Zbornik 13. mednarodne multikonference

INFORMACIJSKA DRUŽBA – IS 2010

Zvezek D

Proceedings of the 13th International Multiconference

INFORMATION SOCIETY – IS 2010

Volume D

Odprta delavnica projekta CONFIDENCE

CONFIDENCE Project Open Workshop

Uredila / Edited by

Igone Velez, Matjaž Gams

12. oktober 2009 / October 12th, 2010
Ljubljana, Slovenia

Zbornik 13. mednarodne multikonference

INFORMACIJSKA DRUŽBA – IS 2010

Zvezek D

Proceedings of the 13th International Multiconference

INFORMATION SOCIETY – IS 2010

Volume D

Odprta delavnica projekta CONFIDENCE

CONFIDENCE Project Open Workshop

Uredila / Edited by

Igone Velez, Matjaž Gams

http://is.ijs.si

12. oktober 2010 / October 12th, 2010
Ljubljana, Slovenia

Uredniki:

Igone Velez
CEIT & Universidad de Navarra, Spain

Matjaž Gams
Odsek za inteligentne sisteme
Institut »Jožef Stefan«, Ljubljana

Založnik: Institut »Jožef Stefan«, Ljubljana
Tisk: Birografika BORI d.o.o.
Priprava zbornika: Mitja Lasič, Jana Krivec
Oblikovanje naslovnice: Miran Krivec, Vesna Lasič
Tiskano iz predloga avtorjev
Naklada: 30

Ljubljana, oktober 2010

Konferenco IS 2010 sofinancirata
Ministrstvo za visoko šolstvo, znanost in tehnologijo
Javna agencija za raziskovalno dejavnost RS (ARRS)
Institut »Jožef Stefan«

Informacijska družba
ISSN 1581-9973

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

004.89:613.98(082)

MEDNARODNA multikonferenca Informacijska družba (13 ; 2010 ; Ljubljana)
Odprta delavnica projekta Confidence : zbornik 13. mednarodne multikonference Informacijska družba - IS 2010, 12. oktober 2010 : zvezek D = Confidence project open workshop : proceedings of The 13th International Multiconference Information Society - IS 2010, October 12th, 2010, Ljubljana, Slovenia : volume D / uredila, edited by Igone Velez, Matjaž Gams. - Ljubljana : Institut Jožef Stefan, 2010. - (Informacijska družba, ISSN 1581-9973)

ISBN 978-961-264-027-9

1. Gl. stv. nasl. 2. Vzp. stv. nasl. 3. Informacijska družba 4. Information society 5. Velez, Igone
252780544

PREDGOVOR MULTIKONFERENCI INFORMACIJSKA DRUŽBA 2010

V svojem trinajstem letu je multikonferenca Informacijska družba (http://is.ijs.si) znova dokazala, da je ena vodilnih srednjeevropskih konferenc, ki združuje znanstvenike z različnih raziskovalnih področij, povezanih z informacijsko družbo. V letu 2010 smo v multikonferenco povezali deset odličnih neodvisnih konferenc. V Sloveniji in po svetu mgroli konferenc. Naša multikonferenca izstopa po širini in obsegu tem, ki jih obravnava, predvsem pa po akademski odprtosti in širini, ki spodbuja nove ideje.

Multikonferenca temelji na sinergiji interdisciplinarnih pristopov, ki obravnavajo različne vidike informacijske družbe ter poglabljajo razumevanje informacijskih, komunikacijskih in družbenih storitev v najširšem pomenu besede. 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.

Na multikonferenci bo na vzporednih konferencah predstavljenih 300 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 34-letno tradicijo odlične znanstvene revije.

Multikonferenco Informacijska družba 2010 sestavljajo naslednje samostojne konference:

- Odprta delavnica mednarodnega projekta Confidence
- Inteligentni sistemi
- Jezikovne tehnologije
- Kognitivne znanosti
- Robotika
- Rudarjenje podatkov in podatkovna skladišča (SiKDD 2010)
- Sodelovanje, programska oprema in storitve v informacijski družbi
- Soočanje z demografskimi izzivi
- Vzgoja in izobraževanje v informacijski družbi
- 3. Minikonferenca iz teoretičnega računalništva 2010.

Zanimivo je, da finančna recesija ni zmanjšala zanimanja za informacijsko družbo, saj je prispevkov primerljivo z lansko konferenco, kljub temu, da se je državno sofinanciranje močno zmanjšalo. Soorganizatorji in podporniki konference so različne raziskovalne institucije in združenja, med njimi tudi ACM Slovenija. Zahvaljujemo se tudi Agenciji za raziskovalno dejavnost RS ter Ministrstvu za visoko šolstvo, znanost in tehnologijo za sodelovanje in podporo. V imenu organizatorjev konference pa 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 2010 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. Tomažu Kalinu. V letu 2010 tudi prvič podeljujemo nagrado za tekoče dosežke. Za aktivno delo pri računalniških tekmovanjih in drugih računalniških dogodkih sta odbora izmed predlogov izbrala Marka Grobelnika. Čestitamo obema nagrajencema!

Franc Solina, predsednik programskega odbora
Matjaž Gams, predsednik organizacijskega odbora

FOREWORD - INFORMATION SOCIETY 2010

In its 13th year, the Information Society Multiconference (http://is.ijs.si) again demonstrated that is is one of the leading conferences in Central Europe gathering scientific community with a wide range of research interests in information society. In 2010, we organized ten independent excellent conferences forming the Multiconference. There are plenty of conferences in Slovenia and all over the world. The broad range of topics and the open academic environment fostering new ideas makes our event unique among similar conferences.

The Multiconference flourishes the synergy of different interdisciplinary approaches dealing with the challenges of information society. 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.

The Multiconference is running in parallel sessions with 300 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 34 years of tradition in excellent research publications.

The Information Society 2010 Multiconference consists of the following conferences:

- Confidence Project Open Workshop
- Intelligent Systems
- Languate technologies
- Cognitive Sciences
- Robotics
- Data Mining and Data Warehouses (SiKDD 2010)
- Collaboration, Software and Services in Information Society
- Demographic Challenges in Europe
- Education in Information Society
- The Third Mini Conference on Theoretical Computing 2010.

Interestinglly, the economic recession is not affecting Information society, judging from the number of single conferences; however, the national funding significantly decreased as a result of crisis. 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 Higher Education, Science and Technology and the Slovenian Research Agency..

In 2010, 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. Tomaž Kalin. Congratulations!
In addition, a reward for current achievements was pronounced for the first. It goes to Marko Grobelnik for his support of the ACM computer competitions.

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.

Franc Solina, Programme Committee Chair
Matjaž Gams, Organizing Committee Chair

KONFERENČNI ODBORI
CONFERENCE COMMITTEES

International Programme Committee

Vladimir Bajic, South Africa
Heiner Benking, Germany
Se Woo Cheon, Korea
Howie Firth, UK
Olga Fomichova, Russia
Vladimir Fomichov, Russia
Vesna Hljuz Dobric, Croatia
Alfred Inselberg, Izrael
Jay Liebowitz, USA
Huan Liu, Singapore
Henz Martin, Germany
Marcin Paprzycki, USA
Karl Pribram, USA
Claude Sammut, Australia
Jiri Wiedermann, Czech Republic
Xindong Wu, USA
Yiming Ye, USA
Ning Zhong, USA
Wray Buntine, Finland
Bezalel Gavish, USA
Gal A. Kaminka, Israel
Miklós Krész, Hungary
József Békési, Hungary

Organizing Committee

Matjaž Gams, chair
Mitja Luštrek, co-chair
Lana Jelenkovič
Jana Krivec
Mitja Lasič

Programme Committee

Franc Solina, chair
Viljan Mahnič, co-chair
Cene Bavec, co-chair
Tomaž Kalin, co-chair
Jozsef Györkös, co-chair
Tadej Bajd
Jaroslav Berce
Mojca Bernik
Marko Bohanec
Ivan Bratko
Andrej Brodnik
Dušan Caf
Saša Divjak
Tomaž Erjavec
Bogdan Filipič
Andrej Gams
Matjaž Gams
Marko Grobelnik
Nikola Guid
Marjan Heričko
Borka Jerman Blažič Džonova
Gorazd Kandus
Urban Kordeš
Marjan Krisper
Andrej Kuščer
Jadran Lenarčič
Borut Likar
Janez Malačič
Olga Markič
Dunja Mladenič
Franc Novak
Marjan Pivka
Vladislav Rajkovič
Grega Repovš
Ivan Rozman
Niko Schlamberger
Stanko Strmčnik
Tomaž Šef
Jurij Šilc
Jurij Tasič
Denis Trček
Andrej Ule
Tanja Urbančič
Boštjan Vilfan
David B. Vodušek
Baldomir Zajc
Blaž Zupan
Boris Žemva
Janez Žibert
Leon Žlajpah

KAZALO / TABLE OF CONTENTS

Zbornik 13. mednarodne multikonference

INFORMACIJSKA DRUŽBA – IS 2010

Zvezek D

Proceedings of the 13th International Multiconference

INFORMATION SOCIETY – IS 2010

Volume D

Odprta delavnica projekta CONFIDENCE

CONFIDENCE Project Open Workshop

Uredila / Edited by

Igone Velez, Matjaž Gams

http://is.ijs.si

12. oktober 2010 / October 12th, 2010
Ljubljana, Slovenia

CONFIDENCE PROJECT

OPEN WORKSHOP

The population in Europe is fast aging due to the increase in life expectancy and decrease in birth rate. As a consequence of this process, the number of elderly will exceed the society's capacity for taking care of them. Therefore, technical solutions are being sought by the EU countries to ensure that the elderly can live longer independently with minimal support of the working-age population. Many of these efforts belong to the area of ambient assisted living (AAL), whose objective is to make daily life easier and safer by placing unobtrusive smart devices and services into the environment. This is also the goal of the European FP7 project CONFIDENCE – Ubiquitous Care System to Support Independent Living FP7-ICT-214986.

The CONFIDENCE project team has already developed and integrated innovative technologies to build a care system. It is not based on privacy-obtrusive technologies such as video surveilance, but on tags, attached to the body, which signals are captured by the specialized sensors and then analysed in PC. The intelligent software is capable to detect abnormal events such as falls at a superior level compared to other approaches. Another innovation of the system developed in the CONFIDENCE project is that it does not only detect falls, but also identify short and long term unexpected behaviours that could indicate health problems.

Thanks to these features, the elderly people will gain the confidence and independence. CONFIDENCE will be a cost effective, non-intrusive and reliable system that will increase the quality of life and security of the elderly and, thus, prolong their personal autonomy and participation in society. Not only will the elderly profit from the system, but also their families and caregivers, since the burden on them will be substantially reduced. CONFIDENCE aims to decrease the need of institutionalisation of the elderlly.

The CONFIDENCE project is in its final year with the emphasis on final improvements of the developed system, dissemination, and extensive testing. This WS presents several papers primarily describing the developed system, and in particular its SW components from the user's point of view. There are three versions of the system: the official with specialized communication modules, and two PC-based versions: the technical one for the technically educated users and the simple one for elderly. There are also six manuals describing the system-user communication.

The CONFIDENCE Workshop is a part of the 13th IS 2010 Multiconference. It provides an international forum for scientists, academicians, and professionals presenting their latest research findings in the various fields of Information Society.

We thank all the authors of the papers and all members of the CONFIDENCE project. We have a feeling of changing the EU future, making it better for all of us.

Igone Velez and Matjaž Gams

PROGRAMSKI ODBORI / PROGRAMME COMMITTEES

Slovenian Programme Commitee

Matjaž Gams, co-chair
Boštjan Kaluža,
Mitja Luštrek,
Violeta Mirčevska,
Rok Piltaver,
Erik dovgan,
Božidara Cvetković

International Programme Committee

Igone Velez, chair
Thomas von der Grün,
Bartsch Carsten,
Stefan Gonnet,
Patrik Karlsson,
Eva Bergstrom,
Narciso González,
Fulvio Tamburriello,
Claudio Sdogati

SHORT-TERM VALIDATION METHOD FOR CONFIDENCE SYSTEM

Božidara Cvetković, Violeta Mirchevska, Erik Dovgan, Boštjan Kaluža, Matjaž Gams
Department of Intelligent Systems
Jožef Stefan Institute
Jamova cesta 39, 1000 Ljubljana, Slovenia
Tel: +386 1 4773498
e-mail: boza.cvetkovic@ijs.si

ABSTRACT

The aims of the Confidence system is the insurance of 24-hour virtual assistant for elderly people in order to replace hospital and caregiver assistance. This system is able to recognize falls and other hazardous situations, and request for caregiver assistance only when needed. In order to insure 24-hour quality assistance the system has to be robust and accurate. To ensure the performance of the system is always as accurate as possible we have introduced methods for short-term validation and for solving possible problems. Those methods will be used during the system fine tuning. After the fine tuning, the system will be ready for the real-life usage.

1 INTRODUCTION

The Confidence subsystem [1] was developed to prolong the independent life of the elderly. It consists of a set of modules that are more accurate if the characteristics of the current user are available. Therefore, these characteristics have to be inserted in the system during its setup. After the setup, the system has to be validated. We have focused on validating of two main modules: 1) activity recognition module and 2) statistics module. The module used for activity recognition [2] can distinguish between eight different activities: lying, standing, sitting, falling, going down, standing up, being on all fours and sitting on the ground. This module accuracy is crucial since all other modules depend on its prediction. To test its accuracy we have defined a scenario that consists a list of activities and appropriate system reactions. The second tested module namely statistics module learns from experience [3]. In real-life usage the module learns by itself. However, since a short-term validation is applied, specific short-term data has to be used as module experience. The validation is done by recording predefined sequences of activities including normal behavior and disability. The statistics module has to recognize the deviance in the human behavior when the scenario with expressed disability is tested. This paper presents the methods for short-term validation of the Confidence system functionality and for fine tuning the selected modules.

2 SCENARIOS

We have defined two scenarios for the short-term validation purposes. The first is the NurembergDemoFall (presented in Table 1) that is used for testing the activity recognition module and one of its submodules independently, namely alarm detection module. Alarm detection module is used to detect the user falls. The second scenario is the NurembergDemoStats (presented in Table 2) that is used for statistics module validation. In addition to validation purposes, both scenarios can also be used for learning purposes. In order to perform the described actions in the scenarios, the person should be a healthy individual able to simulate falls.

2.1 NurembergDemoFall

The NurembergDemoFall scenario presented in Table 1 contains a list of activities that activity recognition module is able to recognize. The scenario is a sequence of activities including normal activities that should not produce an alarm and activities that are considered as hazardous and therefore should produce an alarm.

#Action	Activity	Minimal duration	Description
1	Walking/standin g	5-10sec	**NO ALARM**
2	Sitting down		Sitting down to a chair with normal speed **NO ALARM.**
3	Sitting	5 sec	
4	Standing up		
5	Walking	5-10 sec	
6	Falling		Tripping forward **ALARM.**
7	Lying	10 sec	
8	Standing up		
9	Walking	5-10 sec	
10	Lying down		Lying down to bed normally
11	Lying	10 sec	

12	Standing up		**NO ALARM.**
13	Walking	5-10 sec	
14	Falling down		Loss of consensus **ALARM**
15	Lying	10 sec	
16	Standing up		
17	Walking	5-10 sec	
18	Sitting down quickly		Falling to the chair **NO ALARM**
19	Sitting	10 sec	
20	Standing up		Slide down when trying to stand up from the chair. **ALARM**
21	Sitting on the ground	10 sec	
22	Standing up		
23	Walking	5-10 sec	
24	Lying down		Falling down to the bed **NO ALARM**
25	Lying	10 sec	
26	Standing up		
27	Walking	5-10 sec	
28	Lying down		Lying down firstly on all fours and then lying when trying to reach something under a table **NO ALARM.**
29	On all fours	5 sec	
30	Lying	5 sec	
31	Standing up		
32	Walking	5-10 sec	

Table 1: *The scenario for activity recognition and alarm detection module validation, namely NurembergDemoFall.*

2.2 NurembergDemoStats

The second validated module is the statistics module. It detects abnormalities in human behavior. Therefore, the validation scenario is different with respect to alarm detection and activity recognition validation scenario. This scenario namely NurembergDemoStats presented in Table 2 consists of a list of activities that describe normal course of the day. The scenario starts with the sleeping in the morning and ends with the sleeping in the evening.

#Action	Activity	Minimal duration	Description
1	Lying	1 min	Sleeping
2	Standing up		Visit bathroom
3	Walking	10 sec	
4	Sitting down		
5	Sitting	10 sec	
6	Standing up		
7	Walking / standing	10 sec	
8	Sitting down		Eat breakfast
9	Sitting	10 sec	
10	Standing up		Clean up after breakfast
11	Walking / standing	30 sec	
12	Sitting down		Visit bathroom
13	Sitting	10 sec	
14	Standing up		
15	Walking / standing	10 sec	
16	Sitting down		Read newspaper
17	Sitting	20 sec	
18	Standing up		
19	Walking / standing	30 sec	Household chores
20		20 sec	Prepare lunch
21	Sitting down		Eat lunch
22	Sitting	20 sec	
23	Standing up		Visit bathroom
24	Walking		
25	Sitting down		
26	Sitting	20 sec	
27	Standing up		
28	Walking / standing	10 sec	
29		20 sec	Clean up after lunch
30	Sitting down		
31	Sitting	20 sec	Play solitaire
32	Standing up		
33	Walking	45 sec	Household chores
34	Sitting down		
35	Sitting	20 sec	Solve crosswords
36	Standing up		
37	Walking / standing	20 sec	Prepare dinner
38	Sitting down		
39	Sitting	10 sec	Eat dinner

40	Standing up		Visit bathroom
41	Walking	10 sec	
42	Sitting down		
43	Sitting	10 sec	
44	Standing up		
45	Walking / standing	10 sec	
46		20 sec	Clean up after dinner
47	Sitting down		Watch TV
48	Sitting	30 sec	
49	Standing up		Sleep
50	Walking	10 sec	
51	Lying down		
52	Lying	1 min	

Table 2: *The scenario for statistics module validation, namely NurembergDemoStats.*

3 VALIDATION METHOD

The described scenarios are used for the short-term validation of the system. The purpose of it is to test the system functionality and to validate its accuracy. In case the validation fails the method defines further actions. The following subsections describe the usage of the presented scenarios for the validation purposes.

3.1 NurembergDemoFall Scenario

The NurembergDemoFall scenario is used for validating the activity recognition and consequently the alarm detection module as described in Section 2.1. The validation is done by performing the scenario once. If the activities, alarms and normal situations are correctly recognized, the modules have passed the validation test. The correct module reactions are given in Table 1. The validation can be unsuccessful due to several reasons. For example, input data may be inaccurate as a result of inaccurate input system namely Ubisense [4] calibration. The calibration accuracy can be tested with the usage of the main Confidence screen, namely Control panel, precisely with the indicator of tag positions called side view (shown in Figure 1). Side view has to give the reflection of the real positions of the tags. In case the calibration is satisfactory and the validation fails the activity recognition module has to be additionally tested using the NurembergDemoFall scenario. During the test, the returned activities are shown on activity recognition panel (Figure 2) as part of Control panel. This panel indicates the currently recognized activity of the user. However, the activity recognition may need some time to settle on the activity, but this process duration is no longer than five seconds. In case the activity recognition test is unsuccessful we have to create a new activity recognition model for the current user.

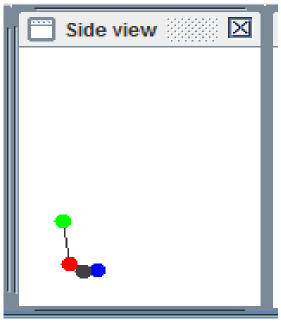

Figure 1: *Side view panel from the Confidence control panel. It indicates the positions of the tags in XZ space. Currently, the tags are in sitting position.*

In order to create a new model, the NurembergDemoFall scenario should be recorded at least four times to collect enough data. Afterwards, three recordings are used for model creation and one for testing the accuracy of the model. The model should be created with Random Forest algorithm in Weka software [5]. The model creation has to be done manually.

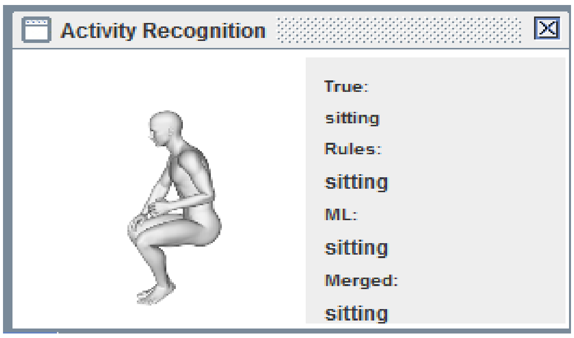

Figure 2: *Activity recognition panel used for monitoring the current activity of the user.*

3.2 NurembergDemoStats Scenario

This scenario consists of a set of activities that represent a normal day. By performing this scenario, the statistics module collects the walking, turning and activities specific user behavior data. Then it compares the current behavior data with the past behavior data in order to recognize significant behavior changes. This is done with the LOF algorithm [7] which does not build a behavior model since it uses the raw data each time when the degree of behavior change is calculated. Although the model is not required, several recordings have to be done in order to activate the statistics module, since the initial behavior data have to be achieved and LOF parameter values have to be defined, e.g., the bound of the returned degree for distinguishing between warnings (significant behavior change) and normal behavior (no significant change). Therefore, for the short-term validation the scenario NurembergDemoStats should be recorded at least five times to collect the behavior data. This data is taken as a normal behavior of the user. The parameters have to be set manually by clicking the appropriate button on the control panel. In real–life environment the parameters are set automatically after a week of recordings. Additional recordings can be done for testing purpose. In addition, one recording should be done with the same scenario but with expressed disability.

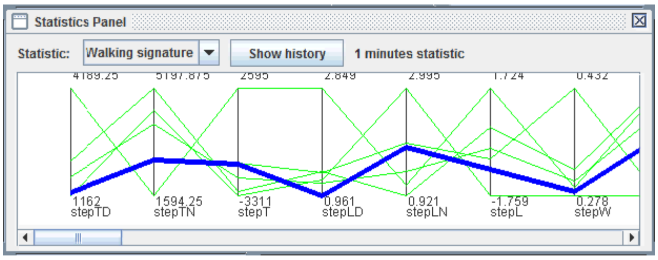

Figure 3: *Statistics panel indicating normal behavior by drawing a blue line on the graph.*

In order to validate the statistics module, two tests have to be done. The first test is consists of performing the scenario with the normal behavior. The statistics panel has to indicate a normal state by drawing a blue line on the graph as shown in Figure 3.The second test consists of performing the scenario with the abnormal behavior (e.g., limping). In this case the Statistics panel has to indicate that something is wrong by drawing an orange line on the graph as shown in Figure 4.

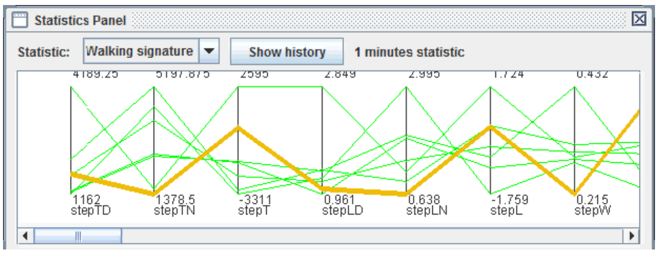

Figure 4: *Statistics panel indicating that it has detected an abnormal behavior. In this case an orange line is drawn on the graph.*

4 CONCLUSION

This paper presents a method for the short-term validation of the Confidence system. This method describes the validation steps, scenarios and actions that have to be performed in case the validation fails.

The further work includes the definition of a long-term validation as an extension of the short-term validation. It will also include the validation of the other modules.

References

[1] Confidence: Ubiquitous Care System to Support Independent Living, http://www.confidence-eu.org

[2] M. Luštrek, B. Kaluža. Fall Detection and Activity Recognition with Machine Learning. Informatica. pp. 205-212. 2009.

[3] M. Luštrek, B. Kaluža, E. Dovgan, B. Pogorelc, M. Gams. Behavior Analysis Based on Coordinates of Body Tags. In Proc. Ambient Intelligence. pp. 14-23. 2009.

[4] Ubisense. http://www.ubisense.net. 15 Sep. 2008.

[5] M. Hall, E. Frank, G.Holmes, B. Pfahringer, P. Reutemann, I. H. Witten. The WEKA Data Mining Software: An Update. SIGKDD Explorations. Volume 11. Issue 1. 2009.

[6] M. M. Breunig, H.-P. Kriegel, R. T. Ng, J. Sander. LOF: identifying density-based local outliers. Proc. of the 2000 ACM SIGMOD international conference on Management of data. pp. 93-104. 2000.

ADAPTATION OF THE CONFIDENCE SYSTEM TO THE USER CHARACTERISTICS AND HIS/HER NEEDS

Božidara Cvetković, Violeta Mirchevska, Erik Dovgan, Boštjan Kaluža, Matjaž Gams
Department of Intelligent Systems
Jožef Stefan Institute
Jamova cesta 39, 1000 Ljubljana, Slovenia
Tel: +386 1 4773498
e-mail: boza.cvetkovic@ijs.si

ABSTRACT

One of the key features of the Confidence system is a possibility of adapting the system to the needs and preferences of its user. The adapting process covers adapting the activity recognition expert rules to the user's posture characteristics and adapting to the preferences of the user. By adding this feature the efficiency of the system is increased and it becomes more user-friendly.

1 INTRODUCTION

The purpose of the Confidence system [1] development is to enable longer independent living for senior citizens. This system will be used by citizens who may not have any experience in using any modern equipment. Therefore the system has to be user-friendly. In order to achieve that we have developed several user-friendly features that can be adapt the system to the current user. The system is set up in the apartment or in the room where the user spends most of his/her day. Used rooms will be different for each user regarding the size of the room and the furniture arrangement. In addition, each user has specific physical characteristics, e.g., posture signature while performing daily activities, speed while performing these activities and height of the user.

The developed initialization procedure adjusts the system to the user It is implemented as a user-friendly wizard that enables defining several user-specific features, e.g., user height, apartment size and furniture positions. This paper presents the initialization procedure, all its steps as the user-friendly wizard.

2 INITIALIZATION PROCEDURE

Initialization procedure consists of four composed steps or categories:

1. System connection and initialization of the modules
2. Basic user information
3. Posture recording
4. Lying locations

The initialization procedure is presented in Figure 1.

2.1 Initialization steps

The task of the first step is the system initialization. It has to be carried out by the system administrator. Due to the real-time environment the system has to start collecting the data from the user in order to start the adaptation process. The data that will be recorded are the positions of the Ubisense tags [2] worn by the user. The second step adapts the system to the user needs. The third step is the most important step in system adaptation since it collects the posture signatures for up to five different postures. This is done as follows. Firstly, the user has to record three basic activities. Afterwards he/she has to choose if the recordings are satisfactory. If not, they have to be repeated. When the recording ends, the acquired data are used by the rule generator, that creates user-adapted rules for activity recognition. The fourth step defines the safe places. A safe place is a location where the user can lay without raising an alarm (e.g., bed). The initialization procedure is presented in details in the following subsections.

2.2 System connection and initialization of the modules

In this step the system is started. This is done as follows. Firstly, the connect button has to be pressed. Then wizard connects to the Ubisense and the database, and starts the system modules. The user can monitor the start-up progress in the white text area of the wizard. If the process of initialization and connection concludes without any problems, the returned message is black and the next button is enabled. Otherwise the returned message is red indicating that there has been an error during the initialization. Modules that have been successfully initialized are marked with OK while ERROR indicates the module and the time when the error occurred. Each error is followed by an explanation how to correct the problem and restart the system.

2.3 Basic user information

This step collects the following data:

1. Name or Code
2. User height

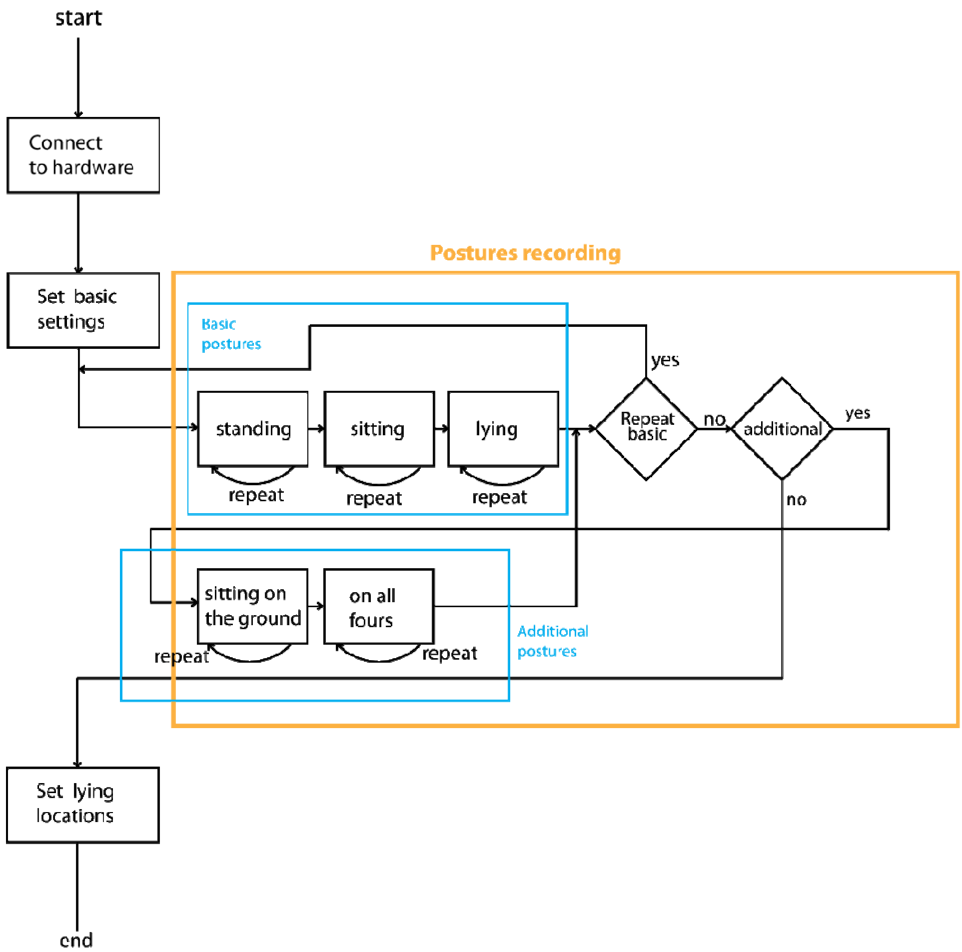

Figure 1: *Diagram of the initialization procedure.*

3. Time for statistics
4. Recording time

The user can be identified by the personalized code or with his/her name. This information is used for personalization of the messages send to the user. The height of the person is used for adapting the alarm detection modules to the user and for scaling the attributes of machine learning model used in activity recognition procedure.

By defining the third parameter, the user chooses when the daily statistics information will be shown.

Finally, the user can define the length of a single recording. If the user is prepared to record longer activities, the recording time can be set to up to five minutes. The shortest activity sequence is set to 30 seconds. However, longer recording time is preferred since more data the system has, more accurate will the generated rules be.

After defining the requested data the user has to submit the information by clicking the save button.

2.4 Posture recording

This step starts with the recording of the basic activities. These activities are standing, sitting and lying. Basic activities are simple and therefore the elderly should not have any problems performing them. The timer on the right side of the screen indicates the time of the current recording. When the required time for the recording elapses, the user

Figure 2: *Posture recording screen showing the recording of the sitting posture.*

can progress to the recording of the next posture. In order to proceed, the recording has to be stopped by pressing the stop button. An example of the posture recording screen is shown in Figure 2.

Figure 3**:** *Recording of the standing posture and waiting for the user to press the start button.*

After the recording time expires, the user can choose to:

- Stop the recording of the current posture (Figure 3)
- Delete the data for the currently recorded posture (Figure 4)
- Repeat the recording for the current posture (Figure 4)

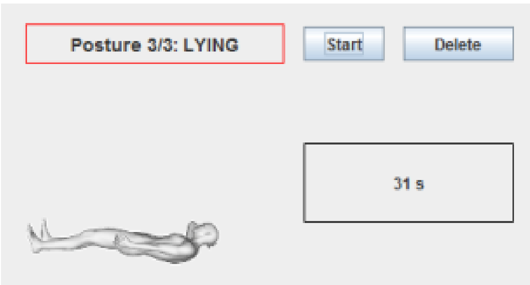

Figure 4: *The user has stopped the recording of the lying posture. The wizard wants to know what would be the next step (e.g., delete the sequence, start again).*

While recording the **standing** posture, the user should stand and walk. During these activities the system collects the information of the user's walking signature.
Sitting activity should be repeated on every sitting location in the room. The user has to sit at each location for the recording duration until stop button is pressed. The recording at a location starts when the start button is pressed.
Lying posture should be recorded at any location where the user may lay. This recording will give the system height of all lying locations as well as posture characteristics. During these recordings the height of the lying locations (e.g., bed) is collected. In addition, posture characteristic are also collected.
In the initialization procedure the recordings of three basic postures are compulsory. Therefore, when these recordings are concluded, the user can end the recording step. However, if the user is prepared to continue the recording, he/she can record additional recordings of the same postures or can record additional postures. These processes are started by pressing the appropriate buttons on the selection screen (Figure 5).

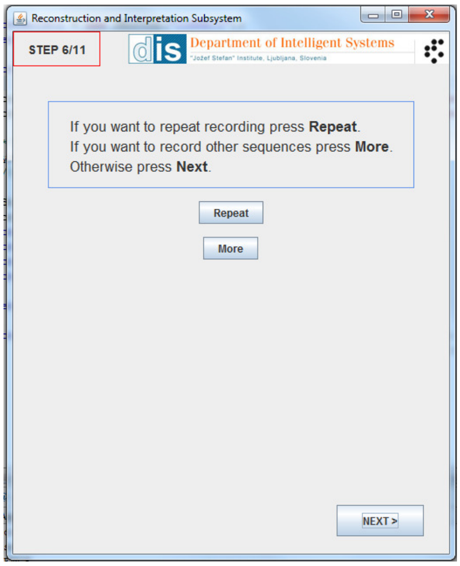

Figure 5: *Selection screen enables to repeat the recording of the basic postures or to record additional postures.*

When the recording concludes, the initialization system generates user-specific expert rules for activity recognition. The rule generator algorithm can be found in [3].

2.5 Lying locations

The initialization procedure concludes with the definition of the lying locations. These lying or safe locations are the locations where the user will lie to sleep or lie down to exercise. The safe locations screen (Figure 6) contains a table in which the user enters the coordinates of the lying locations. The image above the table depicts the direction of coordinates (Figure 7). All locations can be tested by pressing the test locations button that will draw the locations on the room map.

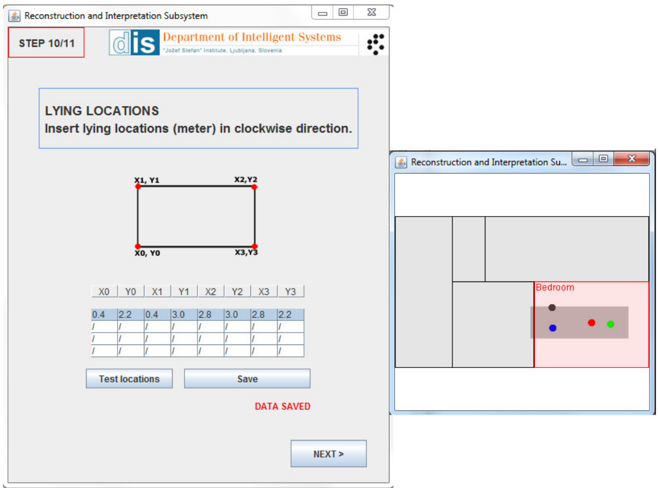

Figure 6: *Definition and test of the safe locations.*

At the end of the initialization process two files are created: (1) person.conf, that contains general user information (e.g., name, user height, places where the user may lay, time when the user wants to get information from the statistics module) and (2) activityRE.txt, that contains a rule engine for activity recognition. The usage of these expert rules increases the accuracy of the activity recognition module. The activity recognition has to be accurate since it is the key part of the Confidence system, since the entire human behavior analysis is based on it [4].

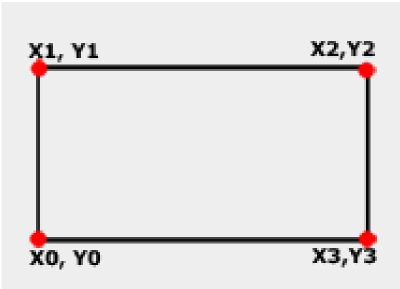

Figure 7: *Direction of the bed coordinates. It is important to test if the bed is on the right positions after pressing save button.*

3 CONCLUSION

The initialization procedure introduces a user-friendly adaptation process. With the adaptation the accuracy of the activity recognition is increased. Besides, the accuracy of the alarm detection is also increased since the rules for detecting alarms are personalized.

References

[1] Confidence: Ubiquitous Care System to Support Independent Living. http://www.confidence-eu.org.

[2] Ubisense. http://www.ubisense.net. 15 Sep. 2008.

[3] V. Mirčevska, M. Luštrek, M. Gams. Combining machine learning and expert knowledge for classifying human posture. In Proceedings of the Eighteenth International Electrotechnical and Computer Science Conference ERK. vol. B. pp. 183-186. 2009.

[4] M. Luštrek, B. Kaluža, E. Dovgan, B. Pogorelc, M. Gams. Behavior Analysis Based on Coordinates of Body Tags. In Proc. Ambient Intelligence 2009. pp. 14-23. 2009.

CONFIDENCE INTERPRETATION AND PREVENTION SYSTEM

Erik Dovgan[1], Božidara Cvetković[1], Violeta Mirchevska[2], Boštjan Kaluža[1], Mitja Luštrek[1], Matjaž Gams[1]
[1]Department of Intelligent Systems, Jožef Stefan Institute
Jamova cesta 39, 1000 Ljubljana, Slovenia
Tel: +386 1 4773393; fax: +386 1 4773131
[2]Result d.o.o., Bravničarjeva 11, 1000 Ljubljana, Slovenia
e-mail: erik.dovgan@ijs.si

ABSTRACT

This paper presents the interpretation and prevention system as a part of the product developed at the EU FP7 project Confidence. This system is able to detect falls and general disability. The tests show that it is reliable and ready for real-world usage.

1 INTRODUCTION

This paper presents the work at the work package 3 of the EU FP7 project Confidence [1]. The main objectives of this work package are the development of a subsystem that reconstructs the user's body in the environment and the development of a subsystem that interprets the body posture within the environment producing an alarm when hazardous situations are detected. Both subsystems have to be integrated in the final system that must be able to gather user position and acceleration from a real-time position and acceleration systems and has to send alarm messages about the detected hazardous situations to an independent portable device. This device is used to communicate with the user and is able to decide whether a hospital or a specialized care-giving institution has to be noticed.
The described system has already been developed. It uses the Ubisense, a real-time localization system [2], and an acceleration system developed at the Fraunhofer Society [3] in order to get the positions and accelerations of the user from dedicated body tags and sends the alarm messages to a simulated portable device. The next steps are the integration of the system with the systems of the other partners on the Confidence project and extensive tests. The system is presented in details in the following sections.

2 IMPLEMENTED SYSTEM

The presented system recognizes hazardous situations from user's movement and reports them to the user/caregiver. In order to do that, several modules have been developed and integrated in the final system. In the following subsections we firstly present the architecture of the whole system. Secondly, we present each module/method that has been developed. Besides, we present the interface that was developed as an extension of the portable device, namely control panel, for the advanced users, system developers and for presentation purposes.

2.1 System architecture

The system has been developed as a set of independent modules/threads. They are organized as a pipeline where a module gathers the data from the previous module(s), processes them and sends them to the next module(s) in the pipeline as shown in Figure 1. The main modules are the reconstruction modules (consisting of posture modules) and interpretation modules (consisting of interpretation and prevention modules). In addition, the communication modules were also implemented that communicate with a localization system and portable device, and that show the system status in details on the computer screen.
The following subsection describes each of the modules in the pipeline. For each module we present its functionality,

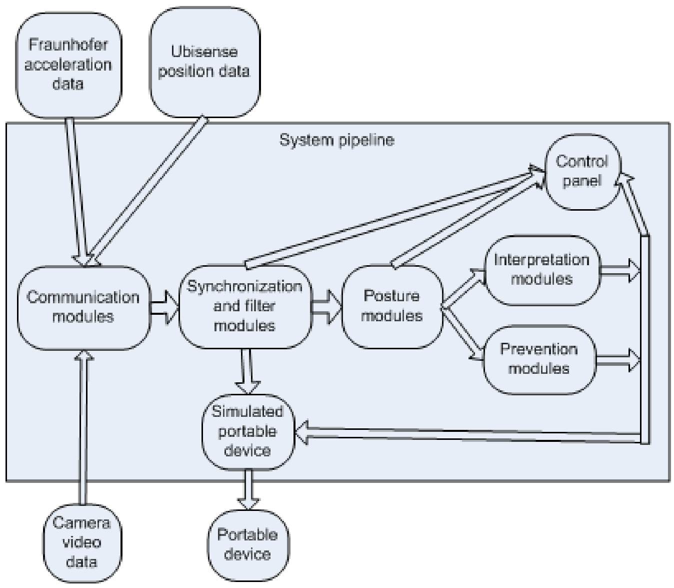

Figure 1: *System pipeline*

Figure 2: *Portable device normal screen*

the previous modules from which it receives the inputs, and its outputs.

2.2 System modules

The first modules of the pipeline are the communication modules that gather the localization data from the Ubisense localization system and the acceleration data from an acceleration system developed at the Fraunhofer Society. In addition, they are able to receive the data from a camera for demonstration purposes. They work asynchronously since the input devices are not able to synchronize with other systems. The received data is stored in a queue in order to be preprocessed with higher-level modules.

Besides the communication modules for sensor data there are two modules that communicates with the user. The first one is the (simulated) portable device. It sends the messages produced by other modules to the user. These messages are short, simple and understandable. When there are no problems, it shows the message in Figure 2. When a button with no special function is pressed, a help screen is shown (Figure 4). The other messages are related to the specific modules and shown in Figure 9 and Figure 11.

In addition to the simple portable device screen, the system has the advanced control panel module. This module shows the system current status and the status of all modules as shown in Figure 3. The screen is divided in the following

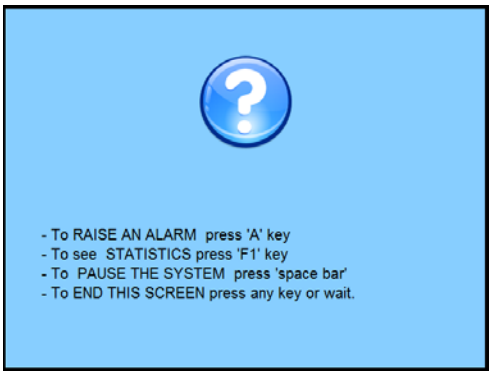

Figure 4: *Portable device help screen*

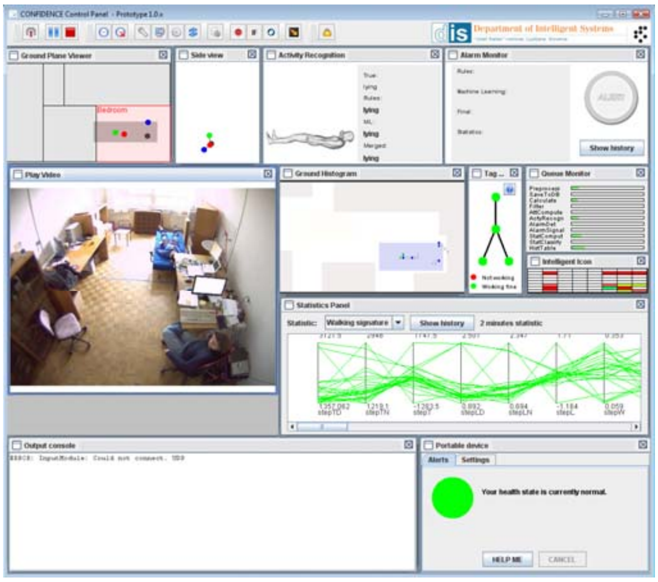

Figure 3: *Control module*

areas. Ground plan viewer and side view show the position of the user (his/her tags) in the controlled rooms and his/her posture. Besides, they show the positions where the user is allowed to lay and the current room name where the user is, as shown in Figure 5. Tag status and queue monitor show the system status, precisely its possible problems as shown in Figure 6. Tag status shows the working and non-working tags while the queue monitor shows if the data in the pipeline are processed in real time or if there is some problem and the data is not processed in real-time, which is shown as data accumulation in some of the showed queues. Video screen shows the current video if the camera is present as shown in Figure 3. At the bottom left side of the screen the system errors are shown. At the bottom right side the simulated portable device is shown. The other windows are connected with the functionality of the other modules and therefore are presented in the following figures: Figure 7 for activity recognition, Figure 8 for alarm monitor, and Figure 10 for ground histogram, intelligent icon and statistics panel.

The data from the communication modules for sensors are sent to the next modules in the pipeline, i.e., synchronization and filter modules, that have two tasks. Firstly, they synchronize the data from different inputs. This is done with a lower frequency compared to the

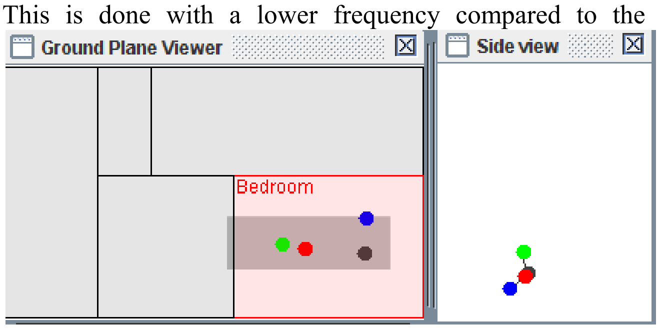

Figure 5: *Ground plane viewer and side view*

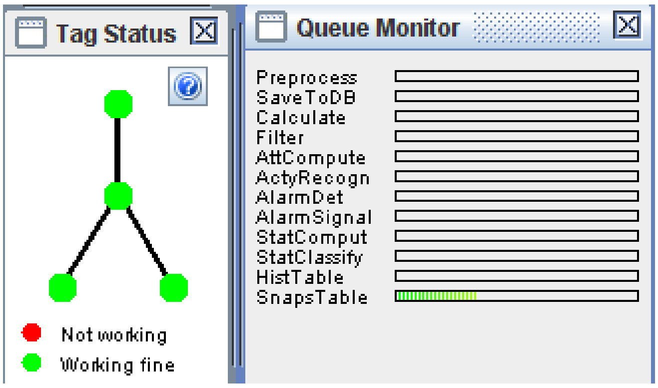

Figure 6: *Tag status and queue monitor*

Ubisense frequency in order to have at least the position data of all body tags. Nevertheless, some position (and acceleration) data can be missing. In order to bypass these shortages the filter modules approximate the position of missing tags. The second task is to filter the noise and smooth the tags' data. This is done with six independent methods. For example, one method corrects the data by taking into account the body anatomic constraints.

The filtered data is the input to the posture modules. These modules consist of two modules working in parallel. The first module uses Random forest classifier [4] in order to get the current user posture, e.g., sitting, standing and walking. The second module consists of expert-knowledge in the form of a set of rules that classifies the current posture. The final posture is selected using heuristics and Hidden Markov Models [5] for smoothing the posture transitions. The detected user posture is shown on the control panel (Figure 7).

At the end of the posture modules the pipeline data flow splits into two directions since user posture is used as the input to the two sets of modules: interpretation and prevention modules.

Interpretation modules detect situations that are potentially dangerous for the user. An example is the user lying immovable for a prolonged time at an unusual place. Such situation may indicate that the user has lost consciousness.

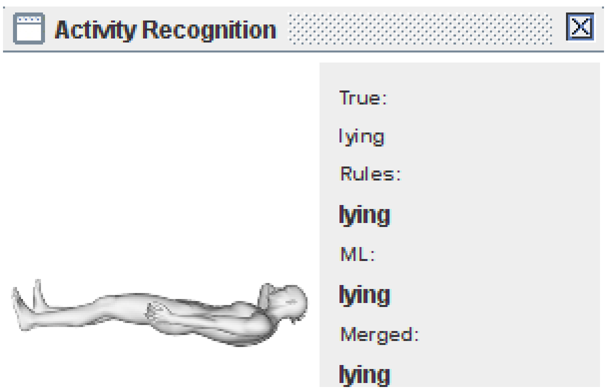

Figure 7: *Activity recognition showing the current activity*

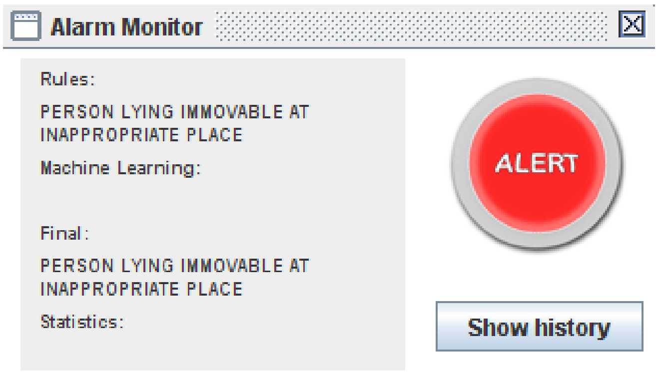

Figure 8: *Alarm monitor showing an alarm*

This is potentially hazardous/alarm situation and therefore it is reported to the user and in the case that there is no response from the user, the hospital or care-giving center is informed. In order to recognize hazardous situations two modules have been implemented. The first module uses expert knowledge while the second uses machine-learning algorithms in order to recognize alarms. The expert knowledge was retrieved from experts' know-how while the machine-learning algorithms, namely C4.5 [6] and SVM [7], use prebuilt models. The final decision is given by fusing both predictions using heuristics. If an alarm is produced, it is shown in control panel (Figure 8) and portable device (Figure 9).

Prevention modules monitor how the user moves and recognize the development of a disability. This is done by collecting the statistic data about the user movement, i.e., monitor user behavior. When monitoring the behavior for a prolonged time, the changes in behavior can be observed. If the change is significant, it may indicate that something is wrong with the user, e.g., if the user begins to limp, he/she might have had a stroke. The behavior change is calculated with LOF [8]. The collected statistic data are gait, turning, activity and spatial characteristics, which are constantly updated with the recent behavior that enables automatic adaptation to the user behavior. When the modules recognize a change at any of those statistics, a warning is fired and shown on the control panel (Figure 10) and

Figure 9: *Portable device showing an alarm*

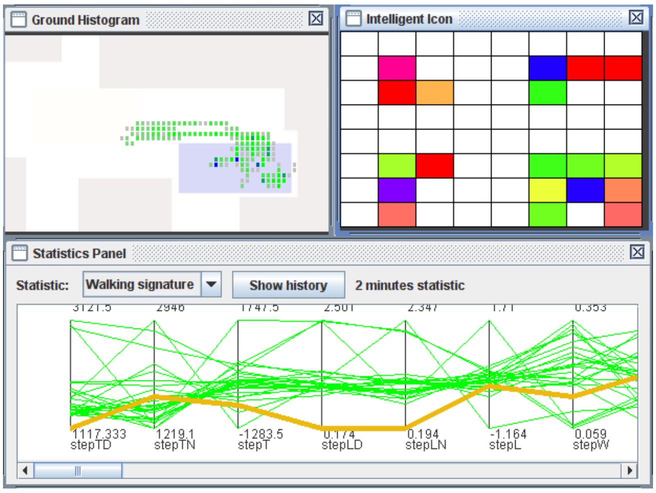

Figure 10: *A warning showed in control panel with the yellow line*

portable device on user's request (Figure 11).

3 MANUALS

Several manuals have been produced describing the presented system and its functionalities. The first one it the System manual that describes the whole system and all of its modules in detail. In addition, it describes the installation of the system and the tag placement.

The second manual is the Recording instructions. It presents how a user can record the data for testing purposes step-by-step. In addition, the preferred scenarios for testing are also described.

The third manual is the User manual that describes the portable device and the possible interaction with it. It shows all the possible screens and messages and the keys that can be used to manipulate with the portable device.

The last manual is the Init wizard. It describes the required initialization of the system when it is used for the first time. It also describes which actions have to be recorded, possible errors during the initialization, and which data must be inserted by the user.

4 SYSTEM TESTING

The system testing was focused on the interpretation and prevention modules. Therefore, the interpretation modules were tested with the following scenarios, where the accuracy is given in brackets: a normal behavior (100%), lying down normally (100%), tripping (97%), fainting (91%), sitting down quickly (possible false alarm, 97%) and lying down quickly (possible false alarm, 100%). In addition, the prevention modules were tested with the following scenarios where results are given in brackets: a normal day (no warnings), a limping day (all the statistics produced at least one warning out of five behavior testing) and a slow day (all the statistics produced at least one warning out of five behavior testing, one statistic produced four warnings).

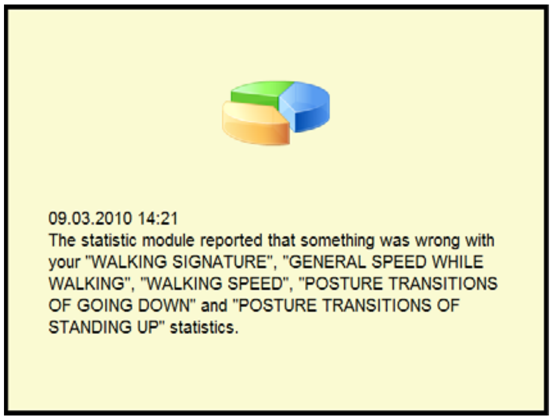

Figure 11: *Portable device showing a warning*

5 CONCLUSION AND FUTURE WORK

This paper presents the system implemented for the work package 3 of the EU FP7 project Confidence. It describes the functionally of the whole system and all its modules. The tests show that the system is reliable and is ready to be tested in the real world.

The future work includes the long-term testing. In addition, this system has to be integrated with the other systems into the final product.

ACKNOWLEDGEMENTS

This work was partly supported by the Slovenian Research Agency under the Research Programme P2-0209 Artificial Intelligence and Intelligent Systems, partly from the European Community's Framework Programme FP7/2007–2013 under grant agreement No. 214986 and partly by the European Union, European Social Found.

References

[1] Confidence. http://www.confidence-eu.org.
[2] P. Steggles, S. Gschwind. Ubisense – a smart space platform. Technical report. Ubisense. 2005.
[3] Fraunhofer. http://www.fraunhofer.de.
[4] M. Lustrek, B. Kaluza. Fall detection and activity recognition with machine learning. Informatica 33(2). 2009. pp. 197-204.
[5] L. R. Rabiner. A tutorial on Hidden Markov Models and selected applications in speech recognition. Proc. of the IEEE 77 (2). pp. 257-286.
[6] J. R. Quinlan. C4.5: Programs for Machine Learning. Morgan Kaufmann Publishers. 1993.
[7] N. Cristianini, J. Shawe-Taylor. An Introduction to Support Vector Machines and other kernel-based learning methods. Cambridge University Press. 2000.
[8] M. M. Breunig, H.-P. Kriegel, R. T. Ng, J. Sander. LOF: identifying density-based local outliers. Proc. of the 2000 ACM SIGMOD international conference on Management of data. 2000. pp. 93-104.

ETHICAL ASSISTIVE ICT CAN ENABLE FREEDOM OF CHOICE OF OLDER USERS

Narciso González, Anna Kämäräinen, Outi Kalla
AGORA Human Technology Center
University of Jyväskylä
Mattilanniemi 2, 40014 Jyväskylä, Finland
Tel: +358 14 260 4426; fax: +358 14 260 4400
e-mail: narciso.gonzalez-vega@jyu.fi

ABSTRACT

The goal of this paper is to present the ethical issues that were relevant at the concept development stage and during the CONFIDENCE project. We propose that the technology must support principles such as human rights, privacy, safety, and dignity. The voluntary contribution of people as participants in research must follow ethical review boards scrutiny of research plans. Also informed consent processes and procedures must be observed in this realm. Important challenges involve ethical issues arising in heterogeneous fields which involve technology, end users, service providers, and informal caregivers. Attempting to maximise the ethical compliance of the results of this ICT project, we explore and suggest preventive measures for possible scenarios of misuse of this or related technology. Concluding, the observation of ethical principles throughout the development process can empower users to make informed decisions on the acceptance of ICT systems and services when these reach the market.

1 INTRODUCTION

The population of the world is growing older and the dependency ratio is increasing in parallel [1]. This demographic phenomenon imposes socioeconomic burdens on the older people, their caregivers, and the health and social care systems [2]. Information and communication technology (ICT) developments can contribute to reduce these multilevel burdens [3].

The project Ubiquitous Care System to Support Independent Living (CONFIDENCE), aims at enabling older people to live in their preferred environment, i.e. their own home, as long as possible with the support of ICT technologies. The system will be able to identify harmful situations, such as falls, and anomalous conditions such as reduced functional ability in the performance of activities of daily living (ADL). Wearable radio frequency (RF) sensors and communication channels are the technologies that support these functions. A more detailed description of the system is presented in [4].

The successful development of this system cannot be conceived without the involvement of older people and relevant stakeholders. This technology involves motor behaviour monitoring and the transmission of information to emergency services or other designated people. This information includes personal identification and the condition of the person, e.g. the person has fallen down. Adherence to ethical principles is of utmost importance in these circumstances.

This paper reports the ethical issues that appeared relevant at different stages of this multidisciplinary research and development project. One ethical aspect is directly associated with the technology under development and how this can affect the potential users would it becomes available on the market. Another ethical aspect within the project is the voluntary contribution of older people and care experts. Some scenarios in which this type of technology could be misused are also presented.

These aspects can be extremely important also for other research and development projects using the same or analogous technologies, as well as for commercial applications. In particular, researchers in the areas of ambient assisted living (AAL), ICT and ageing, eInclusion, and eHealth could benefit from the results of this research.

Additionally, an adequate consideration of the potential ethical issues that can emerge when an ICT system or service is taken into use may contribute to improve user acceptance of the technologies and services. Consequently, a business advantage for such systems could be expected.

2 OBJECTIVES

This paper aims at presenting the ethical issues that appeared relevant at the concept development stage, as well as those which arise during the project and at raising awareness of the potential scenarios in which the technology adopted to implement the CONFIDENCE system might be misused

3 METHODOLOGY

At the concept development stage we reviewed literature on ethics and research papers related to technology and functions analogous to the CONFIDENCE system. These included radio frequency identification (RFID), care systems, personal emergency response systems, and social alarm systems. Data were also collected from voluntary participants through semistructured interviews with older people living independently and focus groups of care service experts. Similar research activities were carried out in Italy and Sweden. In this paper only the results obtained in Finland are reported. Twenty three and 10 older people participated respectively in 2 needs and requirements elicitation studies. Semistructured individual interviews were used to collect information from end users. Care experts participated in focus groups also in 2 research occasions (respectively 10 and 5 experts) with similar requirement elicitation purposes. Both end users and experts provided their opinions on the compliance of the system with ethical principles in addition to the questions directly addressing the requirements for the system.

4 DESCRIPTION OF THE SYSTEM

The CONFIDENCE system prototype consists of wireless RF sensors/tags, a processing unit or base station, and a portable device. The portable device serves as the interface between the user and the system. The software modules localise the tags worn by the user in the three-dimensional space, reconstruct the bodily position of the user, and interpretation algorithms discriminate among normal, emergency, and increased risk level situations. The users are able to control whether the alarms are forwarded to an alarm receiver or not. The intelligence and predictive capabilities of the system represent some of the main innovations of CONFIDENCE.

5 RESULTS

Ethics in the Development of ICT

Ethical issues related to research with human participants are mature. However, when technological innovations are considered, such as CONFIDENCE, there might be issues hard to foresee and arduous to handle. At the beginning of the project, we reasoned that the system ought to support principles such as basic human rights, safety, privacy, integrity, and dignity [5]. It also became apparent that the European and national regulations on personal data processing were relevant [6], [7].

Freedom is perhaps the most valuable of the human rights achieved by human kind. The technology employed in this system shall respect the freedom of choice of the user. The user will be able to decide whether to use the system or not. This might seem obvious. For instance, one has the right to switch on and off the TV. Nevertheless, in the future of interoperable health and care ICT products and services the freedom to use a certain component of the system or not, e.g. a monitoring device which causes inconvenience to the user, might not be so clear. The end user may be responsible for handling appropriately a number of devices in order to obtain an adequate level of care or health service. It can be assumed that the service received depended on the concurrent operation of e.g. 2 devices but the end user switched off one of these. In this context, the service provider could be exempted from responsibility in the case of failing to handle an emergency occurring to the end user. We could imagine that the device the end user switched off, jeopardising his or her safety, was the only one providing user access key to the service. Undoubtedly, this hypothetical case should be prevented by a system which demonstrates sufficient transparency and operative robustness.

The system collects and processes information concerning the users, i.e. 3D bodily posture and motor activity acquired through (RF) tags and sensors [8]. Initially, the mechanism implemented by CONFIDENCE to comply with data processing regulations has been to assign the role of data controller to the user. This is, the data collected and processed by the system belongs to and is managed by the user.

Privacy is also respected because the system is not intended to share data with other systems or services. However, a commercial product based on the CONFIDENCE prototype, might well involve different service providers and interoperation with other care or health systems. The mechanisms to assure respect of privacy in this context should be reanalysed and redesigned as the original settings would not suffice. Ethics and privacy issues in the context of Ambient Intelligence systems can also be found in [9].

The information is relevant for detecting falls and other behaviours that may relate to health problems, and to summon help when there is an emergency. It can be assumed that the principles of beneficence, purpose, and proportionality are satisfied by the current state of development.

The user controls whether an alarm procedure is initiated or not, except when the person is not capable of acknowledging this situation, for example, when the person is unconscious. In the latter case, the system initiates the alarm without the explicit consent of the user at this particular moment. Information and training to the user before adopting the system should guarantee that the informed consent of the user for this situation has been declared in advance of these potential hazardous events.

Ethical aspects in the research with humans

The pioneering field in which ethical guidelines appeared to safeguard the rights of the human participants in research was medicine [10]. Other disciplines such as the social and behavioural sciences and engineering have followed [11], [12]. These have also provided their associates with codes of conduct and ethical guidelines. Freedom, respect for life, justice, beneficence, and privacy are the most salient human rights contemplated in ethical guides.

The project consortium is multidisciplinary and multicultural. In alphabetical order, Finland, France, Germany, Italy, Slovenia, Spain, and Sweden participate in the project. An ethical manual was elaborated [13] in the beginning of the project. This serves as the common ethical reference for the R&D process. Several research activities within CONFIDENCE required the participation of older people, health and social care experts, and family members, or others providing care to older people.

Following a pragmatic approach, two of the partners carrying out research with human participants have established internal ethical committees for this project within their organizations. We direct ethical enquiries to the institutional ethical committee of the university. Ethical approval for two needs and requirements elicitation studies has been obtained from the respective ethical committee of each research site.

During the information consent process, the information sheet and the informed consent were offered to the participants. A requisite for participation in the research was to read and listen to the information provided by the researcher, confirm that the information had been understood, and sign the informed consent form. The information sheet indicated that their participation was voluntary and invited them to read the explanation of the studies. This also stated the purpose of the research, the procedures involved, the potential benefits, risks, discomforts, and precautions of the research. It also described the alternative procedures available to them. In our case, it was indicated that no alternative treatments were available, as these studies did not involve treatment to the participants. The right to withdraw from the study at any time without consequences was also stressed. Confidentiality and anonymity of the information they provided was assured. Their identity will not be disclosed in scientific or other publications, or to third parties. The participants were also reminded of their rights concerning the processing of personal data.

Another section of the information sheet considered the possibility of obtaining incidental findings. These may have significance for the health or well-being of the participant. Often, incidental findings are associated to biomedical research but can appear in other fields as well. Therefore, the participants were asked whether they wanted to be informed or not. Finally, information and contact details were supplied about the persons they could contact concerning the research, i.e. the principal investigator, and the ethical committee which had approved it.

One issue raised by these ethical reviews has been the comprehensibility of the information provided to the participants describing the research. Therefore, we modified this information to ensure that the participants understood unequivocally the purpose of the research and their role. Further research such as usability studies with prototypes of CONFIDENCE will follow similar ethical reviews.

The researchers described the CONFIDENCE system in such a way that the essence of its components and operation was maintained while the participants comprehended this technology. For example, the technical references to communication protocol standards were obviated while the older people and experts understood the principles involved in the RF communications used for the localisation of tags in space. Adding references to the particular standard protocols employed by the system would only cause unnecessary distraction of their attention in the research situations.

Ethical concerns of the participants

In the beginning of the project, 23 older people participated in individual semistructured interviews aimed at collecting information about their needs and requirements for the design of CONFIDENCE. When the end users were asked for the first time about integrity, 18 of the 23 end users considered that the system could violate their integrity. In a follow up question, they characterized their answers about integrity as an abstract concept. Some manifested that the relevance of the system to the end user may justify the use of this technology. Quoted from two end users, they thought that the "system does not violate privacy, if the information collected is confidential" and "if obtaining help relies on the technology, it doesn't violate integrity". However, they also thought that constant monitoring could violate their privacy.

The participants had positive attitudes towards using tags at home. Twenty respondents would use tags. Similarly, 19 of 23 would accept the presence of tags in clothes.

Semistructured interviews with end users at a later stage of the project involved 10 participants. Eight participants thought that the system would not violate their privacy or integrity. However, 8 participants preferred hidden sensors and tags. Our interpretation is that unnoticeable devices would help them to maintain their dignity. If these devices could not be perceived or interpreted by others as care technology the self-esteem of the user would not be affected.

The participants had doubts about who could access the information and if it could be possible to misuse it. One participant pointed out that legal aspects should be considered carefully and formulated "who is allowed to investigate the location of the user?"

Additionally, we asked the participants to provide their opinions about the ethical issues that could arise from using CONFIDENCE. Care experts, who participated in focus groups and end users, reported that the system, as presented to them during these research activities, seemed to respect the rights of the users in terms of privacy, autonomy, integrity, and dignity.

Possible scenarios of misuse

Within the consortium we research, explore, and suggest options to prevent possible scenarios of misuse of this technology. A non exhaustive set of potential cases where this or similar technologies could be misused are presented.

One case, as pointed out by end users, concerns the disclosure of information concerning the ADL of the users. For example, family caregivers might obtain information from the care system about how the older person is doing by default or by setting this feature on the system, e.g. how long time the user is staying at home or how long time this person is going out. Under normal circumstances the users might tell these caregivers about their whereabouts by own initiative. However, in some other circumstances the user might want to keep this information private. In the latter case the user must be able to easily, i.e. not requiring advanced knowledge of the operation of the system, switch on and off the capability of the system to share this information with another person. Yet still in some other circumstances doing so might represent a hazard for the user. Imagine a user with limited cognitive ability that becomes disoriented when leaving the household and is incapable of returning back without assistance. Some ethical dilemmas can emerge even though attention had been paid to these issues in the design and development process of a given care system. By design, such a system could support the rights of self-determination, autonomy, and privacy of the user in some circumstances. On the contrary, under subtly different circumstances some or all of these user rights, including freedom, might not be guaranteed. The rights of the end user might have been handed over to a legal custodian or representative. This could be the case when the rights of the person are in conflict with his or her personal safety. Further elaborations on the use of RF identification and its implications on privacy and freedom can be found for example in [14].

Another scenario that we have considered is the use of information collected by the system for purposes for which it was not intended. A case can be considered where a health insurance company has provided a system such as CONFIDENCE to the older person. The purpose of the system as informed by the insurance company would be to allow the person to obtain help when is needed whether the user is able to summon help or not. The insurance company also has information about the functional ability of the person and by means of this information decides to adjust the coverage or the premium of the insurance policy. There should not be any argument against this practice if these conditions are crystal clear to the user when the insurance agreement is made. In other circumstances, the ethicality or the legal validity of this practice would probably not be supported. By own experience, the terms and conditions of insurance policies are, in general, complex and difficult to understand for the vast majority of the non-professional customers. Therefore, in general, clear and understandable terms and conditions of the insurance providing the system must be guaranteed.

Profiling the user by means of the information gathered by the system for purposes such as advertising or selling products or services must be prevented. This case also falls within the realm of using the system for unintended purposes. A hypothetical situation could materialise with relative ease if we consider the business of proximity marketing enabled for example through Bluetooth connectivity. Self-determination, autonomy, dignity and freedom could be at stake if the users are not informed and have not consented unequivocally to receive this form of advertising. There are similarities with the phenomenon of spam e-mail messages that we experience so often or the unsolicited telephone calls and direct mail marketing that was more prevalent a few years ago.

There will be situations beyond the capacity of the technology to prevent misuse if the users are not aware of the risks involved and the protective actions that they can perform. Furthermore, the users will likely find new uses for which the system was not conceived. To prevent situations like these, the only precaution possible is to ensure that the user is properly informed about the functions of the system and the possible hazards.

Conclusions

The CONFIDENCE project continuously considers ethical issues and data processing regulations from the outset. The partners in the consortium are aware of the ethical issues that may appear as a result of the technologies employed in this R&D activity, and as the users interact with the system. Ethical committees review and provide opinions on the research plans involving human participants. Their opinions have been used to improve the comprehensibility of the information presented to the participants. They cannot make free decisions when the research situation is not completely understood. These have also reassured that the research procedures would not jeopardise the rights of the participants or harm them. According to the opinions of research participants, personal data processing, privacy, and dignity do not seem to be at stake within the development of the project.

The system, as a possible commercial product, shall implement each of the available mechanisms to protect the privacy, dignity, and safety of the older people. Misuse of the system shall be prevented through design and information to the users specifying how they can contribute to maintain their privacy and safety. As a corollary, assistive ICT aimed at supporting older people's independence shall include privacy enabling mechanisms such as access keys and data encryption as minimum specifications.

The contribution of voluntary participants to this project is an invaluable resource towards the development of ethically compliant technologies such as CONFIDENCE to assist older people in the maintenance of their independent living.

We trust that our dedication to ethical issues during the project will transfer to ethically compliant and acceptable commercial applications for the benefit of older people. Products and services that do not comply with ethical principles, such as the ones described in this paper, may render ICT products and services unacceptable for potential users or customers. The reverse could significantly contribute to the success of the product in the market if other necessary requirements are also satisfied, e.g. utility, usability, acceptability, and affordability to name a few. This is also applicable to AAL, eHealth, and other ICT systems which may impact on the freedom, privacy, and dignity of the person.

We would thus recommend to take a systematic ethical standpoint from the start of any ICT concept formation, e.g. AAL or eHealth. The potential end-users, and other stakeholders, e.g. formal and informal caregivers, health professionals, service providers, should be consulted. The information collected should then be translated into the technical specifications and implementations. Development cycles representing changes in the original plans should be accompanied by a revision of the ethical issues through the consultation of users and stakeholders. Additionally, providing comprehensible and sufficient information to the users will be the only means to empower them to make informed decisions. Finally, this process will support their dignity, privacy, and freedom also when they consider acquiring AAL, eHealth, or other systems and services to support their independence and participation in society. In our opinion, this could make a difference between successful and unsuccessful commercial systems.

Acknowledgements

The research leading to these results has received funding from the European Community's Framework Programme FP7/2007-2013 under grant agreement nº 214986.

The Finnish people participating in these research and the interviewers are gratefully acknowledged for their contribution.

CONFIDENCE Consortium: Centro de Estudios e Investigaciones Técnicas de Gipuzkoa, Fraunhofer Institute for Integrated Circuits, Jozef Stefan Institute, IKERLAN-IK4, COOSS Marche, University of Jyväskylä, Umeå Municipality, eDevice, CUP 2000, and ZENON Automation Technologies S.A.

References

[1] United Nations. World Population Prospects: The 2004 Revision. New York, USA, 2004.

[2] World Health Organization. WHO Global Report on Falls Prevention in Older Age. Geneva, Switzerland, WHO, 2007.

[3] J. L. Fozard, J. Rietsema, H. Bouma, and J. A. M. Graafmans. Gerontechnology: Creating Enabling Environments for the Challenges and Opportunities of Ageing. Educational Gerontology, 2000, vol. 26, pp. 331–344.

[4] CONFIDENCE, 2010. Available: http://www.confidence-eu.org.

[5] Charter of Fundamental Rights of the European Union 2000/C 364/01. Official Journal of the European Communities, 2000, no. C364, pp 1-22.

[6] On the Protection of Individuals with Regard to the Processing of Personal Data and the Free Movement of Such Data, Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995. Official Journal of the European Communities, No L 281, pp 31-50.

[7] On Privacy and Electronic Communications, Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002. Official Journal of the European Communities, no L 201, 2002, pp. 37-47.

[8] P.L. Cochran, M.V. Tatikonda,; and J.M. Magid. Radio Frequency Identification and the Ethics of Privacy. Organizational Dynamics, 2007, vol. 36, pp. 217–229.

[9] J. van Hoof, H.S.M. Kort, P. Markopoulos, M. Soede. Ambient Intelligence, Ethics and Privacy. Gerontechnology, 2007; vol. 6(3), pp. 155-163.

[10] World Medical Association. Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects, 1964. Available: http://www.wma.net/e/policy/b3.htm

[11] American Psychological Association. Ethical Principles of Psychologists and Code of Conduct, 2002. Available: http://www.apa.org/ethics

[12] Association for Computing Machinery. Code of Ethics, adopted by ACM Council 1992-10-16. Available: http://www.acm.org/about/code-of-ethics

[13] N. González, K. Larsson, F. Snellman, E. Bergström, F. Tamburriello, M. Antomarini, F. Cesaroni, and I. Vélez. Ethical manual. Research report (D6.1) EC FP7 ICT-Grant No 214986 CONFIDENCE, 2008.

[14] D. M. Wasieleski and M. Gal-Or. An Enquiry into the Ethical Efficacy of the Use of Radio Frequency Identification Technology. Ethics and Information Technology, 2008, DOI 10.1007/s10676-008-9152-z

NEEDS OF OLDER PEOPLE AND PERCEPTIONS OF EXPERTS TO SPECIFY THE CONFIDENCE –SYSTEM

Anna KÄMÄRÄINEN[1], Outi KALLA[2], Narciso GONZÁLEZ[3]
[123]Agora Center, PO BOX 35 40014 University of Jyväskylä, Finland
[1]Tel. +358 14 260 4611 Email: anna.k.kamarainen@jyu.fi
[2]Tel. +358 14 4426 Email: outi.kalla@jyu.fi
[3]Tel. +358 14 4426 Email: narciso.gonzalex-vega@jyu.fi

Abstract: Following the user-centred approach, semi-structured interviews of older people and focus groups of health and social care experts were organized in two stages. These aimed at identifying end-users' needs and requirements for the ubiquitous care system to support older people's independent living, the CONFIDENCE system. At the first stage, the results suggest four main user requirements derived from the data: easy to use, suitability, reliability and need for an alarm centre. At second stage, studies covered all parts of the system..

1. Introduction

Falls are among the most common and serious problems of older people. Both the incidence of falls and the severity of fall-related complications increase steadily after the age of 65 [1]. The group of people over 65 years old is growing faster than any other age group in the world. It has been projected that by 2060 this age group will have grown from 17% in 2008 to 30%. The subsequent effects of falls impact direct and indirect costs to the family, health and social systems [2]. As the number of older people increase, the number of falls and associated expenditure is expected to increase accordingly.

The experience of falls can promote the development of fear of falling in older people. Fear of falling, in turn, can decrease quality of life and speed the decline in the ability to perform activities of daily living (ADL). Moreover, this situation might lead older people to self-imposed isolation, refusal of mobility, and admission to institutional care [3]-[6]. Falls and fear of falling need to be minimised to enable older people to remain autonomous, live in their own homes longer, and to decrease the costs of health and social care for this age group [7].

The CONFIDENCE project has adopted a user-centred approach to support the research and development of a Ubiquitous Care System to Support Independent Living in an attempt to close the gap between users and technology.

The project aims at providing an ICT support to older people who want to live independently for longer periods before a sheltered accommodation would be adopted. Briefly described, this system will be able to reconstruct the user's posture and detect abnormal situations, such as falls or loss of consciousness. The CONFIDENCE boasts many innovative characteristics. The most important ones are the use of RF technology to reconstruct in real time the bodily posture of the user in the three dimensional space and the capability to predict functional decline in the performance of ADL.

1.1 Technology Description

The CONFIDENCE care system will work indoors. This system will be able to reconstruct the user's posture and detect abnormal situations, such as falls or loss of consciousness, raising an alarm if necessary. Furthermore, it will be able to detect changes in the user's behaviour that could entail future health problems and issue a warning. Detection of anomalous behaviour will utilise prior expert knowledge as well as learnt movement patterns of particular users.

The whole system will consist of a central device placed inside the house, which will play the role of a base-station (BS), a small portable device (PD) similar to a mobile phone and some small size and low cost tags wearable by the user in the form of bracelets for wrist and ankle, in the form of necklaces or sewed into the clothes (socks, underwear, etc.). In addition to these ones, other small tags, placed in specific positions such as the corners of the bed, chairs or some other pieces of furniture may be needed indoors in order to increase the accuracy of the system.

The base-station will be able to reconstruct the posture of the body and decide if the user has either suffered a fall or is acting abnormally. When a fall or an atypical situation is detected, the system raises an alarm. Portable device will comprise a GPS receiver and a mobile phone.

When an alarm/warning situation is detected, first the system makes a phone call to the user, who will be able to confirm, inhibit it. If the elderly person confirms the alarm or does not pick up the phone, the system will call a series of relatives or friends. If nobody answers the phone, the system will call the emergency services. In both cases, the system will explain to the call recipient the reasons of the alarm or warning. This way, the user keeps control of the system, which is an important feature and considerably reduces the false alarm rate.

An important characteristic of CONFIDENCE is that the system performance will improve as it is used. Any alarm or false alarm will be taken into account for similar situations in the future, improving the system "intelligence" and making it easier to interpret the user's behaviour. The system will adapt itself to the user and it will become more accurate and its efficiency will increase as time wears on.

1.2 Objectives

The objective of the study at the first stage was to gather inputs about end-users' needs, expectations, viewpoints, and to elicit user requirements for the design and development of CONFIDENCE. The aim of the second stage was to obtain answers to the second research question regarding the opinions and feedback about the technical specifications, e.g. its components, interfaces, and the alarm handling protocol of participants in the first stage.

2. Methodology

The study was conducted at two stages with two user groups. At the first stage, the questions concentrated on personal and institutional needs in daily living conditions. The second stage was conducted after the system's technical specifications were more advanced. At the second stage the questions concentrated on the technical characteristics of the system. The methods chosen to gather information about the needs of the potential end-users of CONFIDENCE have been twofold because two different groups were considered. One group represented older people and are described as end-users The other group was composed of health and social service providers extracted from the public administration, from private companies providing home care, and care in service houses. This group as a whole is described as experts or key informers group.

The end-users participated in individual semi-structured interviews and focus groups were organized for the experts. The contents of the interviews and focus groups were equal. The procedures in the first and second stages were similar. The different goals of the two stages involved thus different levels of detail of information provided, and the questions about CONFIDENCE.

2.1 End-users

During the first stage, 23 people from the city of Jyväskylä, Finland, volunteered for this study (average age 75.5, range 65-92, female = 12, male = 11). The participants were recruited from the Central Hospital, a day centre, and the Centre for Care and Rehabilitation of War Veterans. They all lived in their own homes. During the second stage, ten participants from the sample of the first stage volunteered to participate in individual semi-structured interviews (average = 75, range 68-88, female = 6, male = 4).

2.2 Experts

The expert participants in the focus groups were recruited from the social services in Jyväskylä. In total, ten experts participated in the first focus group and 6 people on the second at first and second stage.

3. Results

3.1 First stage:

The first stage results suggested four main user requirements derived from the data: easy to use, suitability, reliability and need for an alarm centre.

Ease to use

The system must be easy to use and the possible effects of aging do not hinder the use of the system. The most frequent expectation about CONFIDENCE amongst both groups was that it should be simple to use, e.g., that system does not provide too many options. Other expectations included similarity to other familiar technology and expectations that consider the perceptual and motor impairments, e.g., sight, hearing, rheumatism, pain. Poor eye sight and motor problems may impede the use of the system. The system should feature a multi-modal control interface. People with poor eye sight cannot use the system properly if the interaction is only based on a visual display. People with hearing impairments cannot use a speech based interface. Possible ways of interacting with the system can be, at least, a visual display or screen, voice recognition, and alarm sounds.

Suitability

Suitability means that the system fulfils the basic needs, does not cause harm to the users, users are able to use the system taking into account their own cognitive and motor functional capacity, and the users are able to personalise the system. In general, the experts considered that older people are probably not willing to pay for such a system. Instead, they may be willing to obtain the system from the public welfare system. A typical estimated price of the system was 1000€. The end-users revealed that they would not be willing to buy the CONFIDENCE system. Instead, the public health care should provide such a service. In Finland, instruments and security services for old people are provided by the national welfare system instead of the individuals themselves. CONFIDENCE should be durable and affordable. For a very old person, and especially for those suffering memory disabilities, the system should not demand to be removed in certain circumstances such as the shower, so that the person does not need to remember to put it back on.

Reliability

Reliability is an important feature of the system. The system must have low false alarm rates, should be safe and accurate. The experts indicated that an alarm centre would be required to receive and manage the alarms. In general, the end-users would trust the technology in the case of a sudden fall. Two respondents would trust the system depending on the situation. Many participants had doubts about false alarms and thought that false alarms might be frustrating.

Need for an alarm centre

At the design phase, it was thought that users could decide to whom the alarms will be sent and configure the alarm receivers. The end-users and experts were unanimous in the need for an alarm centre. The shared opinion was that health care service, home health care or other public service should have the main responsibility to receive the alarms. In the case of trouble several hopes and suggestions were made. Some wished for a nurse to come and check the situation while few preferred an automatic call to the spouse. Being continuously monitored by the CONFIDENCE system, the opinion of end-users was that the system would help them feel safer by knowing that they will get help after the system has sent an alarm.

4.2 Second stage:

In the second stage, the whole system was discussed. Discussion topics were: the overall system, portable device, tags and sensors, base station and alarm handling.

Overall system

The end-users indicated that the system was complex. Some of the respondents also felt that they could not evaluate the system because it was complicated.

Four fifths of the end-users reported that their health condition would not cause any obstacles which may hinder the use of CONFIDENCE. Two of them indicated that they did not want to dedicate much time to learn how to use the system. Two end-users thought that learning would not take many hours. All but one respondent thought that they would learn how to use the system. One third of the end-users were not willing to teach the system to identify normal daily activities from adverse events and half of them could do that.

Also in the second stage, many end-users had doubts about false alarms and thought that false alarms might be irritating. They also wanted a system as simple as possible. Half of them reported that technical devices did not raise any fears or concerns in general. One third said that learning to use technical devices was difficult and one had memory problems which affect the use of devices.

While discussing the overall system, the possibility to live and feel independently without strict supervision was considered a positive aspect of CONFIDENCE in experts' focus groups. The attitude and support of home help services, nurses, and close relatives is very important. This support could influence how the older people accept the system and their willingness to purchase it. However, people's cognitive decline or disabilities could represent a challenge for the operation of the system.

Portable device

Half of the end-users made reference to the possible complexity of using the portable device. The respondents were worried about whether they would be able to use the device. The other half believed that the portable device would be simple to use.

The size of the portable device was an important feature. Mobile phone- size device can be carried in the pocket easily. However, not every one of the end-users would be willing to carry it all the time. In general, opinions towards the portable device were either positive or neutral.

The voice control/voice interface was described as an important function. Especially, the participants wanted voice connection between the user and alarm receiver.

The experts thought that a portable device was a good idea, but it might also cause design challenges. Multimodal interaction is important for people with hearing or sight disabilities. The device cannot be very big, but has to be big enough to afford good usability. The respondents defined the possibilities of speech contact with an alarm receiver, of stopping alarm, and of raising alarm, as most important features of the system.

Tags and sensors

All of the end-users were willing to accept worn tags and sensors in their homes. Many, however, manifested concerns about power consumption and batteries, which they would not be willing to change often. The size of the tags was unclear to the interviewees. Once the prototypes will be available, the size and its influence on their acceptance will be clarified.

In the focus groups of experts, the small tag size was considered a positive aspect. The amount of tags and sensor was thought to be quite heavy, and this raises worries. The experts were worried about how often the batteries must be changed or charged. Small tags will hold small batteries which are impossible to handle for some old people.

Base station

The end-users showed mistrust towards the base station. Their main concern was about misuse of the information collected and processed by the base station. Though the operation of CONFIDENCE does not need internet access, some participants questioned whether internet access would be necessary. Four fifths of the end-users would allow data collection through the base station and sharing this information with home care services or the health centre. One third of them indicated that it would be important to be able to switch off the monitoring functions whenever they wanted.

Experts were satisfied with the base station. The comments dealt with extra features which may be added to the system later. Suggested additional features could be, for example, blood pressure monitoring.

Alarm handling

Some of the end-users preferred automatic alarms without confirmation of the user. Some preferred confirmation and alarm if the user does not react to the alarm. Many indicated typical waiting times from one to five minutes between an alarm message to the user and user's action before an alarm is issued to the receiver. Two thirds of the end-users mentioned health care, alarm centre or other public service as an alarm receiver. Also children, relatives and spouse were mentioned by many participants.

Experts also thought that alarms should be automatic. After a fall, a person may be disoriented and may not understand the alarm. Approximations of how long the system should wait before sending an alarm were from 30 seconds to 3 minutes. Experts' opinion was that the system should contact the next alarm receiver immediately if the first one is not responding. However, respondents preferred the alarm centre as the alarm receiver over friends or relatives.

1. Business Benefits

The initial area of interest of the CONFIDENCE project is constituted by the aged people whose rate is dramatically increasing in Western societies. In this framework, one of the most relevant areas is to support the independent living of the elderly, giving them the possibility to remain autonomous for most of their life living in their own environment which is normally represented by their family and their home.

Due to its nature, the CONFIDENCE project has a European perspective and its market and competitors have to be considered within these boundaries. EU member states have many similarities in the idea of health and social care and it is reasonable to expect a variety of market situations with small differences.

The aim of the project is to develop a working prototype. Thus, at the moment, a CONFIDENCE-like solution finds its natural market into the set of health and social services provided by the public sector.

2. Conclusions

The Finnish older people and experts who participated in this study have been valuable providers of information at the two stages of needs and requirements elicitation that has contributed significantly to the technical specifications of CONFIDENCE. At the first stage, our aim was to identify end-users' needs and requirements to specify CONFIDENCE. At the second stage, we intended to gather end-user opinions about the system after the technical specifications had matured. In general, our focus was on the understanding of the users' goals, the possible obstacles they could encounter, and how they could avoid these obstacles. It was also important to understand the special needs of users and the context in which the users were immersed. In these interviews, we tried to form a holistic understanding about users' needs in their daily lives.

The majority indicated that they would trust the technology in the case of sudden falls. At the first stage, the most frequent expectation about CONFIDENCE system was that this should be simple to use. At the second stage, respondents were more critical and raised more worries about the complexity of the system. Some of the respondents were afraid that the system would be too difficult to understand. At the first stage, most of the respondents thought that the system would not violate their privacy, but at the second stage some of them showed mistrust. The size of the portable device and tags were important features as well as voice connection between the user and alarm receiver. Ease of use and acceptability are the key issues to take under consideration. Amount of small batteries and how to change batteries raises questions. It may be too difficult for end-users to change the batteries by themselves. At the second stage, the subjects had more information about the system and could present their thoughts and worries more precisely.

The results of this study indicate that the successful implementation of the CONFIDENCE system requires its underlying technologies to be configured in a way which meets the particular needs of the individuals using it. Well-adapted, unobtrusive and easy to use interfaces are key requirements for the end-users. The CONFIDENCE system has the potential to contribute to a health and social care system that respects the independency and privacy of individuals, gives choices about circumstances in which they live, and enables them to maintain or improve their quality of living. The information on the end-users need is an invaluable resource in the development of usable and acceptable technologies to facilitate their independent living.

In accordance with the user-centred approach adopted by this project, the older people, as potential end-users of the CONFIDENCE system, will continue their involvement in other stages of the project. They will evaluate the system design and participate in usability studies. The end-users will also contribute to the validation of the resulting prototypes. Most importantly, the participation of the potential end-users will facilitate the adaptation of the system to their real needs, interaction capabilities, and preferences and contribute significantly to fall detection, identification of risks associated to falls and finally prevention of falls through the intelligence of the system.

References

[1] United Nations (UN). World Population Prospects: The 2004 Revision, New York, USA, 2004.

[2] United Nations (UN). World Population Prospects: The 2004 Revision, New York, USA, 2004.

[3] Bruce, D.G.;Devine, A; Prince, R.L. Recreational physical activity levels in healthy older women: the importance of fear of falling. Journal of the American Geriatrics Society 2002, 50, 84-89.

[4] Delbaere, K.; Crombez, G.; Vanderstraeten, G. Fear-related avoidance of activities, falls, and physical frailty. A prospective community-based cohort study. Age and Ageing 2004, 33, 368-373.

[5] Cumming, R.D.; Salkaeld, S.; Thomas, M. Prospective study of impact of fear of falling on activities of daily living, SF-36 scores and nursing home admission. The Journals of Gerontology A Biological Sciences and Medical Sciences 2000, 55, 299-305.

[6] Mendes de Leon, C.F.; Seeman, T.E.; Baker, D.I. Self-Efficacy, physical decline, and change in functioning in community living elders: prospective study. The Journals of Gerontology B Psychological Sciences and Social Sciences 1996, 51, 183-190.

[7] Lee, F.; MacKenzie, L.; James, C. Perceptions of older people living in the community about their fiar of falling. Disability and Rehabilitation 2008, 30, 1803-1811.

Acknowledgment: The project CONFIDENCE receives funding from the European Community's Framework Programme FP7/2007-2013 under grant agreement No 214986

ALARM DETECTION IN THE CONFIDENCE SYSTEM

Violeta Mirchevska
Result d.o.o., Bravničarjeva 11, 1000 Ljubljana, Slovenia
e-mail: violeta.mircevska@result.si

ABSTRACT

This paper presents an alarm detection module capable of detecting critical situations due to injuries and sudden health problems developed as part of Confidence, a remote health monitoring system. Examples of such critical situations are injury after a fall and fainting. An overview of the design of the module and preliminary results are presented.

1 INTRODUCTION

The population of Europe is ageing, putting immense pressure on healthcare systems which already account for around 9% of the EU's GDP spending.[1] Therefore, sustainable and personalized healthcare is one of the strategic interests of the European society and is encompassed by Challenge 5 of the ICT Work Programme under FP7. Personalized health systems are one of the research focuses under this challenge. These systems will enable more effective care of patients by monitoring patients' health conditions using wearable, portable and implantable systems, providing health profesionals with comprehensive monitoring and diagnostic data. This way, the personalized health systems will enable patients to continue their everyday activities normally, reducing pressure on care centers and increasing patients' quality of life.

The Confidence project [2] aims at developing a ubiquitous health system that will be able to: 1) detect critical situations (e.g. falls, fainting) and 2) changes in users' behavior (e.g. user limping). Target system users are the elderly, to whom this system should provide the necessary confidence and security to participate longer in social life and postpone their attendance of care centers. The reasoning of the system is based on data obtained from real-time localization and accelerometer based systems. In comparison to health systems of its kind, the Confidence system provides less intrusive monitoring of the health conditions of the elderly, throughout its home (no coverage problem).

In Confidence, critical situations due to injuries and sudden health problems (e.g. falls, fainting) are detected by the alarm detection module. These are situations which are reflected in the user lying/sitting at inappropriate place (e.g. on the ground) for a prolonged period of time. In case such situation is detected, the system raises an alarm and informs relevant caregiver about the situation. In order for the alarm detection module to achieve its goals, it must be highly reliable, which means that it must detect all major critical situations without raising too many false alarms. What is more, given the diversity of users, it is difficult to develop a system that will suite each particular user. Therefore, the alarm detection module must be able to adapt to the needs and preferences of its user.

This paper presents the alarm detection module in the Confidence system. Section 2 presents the design of the alarm detection module in Confidence. Achieved results are presented insection 3. Section 4 concludes the paper.

2 ALARM DETECTION

The alarm detection module detects and signals critical situations due to injuries and sudden health problems (e.g. fainting, injury after tripping). In case such situation exists, the module raises an alarm and contacts a relevant caregiver. The workflow of the module consists of four steps (Figure 1):

1. detection of critical situations,
2. notification to user and reception of user feedback,
3. notification to caregiver (if needed)
4. adaptation (if needed).

2.1 Detection of critical situations

In Confidence, critical situations are detected based on history of observed user activity, primarily amount of user lying/sitting at inappropriate place and intensity of movements. The detection is performed in two ways:

1. by a rule engine containing 8 rules defined by human know-how detecting critical situations primarily according to the amount of user lying/sitting at inappropriate place
2. by machine learning models (C4.5 [3] and SVM [3] models)

Additionally, a default rule defined by human know-how is included, which raises an alarm in case no user movement have been detected for very long period of time (e.g. more than half a day).

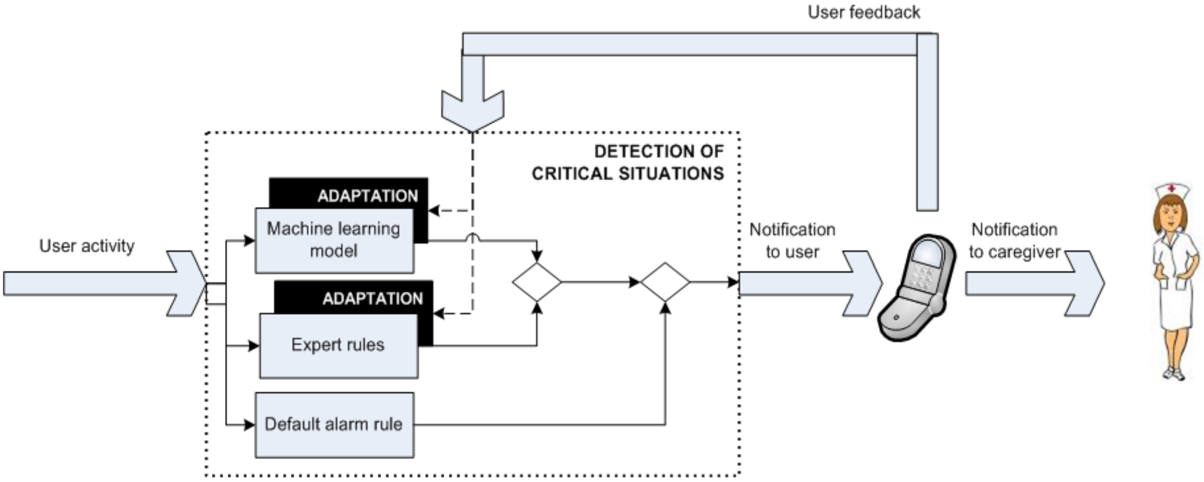

Figure 1 Alarm detection module in Confidence

The output of the alarm detection module is one of following:

1. No alarm
2. Falling detected and user lying/sitting immovable at inappropriate place for a prolonged period of time
3. Falling detected and user lying/sitting at inappropriate place for a prolonged period of time moving
4. User lying/sitting immovable at inappropriate place for a prolonged period of time
5. User lying/sitting at inappropriate place moving for a prolonged period of time
6. User immovable for very long period of time

2.2 Notification to user and user feedback

In case the alarm detection module detected a critical situation, it raises an alarm and notifies the user through a portable device. The notification to the user is included in the module in order to avoid bothering caregivers with false emergencies due to reasoning errors.

For each notification to user, the system receives a feedback which may be one of the following:

1. no response from user – this is considered as a confirmation that the user is in a critical situation.
2. the user confirms the alarm
3. the user cancels the alarm – the system raised an alarm inappropriately

Additionally, the user of the system may trigger an alarm by him-/herself in case the system does not detect a particular critical situation.

2.3 Notification to caregiver

In case the alarm detection module detects an alarm situation and receives no answer from the user or the user confirms the alarm, it notifies relevant caregiver concerning the detected situation. The notification contains a description of the detected situation and the caregiver may see the history of user activity that caused the alarm. Additionally, a caregiver is contacted when the user raises an alarm by him-/herself.

2.4 Adaptation

Each feedback provides new information to the system concerning the detection of critical situations. If the user confirms an alarm or does not give any response to a raised alarm (which is considered as a confirmation), the models for detecting critical situations need not be changed, since this feedback means that alarm is raised at appropriate moment. If the system raised an alarm and the user canceled it, the reasoning of the models for detecting critical situations needs to be changed in order to avoid raising an alarm in such situations. If the user triggers an alarm by him-/herself, the reasoning of the model needs to be changed in a way that will raise alarms in such situations. Model adaptation to user feedback enables improvement in system performance in the long run.

As previously stated, critical situations are detected in two ways: (1) by rule engine and (2) by machine learning models. The problem of adaptation for the rules in the rule engine is defined as a Markov decision process. The machine-learning models are adapted by rebuilding their model every time new data is obtained. Presentation of the process of adaptation of the models can be found in [5].

3 RESULTS

In order to test the performance of the module for detection of critical situations, as well as the Confidence system as a whole, a room resembling a studio apartment equipped with a bed, few chairs and tables was set. The room was devided into the following regions: kitchen, living, room, toilet, sleeping area (bed) and corridor.

3.1 Performance of the models for detection of critical situations

In order to test the ability of the alarm detection module to detect critical situations, a scenario including three situations when alarm must be raised and three possibilities for false alarm was created. The situations in which alarm must be raised are tripping, fainting and falling from the chair, while situations that might lead to false alarm, but actually do not represent critical situations, are jumping in a bed, sitting down quickly and searching under the table/bed. Both jumping in a bed and sitting down quickly contain falling. Falls may be misleading to the system, since they are fundamental indication of a critical situation and represent one of the major problems of alarm detection systems based on accelerometers. Recordings were made for five persons, each repeating the abovementioned scenario 5 times.

The ability of the alarm detection module to detect critical situations was tested with the leave-one-person-out aproach. The following accuracy was achieved: normal behavior (100%), lying down normally (100%), tripping (97%), fainting (91%), sitting down quickly (possible false alarm, 97%) and lying down quickly (possible false alarm, 100%).

3.2 Adaptation capabilities of the models for detection of critical situations

In order to test the adaptation capabilities of the rule engine and the machine learning model for detection of critical situations, true and false alarm scenarios were recorded. True alarm scenarios refer to scenarios in which an alarm should be raised (e.g. user lying on the ground because he/she fell and can not stand up from the ground), whereas false alarm scenarios refer to scenarios which are similar to the true alarm scenarios, however represent situations in which an alarm should not be raised (e.g. user lying on the ground, searching for something under his bed). The recorded true alarm scenarios contain (1) user falling quickly and then lying on the ground moving for 15 s, (2) user falling quickly and then lying immobile for 15 s, (3) user falling slowly and then lying moving for 15 s and (4) user falling slowly and than lying immobile for 15 s. The cases (1) and (2) can be considered, for example, as tripping; where (2) is a situation which results in an injury that prevents movement. The cases (3) and (4) can be considered as falling due to dizziness or fainting. In the true alarm scenarios the user raised alarm after lying on the ground for 7 seconds. Three types of false alarm scenarios were also recorded: (1) user on all fours on the ground for 10 s, (2) user on all fours for 5 s, then lying on the ground for 5 s and (3) user lying on the ground for 10 s. The user is moving in all three cases. These scenarios may represent the user searching for things under the table or bed. They differ from the true alarm scenarios by the length the user stays on the ground and in some cases the amount of movement. Each true and false alarm scenario was recorded five times for the purpose of training. Additionally, all scenarios were recorded five times for testing.

The test runs were performed as follows: Each test started with models that are not able to detect any critical situation (represented by the true alarm situations). True and false alarm training sequences were provided to the models one by one. The training sequences were presented to the models in two ways: (1) all true alarm scenarios first, followed by all false alarm scenarios, and (2) random order. After each new training sequence, the models were adapted and their accuracy for detecting critical situations was tested on each of the five test sequences.

The test showed that the rule-engine and the machine learning models for detection of critical situations were able to learn and adapt their reasoning based on the received user feedback. They both achieved on average 90% accuracy for detection of critical situations at the end of each test run, when all training sequences were presented to them.

4 CONCLUSION

This paper presented the design of an alarm detection module capable of detecting critical situations due to injuries or sudden health problems. The module was developed as part of the Confidence system, an ubiquitous care system to support the independent living of the elderly.

The module detects critical situations with two approaches: (1) a rule engine containing rules defined by human know-how and (2) machine learning models. Experimental results show that the detection of critical situations in this way is reliable.

Important design feature of the Confidence system is the ability of the user to give feedback concerning the detection of critical situations. This feedback is used for real-time adaptation of the alarm detection module. We defined the problem of adaptation of the rules in the rule engine as a Markov decision process. The machine-learning models are adapted by rebuilding their model every time new data is obtained. Experimental results show that, using these methods, the module is able to successfully learn and adapt its reasoning based on received user feedback.

ACKNOWLEDGEMENTS

This work has been done in cooperation with the Department of Intelligent Systems, Jozef Stefan Institute, Ljubljana, Slovenia within the research for the Confidence project. It was partly supported by the Slovenian Research Agency under the Research Programme P2-0209 Artificial Intelligence and Intelligent Systems, partly from the European Community's Framework Programme FP7/2007–2013 under grant agreement No. 214986 and partly by the European Union, European Social Found.

References

[1] European commission, ICT research in FP7, ICT challenge 5: Towards sustainable and personalized healthcare. http://cordis.europa.eu/fp7/ict/programme/overview5_en.html

[2] Confidence. http://www.confidence-eu.org.

[3] I. H. Witten, and E. Frank, *Data Mining: Practical machine learning tools and techniques*, 2nd Edition, Morgan Kaufmann, 2005.

[4] S. J. Russell, and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3rd Edition, Prentice Hall, 2009

[5] V. Mirchevska, B. Kaluža, M. Luštrek, and M. Gams, Real-time Alarm Model Adaptation Based on User Feedback, in UDM 2010: Workshop on Ubiquitous Data Mining in conjunction with the 19th European Conference on Artificial Intelligence, pp. 39 – 43, 2010

USER CENTRIC APPROACH IN THE CONFIDENCE PROJECT EXPERIENCES FROM UMEÅ

Ellinor Nordin, Kristina Larsson
Department of Social Welfare Services
Umeå municipality
Aktrisgränd 17, SE-903 64 Umeå, Sweden
Tel: +46 90 164625; fax: +46 90 77 84 82
e-mail: ellinor.nordin@umea.se

ABSTRACT

In an attempt to close the gap between end-users and technology, this paper presents the expressed needs and requirements for development of the CONFIDENCE system, a care system to support independent living among people 65 years and older. Informants, representing the target group, were 28 men and women with a mean age of 75 years, living in Umeå, Sweden. The participants believed that the portable device could be useful in their active everyday life. As a safety solution the system was thought of as a good way of helping older people feel more secure. Especially in circumstanses when a person is unable to call for help, and there are no people around. Feeling secure was important for staying active, outdoor as well as indoor. Questions about the users integrity were raised, as well as suggestions to further develop the CONFIDENCE system in the future.

1 INTRODUCTION

The proportion of older people (65 years and older) is increasing worldwide [1]. With a larger population of seniors we can expect that they will contribute even more in society, but also that demands for healthcare and social care will increase. From a humanitarian as well as an economic view point, preventive actions are therefore becoming increasingly important and should target the expressed needs from older people themselves.

Normal ageing involves both physical and mental changes due to cellular loss which, for example, affect neuronal transmissions between biological systems [2]. Impact from hereditary, environmental and life style factors further affect the ageing process [3, 4]. Older people are therefore very heterogeneous, and age alone does not label needs nor classify level of functioning. To enhance understanding for the diversity among older people, a continuum of physical function have been proposed to describe a hierarchy of abilities, for example as: physically elite, physically fit, physically independent, physically frail and physically dependent [5]. Feelings of insecurity, fear of falling or fear of becoming ill, may hypothetically be present in all these categories of physical funtion, but are in general more frequent among older people with the multisystem reduction in reserve capacity present in the latter categories [5]. There is a close relationship between functioning, disability and environmental factors that are important when addressing older people's health and well being. Staying secure and confident in one's ability to cope with everyday situations, and activities in daily life becomes increasingly important for independent living and for participating in the society.

To deepen our understanding about how information and communications technologies (ICT) may serve the needs of older people, we have to ask them directly. In doing so, we should also support and enable older people to free themselves from actions determined by habit or illusion, which may be opposite to those wanted, needed, expected or desired by older people themselves their caregivers and families [6].

Although the use of ICT is spreading rapidly, only a minority of older people are actively engaged in their uptake. This implies that most of the existing Internet-based or online services might not be accessible for older people and, hence, cannot be considered very age-friendly technologies. The CONFIDENCE project (within the European Commission under the 7th Framework Program (FP7) - theme 3 "Information & Communication Technologies" ICT 1-7.1 ICT & Ageing) has adopted a user-centered approach to address the research and development of a ubiquitous care system to support independent living in an attempt to close the gap between users and technology. Therefore, an important step in this approach has been to obtain information from end-users about their personal needs in daily living conditions. Other health and social service providers have also been included in this process to add other viewpoints of how CONFIDENCE could contribute to facilitate the independent living of older people in the European Union.

The information obtained about end-users needs throughout this process is, thus, used to derive the technical requirements of CONFIDENCE.

The CONFIDENCE project aims to develop and integrate innovative technologies in order to detect abnormal events such as falls and unexpected behaviors, related to health problems of elderly persons. The target group is persons 65 years or older; cared or not by any kind of home assistance; mobility independent with no particular difficulty with ADL; and at risk of social exclusion as a result of fear of falling. The project is strongly oriented toward the adoption of a "bottom-up" methodological approach. Therefore, the CONFIDENCE system model will be based on the real needs of elderly persons, their family members, caregivers, and other relevant stakeholders and requirements of potential end-users. This paper will describe the outcome of the individual interviews done in Sweden in April 2008 [7] and focus groups interviews done in Sweden in April 2009 [8].

2 The Swedish demography and the participants

At the end of 2009 the Swedish population at the age of 65 years and older reached 18,1% of the population. Among the age group of 65 years and older 55,4% are women and 44,6% men. It is noticeable that the population at the age of 55-64 is a large group in Sweden, measuring up to 12,9% of the whole population [9]. Many elderly, especially women, live alone for the later part of their lives. Statistics in the report "Living Conditions of the elderly, Work, economy, health and social networks 1980–2003", Statistics Sweden (SCB) show that women at the age of 85 years and up stands for three quarters of the single households at the age group. The average life expectancy in Sweden for women is 83 years and for men is 79 years.

The CONFIDENCE project has captured the needs and requirements of the target group by individual interviews and interviews in focus groups. During the individual interviews 15 participants (8 women and 7 men) were interviewed. The participants had the average age of 77, with the oldest participant at the age of 94 and the youngest at 64. On year later, 13 people (8 women and 5 men) at the average age of 74 participated in the focus group interviews with end-users. The age and gender of the participants responds quite well to the demographic structure within this age-span in Sweden.

3 Perception of health among the interviewed

The perceptionon of one owns health status is as important as the actual health status since the confidence in the own body affects the feeling of being secure or in need of help and support. Depending on different health conditions and medical situations the interviewees' definition of security and insecurity varied. A person with reduced eye-sight might find that proper lighting and being able to tell the type of surface are sources of security, while a person with Parkinson's disease finds it insecure to dress because of problems with motor control and balance [7].

Among the elderly interviewed in Umeå, 80% found themselves at good health stating that even with different diseases and experiences of being older the health conditions are fairly good at high ages. One participant experienced the dividing line of feeling of good health first hand after an acute change of health status: "I have always believed my health to be perfect until I one day discovered that I have had an cardiac infraction. Now I keep Nitro-glycerine spray with me wherever I go" [7].

The fear of falling was closely connected to the perception of health among the elderly and related not only to the actual fall but also to health conditions that may lead to falls and unconsciousness. Five out of 15 interviewees answered that they were afraid of falling. But, even those who reported "no fear" often mentioned that they were cautious outside during winter time, or that they did not climb chairs or used their bikes anymore. The fear of falling seemed to limit the interviewees in some ways but not to the same extent as the fear of falling into unconsciousness and not being able to communicate the need for help. One interviewee has the experience of falling into unconsciousness and not being able to move. After one and a half day her son broke in to her apartment and found her laying on the floor in bad condition. The fear of being alone if something would happen was common in the age group [7].

4 Activity and health

Many elderly in Sweden live an active life up to a high age. The findings in the interviews done in Umeå confirm that there were many different types of activities which the elderly take part in. The social, political and sports related associations are a big sector in Sweden and the older generations often stay active in their associations as long as they can. There are also a variety of organisations for seniors and pensioners. Ninety-three percent of the interviewed elderly stated that they participated in social activities and 53% of them did so at least once a week [7].

The physical activities that involve elderly are also manifold. Walking, gymnastics, biking, skiing, dancing and playing Boule are some of the activities that the interviewees mentioned. Among the participants in the individual interviews 80% participated in physical activities and all of these did it at a minimum of once a week [7].

Common health related problems are typically connected to the normal ageing process: brittleness of bones, dizziness, age-related diabetes, dementia, loss of eye-sight and hearing, aching joints and high blood pressure. The interviews also showed that many of the participants used medications to attend for abnormal blood pressure for example. Individual diversities was present among the group of participants. While most of the participants were able to perform the interview at the suggested meeting place at the City Hall, some interviews were done in the home of the participant. This was arranged in order to gather information not only from active elderly but also from people that are at risk of being socially excluded. The interviews showed that the younger participants were less afraid of falling but not the less engaged in the planning of their own future. Most of the participants at the age under 80 took active decisions to make their life more safe by moving from a big house to a smaller apartment or to make sure that their housing doesn't have any obstacles. Many of the younger participants were also active in local senior associations, making themselves heard at the public arena.

An active life style can in many ways contribute to a better health and quality of life. Physical activity, play an essential role for preserving function, and continuity in everyday life is important for physical and mental well-being, functional capacity, social integration and performance [10]. Physical activity can reduce the risk of cardiovascular disease, diabetes, accidental falls, and reduced symtoms of depression and anxiety [11, 12]. It is therefore important to stay active throughout life.

5 Technology for an active life

The development of the CONFIDENCE system supports an active life by not being intruding to the personal life and by making it possible for elderly to live independently without fear of not being able to get help if something happen to them.

The CONFIDENCE system is described by the end-users interviewed as a system that in the future could make it possible for elderly people to lead an active life and participate in social and physical activities longer. Several interviewees found the portable device useful in their active everyday life. Two of the interviewees would have liked to have one with a GPS, so that they could feel secure on their walks in the woods. Others stated that this solution was the one thing that made this system unique – the possibility to be socially active even though you are afraid of falling etc [7] .

Eighty percent of the participants of the individual interviews answered yes to the question "Would you trust in that the technology can save your life in case of a sudden fall or loss of consciousness?". This indicates that people within the target group are willing to rely on technology.

At the same time the end-users were well aware of the down-sides of technology. During the individual interviews, one participant said: "To be able to rely on the technology you have to know how the technology works. Sometimes it feels like the technology has its own life."
Yet another person could identify the complexity of using ICT safety solutions: "The technology is good as long as it allows me to move around freely outside etc, but not if the technology creates isolation."

The end-users were also aware about the possibility that technology can be used in a harmful way by other persons and institutions/organizations, i. e. for supervision and control. The insecurity about what the technology represents and can be used for can be partly explained by the fear of what you do not understand. On the other hand the insecurity can also be explained by the fact that technology in different ways do not live up to the expectations and requirements of the user when it comes to functionality, security and integrity [8].

All participants stated that the balance between the user's security and the user's privacy is important to safeguard during the development of the CONFIDENCE system. At the same time different users may have different needs of security and privacy and this could be a key point for the system to adopt to.

Other studies involving real end-users have illustrated ethical conflicts associated with trying to balance user needs with technological design requirements, and commercial and market opportunities. These studies highlight a need to creatively synthesise ICT and ethics: where the lived expreriences of older people are actively listned to (respect), where older people feel thay have a voice in decisions about their well-being (empowerment), where power differentials that often constrain and marginalise older adults, are confronted (critique), and where ICT solutions enable older people to feel dignified and treated with kindness (concern) [6, 13].

6 Conclusions

The end-users involved in the CONFIDENCE project have showed great interest in the process of finding a technical solution for an independent every day life. Many elderly in Umeå are familiar to the CONFIDENCE project and are interested in discussing ICT and ageing. They are willing to rely on technology as long as they know how the technology works and thereby have a feeling of control. As a safety solution the CONFIDENCE system is thought of as having potential of helping elderly people feel more secure. Security is important for staying active, outdoor as well as indoor. Questions about the user's integrity were raised in many different ways, as well as suggestions to further develop the CONFIDENCE system in the future.

The interviews also confirm that the focus should be on the human beings targeted when developing technical solutions. Technology can be used in many helpful ways, aiding people to live a satisfactory and independent life if developed in accordance to the actual needs and requirements of its future users.

References

[1] OECD. Emerging systematic risks in the 21st century: an agenda for action Paris: OECD Publishing; 2003.

[2] Rowe JB, Siebner H, Filipovic SR, Cordivari C, Gerschlager W, Rothwell J, et al. Aging is associated with contrasting changes in local and distant cortical connectivity in the human motor system. Neuroimage. 2006;32(2):747-60.

[3] Frederiksen H, Christensen K. The influence of genetic factors on physical functioning and exercise in second half of life. Scand J Med Sci Sports. 2003;13(1):9-18.

[4] Lexell J. Ageing and human muscle: observations from Sweden. Can J Appl Physiol. 1993;18(1):2-18.

[5] Spirduso W, Francis K, MacRae P. Physical dimensions of aging. 2nd ed. Champaign: Human Kinetics 2005.

[6] Ghaye T, Melander Wikman A, Kisare M. Participatory and appreciative action and reflection (PAAR) - democratizing reflective practices. Reflective Practice. 2008;9:361-97.

[7] CONFIDENCE. D1.1 User needs and requirements analysis: Project EC FP7 ICT-gant No 214986; 2008.

[8] CONFIDENCE. D1.3 Report on corrected requirements: Project EC FP7 ICT-gant No 214986; 2009.

[9] SCB, Swedish Statistics. Swedish population by age and sex 2009-12-31; 2010.

[10] Eriksson BG, Mellstrom D, Svanborg A. Medical-social intervention in a 70-year-old Swedish population. A general presentation of methodological experience. Comprehensive gerontology. 1987;1:49-56.

[11] Belza B, Walwick J, Schwarz S et al. Older adults perspectives on Physical Activity and Exercise: Voices from Multiple Cultures. Preventing chronic disease. Public Health Research, Practice and Policy 2004;1(4):1-11.

[12] Gillespie LD, Robertson MC, Gillespie WJ et al. Interventions for preventing falls in older people living in the community. Cochrane database of Systematic Reviews 2009, issue 2. Art.No.: CD007146. DOI: 10.1002/14651858.CD007146.pub2.

[13] Melander Wikman A, Jansson M, Ghaye T. Reflections on an appreciative approach to empowering elderly people in home healthcare. Reflective Practice. 2006;7(4):423-43.

3D POSITIONING ALGORITHM FOR WIRELESS SENSOR NETWORKS

Leticia Zamora-Cadenas, Naiara Arrue, Igone Vélez
Electronics and Communications Department
CEIT and TECNUN (University of Navarra)
Paseo Manuel Lardizábal 15, 20018 San Sebastián, Spain
Tel: +34 943 212800; fax: +34 943 213076
e-mail: {lzamora, narrue, ivelez}@ceit.es

ABSTRACT

This work presents a novel three dimensional positioning algorithm that can be used in a Wireless Sensor Network. This Wireless Sensor Network consists of some fixed sensors, whose positions are known, and some mobile sensors, whose positions we want to determine. Each sensor is able to estimate the distance to any other sensor. The proposed algorithm makes use of both the distances among different mobile sensors and the distances among fixed and mobile sensors and it is able to obtain accurate estimations of the position of the mobile sensors. Simulations demonstrate the good performance of the proposed algorithm.

1 INTRODUCTION

Information and Communication Technologies (ICT) can be employed to support independent living of elderly people. As an example, the CONFIDENCE project [1] proposes an innovative care system that has the potential to detect abnormal events or unexpected behaviors in the elderly people using a Wireless Sensor Networks (WSN). This WSN implements a positioning system which determines the location of some tags that are worn by the user. Then, the system will use this information for posture reconstruction and interpretation of the user behaviour.

The positioning system implemented in the CONFIDENCE prototype consists of a group of fixed sensors, whose positions are known and several mobile sensors, whose positions are desired to be estimated. Many other similar positioning systems can be found in the literature [2]–[4]. In this type of positioning systems based on the estimation of the Time of Arrival (ToF) of the signal, the position of each mobile sensor is calculated in two steps. Firstly, the distances between each fixed sensor and the mobile sensor are estimated using ranging algorithms such as [5]–[7]. In a second step, the position of each mobile sensor is determined using these distances. Different positioning algorithms can be found in the literature, such as the Least Square (LS) method [8] or the Recursive Least Square (RLS) technique [9] or the Kalman Filter [10].

Among the positioning systems proposed in the literature for WSN, there are also systems in which the position of the sensors is unknown and cooperative algorithms such as [11]– [13] are used to estimate the position of each sensor of the network. In these systems, each sensor is able to estimate the distance to the rest of the sensors of the network. The positioning algorithms use this information to estimate the position of the sensors.

In this work, a new positioning system has been considered to improve the accuracy of the CONFIDENCE prototype and to reduce its final cost and complexity. On the one hand, the proposed system consists of a set of mobile sensors that are able to estimate the distances to the rest of the mobile sensors of the system. On the other hand, the system has some fixed sensors in known positions which are able to estimate the distances to the mobile sensors. A new positioning algorithm based on the RLS algorithm is proposed to be used in this system. This new algorithm considers as input data the distances among fixed and mobile sensors as well as the distances among the different mobile sensors. This new information leads to an improvement in the estimation of the position of the sensors.

The rest of the paper is organized as follows. Section II presents the classical system model usually used in the positioning systems and resumes the most known positioning algorithms. Section III-A explains the system model considered in this work and the proposed positioning algorithm. Section IV shows the simulation results obtained in the 3D positioning system proposed. Lastly, Section V portrays the conclusions of this paper.

2 POSITIONING ALGORITHMS

2.1 System Model

A classical positioning system for indoor environments is defined by N fixed sensors and M mobile sensors or tags, with $M \geq 1$. These positioning systems are able to estimate with a certain ranging algorithm the distances $\{d_{i,j}\}$ among the i^{th} tags and the j^{th} fixed sensors, with $i = 1, \ldots, M$ and $j = 1, \ldots, N$.

Using the information of the distances $\{d_{i,j}\}$, the positioning algorithms estimate the position of the i^{th} tag, $\boldsymbol{\theta}_i = (x_i \quad y_i \quad z_i)^{\mathrm{T}}$, where $(\cdot)^{\mathrm{T}}$ represents the matrix transpose. To that end, the next equation has to be solved:

$$\mathbf{A} \cdot \boldsymbol{\theta}_i = \mathbf{b}_i \tag{1}$$

where the n^{th} row of the matrix $\mathbf{A}$, with $n = 1, \ldots, N-1$, will be

$$\mathbf{a}_n = 2\cdot\left(X_{n+1}-X_1 \quad Y_{n+1}-Y_1 \quad Z_{n+1}-Z_1\right) \quad (2)$$

and the n^{th} row of the vector b_i, with $n = 1, \ldots, N-1$, will be

$$b_{i,n} = d_{i,n+1}^2 - d_{i,1}^2 + k_1 - k_{n+1} \quad (3)$$

$\left(X_{n+1},\ Y_{n+1},\ Z_{n+1}\right)$ in (2) are the coordinates of the fixed sensor $n + 1$. In (3), $d_{i,n+1}$ is the estimated distance between the i^{th} tag and the $(n+1)^{\text{th}}$ fixed sensor and $k_{n+1} = X_{n+1}^2 + Y_{n+1}^2 + Z_{n+1}^2$.

There are different approaches to obtain the desired vector $\boldsymbol{\theta}$. In the following sections, the Least Square (LS) and the Recursive Least Square (RLS) algorithms are introduced.

2.2 Least Square Method (LS)

In the LS method, the equations system presented in (1) is directly solved, so that [9]:

$$\hat{\boldsymbol{\theta}}_i = \left(\mathbf{A}^{\mathrm{T}}\cdot\mathbf{A}\right)^{-1}\cdot\mathbf{A}^{\mathrm{T}}\cdot\mathbf{b}_i \quad (4)$$

where $(\cdot)^{-1}$ represents the matrix inverse.

2. 3 Recursive Least Square Method (LS)

In order to avoid the matrix inversion of the LS method in (4), the RLS algorithm [10], solves iteratively the $(N-1)$ equations system in (1) in the following way:

$$\hat{\boldsymbol{\theta}}_{ik} = \hat{\boldsymbol{\theta}}_{i(k-1)} + \mathbf{m}_{ik}\cdot\left(b_{i,n} - \mathbf{a}_n\cdot\hat{\boldsymbol{\theta}}_{i(k-1)}\right) \quad (5)$$

where, $\hat{\boldsymbol{\theta}}_{ik}$ is the estimation of $\boldsymbol{\theta}_i$ in the k^{th} iteration.

$$\hat{\boldsymbol{\theta}}_{ik} = \left(\hat{x}_{ik} \quad \hat{y}_{ik} \quad \hat{z}_{ik}\right)^{\mathrm{T}}, \quad (6)$$

and

$$\mathbf{m}_{ik} = \frac{\mathbf{P}_{i(k-1)}\cdot\mathbf{a}_n^{\mathrm{T}}}{\mathbf{a}_n\cdot\mathbf{P}_{i(k-1)}\cdot\mathbf{a}_n^{\mathrm{T}}+1}, \quad (7)$$

$$\mathbf{P}_{ik} = \left(\mathbf{I} - \mathbf{m}_{ik}\cdot\mathbf{a}_n\right)\cdot\mathbf{P}_{i(k-1)}, \quad (8)$$

being $\mathbf{I}$ a $(N-1)$ dimension identity matrix.

With an initial guess of $\boldsymbol{\theta}_{i0}$, (5) is sequentially solved using the $(N-1)$ rows of matrix $\mathbf{A}$ and vector $\mathbf{b}$. This process is iterated R times. Thus, the total number of iterations is $(N-1)\cdot R$.

3 PROPOSED POSITIONING ALGORITHM

3.1 Proposed System Model

Our proposed positioning system for indoor environments will have N fixed sensors and M mobile sensors or tags, with $M \geq 1$. As the classical system, this one is able to estimate by means of a ranging algorithm the distances $\{d_{i,j}\}$ among the i^{th} tags and the j^{th} fixed sensors, with $i = 1, \ldots, M$ and $j = 1, \ldots, N$. Moreover, this system is able to estimate the distances among the i^{th} and the p^{th} tag, $\{r_{i,p}\}$, with $i = 1, \ldots, M$ and $p = 1, 2, \ldots, i-1, i+1, \ldots, M$.

In this new localisation system, more information is available in comparison with the classical system, thanks to the estimated distances between mobile sensors, $\{r_{i,p}\}$. The proposed algorithm is able to improve the estimation of the position of a certain tag i, $\hat{\boldsymbol{\theta}}_i$, using this new information. The estimated positions of the tag i are obtained,

$$\hat{\boldsymbol{\theta}}_i = \left(\hat{x}_i \quad \hat{y}_i \quad \hat{z}_i\right)^{\mathrm{T}} \quad (9)$$

solving the following equation system:

$$\tilde{\mathbf{A}}_i\cdot\hat{\boldsymbol{\theta}}_i = \tilde{\mathbf{b}}_i \quad (10)$$

For each i^{th} tag, the matrix $\tilde{\mathbf{A}}_i$ is defined as

$$\tilde{\mathbf{A}} = \left\{\begin{matrix}\mathbf{A}\\ \hline \boldsymbol{\Delta}_i\end{matrix}\right\} \quad (11)$$

where $\mathbf{A}$ is a matrix with dimension $(N-1)\times 3$, whose n^{th} row is defined by (2) and

$$\left(\boldsymbol{\Delta}_i\right)^{\mathrm{T}} = \left\{\hat{\boldsymbol{\delta}}_1 \quad \hat{\boldsymbol{\delta}}_2\cdots\hat{\boldsymbol{\delta}}_{i-1} \quad \hat{\boldsymbol{\delta}}_{i+1}\cdots\hat{\boldsymbol{\delta}}_M\right\} \quad (12)$$

with

$$\hat{\boldsymbol{\delta}}_p = 2\cdot\left(\hat{x}_p - X_1 \quad \hat{y}_p - Y_1 \quad \hat{z}_p - Z_1\right) \quad (13)$$

and (X_1, Y_1, Z_1) are the coordinates of the first fixed sensor.

Similarly, the vector $\tilde{\mathbf{b}}_i$ is defined for the i^{th} tag as

$$\tilde{\mathbf{b}}_i = \left\{\begin{matrix}\mathbf{b}_i\\ \hline \mathbf{c}_i\end{matrix}\right\} \quad (14)$$

where $\mathbf{b}_i$ is a vector whose n^{th} row is defined by (3)

$$\left(\mathbf{c}_i\right)^{\mathrm{T}} = \left\{c_{i,1} \quad c_{i,2}\cdots c_{i,i-1} \quad c_{i,i+1}\cdots c_{i,M}\right\} \quad (15)$$

And

$$c_{i,p} = r_{i,p}^2 - d_{i,1}^2 + k_1 - \hat{k}_p \quad (16)$$

In (16), $d_{i,1}$ is the estimated distance between the tag i and the first fixed sensor $r_{i,p}$ is the estimated distance between the tag i and the tag p, $k_1 = X_1^2 + Y_1^2 + Z_1^2$ and $k_p = \left(\hat{x}_p\right)^2 + \left(\hat{y}_p\right)^2 + \left(\hat{z}_p\right)^2$.

3.2 Proposed Algorithm

The proposed algorithm solves the system in (1) when the first distance estimations are received. To that end, an initial guess of $\boldsymbol{\theta}_{i0} = [0 \quad 0 \quad 0]$ and an initial value of $\mathbf{P}_{i0} = \boldsymbol{I}$ are considered. For the next position estimations, $\boldsymbol{\theta}_i$ and $\mathbf{P}_i$ are stored and used as initial guess. Thus, the $(N + M - 2)$ equations system in (10) are solved iteratively using the $\boldsymbol{\theta}_i$ and $\mathbf{P}_i$ previously stored. Additionally, every l new received measurements, the matrix $\mathbf{P}_i$ will be reset to the identity matrix.

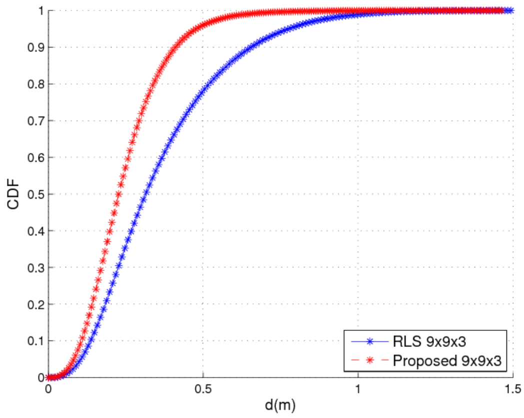

Figure 1. CDF of the positioning estimation of tag i = 1, with μ_d = 0.05 m, σ_d = 0.15 m.

Table I
ERROR IN THE ESTIMATION OF THE POSITION FOR N = 4, M = 4, A ROOM OF SIZE 9X9X3 m^3, μ_d = 0.05 m AND σ_d = 0.15 m

	RLS		Proposed	
Tag	μ_p (m)	σ_p (m)	μ_p (m)	σ_p (m)
i = 1	0.3609	0.2106	0.2470	0.1266
i = 2	0.3529	0.2050	0.2440	0.1248
i = 3	0.3570	0.2086	0.2476	0.1271
i = 4	0.3539	0.2062	0.2465	0.1266

3 SIMULATION RESULTS

A localisation system with N = 4 fixed sensors and M = 4 tags, whose position is desired to know, has been selected to obtain the simulation results of this section. 10^5 different configurations have been considered where the tags moved randomly around the room with a maximum speed of the tags of v_{max} = 5.56 m/s. New ranging estimations are received every Δ = 24 ms. Every l = 15 measurements the matrix $\mathbf{P}$ was reset. A room of size 9x9x3 m^3 has been considered. The fixed sensors have been located in the corners of the room; two of them in one diagonal at 0 m height and the other two sensors in the other diagonal at 3 m height. The error of the distance estimation among sensors is assumed to be normally distributed $N(\mu_d, \sigma_d^2)$.

Table I shows the mean μ_p and the standard deviation σ_p of the position estimation error of each tag for the RLS algorithm and for the proposed algorithm. An error in the ranging estimation of mean μ_d = 0.05 m and a standard deviation σ_d = 0.15 m has been considered for the results in this table. It can be observed that the RLS algorithm has a mean error in the tags localisation of μ_p = 0.36 m. However, our new estimator is able to improve this mean error to approximately μ_p = 0.25 m in all the tags. This implies an improvement of 30.6% in the mean error comparing with the RLS algorithm. Likewise, it can be observed that the proposed algorithm is able to reduce the standard deviation of the error for all the tags.

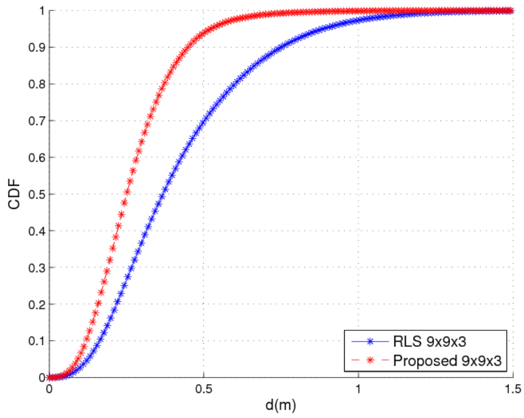

Figure 2. CDF of the positioning estimation of tag i = 1, with μ_d =-0.12 m, σ_d = 0.18 m..

In Figure 1, the Cumulative Distribution Function (CDF) can be observed for the tag i = 1 for the selected room and under the same simulation conditions as in Table I. The CDF provides the probability of the position estimation error to be below a certain distance d. Figure 1 shows that for the room of size 9x9x3 m^3, the RLS algorithm has an error in the position estimation of the sensor smaller than 0.77 m in the 95% of the cases; whereas with the proposed method, the error is smaller than 0.48 m.

Figure 2 shows the CDF of the tag i = 1, considering the values obtained from real measurements with the nanoLOC transceivers [15] after the post-processing explained in [16], μ_d = –0.12 m and σ_d = 0.18 m. Comparing the results in Figure 1 with the results in Figure 2, it can be seen that a bigger μ_d and a bigger σ_d implies a worst localisation of the tags. So, for μ_d = -0.12m and σ_d = 0.18m, the RLS method obtained a localisation error lower than 0.88 m in the 95% of the cases. However, the proposed method has an error smaller than 0.52 m in the 95% of the situations.

If the number of tags, M, is too big, applying RLS to (10) could be computationally costly. For this reason, it could be interesting to reduce the size of the matrix Δ_i, including only M_r < M – 1 rows $\hat{\boldsymbol{\delta}}_p$ to this matrix. To analyze this idea, a system with N = 4 fixed sensors and M = 10 tags placed in a room of size 9x9x3 m3 has been considered. The estimation error in the distance estimation among sensors has a mean of μ_d = 0.05 m and a standard deviation σ_d = 0.15 m. Figure 3 presents the CDF of the positioning error of the sensor i = 1, for different sizes of the matrix Δ_i. It can be observed that it is enough to use the distances from M_r = 3 tags to obtain benefits, obtaining in this case a mean error smaller than 0.52 m with 95% of probability. For each localisation system, given a certain number of sensors M and characteristics (μ_d, σ_d^2) of the error in the distance estimation among sensors, there will be a M_r size of the matrix Δ_i from which the benefits of the algorithm are not worth the increment in complexity.

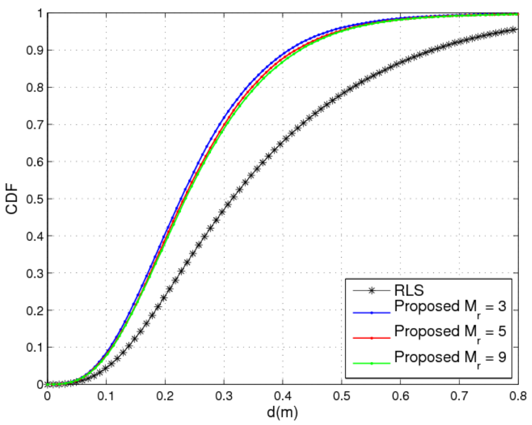

Figure 3. CDF of the positioning estimation of tag i = 2 in a room 9x9x3 m^3, with $\mu_d = 0.05$ m, _d= 0.15 m.

4 CONCLUSION

This paper presents a positioning algorithm for WSN. The proposed algorithm is able to improve the estimation of the position of the mobile sensors due to the use of both the distances among mobile sensors and the distances among fixed and mobile sensors.

The room size as well as the error in the estimation of the distances among sensors affect to the precision of the studied positioning algorithms. The obtained simulation results show that the proposed algorithm improves the estimation of the position in rooms of different sizes. Likewise, it has been observed that the new algorithm is less affected by the room size.

Finally, it has been demonstrated that in systems with a great number of mobile sensors it is not necessary to employ all the estimated distances among mobile sensors. In fact, there is a maximum number of distances from which the benefits obtained from the algorithm do not compensate the increase in complexity.

ACKNOWLEDGMENT

The research leading to these results has received funding from the European Community's Framework Programme FP7/2007-2013 under grant agreement n. 214986. Consortium: CEIT, Fraunhofer IIS, Jozef Stefan Institute, Ikerlan, COOSS Marche, University of Jyväskylä, Umea Municipality, eDevice, CUP2000, ZENON.

L. Zamora-Cadenas holds the Amigos of the University of Navarra grant.

References

[1] Confidence, http:// www.confidence-eu.org/ [accessed: July 31, 2010].

[2] C. Röhrig and S. Spieker, "Tracking of Transport Vehicles for Warehouse Management using a Wireless Sensor Network," in *International Conference on Intelligent Robots and Systems*, September 2008, pp. 3260–3265.

[3] F. Ellinger, R. Eicknoff, A. Ziroff, J. H¨utner, R. Gierlich, J. Carls, and G. B¨ock, "European Project RESOLUTION–Local Positioning Systems based on Novel FMCW Radar," in *Microwave and Optoelectronics Conference*, October–November 2007, pp. 499–502.

[4] D. Mastela, L. Reindl, L. Wiebking, M. Kawalkiewicz, and T. Zander, "Angle tracking using FMCW radar based localisation system," in *International Radar Simposium*, May 2006, pp. 1–4.

[5] N. Arrue, M. Losada, L. Zamora-Cadenas, A. Jim´enez-Irastorza, and I. Vélez, "Design of an IR–UWB indoor localisation system based on a novel RTT ranging estimator," in *International Conference on Sensor Device Technologies and Applications*, July 2010.

[6] Y. Nam, H. Lee, J. Kim, and K. Park, "Two–Way Ranging Algorithms Using Estimated Frequency Offsets in WPAN and WBAN," in *IEEE International Conference on Convergence and Hybrid Information Technology*, vol. 1, November 2008, pp. 842–847.

[7] D. Kang, Y. Namgoong, S. Yang, S. Choi, and Y. Shin, "A Simple Asynchronous UWB Position Location Algorithm based on Single Round–Trip Transmission," in *IEEE International Conference on Advanced Communication Technology*, vol. 3, February 2006, pp. 1458–1461.

[8] G. Shen, R. Zetik, and R. S. Thoma, "Performance Comparison of TOA and TDOA Based Location Estimation Algorithms in LOS Environment," in *Workshop on Positioning, Navigation and Communication*, March 2008, pp. 71–78.

[9] Y. Chu and A. Ganz, "A UWB–based 3D Location System for Indoor Environments," in *IEEE International Conference on Broadband Networks*, vol. 2, October 2005, pp. 1147–1155.

[10] S. M-Kay, *Fundamentals of Statistical Signal Processing. Estimation Theory*. Prentice Hall, 1993.

[11] N. Patwari, J. N. Ash, S. Kyperountas, A. O. Hero, R. L. Moses, and N. S. Correal, "Locating the Nodes: Cooperative Localization in Wireless Sensor Networks," *IEEE Signal Process. Mag.*, vol. 22, no. 4, pp. 54–69, July 2005.

[12] D. Niculescu, "Positioning in ad hoc sensor networks," *IEEE Netw.*, vol. 18, no. 4, pp. 24–29, July–August 2004.

[13] U. A. Khan, S. Kar, and J. M. F. Moura, "Distributed Sensor Localization in Random Environments Using Minimal Number of Anchor Nodes," *IEEE Trans. Signal Process.*, vol. 57, no. 5, pp. 2000– 2016, May 2009.

[14] *nanoLOC TRX Transceiver (NA5TR1) Datasheet*, Nanotron Technologies GmbH, 2008.

[15] L. Zamora-Cadenas, N. Arrue, A. Jim´enez-Irastorza, and I. V´elez, "Improving the Performance of an FMCW Indoor Localization System by Optimizing the Ranging Estimator," in *The Sixth International Conference on Wireless and Mobile Communications*, September 2010, accepted.

AUTOMATIC DISEASE RECOGNITION FROM MOVEMENT ANALYSIS

Bogdan Pogorelc
Department of Intelligent Systems
Jožef Stefan Institute
Jamova 39, 1000 Ljubljana, Slovenia

and

Špica International d.o.o.
Pot k sejmišču 33
1231 Ljubljana, Slovenia
Tel: +386 1 477 32 30
e-mail: bogdan.pogorelc@ijs.si

ABSTRACT

This paper describes the detection of diseases manifesting in movement. It uses Support Vector Machines for training a classifier, which classifies walking into normal walking and walking with hemiplegia, Parkinson's disease, pain in the back and pain in the leg. The obtained classification accuracy is 85-95%. Also, the study of the impact of tag placement and noise level on the accuracy of detection of health problems is presented. It can be used as a guidance in future studies in the increasingly important area of ambient assisted living.

1 INTRODUCTION

Developed countries are dealing with the fast aging of their population. It is estimated that by 2050, the number of people over 60 in Europe will have doubled to 40 % of the total population or 60 % of the working age population [1]. Consequently, this could overwhelm the society's capacity for taking care of its elderly members. To avoid this problem, researchers wordlwide seek new technical solutions to ensure that the elderly can live longer independently with minimal support of the working-age population. The research in the present paper is focused toward that same goal, as well.

In the paper we propose an intelligent and ubiquitous care system for monitoring elderly in order to recognize a few of the most common and critical health problems of the elderly, which can be detected by observing and analyzing the characteristics of their movement. These health problems are: hemiplegia, Parkinson's disease, pain in the leg and pain in the back.

The developed system is designed so that the observed user wears a number of tags placed on the body. The coordinates of the tags are acquired by sensors situated in the apartment, which makes it possible to reconstruct the user's posture and detect potential diseases. The objective of our research is to discover to what extent the automatic detection of diseases with motion capture system is possible.

2 RELATED WORK

For the automatic recognition of movement pattern, the movement must be captured first. For this purpose many types of motion capture devices exist. The most common are inertial sensors, nowadays usually in form of MEMS (Micro-Electro-Mechanical Systems)-based inertial systems composed of accelerometers and gyro sensors [2]. The second widely used approach uses video image processing for reconstruction of the human body movement. The third approach uses cameras in combination with tags attached to the body. Usually infra-red (IR) cameras are used and the body posture is reconstructed from the position of tags [11]. There exist also some specific measurement devices for recognition of tremor – symptom in Parkinson's disease, but not in hemiplegia, pain in the leg and pain in the back. Tremor can be assessed with variety of techniques, including the sensors for measurement of the angle of joint deflection in tremor type joint movements [3] and with electromyography [4].

For our study, the IR-camera system with tags attached to the body [11] was used. Based on the time series of captured positions of tags, machine learning was used to classify person into healthy person or into person with a specific disease.

We did not address the recognition of activities of daily living such as walking, sitting, lying, etc. and detection of falling, which has already been solved [7, 13, 14] but were solving more challenging task, which is recognition of diseases.

In related work, medical research is usually done in the way that motion capturing devices are used for capturing of movement which is later examined by medical experts. This is also the case in [18], where a system for long-term monitoring of gait in Parkinson's disease (PD) is presented. The characteristics of every stride taken were acquired using a lightweight ankle-mounted sensor array that saved the data into a small pocket PC. Stride was calculated from the vertical linear acceleration and pitch angular velocity of the leg with an accuracy of 5 cm. In comparison to ours, the described approach was meant for the monitoring of progress of PD for the known PD patient and was not used for early automatic detection of PD or other health problems.

The work [3] presents the sensors for measurement of the angle of joint deflection in tremor type joint movements, which can be used also to asses PD. However, the sensor systems are too big and would prevent users from doing activities of daily living if the systems would be worn all day. The same as the system described previously it has major drawback in comparison to our approach, because the system cannot automatically recognize PD or any other disease.

Using similar motion capture system as in our approach the automatic distinguishing between health problems such as hemiplegia and diplegia is presented [12]. The classification accuracy of 92.5 % was reported. This was achieved with Self-Organizing Maps whose features were wavelet-transformed gait characteristics such as walking speed and stride length. Our accuracies were comparable despite more noise and fewer tags (and probably also lower sampling frequency – this is not reported in the related paper).

An important part of the research presented in this paper is the study of the impact of the placement of tags on the user's body and the amount of noise in tag coordinates on the classification accuracy. The closest work in this respect that we are aware of investigated the placement of accelerometers for fall detection [6] Their finding was that the head provides optimal accuracy, but is impractical, wrist is not appropriate and waist is a good option.

3. MATERIALS AND METHODS

3.1 Selection of the Observed Diseases

For the development of our disease detection system we focused on four health problems in accordance with the suggestions received from the collaborating medical experts. The specific health problems for detection were suggested based on the incidence in the elderly aged 65+, medical significance and the feasibility of their recognition from the observed subjects' movements. The following four health problems were chosen as the most appropriate:

Parkinson's disease: a degenerative disease of the brain (central nervous system) that often impairs motor skills, speech, and other functions. The symptoms are frequently tremor, rigidity and postural instability. The rate of the tremor is approximately 4–6 Hz. The tremor is present when the involved part(s), usually the arms or neck, are at rest. It is absent, or diminished with sleep, sedation, and when performing skilled acts.

Hemiplegia: is the paralysis of the arm, leg and torso on the same side of the body. It is usually the result of a stroke, although diseases affecting the spinal cord and the brain are also capable of producing this state. The paralysis hampers movement, especially walking, and can thus cause falls.

Pain in the leg: resembles hemiplegia in that the step with one leg is different from the step with the other. In the elderly it usually means pain in the hip or in the knee.

Pain in the back: There is also similarity to hemiplegia and pain in the back in the inequality of steps; however, the inequality is not as pronounced as in walking with pain in the back.

3.2 Construction of the Features

A physician usually diagnoses such health problems while observing a patient's gait (i.e. posture and the walking pattern). Since the gaits of patients with the observed four health problems look similar to each other, a physician needs to pay attention to many details that need to be transformed into computable quantities. In practice, the observed four health problems can be detected by the distinctive walking patterns [8]. For the task of the automatic disease detection we proposed and tested the following 13 features, such as:

- Quotient between {difference between maximal and minimal height of the left and maximal and minimal height of the right ankle}
- Absolute difference of {difference of maximal and minimal speed of the left and difference of
- Absolute difference of average heights of the right and the left shoulder.

In our research we used 122 recordings of 5 persons performing the activities of interest:

- 25 recordings of walking normally.
- 25 recordings of walking with hemiplegia (the result of stroke).
- 25 recordings of walking with Parkinson's disease.
- 25 recordings of walking limping due to pain in the leg.
- 22 recordings of walking limping due to pain in the back.

Due to the unavailability of persons with the diseases of interest, some recordings were made under the supervision of a physician by healthy volunteers imitating patients.

The recordings consisted of the coordinates of 12 tags worn on shoulders, elbows, wrists, hips, knees and ankles, sampled with 10 Hz. Tag coordinates were acquired with

Smart infrared motion capture system [11] with 0.5 mm standard deviation of noise.

To test the robustness of the approach, we added varying degree of Gaussian noise to the raw coordinates. To make the variation of noise more genuine, the Ubisense UWB Real-Time Locating System [16] noise was added to the tag coordinates. The standard deviation of the noise measured in the Ubisense system was 4.36 cm horizontally and 5.44 vertically. We hereafter refer to the levels of noise in multiples of the Ubisense noise. The Ubisense system itself was not suitable for the experiments because it supports at most four tags with the sampling frequency of 9 Hz; if the number of tags is increased, the frequency is first halved and then reduced even more. Additionally, its noise can of course only be varied upwards, which also limits the exploration of the noise and tag-placement space – one of the main objectives of our research. As a preprocessing step, the data was smoothed with Kalman filter [15].

The machine learning task was to classify walking into five classes: four types of walking with the chosen health problems and the fifth without health problems as a reference. The classifier was trained on the recordings described under data acquisition, which were labeled with the type of walking. For each recording the feature vector consisted of the 13 features averaged over the recording. These vectors were used as training data for several machine learning algorithms [5], of which the Support Vector Machine (SVM) algorithm implemented in Weka [17] achieved the best performance. Since wearing the full complement of 12 tags may be annoying to the user, we investigated ways to reduce the number of tags. In addition, the interplay between tag placement and noise level was studied.

The experimental results were obtained by leave-one-person-out method, which means that the recordings of all the persons but one were used for training and the recordings of the remaining person for testing. The intention was not to overfit the classifiers to the specific persons in the training recordings, so the results show the expected classification accuracy on a previously unseen person. In real life the user would start wearing the tags when he would be healthy, thus the system would be trained on other users with various diseases. We also obtained results with ten-fold cross validation for comparison, but we do not report them in full.

The classification accuracy with respect to the tag placement and noise level was computed.

In the first experiment, we added Gaussian noise with standard deviation (σ) from none to 10 cm. We performed 4 algorithms of supervised learning using 10-fold cross validation and 1 algorithm of unsupervised learning in Weka. The results of classification accuracy for supervised methods and percentage of correctly clustered instances are shown in **Table 1** and **Figure 1**.

		Added noise				
		0mm	1mm	1cm	5cm	10cm
Algorithms	C 4.5	97.5	98.4	98.4	87.7	87.7
	ANN	100	100	100	91.8	91.8
	SVM	100	100	100	91.8	90.2
	Random Forest	100	100	100	95.1	91.0
	K-means	100	100	100	89.3	77

Table 1: Comparison of algorithms

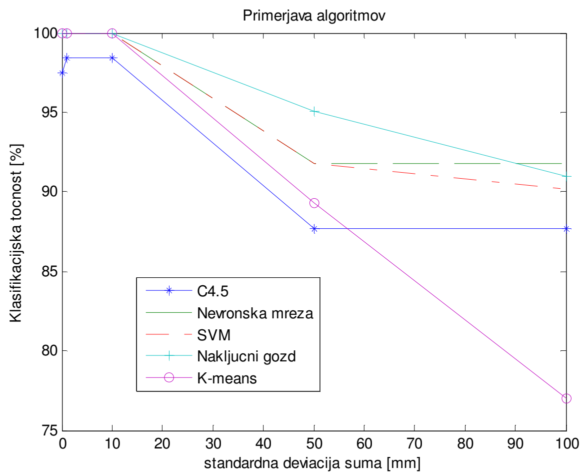

Figure 1. Classification accuracy with respect to the number of tags and noise level for detection of specific health problems.

4. CONCLUSION

We presented the system for automatical recognition of diseases of elderly, manifesting in movement pattern. Infrared motion capture system was used to capture movement. Time series of detected positions of body parts was transformed into form for SVM classifier using carefully designed features.

The automatic detection of health problems is rarely addressed, however our results are quite promising (accuracy 85–95 %). Moreover, the proposed recognition system is suitable for embedded systems due to its relatively small memory footprint and low computational complexity.

We have also studied the impact of tag placement and noise level on the accuracy of detection of health problems. In general more noise resulted in lower accuracy, as expected. The number of tags sometimes also behaved as expected, i.e., fewer tags resulted in lower accuracy. These results can be used as guidance in future studies in the increasingly important area of ambient assisted living.

ACKNOWLEDGEMENTS

Operation part financed by the European Union, European Social Fund. Author thanks Martin Tomšič, Bojan Nemec and Leon Žlajpah for their help with data acquisition, Anton Gradišek for lending his medical expertise, Rok Piltaver and Zoran Bosnić for discussion.

REFERENCES

1. S. Toyne, Ageing: Europe's growing problem. BBC News. http://news.bbc.co.uk/2/hi/business/2248531.stm, 2009-01-19.
2. D. Strle, V. Kempe, "MEMS-based inertial systems", Informacije MIDEM 37(2007)4 Ljubljana, pp. 199-209.
3. S. Ribarič, J. Rozman, "Sensors for measurement of tremor type joint movements", Informacije MIDEM 37(2007)2, Ljubljana, pp. 98-104.
4. J. Trontelj, J. Trontelj and L. Trontelj, "Safety Margin at mammalian neuromuscular junction – an example of the significance of fine time measurements in neurobiology", Informacije MIDEM 38(2008)3, Ljubljana, pp. 155-160.
5. Kononenko, I., Kukar, M. Machine Learning and Data Mining: Introduction to Principles and Algorithms. Horwood publ., 2007.
6. Bourke, A.K., Scanaill, C.N., Culhane, K.M., O'Brien, J.V., and Lyons, G.M. An optimum accelerometer configuration and simple algorithm for accurately detecting falls. In *Proc. BioMed 2006* (2006), 156–160.
7. Confidence: Ubiquitous Care System to Support Independent Living. http://www.confidence-eu.org.
8. Craik R., and Oatis C. *Gait Analysis: Theory and Application*. Mosby-Year Book (1995).
9. Harrison RD. Harrison's principles of internal medicine. New York: McGraw-Hill, 14th edition, 1998.
10. Perry J. Gait Analysis: Normal and Pathological Function. McGraw-Hill, Inc., 1992.
11. eMotion. Smart motion capture system. http://www.emotion3d.com/smart/smart.html.
12. Lakany, H. Extracting a diagnostic gait signature. *Pattern recognition 41* (2008), 1627–1637.
13. Luštrek, M., and Gams, M. Prepoznava položaja telesa s strojnim učenjem. In *Proc. IS'2008* (2008), 30–33.
14. Luštrek, M., and Kaluža, B. Fall detection and activity recognition with machine learning. *Informatica 33,* 2 (2009), accepted in publication.
15. Maybeck, P.S. Stochastic models, estimation, and control. *Mathematics in Science and Engineering 141* (1979).
16. Ubisense. http://www.ubisense.net.
17. Witten, I.H., and Frank, E. *Data Mining: Practical Machine Learning Tools and Techniques (2nd edition).* Morgan Kaufmann (2005).
18. Moore ST, et al., Long-term monitoring of gait in Parkinson's disease, Gait Posture (2006), doi:10.1016/j.gaitpost.2006.09.01

Indeks avtorjev / Author index

Uredniki:

Igone Velez
CEIT & Universidad de Navarra, Spain

Matjaž Gams
Odsek za inteligentne sisteme
Institut »Jožef Stefan«, Ljubljana