Preparing Data for Urban Traffic Simulation using SUMO

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Abstract. The ever increasing world population, added to the always present need of human transportation, makes road traffic in the big cities a huge and urgent issue, and, consequently, the target of substantial investigation. This paper introduces the first task of a larger project called COSMO. Using the city of Coimbra as the base, the goal of this project is to simulate the city traffic using a microtraffic simulator. For that, the SUMO platform was used and different experiments were conducted varying the number of cars being simulated, as well as other variables. At the end, the results show that the selected simulator was capable of simulating the Coimbra urban traffic in a realistic fashion, using an origin-destination matrix based on real data and routing algorithms. These results show that the simulator can be used in future works related to urban traffic, namely in road network management.

Keywords: Traffic Simulation, Origin-Destination Matrix, Intelligent Transport Systems

1 Introduction

The inhabitants of urban areas follow a lifestyle that stands on the ability to travel within the city for both work and leisure. Because of these needs, the city road planning has become a major issue in the last decades. Due to historical reasons mainly concerned to the unsupervised development of the cities, problems like narrow roads lack of parking places and the inexistence of alternative routes for some critical places makes city road network planning a very complex problem. Associated with this reality, a number of problems arise, being traffic congestions the one with the most impact in the daily life of the citizens. This particular point can be measured by the time spent on the road to complete relatively short paths, which contributes not only to a decrease in the lifestyle quality but also to possibly aggravate existing health issues such as irritability, stress among others. Furthermore, these congestions also lead to environmental problems with the increased CO_2 emissions as well as other polluting chemicals. Also, economical issues arise, from the increased fuel consumption in traffic congestions, allied with the increasing crude prices.

In order to address the road network planning issue, the first step consists in collecting real data in order to identify the critical problems in a specific city context. The use of a simulator capable of providing visual feedback based on the collected data not only allows for an easier identification of those critical problems but can also be used as a testbed for future developments to the road network. Theses developments can be composed by changes to the structure of the road network itself or new routing mechanisms.

In this work, which is part of the COSMO project (described bellow), we focus on the use of a simulator to interpret and simulate the city traffic based on the collected data. For that, Coimbra city was used as the first case study mainly due to its topography.

The remainder of this paper is organized as follows: Section 2 presents the Cosmo Project, Section 3 illustrates the literature review regarding to traffic simulators, Section 4 details the selected traffic simulator. Section 5 pinpoints and discusses the obtained results. Section 6 presents final remarks about the approach and discusses future work.

2 COSMO Project

In the COSMO project (COllaborative System for Mobility Optimization) the authors propose to look at the city as a Complex System, where each citizen/-driver is an agent with a local vision of the environment. The principle is to use heterogeneous information collected on city mobility (GSM, GPS, Road Sensors, Information Services, Historical data) to exercise influence on the individual agent behavior in order to optimize the city efficiency (e.g. energy consumption). This way, when reaching pre-congestion levels of network charge, individual drivers will be lead to collaborate in alternative, and minimally competing, routes. In this scenario, several research challenges are raised:

- How to predict distributed network load? In order to prevent the appearance of congestions, these situations have to be detected in early phase of their formation, and the individual behavior of the agents should be led to a synchronized collaborative behavior in a way that increases the whole system efficiency;
- How to fairly synchronize drivers? The system cannot favor one driver over the other more than within reasonable limits. Mutual dependencies will increase considerably the complexity of the choice;
- How to communicate with individual drivers? Will it be realistic to assume that high quality wireless access will be available in every vehicle? Or would the traditional Variable Message Signs become a proper option? If so, where should these signs be placed?

These challenges are tackled from the perspective of Complex Systems, Ubiquitous Computing and Intelligent Transport Systems. The main purpose of this project is to study these issues and develop a collaborative traffic routing/control system. The system should use the collected information to predict realistic traffic network load and present advice to users, by providing individually tailored network loads, in order for them to have a less selfish behavior. The developed system is to be applied in a controlled micro-simulation environment, for this point Sumo was chosen, which allow the testing and validation of the various aspects of research, as well as the study the behavior of the system according to a number of dimensions, including driver adherence rate, link capacity, driver profiles and synchronism model.

3 Related Work

Simulators are part of the category of analytical tools that are used to analyze various types of data, such as traffic flows, financial transactions or pathogens spreading disease through a population. They make it possible to assess the effects of various changes to the environment without altering the real world making a cheap and safe way to predict the effectiveness of the proposed modifications.

The simulation type that is the most adequate for this project is the traffic microscopic simulation that represents the process of creating a model of a certain network, observing and executing interactions between the agents of the system, which as previously referred, are an autonomous entity with individual characteristics, goals and decision making mechanisms that can greatly vary within a population. Chen and Cheng [4] analyzed a wide range of agent-based traffic simulations systems and divided them into five different categories:

- agent-based traffic control and management system architecture and platforms;
- agent-based systems for roadway transportation;
- agent-based systems for air-traffic control and management;
- agent-based systems for railway transportation;
- multi-agent traffic modeling and simulation.

Given the characteristics of this project, the adequate category is the multi-agent traffic modeling and simulation. In the mentioned paper the authors refer two open source agent-based traffic simulators:

- Multi-Agent Transport Simulation Toolkit (MATSIM) [7], a toolbox for the implementation of large-scale agent-based transport simulations and is composed of several individual modules that can be combined or used standalone. It allows for demand-modeling, traffic flow simulation and to iteratively run simulations.
- Simulation of Urban Mobility (SUMO) [2], a portable microscopic road traffic-simulation package that offers the possibility to simulate how a given traffic demand moves through large road networks.

In addition to these two simulators, other solutions exist, such as Vissim [5] or Transims [8], among others. Some comparison studies have been performed between two or more of these simulation platforms [9] [3] [6]. Based on some of these studies, and the more recent developments made to each of the simulation platforms, SUMO was the adopted one. This decision was made partly due to the commercial nature of Vissim (which presented a very good performance), as well as the recent developments that eliminated some of the drawbacks presented by SUMO in earlier analyzed versions.

4 Simulation Environment

As mentioned before, several simulation platforms were analysed; of these, SUMO (Simulation of Urban MObility) was chosen as the traffic simulator. SUMO is an open source tool and a microscopic road traffic simulation package that supports different types of transportation vehicles. Every vehicle has its own route and moves individually through the network. This tool supports traffic lights and is space continuous and time discrete (the default duration of each time step is one second). There are three main modules in the SUMO package:

- SUMO, which reads the input information, processes the simulation, gathers results and produces output files. It also has an optional graphical interface called SUMO-GUI;
- NETCONVERT, a tool to simplify the creation of SUMO networks from a list of edges. It reads the input data, computes the input for SUMO and writes the results into various output formats, such as XML, CSV or VISUM-networks. It is also responsible for creating traffic light phases;
- DUAROUTER, a command line application that, given the departure time, origin and destination, computes the routes through the network itself using the Dijkstra routing algorithm.

As input data, SUMO needs three main files, representing routes, nodes and edges. The nodes and edges files represent the vertexes and edges in the road graph, respectively. The routes file represents the traffic demand and includes information about all the agents involved in this simulation and their characteristics (departing time, maximum acceleration, maximum deceleration, driving skill, vehicle length and color) and route (list of edges). In terms of outputs, there are different types available, such as:

- a raw output that contains all the edges and all the lanes along with the vehicles driving on them for every time step, which results in a considerable large amount of data;
- log-files created by simulated detectors (a simulation of induct loops with the ability to compute the flow, average velocity on the lane, among other values) are written using the CSV format. This data can be aggregated for specified time intervals which may be configured by the user.

Finally, this simulator offers a way to measure some metrics such as fuel consumption or pollutant emission, based on the Handbook of Emission Factors for Road Transport (HBEFA) database. According to HBEFA's website[1], it was "originally developed on behalf of the Environmental Protection Agencies of Germany, Switzerland and Austria" and is now also supported by Sweden, Norway, France and the JRC (Joint Research Centre, of the European Commission). It provides emission factors per traffic activity, i.e., it offers a way of measuring CO_2 emissions and fuel consumption, among other pollutant factors, for various vehicle categories (such as passenger cars, light duty vehicles, heavy duty vehicles, buses, coaches and motorcycles), being suitable for a wide variety of traffic situations.

5 Experimental Results

In order to be able to run tests in Coimbra, we firstly needed to obtain a map of the city, compatible with SUMO. The SUMO module Netconvert offers a way to import digital road networks from various sources (such as VISUM or OpenStreetMap) and creates networks usable by the other SUMO modules.

Regarding the inexistence of Coimbra network in VISUM or OpenDrive, we opted the OpenStreetMap format (Figure 1). By accessing the OpenStreetMap website we can search for the desired city and easily export that data into an XML file.

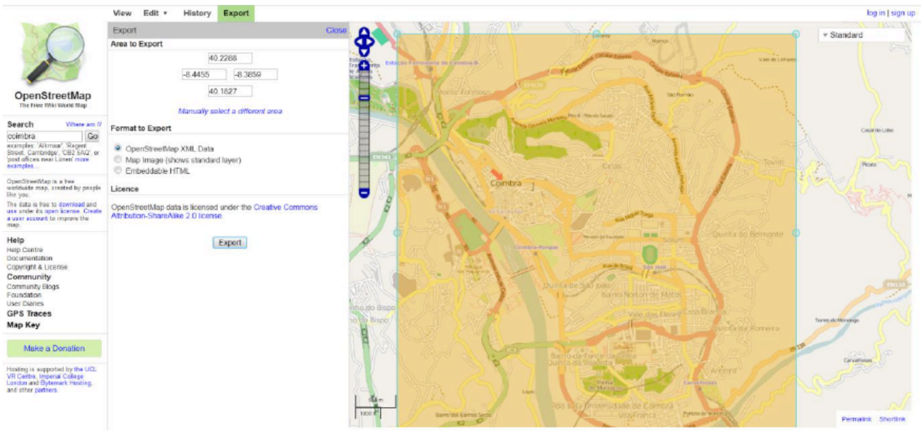

Fig. 1. Front End of the OpenStreetMap website for Coimbra city

After this process, we experimented with the generated network in order to evaluate the outcome of this conversion. We found out that there were some

[1] More information available online at `www.hbefa.net`

errors in the generated SUMO network such as the conversion of pedestrian roads into vehicle roads. In order to filter out the pedestrian roads, and also to correct some other minor errors, the JOSM tool was used, which is an OpenStreetMap editor written in Java. The current version of SUMO offers the option of filtering out certain types of roads while converting a map, but at the time this option was unavailable. Another problem that we found, and corrected, was that the Netconvert module, by default, adds a turnaround possibility for almost every edge, making the network map unrealistic and somewhat confusing (Figure 2).

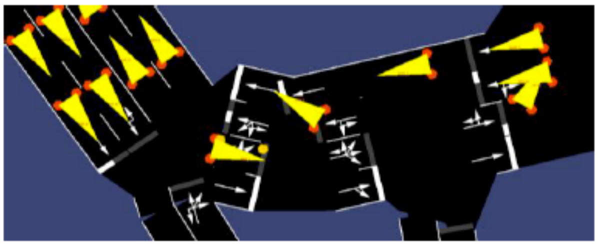

Fig. 2. Edges with unrealistic turnarounds

Then we created a route set and using the SUMO GUI we identified the zones responsible for creating the more relevant bottlenecks. These areas contained several problems that range from an incorrect number of lanes to faulty connections between edges. Having corrected the previously referred faults, we believed the map to be ready for the testing process.

5.1 Coimbra Routes

With a corrected version of the map, it was time to generate the correspondent traffic demand. To complement the real city map we needed realistic traffic information. The work by Dr. lvaro Seco and Nuno Norte Pinto [36] provided this information in the shape of an Origin-Destination (OD) matrix regarding the city of Coimbra. An OD matrix consists of a table that matches trips origins and destinations and also displays the number of trips going from each origin to each destination. In order to create the traffic demand based on this OD matrix, we first needed to analyze its data. This matrix was divided into several zones as can be seen in Figure 3 and these zones referred to inner and outer city traffic.

There were numerous zones referred to outer city traffic so, given that in this project we were mostly interested in studying traffic within a city, we decided to group these several outer city zones into 7 zones, which match the existing city entrances (Figure 4) : North (IC2), Northeast, East, Southeast, Southwest (Europa Bridge), West (Santa Clara Bridge) and Northwest (Aude Bridge).

The data in this matrix comprises 60.000 trips and corresponds to the morning period (7h30 to 10h30) with the duration of three hours. To make the testing

Fig. 3. Coimbra OD matrix zones

process feasible, given the considerable map size, we decided to use 10.000 trips with an insertion period of one hour, i.e., vehicles are inserted at uniform time intervals during one hour. To make simulation environment more realistic, we inserted 2.000 vehicles at the beginning of the simulation (in the first time step) while the rest of the vehicles were inserted during the simulation.

In SUMO, route definitions are as follows:

Listing 1.1. Rout Definition

```
<vehicle id = "0" type = "type1" depart = "0" color = "1,0,0">
<route edges = "id_beginning id_middle id_end"/>
</vehicle>
```

This means that each trip is defined as a collection of the id of the edges that comprise that trip. The main difficulty was establishing the match between the OD matrix's zones and the ids present in the SUMO network. Firstly we experimented with two id values per zones but as a result the entrance of cars in the network was very slow. This is due to the fact that SUMO inserts vehicles in a pre-determined position in each edge and does not insert another vehicle unless there is space for that insertion. This means that the simulator would have to wait until there was enough room to insert each new vehicle, greatly increasing the simulation time. It also means that it would not be possible to achieve the desired effect given that this fact significantly delayed the insertion of vehicles and making it impossible for some vehicles to be inserted within the previously defined time slots.

Fig. 4. Coimbra city entrances

In order to overcome this limitation, more id values were added to the trip generation process. It was not possible to define a constant number of ids per zone given that the number of roads in each zone was not uniform. However an average amount of approximately 7 id values was defined per zone.

This id search process lead to significant time consumption given that most zones defined in the OD matrix do not exactly match street names and so these id values were manually defined. However, it allowed for a much smoother insertion of vehicles.

5.2 Coimbra Map Problems

After experimenting with the OD routes we concluded that the results were still not satisfactory. An experiment with 10.000 vehicles lasted 27.000 seconds, i.e., approximately 7 hours, which is a very large and unrealistic amount of time, when compared to travel times observed by the authors on a daily basis.

We came to the conclusion that this was due to problems with the simulator and also with the used network. So, we started to study how to further improve the quality of the network in order to obtain more realistic results. The following figures show some of the problems we encountered

In the leftmost image of Figure 5 we show an example of halted vehicles, each queue apparently blocking each other. In the rightmost image we see the red vehicles giving total priority to the blue vehicles, waiting until there was no blue vehicle left in order to advance. It appears that SUMO has some issues when it comes to detecting whether or not the leader is occupying the junction and therefore blocking the passage. In Figure 6 we can see that, although the

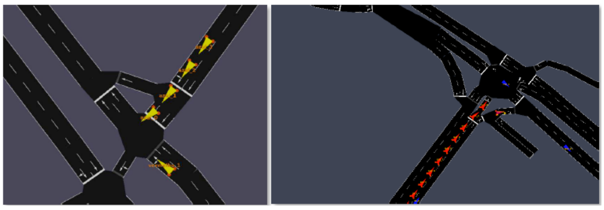

Fig. 5. Hesitation situations

vehicle on the right lane (highlighted in green) wants to go forward and there does not seem to be any obstacle in front of him, it does not advance. However it considers that the other vehicle is in its way and therefore will only move once the other vehicle has also moved, causing an unrealistic and unnecessary queue.

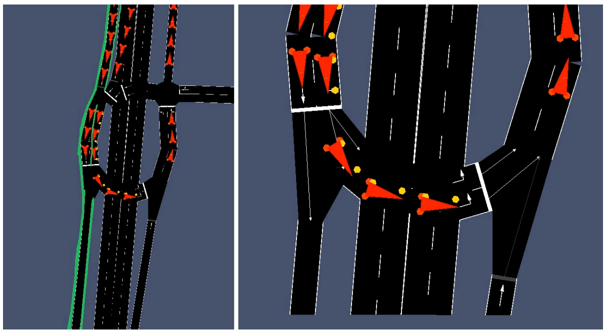

Fig. 6. Junction problems

We noticed that some of these zones lacked traffic lights - that were somehow lost in the conversion. Therefore, with the intent of reducing the hesitation that appears to occur in Figure 5, we added traffic lights in the areas that were most affected by congestion: *Portagem, Avenida Fernão de Magalhães and Casa do Sal*. The addition of traffic lights appears to improve the ordering of traffic, reducing the hesitation phenomena. However, while solving one problem it creates another - due to the addition of traffic lights in some junctions, vehicles are often stopped at intersections (Figure 7).

SUMO is a collision-free simulator and therefore safety is paramount. So its vehicles require a large gap to competing vehicles in order to decide to move forward as a few experimentations demonstrated. This highly defensive attitude can partially justify this problem.

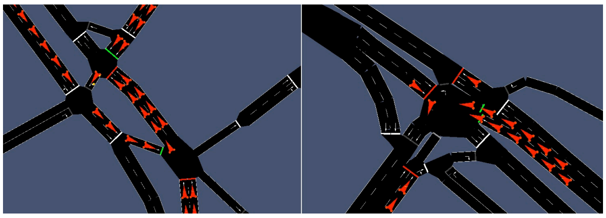

Fig. 7. Traffic light problems

6 Conclusion and Future Work

We described the representation of Coimbra's road network within the SUMO simulation environment. We start by analyzing the construction of the road network of Coimbra by importing data from Open Street Maps and the issues that this operation raises. Although some issues have been detected, these have been satisfactorily overcome. To test the simulation environment we employ real traffic data, in the form of an origin-destination matrix, gathered from the city of Coimbra. The use of this data in the simulation is also discussed and analyzed, allowing us to identify the situations where the behavior of SUMO's vehicles deviates from the expected behavior of Coimbra's drivers. We indicate and discuss the mitigation actions taken to minimize these issues and the consequences of such measures. Overall, the results indicate that SUMO was capable of simulating the Coimbra urban traffic in a realistic fashion, validating its adequacy for testing routing algorithms in real-world scenarios. The areas identified in the previous section as critical in terms of congestions correspond to the actual critical areas where congestions occur in real life. Furthermore, it has sometimes been observed that a congestion in one of those critical spots (Portagem) propagates to other spots (Casa do Sal, ...), which, given the city road network configuration, can cause a city-wide congestion, which limits traffic in and out of the city. These problematic areas and their tendency towards congestion propagation were correctly identified in the simulator, which together with the above mentioned problems in network representation leads to the large observed congestion times.

Future research will focus on the development and test of distributed route planning algorithms, which should minimize travel time while promoting fuel efficiency, and reducing CO_2 emissions. The preliminary results obtained using a nature-inspired approach – namely, on ant colonies – are promising indicating significant improvements on all considered aspects.

Acknowledgments. This work was partially funded by the Portuguese Foundation for Sciente and Technology(FCT) under project COSMO with reference PTDC/EIA-EIA/108785/2008.

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