A Visual Simulation of Car-Traffic Flow on a Crossing

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Abstract: In order to understand information of geographic information systems(GIS) exactly and easily, visualization technique becomes important. In this paper, we consider car-traffic which is one of the information accompanying with a map. Then, a visual simulation method is proposed for car-traffic flow at crossing with the cell-automaton and the ray tracing method. We simulate the various situations and discuss about changes of traffic.

1. Introduction

Recently, the research on geographic information systems (GIS)[1] has been actively studied and developed. In GIS, visualization tools such as computer graphics(CG) are useful for us to understand several kinds of information related to maps. Namely, visualization of traffic flow is important since the information on the flow is usually too complex to understand immediately. In addition, some car-navigation systems can obtain information on the current car-traffic jam in the neighbor area. In order to make drivers and analysts of traffic control understand the current situation more easily, the flow should be visible.

In this paper, a visual simulation is proposed for car-traffic flow on roads, namely crossing in which traffic jam occurrs frequently. In the proposed method, roads are defined as a set of cells. Each cell has parameters with respect to moving and/or stopping cars, which are calculated by cell-automaton model based on the given rate of flow, cycles of signals and rates of direction. From the method CG images of the urban space with the car-traffic flow are generated by the ray tracing algorithm[2], which shows smoothness and/or jam at the crossing.

2. Characteristics of the traffic

The traffic on roads is composed of cars, bicycles, pedestrians and so on, and each component has characteristics [3][4][5].

The traffic density is the number of passsing a certain point on a road per a certain time. The traffic density in an hour is called the rate of flow. This traffic density changes by time, area and traffic lane.

Among various forms of roads, the straight road, the T-junction and the cross road are fundamental. A crossing is defined by two and more roads cross on a plane. As soon as signal changes from red to green, stopping cars start one by one. The signal is controlled by cycle, which is time series of the signal indication demands.

A series of the signal indication is green, yellow, red and so on. The traffic jam occurrs when the demand of traffic density exceeds the traffic density at a concerned place. It is possible that the traffic jam also occurrs by the cycles of signals and so on.

3. Proposed algorithm with a cell-automaton model

We here present an outline of the proposed algorithm:

Step1: Set a form of the road(a straight line, a T-junction or a crossroads). Also set the rate of flow on roads, cycles of signals, rates of turning right or left.

Step2: Calculate whether cars are coming or not per time. If cars are coming, put an information on cars into cells.

Step3: Calculate condition of signals from cycles of signals.

Step4: Determine a condition of next steptime cells with the proposed cell-automaton model considering a condition of present signals.

Step5: Generate 2-d or 3-d images from the information of cells in Step4.

Step6: Generate CG animation from the obtained images in Step5.

3.1 Division of cells

In this paper, the information on cells at the next step time are decided by one of present neighbor cells in the given urban area by cell-automaton model. We divide road into cells which is almost equivalent to size of a car. Figure 1 shows an example of division in the crossroads.

Each cell has the following parameters:

- presence of cars

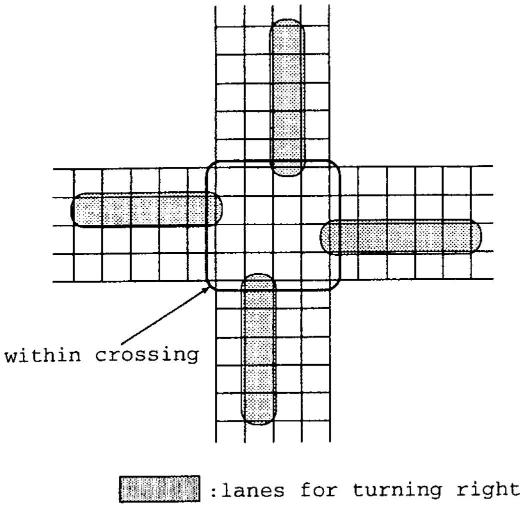

Figure 1. Road composed by cells(crossroads).

- velocity of cars
- direction of cars

Also the given crossing has the following data:

- rate of flow
- cycles of signals
- rates of direction to which cars move (turning right/left or going straight)

From the above, status of each cell at the next steptime is determined by the following algorithm:

Step1 Choose a cell $C_{i,j}$ according to the direction of the given traffic flow.

Step2 Determine the parameters of the neighbor cells at the next steptime in consideration of the parameters of $C_{i,j}$.

Step3 Execute Step1 and 2 for all cells.

Step4 Update steptime.

3.2 Movement of cars

In this paper, the car moves a cell in the steptime. The rule of the movement are as follows(see Figure 2):

Straight If there isn't a car in the forward cell, the car moves the cell at the next time:

$$C_{i,j+1}[t+1] = C_{i,j}[t],$$

t : time.

Stop, Start When the forward car stops, the backward car stops at the next time. When the forward car starts, the backward car starts at the next time.

Stop:

$$C_{i,j+1}[t+1] = C_{i,j+1}[t] \quad \text{for Car1,}$$
$$C_{i,j}[t+1] = C_{i,j-1}[t] \quad \text{for Car2,}$$

t : time.

Start:

$$C_{i,j+2}[t+1] = C_{i,j+1}[t] \quad \text{for Car1,}$$
$$C_{i,j}[t+1] = C_{i,j}[t] \quad \text{for Car2,}$$

t : time.

Right In the case of turning right, cars use the right lane. When there aren't oncoming cars, the car turns right. When there are oncoming cars, the car turns right after oncoming cars pass.

If there are cars in $C_{i+2,j+1}[t], \ldots, C_{i+2,j+5}[t]$,

$$C_{i+1,j}[t+1] = C_{i+1,j}[t] \quad \text{for Car1,}$$
$$C_{i,j-1}[t+1] = C_{i,j-1}[t] \quad \text{for Car2,}$$
$$\vdots \qquad\qquad \vdots$$

If there aren't cars ahead,

$$C_{i+2,j+1}[t+1] = C_{i+1,j}[t] \quad \text{for Car1,}$$
$$C_{i+1,j}[t+1] = C_{i,j-1}[t] \quad \text{for Car2,}$$
$$\vdots \qquad\qquad \vdots$$

t : time.

Left In the case of turning left, the car turns left without considering oncoming cars. The turning right cars wait for oncoming cars turning left.

$$C_{i-2,j-1}[t+1] = C_{i-1,j-2}[t] \quad \text{for Car1,}$$

t : time.

Figure 2 shows examples by the proposed algorithm.

3.3 Rules of signals

In this paper, We assume that signals change from green via yellow to red. When signal is yellow, cars going straight and turning left must stop and only cars turning right can move. When signal is red, all cars stop and other road signal is green.

3.4 Genration of CG images

Here, we use a ray tracing algorithm for generating CG images, since realer images are comprehensible if there are many objects in the case of 3-d images.

From the obtained parameters of all cells at each

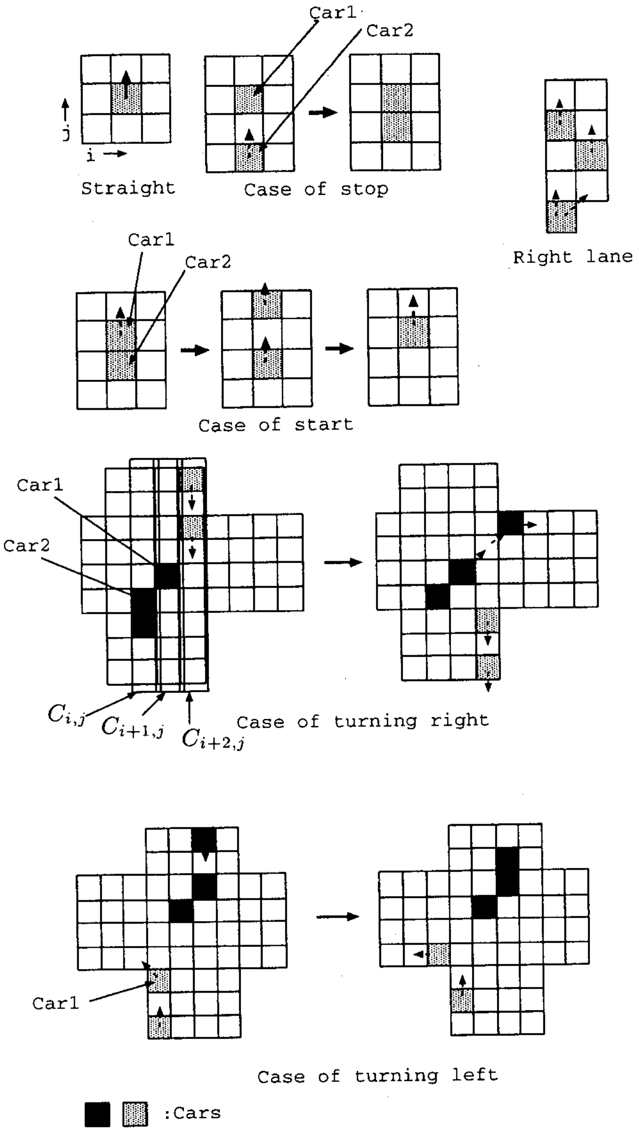

Figure 2. Movement of cars

steptime, CG images can be generated in 2-d and 3-d as CG animation. We check information on cells and color cells which have cars and structures in 2-d. In case of 3-d images, we generate images, by we place a sphere and a rectangular solid at cells which have cars and structures, respectively.

4. Simulation

We generate CG images from information of cells, i.e., rate of flow, cycles of signals and rates of direction. Here, cells are 5m square and an average speed is maximum 40 km/h in the area which has a few cars at traffic jam[4]. So it determines that cars move a cell in 0.5 seconds. The all cells are assumed to have no cars at first.

Figure 3 shows an image under the condition that the ratio of the flow is the same with respect to three directions (straight, right and left). Figure 4 shows an image when the ratio is different. Comparing Figure 3 with 4, we can easily understand that the car flow is influenced by the ratio. In Figure 3, the cars are located apart. While in Figure 4, the lane for turning right is filled with the cars. Therefore we understand that the traffic jam may be occurred.

Figure 5 and Figure 6 show 2-d images of Figure 3 and Figure 4, respectively. The computation time of 2-d images is shorter than one of 3-d images. Figure 7 shows influence of traffic flow by difference of rate of flow. It is seen that there are many cars near crossing. Figure 8 shows that the traffic condition changes by cycles of signals. It is seen that the traffic jam may be occurred by the cycles of signals. Table 1 shows the parameters of each Figure.

Table 1. parameters of each Figure

	rate of flow	cycles of signals		
		green	yellow	red
Figure 3	500	30	15	30
Figure 4	500	30	15	30
Figure 7	1200	30	15	30
Figure 8	500	20	5	20

	rates of direction			computation time
	right	left	straight	
Figure 3	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	14.78
Figure 4	$\frac{7}{10}$	$\frac{1}{10}$	$\frac{2}{10}$	15.48
Figure 7	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	26.38
Figure 8	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	13.41

5. Conclusion

In this paper, we have proposed a visual simulation of car-traffic flow on a crossing in the use of cell-automaton model. From the method, 2-d and 3-d CG images of the flow can be obtained in the relatively low computational cost.

In a future paper, corresponding to more complex structure of roads and the realization of movements of cars considering acceleration or deceleration should be considered. The simulation in the use of the geographic information also should be considered.

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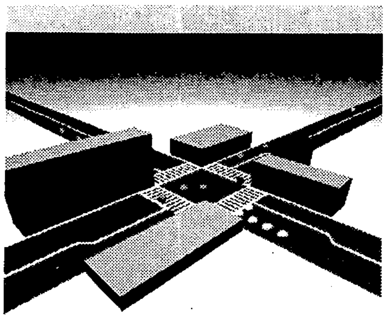

Figure 3. A 3-d crossroads

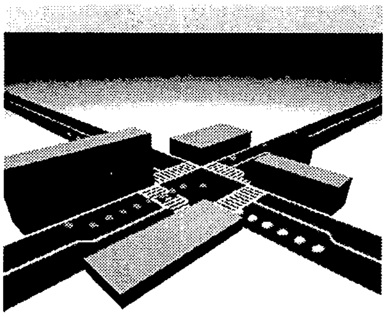

Figure 4. An image under different rates of turning right or left

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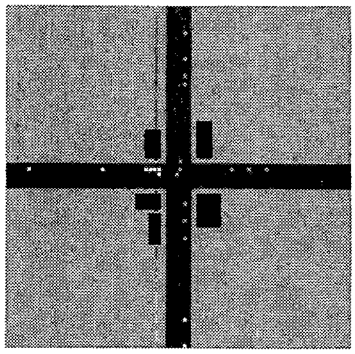

Figure 5. A 2-d image of a 3-d image

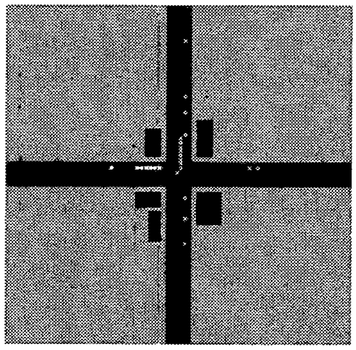

Figure 6. A 2-d image of a 3-d image

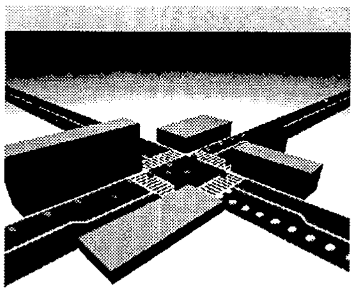

Figure 7. An image under different rate of flow

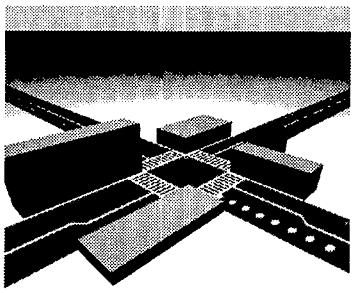

Figure 8. An image under different cycles of signals