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Trends in Real-time Traffic Simulation

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Abstract

Traffic simulation models and software tools have been developed for the purpose of traffic modelling, planning and to analyse different strategies in traffic control during simulations. Traffic simulation models and tools are increasingly used in real-time for traffic management with the use of area-wide online traffic data. A comparison of 17 simulation software tools has been conducted by analysing scientific papers and technical specifications. An online survey with the focus on realized functionalities and planned improvements has been conducted together with traffic simulation tool developers and product managers. Particular emphasis was placed on the flexibility and adaptively of real-time simulation solutions in the context of heterogeneous road networks (urban, interurban, rural) and other special requirements in non-mainstream regions. It has become apparent that simulation software tools have many challenges in the application of simulating road conditions of complex heterogeneous road transportation networks and heterogeneous traffic with a small amount of real-time data.

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Keywords: Traffic Simulation Software; Advanced Traffic Management Systems; Heterogeneous Road Networks; Adaptability; Real-time Capability; Trends

1. Introduction

This paper presents the results of an evaluation process of traffic simulation systems of the successfully completed project "Intelligent Transport Systems Austria West" which was commissioned by the Office of the Provincial Government of Upper Austria and sponsored by the Austrian Climate and Energy Fund. The aim of the project was to implement and introduce a simulation software tool for providing real-time traffic estimation and short-term traffic predictions for the lower-priority roads of Upper Austria. This network includes about 6000 kilometers of heterogeneous roads: urban streets in cities and towns as well as rural roads with sharp/blind bends,

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bottlenecks, inclines and pedestrian crossings or roads with two or more lanes without intersections and the traffic impact of which is similar to that of a motorway. In addition, heterogeneous traffic has to be taken into account: cars, trucks, busses, agricultural tractors, motorbikes, bicycles and pedestrians.

Roadside detectors are expensive and can only measure traffic volume at single points, which are nodes of the road network. To describe the current traffic situation of a heterogeneous road network an online sensor-integrated software tool has to be implemented to simulate and estimate the current traffic conditions in sections without real-time sensor information by abstraction of real world conditions by developing computer models (Ratrout et al., 2009).

Ni (2001) defines five driving forces, which lead to a continuous development of traffic simulation systems:

- The advances in traffic theory;
- The continuing improvement in computer hardware technology;
- The similar improvement in software technology;
- The development of the general information infrastructure;
- The society's demand for more detailed analysis of the consequences of traffic measures and plans.

A literature review revealed that in the last few years no comparison of traffic-simulation tools has been published. Technical documents have been evaluated. An online survey with developers and product managers has been conducted. In addition predictions of future trends in traffic simulation software have been collected on basis of expert interviews.

2. Literature Review

Since the late 1990's there have been published at least 24 reports on simulation system comparison (Ratrout et al., 2009, Kotushevski, 2009, Jones et al., 2004). By analysing these evaluations, it appears that there was no comprehensive comparison study since the "SMARTEST" project coordinated by the University of Leeds and funded by the European Commission, published by Barceló et al. (2000). Considering the facts mentioned by Ni (2001) and that there has not been a comprehensive analysis with the focus on real-time traffic simulation of heterogeneous road networks, this study performs this function to give an overview of the current functionality as well as the development over the last years.

While the review report of "SMARTEST" has a focus on modelled ITS functionalities like co-ordinated traffic signals, variable message signs or different types of route guidance (Barceló et al., 2000), the study of Kotusevski and Hawick (2009) aimed at the evaluation of usage and performance measurement. Topics like licensing, operating environments, computing power, documentation, graphical user interfaces, maximum size of the modelled area, output types and other factors have been analysed (Kotushevski, 2009). The main challenges in traffic simulation are the lack of detail, the lack of flexibility and the costs to build models which is time an labour-intensive. These problems can be countered by multi-scale resolutions like hybrid models, through parallel and distributed execution and object based simulation models (Ni, 2006). Simulators are able to approximate traffic volume also for sections without (real-time) detector's data and so minimize expanses for additional road-side sensors by the use of vehicle probe data and an on-going updated demand model (University of Leeds, 2000).

3. Methodology

Therefore, feature specifications of available software tools and their attributes used in previous studies have been merged and extended with new software products and additional attributes. In total 17 simulation tools have been reviewed. The records were updated based on facts gathered from available technical specifications and published reviews. Additionally traffic simulation software developers and product managers were invited to update the feature-list of their products and to publish information on further developments planned.

Second, expert interviews with traffic managers, engineers, consultants and academics in the field of traffic simulation have been conducted. The results of the open questions were used to obtain information about trends in traffic management that affects or is affected by traffic simulation systems. The international experts were asked to give their opinions and appraisements for the three different perspectives market, developer/seller and decision maker/user from their point of view. A further focus of the interviews was traffic management of heterogeneous road networks and its impact on development of traffic simulation. By the application of methods of qualitative content analysis by Mayring (2000) and after encoding the content according to Bortz/Doering (2006) the results were collated methodically.

4. Comparison study

As part of this study, a survey was conducted to ascertain the current state of traffic simulation programs. The questionnaire was based on SMARTEST by the University of Leeds (2000). As new fields of application have developed over the last few years, a lot of additional functionalities of other publications were added (Kotushevski et al. 2009, Jones et al., 2004, Adams et al., 2000, Chen et al., 1999, Ben-Aktiva, 2007). The aim was to provide an overview of as many products as possible. The outcome of the study is an overview of 17 products listed in the two tables below. The information was gathered either by the questionnaire or from literature (Ben-Aktiva et al., 1998, Liu, 2007, ATMS R&D and Systems Engineering Program Team, 2006, Intelligent Transportation Systems Program, 2001, User's Guide for MITSIMLab and Road Network Editor (RNE) (2001), Boxill et al., 2000, Al-Hamid Al-Dmour, 2011, Bloomberg et al., 2000). Extracts from the results are divided in 9 category groups, including functionalities which proved to be important for the use of real-time traffic simulation models in heterogeneous road networks.

Table 1: Comparison of traffic simulation programs (part I)

Key: O............... No X............... Yes ! .... (further) improvement [empty] not given	Aimsun 7	Cube Voyager/Avenue	DRACULA	DynaMIT	FLEXYT-II	FreeSim	Integration	MITSIMLab	PELOPS	PLANSIM-T	Quadstone Paramics	S-Paramics	SITRA-B+	SUMO	TransModeler	TSIS-CORSIM	VISSIM
Flow model category																	
macroscopic model	X	O	O			X		O	O		O	O		O	X	O	O
mesoscopic model	X	X	O	X		O		O	O		O	O		X	X	O	O
microscopic model	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Model size restrictions																	
limit of crossings		X	O			O			X!		X	O	X	O	O	X	
limit of links		X	O			O			O		X	O	X	O	O	O	
limit of edges			O			O						O		O	O		
limit of street categories	X!		O			O			X!		X	O		O	O		
limit of lanes	X!		O			O			X		X	O		O	O	X	
limit of vehicle types		X	X			O			X		X	O		O	O		
limit of driver profiles			O			O			O		X	O		O	O		
limit of public transportation routes			O			O					X	O		O	O	X	
ITS functionalities																	
co-ordinated traffic signals	X		X		X	O	X	X	X!	X	O!	X	X	X!	X!	X	X
adaptive traffic signals	X	X	X		X	O	X	X	X!	X	X!	X	X	X!	X!	X	X

Table 2: Comparison of traffic simulation programs (part II)

Key:
O............... No
X............... Yes
! .... (further) improvement
[empty] not given

	Aimsun 7	Cube Avenue	DRACULA	DynaMIT	FLEXYT-II	FreeSim	Integration	MITSIMLab	PELOPS	PLANSIM-T	Quadstone Paramics	SITRA-B+	S-Paramics	SUMO	TransModeler	TSIS-CORSIM	VISSIM
public transport priority	X	X	X		X	O	X	X	O	X	X	X	X	O!	X	X	X
ramp metering					X	O	X	X	X	X	X	X		O!	X	X	X
freeway flow control	X			X	X	X	X	X	X		X	X		O	X	X	X
adaptive cruise control						O			X!			O		O		X	
automated highway system						X			X!	X		O		O			
autonomous vehicles						O			X!			O		O			
v2v/v2i communication						X			X!		X!	O		X!	X!		X
automatic debiting & toll plazas					X	O	X		O		X	X		O	X	X	X
zone access control					X	O			O	X	X	X		X!	X!		
incident management	X		X	X	X	O	X		O		X	X	X	O	X	X	
variable message signs	X		X	X		O	X	X	X!	X	X	X		X!	X!		
static route guidance						X	X	X	X!	X	X	X	X	X!	X		X
dynamic route guidance	X	X		X		X	X	X	O!	X	X	X	X	X!	X		X
vehicle type specific barred turningmovement and link/lane closures						O			O		X	X		X!	X	X	
multimodal traffic	X	X				O		X	O		X	X		X!	X		
parking guidance						O			O	X	X	X	X	O!	X		X
public transport information						O	X		O	X	X	O		O	O		X
probe vehicles						X	X		X!	X	X	O	X	X!	X		X
street restrictions																	
speed limits	X	X	X			X		X	X			X		X	X	X	
weight	X					O			O			X		O	O		
vehicle height	X					O			O			X		O	O		
vehicle width	X					O		X	O			X		O	O		
vehicle type specific lane use (e.g. bus lane)	X											X		X	X	X	
Modelled objects and phenomena																	
cars	X!	X	X	X	X	X!	X	X	X!	X	X	X	X	X!	X	X	X
commercial vehicles/trucks		X	X		X	X!	X	X	X!	X	X		X	X!	X	X	X
(motor) cyclists		X			X	O			X!				O	X!	X		X
pedestrians		X	X		X	O			O!		X		O	X!	X	X	X
public transport vehicles on road	X	X	X		X	X!	X	X	O	X	X	X	X	X!	X	X	X
trains and streetcars/trams	X	X	O			O		O				X	X!	X	X	X	
abnormal loads/vehicles	X					O		O		X		X	O!	O			

Table 3: Comparison of traffic simulation programs (part III)

Key: O............... No X.............. Yes ! .... (further) improvement [empty] not given	Aimsun 7	Cube Voyager/Avenue	DRACULA	DynaMIT	FLEXYT-II	FreeSim	Integration	MITSIMLab	PELOPS	PLANSIM-T	Quadstone Paramics	S-Paramics	SITRA-B+	SUMO	TransModeler	TSIS-CORSIM	VISSIM
hazardous materials transportation	X					O		O				O	O	O			
parking vehicles		X	X			O	X	O			X	O	O!	X	X	X	
searching for parking space						O			O		X	X	X	O!	X	X	X
weather conditions			X	X		X!		X	X				O	O!			
traffic calming measures			X		X	X!	X	X	O		X		X	X!	X		X
congestion	X	X	X			X!			X!	X	X		X	X!	X	X	
queue length	X	X	X	X	X	O		X	O		X	X	X	X!	X	X	X
variable travel times	X		X	X	X	X!		X	O		X	X	X	X!	X	X	X
overtaking on dual carriageway roads			X			O		X	X!		X		X	X!	X	X	X
overtaking on single carriageway roads			X			O			O!				X	O!	X		
predictable incidents (e.g. roadworks)	X		X	X	X	X!	X		O		X	X	X	X!	X	X	X
incidents random-in-nature (e.g. accidents)			X	X		X!	X		X!		X		X	O!	O	X	
roundabouts		X	X		X	O	X	X	O	X	X	X	X	X!	X	X	X
queue spill back				X	X	O	X	X	O	X	X	X	X	X!	X	X	X
steep grades		X				O		X	X		X		X	X!	X	X	
cornering ability at blind corners						O			X				O	O!			
driveability at blind bend						O			X		X		O	O!			
mix of users/variety of driver profiles		X	X	X		O		X	X!		X		X	X!	X	X	
real-time data integration and analysis																	
roadside devices	X		X	X	X	X	X	X	X!	X	X!	X	X	X!	X	X	X
(x)FCD/FVD/Probe data						X!			X!		X!		O	X!			
V2I						X!		X	X!		X!		O	X!	X		
others																	

Comparing the up-to-date results shown above with earlier studies it seems that some simulation systems have been developed faster than others. It also reveals a further development of some products to adapt them to new fields of application. Due to the fact that traditional simulation programs have not been developed for being used in this area this step seems to be necessary (Boxill, 2000).

5. Trends in traffic simulation supporting ATMS

Table 4: Interviewees, Feb-Mar, 2013

Name	Position	Company	Country
Ramachandran Balakrishna	Senior Transportation Engineer	Caliper Corporation	USA
David Trošt	Traffic Planner	PNZ Ltd.	Slovenia
Ryota Horiguchi	CEO	i-Transport Lab	Japan
Parth Bhavsar	PhD Candidate	Clemson University	USA
anonymised	-	-	-
anonymised	WW-Leader	IBM	Netherlands
anonymised	-	-	-
anonymised	-	-	-
anonymised	Researcher	German Aerospace Center	Germany
Daniel Krajzewicz	Researcher	German Aerospace Center	Germany
Andreas Köglmaier	Regional Director	Citilabs Inc.	USA

5.1. Traffic simulation systems (TSS) are used by different user groups and need to provide a lot of different functionalities.

There are different user groups of TSS such as researchers, consultants, high priority road operators or city and road authorities. As they have to solve different traffic problems, they ask for different product functionalities. For urban planning and the design of traffic light control plans, offline simulation is sufficient. For travel time prediction and incident management in traffic management centres online real-time simulation is critical. Many users are looking for microscopic details on a macroscopic level. That may be interpreted as they ask for TSS, which require less data input and calibration for providing realistic results on detailed levels. On the other side vendors of TSS try to provide products which might deal with all the different fields of application. Therefore, they deliver simulation tools offering increasing functionalities. These many functions cannot be handled by most users. In fact, some offers remain unclear and users have to customize the products.

It is estimated that an increasing amount of city and road authorities will use these systems more often in future. Regarding the current trends, additional groups, such as public transportation providers will use TSS. Additionally, all these user groups will require more functionality to might deal with further tasks. City and road authorities will use TSS not only for traffic management, but also to evaluate energy consumptions and emissions due to the general trend to assess the environmental impact of traffic and to optimize energy consumption. Therefore, requirements on TSS will increase.

5.2. Using TSS for ATMS & real-time simulation causes special requirements on TSS.

The use of real-time traffic simulation is relatively new and from a market perspective still underestimated. Today, there are very limited real-world applications of real-time systems. Most of these applications are academic research case studies. There are many vendors, but only a few of them are deliver suitable products that fit for those real-time applications. These well-established products have a stable user community. To operate real-time TSS good behavioural models, driver response and prediction algorithms are needed. The trend of using TSS for ATMS has created increased interest in mesoscopic solutions, their ability to scale wide areas without too much loss of fidelity in representing traffic dynamics. Yet, vendors of TSS do not offer all of these functionalities in one single product. By providing interfaces in TSS vendors ensure, that missing functionalities can be implemented. However, for customizing TSS, a lot of research, coding and calibration must be done. Therefore, it needs more than a tool from a user's perspective. Real-time traffic simulation needs a bundle of software tools, knowledge and sometimes know-how. Another challenge will be to process great volumes of data provided by vehicles, mobile phones or roadside sensors. They all have to be integrated in TSS to provide real-time traffic estimation, prediction and predictive route guidance. Predictions are required in order to anticipate congestion and drivers‘ response to any guidance that is disseminated to them. Some real-time systems without sophisticated prediction models exist in practice. Real-time predictive methodologies are still in the research/academic domain.

5.3. A detailed network model is required.to can simulate traffic on heterogeneous roads.

The requirement of a detailed network model is not just necessary for planning but also for real-time simulation. In both cases, there are long- and short-range trips interacting on the network. Also, if incidents in random or congestion occur on high priority roads, minor roads become more important, because they serve for diverted traffic. However, most study tasks are already working with heterogeneous road networks and as a result, TSS have different road categories integrated today.

5.4. Geographic information systems (GIS) are an important tool for efficient use of TSS.

GIS as a supporting system for TSS play an important role to provide a link between planning, forecasting, operations and management tasks, yielding new insights into each of these areas and more intelligent decision - making to improve efficiency. Additionally GIS would improve data consistency. One key feature of GIS is to provide large-scale maps to develop geographically accurate road networks. However, the potential of GIS to fuse data together from different contexts as a common platform is often not recognized by vendors. This may lead to a misleading product development, that drift away from interoperability and leave customers confused as how to integration should be performed.

5.5. TSS in rural areas have to deal with different challenges.

Comparing rural areas with urban and inter-urban areas it arises, that rural areas have to deal with motorized and non-motorized traffic. Due to the fact that pedestrians, bicycles, cars, trucks, busses, etc. interact on these roads, parameters require a calibration. Freight traffic also needs to be properly calibrated to be able to take into account the effects of trucks on traffic congestion. To model heterogeneous traffic it is possible to change parameters in microscopic simulation systems and develop mesoscopic models. TSS need to adapt their methods of assignment on the different road categories rural, interurban and urban. In some cases legacy asset management and network information systems have to be replaced with more comprehensive database solutions. Additionally, poor data quality, a small amount of real-time data and communication costs in remote rural areas are common challenges – not only for operators, but also for vendors.

5.6. TSS must provide efficient mechanisms to customize and calibrate models.

To model and simulate heterogeneous networks, users would like to have modular software tools but differently scaled models. While some want microscopic models, others tend to use mesoscopic models and still others want some multi-resolutional models. When it comes to heterogeneous traffic, motorized and non-motorized, and their interaction with each other, there is a need to have a simple or automated calibration method. If the amount of one-track vehicles rises to more than five per cent of the total volume of traffic parameter calibration will struggle. Thus, simulation of heterogeneous traffic will fail in development countries.

6. Conclusions

A state-of-the art review report has been drawn up. The results of the evaluation show, those existing simulation systems can estimate current traffic situation and predict traffic conditions.

Most of the simulation tools are designed for "urban", "interurban" or "combined" road networks and can deal with real-time data. No system delivers all functionalities; no system seems to have a focus on a single field of application. Some of these systems use hybrid models (micro+meso, micro+macro, micro+meso+macro); some of them have limitations in links, etc. A detailed network model is necessary. A GIS data based network model would improve data consistency and efficiency, which is often not recognized by software vendors.

There is a lack of online traffic simulation software applications specially designed for heterogeneous road transportation networks in peripheral regions. Regarding the rising performance of traffic simulation systems, future research could be done to further develop this functionality in simulation systems to can use them better for providing real-time traffic information and short-term traffic predictions in mixed wide areas (rural, urban, inter-urban) by the use of vehicle probe data without focusing only on highways, highly-ranked arterial roads and conurbations. Customization provides more room to develop future applications but also overstrains some users.

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