PILOT EXPERIMENT FOR PROFILE SIGNAL CONTROL SYSTEM

Hiroshi MATSUMOTO(1), Masafumi KOBAYASHI(2), Shigeki Nishimura(3)
Sumitomo Electric Industries, ltd, 4-11-28, Minami-senba, Chuo-ku, Osaka, 542-0081 Japan
TEL: +81-6-6258-5521, FAX: +81-6-6258-5522 (1)
Sumitomo Electric Industries, ltd, 1-1-3, Shimaya, Konohana-ku, Osaka, 554-0024 Japan
TEL: +81-6-6466-8287, FAX: +81-6-6466-5727 (2)(3)
E-mail: hiroshi-matsumoto@sei.co.jp (1), kobayashi-masafumi@sei.co.jp (2), nishimura-shigeki@sei.co.jp (3)

ABSTRACT

The profile signal control is a new decentralized signal control system that utilizes the vehicle arrival forecast from the upstream. The National Police Agency decided to conduct the model deployment initiatives to clarify requirements for nationwide development of this system. Then this signal control method had been evaluated in Kanagawa Pref. and Ehime Pref. in 2006, and Mie Pref. and Miyazaki Pref. in 2007, where signal controllers were controlled by central computers of the traffic control centers. As the next step, the evaluation had to be conducted in the different traffic environment for two years since fiscal year 2008. Then some area in Saku City of Nagano Pref., where signal controllers were controlled locally based on Time-of-day parameters, was chosen as the test bed. The target date of operation start is early in 2009. In this paper, the outline of the system we developed for the profile signal control and the simulation evaluation aiming to clarify the basic performance before the experiment is shown.

OVERVIEW FOR PROFILE SIGNAL CONTROL SYSTEM

The verification experiment of the next generation signal control system, that became basic of the profile signal control, was executed as a showcase of ITS Nagoya World Congress in 2004\(^1\). The outline of the profile signal control is shown. 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 minute)\(^2\). 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 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 profile information, can become one of the solutions. The main features of the system we developed for the profile signal control are the followings.

- Input information is the traffic arrival forecast information exchanged with the signal controller installed in the upstream. Each signal controller can exchange various information directly with the adjacent signal controller by adopting DATEX/ASN based on UD-type communication\(^3\) which was standardized internationally in 2008.
- Calculate the signal waiting time, which is called “delay-time” of an individual
vehicle based on the real-time simulation operation, and decide green time that the delay-time is minimized.

- 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 center. As for autonomous mode, the signal controller in itself judges the relative offset between adjacent intersections.

Hybrid mode is improved to be able to refer to offsets parameters pre-set in the signal controller, if the signal controller does not receive the instruction from the center.

**OUTLINES OF MODEL DEPLOYMENT INITIATIVE**

The National Police Agency decided to conduct the model deployment initiatives to clarify requirements for nationwide development of this system. Then this signal control method had been evaluated in Kanagawa Pref. and Ehime Pref. in 2006, and Mie Pref. and Miyazaki Pref. in 2007, where signal controllers were controlled by central computers of the traffic control centers. As the next step, the evaluation had to be conducted in the different traffic environment for two years since fiscal year 2008. Then some area in Saku City of Nagano Pref., where signal controllers were controlled locally based on Time-of-day parameters, was chosen as the test bed. The target date of operation start is early in 2009. Figure 2 shows the outline of the area. The area is composed of 30 intersections in National Highway Route 141 and elsewhere. The entire is roughly 9km in length. Saku Interchange of Joshinetsu Freeway and Sakudaira St. where super express of Nagano line stop are near the area.
OVERVIEW FOR SIMULATION SYSTEM

So far, traffic simulator is widely used 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 3 shows the outline of the system.
As for the interface between the signal control system and PC, general purpose interfaces 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 virtual signal lights on the traffic simulator are controlled. As a result, the actual signal control system can control a virtual field the traffic simulator 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\(^{(4)}\) 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 4 shows the road network.

SIGNAL CONTROL CONDITION

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

SIGNAL PERFORMANCE EVALUATION

The compared signal control methods are the following three methods.
(1) Pre-timed 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) Profile signal control (Hybrid mode)
(3) 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>
<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>Pre-timed Control</td>
<td>202430.7</td>
<td>—</td>
<td>3937.58</td>
<td>—</td>
</tr>
<tr>
<td>Hybrid mode</td>
<td>148181.8</td>
<td>26.8</td>
<td>3005.58</td>
<td>24.4</td>
</tr>
<tr>
<td>Autonomous mode</td>
<td>137450.2</td>
<td>32.1</td>
<td>3011.64</td>
<td>24.2</td>
</tr>
</tbody>
</table>
Figure 6 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 7 for 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 Pre-timed Control. Moreover, the profile signal control carefully fine-tunes the split according to the traffic change.

Figure 7 Cycle length and Split (profile signal control)

CONCLUSION

It is thought that Hardware-in-Loop Simulator for TCS is very effective to evaluate the decentralized signal system 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 very effective when the traffic volume varies under the near-saturated traffic condition.

REFERENCES

(2) H.Skakibara, T.Usami, et al., “MODERATO(Management by Origin-Destination Related Adaptation for Traffic Optimization)”, The 6th World Congress on ITS ’99 Toronto