USING CELLULAR AUTOMATA IN TRAFFIC MODELING

Monica Dascalu, Sergiu Goschin
“Politehnica” University of Bucharest, Bd. Iuliu Maniu 1-3, Romania;
E-mail: monica@agni.arh.pub.ro, sergiu@atlas.cpe.pub.ro

Eduard Franti
IMT – Bucharest, Erou Iancu Nicolae Street 32B, Bucharest, Romania
E-mail: edif@atlas.cpe.pub.ro

Key words: Traffic modeling, cellular automata.

Abstract: The paper presents a traffic simulator intended to be used in Bucharest, Romania, in order to solve usual traffic problems and obtain better traffic management performances with the same basic route network. The simulator makes short time traffic predictions starting from data extracted from real traffic. Usually, traffic predictors use statistic methods instead of simulation techniques. The advantage of a performant simulation over statistic prediction comes mainly from its ability to treat the untypical situations, exactly the ones that need a precise prediction. The traffic simulator is based on cellular automata model, a very simple and regular massive parallel model, which is able to make real time computations in such complex situations that the traffic simulations imply. The cellular automata simulator has been adapted to the topology given by the Bucharest city center map and its performances were tested in various real situations. The simulation proved to be very performant in cases like two-lane streets intersections, narrowing due to accidents or street repairs etc.

1 INTRODUCTION

At present, in Romania there aren’t significant achievements in the domain of improving the traffic, although this problem is considered priority by the local administration. In Bucharest especially, crowded traffic affects the transportation efficiency and also produces a pollution that could be avoided. The research reported here offer valuable solutions for the traffic problems and also can be considered as one of the activities aiming to implement the “information society” in our country.

Computing systems can contribute to the traffic engineering in several ways, like for instance: to set the most efficient traffic lights timing, the design of the roads network, traffic simulation, the detection of the traffic problems. In respect of the traffic’s safety, valuable contributions can be made in the following domains: the detection of the traffic incidents (traffic jams and accidents), the detection of the bad weather conditions, etc.

The road design problems in an urban area refer less to the initial design (because few urban areas are directly built, they rather “grew up” in time) and more to establish, for instance, the by-pass lines of the zones under repair. These repairs always seem to be done in the most inconvenient places and at the moment which involves the greatest loss of time. The narrowing of the highways (if only part of the lanes is under repairs) may also dramatically affect the road traffic.

Crowded traffic conditions are frequent in any city. In the small towns, this happens only in the morning or at the rush hours, while in the large cities it happens almost all the time, especially at the main crossroads, (which is also the case of Bucharest), and it may quickly lead to the “saturation” of the road system.

The management of the urban traffic based on traffic lights is widely spread, but few people know that different settings of the traffic lights may lead very different results. The best timing rate is considered that one that can ensure a continuous traffic, without jams and producing lowest length of the lanes at the traffic lights.

How can one find this optimum setting? A simple and efficient method is to simulate the traffic on a sequence of crossroads with different time settings: this is an additional reason for the development of a traffic simulator. Any realistic
solution for the urban traffic involves an efficient use of the existing road network, although one can make changes with remarkable consequences – for example, by adjusting the traffic lights system, their location and their timing, according to the results foreseen by simulations of the road traffic (as it has been already realized in Tokyo).

Because of the importance of the traffic problem, there have been developed a certain number of strategies and of algorithms, aimed at studying the dynamic of the urban traffic [3]. The best results in simulation have been obtained by now with the neural networks model, but there are also promising results obtained with cellular automata model. We have chosen cellular automata instead of neural networks because of the expanding capabilities of cellular automata. Increasing the street network size and complexity does not imply new training, but only the appropriate changes in cellular automata topology.

2 TRAFFIC SIMULATOR WITH CELLULAR AUTOMATA

Most of the traffic simulation methods developed by now are based on previous data basis; this is why the period necessary to update the traffic evolution is so long (several hours or even days). There hasn’t been finalized yet any quick and efficient system for accessing and consulting this data, so that they could be used by any participant to the traffic. The existent systems, although very useful, do not involve a performant traffic prediction (by statistic means or by simulation), but only the broadcast of the traffic situation.

Generally, the models used in the traffic simulators are neural networks, and, recently, cellular automata. The modeling based on cellular automata involves a so to say microscopic approach. Essentially different to the global, macroscopic approach, the so-called “traffic flow”, the microscopic approach begins at the microscopic level of the vehicles. The use of the cellular automata in modeling has certain advantages, as compared to other types of models, and this determined the choice of this model.

The most important of its advantages are the following:
- the model is simple and regular (its complexity doesn’t grow when the size of the modeled system and of the data base is increased);
- the massive parallelism and robustness of the model, which involves an efficient data processing and a high global tolerance in respect to local failures;
- once the local interactions between the cells are solved, the system can be increased up to any size, without any other modeling problems;
- the model is suggestive and the interpretation of the results is usually direct.

The results of the scientific research and the experiments reported in the scientific literature prove that the traffic simulation with cellular automata is an interesting and useful research topic, which hasn’t been exhausted or completely finalized. Cellular automata model consists of a regular network of identical cells, that perform elementary computations. Each cell is practically a finite state machine with elementary evolution rules. The entries for the local interactions between the cells are the current state of each cell and the states of the neighbouring cells.

The global state of cellular automata is given by the set that contains the states of all cells. The local states (cells’ states) are updated concurrently...
according to local laws that depend on local conditions (the states of the neighbouring cells). In the particular case of traffic modeling, each cell correspond to a road fragment, and the neighbouring cells involved in the next state’s computation is an important factor that affects the performances of the model. The main idea, as illustrated in figure 1 for a single lane is to define the cells as elementary space units of the road, equivalent to a possible position of a vehicle. The state of the cell encode both the presence (or absence) of a vehicle and its speed. The next state of the cell depend on whether there will be another car arriving at its position.

For a cellular automata with \( N=5 \) there are 32 different states:

\[
\begin{align*}
5: & \quad 11111111111110000000000000000000 \\
4: & \quad 11111111000001111111000000000000 \\
3: & \quad 11110000111100001111000011110000 \\
2: & \quad 11001100110011001100110011001100 \\
1: & \quad 10101010101010101010101010101010
\end{align*}
\]

We will consider cell \( \bullet \) the current cell for the following network configuration \( \bullet \circ \circ \circ \circ \) and the left to right sense moving in this situation the cars can have only two possible velocity (this rule maintain constant the cars number). The local rule for cellular automata cell is, according to the figure 1:

\[ R : \quad 1111110100011101111111010001110 \]

The model was implemented in a cellular automata simulator for traffic written in Visual Java++. The main window of the traffic simulator is presented in figure 2. The input data are: the map topology, the number and position of the intersections, the number of streets for each intersection, the number of lanes for each street, the cellular automata rule (this define the car speeds and accelerations), the length of the streets. The input is done through special files.

The simulator has previously defined a number of typical crossroads, depending of the number of streets (3 or 4), the number of lanes for each street, the turning left/right rules and the presence/absence of light signals. In addition to the local parameters and the local computing there are some conservation laws that link together the different sections simulated. Thus we avoid the need of exhaustive data obtained from the traffic, which would rise serious transmission and processing problems.

The linear space of the roads is divided in elementary units which are the cellular automata’s cells. The vehicles are indirectly represented through the state of the cells, that encode the presence of the vehicle and the vehicle’s speed. Therefore, there is no need for supplementary conversions and computing for visualization of the simulation and data input.
3 APPLICATIONS AND EXPERIMENTS

The typical tests refer to the right prediction of the following data: the number of cars that cross an intersection (a) and the number of cars that cross a central street (b) during one day. The simulation refers to a period of 10 minutes – 2 hours.

The results obtained after each 10 minutes interval is compared to real data obtained from traffic. Figure 3 gives the predicted/simulated results over time, compared to real data for one central street and intersection. For these graphics we have used the program Matlab, taking the output of the simulator and measured data from traffic as input.

Figure 4a and b gives the simulated results for 24 hours for different streets.

4 CONCLUSION

The paper presents a traffic simulator that uses an adaptation of cellular automata model and can simulate real traffic conditions on a complex road network. The model has been adapted to the map of the center of the city of Bucharest and was tested with a set of data from real traffic. Many conditions like multiple lane traffic, crossroads and traffic lights timing were introduced in the model. The main advantage of the simulator is the parallel processing due to the cellular automata model.

The cellular automata simulator needs more tests and details of implementation before it will become a public product. Some specific features as parkings and pedestrian crossings have to be considered in the future in order to complete the model.

REFERENCES


Figure 4b: Traffic simulations for 24 hours for different streets.