Simulator Training for Decision Making Intelligence Enhancing in Bicycle Routes Designing and Planning System

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Abstract. The European Commission decisions promote using clean transport methods, and one of which is cycling. In order to ensure the successful functioning of an integrated urban transport system cycling has to be one of its components, which naturally fits into the overall intermodal transport system. Due to limited funding it is important to understand which bike path network would be more efficient and usable for municipality and cyclists. The multi agent-based (MAS/ABM) bicycle path network and exploitation simulator (VeloRouter) allows paths occupancy simulation, but quality of the results depends on the simulator right training.

Keywords: Agent-based simulation, justified design and planning, bicycle routes planning.

1 Introduction

The European Commission Decision C 6776 established the specific European Transport Specific Programme implementing Horizon 2020, Part 11 "Smart, green and integrated transport" [1], which promotes clean transport i.e. cycling as a part of the overall intermodal transport system. This means that bike paths, racks and the lease network must correspond to the transport schema. Unfortunately, the lack of financial resources makes it impossible to construct bike paths wherever it would be desirable.

Therefore, it is important to understand which bike path network would be more efficient and ensure the greatest possible population transfer to bicycles. Cyclists are interested in justified selection of the route to avoid the problems for travellers related with terrain, quality of route and occupancy during the travel time. So, intelligent route planning is important task.

The idea for VeloRouter originated in FP7-ICT-2011-7 FUPOL project No. 287119 (2011-2015) “Future Policy Modelling” [2]. This gave the opportunity to perform

market research and understand the needs of potential users. The market analysis involves significant amount of different bicycle routes planners [3].

In conformity with the requirements Skopje Bicycle Inter-Modality Simulator (http://www.fupol.eu/en/news/skopje-bicycle-inter-modality-simulator) [4] was created to find a useable solution for bicycle stations deployment in the City of Skopje. To encourage intermodal transport, the citizens are also involved in the collection of ideas on how bicycle inter-modality can be fostered using a ticketing mechanism. The system helps the municipality of City of Skopje to improve the scheduling and resource planning, initiation and creating new projects involving the bicycle area in Skopje city. The above-mentioned simulator can be considered analogous to VeloRouter, however solution commenting and statistics aggregation capabilities here are limited. Simulation algorithms and results are focused on the needs of a specific large municipality and does not entail a detailed analysis of individual cyclists. Adaptation of the product is difficult and it is intended for use in large cities, which significantly limits the potential audience.

Based on the analysis above and achieved results, it can be concluded that cycling route design and planning products mainly offer the capability of publishing cycling routes, but do not provide functionality necessary for municipalities to design suitable bicycle path network, which is critical for sustainable urban transport scheme, where component of green transport is growing.

2 VeloRouter - Simulator for Intelligent and Justified Decision Making

The multi agent-based bicycle path network and exploitation simulator (VeloRouter) (see Figure 1) is designed in the Repast Symphony environment and uses OpenStreetMap spatial data.

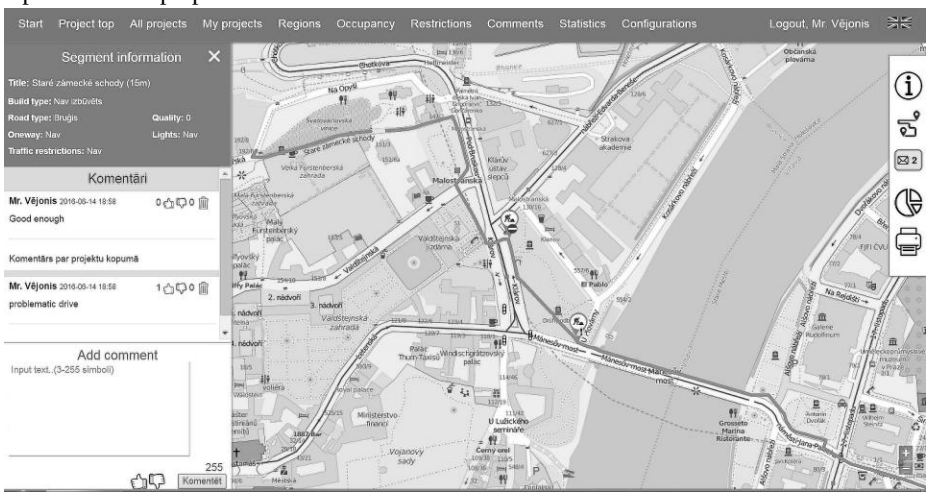

Fig. 1. VeloRouter route design desktop.

The technology has dual applicability as it is adapted to both the needs of municipalities and cyclists. Each agent is a cyclist or a group of cyclists that move on a chosen route considering route occupancy, traffic restrictions and the quality of the route.

VeloRouter provides municipalities with bicycle path discussion on the web and geofencing opportunities by receiving feedback from cyclists.

VeloRouter user authentication and authorisation is ensured using social networks: Facebook, Linked-in, Twitter, ResearchGate etc., given that cyclists are avid users of social technologies, whereas municipalities have the option to use individual registration options.

VeloRouter has both opportunities for municipality un cyclists. The municipality is interested in some basic question: Is the offered cycling route map satisfactory? This is recognized by summarizing potential comments and statistics analysis. Behind basic the second question is: Which potential cycling route sections should be built first?

The cyclists have the opportunities not only to send a message to the municipality, but also to publish his routes designed for public discussion. The cyclists want to know what the occupancy of a route will be in certain meteorological conditions on a specific date, as well as if the route is suitable for the travellers group i.e. terrain etc.? MAS/ABM based occupancy simulator can give the answers on the questions mentioned and provides monitoring of bicycle path network development scenarios and changes management.

3 How to Train the Simulator for Justified Decision Making

There are two ways of route planning in VeloRouter: with and without occupancy simulation, which can be switched off to reduce waiting time for data processing. Capability of Occupancy simulation determines simulator teaching or training to ensure confidence of the occupancy forecast.

More or less training or teaching of the simulator is substituted by tuning by other researchers however not always it is the same. Anyway tuning and teaching of the simulator is still open question therefore amount of real publications is few. The research related with teaching of simulators are done by Kux [5], Denekena [6], Akhlaghinia [7], Tschirner [8], Chowdhary [9] and perhaps other colleagues, however in Scopus and Web of Science this contribution cannot be easy recognized. Perhaps we can wondering about it, but really this is interdisciplinary area something between didactical and precise sciences and not so much researchers are ready to work in so challenging areas.

3.1 MAS/ABM Occupancy Simulation Model

The MAS/ABM occupancy simulation model can be specified by three main components: input and output data, and algorithm as well.

Input data:

- Number of cyclists;
- Type of day (working day, holiday, all days);
- Start time (hh:mm interval);
- Weather probability (summer: April – September, winter: October - March),
    - Summer day with precipitation (no, not likely, likely, yes),
    - Summer day without precipitation (no, not likely, likely, yes),
    - Winter day with precipitation (no, not likely, likely, yes),
    - Winter day without precipitation (no, not likely, likely, yes);
- Route (start and end points);
- Weather conditions (specific date and hour),
    - Temperature (C),
    - Snow (mm),
    - Rain (mm),
    - Atmospheric pressure (hPa),
    - Wind,
        - Speed (m/s),
        - Direction (meteorological degrees).

Output data:

- Route occupancy per minute (data structure),
    - Route section (ID),
    - Day,
    - Minute,
    - Occupancy;
- Route section occupancy in total over days (total) (data structure),
    - Route section (ID),
    - Day,
    - Occupancy.

Occupancy simulation algorithm is the following (see Figure 2). The basis is occupancy data stored in Travels and Intentions data Base (O_{CD}). Occupancy data contains the number of cyclists, which is considered the smallest entity. The entity represents a specific cyclist who uses the roads. For each such cyclist an agent has to be created, which, based on other attributes and input data, will participate in traffic at a specific time and day. The data containing all occupancy entries is read from (O_{CD}).

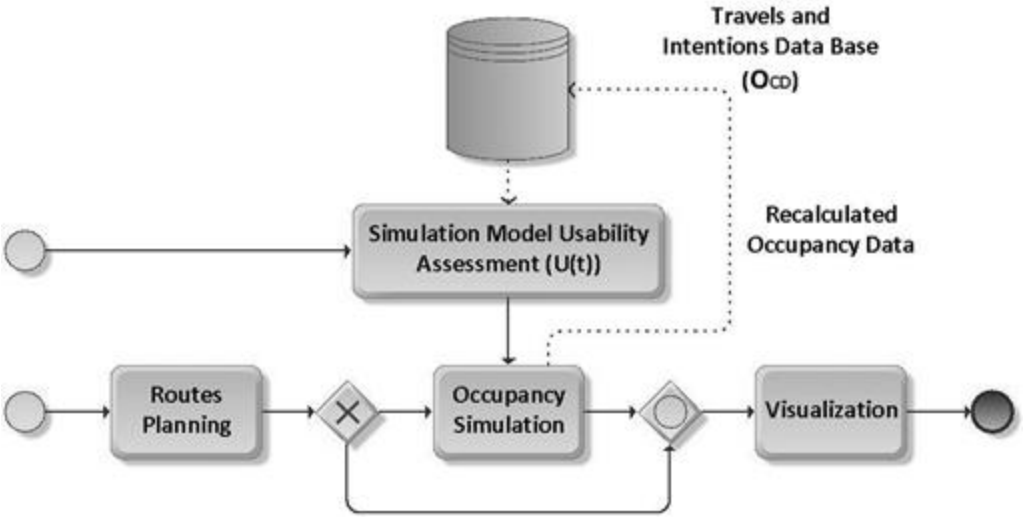

Fig. 2. Occupancy simulation procedure.

When all occupancy data entries are processed, load data is saved to the (O_{CD}). To estimate the load of each route, initially the attributes of each cyclist are calculated.

After it is determined whether he participates in traffic, the following conditions are checked:

- Is it an appropriate season to be cycling?
- Is it an appropriate day (working day / holiday) for the specific cyclist to be cycling?
- Is the weather appropriate for the specific cyclist to be cycling?
- Is road load adequate for the specific cyclist to be cycling?

The cycling route is calculated for each occupancy entry during each simulation session. If one occupancy entry consists of multiple cyclists, then all take one route, but the time can vary.

The route is recalculated each time to be up-to-date based on the version of each route calculation algorithm, as for example road restrictions can change on a daily basis.

Weather data are retrieved from the *WeatherForecast* service, which sends forecast information for the day by the hour, therefore if cycling takes longer than an hour it is possible to simulate whether the trip has to be interrupted.

The MAS/ABM model verification does not rise problems, however validation results of each use case depends on the capacity of (O_{CD}), therefore it can be done during later stages of the project introduction.

3.2 Occupancy Simulator Training

Occupancy Simulation model is trained and automatically tuned by initial data from Travels and Intentions data Base (O_{CD}). There context-steering training approach is used [10]. Not always the tutoring subject has to be intelligent being. In case of Intelligent Tutoring System (ITS) it can be simulator that gets smarter depending on (O_{CD}) accumulated knowledge.

Related with context capturing [11] the data to (O_{CD}) are transferred through different channels as it is defined [12] in Occupancy simulation context data capturing and assessment model (see Figure 3).

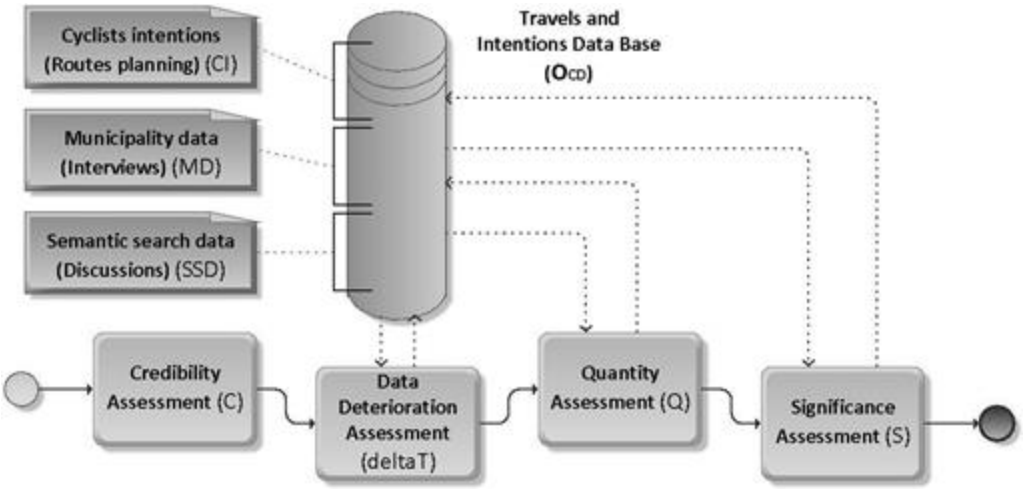

Fig.3. Occupancy simulation context data capturing and assessment.

Lower credibility data (C^{CI}) are Cyclists (CI) intended route plans that depend on season and meteorological conditions. It is just intention set that can be realised, but may also not occur. Higher credibility data are the one collected by municipality staff (C^{MD}), interviews in mass events and marker places. However highest credibility data are collected automated by filtering semantic webs (C^{SSD}). Although it is possible if question is not politicized, that initiates activities of "opinion army" to propagate the "correct" opinion. Also in this case, of course, it is possible to detect artificially generated opinions and exclude them from total assessment similar to DDoS [13] attacks, however it would be too expensive for cycling path planning.

In conformity with Credibility Assessment Rate (C), where

$$C = \langle C^{SSD}, C^{MD}, C^{CI} \rangle \quad (1)$$

and

C^{SSD} - credibility of semantic search data,
C^{MD} - credibility of municipality data,
C^{CI} - credibility of Cyclists data,

initial data credibility all the time is assessed.

Travels and Intentions data Base (O_{CD}) stored data quality (Q) depends on volume of the data i.e. from total number of respondent opinions that are related with specific planning region. If planning region includes several thousand cyclists, but only several persons have shared their opinion, then modeling result credibility level cannot be the highest.

Collected data credibility is not constant, but is changing in time. It is influenced by both construction of new bike paths and socio-economical factors. In fact, usability is associated with data deterioration (ΔT).

When data is getting outdated, its significance in the procedure of Occupancy simulation decreases. Data significance is regularly recalculated $S = S(Q, \Delta T)$. It means that Occupancy simulation forecast in each session can have different credibility as the influence of the set (O_{CD}) is different, where

$$(O_{CD}) = (CI, MD, SSD, S) \quad (2)$$

and

CI - cyclists data,
MD - municipality data,
SSD - semantic search data,
S - significance of stored data.

Training performance of Occupancy Simulation model is proportional to (O_{CD}) context data quantity and credibility, but usability (U^M) of Occupancy Simulation model (see Figure 2) can be specified as:

$$U^M(t_i) = U^M_{t_{i-1}} + U^M_{\Delta t_i} \quad (3)$$

where $= \underset{1,N}{\longrightarrow}$, and is limited by computing resources capacity, but Δt_i - reflects training time or interval between (O_{CD}) updates.

Simulator training quality is determined by the simulator validation results that are based on modeling data statistics comparison with output data of real functioning bicycle route planning and exploiting system. Comparison is done using Kolmogorov-Smirnov testing [14]. It can be noted that this validation type is useful only if (Q) is comparable with number of potential cyclists in planning region.

4 Conclusions

VeloRouter is one of the first open source simulators that takes into account municipality tasks and is cyclist-friendly.

Agent-based simulation supports relatively precise load prediction so unpleasant incidents during a trip can be limited. However main MAS/ABM application bottleneck is necessity to know location of each agent on the map asking for significant calculation

resources if agent amount or the size of planning region are growing. However using Cloud and High Performance Computing (HPC) solutions [15] it is possible to remove bottleneck without simulation algorithm changes.

VeloRouter enables continuous occupancy assessment on the planned routes, which are determined by the amount and quality of context captured data in PostgreSQL database. Such a way Occupancy Simulator is trained to increase the assessment credibility.

The main tasks for further development are the use of semantic analytics and visualization results in a manner that corresponds to the user's perception, as well as their virtualisation and VeloRouter integration into a municipalities information systems

References

1. EC. European Commission Decision C 6776.: Horizon 2020. Part 11. Smart, green and integrated transport. [online] Available at: <http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-transport_en.pdf> [Accessed 15 February 2016] (2016)
2. Piera, M.-A., Buil, R., Ginters, E.: State space analysis for model plausability validation in multi agent system simulation of urban policies. In 25th European Modeling and Simulation Symposium (EMSS 2013). Athens, Greece, Code 100159, pp. 504-509 (2013)
3. Sonntagbauer, S., Ginters, E., Aizstrauta, D., Lapans, A., Valtenbergs, V., Sakne, I. et al.: D4.1 - FUPOL Simulator Software Requirements Report, 231 (2013)
4. Buil, R., Piera, M.A., Gusev, M., Ginters, E.: MAS Simulation for Decision Making in Urban Policy Design: Bicycle Infrastructure. In Proceedings of 17th International Conference of Harbour, Maritime & Multimodal Logistics Modelling and Simulation (HMS 2015), 21-23 September, Bergeggi, Italy (2015)
5. Kux, S., Mehnert, R.: Methodology for Automated Tuning of Simulation Models for Correlation with Experimental Data. In SAE technical Papers, Vol. 5, doi:10.4271/2013-26-0117. 13 (2013)
6. Denkena, B., Winter, F., Hauck, S.: Teaching of process-oriented simulation models - Use of machine data for imaging the machine failure behavior. Productivity Management, Vol.21, Issue 3, pp. 62-64 (2016)
7. Akhlaghinia, M. J., Lotfi, A., ; Langensiepen, C., Sherkat, N.: Occupancy simulator for a single-occupant ambient intelligent environment. In 7th IEEE International Conference on Cybernetic Intelligent Systems. pp.1-6. IEEE. London (2008)
8. Tschirner, S., Liang, X., Wang, Y.: Model-based validation of QoS properties of Biomedical Sensor networks. In Proceedings of the 8th ACM International Conference on Embedded Software, EMSOFT'08. pp. 69-78. Atlanta, GA; United States (2008)
9. Chowdhary, Abhisek, R.: Application of self-tuning High-fidelity Dynamic Simulation model for Soft-sensing. In Proceeding of 8th International Conference on the Foundations of Computer-Aided Process Design (FOCAPD). Computer-Aided Chemical Engineering. Vol. 34 pp. 687-692 (2014)
10. Rose, D. E.: Context based learning. Encyclopedia of the Sciences of Learning. pp. 799-802, Springer (2012)
11. Perera, C., Zaslavsky, A., Christen, P., Georgakopoulos, D.: Context Aware Computing for The Internet of Things: A Survey. IEEE Communications Surveys & Tutorials Journal, Vol.16, Issue 1, pp. 414-454 (2013)
12. Bettini, C., Brdiczka, O., Hericksen, K. et al.: A survey of context modelling and reasoning techniques. Pervasive and Mobile Computing, Vol.6, Issue 2, pp.161-180 (2010)

13. Rajkumar, Nene, M. J.: A Survey on Latest DoS Attacks: Classification and Defence Mechanisms. International Journal of Innovative Research in Computer and Communication Engineering, Vol.1, Issue 8, pp.1847-1860 (2013)
14. Corder, G. W., Foreman, D. I.: Nonparametric Statistics: A Step-by-Step Approach. ISBN 978-1118840313. Wiley (2014)
15. Dongarra, J.I., Van der Steen, A.J: High Performance Computing Systems: Status and Outlook. Acta Numerica. doi:10.1017/S09624929. pp. 1-91. Cambridge University Press (2012)