ITSUMO[†]: an Intelligent Transportation System for Urban Mobility

Bruno Castro da Silva[†], Robert Junges[†], Denise de Oliveira[‡], and Ana L.C. Bazzan[†*]
Instituto de Informática, UFRGS
Caixa Postal 15064, CEP 91.501-970 Porto Alegre, RS, Brazil
{bcs,junges,edenise,bazzan}@inf.ufrgs.br

ABSTRACT

This paper presents an overview of ITSUMO, a microscopic traffic simulator based on cellular automata. The implementation uses agent technologies with a bottom-up philosophy in mind. We give an overview of the system and some details of its modules (data, simulation, driver and information/visualization).

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence *Multiagent systems, Intelligent agents*

General Terms

Human Factors

1. INTRODUCTION AND MOTIVATION

The increasing urban mobility challenges traffic engineers, urban planning experts, and researchers involved with optimization and information technology. Urban mobility both produces information and increases the demand for it. In order to produce the information to be broadcasted, a fast simulation model is necessary. We use the Nagel–Schreckenberg approach [3] which is a microscopic model for traffic simulation based on cellular–automata (CA).

The motivation for the development of the simulation module is threefold. First, although several similar tools exist, these are built normally with the objective to tackle isolated problems. Second, in general, one has no access to the source code regarding both commercial and academic tools. Finally, we see this domain as a very rich area for experimenting some agent-based techniques, especially modelling and simulation of drivers (agents).

Therefore, driven by the incentives given by Brazilian funding agencies regarding free software, we have developed ITSUMO – Intelligent Transportation System for Urban Mobility [4]. One of the aims of the project is to create an information system for urban mobility capable of integrating different functionalities, such as a simple traffic control (mostly based on control of traffic lights), traffic management and real-time information providing via internet and/or mobile phone. The idea is to distribute the system under free-software license. The system has been used to investigate route choice scenarios [1], as well as control (refer to `http://www.inf.ufrgs.br/~mas/traffic/itsumo/demo` for screen shots and other publications).

To address these objetives, it is possible to define drivers as intelligent agents and to plug each driver model as a module in the simulation system. This approach is in contrast with the current models, which are purely reactive and ignore drivers' mental states (informational and motivational data). The kernel of the simulator was programmed using the object-oriented paradigm. The idea is that anyone can aggregate further code when necessary. A XML-based database, used to define the network objects, and a visualization module are also part of the package.

2. MICROSCOPIC SIMULATION MODEL

Basically, there are two approaches to model traffic movement: the macroscopic and the microscopic. The former is mainly concerned with the movement of platoons of vehicles, focusing on the aggregate level. It considers only averaged vehicle densities but not individual traffic participants. In the microscopic model of simulation, each object can be described as detailed as desired, thus permitting a more realistic modeling of drivers' behavior. In the microscopic approach both travel and/or route choices may be considered, which is a key issue in simulating traffic since those choices are becoming increasingly more complex. Also, individual traffic lights can be modelled according to several approaches, from classical off-line coordination to recently proposed ones (negotiation, communication-free, via game theory, reinforcement learning, swarm intelligence, etc). In fact we have been using this model and simulator to investigate different aspects of the problem: route choice, traffic lights coordination and control, etc.

In order to achieve the necessary simplicity and performance, we use the Nagel–Schreckenberg model [3]. In short, each road is divided in cells with a fixed length. This allows the representation of a road as an array where vehicles occupy discrete positions. Each vehicle travels with a speed based on the number of cells it currently may advance without hitting another vehicle. The vehicle behavior is expressed by rules that represent a special form of car–following behavior. This simple, yet valid microscopic traffic model, can be implemented in such an efficient way that is good enough for real-time simulation and control of traffic. Given that every vehicle has a nonnegative integer speed (v, limited to $vmax$), the following four rules are verified simultaneously for all vehicles in a CA way: movement (each vehicle advances v cells at each time step); acceleration (each vehicle's speed is increased by one

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[†]project and authors supported by CNPq

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unit, up to $vmax$ or the gap – the number of empty cells in front of a vehicle); interaction (if the vehicle ahead is too close, v is decreased by one unit; and randomization (vehicles decelerate with probability p in order to simulate the nondeterministic dynamics of vehicle movement). Although these rules might seem too simplistic, investigations reported in the literature showed that the cellular automaton model is capable of reproducing macroscopic traffic flow features including realistic lane changing behavior.

3. DESCRIPTION OF THE SIMULATOR

ITSUMO can use both off-line information (maintained by different providers), and on-line (e.g. traffic flow). The information regarding the network is stored in a XML file. In addition to the CA approach, one can also define other driver decision-making procedures via a special, optional, module. If the user does not define particular classes of drivers, then the simulation is performed using the standard driver model described in Section 2. A visualization module retrieves data originated from the microscopic simulation and exhibits a graphical representation of the traffic simulation. The ITSUMO system is thus composed by four distinct modules: the data module, the simulation kernel, the driver definition module, and the visualization module.

3.1 Data Module

This module creates, updates, and stores (XML file) both the static and the dynamic objects to be used in the simulation, as for instance the cartesian coordinates of the intersections. The main attributes are described below:

- **General Settings**: topology name, traffic system orientation (right-handed, left-handed), cell size, frequency of sensor measurements, deceleration probability, etc.;
- **Network**: network name and its settings;
- **Node**: cartesian coordinates of the intersection;
- **Street, Section, Laneset, Lane**: street name, section name, whether it is preferential, delimiting nodes, laneset length, maximum speed, and width for the lane;
- **Turning Probabilities**: set of allowed vehicle movements and their probabilities;
- **Signal Plan**: set of lane-to-laneset allowed movements in a specific order, cycle time and offset;
- **Sink and Source**: nodes for removal and insertion of vehicle according to given values;

3.2 Simulation Module

This module was developed using C++ over the microscopic model presented before. However it also solves an issue inherent to the basic microscopic model described in Section 2, namely the difficulty to represent urban scenarios.

The simulation occurs in discrete steps and is implemented as a series of updates in the drivers' decisions of movement, followed by simultaneous updates in the vehicles' positions in the network. Each update in a node or traffic light may modify its current behavior. The simulation output can be formatted according to the user needs. The most usual formats are the "cell map" and the "laneset occupation map". The former indicates which portions of the lane are occupied by which vehicle, providing the most detailed output possible. On the other hand, the "laneset occupation map" is a high-level output which specifies the rate of occupation (density) for each laneset in the network.

3.3 Driver Modelling Module

Modeling drivers' behavior can be approached in different ways, depending on the purpose of the simulation. In most cases, the objective is to simulate the collective or macroscopic behavior. However, this behavior emerges out of individual ones. Simple algorithms, like the Nagel–Schreckenberg model, can be used to describe vehicles movement without loosing significant simulation fidelity with reality. However, other behaviors can be implemented, normally out of two different components: decision about movement and planning. The former is responsible for a vehicle's short-time movement, while the planning decision is related to a more sophisticated decision-making, e.g. which direction to turn and what to do when facing a jam.

3.4 Visualization Module

This is the module that allows the graphical visualization – either in a macroscopic or microscopic level – of the simulation results. At a macroscopic level, the visualization considers only data which reflect the overall behavior of the network, providing an useful tool to capture the big picture of what is happening in a specific scenario. It is useful to provide this kind of information via the internet, as it has been the case in [2]. The microscopic level provides an interface through which one can see, both in 2D and 3D manner, individual vehicles movement. In order to obtain a more realistic and detailed visualization, these modules are developed using OpenGL, enabling features such as walk-through navigation and detail-focused interfaces.

The visualization of data at microscopic level is the kernel of the information system for the traffic engineer and/or the urban planning experts. At this level, the whole system can be used to perform *what-if* simulations.

4. FINAL REMARKS

The ITSUMO system is capable of dealing with several aspects of the simulation of a traffic scenario, such as the driver behavior, traffic lights coordination, traffic jam prediction, among others. The ITSUMO system provides an useful tool to simulate traffic conditions and to support urban planning tasks.

We plan to extend ITSUMO to consider other kinds of information such as those related to weather forecast and information providing via internet and/or mobile phone.

5. REFERENCES

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