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A REVIEW ABOUT MULTIMODAL TRAFFIC SIMULATION TECHNIQUES

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Abstract:-One of the current challenges in urban planning concerns the urban transportation involving multi-mode transportation. One of the ways to evaluate di erent situations in order to make decisions of how, when and where to invest is using multimodal traffic simulation. This paper presents a review about multi-modal traffic simulation, identifying the state of art and directions for future work.

Keywords:-Traffic simulation, multimodal simulation, public transportation, Smart cities, Public Transportation Simulation.

I. INTRODUCTION

Given the continuous population growth in bigCities and the impact caused by the growing number of vehicles, it becomes necessary to create an adequate urban plan in order to minimize travel time and increase the quality of life of the whole population. The growing number of private vehicles, besides its known environmental impacts, makes it hard to travel in-side urban centres, especially in the so called \peak hours". Besides, what would take minutes in ideal conditions ends up taking, in extreme cases, several hours in stressful conditions, both in the case of the overcrowded public transportation and in the traffic jam at the roads used for individual transportation vehicles?

It is important for the gures of power that are responsible for planning transportation systems and roads to have adequate tools to help them at this task. Hence, this paper intends to present a review about the works done on multimodal transportation simulation systems. We intend to clear the following issues on this topic:

What are the most recent works on simulation involving more than one side transportation method?

What are the simulation methods used in those works; what are the proposed evolution proposed by the

Authors of those papers;

The review in this article is part of a research project called simulation of urban traffic conditions using multiple modals", in which we intend to develop a urban travel multimodal combined simulation model, fed with statistical information of point of origin and destinationin urban centers and data on decision factors that make the user select one model above others. Hence, it will be possible for the transportation system planner to simulate the cause and relationships among modals. This will allow for the perfection of the transportation systems distribution identifying the work conditions in which there will be the maximum ux in a given scenation. Hence, the main goal of this research project is to help perfect urban tra c planning.

This paper is organized as follows. Section II presents a brief context on the issue, in order to give the readers information on the main types of simulation in this area. Section III describes the methodology we uses to extract and analyze articles. Section IV contains the analysis of the chosen articles, presenting general considerations and going deeper in some aspects of their content that we considered most interesting for the scope of this work. Section V contains a brief description of the main tools used for transport simulation. Finally, the Section VI presents some nal considerations on the analysis performed and also some possible paths tho be explored in future works.

II. CONTEXTUALIZATION:

Before describing the methodoloy and analysis of the articles we research in this review process, it is important to present some concepts related to the tra c simulation classi cation that we will mention in this paper. Multimodal transport simulation is the one that involves more than one way of transportation or travel. This simulation can involve several motorized transportation methods (public and private) as well as non-motorized mechanisms, such as by foot and by bicycle.According to Barceló [2], we can classify vehicle tra c simulation in three types: microscopic, macroscopic and mesoscopic. Microscopic simulation is \based on the description of the movement of each individual vehicle in the tra c ow " [2], in which each relevant aspect and behavior of a speci c vehicle must be considered: acceleration, desacceleration, lane changes, and many others, depending on context. That is, differently from the micro-scopic simulation that uses the individual as its basis, macroscopic simulation consider the mass of vehicles as something unique and its behavior is the study object. Its origin comes straight from uid mechanics.

Finally, mesoscopic simulation is the simplification that intends to capture the essential points of the dynamic, while demanding less data and hence is computationally more e cient than microscopic models" [2]. This model tries to put together some aspects of microscopic simu-lation with others from the macroscopic ones in order to represent the dynamic behavior.

These three models are not only restricted to vehicles: it is possible to understand them as valid also for other forms of displacement, such as, pedestrians. This can also be seen by the use of this terminology in the papers we are going to analyze.

III. METODOLOGY

In order to identify the articles related with the state of art, we performed a review process on the basis of an exploratory research performed before in order the authors to get familiarized with the main terms and concepts of this eld of study. From this exploration we identifies the keywords relative to the concepts related to the questions we posed and its variations in the context, which are presented.

In order to select the sources, two points were used as main criteria: availability of the whole articles and relation-ships to the main conferences and journals in this eld. Data sources that index articles from third parties were not consider, because of the noise in the communication (articles whose text we cannot read entirety, for instance, do not allow for the correct interpretation of their results, having their meaning restricted to the interpreta-tion of the intervening third party). Hence, the following sources were adopted:

- ACM: ACM Digital Library
- IEEE: IEEExplore
- Springer: Springer Link
- Elsevier: SciVerse Scopus

Notice that these are also the most respected sources in the scientific community, having among its publications most of those journals that are classified in the higher sets of quality assessment processes such as QUALIS.

For each of the data sources we created a search key from the set of keywords we described before. Not necessarily all terms would be present given that, in some cases, the search became too restrictive. For instance, several articles selected do not contain in their title or abstract the expression Intelligent Transportation Systems. For example, the words tra c and simulation are widely used in works on data transmission optimization on communi-cation networks. In order to avoid papers on data tra c, we excluded works that contained the keywords broadband and wireless.

After nding and sownload the articles according to the search keys presented, we (selected) the articles

The selected articles were fully read and we analyzed the relevant points of each one of them, identifying the type of simulation, its goal, the transportation methods analyzed and how each one is treated in the implemented system and the future works suggested by the authors. From these data, we performed the following analysis.There are of microscopic simulation, there being a single work on mesoscopic models and only two macroscopic ones, and out of these, one of them used two models, as we will see in the papers analysis we perform later. One of the results was classified as not because de papers presented did not have the goal of simulation traffic density but the optimization of a transportation network using for that a simulation of the displacement and the behavior of the agents.

The prevalence of the microscopic simulations was expected given that the type of work that represents each vehicle and person individually and therefore allows the detailed simulation of real traffic conditions.

The distribution of papers according to the forecast transportation methods can be seen in Figure 3. In spite of most of the works involving tra c simulations concen-trate on motor vehicles, when we involve more that one method, the majority of the second main component is the pedestrian.Considering the displacement simulation models, most of the papers study are of general purpose or a combination between pedestrians and vehicles (typically at crossing)

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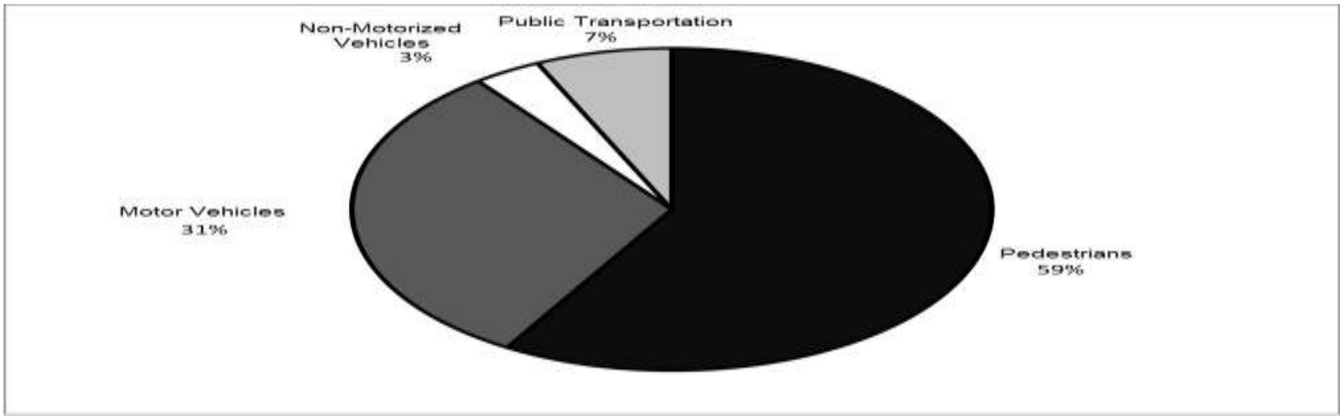

Fig. 3. Distribution of articles according to the transportation method approached

IV. GEOGRAPHIC DISTRIBUTION OF THE PAPERS:

Our attention is called by the geographic distribution of the institutions where the authors work. There is a massive presence of Asian institutions, more especiallyChinese, among the articles we analyzed. We can imagime that this presence is due manily to demographic conditions and to the growth both economic and scientific of a few countries in that region. These factors have taken to a big increase in the number of vehicles in circulation without the necessary increase in infrastructure and safety, resulting in a high number of accidents, as pointed out as justification of several of the analyzed papers.

When there is pedestrian presence in the papers, the main methods chosen to simulate their behavior are: cellular automata, such as in [3, 8, 10, 14, 19], agents (microscopic simulation), such as in [11, 12, 18, 21], or using a toolSpecial for microscopic simulations, VISSIM [1], from the PTV software company[2], such as in [4, 15{17], which do not specify how the set the tool parameters for their simulations.

Some papers have di erent simulation proposals. In [22] a model based on hidrodynaics is presented for crowd simulation is presented, that is, a macroscopic model. The paper [9] uses a model that, in spite of being based on agents, has some abstractions that are characteristic of macroscopic simulations, resulting in a mesoscopic model, the single one found in this research.

For vehicle simulation, the most used model is car following or some variation [8, 19]. The car following model is characterized by a ordinal di erential equation that describes completely the position and speed dynamics of each vehicle, as well as its speed and distance to the next vehicle or any obstacle.

In some cases the vehicle role is secondary in the simu-lation. Hence the authors decided to simplify their repre-sentation (in general, limiting their behavior in variations in accelation or space occupation in the environment), as can be seen in [14]. Two articles proposed improvements in the transitions of cellular automata models [3, 19]. The rst one presents a set of prede nes rules for vehicle bidimensional displace-ment, and the second proposed a more complex approach, involving probabilistic variables for decision making of the direction to follow, forecasting that themodel answers not only to change of direction situations (bidimensional displacement), as well as changes in unidimensional dis-placement. On the other hand, the articles [8, 10, 14] use the automata model with no variations to implement simulations in their respective scenarios.

Four papers use the agents model [11, 12, 18, 21] to simulate th pedestrian decision model when choosing the best path. Out of those, three papers [11, 18, 21] show simulations that try to fully understand the pedestrian displacement model, while the paper [12] is concerned solely with the decision on the fastest route, estimated time and possible obstacles. In all those works, in spite of the creation of speci c simulation environments, the author mention that those models can be used in di erent environment types, what seems likely given their description.

Fuzzy logic is used when considering the decision process in the studies conducted in [6, 7, 16]. The rst one uses fuzzy variables to control the decision taking process by an intelligent semaphre, in order to make the wait smaller, both to pedestrian and vehicles. The other two simulate the decision making process and path planning by a cyclist to cross a street, based on the analysis of existing obstacles, speed, possible paths and colision risks.

V. TRAFFIC SIMULATION TOOLS:

Traffic simulation or the simulation of transportation systems is the mathematical modeling of transportation systems (e.g., freeway junctions, arterial routes, roundabouts, downtown grid systems, etc.) through the application of computer software to better help plan, design and operate transportation systems.[1] Simulation of transportation systems started over forty years ago,[2] and is an important area of discipline in traffic engineering and transportation planning today. Various national and local transportation agencies, academic institutions and consulting firms use simulation to aid in their management of transportation networks.

Simulation in transportation is important because it can study models too complicated for analytical or numerical treatment, can be used for experimental studies, can study detailed relations that might be lost in analytical or numerical treatment and can produce attractive visual demonstrations of present and future scenarios.

To understand simulation, it is important to understand the concept of system state, which is a set of variables that contains enough information to describe the evolution of the system over time.[3] System state can be either discrete or continuous. Traffic simulation models are classified according to discrete and continuous time, state, and space.[4]

Aimsun[3] is a tool that allows for modelling and mi-croscopic, macroscopic and mesoscopic simulation. Among its main characteristics is efficiency, for allowing real time models that include more than 10,000 intersections and 5,000 km of roads in a personal computer using multi-nucleus architecture; presence of two models two simulate driver behavior: dynamic user equilibrium and stochastic model of route decision (integrated to the car following main applications, according to the responsible company are: simulation and analysis of using reversible roads and reserved roads in special time tables, change of semaphore timing, impact analysis of new roads, public transportation evaluation and security analysis and traffic forecast during major eventsand lane-changing models); and simulation of the inter-action of pedestrians and vehicles (having the ability to simulated more than 30.000 pedestrians).

PARAMICS [4] allows dynamic modelling of roads (for instance, resersible roads and road exclusive to buses in speci c timetables), as well as public trnasportation (routes and schedules of transportation services, including modelling bus stops and passengers entering and leaving the buses). It allows the description of di erent classes of vehicles with type, journey purpose and dynamics. Each vehicle has as attribute (con gured by the user) to describe his agressiveness or caution in the decision process. The decision to change or keep the lane (by the driver) is based on the distance necessary for the next manouever. Collaborative driving during tra g jams is also modelled. As to the decision on the route, the tool allows an ample variation from all cars taking the same route as well as all cars using dynamic routes (based on stochastic methods). The choice of dynamic routes also takes into account the current state of traffic jam varied by the driver. Concerning functionalities for simulation analysis we can highlight the following: comparative analysis of di erent models or simulated situations, average speed quanti ca-tion, pollutant emissions, dealys and events, saturation analysis and alternative route analysis.

SUMO[5] is an open source tool for simulation using microscopic model It is highly e cient being capable of simulating in a personal computer 10,000 roads with 100,00 vehicles; modelling di erent types of vehicles; di er-ent algorithms for route determination; modelling parallel views allowing the dynamic change of road direction and personalized behavior for each semaphore.

VISSIM [6] is a simulator developped by the company PTV[7] that uses the microscopic model. Its main function-alities are: change of lane considering three criteria (mini-mum bene t needed to change lane, minimum speed neces-sary for the manouever and timespent), besides modelling cooperative behavior (when a driver avoid risk situations during lane change) and non cooperative; variable time to park the car according to the type and size of parking spot; smooth acceleration and desacceleration when distancing or approaching obstacles; projected routes considering the current tra c situation and the tra c forecast for the next instants. Besides this tool, PTV also has a pedestrian simulator (VISWALK [8]) that can be used together with the traffic simulator.

[4] http://www.sias.com/ng/spcurrentrelease/spcurrentrelease.htm

[5] http://sumo.sourceforge.net
[6] http://www.ptvamerica.com/software/ptv-vision/vissim
[7] http://www.ptvamerica.com
[8] http://www.ptvamerica.com/software/ptv-vision/viswal

VI. CONCLUSION

This paper presented a review on the state of the art of urban tra c multimodal simulation. Given the analyzed articles, we can see a high volume of pa-pers involving

microscopic simulations of crossing and semaphores what shows a concern of the authors with e ciency and optimization of the time in those situations, as well as an attempt to identify and reduce accident conditions at those points.
It also evident from those article the solid position of the cellular automata models for pedestrian behavior simulation as well as the position of the car following model to simulate vehicle behavior, as well as the constant use of the VISSIM tool for simulations.

Something that draws the attention is the small presence of duly validated models, which is evident by th elack of empirical information collected for the proposed scenarios as well as the technical and operational di culties for that activity, given the huge amount of work involved, what makes us question the e ciency of the governments to gather this information and consequently use it for planning, what may be the goal of future research.

Finally, another point that deserves attention in this review is the lack of mention to public transportation systems, with the exception of an alternative method pro-posed and one work tha tstudies the user decision process, that is, as an auxiliary method (without the simulation of the method per se), as well as the absence of studies that involve more than one transportation method with a global view on e cieny and cause and e ect relationships, being these data an indication of points to be explored in future works. This theme in particular is extremely important when thinking about smart cities and has been so far the object o ittle work.

As futurework, we intend to extend one of the tra c simulation tools in order to allow for the analysis of the impact caused by changes in public transportant on rails on the tra c of big cities.

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