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Data Transmission Strategy of Probe Vehicle in Floating Car Traffic Monitoring

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Abstract—The floating car data (FCD) method is an example of the applications of the Intelligent Transportation Systems (ITS) where the traffic data are provided by means of the information and communication technology. In the FCD method, the traffic data are collected, manipulated, and transmitted by probe vehicles via a wireless network to a designated server where the data are stored, manipulated, and displayed in conjunction with a digital map. The method is capable to provide near real-time traffic data but its performance strongly and mainly depends on the reliability of the wireless network. In this work, the traffic data transmission strategy in the FCD method is discussed and its effect to the timeliness of the traffic data is described. As the results, it is found that when the data transmission strategy is not properly designed, a delay in a transmitted packet of data directly affects and intensifies the subsequent data transmission. We propose a transmission strategy to minimize the time delay and experimentally demonstrate that the strategy can reduce the time delay significantly.

Keywords—Floating car data; virtual trip line; normal distribution, intelligent transportation system; probe vehicle.

I. INTRODUCTION

Providing real-time traffic data is very important for various purposes including for optimizing road networks. Traditionally, the traffic data are recorded using loop detectors implanted beneath road surface at measurement points. Figure 1 shows a typical installation of the loop detector.

![Loop Detector](image1.png)

Fig. 1. The illustration of the loop detector installation.

The loop detector has many advantages and disadvantages. One of its advantages is that the loop detector can provide various traffic information such as traffic velocity and volume. The detector is also relatively cheap. However, it has rather limited area coverage and can only provide traffic information at the point where the detector is implanted. Thus, many detectors should be used to cover a wide road network. The detector is also prone to errors and malfunction. In California, the United States, 30% of the 25,000 deployed loop detectors do not work properly in the daily basis [1].

Floating Car Data (FCD) traffic monitoring is a rather new method. The method also requires low cost but it has wider area coverage. The technique relies on what is called the probe vehicle, which is a vehicle enriched with traffic measurement sensors, and moves within the traffic. The traffic information are gathered using this vehicle and are transmitted to a designated server for further processing and dissemination. For more detail description regarding the system, we advise the readers to consult [2, 3].

Various aspects of the FCD method have been discussed in great length. The types of the commercial vehicles in operations that suitable for FCD method are discussed in [4] and [5]. The former studied the use of a taxi fleet and the latter studied a bus fleet and their feasibility to be the probe vehicles. In addition, [5] evaluated the use of FCD method to estimate the travel time. The use of the FCD method for traffic monitoring has also been demonstrated on the traffic along a highway segment with 16-km length [1] and on the Roma Ring Road in Roma, Italy [6]. The potential security breach of the traffic data by the FCD method was discussed by [7].

However, transmitting the traffic data over a wireless network may face some uncertainties due to the inherent nature of the network. In this article, we discuss algorithms to achieve high level of data reliability of the FCD system. Finally, we empirically evaluate the timeliness of the traffic data gathered by the proposed method.

II. RESEARCH METHOD

The flow of the traffic information in the Floating Car Data (FCD) monitoring system is illustrated in Fig. 2. The traffic information is mainly the traffic velocity, and in this method, the velocity is quantified by the probe vehicle and a measurement unit, which is a smart-phone in the case depicted in the figure. However, other measurement units can also be
used. The traffic information is then transmitted to the web database. Finally, the traffic data within the web database can be accessed by users via web-clients. For more detail explanation regarding the system, we advise the readers to consult [3].

The system assumes that the probe vehicle travels at a velocity, which reasonably represents the traffic velocity. Thus, by measuring the probe vehicle velocity, one can estimate the traffic velocity. This estimate, as devised by many previous publication such as [6], is accurate when the number of probe vehicles in comparison to the traffic volume exceeds certain small threshold. This indicator is often called as the penetration rate and its threshold is about 2–5% for the highway road [8]. Higher penetration rate is required when the variation of the traffic velocity is higher as in the case of the traffic in urban roads.

As depicted in Figure 2, the FCD system can be divided into three sub-systems. The first sub-system is the probe system that contains the probe vehicle and a geo-location unit. In the current implementation, we use the global positioning system (GPS) for the geo-location via a smartphone. The second sub-system is web-database is designed to receive the traffic data and overleys the data on top a digital map. The third sub-system is the web client and is designed to provide an interface of access to the traffic information. The typical interface of the third sub-system is reproduced in Fig. 3.

In the current implementation, we use smart-phone to determine the geo-location of the probe vehicle. And, the geo-location data are used to estimate the probe vehicle velocity. Smart-phone is a hand-held device that integrates the functionality of a mobile phone with other features but mainly with a geo-location functionality. This type of phones has also been used for various traffic management applications [10].

The phone is attached to a probe vehicle and is used to measure the probe vehicle position, velocity, and heading. Finally, those data and related timestamps are transmitted to a server via a wireless network using a simple HTTP request; see Fig. 4 for the example of the data transfer mechanism. However, for the current experiment, the recorded data also contain the time when the data are gathered and the time when the data are transferred. In the server side, those data will be added with the time when the data are received by the server. Prior the experiment, the client clock system and the server clock system are synchronized.

![Traffic Flow Diagram](image1)

**Fig. 2.** The flow of traffic information by the floating car data system [2].

![ITS Monitor](image2)

**Fig. 3.** An example of the traffic information in a mobile web client [9].

![Traffic Map](image3)

**Fig. 4.** A typical HTTP request to transfer data from the measurement unit to a web-server.

In the current work, we test the data transmission algorithm by using a probe vehicle enriched with ten smart-phones of the same type, Samsung Galaxy Fame GT-S6810. Each phone is installed with the developed client application. We drive the probe vehicle along the Jakarta Inner Ring-Road in Jakarta, Indonesia (see Fig. 5). The road has a length of 45 km. The road mostly has three vehicular lanes except in the interchanges where the number of lanes is reduced to one or two lanes. During the test, the probe vehicle is maintained on the central lane if possible. The lane is the closest lane to the GIS lane.

### III. Data Transmission Strategy

When transmitting data over a wireless network, the transmission may fail for a number of reasons. It may fail because the transmitting device is located within a dead zone, uncovered by the surrounding cell towers; it may fail because the surrounding high-rise buildings block the radio signal; and it may also fail due the limitation of the available bandwidth.

To obtain near real-time traffic information, the geo-location data of each running probe vehicle must regularly be transmitted to the designated server. For the reason, in the current development, we use the Handler class of the Android SDK that allows an application to execute an action after a specified interval.
The most basic transmission strategy is advised in Fig. 6. The strategy incorporates a Runnable object that can be executed by a Handler object after a period of time.

The data transmission characteristics of the basic algorithm are graphically shown in Fig. 7. It shows that when the fourth traffic data require a long transmission time, but within the timeout threshold, the subsequent traffic data during the time span of 5–10 s could not be recorded, leaving a gap of 5 s. On another scenario, at time 11 s, the traffic data are recorded but are failed to be delivered after a few attempts. Hence the data at 11 s will be discarded and a new traffic data will be captured. Similar to the first case, the traffic data during the time span of 12–16 s can not be recorded.

The more advanced strategy is advised in Fig. 8. In here, we create two Handlers, namely captureHandler and transmitHandler, where each Handler represents a thread. Instead of directly sending the recorded data, we first arrange those data in a queue. Next, we check the state of transmitHandler, and execute the thread if it is not currently executing anything.

The transmitHandler should first prepare the array of data to be sent by duplicating the content of the queue. Then, the Handler will send the all available data at once to the designated server. The array of data, which is submitted to the server, will be removed from the queue once we receive a positive confirmation from the server. Finally, the thread will rerun itself when there is any new data added to the queue.

The data transmission characteristics of the the advanced strategy are graphically shown in Fig. 9. The figure shows that when the fourth traffic data require a long transmission time, but within the timeout threshold, the subsequent traffic data during the time span of 5–10 s will be stored in the queue and will be transmit at once at time 10 s. On another scenario, at time 11 s, the traffic data are recorded but are failed to be delivered during the specified threshold duration. In this case, the traffic data will be appended to the data recorded during time 12 s and time 16 s. Those data will be transferred at once at time 16 s.

IV. RESULTS AND DISCUSSION

In this section, we discuss the delay of the data transfer of the basic strategy and more advanced strategy, which involving a queuing array. The results of our analysis are presented in
Table I for the data descriptive statistics, Fig. 10 for the data histograms, and Fig. 11 for the delay data structure.

Table I shows the descriptive statistics of the delay data. The last column, improvement, is simply a ratio of the statistics of the basic strategy and that of the advanced strategy. The ratio measures the level of improvement given by the advanced strategy with respect to the basic strategy.

Firstly, we look into the descriptive statistics of the central tendency: the mean, the median, and the mode. The mean of the delay data is 5.1 min for the basic strategy and only about 0.2 min for the more advanced strategy; thus, the advanced strategy improves the mean data by about 31 folds. The median values are 0.718 min for the basic strategy and 0.026 min for the more advanced strategy; thus, the median delay is reduced by a factor of 24 by the advanced strategy. The last central tendency is the mode and its value is 0.035 min for the basic strategy and 0 for the advanced strategy.

Using the central tendency indicators, we conclude that the advanced strategy is significantly more superior than the basic strategy.

Secondly, we look into the descriptive statistics of the data spread. In this case, we focus on the standard deviation, the range, and the percentiles. The delay data of the basic strategy spread by a standard deviation of 7.4 min, and the advanced strategy by about 0.3 min, or about 24 times smaller. In term of the range, the advanced strategy provides a spread of 2.6 min, and the basic strategy is more than an half hour. It is remarkable to see that the 95% of the recorded delay is below 0.818 min and 100% data are transferred within 3 min.

As for the distribution of the delay data, the two strategies seem to produce delay data as distributed according to the exponential distribution function, as expected, see Fig. 10. About eighty percents of the delay data occur for duration less than 10 min for the basic strategy and less than 30 s for the advanced strategy.
V. Conclusions

The Floating Car Data (FCD) method uses one or more probe vehicles within traffic to measure and report the status of the traffic. Thus, the traffic sensor in the probe vehicle travels together with the traffic. The method is distinctly different than the traditional method, which is based on the loop detector. The loop detector is fixed at a point and reports the traffic data as an average of the vehicles in the traffic. Consequently, the resulting traffic information from the two strategies may be different in some extent. In the current work, we focus on the timeliness of the traffic data obtained by the FCD method. Further, we propose two traffic information gathering and transferring strategies, and experimentally verify the strategies. As the results, we find that the time difference between the time when the data arrived in the server and the time when the data are recorded are rather random and are distributed following the negative exponential distribution. We also find that that the advanced strategy with a queuing array performs remarkably better to address the problem of unreliable communication infrastructure between the client vehicle and the designed server.

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