Traffic Simulation Software in the Context of Mobility Policy Support System

Maj Smerkol
maj.smerkol@ijs.si
Jožef Stefan Institute
Jamova cesta 39
Ljubljana, Slovenia

Žan Počkar
zan24pockar@gmail.com
Jožef Stefan Institute
Jamova cesta 39
Ljubljana, Slovenia

Alina Machidon
alina.machidon@ijs.si
Jožef Stefan Institute
Jamova cesta 39
Ljubljana, Slovenia

Matjaž Gams
matjaz.gams@ijs.si
Jožef Stefan Institute
Jamova cesta 39
Ljubljana, Slovenia

ABSTRACT

Due to novel challenges in large cities' traffic landscape the decision makers face more and more complex situations that are hard to understand while changes to these compound systems of road infrastructure, drivers and other actors can cause hard to predict undesired effects. As part of the H2020 Urbanite project a mobility policy support system is in development. One of the important aspects of this system is an appropriate traffic simulation system that enables non-invasive and cheap evaluation of proposed policies. Simulation results will be further analysed using advanced AI methods that will allow detection of unexpected events and identification of proposed solutions' negative aspects. We evaluated different traffic simulation software packages in the context of supporting mobility policy development. While included simulation software packages mostly provide similar feature sets and capabilities they differ in technology and maintenance status which has implications on the ease of integration and general usability for the project.

KEYWORDS

traffic, simulation, mobility policy, traffic modelling, artificial intelligence

1 INTRODUCTION

European cities are facing new challenges in the form of novel and innovative mobility solutions. On one hand disruptive start-ups are providing mobility on demand using different car sharing models while citizens are also starting to use micro-mobility devices, such as e-scooters and similar devices. These innovations have unforeseen consequences such as e-scooters causing traffic accidents in pedestrian zones, disruptions in the traditional public transport industry that have trouble competing with new business models and electric charging points exacerbating existing problems like the growing demand for public car spaces.

In order to analyse and understand the complex systems of city traffic a novel AI-aided software ecosystem URBANITE is being developed as part of the Horizon2020 European research programme. The URBANITE project is focused in developing a smart city system that will help decision makers in cities handle these new challenges. The project will provide a data management platform supporting the whole data harvesting process including collection, aggregation and provisioning the data, a decision support system including AI based predictive algorithms and simulation models and a social policy lab build upon co-creation session and the empirical analysis of trust, impact, benefits and risks of all stakeholders in the project.

This mobility policy support system will support the decision makers throughout the process of policy design and implementation. The core system includes a data harvesting and curation module, an intelligent algorithmic package and an advanced visualization module. The traffic simulation tool is one of the main components of such an ecosystem, providing information on the expected results of policy and the possibility of discovering unforeseen consequences of policy changes.

The results of traffic simulations will be further analysed using AI methods for problematic and unexpected traffic events. The traffic data will be linked to other relevant data such as weather condition, street noise levels and air pollution levels. Using linked data the traffic simulation will also be informed about demographic statistical data, such as percentage of household owning cars, general income and education levels etc. Thus the system will be able to take into account commuters preferences using the Belief-Desire-Intention cognitive architecture [6].

2 TRAFFIC SIMULATION

As a tool for municipality decision makers the ecosystem needs to provide accurate and easy to understand information on demand. Since implementing changes to traffic policy is very expensive and takes a lot of time, simulating traffic is a better option. Thus the users can analyse outcomes from traffic policy changes including changes to public transport, car parking and even changes to the infrastructure itself. Traffic simulations are in the realm of operational research, which deals with utilizing the use of available resources in an optimal way while reducing the negative co-products and outcomes.

We can categorise traffic simulations based on the level of detail simulation provides:

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- **Macroscopic traffic simulation** does not simulate individual cars but instead treats traffic flow like a fluid or a gas [3], moving through a network of pipes. This allows for good estimations of general road network capacity and helps identify bottle-necks that cause traffic jams.
Since the traffic flows are usually generic, therefore not split by mode of transport (driving a car, taking the bus, freight trucks etc.) macro simulators often cannot provide detailed analysis of generated pollution, noise or strain on the road surface. The LWR (Lighthill-Whitham-Richards) models common in macroscopic traffic simulators have trouble simulating shock wave traffic jams and phantom traffic jams, which can be problematic when simulating longer road segments or motorways [9].
- **Mesoscopic traffic simulation** deals with traffic flows but takes individual vehicles into account in certain cases, most commonly at junctions (nodes in the network). This technique is a compromise between amount and accuracy of the data generated and the amount of computing power and time needed to produce results [1].
- **Microscopic traffic simulation** simulated individual cars as they move through the network. The results can be analysed per individual rather than only the general traffic flow and different types of vehicles can be simulated. Different types of vehicles can also have different properties, therefore we can accurately predict vehicular noise and generated pollution (e.g. heavy freight traffic produces more noise and pollution than car traffic). Different types of vehicles can also be simulated using different models or with different parameters, such as acceleration and braking [4].
Microscopic traffic simulations are usually implemented using agent-based modelling, where each person in a city is represented as an individual agent. Each agent plans their trips according to their own scoring function, optimizing their own plan locally. Usually, agents re-plan their trips multiple times before an equilibrium is reached where all agents are somewhat satisfied, but global optimum is not reached. This is more realistic than globally optimized plans as humans planning their trips have limited knowledge of the traffic system state.
- **Submicroscopic traffic simulation** simulates vehicles using physical models, including steering, power train, braking and suspension of the vehicle. These are extremely computationally demanding and not commonly used in traffic related operational research. Submicroscopic traffic models have been shown to simulate lateral movement (lane switching, trajectory negotiation) with high accuracy [5].

For the purposes of the project a microscopic simulation is needed for tasks such as predicting noise and pollution levels and parking spaces demand. For preliminary quick results a macroscopic traffic

Depending on how the simulators treat time and space, we can further categorize them into

- **time and space continuous models:** traffic flow models (equation models, usually using Ordinary Differential Equations or Partial Differential Equations), pedestrian movement (integration over path) etc.
- **time and space discrete models:** cellular automata traffic models (e.g. rule 184 - not commonly used anymore) and numeric models with limited precision (PDE based models, ODE based models, some Monte Carlo methods).

Other combinations of time and space discrete and continuous including discrete/continuous state can be identified.

3 SIMULATION SOFTWARE PACKAGES

Simulator is a software package used to test, replicate and predict real world traffic situations. They require a lot of processing power to be as accurate as possible. Processing power needed is largest for running microscopic simulations. Commonly multi agent based they require to locally optimize plans for each agent.

To run a minimal traffic simulation we need a representation of the city road network and a representation of the population that includes data informing agent's planning decision[1]. Most traffic simulation software also allows other inputs:

- public transit lines and schedules,
- locations and capacities of parking places and public parking houses
- details about existing vehicles (e.g. a segmentation of vehicles based on European emission standards),
- bicycle lanes included in the road network,
- number of available taxi cabs,
- locations of electric charging stations etc.

3.1 Evaluated software packages

We have evaluated the following packages:

- SUMO (Simulating Urban MObility [4]
- MATSim (Multi-Agent based Traffic Simulation [10],
- PTV Vissim [2] [7] and PTV Visum [8],

3.2 Reasons for simulating traffic

Implementation of a new mobility policy is a long and expensive process. Solving the problem of a single congested road may results in other problems that can hardly be predicted without some computational help. Traffic simulations allow the traffic engineers to see the impact of changes without testing them out in real world, which would take a lot of time and is very expensive. Some changes to the road network may also need invasive actions such as relocating citizens. There needs to be strong evidence that the results will have positive impact before implementing such changes.

Traffic simulations also allow cities to gain more insight into the city traffic patterns by identifying common trip patterns, providing data about pollution and noise levels in residential areas or identifying the areas where certain problem arise, such as low parking space capacities.

Some of the use cases identified in the project are:

- traffic pattern recognition,
- analysis of mobility modality - comparing travel by car, bike, public transport or by foot,
- analysis of public transport - line usage, congested lines,
- identification of districts affected by noise and air pollution,
- analysis of traffic accidents - most affected junctions or roads etc,
- analysis of universal access to facilities,

[1]To inform planning and routing choices of an agent one can take into account their financial status, largest allowed lateness of arrival, whether or not they own a car etc.

Figure 1: Part of a traffic simulation of Bilbao, made with MATSim. Triangles represent a sampled subset of the vehicles in the network, where cyan-colored vehicles are moving at high speed and pink-colored vehicles are stationary - either waiting at traffic lights or stuck in traffic.

- identification of bicycle traffic patterns and bicycle traffic jams,
- comparison of expected traffic trends with actual traffic trends and
- analysis of capacities and demand for parking places.

Through the use of advanced simulators one can simulate different aspects of traffic. All simulators considered for the project include multi-modal approach supporting at least car, public transport, bike and walk modes. Multi-modality supporting changing mode of transport during one trip is vital for our goal of simulating the complex interactions between different parts of the traffic system. Support for multi-modality in traffic simulation packages is quite widespread, but most do not have a great variety of transport mode options. While using a car or other similar transport modes such as taxi cabs or car sharing are almost ubiquitously supported others are missing - even public transport support is lacking in some of them. The biggest obstacle is simulation of bicycle traffic.

3.3 Evaluation results

3.3.1 PTV Visum and PTV Vissim. PTV Group is a major company in the field of traffic management and both products are the industry standards for macroscopic traffic simulation and microscopic traffic simulation, respectively. While not useful for the project due to copyright restrictions and proprietary source code we have included them in order to compare with other open source tools.

PTV Visum is a macroscopic traffic simulation tool that support multi-modal transport and transit. It's primary purpose is analysis of large, regional road networks it can also be used on the level of a city.

PTV Vissim is a microscopic traffic simulation tool that supports multi-modal transport and many other advanced use cases such as indoor pedestrian traffic simulations and quasi-realistic 3D visualization. While Vissim can interact with GIS data sources it does not support importing open data sources and is primarily used to simulate small road subnetworks such as complex junctions that are usually designed using the inbuilt network manager.

These tools are not extensible by third parties and while they provide beautiful user interfaces therefore not usable for the projects.

3.3.2 SUMO. SUMO is an open source, microscopic and space and time continuous traffic simulation software package. It supports multi-agent based multi-modal simulations. SUMO is a relatively old and mature software package that supports most of the identified use cases. It has been used in many real-world cases with good success. SUMO package contains all the tools needed to prepare a network, run a simulation and analyze the results.

It is a complete package containing a full set of GUI tools which can prepare the network, model traffic demand, run the simulation and visualize the results. The GUI simulator application allows even inexperienced users to set up simple simulations. However the true power of the package is unveiled when working with the command-line interface (CLI). There are a lot of utilities and tools included to manipulate the configuration of the scenario and to set up the network.

However due to its monolithic nature (excluding CLI tools that are mostly implemented as python scripts) it is not easily extensible and adaptable to the project's specific needs. Some of the problems we have encountered are out of date documentation, the simulation crashing due to lack of memory available [2], lack of informative error reports that slow down the workflow and lack of support for simulating bicycle traffic [3].

3.3.3 MATSim. MATSim is a java based framework which provides the user with multitude of tools which are used to run agent-based large-scale simulations. MATSim's strengths lie in its adaptability and malleability for user preferences. MATSim includes tools which can be used to set up different simulations

[2] The memory problems were solved by compiling for 64 bit systems and running on a machine with more than 8GB of main memory.

[3] Bicycle traffic can be simulated, however bicycles can either behave like slow cars and drive on the roads or like fast pedestrians and drive on sidewalks. Collision between bicycles is hard to model and detecting bicycle traffic jams is not possible.

and analyze the results. It does however not include a visualizer, a third party visualizer was used to generate video, a frame from which is seen in figure 1. MATSim is the most demanding to work with in comparison with the other simulators discussed in this section.

Unlike other simulators MATSim is primarily run from command line and needs programming knowledge to operate beyond most basic simulations. A simple GUI application is available but it only supports most basic simulations, advanced simulations have to be developed by implementing a custom Java simulation controller class or extending the default GUI applications class.

Unlike other simulators where the agent is a person which boards and operates vehicles in MATSim the basic unit is a car. This means that while its motorized aspects of simulation are superb, simulating pedestrians and cyclists in larger volumes is less accurate. Simulating pedestrian and bicycle traffic is a need for the project and this presents a problem, but due to the extensibility of the framework we believe we can overcome it.

4 DISCUSSION

A microscopic traffic simulation software package is needed in the project URBANITE in order to inform AI based methods for predicting traffic trends, identifying traffic patterns and understand the complex interactions between elements of the city traffic system. We have evaluated multiple available open source and closed source software packages in the terms of how well they cover identified use cases and the complexity of integration into a larger mobility policy support system.

We have discovered that except for the user experience, industry standard traffic simulation software is on par current state of the art research projects. Due to ease of integration and extensibility of the framework the best choice for the project is MATSim even as it has missing functionality (only most basic visualizations are included and simulating bicycle traffic is hardly supported).

Finally, due to large amount of computer power needed to run such simulations, for the project we will complement microscopic traffic simulations with faster and less precise macroscopic traffic simulations. Thus we will be able to run optimization algorithms and evolutionary algorithms to discover possible solutions to traffic problems.

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REFERENCES

[1] Felipe de Souza, Omer Verbas, and Joshua Auld. 2019. Mesoscopic traffic flow model for agent-based simulation. *Procedia Computer Science*, 151, 858 –863. The 10th International Conference on Ambient Systems, Networks and Technologies (ANT 2019) / The 2nd International Conference on Emerging Data and Industry 4.0 (EDI40 2019) / Affiliated Workshops. ISSN: 1877-0509. DOI: https://doi.org/10.1016/j.procs.2019.04.118. http://www.sciencedirect.com/science/article/pii/S1877050919305824.

[2] Martin Fellendorf and Peter Vortisch. 2010. Microscopic traffic flow simulator vissim. In *Fundamentals of traffic simulation*. Springer, 63–93.

[3] Dirk Helbing, Ansgar Hennecke, Vladimir Shvetsov, and Martin Treiber. 2001. Master: macroscopic traffic simulation based on a gas-kinetic, non-local traffic model. *Transportation Research Part B: Methodological*, 35, 2, 183–211.

[4] Pablo Alvarez Lopez, Michael Behrisch, Laura Bieker-Walz, Jakob Erdmann, Yun-Pang Flötteröd, Robert Hilbrich, Leonhard Lücken, Johannes Rummel, Peter Wagner, and Evamarie WieBner. 2018. Microscopic traffic simulation using sumo. In *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*. IEEE, 2575–2582.

[5] freddy a mullakkal babu, Meng Wang, B. Arem, Barys Shyrokau, and Riender Happee. 2020. A hybrid submicroscopic-microscopic traffic flow simulation framework. *IEEE Transactions on Intelligent Transportation Systems*, (May 2020). DOI: 10.1109/TITS.2020.2990376.

[6] Lin Padgham, Kai Nagel, Dhirendra Singh, and Qingyu Chen. 2014. *Integrating BDI agents into a MATSim simulation*.

[7] [n. d.] PT Vissim product website. https://www.ptvgroup.com/en/solutions/products/ptv-vissim/. Accessed: 2020-07-03. ().

[8] [n. d.] PT Vissim product website. https://www.ptvgroup.com/en/solutions/products/ptv-visum/. Accessed: 2020-07-02. ().

[9] Durgesh Vikram, Partha Chakroborty, and Sanjay Mittal. 2013. Exploring the behavior of lwr continuum models of traffic flow in presence of shock waves. *Procedia - Social and Behavioral Sciences*, 104, 412 –421. 2nd Conference of Transportation Research Group of India (2nd CTRG). ISSN: 1877-0428. DOI: https://doi.org/10.1016/j.sbspro.2013.11.134. http://www.sciencedirect.com/science/article/pii/S1877042813045254.

[10] Kay W Axhausen, Andreas Horni, and Kai Nagel. 2016. *The multi-agent transport simulation MATSim*. Ubiquity Press.