Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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Annals of DAAAM International

CALCULATION OF TURNING PROBABILITIES AT THE INTERSECTION

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Abstract: *We are presenting our method for the reconstruction of vehicles' movement through an intersection. This method allows getting information about turning of vehicles by using of data obtained from simple sensors, such as induction loops, IR gates or similar devices. It allows semi-automatic calculation of number of vehicle in each direction in the intersection.*
Key words: *simulation, scenario, traffic, measurement*

1. INTRODUCTION

One of the most important points in simulation is calibration of simulator. In traffic simulation, this means to get as many data as possible about behaviour of drivers on the streets. There are several methods how to do this, depending on sensors, which are available in simulated city. The most common methods are based on using of the induction loops (Klein et al., 2006), sensors placed below the surface of a road and capable of detecting sufficiently large moving metal objects. Another well known method is using of cameras, mounted on the traffic lights (or on other pylons installed on crossroads), connected with image recognizing system (Deng, 2006). Such system can recognize vehicles in the image and count number of passing vehicles or determine length of a queue. It is also possible to use IR gates or radar-based system to count passing vehicles (Klein at al., 2006). The last traditional method is using of probe vehicles (Comert, 2009). It requires having a sufficient amount of vehicles equipped with tracking device (for example cabs or vehicles of public transportation) moving in the traffic network. Position of vehicles can be passed directly to monitoring system, or stored and used for off-line reconstruction of traffic situation. The last recently examined approach is similar. Instead of using specific hardware installed in the selected vehicles, it is based on observation of motion of cell phones. With wide spreading of cellular phones amongst people and density of base stations in the cities, it is possible to track phones' positions with high precision. But using of such technology is bringing concerns about security and privacy (Cooper at al., 2009).

2. SCENARIO USING

We are focusing on the testing and comparing different methods of dynamic traffic control (Lipka & Herout, 2009). Our basic tool is JUTS (Java Urban Traffic Simulator), traffic microsimulator based on cellular automatons (working in similar way as Nagel-Schreckenberg model (Nagel & Schreckenberg, 1992)). One of typical characteristics of traffic flow is its nonlinear behaviour (Shang at al., 2005) and changes in time. Due to this, dynamical traffic control may achieve better results, than using of static control, even if it is optimized for the specific crossroad and time period. In order to test different methods of traffic control, we are using the scenarios, which contain long-term description of driver's behaviour / traffic flow in the simulated network. This allows us to test traffic control in changing conditions, and to use the same conditions for all tested methods.

Sensors mentioned in previous section can provide only data about amount of vehicles passing through observed lane. But in the simulation, we need also information about turning. Sensors cannot provide it automatically, and it is very time demanding to collect such data manually, by observation of the intersection. Because in each scenario, tens of crossroads are used, it was necessary to create at least semi-automatic system, which will allow deriving information about turning from available sensor data.

3. RECONSTRUCTION OF TURNING DATA

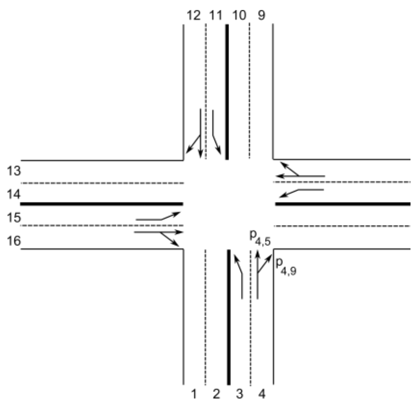
The only information we have from the sensors is number of cars, which passed through the one lane into the observed intersection. They are counted by induction loops placed in the upstream lanes. This can be used to determine the number of cars turning in different direction. We have created semi-automatic way to compute turning probabilities.

Let's assume that we have the intersection as shown at Fig. 1. We know how many cars has entered crossroad, this information is easily accessible. We may also expect that similar measurements are performed on the all adjacent intersections. From their upstream lanes, we can determine the amount of cars that passed through the downstream of our intersection. General shape of the equation for downstream lane *n* will be:

$$V_n = \sum_i V_i p_{i,n} \quad (1)$$

where V_n is number of vehicles incoming into downstream lane *n*, *i* is member of set of all lanes from which vehicles are injected into lane *n* and V_i is overall number of vehicles entering the crossroad in lane *i*. Probability $p_{i,n}$ describes the probability, that vehicle from the lane *i* will turn to lane *n.* The crossroad can be described by the system of linear equations, where each equation represents one downstream lane.

Also, we know that all vehicles from the upstream lane will pass through the intersection, so the sum of turning probabilities in one lane has to be 1. In our case, four equations will be created. Knowing this, we may construct the system of
Fig. 2. Intersection 1
linear equations for crossroad from Fig. 1, with 12



equations ((2) and (3)) and 8 variables. Four of our equations will be Fig.1. Diagram of intersection 1 trivial (in lanes 2, 6, 10 and 14 - for example, on our crossroad, to lane 14 vehicles can ride only from lane 3), by solving the remaining 8 equations, we may determine turning probabilities for all directions. Full description of crossroad will be

$$
\begin{aligned}
V_2 &= V_7 & V_1 &= V_{12}p_{12,1} + V_{16}p_{16,1} \\
V_6 &= V_{11} & V_5 &= V_4p_{4,5} + V_{16}p_{16,5} \\
V_{10} &= V_{15} & V_9 &= V_4p_{4,9} + V_8p_{8,9} \\
V_{14} &= V_3 & V_{13} &= V_8p_{8,13} + V_{12}p_{12,13}
\end{aligned}
\tag{2}
$$

$$
\begin{aligned}
p_{4,5} + p_{4,9} &= 1 \\
p_{8,9} + p_{8,13} &= 1 \\
p_{12,1} + p_{12,13} &= 1 \\
p_{16,1} + p_{16,5} &= 1
\end{aligned}
\tag{3}
$$

Because it is easier to work with matrix form of system of linear equations, we may use the last four equations (3) to express one of probabilities and substitute in the rest of the system (2), so we will have four non-trivial equations for four variables.

It is also possible, that the crossroad will be more complicated, and vehicles from the lanes 3, 7, 11 and 15 will have choice from two directions – to continue straight or to turn left. This won't cause any problems with automatic solution, for such choice will change trivial equations for lanes 2, 6, 10 and 14 to non-trivial, and also adds more equations with probabilities. As an example, if we allow straight ride and turning to left in lane 3, one equation will be added and two other changed:

$$
\begin{aligned}
V_{10} &= V_3p_{3,10} + V_{15} \\
V_{14} &= V_3p_{3,14} \\
p_{3,10} + p_{3,14} &= 1
\end{aligned}
\tag{4}
$$

Also this system of equations can be solved easily, combined with equations mentioned previously.

This is the best situation, where turning probabilities may be calculated fully automatically. As you may noticed, one equation is created for each downstream lane, so the whole system of equations can be solved if there is at maximum the same amount of branching as downstream lanes. However, it may happened, that there is more branching that downstream lanes. New variable is added to the system of equations with each new branching of the traffic streams. Paradoxically, this is typical for simple intersections as you may see at Fig. 2. When there are no turning lanes, vehicles are branching into three directions in each upstream lane. In such case, the resulting system of equations is parametrical and it is necessary to choose one of probabilities manually. In case of crossroad on Fig. 2, we will obtain 4 equations for the downstream lanes, but with 8 variables, so 4 variables will have to be selected manually.

4. DATA ADJUSTEMENT

The data obtained from sensors (induction loops) also cannot be used without adjustments. All sensors are counting vehicles in the same time, typically 15 minutes. This is causing, that overall number of vehicles entering the intersection can be different from number of vehicles leaving the intersection. It is because at the beginning of measuring interval, there are vehicles in the intersection, which will not be counted as entering, but they will be counted in the downstream lane. Similar situation occurs at the end of the measuring interval. Vehicles counted by the sensors at the upstream lane will be at the end of measuring interval in the intersection and will not be counted by sensors at the downstream lane. As we mentioned before, there are no sensors directly at the exits of the Diagram

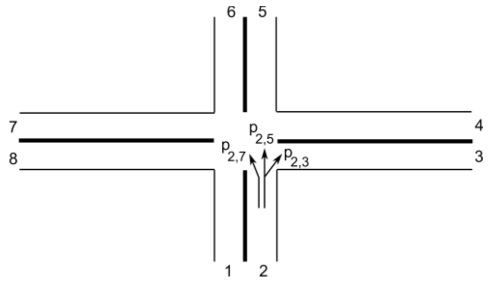


Fig. 2. intersection 2

intersection, instead of them, sensors at enters of the adjacent intersections are used. Because of this, number of vehicles counted only at one end may be significant. Even one missed vehicle will make exact solution of system of equations impossible.

To adjust this, we are using simple algorithm, based on conservation law. In the first step, overall number of vehicles incoming into the intersection is compared. If these numbers are equal, the system of equations will be solvable. If not, half of the difference is subtracted from the lane with highest number of vehicles and the same number is added to the lane with the smallest number of vehicles.

We have checked our method on four intersections, by comparing our results with manually collected data about turning. Difference between observed reality and result obtained by our method from automatically collected data never differ by more than 5%.

5. CONCLUSION

We have presented our method for reconstruction of turning directions at the intersection. We have shown that even by using of the simplest sensors, the amount of turning vehicles can be estimated by semi-automated process. This estimation is most effective on large intersections with many branching lanes.

7. ACKNOWLEDGEMENT

This work is partially supported by Ministry of Education, Youth, and Sport of Czech Republic – University spec. research – 1311.

6. REFERENCES

Comert, G. Cetin, M. (2009). Queue length estimation from probe vehicle location and the impact of sample size. *European Journal of Operational Research*. Vol. 197, No. 1, p. 196 – 202. ISSN: 0377-2217

Cooper, A. K.; Ittmann, H. W., Stylianides, T.; Schmitz, P. M. U. (2009). Ethical issues in tracking cellular telephones at an event. *Omega*, Vol. 37, No. 6, p. 1063-1072. ISSN: 0305-0483

Deng, D. (2006). Self Awareness and Adaptive Traffic Signal Control System for Smart World. *Lectur Notes in Computer Scinece*, Vol. 4158. p. 163-172. ISBN 3-540-38619-X

Klein, L. A.; Milton, M. K.; Gibson, R.P. (2006). *Traffic Detector Handbook: Third Edition – Volume I*. U.S. Department of Transportation. Publication No. FHWA-HRT-06-108. Georgetown Pike

Nagel, K. Schreckenberg, M. (1992) A cellular automaton model for freeway traffic. *Journal de Physique I*. Vol. 2, No. 12, p. 2221-2229. ISSN: 1155-4304

Lipka, R.; Herout, P. (2009). System for comparison of traffic control agent's performance. *Proceedings of 23rd European conference on Modelling and Simulation*. p. 151-157. Madrid, June, 2009. ECMS, Madrid

Shang, P.; Li, X.; Kamae, S. (2005) Chaotic analysis of traffic time series. *Chaos, Solitons and Fractals*.Vol. 25, No. 1, p. 121-128. ISSN: 0960-0779