SIMULATION EVALUATIONS FOR PROFILE SIGNAL CONTROL SYSTEM

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ABSTRACT

The National Police Agency decided to execute the model deployment initiative from fiscal year 2006 to clarify the problems and what should be for nationwide development of the profile signal control system. The profile signal control system is a new decentralized signal control system that utilizes the vehicle arrival forecast exchanged with the upstream signal controller. In this paper, the simulation evaluation aiming to clarify the performance of the profile signal control system is shown. An actual signal control system was connected directly with a personal computer in which the traffic simulator was installed. As a result of the simulation evaluations, the effect of the profile signal control system was confirmed compared with conventional control methods.

INTRODUCTION

In Japan, most signal controllers in the whole area of the city are remotely controlled by a central computer installed in the traffic control center. The current typical signal control method in Japan decides the control parameters based on the traffic volume for a certain period such as cycle length measured with vehicle detectors. One of the problems of the system is the “control delay” until the measurement value of the detector is fed back to the signal control parameters. The new signal control method that is called the profile signal control is a decentralized control method by the intelligent signal controller that decides green time minimizing delay-time that is vehicle waiting time at the intersection with the simulation calculation based on input information as for the vehicle arrival timing in the future. The National Police Agency decided the model deployment initiative to be executed aiming to clarify what should be and the problem for a nationwide deploying this control method. In this paper, the simulation evaluation result of execution aiming to clarify the basic performance before the model deployment initiative is shown.

OVERVIEW FOR PROFILE SIGNAL CONTROL

The profile signal control system is a new real-time signal control method developed to solve the control delay. The verification experiment of the next generation signal control system was executed as a showcase of ITS Nagoya World Congress in 2004(1). And UTMS society set up the communication interface standards of the profile signal control based on the experiment signal control system(2). The outline of the profile signal control is shown...
below. The conventional system in Japan decides the signal control parameters (cycle and split and offset) based on the observed past traffic every fixed control time (for ex. 5 minutes, 2.5 minutes and 1 minute). Therefore, signal control might not be suitable occasionally. When a traffic situation changes rapidly, congestion might occur because of the delay to update the signal control parameters. One of the means to solve this control delay problem is to forecast the change in a traffic situation beforehand, to forestall the signal control parameters based on the forecast, to optimize, and to execute the control in real-time. It is expected that the profile signal control that executes optimization based on the vehicle arrival forecast, which is called “profile” information, can become one of the solutions. The main features of the profile signal control are the followings.

- Input information is the traffic arrival forecast information exchanged with the signal controller installed in the upstream.
- Calculate the vehicle waiting time for traffic signal, which is called “delay-time” of an individual vehicle based on the real-time simulation operation, and search the optimum green time when the delay-time is minimized.
- The calculation of optimum green time is repeated every several seconds to realize the real-time control.
- Decentralized signal control system by the intelligent signal controllers.
- Two methods can be selected to maintain the offset between intersections. As for hybrid mode, offsets are based on the instruction from the central computer. As for autonomous mode, the signal controller in itself judges the relative offset between the designated an adjacent intersection.

**OVERVIEW FOR SIMULATION SYSTEM**

So far, traffic simulator is used widely to evaluate the traffic environment under an equal environment with a real field. However, as for signal control, many traffic simulators can execute only a simple signal control of a fixed control etc... When the engine of the signal control function of high performance had been introduced to the traffic simulator, it is necessary to maintain it in parallel with the upgrade of an actual signal control system only for the traffic simulator. Moreover, even if the evaluation of the algorithm (software) was able to be done, it was difficult to do the overall evaluation including the mechanism side (hardware). It is thought that it is effective to connect an actual signal control system directly with PC installed the traffic simulator as a means to solve these. In this paper, this system is called Hardware-in-Loop Simulator for TCS (Traffic Control System). Figure 1 shows the outline of the system. As for the I/F between the signal control system and PC, general purpose I/F such as a point of contact that the signal controller originally possesses are adopted. Then all domestic signal systems can be connected with no modifications. That is, when a virtual detector that sets on the traffic simulator detects a vehicle existence, the information is input to the signal controller at every 100ms cycle. Signal lights information decided based on detector information is output from signal controller to the traffic simulator at every 100ms cycle, and a virtual signal lights on the traffic simulator is controlled. As a result, the actual signal control system can control a virtual field that the traffic simulator produces and the evaluation of the actual signal control system becomes possible. And it is desired to adopt a widely used and highly evaluated traffic simulator for the persuasive system evaluation. Therefore, this system adopts VISSIM(3) simulator.
SIMULATION RESULTS

Toward the profile signal control installation, the simulation evaluation by Hardware-in-Loop Simulator for TCS was done. The detail of simulation conditions and simulation results are shown below.

ROAD NETWORK

This system is not suitable for the evaluation of the large scale network because the actual signal controllers are needed. The target of this system is a more microscopic traffic behavior. And it is thought that the coordinated intersection group is a minimum unit to evaluate the basic signal control function. Five intersections network in a simple crossroads is targeted in this evaluation. The detectors for the measurement of the inflow traffic to a critical intersection, which is the central intersection No.4, are arranged at 150m in the upstream point and the detectors for the congestion measurement are arranged at 300m, 500m, 750m and 1000m point based on a standard arrangement. Figure 2 shows the road network.
Signal control condition is very simple. It has 1 ring. The ring has 2 phases. The total loss time is 12 sec, that is Yellow-3 sec and All Red-3 sec for each phase. And the range of cycle length is from 80 sec to 150 sec.
TRAFFIC CONDITION

It is thought that the influence of the performance of the signal control for the traffic condition is large when the traffic flow changes under the near-saturated traffic conditions. Therefore, this paper shows the result of the simulation evaluation under the near-saturated condition. To generate the near-saturated condition, traffic volume is designed under the condition that the cycle length is 150 sec, which is the upper bound. Moreover, to confirm the influence of the control delay to the change in a traffic situation, the ratio of the traffic of a main road and a minor road is varied. (The traffic flow occurs at random based on the Poisson distribution.)

Table 1 Traffic condition

<table>
<thead>
<tr>
<th>Traffic generation point</th>
<th>Number of the traffic generation (Num./Hour・Lane)</th>
<th>Pre-running time (10 Min)</th>
<th>Near-saturated time 1 (30 Min)</th>
<th>Near-saturated time 2 (30 Min)</th>
<th>Near-saturated time 3 (30 Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main road</td>
<td></td>
<td>East</td>
<td>400</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>West</td>
<td>720</td>
<td>1071</td>
<td>864</td>
</tr>
<tr>
<td>Minor road</td>
<td></td>
<td>North</td>
<td>480</td>
<td>459</td>
<td>576</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South</td>
<td>340</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Ratio of traffic</td>
<td></td>
<td></td>
<td>70:30</td>
<td>60:40</td>
<td>50:50</td>
</tr>
</tbody>
</table>

SIGNAL PERFORMANCE EVALUATION

The compared signal control methods are the following four methods.

(1) Fixed time control that the signal control parameters are adjusted based on the average traffic. The cycle length is 150 sec and split is 60:40.

(2) MODERATO\(^4\) that generates the signal control parameters automatically every minute based on the load factor calculated from the inflow traffic volume and the congestion length. The load factor is defined as below.

Load Factor = \((V + \alpha \cdot L)/S\)  
- \(V\): traffic volume \(L\): congestion length \(S\): saturated flow

(3) Profile signal control (Hybrid mode)

(4) Profile signal control (Autonomous mode)

Table 2 shows the simulation evaluation results under a near-saturated traffic condition. Thus, the effect of a decrease at the delay-time and stops in the profile signal control can be confirmed.

Table 2 Delay-time and Stops

<table>
<thead>
<tr>
<th>Method</th>
<th>Delay Time (Vehicle・Sec)</th>
<th>Effect (%)</th>
<th>Stops (Num.)</th>
<th>Effect (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Control</td>
<td>187307.6</td>
<td>—</td>
<td>3753.05</td>
<td>—</td>
</tr>
<tr>
<td>MODERATO</td>
<td>155225.3</td>
<td>17.1</td>
<td>3063.58</td>
<td>18.4</td>
</tr>
<tr>
<td>Hybrid mode</td>
<td>124806.6</td>
<td>33.4</td>
<td>2774.79</td>
<td>26.1</td>
</tr>
<tr>
<td>Autonomous mode</td>
<td>127657.5</td>
<td>31.8</td>
<td>2618.71</td>
<td>30.2</td>
</tr>
</tbody>
</table>
評価指標: 遅れ時間(1分)

シミュレーション経過時間[s]
遅れ時間[台*s]

Fixed time control

MODERATO

Profile (Hybrid Mode)
Figure 4 shows the delay-time record of the time series in the west bound and north bound every minute for each signal control method. The profile signal control can follow the change in the traffic condition. And the delay-time is suppressed.

**SIGNAL PARAMETER DISPERSION**

The transition of control parameters of the critical intersection No.4 is shown in Figure 5 and Figure 6 for MODERATO and the profile signal control. The trend of the split of the main road is similar, but the response against the change of the traffic condition of the profile signal control is quicker than that of MODERATO. Moreover, the profile signal control carefully fine-tunes the split according to the traffic change.
CONCLUSION

It is thought that the evaluation by Hardware-in-Loop Simulator for TCS is very effective to evaluate the decentralized signal system influencing mutually like the profile signal control. Because it actually suits and is appreciable of not only the evaluation of the algorithm but also mechanism such as the delay of the communication between signal controllers and the influence of the gap of the processing timing, etc.. And the simulation result shows that the profile signal control is effective when the traffic volume varies under the near-saturated traffic condition.

REFERENCES

(3) VISSIM, http://www.english.ptv.de/cgi-bin/traffic/traf_vissim.pl