Traffic Flow Monitoring Utilizing On-vehicle Devices of Spacing Measurement

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1 INTRODUCTION

Observing traffic flow is important for road administrators to decide their policy and to operate traffic management and control measures in road networks. In most cases the observed data called as traffic state, that often consist of flow rate q, density k and speed v. The observation methods are roughly divided to two categories from their point of view, Eulerian observations and Lagrangian ones.

Eulerian observation that observes traffic flow from fixed points is the most popular observation method. Traffic detectors such as loop detectors and supersonic detectors are often used in such cases. These detectors provide flow rate q, density k and speed v at installed points. However, it is difficult to densely install them throughout road network because of the costs of installation and maintenance.

Lagrangian observation is another concept of the observation methods. This observation method observes traffic flow from the vehicles driving in road networks. One of the typical methods of this concept is observation by GPS-equipped probe vehicles. A probe vehicle reports its position during its travel. Using that data, the vehicle's trajectory, speed v, and travel time are easily identified, but flow rate q and density k are not.

The conventional methods including both Eulerian and Lagrangian observation are insufficient to observe the fundamental variables of traffic flow throughout the entire road network. In order to obtain detailed information of traffic state from the Eulerian and/or Lagrangian observation data, many previous studies investigated on traffic state estimation. One of the most common approaches of traffic state estimation uses data assimilation methods such as Kalman filter or its variation methods. These methods are aiming to obtain higher resolution or precision traffic state from the observed data. The methods rely on the filtering methods whose state equations are macroscopic traffic flow model. Various data sources are used in this approach, such as fixed detector [1], probe vehicle and fixed detector [2] and solely depends on probe vehicles data [3, 4]. However, there are only a few studies on traffic state estimation only with Lagrangian observation and it assumed significantly high probe vehicles penetration rate, or assumed strong assumptions on q−k relation. It may be due to defects of current Lagrangian observation methods, GPS-equipped probe vehicles. One of the defects of the GPS-equipped probe vehicles data is lack of the fundamental variables, namely flow rate q and density k. If the penetration rate of the prove cars becomes 100%, flow rate can be directly observed. However it might not be easy because of drivers' incentives and privacy issues.

Recently, a new technology has been developed in Automotive Engineering field. It is to measure the spacing between a vehicle and its leading vehicle, obstacles, pedestrians and others in real time by on-vehicle devices [5, 6]. This technology was developed to enhance driving safety and be used for warn driver or automatically control vehicle when caution is required. Furthermore, there are research and development projects for fully automated vehicle (i.e., autonomous vehicle or driverless vehicle) that are driven by artificial intelligence using various sensing technologies including the spacing measurement technology [7]. These devices and autonomous vehicles begin to be applied for practical use. For instance, the IEEE anticipated that 75 percent of vehicles on entire road network will be autonomous by 2040 [8]. Although this technology is anticipated to spread, usage of data from this technology are limited in only Automotive Engineering field. This technology may be useful in Transportation Engineering field.

Our objective in this study is to develop a traffic state estimation method utilizing probe vehicles data that contains both spacing and position information, and not depends on any Eulerian observations. The evaluation of the methodology from the point of view of the efficiency and the accuracy are also to be examined.

2 METHODOROGY

In order to formulate the traffic state estimation method, stochastic relation between traffic density k at specific road sections and spacing s of vehicles that are traveling on correspond sections is assumed. Parameters of the assumed stochastic relation model are estimated from observed probe data (position x and spacing s). In order to consider the consistency of the traffic flow in the estimation, the proposed method considers flow conservation condition. Advantages of the method is not to require any fixed detectors, as well as not to depend on road section specific conditions like predefined $q-k$ or $k-v$ relations. For that reason, this method may be robust against changes in traffic condition such as incident, weather change and others. Figure 1 is a conceptual image of this study.

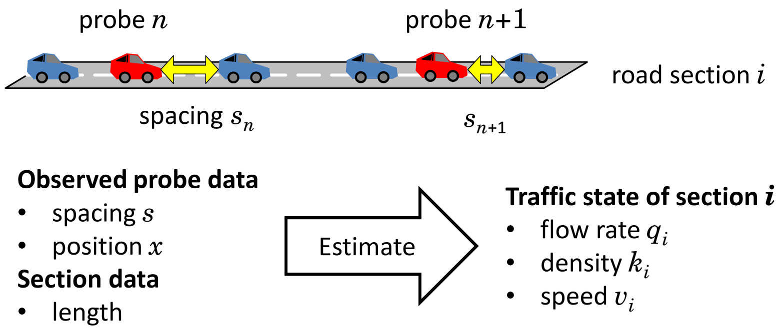

Figure 1: Concept of this study

3 RESULTS AND DISCUSSION

In order to validate the proposed methodology, experiments by microscopic traffic simulator are conducted. Numerical characteristics like its precision for various situations (e.g., traffic conditions, penetration rate of the probe vehicles, etc.) are examined. Figure 2 shows one of the results of the analysis under a scenario of 5 % probe vehicles penetration rate. According to Figure 2, the proposed method tend to slightly overestimate flow rate. An error index, mean absolute percentage error (MAPE[1]), of the result is 25.8 %, thus it can be said that the accuracy of estimation is not bad.

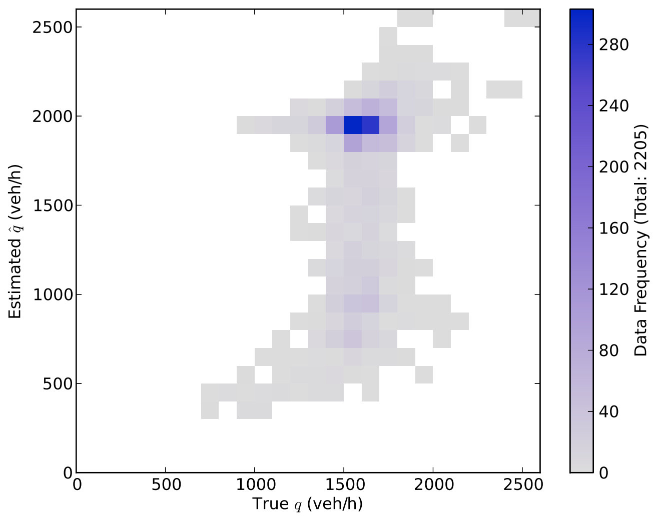

Figure 2: A scatter plot on true−estimated flow rate q

[1]MAPE $= \frac{1}{I}\sum_i^I \left|\frac{q_i - \hat{q}_i}{q_i}\right|$ where q_i is true value of flow rate, $\hat{q}_i$ is estimated value of flow rate, i is unit number of estimation, I is total number of unit of estimation.

As the result of the analysis, conditions when the proposed methodology is effective and accurate are revealed quantitatively. For example, ununiformity of traffic density, especially vehicles platoons, effects negatively on the estimation accuracy. The results also show that the characteristics of the estimation accuracy is different from existing traffic state estimation methods. As a conclusion, the developed method thought to be good traffic flow monitoring method under certain conditions, such as high traffic demand.

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