An Improvement of Speed Estimation from Single Loop Detector Data for Advance Traveler Information System

Hokkaido University　○Internship Trainee　Piti Rotwannasin*
Hokkaido University　Professor　Takashi Nakatsuji

1. Introduction

In recent years, Advance Traveler Information System (ATIS) which is one of the ITS applications was promoted in order to provide travel information especially traffic information in term of travel time information to traveler. Both direct and indirect travel time measurement can be determined but direct measurement data is based on sample data which is quite small compared with large number of population and also operation cost is quite high. So, indirect measurement was normally proposed to use in traffic information analysis instead of direct measurement.

The conventional traffic surveillance which widely use is inductive loop detector both single and dual loop type. There are four measurements that are made by a traffic management system including volume, occupancy, speed, and vehicle length but only occupancy and volume are available from single loop detector. Single loop detector is widely use more than dual loop detector although modern traffic surveillance which are out of pavement detectors intend to replace single loop detector using wayside mounted sensors, e.g., the Remote Traffic Microwave Sensor (RTMS) traffic surveillance but its work same as single loop detector operation [1].

Due to previous researches, speed estimation method based on volume and occupancy available from single loop detector is derived to estimate speed, e.g., [1] and [2]. However, it was shown that previous speed estimation methods can not work well under high number of truck or long vehicle and congested condition. Although Unscented Kalman Filter technique was proposed [3] and work quite well under congested condition but it has some rooms that can be improved to get speed estimation more accurate. The objective of this paper is to propose an idea of estimate traffic speed from single loop detector data for ATIS.

2. Previous Speed Estimation Method

Coifman [4] proposed the improvements of speed estimation using single loop detector that assume vehicle length and vehicle velocity are uncorrelated. Speed estimation was based on volume, occupancy, and g value as shown in equation 1.

$$\bar{s}_s(i) = \frac{N(i)}{T(i) \cdot O(i) \cdot g} \tag{1}$$

Where i is time interval index, $\bar{s}_s(i)$ is space mean speed, $T(i)$ is time interval duration, $O(i)$ is occupancy, and g is parameter related with vehicle length. In practical, operation agency defined vehicle length to be constant. For the fact that, this approach fails to account caused by percentage of long vehicle may change during the day or the simple may not include typical vehicle length. Particularly during low flow, when the number of vehicle in a sample is small, a long vehicle can simply skew occupancy because it takes more time for passing the detector.

Coifman et al. [5] presented a different approach, using a new aggregation methodology to estimate velocity and reduce the impact of long vehicles in the original traffic measurement. Median velocity was proposed instead of mean velocity that he argued that median velocity is less sensitive than mean velocity from various vehicle lengths influence. There are many researchers that investigated techniques to reduce the influence of long vehicles, for example Pushkar et al. [6], Dailey [7], and Wang and Nihan [8]. Benekohal and Girianna [9] noted that it is, “necessary to encourage state DOTs to include classification counts in their annual traffic monitoring program.” As noted in a research statement from the TRB Committee on Highway Traffic Monitoring [10], “Classification based solely

* On leaved from Civil Engineering Department, Engineering Faculty, Chulalongkorn University, Bangkok, Thailand.

on vehicle length is an alternative to axle-based classification but there has been no systematic study of how will it works or how it should work."

Due to TRB's research statement, there are many researcher presented their study to fill research gap, for example Coifman and Kim [1] refined three unconventional techniques for estimating speed at a single loop detector that brings length based vehicle classification to single loop detectors, including moving median method, sequence method, and distribution method. Zhang et. al. [11] presented how to estimate large truck volume using single loop detector data, unscented kalman filter algorithm is used to generate speed estimation and the mean effective vehicle length of each time interval. Kwon et al. [12] proposed method to estimate truck traffic volume from single loop detector using lane-to-lane speed correlation. However, those proposed methods have limited to apply for estimating speed only bimodal vehicle distribution which are short and long vehicle length. The proposed method also can not clearly differentiate vehicle types during heavy congestion.

Due to loop detector data is limited, dynamic mean effective vehicle length in each time interval can not be accurately measured by single loop detector also affected speed estimation. Ye et al. (2006) proposed Unscented Kalman Filter for estimating space mean speed in each time interval based on single loop detector data without the consideration of vehicle length variance in each time interval. UKF was proposed to estimate speed instead of previous studies that attempt to estimate traffic speed based on traffic stream relationship with constant g estimator method and dynamic g estimator in each time interval. The comparative result was shown that UKF speed estimation is accurately estimated better than two previous methods that it yields the lowest MAE, lowest RMSE, and also the least spread of error range. Moreover, it is found that the MAE and RMSE tend to be lower when time interval duration is larger and UKF can still maintain good estimations when the time interval is as small as 20 seconds and only an overall average of individual vehicle lengths and the detector length are needed for estimates. However, Ye et al. [3] recommended that average vehicle length on location is needed and usually can be easily measured from vehicle classification of that location or from historical data. By the way, the effective vehicle length distribution should be concerned to obtain a good value that accurate results can be achieved.

3. UKF Speed Estimation using Single Loop Detector Data

To include estimated dynamic effective vehicle length into the updating algorithm of UKF, there have several considerations to be concerned as followings:

1) How to deal with high number of truck traffic.
2) How to deal with multimodal vehicle length distribution.
3) How to deal with congested condition.
4) How to combine the probe data with the fixed detector data in case of traffic data are available from both sources.

4. Conclusion

An improvement of speed estimation from single loop detector for ATIS is necessary. UKF will be applied to update speed estimation as real-time feedback manner. In order to improve UKF speed estimation, effective vehicle length distribution under heterogeneous traffic will be concerned. It hope that speed estimation will be more accurate than previous research method.

5. References

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