, kako je uporaba tega sodobnega učnega okolja vplivala na aktivnosti učencev in posledično na njihovo znanje. Ugotovila sem, da so učenci poleg močne motivacije za delo pridobili vsa znanja po učnem načrtu, hkrati pa so izboljšali pisno izražanje, pravopisni zapis napisanega in pridobili veščine uporabe sodobne tehnologije, dela z blogom in sporazumevanja v spletnem okolju. Ozavestili pa so tudi odgovornost pri objavljanju prispevkov in izjav na spletu.

Ključne besede: blog, pisno sporočanje, sodobna učna okolja, izbirni predmet šolsko novinarstvo

Abstract
In the contribution, the use of blog in the elective subject of school journalism is presented. As a contemporary learning environment, the blog, students came across for the first time. They totally seized it as a way of an active involvement in creating an online newspaper. With the study of this case I tried to discover how the use of this contemporary learning environment influenced the activity of students and consequently their knowledge. I found out that students, beside the strong motivation for work, also gained all the knowledge according to the school curriculum. They also improved their written communication, spelling and gained the skills for the use of modern technology, working with blogs and communicating in the web environment. Students became aware of the obligation and responsibility of publishing contributions and statements on the web.

Keywords: blog, written communication, contemporary learning environment, elective subject school journalism

Motivacijska podpora sodelovalnemu učenju v spletnem učnem okolju

Motivational Support for Collaborative Learning in Online Learning Environment

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Povzetek
V članku predstavljamo motivacijsko podporo za sodelovalno učenje v spletnem učnem okolju Online Presence for Learning (OP4L) s tehničnega, pedagoškega in socialnega vidika. V tem spletnem učnem okolju, ki temelji na orodju Moodle, dajemo poudarek prilagodljivemu in prilagojenemu sodelovalnemu učenju, vključujemo intenzivnejše mentorstvo, medsebojno komunikacijo z različnimi komunikacijskimi orodji in dostop do spletnih virov neposredno iz učnega okolja z namenom učinkovitega in hitrega reševanja nalog. Dvainšestdeset študentov, razdeljenih v sedem skupin, je reševalo nalogo tri tedne. V prvem tednu so razpravljali o ideji za rešitev zastavljenega problema in predlagali rešitev. V drugem tednu so sprogramirali programe v programskem jeziku C in jih v tretjem tednu med seboj ocenili. Sodelovalno učenje je bilo podprto z možnostjo uporabe elektronske pošte in Moodle klepeta, kakor tudi s pošiljanjem sporočil neposredno iz učnega okolja na Facebook. Tako študentom ni bilo potrebno zapustiti učnega okolja in prekinjati učnega procesa. Rezultati so pokazali pozitivni odziv študentov na sodelovalno učenje v predstavljeni obliki.

Ključne besede: sodelovalno učenje, spletno učno okolje, motivacija, e-učenje

Abstract
In this paper, we present a motivational support for collaborative learning in online learning environment Online Presence for Learning (OP4L) from technical, pedagogical and social aspect. In this online learning environment that is based on Moodle, we emphasize flexible and adapted collaborative learning; we include intense mentorship, intercommunication with various communication tools and access to Web sources directly from learning environment with the purpose of effective and quick completing of the tasks. Sixty-two computer science students, who were classified into seven groups, were performing the task three weeks. In the first week, they were discussing the idea for solving the given problem and suggested the solution. In the second week, they programmed the programs in programme language C and in the third week assessed them.

Collaborative learning was supported with an opportunity to use e-mail and Moodle chat, as well as to send messages directly from the learning environment on Facebook. So, the students did not have to leave the learning environment and interrupt a learning process. The findings have shown positive students' feedback on collaborative learning in presented form.

Keywords: collaborative learning, online learning environment, motivation, e-learning

Načrtovanje E-učnega okolja za programe glasbenega izobraževanja

An E-learning Environment Planning For A Music Education Program

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Povzetek
Informacijsko komunikacijska tehnologija (IKT) vse bolj posega tudi na področje glasbenega šolstva. Z njo lahko danes informacije v različnih oblikah, kot so: govor, zvok, glasba, notni zapis, slika, grafika, animacija in video, hkrati uporabljamo in predstavljamo. Skupek teh tehnologij in medijev lahko pojmujemo kot sodobni multimedijski sistem, ki nam služi pri izbiri, načrtovanju in oblikovanju učnega okolja.
V prispevku je predstavljen primer dobre prakse načrtovanja učnega okolja (ang. Learning Management Systems), upravljanja, oblikovanja in uporabljanja multimedijskih e-gradiv. Seveda mora biti tako učno okolje zasnovano na enostavnosti uporabe, učinkovitem upravljanju, možnosti neodvisne priprave glasbeno-izobraževalnih vsebin in personalizaciji.

Ključne besede: e-izobraževanje, IKT, multimedijska e-gradiva, multimedijski sistemi, učno okolje, upravljanje, uporabljanje

Abstract
Information Comunication technology (ICT) is more and more usefull also for a Music education environment. With its help we can use and present an information in many different ways such as: a speech, a sound, a music, a music record, a picture, a graphic, an animation and a video. Together, these technology and media-instruments can be named as a Modern Multimedia System, which we can use to choose, to plan and to form an education environment.
In this subscription is presented a good practical work of Learning Management Systems and to manage, to form and to use a Multimedia e-learning material. Of course, this Learning environment should be designed in an easiest-way of using, effective management, a possibility of independent preparation of music-educational contents and personification.

Keywords: e-learning, ICT, multimedia e-learning material, multimedia systems, learning environment, management, employment

Učna ura skledni trikotniki

A School Lesson Compatibles Triangles

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Povzetek
V današnjem času je uporaba računalnika pri pouku že samoumevna. Pri matematiki je na voljo pestra izbira programov in pripomočkov, s katerimi si lahko pomagamo pri podajanju učnih vsebin, utrjevanju in preverjanju znanja. Trikotnik Zakotnik je eden izmed takšnih pripomočkov. Namenjen je za učno snov Trikotniki pri matematiki v 7. razredu. Uporabljamo ga lahko kot uvodno motivacijo ali z njegovo pomočjo izpeljemo celotno učno uro.
Pripomoček je pripravljen v obliki spletnih snopičev z enotnim izgledom (podobno, kot so narejene predstavitve v PowerPointu). Na vrhu je glava z naslovom teme, na desni usmerjevalne ikone za listanje v snopiču, meni, tiskanje, pomoč in opis. V osredjem delu je področje vsebine. Pripadajoči opis je v padajočem oknu, ki je na začetku prikazan. S tipko Enter se skriva in prikazuje.
V prispevku bo prikazana izvedba uvodne učne ure Skladni trikotniki s pomočjo tega pripomočka.

Ključne besede: računalnik, matematika, pripomoček, skladni trikotniki

Abstract
Nowadays the use of computers in school lessons is obvious. There is a wide variety of programme and tool options available for Mathematics that support knowledge transfer, revision and testing. “Trikotnik Zakotnik” is one of them. It is suitable for the topic Triangles for Maths in grade 7. It can be used as an introductory motivation or we can spend the whole lesson teaching with it. The tool is a set of web pages with the same form resembling Power Point presentations. At the top one can find a heading with a topic title and on the right there are icons for browsing, menu, printing, help and description. In the main part there is the contents area. The belonging description is in a combo box that appears at the beginning and with the use of enter key it can be visible or hidden.
The article will present an introductory school lesson for Compatibles triangles with the use of Trikotnik Zakotnik tool.

Keywords: computer, Maths, tool, compatibles triangles

E-učenje in spletna učilnica »Glasba z Orffovimi glasbili«

E-learning and Virtual Classroom »Playing Music with Orff Instruments«

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Povzetek
Sodobna tehnologija se vključuje v pouk. Pomembno vlogo igra e-učenje in ostale oblike spletnega učenja in poučevanja. Pri poučevanju glasbene vzgoje uporabljamo različno programsko opremo, notacijske programe. V prvem delu prispevka predstavljam notacijski program in spletno učilnico Finale Note Pad, v drugem delu pa spletno učilnico »Glasba z Orffovimi glasbili«. V tej učilnici so zapisane skladbe s priredbami za Orffova glasbila v programu Finale Note Pad. Namen prispevka je izpostaviti pozitivne izkušnje uvajanja e-učenja v interesno dejavnosti Orffov krožek. V to dejavnost so vključeni učenci od drugega do šestega razreda. V letošnjem šolskem letu je poskusno zaživela spletna učilnica, v katero sem postavil skladbe z zapisanimi spremljavami. Učenci lahko poslušajo skladbe doma, prav tako pa lahko istočasno prisluhnejo zapisanim spremljavam za različna Orffova glasbila. Seveda morajo imeti tudi na domačem računalniku naložen notacijski program Finale Note Pad. V klasični učilnici pa računalnik zamenjajo avtentična glasbila, na katera učenci odigrajo zapisane spremljave. Delo v interesni dejavnosti je prav s pomočjo te učilnice potekalo hitreje in učinkovitejše. Predstavljen primer kaže številne prednosti poučevanja glasbene vzgoje z uporabo IKT, saj spodbuja notranjo motivacijo, samostojnost in lastno aktivnost ter raziskovanje in konstruktivistični pristop k učenju.

Ključne besede: osnovna šola, drugo triletje, IKT, e-učenje, spletna učilnica

Abstract
Modern technology is becoming an integral part of teaching. E-learning and other forms of virtual learning and teaching play an important role in this. We can use different software and notation programs while teaching music. In the first part of the article I present the notation program and virtual classroom Finale Note Pad while in the second part the virtual classroom "Playing music with Orff instruments" is described in more detail. Here, the tracks with musical adaptation for Orff instruments are written in Finale Note Pad. The purpose of my article is to expose the positive experience of introducing e-learning into the Orff after-school activity for pupils aged 8 to 12 years. This year I have set up an experimental virtual classroom with tracks and accompaniments. The pupils can listen to the tracks on their home computer while at the same time listening to the musical accompaniment for different Orff instruments. Finale Note Pad is of course a prerequisite. Afterwards, at school, the computer is replaced with authentic instruments on which the pupils can play written accompaniments. This makes the teaching faster and more efficient. The article therefore exposes numerous advantages of teaching music through the use of ICT for it encourages intrinsic motivation, independence, self-activity and research as well as a constructivist approach to learning.

Keywords: primary school, second triennium, ICT, e-learning, virtual classroom

Računalnik: (ne)pogrešljiv pripomoček v življenju – (pre)slab nadomestek življenja

Computer: (In)dispensable Tool in our Life - (Too)poor Alternative of Life

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Povzetek
Moj prispevek je razmišljanje o tem, kar nam informatizacija šole prinaša, ni znanstveno delo o dobrih in slabih straneh, ki jih prinaša informatizacija procesov v sodobni šoli. Z informatizacijo so poti skrajšane, olajšana je izmenjava gradiv, prihranjen je čas, omogočena je večkratna uporaba in spreminjanje, prilagajanje gradiv. Hkrati pa se bojim, da s tem slabijo socialni stiki, odnosi… Jaz vsekakor vidim več koristi kot slabega. Sem tudi ena od uporabnic vseh elektronskih naprav na naši šoli in pomoč v sili (F1) za sodelavke, ki so v IKT po večini precej bolj nemočne ali mogoče bolje rečeno nesigurne… Kljub temu, da sem velika IKT zagovornica in uporabnica, imam pri informatizaciji nekaterih procesov pomisleke.

Ključne besede: e-gradiva, e-komunikacija, e-redovalnica, e-dnevnik, e-nadzor

Abstract
I'm thinking about what informatization is bringing in our school in my contribution. It isn't a scientific work about good and bad sides of informatization of processes in our school. Many paths are shortened with informatization, our time is spared, exchanging of material is eased and it can be changed, used repeatedly and in many various ways. I fear at the same time that social cohesion is getting poorer because of that. I definitely find more benefits than disadvantages, I'm also one of the users of all electronic devices in the school, when and wherever is possible. I'm also the first aid (F1) for colleagues, that are mostly much more powerless or unsure… I'm ICT defender and user, but I also concern about some processes getting electronic.

Keywords: e-material, e-communication, e-evaluation book, e-recording of pupils presence (school record book), e-control

Uporaba prostodostopnih matematičnih storitev kot motivacija pri učencih z učnimi težavami

Utilizing Freely-Avaliable Online Maths Teaching Services to Motivate Pupils with Special Needs

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Povzetek
Vsak dan se srečujemo z učenci, ki so zelo različni glede na predhodno znanje, sposobnosti in interese. Prava umetnost je poiskati oblike dela, ki omogočajo vsem, da v največji meri razvijejo svoje potenciale in poleg tega pri učenju uživajo. V prispevku je predstavljen način vključevanja IKT v delo z učenci, ki imajo učne težave. Informacijsko komunikacijska tehnologija je v mnogih primerih dobrodošla pomoč pri delu z otroki s posebnimi potrebami, saj se pogosto zgodi, da motivacija teh učencev pri klasičnem načinu posredovanja snovi in preverjanju znanja upade, saj se prevečkrat srečajo z neuspehom. Prispevek se osredotoča na uporabo različnih prostodostopnih, enostavnih storitev, ki lahko učencem z učnimi težavami olajšajo doseganje ciljev pri matematiki. Računalniške igre omogočajo aktivno učenje učencev in predstavitev snovi na zabaven in privlačen način, kar pozitivno vpliva na motiviranost za učenje.

Ključne besede: učne težave, brezplačni programi, ideje za poučevanje, čustveni dejavniki

Abstract
Every day we work with pupils whose abilities, interests and knowledge are widely different. It is a challenge to find an approach that allows everyone to fully develop their potential, whilst making learning an enjoyable experience. This article presents one way to include ICT in working with pupils with learning disabilities. Information-communication technology is a welcome help in working with children with special needs. Namely, it often happens that the motivation of these children decreases in the classical way of mediating school material and examining knowledge as they face failure too often. The article focuses on the use of different freely-accessible, simple services that can help children with learning disabilities achieve the goals in mathematics. Computer games enable active learning and presentation of new learning material in a fun and attractive way, which has a positive impact on learning motivation.

Keywords: learning disabilities, free software, ideas for teaching, emotional aspects

Razvijanje učenčevih sporazumevalnih zmožnosti z e-dopisovanjem

The Development of Students' Communication Skills Through E-writing

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Povzetek
Temeljni cilj pouka slovenščine je razvijati učenčevo sporazumevalno zmožnost, to je zmožnost sprejemanja in tvorjenja besedil. V slovenščino prevedeni in slovenskemu učnemu načrtu prirejeni e-projekt *Moja, tvoja, naša podoba*, ki je izvorno sicer nastal v nemščini, nato pa bil ponujen tudi v drugih evropskih jezikih in je bil namenjen komuniciranju v tujih jezikih, razvija tako sporazumevalno kot digitalno zmožnost udeležencev v projektu.
V projektu je učenec aktiven subjekt učnega procesa. Kakovostno pripravljeno gradivo ga vodi k premagovanju jezikovnih težav. Voden je tako vsebinsko kot oblikovno. Na portalu je pripravljeno tudi didaktično gradivo za učitelje, npr. učni listi, učne priprave, različna navodila oz. usmeritve ipd.

Ključne beside: e-dopisovanje, e-projekt, razvijanje sporazumevalne zmožnosti z uporabo IKT

Abstract
The basic aim of the Slovene language lessons is to develop students' communication skills, or better said, to improve their reading, listening, speaking and writing skills, which consequently leads them to an improved general comprehension and acquisition of the language. Translated into Slovene with several adaptations to Slovene lessons plan, *The Image of the Other* e-project, which was originally created in German (*Das Bild der Anderen*) and subsequently translated into other European languages in order to improve the communication in foreign languages, develops the communication and digital skills of the students involved in the project.
In the project, the student is the active subject of the learning process. The extremely well-prepared materials enable the student to solve several language difficulties. The project guides the student through content and form. In the teachers manual there are didactic materials for teachers – worksheets, lesson plans, as well as several instructions and directions.

Keywords: e-writing, e-project, communication skills development through ICT

Projekt EdUmatics – kako pomagati učiteljem matematike pri vpeljavi IKT v poučevanje

Project EdUmatics – How to Support Math Teachers to Integrate Technology within their Classrooms

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Povzetek
V gradivih, ki so nastali v okviru 3 leta trajajočega (2009-2012) evropskega Comenius projekta EdUmatics, v katerem je sodelovalo dvajset srednjih šol in fakultet iz 7 evropskih držav se prepletajo izkušnje in znanja učiteljev in raziskovalcev iz različnih izobraževalnih sistemov. Vsem je skupen cilj izobraziti učitelje za uporabo IKT pri poučevanju matematike na srednjih šolah. V okviru projekta EdUmatics je bila razvita vrsta gradiv in postopkov, uporabnih v različnih oblikah izobraževanja učiteljev.

Ključne besede: e-izobraževanje, IKT, stalno strokovno izpopolnjevanje učiteljev, matematika

Abstract
The Comenius EdUmatics Project (2009-2012) brought together twenty school and university partners from seven EU countries to collaborate on the design of a resource to support secondary mathematics teachers to integrate technology within their classroom practice.
The resulting resources offer a range of tasks and activities suitable for adaptation within professional development and teacher training courses.

Keywords: e-learning, ICT, in-service teachers training, mathematics

Kreativno ustvarjanje z IKT

Creative Writing with ICT

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Povzetek
Avtorici se zavedata, da je pri pouku slovenščine poleg razvijanja bralne pismenosti ključnega pomena tudi razvijanje kreativnega izražanja. Vloga le-tega v učnem načrtu sicer ni izrazito poudarjena, je pa implicitno vključena v raznovrstne cilje in dejavnosti, če jih učitelj le prepozna oz. zazna. Upoštevaje močan motivacijski element IKT, avtorici tako nakazujeta dejavnosti/možnosti kreativnega ustvarjanja, katerih cilj ni produkcija vrhunskih umetniških del, temveč so sestavni del učnega procesa in motivacije ter vzpodbujanja želje po pisanju, ustvarjanju. Nanizane so nekatere možnosti, ki presegajo neustvarjalno branje, pomanjkanje interesa in zunanje motivacije ter nizko bralno kulturo in bogatijo skromen besedni zaklad.

Ključne beside: kreativno pisanje, slovenščina, IKT

Abstract
The authors, teachers of Slovene language are aware of the meaning of reading literacy as well as creative writing. Although the role of creative writing is not clearly specified in curriculum, the teachers should be able to detect it within different activities. The authors present some types of creative writing combined with ICT, which is very powerful tool for pupils. The main focus of presented activities is not on producing artistic literary works, but on motivating for learning and writing in order to avoid uncreative reading, lack of interest and motivation and low reading ability on one hand and expand vocabulary on the other.

Keywords: creative writing, Slovene language, ICT

Raba spletne učilnice za mednarodni projekt na primeru projekta Donau Online

The Use of E-learning Platform for an International Project on the Example of the Donau Online Project

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Povzetek
Spričo paradigmatskega prehoda iz transmisijskega modela znanja v konstruktivistični model prihaja do spremenjenega pojmovanja znanja, ki predpostavlja večjo odgovornost učečega se za svoje učenje in vedno bolj ozadnjo vlogo učitelja, predvsem pa bogato učno okolje. Pogosto se ta paradigmatski preobrat povezuje tudi s tehnološkimi spremembami, kot je informacijsko-komunikacijska tehnologija. Na tem področju pa v zadnjem desetletju pospešeno nastajajo t. i. spletna učna okolja, ki omogočajo izvedbo poučevanja/učenja na daljavo. Srednješolska razreda iz Celja in Domžal sta se udeleževala projekta Donau Online (Donava online), ki je preko teme Donava povezal prek štirideset razredov iz Podonavja. Razredi so sodelovali preko spletnega učnega okolja Moodle v obdobju pet tednov in pri tem izdelali filme, predstavitve in avdioposnetke. V prispevku raziskujemo zvezo med rabo spletne učilnice, partnerskimi razredi in končnimi izdelki. Ugotavljamo, da so bile možnosti za delo preko spletne učilnice le deloma izkoriščene, čeprav odgovori dijakov dajejo drugačen vtis.

Ključne besede: spletno učno okolje, mednarodni projekt, srednja šola, primerjava, nemščina, Donava

Abstract
In the face of the paradigm shift from the transmission model of knowledge into the constructivist model of knowledge it comes to an altered understanding of knowledge which requires a greater responsibility of the learner for his own acquisition of knowledge and an ever more profound role of the teacher, but above all it implies a rich learning environment. Often this paradigm shift is connected with changes in technology such as rise of information communication technology. In this area in the last decade, the so called e-learning environments are developed that enable distance learning. Two high school classes from Celje and Domžale took part on the Donau Online Project which connected, over subject Danube, more than forty higher secondary school classes from the Danube region. The classes cooperated over the e-learning environment Moodle in the period of five weeks, and they produced videos, presentations and podcasts. In the article, we research the connection between the use of e-learning environment, the partner classes and the end products. We asses, the possibilities for working over the e-learning platform were only partially exploited though the responses of the pupils give a different impression.

Keywords: e-learning environment, international project, upper secondary school, comparison, German, Danube

Učenje tujega jezika na daljavo

Distance Learning Foreign Language

Lorena Mihelač

Povzetek

Članek predstavlja primer učenja tujega jezika na daljavo v jezikovnem projektu »Tečaj slovenskega, latvijskega in angleškega jezika po korakih«, ki je bil sestavni del Comenius bilateralnega projekta »The applicability of the school subjects in the student's real life« od leta 2010 do 2012. Začetek jezikovnega projekta sega v same začetke bilateralnega Comenius projekta, leta 2010, ko sta sodelujoča partnerja (Slovenija in Latvija) ugotovila, da ni nobenega jezikovnega tečaja in prav tako ne slovarja ali učbenika, ki bi sodelujočim dijakom ter učiteljem pomagal naučiti se slovenskega oziroma latvijskega jezika. Projekt je torej nastal kot posledica neobstoječih tečajev, učbenikov in slovarjev za učenje latvijskega jezika v Sloveniji in prav tako obratno, slovenskega jezika v Latviji. Glede na zahteve bilateralnega projekta »The applicability of the school subjects in the student's real life«, kjer je med ostalim tudi dokaj velik poudarek na učenju jezikov, sta se oba partnerja, oz. oba koordinatorja, v posvetovanju z Nacionalnimi agencijami za Comenius projekte odločila, da bosta predlagala lastni slovensko-latvijsko-angleški slovar in tečaj jezika za dijake in učitelje, sodelujoče v Comenius projektu. Posebnost projekta je, da sloni na uporabi treh jezikov (slovenski, latvijski in angleški), katerih učenje se prepleta v tradicionalni (pisni) obliki in v sodobni obliki z uporabo modernih tehnologij.

Ključne besede: Comenius bilateralni projekt, učenje jezika na daljavo, IKT

Abstract

The paper represents an example of distance learning of foreign language in the language project »Slovenian, Latvian and English course in short steps«, which was a part of the Comenius bilateral project »The applicability of the school subjects in the student's real life« from 2010 till 2012. The language project has began at the same time as the bilateral Comenius project, in 2010, when the partners from Slovenia and Latvia has found out, that there is no language course as no text book or dictionary, which could help the students and the teachers involved in the Comenius project to learn slovenian or latvian language. Therefore, the project has been developed because of the non existing text books, dictionaries and courses to learn latvian language in Slovenia and slovenian language in Latvia as well. Regarding the special requirements of the Comenius bilateral project »The applicability of the school subjects in the student's real life«, where the emphasis is among other on learning foreign languages, the partners have decided to offer their own text book, dictionary and a language course for all the students and teachers involved in the Comenius project. A peculiarity of the language project »Slovenian, Latvian and English course in short steps« is, that it is based on the use of three languages, slovenian, latvian and english language, which are learned in the traditional way (written) and modern way, using moder ICT technology.

Keywords: Comenius bilateral project, distance learning foreign language, ICT

Izbirni predmet Informacijsko opismenjevanje in spletna učilnica na Osnovni šoli dr. Vita Kraigherja

Virtual Classroom for Teaching the Information Literacy at Primary School dr. Vita Kraigherja, Ljubljana

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Povzetek
V prispevku je predstavljena spletna učilnica, ki je nastala v letu 2012 za potrebe izvajanja izbirnega predmeta v osnovni šoli Informacijsko opismenjevanje v prihajajočem šolskem letu. V prispevku ni predstavljena tehnična izvedba izdelave spletne učilnice v okolju Moodle, pač pa izbor vsebin in gradiv ter dejavnosti, ki jih lahko za izvajanje pedagoških ur vključimo v spletno učilnico za ta izbirni predmet.

Ključne besede: informacijsko opismenjevanje, informacijska pismenost, izbirni predmet, osnovna šola, spletna učilnica

Abstract
This paper presents a virtual classroom, that was formed in 2012 to teach a subject Information Literacy in primary school. The paper does not present much of the technical implementation of the online classroom, built in Moodle, but the choice of content, materials and activities included.

Keywords: information literacy, elective subject, primary school, virtual classroom

Uporaba računalnika v različnih starostnih obdobjih

Computer Use in Different Age Groups

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Povzetek
V prispevku predstavljam, kako se spreminja usposobljenost za delo z računalnikom skozi različna starostna obdobja. Prav tako me je zanimalo, kako se v zadnjih desetih letih spreminja odnos do računalnika pri osemletnikih. Zvemo, v kolikšni meri starši določajo, koliko časa naj otrok preživi za računalnikom, in v kolikšni meri so otroci in mladostniki seznanjeni z nevarnostmi interneta.

Ključne besede: uporaba računalnika, internet, nevarnosti interneta

Abstract
The article illustrates how computer literacy changes through different stages of life. My point of interest was also how in the last ten years the attitude towards the computers in eigh year old children has changed. The research has indicated the extent to which parents decide the time of the child spent on the computer and the degree to which children and youngsters are familiar with dangers of the internet.

Keywords: computer use, internet, dangers of the internet

Šport in zdravje

Health and Sport

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Povzetek
Vsebine e-gradiva, Šport in zdravje, sledijo vsebinam in ciljem učnih načrtov za športno vzgojo. Vsebujejo teoretične in praktične vsebine, ki zaradi načina podajanja predstavljajo pravi izziv za poučevanje in učenje.
Izobraževanje v smislu podajanja teoretičnih znanj, demonstracije vaj preko video posnetkov, prikaza slik in animacij za pravilno izvajanje vaj, nam z možnostjo uporabe IKT tehnologije omogoča posredovanje informacij v načinu, ki je današnji mladini sprejemljivejši.
Ugotovitve, da vedno več otrok v starosti od 15 do 19 let pestijo problemi slabe drže in posledično bolečine v hrbtenici in prekomerna telesna teža, pri dijakih športnikih pa poškodbe kolenskega sklepa in hrbtenice, so zaskrbljujoče. Posledično sva precejšen del e-gradiva namenila vsebinam naravnanim na preventivo pred poškodbami oziroma vadbi po rehabilitaciji in osveščanju dijakov o zdravem načinu življenja.
Nazorno pokazane vsebine e-gradiv, video posnetki, sličice ali animacije in s tem povezana kratka in jasna teoretična razlaga, bodo v veliko pomoč učiteljem športne vzgoje in trenerjem, saj pri demonstraciji niso vezani le na svoje sposobnosti. Hkrati jim ta način podajanja vsebin med vadbo omogoča, da vadeče tekom vadbenega procesa opazujejo, opozarjajo in odpravljajo njihove napake.
Predvsem je pomembno, da so vsebine dostopne širšim uporabnikom, kadarkoli in kjerkoli. Pogoj je le računalnik in dostop do interneta.
S pomočjo e-gradiva si lahko izračunamo indeks telesne mase, določimo intenzivnost vadbe, ugotavljamo porabo kalorij v določenem času za izbrano aktivnost. Lahko se preizkusimo v poznavanju pravil izbranih športnih iger, rešujemo kvize, opremljamo planince, gornike, nogometaše, košarkarje, se sproščamo, izobrazimo glede svojih prehranjevalnih navad,… .
Z uporabo sprostilnih vaj bomo v času predavanja, izvedli aktivni odmor in s tem sprostili napetosti v mišicah. Vse to in še kaj več nam omogoča uporaba nastalega e-gradiva.

Ključne besede: motivacijski vidik, preventiva, individualizacija in diferenciacija, samorefleksija, medpredmetno povezovanje

Abstract
The content of e-learning sports and health materials follows the content and objectives of the physical education curricula. It offers theoretical and practical contents which present a real challenge for teaching and learning.

Education in terms of passing theoretical knowledge, demonstration and tutorials via video clips, images and animations for the proper execution of exercises, allows us with the use of ICT technology to pass information in a way that is more acceptable by today's youth.
The fact that an increasing number of children between the ages of 15 and 19 suffer from problems of poor posture and, consequently, back pain or are overweight, and that many young athletes suffer from injuries of the knee joint and spine, is alarming. Consequently, we devoted a considerable part of the project to the injury-prevention-oriented content, exercises for the rehabilitation of students and raising awareness about healthy lifestyle.
E-learning materials, videos, graphics and animations which are accompanied with short and clear theoretical explanation are easy to use and should help teachers of physical education and coaches. The educators will not have to depend only on their own abilities while demonstrating, and what is more, this way of exercise allows coaches and teachers to observe, note and correct the mistakes of the trainee during the training process.

It is particularly important that the content accessible to the general users, anytime and anywhere. The condition is only a computer and Internet access.
Using e-learning materials can calculate body mass index, determine exercise intensity, we find calories in time for the selected activity. You can test each other's rules, a number of sports games, solve quizzes, equipping hikers, mountaineers, football, basketball, relax, educate about their eating habits ....
Using relaxation exercises during the lectures we had made an active break, thereby releasing tension in muscles. All this and much more allows us to use the resulting e-learning materials.

Keywords: incentive, prevention, individualization and differentiation, self-reflection, interdisciplinary integration

Uporaba QR-kod pri pouku

Usage of QR Codes at School

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Povzetek
Sodobna družba zahteva drugačen način poučevanja, v katerem je v središču učenec, pri pouku pa se uporablja moderna informacijsko-komunikacijska tehnologija. QR-kode so dvodimenzionalne kode, ki jih lahko odčitavamo in prebiramo preko pametnih naprav ali spletnih kamer. Vključujejo lahko besedilo, URL-povezave, SMS-sporočila, zvočne ali videoinformacije itd. So zelo preproste za uporabo in mnogi učitelji ugotavljajo prednosti njihove uporabe pri pouku. Učenci lahko dostopajo do informacij preko njih kadarkoli, kjerkoli, potrebujejo le napravo, ki omogoča odčitavanje kod. Uporabljene so lahko na različne načine – na knjigah, delovnih listih z namigi, z dodatnimi informacijami v različnih oblikah: besedah, zvoku ali videu. Učitelj lahko učence spodbuja k izdelavi kod.

Ključne besede: informacijska družba, m-učenje, internet, QR-kode, pametne naprave

Abstract
Modern society demands different way of teaching. The learning process is focused on the student and involves use of information and communication technology. QR codes are two-dimensional codes that can be scanned and read using smart devices or webcams. These small codes can include text, URL link, SMS message, video or audio information … They are very simple to use and many teachers have already found them useful in classroom. Students can access them everywhere they want, anytime they want, they only need a QR code scanning capable device. QR codes may be used in various ways – as a treasure hunt, in the books, in worksheets with helpful hints or more information in different formats – words, audio or video. Teacher can engage students with stimulating them with making their own QR codes.

Keywords: information society, m-learning, internet, QR code, smart devices

Vloga učitelja in poučevanje v digitalni dobi

Teaching in the Virtual World and the Role(s) of a Teacher

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Povzetek
Učitelj 21. stoletja ne le poučuje, ampak mora (pre)poznati učenčeve potrebe po učenju. Poleg poučevanja tudi sooblikuje učni načrt ter pouk, raziskuje svoje predmetno področje in se v njem izpopolnjuje, sodeluje s strokovnjaki tega področja, ter potrjuje uspešnost učnega procesa. V dobi virtualnega sveta in hitro razvijajočih se informacijsko-komunikacijskih tehnologij (IKT), kjer je tudi pojem učilnice, poučevanja in učenja dinamiziran, mora učitelj poleg tehničnega znanja na področju IKT poznati tudi specifiko spletnih okolij (tj. njihovo filozofijo in psihologijo), ter njihove slabe plati obrniti v prednosti. Uspešnost poučevanja na spletu oz. s pomočjo IKT tehnologije zahteva poleg tehničnega znanja (tj. e-kompetenc) od učitelja organizatorja tudi kreativen pristop, ki postavlja v center učenja učenca, učitelj pa v procesu poučevanja vedno znova vrednoti uspešnost pouka.

Ključne besede: učenje; digitalno okolje; IKT; vloga učitelja; nova paradigma učenja; e-kompetence

Abstract
Being a 21st century teacher is a challenging task, since a teacher does not *only* help a learner to learn, but also understands their needs to learn and uses these as a cornerstone for their teaching approach. Their roles include also designing a course and evaluating a teaching-learning process, which, all in all, calls for a well-educated person. With the emergence of information-communication technology (ICT), a teacher has also obtained a role of an e-class organizer, manager, moderator and facilitator of a learning process, someone who understands also the peculiarities of cyberspace (philosophy and technology wise) and turns its drawbacks into advantages. The effectiveness of an ICT supported class demands from a teacher in addition to technical knowledge (i.e. possessing e-competences) also an innovative and reflective teaching approach that centers on learners. This is accompanied by a continuous evaluation of the course and the ICT tools used to carry out a lesson successfully.

Keywords: learning, ICT technology; roles of a teacher; new learning/teaching paradigm; e-competences

Povežimo se brezžično in medpredmetno

Wireless and Intersubject Connections

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Povzetek
Tudi pri športni vzgoji v osnovni šoli lahko uporabimo sredstva informacijsko komunikacijske tehnologije. Zelo uporaben pripomoček je na primer mobilni telefon srednjega cenovnega razreda, ki podprt z ustrezno aplikacijo, s pomočjo GPS naprave meri premikanje po prostoru ter nadmorsko višino. V kombinaciji s časom trajanja vadbe in podatki o srčnem utripu, ki jih sprejema preko Bluetooth povezave z merilcem srčnega utripa, omogoča kontrolo aktivnosti na visokem nivoju. Preko brezžičnih LAN povezav lahko mobilni telefon povežemo v omrežje, kar nam omogoča povezovanje z ostalimi šolskimi predmeti. Učenci lahko svoje podatke koristno uporabijo za razumevanje vsebin pri posameznih predmetih. Namen prispevka je predstaviti, kako z učenci 9. razredov OŠ Koroška Bela uporabljamo omenjeno aplikacijo ter kako se zbrane podatke, da uporabiti pri ostalih predmetih.

Ključne besede: šport, mobilni telefon, povezovanje, merjenje, uporaba pridobljenih podatkov

Abstract
Even in physical education in elementary school ICT resources can be used. Very useful tool is a mobile phone mid-market, which can measure moving around and altitude - if is supported by the appropriate application and GPS device. In combination with the duration of exercise and heart rate information which is received by Bluetooth connection to heart rate belt, activity may be controlled at a very high level. Via wireless LAN connections, mobile phone can be connected to the network, which enables integration with other school subjects. Students can use their data for understanding the content in these subjects. My intention is to present how the students 9th grade PS Koroška Bela use this application and how the collected data can be used in other subjetcs.

Keywords: sport, mobile phone, connection, measuring, use of colleced data

Obravnava Pitagorovega izreka nekoliko drugače

A Different Approach to Pythagorean Theorem Teaching

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Povzetek
V članku predstavljam primer izvedene učne ure z vnaprej pripravljenimi elektronskimi gradivi. Gradiva so narejena s programom za dinamično geometrijo. Predstavljam uvodno uro iz vsebinskega sklopa Pitagorov izrek. Za nekoliko drugačen način učne ure sem se odločila zato, ker je način dela s klasičnimi učnimi listi ali samo s prepisovanjem iz table učencem velikokrat dolgočasen.
Ura je bila izvedena z učenci tretje nivojske skupine osmega razreda. Učenci so dela z računalnikom vajeni, zato dodatnega rokovanja z ustreznimi orodji niso potrebovali. Navodila za delo sem izpisala na papir. Opisani način dela se razlikuje od tistega, ki smo ga bili morda vajeni. Učiteljeva vloga ni več enaka kot pred časom. Kar naenkrat glavno vlogo prevzamejo učenci. Učitelj pa je le oseba, ki usmerja in vodi učence k skupnemu cilju. V skupini je bilo 16 učencev.
Elektronska gradiva so zastavljena v smislu samostojnega učenja in raziskovanja. Sledijo si po vrstnem redu osvajanja novih pojmov. V nasprotju s klasičnim načinom dela je tu namesto učitelja aktiven učenec. S pomočjo že vnaprej pripravljenih nalog in aktivnosti učenec sam odkriva določene zakonitosti ter nove pojme. Zaradi lastne aktivnosti učenca, je znanje pridobljeno na tak način trajnejše.

Ključne besede: Pitagorov izrek, dinamična geometrija, elektronska gradiva, samostojno učenje, raziskovanje

Abstract
The article presents a lesson taught with the help of electronic material prepared in advance. Dynamic geometry was used for the preparation of the lesson. The introductory lesson presenting Pythagorean theorem is described. A slightly different approach was used because working with the help of handouts or a blackboard is often boring.
The lesson was taught to eighth grade pupils in the highest ability group. As the pupils were already familiar with computer use, additional training to familiarize them with the appropriate tools was not necessary. The pupils were given instructions written on paper. As the role of the teacher has changed over the years and pupils have taken the main role, the teacher only directed and guided them towards a common goal. There were 16 pupils in the group.
Electronic material is designed to enable independent learning and research. It is presented in the order of the acquisition of new terms. In contrast with the common approach, a pupil is more active than a teacher. With the help of exercises and activities prepared in advance pupils discover certain laws and new terms on their own. Therefore, the knowledge acquired in this way is retained longer.

Keywords: Pythagorean theorem, dynamic geometry, electronic material, independent learning, research

Analiza kakovosti skupinskega dela pri študentskih projektih

An Analysis of the Quality of Team Work in Student Projects

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Povzetek
V članku analiziramo kakovost skupinskega dela pri projektih, ki od študentov zahtevajo razvoj (skoraj) realnega sistema po metodi Scrum. Analiza zajema 5 dimenzij, ki so v literaturi navedene kot najbolj pomembne za uspešno delo razvojnih skupin, ki delujejo po načelu samoorganizacije. Prikazani so rezultati za 33 skupin študentov, ki so v študijskem letu 2011/12 poslušali predmeta Tehnologija programske opreme in Sodobne metode razvoja programske opreme, ter njihova primerjava z ocenami skupinskega dela profesionalnih razvijalcev. Rezultati primerjave kažejo na ujemanje pri najslabše ocenjenih dimenzijah in precejšnjo podobnost pri povprečnih ocenah ostalih dimenzij. Vendar pa so ocene profesionalnih razvijalcev precej bolj enotne kot ocene študentov.

Ključne besede: skupinsko delo, samoorganizacija, agilni razvoj programske opreme, Scrum

Abstract
In this paper we examine the quality of team work on agile projects using Scrum that require the students to develop an (almost) real-life application. The analysis covers 5 dimensions that are in literature addressed as the most important for the successful work of agile development teams. We show the results for 33 groups of students who in academic year 2011/12 attended the courses Software technology and Modern methods of software development. We also compare the results with those obtained from professional developers. The comparison shows the match in the dimension that earns the lowest score, whereas the assessment scores in other dimensions are fairly similar. However, the assessment scores of professional developers are significantly more uniform than those of students.

Keywords: teamwork, self-organization, agile software development, Scrum

Ali ima virtualno terensko delo v biologiji in ekologiji prihodnost?

Does Virtual Field Trip have a Future in Biology and Ecology?

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Povzetek
Virtualno terensko delo predstavlja podporno okolje za spoznavanje učnih vsebin, ki je v prvi meri namenjeno predstavitvi obstoječih poti, kot pripomoček za pripravo na klasično terensko delo in ne nazadnje tudi kot samostojno okolje za reševanje nalog na računalnikih.
V prispevku so predstavljene ključne komponente modela virtualne učne poti *Sprehod po Mariborskem otoku*, ki so se na testiranjih izkazale za pomembne. Z interaktivnostjo poti učence iz zdolgočasenih obiskovalcev spremenimo v raziskovalce, fleksibilnost pa omogoči nešteto možnosti sestave in uporabe. Z digitalizacijo novih, že obstoječih, učnih poti bi le-te postale dosegljive tudi širši javnosti, hkrati pa bi omogočale varno okolje za pripravo ali urjenje. Vprašanje torej ni, kateri način je boljši, temveč kako klasično in virtualno delo združiti, da bodo doseženi rezultati še učinkovitejši za doseganje znanja pri biologiji in ekologiji.

Ključne besede: virtualna naravoslovna učna pot, virtualno terensko delo

Abstract
The virtual field trip presents the new supporting environment for learning. Mainly it is used for the promotion of the already developed real field trips, for the work as a didactical tool before or after the real engage, and finally, for the substitution for the real field trips engaged in a safer and cheaper virtual environment.
In this study the key features of the virtual field path *The walk on Maribor Island* are presented that have proven to be of greater importance. Interactivity of the exercises transforms students from bored visitors to the active researchers. The adaptability of the virtual field trip enables various options for the usage and development of personalized field paths. Finally, the digitalisation of the existing real field paths provides the promotion and makes them reachable for the general public as the tool for preparation before or the practice after the real field trip. The question in this case is not which method is better, but how to combine the real and virtual field trips to achieve optimal results in the knowledge gain in biology and ecology.

Keywords: virtual field trip, virtual nature trail

Uporaba multimedijske tehnologije pri poučevanju otrok s posebnimi potrebami

The Use of Multimedia Technology in Teaching Children with Special Needs

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Povzetek
Multimedija ali večpredstavnost je pogosto sredstvo izboljšave kakovosti pouka in uspešnejšega poučevanja dijakov s posebnimi potrebami, natančneje s primanjkljaji na posameznih področjih učenja ter s čustvenimi in vedenjskimi motnjami. V VIZ smo se vključili v projekt, kjer smo uporabili video kot večpredstavnostno učno sredstvo, s katerim bi zajeli učenje kot celosten proces in spodbujali samostojno učenje dijakov.

Ključne besede: multimedija (večpredstavnost), namen uporabe multimedije pri poučevanju, video pri pouku

Abstract
Multimedia or multi presentation is a common means of class improvement and more successful teaching of youngsters with special needs, in particular youngsters with deficits in different areas and emotional problems. In VIZ Višnja Gora we are included in the project where we have used video as a multi presentation teaching means, with which we would encompass teaching as a whole process and encourage youngsters' independent learning.

Keywords: multimedia (multi presentation), purpose of multimedia usage with teaching, video during class

Kaj lahko za video v e-izobraževanju odkrijemo v spletnem trženju

What Can We Discover in Internet Marketing for Video in E-learning

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Povzetek
Video bo po raziskavah ponudnikov komunikacijske opreme predstavljal 50% vsebin in kar 90% prometa v Internetu od leta 2013 naprej. Zaradi gospodarske recesije so v šolskih organizacijah sredstva za nabavo opreme za izdelavo video in na splošno multimedijskih učnih vsebin zelo omejena. Po drugi strani nas dnevno spremljajo objave novih informacijskih izdelkov (e-knjige, e-tečaji, video vodiči ipd) predvsem na področju spletnega trženja. In prav spletni tržniki uporabljajo recepte, ki za video delujejo. V tem prispevku bomo pregledali, kako lahko izkušnje spletnega trženja uporabimo za bolj privlačne, bolj kakovostne in uporabniško prijazne video posnetke v promociji, izvajanju in evalvaciji e-izobraževanja.

Ključne besede: multimediji, video, spletno trženje, multimedijska produkcija, SCORM

Abstract
Video will according to communication vendors research represent more than 50% of web content with more than 90% of Internet traffic from 2013. Equipment fonds for video and generally multimedia production are very limited due to economic recession. On the other hand announcements of new information products (e-books, e-courses, video guides etc.) especially in internet marketing are appearing daily. And for video internet marketers use recipes that work. In this paper we will give an overview how internet marketing experience and case studies can be used to create more attractive, more professional and user friendly videos in e-learning promotion, execution and evaluation.

Keywords: multimedia, video, internet marketing, multimedia production, SCORM

Podpora informacijske tehnologije pri izvajanju samoocenjevanja v izobraževalnih organizacijah

Information Technology Support for Slef-Assessment in Educational Organizations

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Povzetek
Poslovno odličnost po modelu EFQM (Evropske fundacije za kakovost) dosega organizacija v javnem in zasebnem sektorju takrat, ko presega pričakovanja svojih partnerjev in odjemalcev, predvsem pa standardov in normativov, ki jih postavljata okolje in zakonodaja. Organizacije, ki delujejo po načelih tega modela, so lahko voditelj in nosilec razvoja na svojem področju ter vzpostavljajo ter upravljajo odnose z vsemi svojimi deležniki. Vzpostavljanje celovite kakovosti poslovanja in delovanja zahteva tudi uvajanje sistema stalnih izboljšav**.** Samoocenjevanje je ključni del tega procesa. Z ustreznim pristopom in pripravami je možno v kratkem času brez znatnih dodatnih obremenitev delovnih procesov izvesti proces samoocenjevanja.

V prispevku je natančneje predstavljen sistematično zasnovan pristop izvedbe samoocenjevanja in iskanja ter urejanja predlogov možnih izboljšav za vzpostavljanje sistema stalnih izboljšav ter doseganje trajnostnega razvoja izobraževalne organizacije. Prikazan je praktični primer uvajanja sistema izboljšav z uporabo orodja informacijske tehnologije in izvedeni projekt ugotavljanja zadovoljstva zaposlenih na področju enega od meril modela. Predstavljen je pristop in izvedba projekta na eni ljubljanskih srednjih šol in rezultati, doseženi v teku projekta.

Ključne besede: samoocenjevanje, izobraževanje in šolstvo, celovito obvladovanje kakovosti/delovanja, sistem stalnih izboljšav

Abstract
The business excellence according to the EFQM (European Foundation for Quality Management) achieved by organization in public or private sector means exceeding expectations of partners and customers especially standards and normatives set by environment and legislation. The organizations following the model's principles tend to be leaders and bearers of development in their sector and want to establish and manage relations with all their stakeholders. Establishing holistic quality and business management system demands also introducing the continuous improvement system. Self assessment is essential part of this process. Corresponding approach and preparation enable the introduction of the self-assessment process in a short time without significant additional burdening of the working process.
The paper presents a systematically designed approach of self-assessment and searching and prioritizing the improvement proposals in order to establish a system of continuous improvement and

sustainable development of an educational/training organization. A practical example of introducing improvement with the use of the IT tool is presented. The project was performed in a form of questionnaire from one criteria of the EFQM model, which was worked on by groups of employees. The approach, performance and results are shown from the course of the project performed at a secondary school in Ljubljana.

Keywords: self-assessment, education and training, total quality management, continuous improvement process

Interaktivne poučne igre za razvijanje matematičnega mišljenja v predšolskem obdobju

Interactive Educational Games for Developing Mathematical Thinking in Preschool Period

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Povzetek
Igra je ključnega pomena za razvoj vseh otrokovih sposobnosti. Poleg igre ima pomembno vlogo pri spodbujanju matematičnega mišljenja tudi odrasli, še posebej, če vključuje računalnik in interaktivne igre. Dejavnosti z računalnikom morajo biti skrbno načrtovane, da lahko realiziramo zadane cilje. V prispevku so predstavljene tri spletne strani, ki ponujajo zanimive in primerne interaktivne igre ter naloge, namenjene predvsem predšolskim otrokom.

Ključne besede: pomen igre, pomen odraslega pri uporabi računalnika, interaktivne poučne igre

Abstract
Playing is essential for development of all child's skills. Besides playing, also adult plays an important role in developing mathematical thinking, especially if computer and interactive games are involved. Activities with computer have to be carefully planned in order to achieve set goals. In the article we present three web pages, which offer interesting and appropriate interactive games and tasks, suitable mainly for preschool children.

Keywords: meaning of playing, meaning of adult with computer use, interactive educational games

Uporabnost spletnih učilnic šolske knjižnice OŠ Prule

Usefulness of the E-classrooms of School Library of Primary School Prule

Gregor Škrlj

Povzetek

V osnovnošolski knjižnici, ki podpira vzgojno-izobraževalno dejavnost šole, vedno bolj združujemo klasično in sodobno poučevanje. Poučevanje poteka v medpredmetnih povezavah ob uporabi novih tehnologij. S tem krepimo in razvijamo temeljne pismenosti učencev (informacijsko, računalniško, digitalno) in razvijamo kompetence. Prispevek prikazuje primere spletnih učilnic in uporabnost petih spletnih učilnic v osnovnošolski knjižnici pri knjižničarjevem delu. Predstavljene bodo posamezne spletne učilnice, ki jih za potrebe pouka in spletno uporabo pripravlja šolski knjižničar.

Ključne besede: šolska knjižnica, spletne učilnice, Moodle, knjižnično informacijska znanja, pouk, osnovna šola, kompetence

Abstract

In primary school library, which supports the educational activities of the school, we are increasingly combining traditional and modern teaching. We teach by using new technologies and interdisciplinary connections. By strengthening and developing learners basic literacy (informational, computer, digital) and they develop skills. The article presents examples of the usefulness of primary school library e-classrooms.

Keywords: school library, e-classrooms, Moodle, library information skills, lesson, primary school, competencies

Inovativni pristopi pri uporabi IKT – film kot primer dobre prakse

Innovative Approaches to the Use of ICT – Film as an Example of Good Practice

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Povzetek
Namen pričujočega prispevka je predstaviti učenje in poučevanje nemškega jezika v dijaškem domu kot vzgojno izobraževalni ustanovi, kjer se specifika dela nekoliko razlikuje od dela v šoli. Tako je tudi pri pouku jezika, ki se ga dijaki udeležujejo pretežno individualno, izven časa, ki je z domskim redom predviden za učenje, saj tovrstni pouk poteka v obliki prostočasne interesne dejavnosti.
Na tem mestu je izpostavljeno delo z dijaki, ki so bili v okviru projekta Love Language & more, ki je osnovan s strani Evropske komisije, znotraj podprograma Leonardo da Vinci – prenos inovacij, vključeni v testiranje učinkovitosti posameznih didaktičnih enot priročnika za učitelje ob upoštevanju tipov učečih se po Gardnerjevi teoriji mnogoterih inteligenc. Pri tem igra pomembno vlogo tudi uporaba informacijsko komunikacijske tehnologije (IKT), saj ima uporaba slednje pomemben doprinos k učinkovitemu kombiniranju besednega, grafičnega, zvočnega in video posredovanja znanja ob upoštevanju različnih tipov učečih. V ospredje je postavljena uporaba računalnika in interneta ter pomen filma kot učnega pripomočka ali na dejavnostih temelječega projekta.

Ključne besede: dijaški dom, prosti čas mladostnika, nemški jezik, IKT, tipi učečih, film

Abstract
The purpose of the paper at hand is to present the learning and the teaching of the German language in a boarding school as an educational institution where the work specifics are somewhat different than the work in school. The same applies for language teaching classes which the students attend mainly individually and outside the hours designated by the boarding school policy for language learning since the teaching course is carried out in the form of extracurricular activities.
Here, the emphasis is put on the work with students who were, within the Love Language & More project founded by the European Commission, and within the Leonardo da Vinci sub-programme – Transfer of Innovation, included in performance testing of individual didactic units within the handbook for teachers, taking into account the types of learners according to the Gardner's theory of multiple intelligences. The use of information and communication technology (ITC) plays an important role here since its use contributes greatly to the effectiveness of the combined verbal, graphical, audio, and video communication of information, taking into account various types of learners. The focus is on the use of computer and internet, as well as the significance of film as a teaching tool or as an activity-based project.

Keywords: boarding school, free time, german language, ICT, types of learning styles, film

Zagotavljanje informacijske varnosti v slovenskih osnovnih šolah

Providing IT Security in Slovenian Elementary Schools

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Povzetek
Informacijska varnost je zelo zahtevno in težko obvladljivo področje. Pri zagotavljanju informacijske varnosti moramo predvideti vse morebitne nevarnosti, saj je informacijski sistem varen toliko, kot je varen njegov najšibkejši člen. Najbolj tipična področja, ki jih moramo pri zagotavljanju informacijske varnosti upoštevati so: sistemska varnost, varnost podatkov, omrežna varnost, fizična varnost, organizacijska varnost.
Zagotavljanje informacijske varnosti v osnovni šoli se zdi na prvi pogled zelo enostavno opravilo, vendar temu nikakor ni tako. Rezultati raziskave, ki smo jo izvedli med slovenskimi osnovnimi šolami, kažejo, da za informacijsko varnost v osnovnih šolah po Sloveniji ni najbolje poskrbljeno. Informacijska varnost je namreč individualna skrb vsake posamezne šole, zato ne moremo govoriti o nekih skupnih in celovitih rešitvah, kot jih npr. uporabljajo ponekod v tujini. V Sloveniji sicer deluje nekaj državnih institucij, ki osnovnim šolam pomagajo pri zagotavljanju informacijske varnosti, vendar bo potrebno na tem področju še marsikaj izboljšati.
V prispevku smo predstavili stanje na področju zagotavljanja informacijske varnosti v slovenskem šolstvu. Predstavili smo tudi nekatere dobre prakse, ki se jih poslužujejo v tujini. V skladu s temi smo oblikovali splošne smernice za izboljšanje informacijske varnosti, ki smo jih uporabili pri prenovi informacijskega sistema na OŠ Neznanih talcev Dravograd. Menimo, da je opisani pristop uporaben tudi za ostale osnovne šole v Sloveniji. Ker ne zahteva velikih finančnih vložkov, ima s tega stališča veliko praktično vrednost.

Ključne besede: informacijska varnost, smernice, osnovna šola, odprtokodna programska oprema, Open School Server

Abstract
The field of IT security is very demanding and difficult to manage. In providing IT security we need to foresee all possible risks, since an information system is only as safe as its weakest link. The most typical fields we must consider in providing IT security are: system security, data security, network security, physical security, organization security.
Although at a first sight providing IT security in an elementary school seems a very simple task, this is not the case. The results of the research we conducted among Slovenian elementary schools have shown that their IT security is not entirely taken care of. IT security is something each school has to take care of itself, so we cannot speak about common and overall solutions, which for example are used in some places abroad. In Slovenia there are some state institutions which help elementary schools with providing IT security, however several improvements are still needed in this field.

In our contribution we have presented the situation in the field of providing IT security in Slovenian schools. We have also presented some good practices used abroad. In accordance with these good practices we have developed general guidelines for improving IT security, which we used to reform the information system at the elementary school Osnovna šola Neznanih talcev Dravograd. We believe the described approach is also useful for other elementary schools in Slovenia. Since it does not require large financial contributions, it has in this context a great practical value.

Keywords: IT security, guidelines, elementary school, open source software, Open School Server

Poučevanje in učenje angleškega jezika stroke v oblaku

Teaching and Learning English for Specific Purposes in the Cloud

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Povzetek
Tudi izobraževanje se je preselilo v oblake. Prispevek prikazuje primere medpredmetnega povezovanja angleščine kot jezika stroke v oblaku s pomočjo orodij Spleta 2.0. Angleščina kot jezik stroke se nanaša na specifične discipline (mehatronika, informatika, elektroenergetika) in je osredotočena predvsem na novo besedišče, slovnico, spretnosti učenja in predstavitve strokovne teme. Orodja v oblaku omogočajo ustvarjanje, izmenjavo, raziskovanje, hranjenje in sodelovanje ter tako nudijo učinkovito in raznoliko sodelovanje za doseganje učnih ciljev pri učenju tujega jezika. Študentje so motivirani, da študirajo in predstavljajo teme, ki so medpredmetno povezane s strokovnimi predmeti, na ustvarjalen način. Možnosti, ki se izobraževanju ponujajo v oblaku, so brezmejne za vsa predmetna področja in na vseh nivojih izobraževanja za študente, učitelje in inštitucije.

Ključne besede: izobraževanje, oblak, orodja Spleta 2.0, medpredmetno povezovanje, angleščina kot jezik stroke, sodelovanje, raziskovanje, ustvarjalnost

Abstract
Education has gone into the cloud. The aim of this article is to present some examples of cross-curricular learning of English for specific purposes in the cloud, using Web 2.0 tools. English for specific purposes is related to specific disciplines (mechatronics, informatics, electroenergetics) and is centered on the activities in terms of new vocabulary, grammar, study and presentation skills. Cloud-based tools help to create, share, interact, research, save and collaborate from anywhere and at anytime thus providing a variety of ways of attaining the goals set in the learning process of ESP. Students are motivated to learn and visualize interconnected topics in a creative way. The educational possibilities that open up in the cloud are endless in all content areas and grade levels for students, teachers and institutions alike.

Keywords: education, cloud, Web 2.0 tools, cross-curricular learning, English for specific purposes, collaboration, research, creativity

Uporaba spletnega socialnega omrežja v osnovni šoli

The Use of Social Network in the Primary School

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Povzetek
Živimo v informacijski dobi, kjer je na voljo neskončno možnosti za izobraževanje. Ena izmed teh je tudi uporaba svetovnega spleta in vseh storitev, ki jih ponuja. Zato je potrebno v učni proces vključiti dejavnosti, ki bodo vzpodbujale interese učencev, jih motivirale za učenje, jim omogočile sodelovalno delo in interakcijo ter izmenjavo znanj. Ena izmed takšnih dejavnosti je zagotovo spletno socialno omrežje Facebook. Učencem in učiteljem ponuja številne možnosti za formalno in za neformalno učenje. Iz izkušenj trdimo, da je uspeh uporabe socialnega omrežja v veliki meri odvisen od vsebine, prav tako pa je pomembno, da učitelji spremljamo učence in da tudi sami uporabljamo socialno omrežje. S tem bomo uspeli učenje dvigniti na višjo raven, vzpodbuditi izmenjavo znanj in omogočiti osebnostni razvoj.
Naš cilj je opredeliti pojem socialnega omrežja, predstaviti pomen socialnih omrežij v izobraževanju, izpostaviti načine uporabe Facebooka kot primer socialnega omrežja v osnovni šoli in predstaviti tri primere dobre prakse uporabe Facebooka pri osnovnošolcih. Kot največjo dodano vrednost socialnega omrežja zaznavamo, da omogoča tako učiteljem kot učencem spremljanje dela drugih, dodajanje lastnih prispevkov, komentiranje svojih in prispevkov drugih uporabnikov.

Ključne besede: socialna omrežja, osnovna šola, Facebook, komunikacija, sodelovanje, interakcija

Abstract
We live in an information era, where immense possibilities for education are available. One of these is the use of World Wide Web and all of its services. It is therefore necessary to incorporate activities into educational process which will encourage pupils' interests, motivate them to learn, enable them to collaborate, interact, and exchange their knowledge. One of such services is definitely the Facebook. It offers the teachers and pupils many opportunities for formal and informal learning. According to our experiences, we can confirm the fact that the success of using social networks is largely dependent on the content. It is also important that teachers use social network regularly and monitor the pupils. With these facts we will be able to bring the education to a higher level, to encourage the exchange of knowledge and to enable personal development.
Our goal is to define the concept of the social network, present its importance in education, highlight the ways how to use Facebook as an example of social network in primary school and present three examples of good practice how to use Facebook in primary education. Allowing both, teachers and pupils, monitor the work of others, adding their own contributions, comment their own and the contributions of other users are the greatest values of the social network.

Key words: social network, primary school, Facebook, communication, collaboration, interaction

E-preverjanje in ocenjevanje znanja pri pouku slovenščine

E-assessment and Evaluation of Knowledge at Slovenian Lessons

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Povzetek
Preverjanje in ocenjevanje znanja, ki sta sestavni del učnega procesa, predstavljata za vse osnovnošolce pomemben, a žal manj privlačen del šolanja. Z namenom dodatno motivirati učence za učenje in usvajanje na novo pridobljenega znanja moramo učitelji slediti tudi alternativnemu preverjanju in ocenjevanju znanja, kamor uvrščamo računalniško podprto preverjanje in ocenjevanje znanja. In ravno zato moramo biti učitelji pri sestavljanju testov ne le dobro podkovani, temveč tudi inovativni. V prispevku je predstavljena ena izmed netipičnih, a toliko bolj privlačnih možnosti za ocenjevanje znanja, ki hkrati omogoča hitro in enostavno analizo ocenjevanja.

Ključne besede: slovenščina, e-preverjanje in ocenjevanje znanja

Abstract
Assessment and evaluation of knowledge which are a basic part of the learning process represent for all elementary school pupils a significant, but unfortunately less attractive part of education. With the purpose to additonally motivate pupils to learn and acquire new knowledge teachers must also follow the alternative assessment and evaluation of knowledge to which computer-aided assessment and evaluation of knowledge is classified. And that is why teachers must not only be well versed in composing tests but also be innovative. In the article one of the atypical however even more attractive possibilities of knowledge evaluation which simultaneously enables fast and easy evaluation analysis is presented.

Keywords: Slovenian, e-assessment and evaluation of knowledge

Projektno delo in računalnik za otroke in mladostnike s posebnimi potrebami

Project Work and ICT for Children and Teenagers with Special Needs

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Povzetek
Pri načrtovanju in uresničevanju vzgojno-izobraževalnega dela uporabljamo veliko sodobne tehnologije, primerne razvojni stopnji in posebnostim otrok in mladostnikov z lažjo in zmerno motnjo v razvoju. V večini primerov so le ti zelo dojemljivi za novosti, predvsem na področju informacijsko komunikacijske tehnologije. Sam namen projekta je bil bolje spoznati vse pridružene članice Evropske unije s poudarkom na Sloveniji; naš pa, da tudi učenci s posebnimi potrebami na čim bolj inovativen, zanimiv, poučen in igriv način spoznajo države Evropske unije in sodelujejo z ostalimi osnovnimi šolami treh gorenjskih občin.

Ključne besede: otroci in mladostniki s posebnimi potrebami,projektno učenje,motivacija, računalnik

Abstract
In primary school for children with special needs we use a lot of modern ICT that is adjusted to their needs and abilities. In most cases they are very interested for and they understand the principals of work very quickly.
In the project, that will be introduced in article, was the main goal to get knowledge about EU members with emphasis on Slovenia in innovative, interesting, playful and educational way through ICT on one hand and on the other hand with collaboration with other primary schools from Gorenjska.

Keywords: children and teenagers with special needs, project learning, motivation, ICT

Z IKT hitreje in enostavneje do analize rezultatov meritev pljučnih prostornin

With ICT more Quickly and Easily to the Analysis of Results of Lung Volumes' Measurements

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Povzetek
Zdravje prebivalcev Zasavja je bolj ogroženo zaradi onesnaženja kot drugod po Sloveniji. Ugotovili so, da so kronične bolezni dihal pri otrocih na močneje onesnaženih območij celotnega Zasavja 2,2-krat pogostejše kot pri otrocih, ki živijo na malo onesnaženih območjih (Vudrag, 2008). Raziskava je bila izvedena v Zasavju na populaciji zasavskih osnovnošolcev.
V našo raziskavo smo s pomočjo spletne ankete, ki nam jo je omogočila aplikacija Lime Survey, vključili 77 dijakov GESŠ Trbovlje. Njihova povprečna starost je znašala 17,25 ± 1,5 let. Meritve pljučne kapacitete s pomočjo spirometra so izvedli zdravstveni tehniki Bolnišnice Golnik. Izmerjene rezultate smo statistično obdelali s pomočjo računalniškega programa Excel. Ugotovili smo, da izmerjene vrednosti FEV_1/FVC, ki so pokazatelj obstruktivne pljučne bolezni, ne odstopajo od norme, niti pri fantih niti pri dekletih. Poleg kajenja, ki je najpomembnejši dejavnik tveganja za nastanek obstruktivne pljučne bolezni, so še preostali dejavniki tveganja: onesnaženje zraka, slabši socialno-ekonomski status, pogostejše okužbe dihal v otroštvu, družinska obremenitev (Gržetić-Romčević, 2008). Dobljeni rezultati ne potrjujejo naše predpostavke, da bo pljučna kapaciteta pri naših preiskovancih nižja od dane norme. To lahko razložimo s tem, da je pojavnost obstruktivne pljučne bolezni vezana na višjo starost, intenzivnost kajenja in daljšo izpostavljenost onesnaženemu okolju.
Z aplikacijo Lime Survey smo hitreje in bolj enostavno pridobili pomembne podatke o preiskovancih pred samo meritvijo s spirometrom. Orodje Excel pa nam je omogočilo izdelavo natančne statistične analize pridobljenih rezultatov spirometrije.

Ključne besede: aplikacija Lime Survey, Excel, spirometrija, pljučna kapaciteta, kronična obstruktivna pljučna bolezen

Abstract
The health of the Zasavje population is more endangered due to the pollution than it is of the population in the rest of Slovenia. It was discovered that possibility of chronic respiratory diseases in children who lives in polluted areas of Zasavje are 2,2–times higher than in children living in less polluted areas (Vudrag, 2008).
In our study we included with use of online survey that it made possible application Lime Survey, 77 students of GESŠ Trbovlje. Their average age was 17,25 ± 1,5 years. The measurements of lung

capacity by spirometry were carried out by Golnik Clinic medical technicians. The measured results were statistically analyzed using Excel computer program. We found that the measured values of FEV_1/FVC, which is an indicator of obstructive pulmonary disease, do not differ from the norm, either at boys or girls. In addition to smoking, which is the most important risk factor for obstructive pulmonary disease, the remaining risk factors are: air pollution, poor socio-economic status, frequent respiratory infections in childhood, family burden (Gržetić-Romčević, 2008). The obtained results do not support our hypothesis that the lung capacity in our subjects is lower than the given norm. This can be explained by the fact that the incidence of obstructive pulmonary disease is linked to higher age, smoking intensity and longer exposure to environmental pollution.
With Lime Survey application was faster and easily obtain important information on the subjects just before the measurement with spirometry. Excel tool has enabled us to made accurate statistical analysis of obtained spirometry results.

Keywords: application Lime Survey, Excel, spirometry, lung capacity, chronic obstructive pulmonary disease

Računalniško podprti pouka fizike v srednji šoli – študij primera

The Computer-Based Instructions in a Physics Course in the Secondary School – Case Study

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Povzetek
V zadnjih štirih letih poteka v Sloveniji intenzivna posodobitev srednješolskih učnih programov. Posodobitev vključuje tri večja področja: uvedbo posodobljenih učnih načrtov, spremembe pri izvedbi mature iz posameznih predmetov in iskanje novih, aktivnejših oblik poučevanja. Osnovno vodilo posodobitve je poiskati tiste učne pristope oziroma metode poučevanja, ki bi omogočale dijakom doseganje globljih - višjih nivojev znanja. V posodobitvi aktivno sodelujemo tudi raziskovalci na področju poučevanja fizike, združeni v večih projektih, kot sta npr. Razvoj naravoslovnih kompetenc in projekt Posodobitev gimnazije. V članku prikazujemo del aktivnosti avtorske skupine, ki aktivno sodeluje v obeh projektih, s poudarkom na analizi učinkovitosti računalniško podprtega pouka fizike v srednji šoli. V raziskavi smo, po izvedenih učnih urah iz izbranih poglavij Elektrike, preverjali znanje dijakov, pri čemer smo eno skupino dijakov (eksperimentalna skupina) poučevali z uporabo interaktivnih gradiv, ki smo jih posebej izdelali za raziskavo. Drugo skupino dijakov (kontrolna skupina) smo poučevali na tradicionalni način – frontalno, z metodo razlage in demonstracije. Testirali smo pet taksonomskih stopenj oziroma nivojev znanja dijakov: poznavanje, analizo, sklepanje, primerjavo in ovrednotenje. Rezultati dijakov eksperimentalne skupine so bili boljši od rezultatov dijakov kontrolne skupine na vseh taksonomskih stopnjah. Z rezultati študije smo potrdili našo domnevo, da je računalniško podprt fizike v srednji šoli eden izmed možnih učnih pristopov, ki omogoča doseganje višjih taksonomskih nivojev znanja ter tako lahko predstavlja uspešno dopolnitev, v izbranih primerih pa tudi alternativo tradicionalnemu poučevanju fizike.

Ključne besede: tradicionalni frontalni pouk, informacijska in komunikacijska tehnologija (IKT), simulacije, računalniško podprt pouk fizike

Abstract
In the last four years there has been intensive renovation of education across high schools in Slovenia. This renovation has focussed on three main areas, firstly, the introduction of new curriculums, secondly, changes to general examinations before leaving high school and thirdly, the search for new and innovative methods of teaching. The main purpose of this change is to discover what kind of teaching approaches and methods will enable students to reach a higher level of knowledge. This programme of renovation has included participation from Physics Education Researchers who have been involved with important projects such as the Development of Science Competences and The

Renovation of the Gymnasium. In this paper we present a review of activities of the authors group that has actively participated in both projects, with emphasis on analysing the successfulness of the computer-based lessons in a Physics course in the secondary school**.** This research examined the knowledge of third-year high school students after carrying out lessons specifically on the topic of Electricity. In one group (experimental group) students were taught using interactive materials, which we prepared specially for this study. The second group (control group) were taught traditionally - expository teaching and demonstration method were used. Five taxonomic levels were assessed: Knowledge, Analysis, Inference, Comparison and Evaluation. The study showed that the results of the students from the experimental group were significantly better than the results of the students from the control group on every taxonomic level. These results offer support for the assumption that computer-based lessons may enable students to reach higher levels of knowledge and could therefore be an effective completion or alternative to traditional approaches.

Keywords: ex cathedra teaching, information and communication technology (ICT), simulations, computer-based physics` lesson

Domače delo v spletni učilnici Moodle

Homework in Moodle E-learning Platform

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Povzetek
Prikazana je primerjava domačega dela pred in po uvedbi spletne učilnice Moodle. Pol leta so dijaki domače naloge delali na običajen način, vendar so se pri tem precej zanašali na pravilnik, ki učitelju ne dovoli sankcioniranja nedela doma. Drugo polovico leta so dobivali domače naloge v spletni učilnici. Opravljene naloge pred uvedbo je učiteljica beležila v tabelo, medtem ko je po uvedbi spletne učilnice, delo dijakov spremljala le preko statistike dostopov. Z uporabo IKT smo dijake navdušili za domače delo. Iz rezultatov eksperimenta lahko povzamemo, da lahko premišljena uporaba spletne učilnice poveča samoregulacijsko učenje najstnikov.

Ključne besede: spletna učilnica, Moodle, samoregulacijsko učenje, domače delo

Abstract
The paper shows an influence on doing homework with or without using Moodle e-learning platform. Two different approaches of doing homework are compared. First approach describes the results of doing homework on classical way for the six month. The results were influenced by the rule, that the teachers may not sanction the students without homework. An overview of results was presented in the table. The second approach presented the results of doing homework using Moodle e-learning platform for the next six month. The result was presented as number of student's accesses to e-learning platform. Implementation of ICT has increased the interest for doing homework. The experiment confirms that appropriate employment of Moodle e-learning platform improves students self regulation of learning.

Keywords: e-learning platform, Moodle, self-regulation of learning, homework

Gremo na radio!

Let's go to the Radio!

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Povzetek
V šolskem letu 2011/12 je OŠ Šmartno pod Šmarno goro sodelovala z naciolano radijsko postajo »Radio Slovenija«. Aktivnosti pri nastajanju in evalvaciji enourne mladinske radijske oddaje »Radio HUDO« so potekale skozi celo leto. Predmet radio je bil od vsega začetka načrtovan v obliki projekta z namenom izdelati oddajo, ki jo bo poslušalo v soboto dopoldan med deveto in deseto uro občinstvo po vsej Sloveniji. Profesionalna IKT oprema nacionalnega radia in klasična šolska IKT oprema sta se intuitivno prepletali v vseh fazah dela: od skupinskega urejanja scenarija preko snemanja anket, intervjujev, reportaž in obdelave zvočnih sporočil in nenazadnje do oddajanja naših sporočil preko radijskih valov in objave na spletnih straneh šole in www.rtvslo.si ter dokumentiranj na socialnem omrežju Facebook.

Ključne besede: radio, IKT oprema, praktično delo, Radio Slovenija

Abstract
In the school year 2012 the primary school Osnovna šola Šmartno pod Šmarno goro cooperated with the national radio station »Radio Slovenija«. The activities of creation and evaluation of a one-hour youth radio show called »Radio HUDO« were spread throughout the whole school year. The school subject Radio had been planned beforehand as a project to create a radio broadcast to be aired on a Saturday morning between 9 AM and 10 AM nationwide. The use of professional ICT equipment and of standard school ICT equipment were intuitively intertwining through all of the phases of the work: from the cooperative scenario editing, through recording of queries, interviews, reports and sound editing and finally to the broadcasting of the show through the radio, the publishing on the school's website and on the www.rtvslo.si and to popularizing the show on the social network Facebook.

Keywords: radio, ICT equipment, learning by doing, Radio Slovenija

Učenje s tabličnimi računalniki

Learning with Tablet PC

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Povzetek
Uporaba tabličnih računalnikov v izobraževalne namene je vzbudila veliko pozornost in tudi pričakovanja. Izvajanje pouka različnih starostnih skupin dijakov pri različnih predmetih in kasnejša analiza rezultatov je pokazala veliko prednosti tabličnih računalnikov (tehnologija na dotik) v primerjavi s papirnatimi zvezki in posledično smiselnost uporabe le-te na različnih področjih izobraževanja, čeprav so še vedno vidne tudi nekatere "otroške" bolezni nove tehnologije.

Zagotovo bo prihajajoča IKT tehnologija, v katero sodijo tudi tablični računalniki v povezavi z računalništvom v oblaku, v doglednem času popolnoma nadomestila papirnate oblike "shranjevanja" podatkov.

Ključne besede: tablični računalniki, programi za tablične računalnike, novi načini izobraževanja, informatika

Abstract
The use of the tablet computers for educational purposes has risen a great attention and expectations. The analysis of the results of the classical lessons with noteboox compared to the lessons with tablet computers among the students of different age groups and at various subjects has shown a lot of advantages of tablet computers (touch technology) and the viability of its use on the different areas of education, although they are still visible some signs of children's diseases of new technology.

The ICT technology that is coming, into which belong tablet PCs in connection with cloud computing, will shortly and completely replaced the paper way of saving datas.

Keywords: tablet PC, tablet PC applications, new ways of education, informatics

Arnes videokonference - kaj je novega po 9-ih letih?

Arnes Videoconferencing – What's New after 9 Years?

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Povzetek
O videokonferencah je bilo že marsikje veliko povedanega in marsikdo je videokonferenco že tako ali drugače kdaj uporabljal. Vendar je še posebej v Sloveniji prepad med teorijo in prakso pri videokonferencah zelo pogosto ogromen in videokonferenčna izkušnja niti približno ni takšna, kot je bila pričakovana, videokonferenca pa ne opravlja svoje naloge. Kje so vzroki za to?
Arnes od l. 2003 nudi vsem organizacijam s sobnimi videokonferenčnimi sistemi H.323 celovito storitev, ki vključuje večtočkovne videokonference, dostop do videokonferenc s poljubnim telefonom priključenim v javno telefonsko omrežje, snemanje videokonferenc in s pretočnim videom prenos videokonferenc na splet ter vključitev videokonferenčnih sistemov organizacij v mednarodno videokonferenčno omrežje. Z nadgradnjo osrednjega videokonferenčnega strežnika v l. 2011 videokonference podpirajo visokokvalitetno sliko do vključno polne visoke ločljivosti FullHD 1080p, tekoče osveževanje slike do 60 slik/s in prenos zvoka, primerljivega s kvaliteto glasbe z zgoščenk. Od konca leta 2011 je na voljo nov videokonferenčni portal ArnesMCU, na katerem lahko uporabniki samostojno upravljajo s svojimi videokonferenčnimi sobami ter snemajo in prenašajo dogajanje v videokonferenci v živo na splet. Vse to poteka na Arnesovih strežnikih. V letu 2012 so se odprle nove možnosti brezplačne uporabe videokonferenc na Windows in Mac računalnikih, pa tudi na mobilnih napravah (tablice, pametni telefoni).

Ključne besede: videokonference, MCU, H.323, SIP, HD, FullHD

Abstract
Much has been written about videoconferencing, and many people have already used videoconferencing. However, the gap between theory and practice, particularly in Slovenia, is enormous, videoconferencing experience is not even close to what was expected, and videoconferencing is failing to fulfil its role. Why?
Since 2003, Arnes has offered all organisations with H.323 room videoconferencing systems a comprehensive service, including multipoint videoconferences, access to videoconferences from any telephone connected to the public telephony network, recording videoconferences, streaming videoconferences on the web, and connecting the videoconferencing systems of organisations to the international videoconferencing network. The upgrade to the main videoconferencing server in 2011 means that videoconferences now support high quality images up to and including FullHD 1080p, refresh rates up to 60 frames/s, and transmission of CD-quality audio. The new ArnesMCU videoconferencing portal has been available since the end of 2011, allowing users to independently administer their videoconferencing rooms and to record and transmit live videoconferencing events on the web. All of this runs on Arnes' servers. New opportunities were created in 2012 for the use of videoconferencing on Windows and Mac computers, as well as mobile devices (tablets, smartphones) free of charge.

Keywords: videoconferences, MCU, H.323, SIP, HD, FullHD

Kompetenca za spremembe

Competence for Changes

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Povzetek
V članku so predstavljeni pomen ključne kompetence učenje učenja za pripravo mladih na spremembe, ki jih čakajo v prihodnosti, in vplivi uporabe računalnikov in z njimi povezane informacijske tehnologije na to kompetenco. V tem smisli je predstavljen model učenja z uporabo e-listovnika.

Ključne besede: učenje, učenje učenja, digitalna kompetenca

Abstract
The article presents the importance of key competencies learning to learn to prepare young people for the changes that await them in the future, and the impact of computers and related information technology on this competency. In this sense a model of learning with e-portfolio is presented.

Keywords: learning, learning to learn, digital competency

Brezplačne IKT storitve za vsak vzgojno-izobraževalni zavod

Free ICT Services for Each Educational Institution

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Povzetek
V slovenskem vzgojno-izobraževalnem prostoru se vse bolj uporablja informacijsko-komunikacijska tehnologija v različne namene prek različnih storitev. Učitelji/vzgojitelji jo vse več uporabljajo za delo pri pouku, sodelovanje s starši, delo na daljavo. Brezplačnih IKT storitev za vzgojno-izobraževalne je v zadnjem času vse več. V prispevku izpostavljene storitve so ne samo slovenske (Arnes) temveč tudi najkakovostnejše. Predstavljene so z vidika organizacije in z vidika uporabnika.

Ključne besede: IKT storitve za zavode, Arnes, e-kompetentni učitelj, e-kompetentni vzgojitelj

Abstract
Slovene education institutions growingly use Information-communication technology for a wide range of purposes such as teaching, communication with parents, distance learning. The number of free ICT services has been increasing lately. The article points out not only Slovene services (Arnes) but also those of highest quality from both the organizational and user's point of view.

Keywords: ICT services for schools, Arnes, e-competent teacher, e-competent educator

Primerjava dveh modelov kakovosti v izobraževanju

Comparative Analyses of Two Models of Quality in Educations

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Povzetek
Kakovost v izobraževalni dejavnosti je težko natančno opredeliti, pojmujejo jo na najrazličnejše, lahko tudi nasprotujoče si načine. Izobraževalne ustanove se med seboj zelo razlikujejo po programih, po načinu izvajanja, organizacijski kulturi, po dejavnostih. Posledično je pojmovanje kakovosti izobraževanja zelo različno in s tem je povezana tudi izbira modela za presojanje kakovosti.
V prispevku prikažemo primerjavo dveh modelov kakovosti, slovenskega in ameriškega: Ponudimo odraslim kakovostno izobraževanje (POKI) in Malcolm Baldrige National Quality Award (MBNQA). Povzeti so splošni koncepti kakovosti in odličnosti v izobraževanju. Predstavljena je povezava med kakovostjo izobraževanja, razvojem kompetenc ter organizacijsko kulturo v izobraževalnih inštitucijah.
Z natančno kvalitativno primerjavo modelov POKI in MBNQA smo opredelili podobna ali enaka področja. Za določene elemente modela MBNQA in POKI nismo našli dovolj velikih podobnosti in smo jih klasificirali kot pomembno različne.

Ključne besede: kakovost, izobraževanje, evalvacija, model kakovosti, izobraževalna organizacija

Abstract
It is difficult to accurately define quality in the field of education; it is defined in various different ways, sometimes even ways that are contradictory. Educational institutions do not only differ by their programmes, but also by the execution of the programmes, by organisational culture, and by their activities. Consequently, the definition of quality education differs, as well as, the model chosen for quality assessment.
In the article the comparison of two quality models is explained, Slovenian and American: Offering Quality Education to Adults (OQEA) and Malcolm Baldrige National Quality Award (MBNQA). Basic quality and excellence concepts in education are presented. The relationship between the quality of education, the development of competences and the organisational culture in educational institutions, is also explained.
With a detailed qualitative comparison of both above mentioned models, the similarities and the differences were defined. However, there were some elements of MBNQA and OQEA models where the similarities were not substantial enough and therefore the elements were classified as significantly different.

Keywords: quality**,** education, evaluation, quality model, educational organization

Izdelava 3D fotografij v šoli

Creating 3D Photographs in School

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Povzetek
Poznamo različne načine izdelave 3D fotografij. Med najenostavnejšimi in zato najprimernejšimi za uporabo v šoli so anaglifi. V prispevku je na primeru opisan postopek izdelave anaglifa, katerega cilj je spodbuditi učitelje, da to metodo preskusijo sami ali skupaj z učenci. Za izdelavo anaglifa, objekt fotografiramo z običajnim fotoaparatom z dveh točk, ki sta med seboj oddaljeni nekaj centimetrov. Fotografiji odpremo z brezplačnim programom StereoPhoto Maker. Z nekaj kliki fotografiji poravnamo in izdelamo anaglif, ki si ga ogledamo z rdeče-modrimi ali drugimi dvobarvnimi očali. Celoten postopek lahko opravimo v nekaj minutah, zato je primeren tudi za samostojno delo dijakov ali učencev pri različnih projektih.

Ključne besede: 3D fotografija, anaglif, tehnologija, projekt

Abstract
Different techniques of creating 3D photographs are available today. Anaglyphs are among easiest and thus most appropriate for use in school. Article presents procedure to create anaglyphs. Teachers are invited to test the method by themselves or with the students. We use camera to take pictures from two positions that are a couple of centimeters apart. We open pictures in free software StereoPhoto Maker. With a couple of clicks we align the photographs and make anaglyph. We can see the anaglyph with red-cyan or other two-color glasses. Entire procedure can be performed in a couple of minutes and can be used by students at different projects.

Keywords: 3D photography, anaglyph, technology, project

Izdelava simulacij z Easy Java Simulations

Creating Simulations with Easy Java Simulations

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Povzetek
Easy Java Simulations, skrajšano EJS, je odprtokodni program za izdelavo simulacij v Javi. Z EJS lahko preproste izdelamo preproste simulacije brez znanja programiranja. Ob dodatnem programiranju v Javi pa lahko izdelamo kompleksnejše simulacije. V prispevku je na primeru enakomernega gibanja in poševnega meta prikazana izdelava preprostih simulacij po korakih. Obe simulaciji lahko ob besedilu in slikah samostojno izdela vsak učitelj. Prikazano je, kako z majhnimi spremembami spremenimo simulacijo. Simulacije, izdelane z EJS, lahko uporabimo pri pouku za boljšo nazornost razlag, pri domačih nalogah ali v kombinaciji z laboratorijskimi vajami.

Ključne besede: simulacije, Easy Java Simulations, EJS, Java, programiranje, fizika, gibanje

Abstract
Easy Java Simulations, abbreviated EJS, is an open source program for creating Java simulations. EJS can be used to create simple simulations without any knowledge of programming. Using additional programming in Java, more complex simulations can be created. Step by step tutorial is used to show how simple simulations of uniform motion and projectile motion can be created. Any teacher can create both simulations following the descriptions and pictures. It is also demonstrated how simulations can be changed by applying small changes. Simulations created with EJS can be used to better present the topic in class, for homework or in combination with laboratory work.

Keywords: simulations, Easy Java Simulations, EJS, Java, programming, physics, motion

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