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A Micro-Simulator for Traffic Signal Control Based on A Modified Cellular Automaton Traffic Flow Model

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Abstract: In recent years, many traffic signal control methods have been proposed to reduce traffic jams. However, the experiments of the methods were difficult to perform in real road networks. In order to prove the effectiveness of the methods, traffic simulations by using a traffic simulator were required. Although various traffic simulators have been developed, the most of simulator was not specified for simulation of traffic signal control. A micro traffic simulator for simulation of traffic signal control is introduced in this paper. The micro-simulator is based on a Cellular Automaton (CA) model, which is a model of artificial life. Furthermore, the CA traffic model is modified according to features of traffic flows at intersections in order to reproduce the traffic situation of urban area. The usability of the proposed CA traffic model is evaluated through the analysis of relationship between traffic density, average speed, and traffic flows. Moreover, the micro-simulator is applied to evaluate traffic signal control methods.

Keywords: Traffic model, Cellular Automaton, Traffic Flow, Simulation.

1 INTRODUCTION

In recent years, many traffic signal control methods have been proposed to reduce traffic jams. However, the experiments of the methods were difficult to perform in real road networks. In order to prove the effectiveness of the methods, traffic simulations by using a traffic simulator were required. On the other hand, many traffic simulators were developed such as the TRANSIMS, SUMO, and VISSIM and so on. However, the most of simulator was not specified for simulation of traffic signal control. A micro traffic simulator for simulation of traffic signal control is introduced in this paper. The micro-simulator is based on a Cellular Automaton (CA) model, which is a model of artificial life. Furthermore, the CA traffic model is modified according to features of traffic flows at intersections in order to reproduce the traffic situation of urban area. The usability of the proposed CA traffic model is evaluated through the analysis of relationship between traffic density, average speed, and traffic flows. Moreover, the micro-simulator is applied to evaluate traffic signal control methods.

2 MODIFIED CELLULAR AUTOMATON TRAFFIC FLOW MODEL

Cellular Automaton (CA) models are conceptually simple, thus a set of simple CA rules can be used to produce complex behavior. Through the use of powerful computers, these models can encapsulate the complexity of the real world traffic behavior and produces clear physical patterns that are similar to those we see in everyday life. The proposed CA urban traffic model is built based on the SchCh model (highway traffic model).

2.1 Road setting and movement rule

In the proposed CA traffic model the default size of a cell is 7.5m, and an example is shown in Fig.1. The lane number is determined according to the real road and, right-turn only lane also considered in the model.

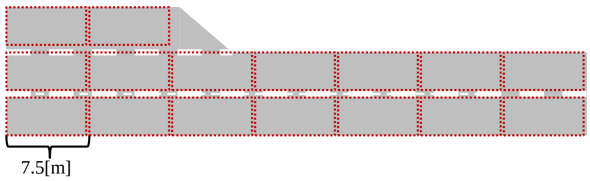

Fig. 1. Cell setting of road

2.2 Rules of Inflows and outflows

A vehicle will be created according to the inflow rate, and the travel direction will be determined according to the ratio of different travel direction. Here, the travel direction is the road's number, and a vehicle pass the intersection to move designated road according to the travel direction. An example is shown Fig.2.

The rules of inflows as follows:

Rule 1: *if* $\boldsymbol{inR} < rand()$,
than create a vehicle.

Rule 2: *if* $\boldsymbol{Dir}_d < rand() < \boldsymbol{Dir}_{d+1}$,
than set the travel direction to d.

Here, ***inR*** is the inflow rate, $\boldsymbol{Dir}_d$ is the ratio of the travel direction, *rand*() is random number within [0, 1]. The ***inR*** and $\boldsymbol{Dir}_d$ is determined according the equation (1), (2) with the measured traffic data. In the equations, *k* and m is the cycle number, *Ct* is the cycle length, *Ln* is the lane number, *d* is the different road number, *I* is the traffic volume of inflows, *O* is the traffic volume of outflows.

$$InR = \frac{\sum_{m=1}^{m=k-1} I_m}{\sum_{m=1}^{m=k-1} Ct_m \bullet Ln} \quad (1)$$

$$Dir_d = \frac{\sum_{m=1}^{m=k-1} Od_m}{\sum_{m=1}^{m=k-1} O_m} \quad (2)$$

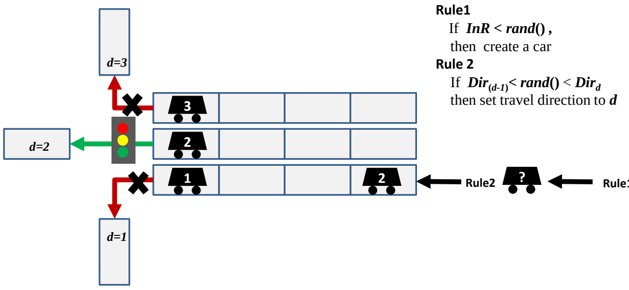

Fig. 2. Inflow and outflow

2.2 Rules of movements

In proposed CA traffic model, a vehicle can be accelerated up to maximum speed, and can change the road lane. In addition, particular rule will be used at the right-turn only lane. Specific rules are as follows:

Step 1: check cell
if the cell *i*+1 is empty,
than go to step 2;
else go to step 4.

Step 2: move one cell
Move the vehicle to i+1 cell.
if i+2 is the empty,
than go to step 3,
else stop.

Step 3: random accelerate
if $\boldsymbol{P}_{acc} < rand()$,
than move to cell i+2
else stop.

Step 4: check multi-lane
if the road is the multi-lane
than go to step 5.
else stop.

Step 5: move to parallel lane
if the parallel cell j, j+1, j-1,j-2 are empty,
than move the vehicle to cell j+1.
else stop.

Here, $\boldsymbol{P}_{acc}$ is determined by equation (3). P_0 is the set value; *Td* is the traffic density of the road.

$$P_{acc} = P_0 - Td \bullet rand() \bullet 0.1 \quad (3)$$

If the travel direction of a vehicle is right-turn, the vehicle moves to the right turn exclusive lane, even when there is no obstacle. As an example, the rule of movements is shown in Fig.3.

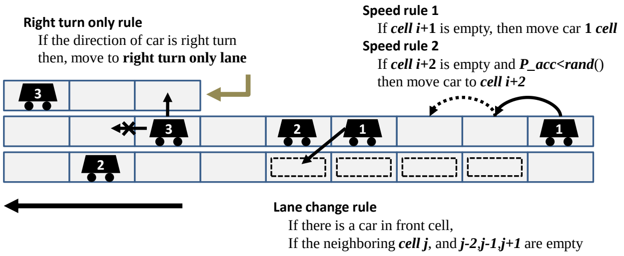

Fig. 3. Movements

3 MICRO SIMULATOR

A micro traffic simulator is developed based on the modified CA traffic flow model. The procedure of the simulator is shown Fig.4.

Step 1: Initialization
To set the intersection, and road length, lane number, inflow rate, ratio of different travel direction at each road. The traffic signal of each intersection can be obtained by using the empirical equations (Webster's formulations), also it can be changed by an interface.

Step 2: initial parameter
To set the simulation time (St), set the count time of each intersection (Ct), and set the cycle (k) of each intersection. Here, each intersection has respective Ct and k.

Step 3: Step check
If reach the simulation time, than go to step 15,
else continue next step.

Step 4: CA (1/2)
Move the vehicles according to CA rules (in/outflows)

Step 5: CA (2/2)

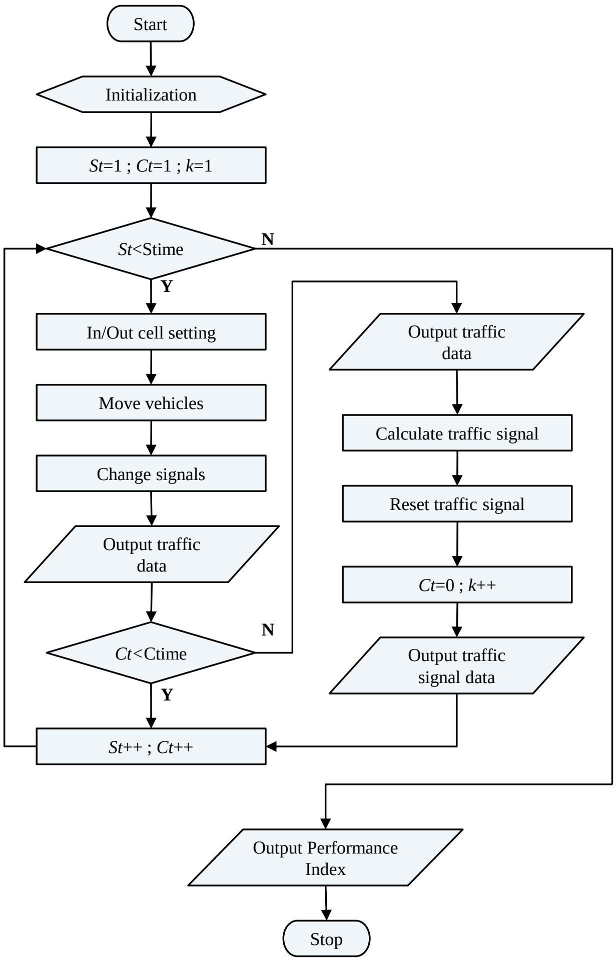

Fig. 4. Procedure of micro traffic simulator

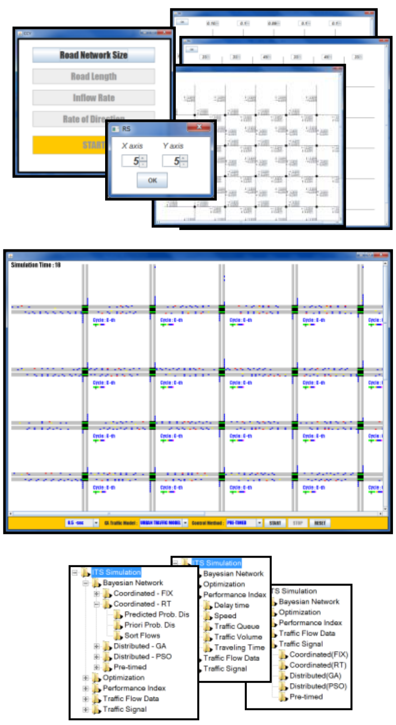

Fig. 5. Initial settings, Frame of simulator, and file structure

Move the vehicles according to CA rules (movements)

Step 6: Change signals

To change the signal phases of each intersection, according to the Ct with the parameters of traffic signals.

Step 7: Record 1

To record moved cells

Step 8: Cycle check

If reach the cycle time, than go to step 10, else continue next step.

Step 9: Count

To counts simulation time (St) and cycle time (Ct) of each insertion, go to step 3.

Step 10: Record 2

To record traffic volume data of each intersection, and cycle number, intersection number.

Step 11: Calculation of Signal

To calculates the traffic signal of next cycle. If there no calculation algorithm is implemented the pre-timed signal will be used continued.

Step 12: Traffic signal reset

Reset the traffic signals of intersection.

Step 13: Parameter reset

Set the Ct to 0, and count the cycle k.

Step 14: Record 3

To record updated traffic signals.

Step 15: Record 4

To record PI(Performance Index). The PI will be calculated with the recorded data.

The frame of initialization and simulation are shown in Fig.5 as an example.

4 SIMULATION

To evaluate the usability of proposed CA traffic model, two kinds of the simulation were carried out. The first simulation is that analyze the relationship between traffic density, average speed, and traffic flows. Here, a diagram of relation between the traffic flux and the traffic density called the fundamental diagram of traffic flow. Generally, the fundamental diagram of traffic flow has some characteristics as follows;

1) When the density is 0, flow will also be 0, since there are no vehicles on the road.
2) When the number of vehicles gradually increases the density as well as flow increases.
3) When more and more vehicles are added, it reaches a situation where vehicles can't move. This is referred to as the jam density or the

maximum density. At jam density, flow will be 0 because the vehicles are not moving.

On the other hand, the average speed generally maintains 30-40[km/h], and when the average speeds smaller than 20[km/h] the road will be considered as a traffic jam in urban area

Fig.6 shows the fundamental diagram of proposed CA traffic model, and the Fig.7 is the relation between traffic density and speed, the Fig.8 is the relation between traffic flow and speed.

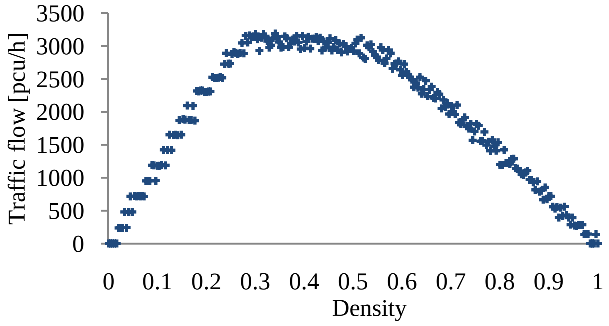

Fig. 6. Fundamental diagram of traffic flow

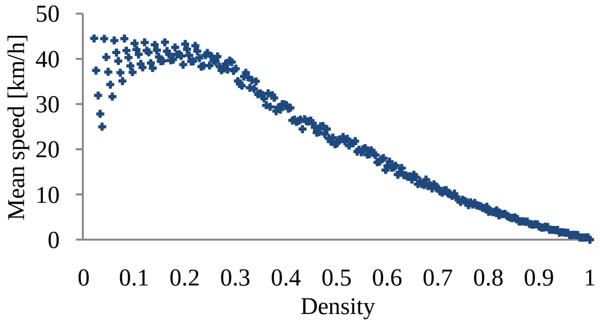

Fig. 7. Relation between traffic density and speed]

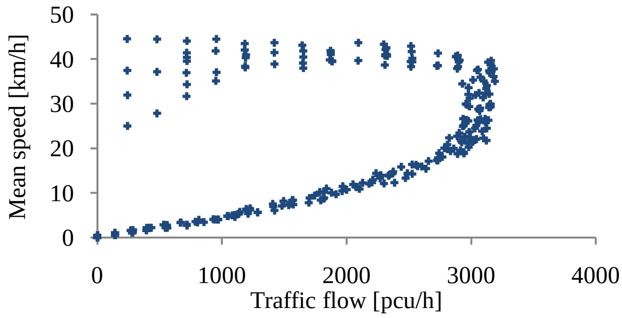

Fig. 8. Relation between traffic flow and speed

Table 1. Comparison of traffic flows

Traffic flows	Actual Data [pcu/h]	By simulator Mean(10times)	Mean error
In	2,325	2,362.7	0.7 %
Out	2,229	2,212.9	-1.6 %

The second simulation is comparison of the actual traffic flow data and simulated traffic data by using the micro simulator. The results are listed in table 1. These figures and the table can prove that, the modified CA traffic model can reproduce the traffic flows of urban areas very well.

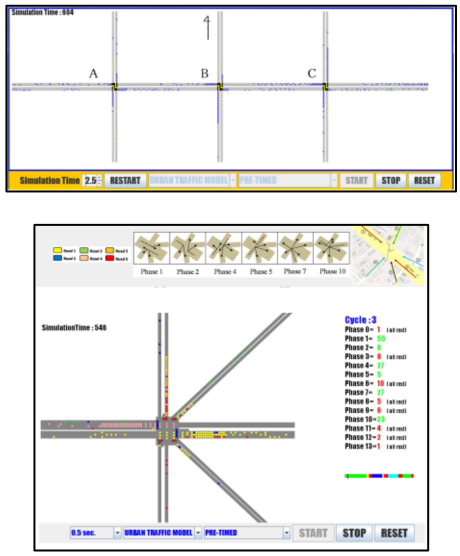

Fig. 9. Example of simulations

The micro simulator has been applied to evaluate several traffic signal control methods. Examples of the crossroad intersection and multi-way intersection are shown in Fig.9.

5 CONCLUSION

A micro traffic simulator is built up based on a modified CA traffic model. Through simulations the usability of the proposed CA traffic model is evaluated. As the future work, first is to improve the GUI, second is to add the vehicle category.

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