Advanced Traffic Signal Control System Installed in Phuket City, Kingdom of Thailand

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Along with the economic development, traffic has increased in the Kingdom of Thailand and traffic congestion has become a problem in urban areas. To solve this problem, some districts of the major cities of Bangkok and Chiang-Mai are equipped with centralized traffic control systems. Most signalized intersections, however, are not connected to the centralized systems, and signal controllers give predetermined green signal times to the vehicles at intersections.The predetermined green times do not fit the traffic demand that changes dynamically during peak period, so the traffic police is forced to control traffic manually.SEI has designed a new signal control system that is combined with an image processing vehicle detector and an advanced signal controller. The image processing vehicle detector was modified to detect information useful for signal control, and the signal controller was improved so as to calculate the green times that fit the changing traffic demand. The new signal control system is installed at six main intersections in Phuket City by January 2004, and the system has realized smooth and safe traffic at these intersections. This paper introduces the new signal control system in Phuket City.

1. Introduction

Sumitomo Electric Industries, Ltd. (SEI) has installed a traffic signal control system, which combines newest traffic signal controller with spatial-measurement-type image processing type detector (hereinafter referred to as the "image processing type detector" or "IDET"), to the six most congested intersections in the City of Phuket in August 2003 and January 2004. The system has realized safe and smooth traffic flows at these intersections. In Thailand, the centralized traffic control systems, which have the central processing computers set at the police headquarters, are installed in some cities including Bangkok and Changmai. The other cities employ the stand-alone fixed-time signal controllers, which operate based on the pre-set signal parameters. The traffic control system installed in Phuket employs the traffic signal controllers that incorporate some of the functions of the centralized system and are equivalent to the systems operated in Japan.

2. Traffic Condition in Thailand

The GDP growth rate of Thailand maintains a high level reaching approximately 5%, and the number of vehicles owned is also increasing. In every city including Bangkok, heavy traffic congestion occurs at main intersections in the morning and evening peak periods. Because most traffic signal controllers installed at these intersections are the fixed-time controllers, they are not able to respond to changes in traffics. Traffic police officers are therefore forced to control traffic manually during peak traffic periods.

Photo 1. Manual Traffic Control by Police Officer

3. Significance of New Traffic Signal Control System

A common method for solving such problem is to carry out the optimal control of traffic signals at a traffic control center using information collected by the vehicle detectors installed at roadsides. The traffic control centers in Japan and Thailand were constructed under this concept. Construction of traffic control centers, however, requires huge amount of cost and time. The traffic signal control system installed in Phuket calculates optimal traffic control by the computer loaded in each traffic signal controller, thus realizing the decrease of traffic congestion at an inexpensive cost.

4. System Configuration

In this section, the configuration of the system installed in Phuket city (hereinafter referred to as the "Phuket type" system) is explained by comparing the system with the centralized system.

4-1 Centralized Type

In Japan, more than 180,000 intersections are signalized, and 35% of the signalized intersections are connected with the traffic control centers by communication lines (as of year 2003). An example of the configuration of a centralized type system is shown in **Fig. 1**.

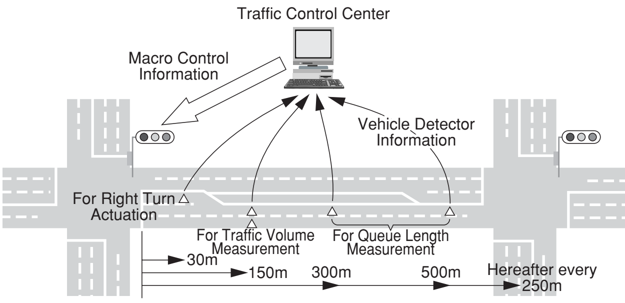


Fig. 1. System Configuration of Centralized System

(1) Vehicle Detectors

Ultrasonic detector, a vehicle detector that emits ultrasonic wave, is used widely. As shown in **Photo 2**, the detector measures pulse reflection time and detects the existence of vehicle beneath.

The general installation points of vehicle detectors are shown in **Fig. 1**. A vehicle detector actuated by the movement of a vehicle turning right is installed over a right turn lane at around 30 m from stop line. A detector for traffic volume measurement is placed at 150 m from stop line. The detectors for vehicle queue length measurement are placed at 300 m, 500 m, and at every 250 m from then on. As previously explained, ultrasonic detector measures the traffic volume of the lane directly beneath it, thus, the measurement accuracy for congestion queue length depends on the detector intervals. If detectors are installed at short intervals, it is possible to obtain more accurate data. However, costs for installation and maintenance increase as well. Based on the authors' experiences and simulation result, it is economically recommendable to install detectors at 250 m intervals. Collected data will then be transmitted to the traffic control center to convert into predicted queue length, hourly traffic volume, and other traffic information used for traffic signal control.

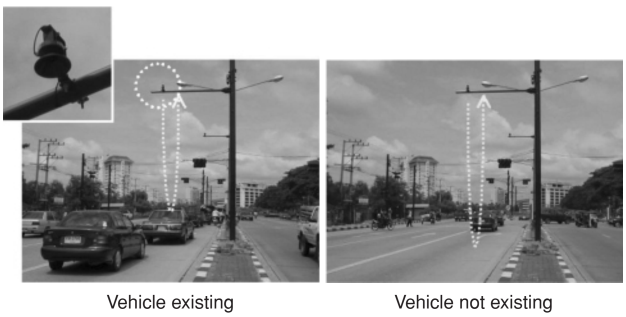


Photo 2. Ultrasonic Vehicle Detector

(2) Traffic Signal Control Method

The function of a traffic signal controller consists of the macro control function that operates every 2.5 minutes or every cycle, and the micro control function that operates every 0.1 seconds. The macro control operates on central equipment and determines traffic signal parameters based on traffic volume data and congestion information collected by the detectors. The micro control operates on local traffic signal controller. The system detects the vehicles that enter into intersection and determines the optimal green time based on the standard green time determined by macro control, as shown in **Fig. 2**. For example, data on right-turning vehicles collected by a detector is transferred to the traffic signal controller for right-turning-vehicle-actuated control. Gap-actuated control like right-turning-vehicle-actuated control is not the only function of micro control. Public transportation priority control, which preferentially allocates green time to public transportation vehicles, and dilemma control, which either extends or shortens green time when vehicle enters into intersection at high speed and reduces accident occurrence rate, are the other functions of micro control.

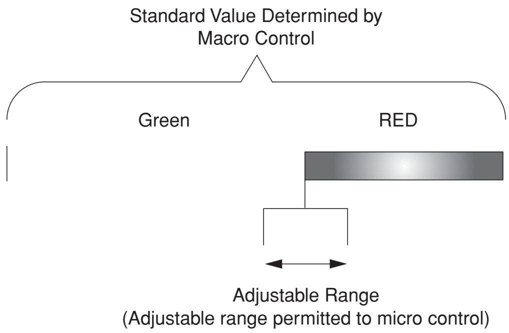


Fig. 2. Macro and Micro Controls

4-2 Phuket Type

The system configuration is shown in **Fig. 3**. In the Phuket type system, traffic signal controller and detectors operate without being connected to the center. Vehicle detectors are also installed near intersections for collecting traffic volume information.

(1) Vehicle Detectors

Vehicle detector for right-turn-vehicle-actuated control is installed at 20-30 m from the stop line on a right turn lane and detector for vehicle volume measurement

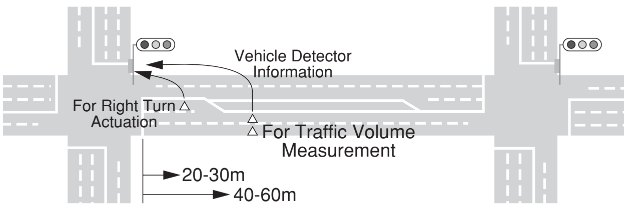


Fig. 3. System Configuration of Phuket Type System

is installed at 40-60 m upstream from the stop line. For the system in Phuket, image processing type detectors were used instead of ultrasonic detectors. The functions of image processing type detectors and the reason for their replacement will be explained in Section 5.

(2) Traffic Signal Controller

The latest local traffic signal controller has macro and micro control functions. Moreover, the controller can be connected with a traffic control center to operate as a part of a centralized system. The functions of traffic signal controllers will be described in Section 6.

5. Image Processing Type Vehicle Detector

This section explains the image processing type detectors used in the Phuket type system.

5-1 Overview

A camera unit can be installed at 8-10 m above the road surface and can collect traffic data listed in **Table 1**. In the Phuket type system, the camera units are installed on traffic signal poles as shown in **Fig. 4**. When using ultrasonic detectors, setting up of a new pole is required for each unit. When using image processing type detectors, however, each unit can be installed on a traffic signal pole, and therefore is preferable for aesthetic and cost reasons.

Table 1. Measurement Items

Measurement Item	Number of Measurable Lanes
Traffic Volume / Occupancy	4 lanes
Speed	4 lanes
Vehicle Type (L/S)	4 lanes
Vehicle Presence	4 lanes
Queue Length	2 lanes

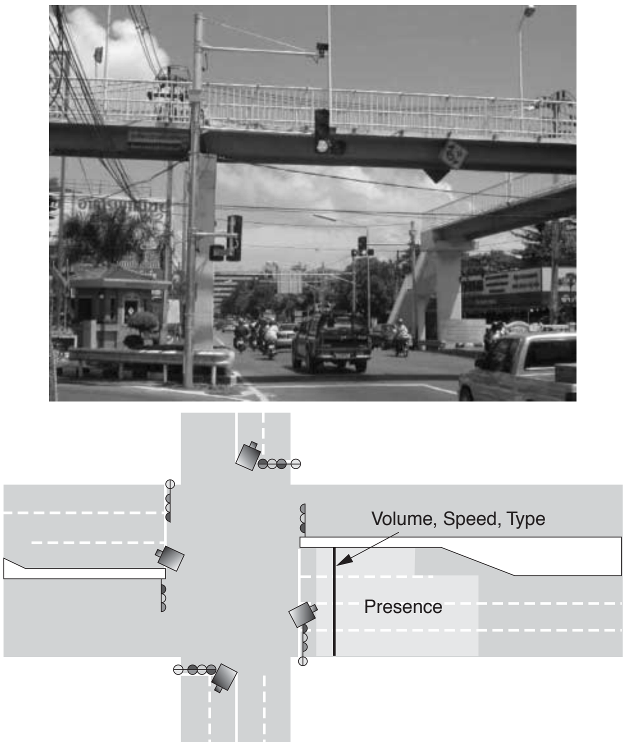


Fig. 4. Overview

5-2 Improvement of Functions

On the construction of the Phuket type traffic signal control system, SEI improved the image processing type detector' s function to make traffic signal controller operate more appropriately according to traffic condition.

(1) Vehicle Existence Detection

It is important in micro control to understand the behavior of vehicles that approach to the intersection. In general, a vehicle passes the stop line every 2 seconds on each lane under congested condition (as shown in **Fig. 5**). This traffic performance is called saturation flow. In gap-actuated control, the distance between two vehicles is measured and if the distance in seconds is 3-4 seconds (as shown in **Fig. 6**), the traffic controller judges that the saturation flow stopped and ends green signal accordingly. In the case of ultrasonic detectors, the detectors are installed at 20-30 m upstream from the stop line on a right turn lane and at 40-60 m upstream from the stop line on a through-traffic lane for detecting the above mentioned traffic condition. Traffic condition between stop line and detectors is an estimated value. The image processing type detectors installed in Phuket can detect vehicle presence lane by lane in a

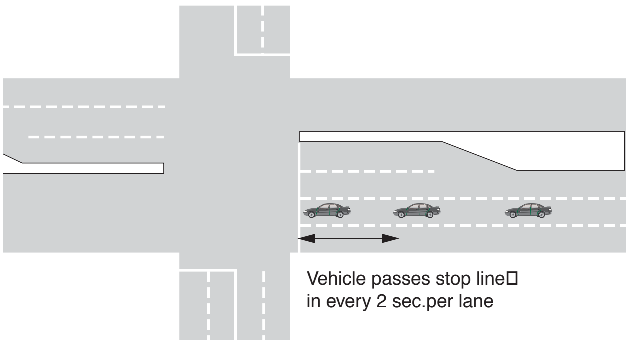


Fig. 5. Definition of Saturation Flow

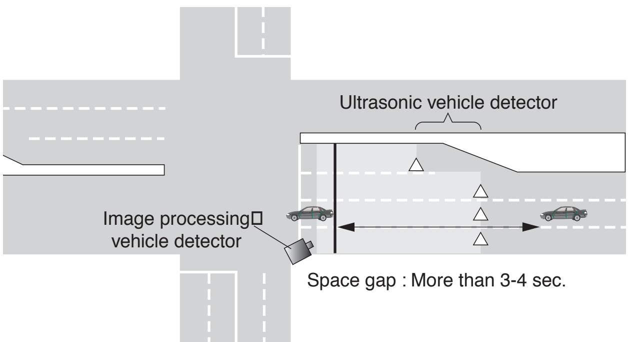


Fig. 6. Determination of Green Signal Termination

detection area, which is 20-60 m upstream from stop line, by a single camera unit. This leads to the perfect detection of vehicle existence at intersections, and allows accurate termination of green signal time.

(2) Exit-Blocking Detection

It is preferable to end green time and assign it to the other direction when spillback from downstream intersections reaches to the controlled intersection and vehicles cannot pass trough the intersection. An image processing type detector measures the speed of each vehicle in the detection area. When vehicles are not moving for a certain period of time in the detection area, the detector turns off vehicle existence signal, or in other words, the detector judges that there are no vehicle passing through the intersection and ends green signal. In this way the system can eliminate unnecessary green time.

6. Traffic Signal Controller

As explained earlier, some of the functions of the centralized system are incorporated into local traffic signal controllers in the "Phuket Type" system.

Table 2 is the comparison of macro control between the "Centralized Type" and "Phuket Type" systems.

The overview of macro control realized in the Phuket type system is explained below. Because micro control is the original function of traffic signal controllers, the controllers in the Phuket tye system have this function from the beginning.

Table 2. Comparison of Macro Control

Control Type / Control Item	Centralized	Phuket Type
Split Control	Actuated Control	Actuated Control
Cycle Control	Actuated Control	Fixed Time / Actuated Control
Offset Control	Actuated Control	Fixed Time Control

6-1 Split Control

The most effective signal control technique for reducing congestion at intersections is split control. In a centralized system, the split value of each signal aspect is calculated to become equal, based on traffic volume information during smooth traffic and on congestion queue length information during traffic congestion. In the Phuket type system, because detectors for measuring congestion queue length were not installed, it is not possible to recognize the occurrence of congestion. During traffic congestion, the results of micro control are reflected on split calculation as follows.

① In a certain signal aspect, when green time reached the maximum adjustable range, it is judged that green time is not sufficient or congestion has occurred.

② The standard green time for that direction will be increased at the next split calculation (macro control).

6-2 Cycle Length Control

In Phuket city, at intersections where no offset control is required since distances between intersections are long, the "cycle-less control" method, which adjusts signal cycle lengths according to the incoming traffic volume of each cycle, was employed. For those intersections that require offset control, cycles were adjusted based on time of day (TOD) data, due to the reason explained in Section 6-3.

6-3 Offset Control

At intersections where the distances between are less than 300 m, offset control is employed to adjust the start time of green signal at each intersection, so that vehicles are able to pass through the intersections with minimum stops. If the cycle length of each intersection differs, it is impossible to maintain the difference in signal start time. The cycle length of each intersection must hence be equalized. Furthermore, because the time difference of the start of green signal is adjusted on the second time scale, the clock in each controller must be adjusted in like manner. In the case of centralized system, signal cycle lengths, traffic information, and signal control parameters are administrated collectively. Therefore, green signal start time will not deviate from the standard time. On the other hand, in the Phuket type system, traffic information cannot be administrated collectively via a traffic control center, and signal control will be executed based on preinstalled time-of-day data.

On this occasion, if the built-in clock of each signal controller is inaccurate, the green signal start time will deviate from the standard time. Thus, the signal controllers in Phuket are equipped with a GPS system to adjust the clock every hour.

7. Effect of Installed Systems

With regard to the three intersections in which the system developed by SEI was installed in August 2003, an investigation to check the effectiveness of the system was carried out by Chulalongkorn University after the installation. As for one intersection, however, "ex-ante data" could not be collected since other construction work was taking place at the time of traffic investigation. Therefore, the system' s effectiveness was investigated and compared for the two intersections only.

(1) Congestion Status

At one intersection, traffic congestion improved dramatically. At the other intersection, however, an intersection located 80 m down the street affected that intersection, and the intersection' s effectiveness therefore could not be proven. The problem was solved in January 2004 when a traffic signal controller was installed at the downstream intersection and offset control was realized.

(2) Road Users' Evaluation

More than 90% of the road users were satisfied with SEI' s system. They were satisfied especially with traffic order and safety at right turning situation. The road users' evaluation showed that they preferred adaptive control to manual control by police officers.

8. Conclusion

By constructing a traffic control center and installing vehicle detectors at roadsides, the traffic signal control that optimally corresponds to various traffic conditions can be realized. It was reported that by constructing a control center and connecting intersections with the center, traffic congestion was improved by 15-20%. The construction of centralized system, however, requires a large amount of time and cost. There is a large difference in adaptability to changes in traffic conditions between the intersections controlled using TOD data and intersections controlled collectively via a control center. To compensate for this difference, the Phuket type system that can adapt to traffic condition changes has been developed.

The traffic signal controllers used in this system are expandable for use in the centralized system. Therefore, it is possible to first install the system into the congested intersections at different locations and then construct a control center after the number of the system-installed intersections has increased to a certain extent.

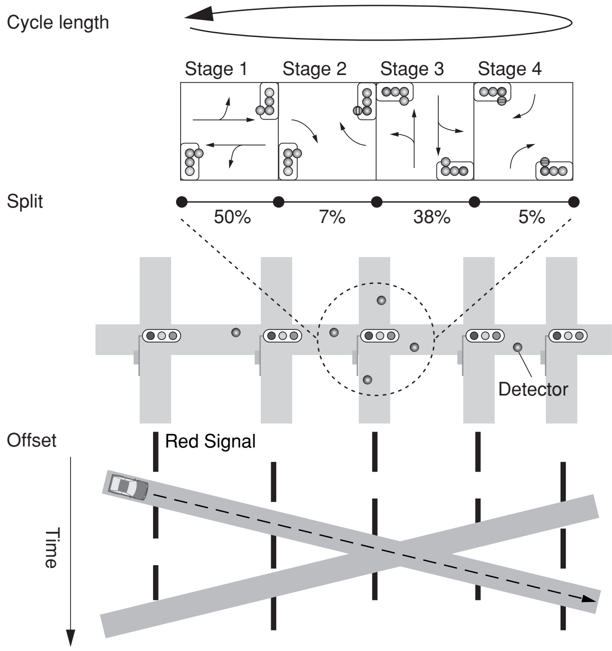
The authors are expecting to install this system into the intersections with decentralized traffic control in the near future.

{Explanatory Note}

*1 Traffic Signal Control Parameters:

Traffic signal control parameters are composed of cycle length, split and offset. One cycle is a complete sequence of signal aspects, and the time required for one cycle is called cycle length. Cycle length is normally adjusted to become long at high traffic volume conditions and adjusted to become short at low traffic volume conditions.

Split is a percentage of a cycle length allocated to the green signal aspect and is calculated based on the traffic demand ratio of each direction. Offset is the time difference between the start time of the green signal at one intersection and the start time of the green signal at the other corresponding intersection. The offset is adjusted so that the vehicles can pass intersections with minimum delay time and minimum number of stops.



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