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Estimation of missing flow at junctions using control plan and floating car data

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Abstract

This paper proposes a new and consistent approach for estimating missing flow by analyzing data from SCATS (containing both flow and timing plan at junctions) and FCD (Floating Car Data). SCATS system provides flow data and timing plan at a 5-minute interval, while FCD contains information of taxi trajectories with speed and position for each vehicle at a 30-second interval.
Two objectives are defined in this paper: 1) to summarize major methods of flow estimation and create a generalized framework in flow estimation, 2) to research for the possibility of improving utilization of traffic flow data, by comparing methods from multiple aspects, to provide accurate and reliable source for traffic research and application.
The paper devises three consistent methods to estimate missing flow at junctions. Firstly, historical flow data of a specific lane is used to make an initial estimation. Flow estimation values are estimated from each single lane and normalized to further complement Secondly, flow values from adjacent lanes with similarities are processed to compare with the estimated lane, for which timing plan is applied to identify relevant control group (same turning lanes) with their relative phase time proportions. Proportions and flow rate from observed lanes on the same control group are normalized to make an estimation at missing lanes. Thirdly, the information of FCD (such as speed) is used to estimate corresponding flow value. Typically detected flow and FCD speed relationship is established from junction streams. This relation is then applied back to the stream to calculate traffic flow. Each of the methods is expected to perform under varying situations. If all the results are proved to be reliable to a certain degree, they can be iterated for mutual verification and consistency.
This methodology has been applied to Changsha municipality in China. Initial results indicate that suggested methods give promising indication that almost all missing lane flow could be recovered using these three methods. Further research is ongoing to investigate specific data fusion mechanism or interchangeable data source for traffic state estimation and its quality. Further research will also consider adjacent junctions within a given area to understand how data and flow relationship works at the network level.

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1. Introduction

1.1. Background

The signal control scheme at junctions is influenced by traffic flow and traffic status significantly. Especially for adaptive traffic control system such as SCATS (Sydney Coordinated Adaptive Traffic System), which adapt signal plan based on the traffic volume and saturation degree, while both factors are derived from the flow data detected at loop near junction. Thus, Traffic flow detection is crucial for accurate traffic state estimation and efficient traffic management in urban areas and on freeways. However, due to system or device failure, traffic flow obtained from the urban traffic control system shows frequently irregularity. For example, 5-10% on average of the available data from dual loop systems in Dutch freeway networks are missing or unreliable (Van Lint & Hoogendoorn, 2009). Similar situations exist in urban traffic monitoring systems. This fact can be further demonstrated in section 1.2 by using the data SCATS as a case. Reliable flow data are crucial no matter in ex-post or real-time situation; if the availability of flow data is not sufficient, the missing data estimation at junctions or on road section is necessary. Traffic flow acts as a significant role in accurate traffic state estimation and efficient traffic management both in urban areas and on freeways.

Previous studies have sought to improve the quality and comprehensiveness of raw observation data from monitoring systems. They consider the problem from varying aspects. On the one hand, some researchers deal with the problem by focusing on the coherence of traffic flow on road section; for instance, Chen et. al. (2003) apply an imputation method to filter out bad data samples and to form a complete clean data set from single-loop systems. This method considers the relations of detected flow corresponding to their relative locations, and it can be applied in both urban and freeway networks. On the other hand, some tackle the problem by emphasizing the similarities of flow pattern over a time cycle, which is more commonly used; for example, Wall et. al. (2003) present a time-series algorithm for correcting errors in freeway traffic management system archived loop data. Except for getting reference traffic values directly from time or space, some use more complex way to estimate flow and achieve much more insight at the same time. For example, Treiber and Helbing (2002) develop an adaptive smoothing method based on the notions from the first-order traffic flow theory, to reconstruct and clean flow observations from dual-loop systems. This approach has been further generalized by Van Lint and Hoogendoorn (2009) to fuse multiple data sources. Yuan et. al. (2012) apply a regression analysis from inductive statistics to estimate multi-class and multi-lane flow counts from generic freeway surveillance systems. It is based on the correlation between lane and class disaggregated counts. These researchers and studies involve the estimation or prediction of traffic flow to some extent. However the topic is seldom raised separately and comprehensively to be generalized into a framework. In this paper, the focus will be given on the estimation of missing traffic flow at urban junction. It follows a concept to estimate the traffic state by checking the consistency and generic pattern of multiple data sources, which is similar to the concept derived by Ou et. al. (2013) who developed a series of data fusion methods using data-data consistency.

1.2. Research question

The paper aims at developing a generalized and cross-compared methodology for missing flow estimation at junctions, using available data sources. The main research question then is: what are the good ways to estimate missing flow at junction when loop detectors fail? Several sub-questions are formulated as: what is the data quality at junctions in a traffic control system such as SCATS system? what are available methods for missing flow estimation? how do the methods work in missing flow estimation?

The question of data quality will be answered in the following part of section 1; methodology the paper is introduced in section 2, while experiments setup of case study is given in section 3. In section 4, the results of experiment are provided followed by analysis and comparison. Finally the conclusion is given in section 5.