Transportation Research Part C 72 (2016) 45–59

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Headway-based bus bunching prediction using transit smart card data

Haiyang Yu, Dongwei Chen, Zhihai Wu, Xiaolei Ma *, Yunpeng Wang

School of Transportation Science and Engineering, Beijing Key Laboratory for Cooperative Vehicle Infrastructure, Systems, and Safety Control, Beihang University, Beijing 100191, China

ARTICLE INFO

Article history:
Received 19 August 2015
Received in revised form 10 September 2016
Accepted 17 September 2016

Keywords:
Bus bunching prediction
Headway irregularity
Least squares support vector machine
Transit smart card

ABSTRACT

Bus bunching severely deteriorates the quality of transit service with poor on-time performance and excessive waiting time. To mitigate bus bunching, this paper presents a predictive framework to capture the stop-level headway irregularity based on transit smart card data. Historical headway, passenger demands, and travel time are utilized to model the headway fluctuation at the following stops. A Least Squares Support Vector Machine regression is established to detect bus bunching with the predicted headway pattern. An empirical experiment with two bus routes in Beijing is conducted to demonstrate the effectiveness of the proposed approach. The predictive method can successfully identify more than 95% of bus bunching occurrences in comparison with other well-established prediction algorithms. Moreover, the detection accuracy does not significantly deteriorate as the prediction lead time increases. Instead of regularizing the headways at all costs by adopting certain correction actions, the proposed framework can provide timely and accurate information for potential bus bunching prevention and inform passengers when the next bus will arrive. This feature will greatly increase transit ridership and reduce operating costs for transit authorities.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Transit authorities have been striving to improve transit service quality to attract more transit riders, satisfy passenger demand, and reduce operating cost (Ding et al., 2015, 2016). The level of service enhancement largely relies on whether the transit system can be operated as reliable as it was designed (Bellei and Gkoumas, 2010). However, buses may not always adhere to the planned schedule at each stop, a situation that may cause great frustration for transit riders (Watkins et al., 2011). One of the consequences of an irregular transit service is bus bunching, in which two or more buses that should be evenly running along the same route simultaneously arrive at the same stop. The potential reasons behind this phenomenon are unstable traffic conditions and excessive boarding/alighting passenger demands. If a bus is slightly delayed due to traffic congestion, the bus has to pick up more passengers than expected at the next bus stop. The extra passenger demand further aggravates the bus delay. In contrast, the next bus will experience low passenger load and save more dwell time (Fonzone et al., 2015). This outcome can exponentially expand to the following stops and eventually yield little or zero headway for the two buses. Bus bunching increases the waiting time for passengers and deteriorates in-vehicle comfort level due to overcrowding (Bie et al., 2015). Transit authorities may also lose loyal customers with such unreliable transit service

* Corresponding author.
E-mail addresses: hyyu@buaa.edu.cn (H. Yu), chendongwei@buaa.edu.cn (D. Chen), zy1513318@buaa.edu.cn (Z. Wu), xiaolei@buaa.edu.cn (X. Ma), ypwang@buaa.edu.cn (Y. Wang).

http://dx.doi.org/10.1016/j.trc.2016.09.007
0968-090X/© 2016 Elsevier Ltd. All rights reserved.

and cause revenue reduction. When bus bunching occurs, an overcrowded bus is usually followed by a near-empty bus. This situation will waste the already limited resources and increase the operating costs for both transportation agencies and transit companies.

Transit authorities have developed corrective measures to overcome the negative effect of bus bunching. The typical countermeasures include bus holding, speed adjustment, stop-skipping, short-turning, and passenger demand reduction. However, these corrective methods are reactive and may dissatisfy the passengers waiting at stops or sitting in the bus. For instance, stop-skipping allows drivers to intentionally bypass several stops for service recovery. However, this may change the destinations of those passengers who are already onboard and frustrate or anger them. Adopting proactive strategies to monitor irregular headways and alert possible bus bunching in advance to prevent transit service breakdown is preferable. Therefore, the objective of this study is to predict the occurrence of bus bunching through irregular headway fluctuation. From the perspective of passengers, knowing the time interval between two consecutive bus runs (i.e., stop-level headway) helps them anticipate the arrival of the next bus. With this information, passengers can more efficiently plan their trips to save time. From the perspective of transit operators, the stop-level headway is a good indicator of bus bunching. If the predicted headway is too small, bus bunching will likely happen, and corresponding countermeasures can be made before two buses simultaneously arrive at the next stop.

The recent advent of Automatic Fare Collection (AFC) (i.e., Smart Card) can reduce the high cost and manpower resources for manual data collection method, as well as accelerate the passenger boarding and alighting process through contact-less cards and card readers. The data gathered by the AFC system contains abundant temporal and spatial information of individual passengers and can be utilized to quantify transit performance, improve transit operation, and understand travel behavior. This study aims to leverage transit smart card data into bus bunching detection by forecasting stop-level headway in varying time horizons. Although smart card data suffer from several data quality issues (Robinson et al., 2014), they can store each passenger's boarding time and location. This information can be used to calculate the stop-level bus headway and passenger demands along with inter-stop travel time. Both passenger demand and travel time uncertainties are highly correlated to the bus bunching phenomenon and can be fed back into intelligent algorithms to prevent the upcoming bus bunching in the following stops. Passengers can likewise reduce their anxiety by knowing when their next buses will arrive.

The major contributions of this study are threefold: (1) A novel data-driven approach is proposed to predict the fluctuation of bus headway at each stop based on smart card data. (2) The emergence of bus bunching can be found by mining the headway irregularity at consecutive bus stops. (3) The lead time (i.e., the number of stops ahead of the stop where bus bunching map occurs) to detect bus bunching occurrences is investigated. The sooner bus bunching can be found, the more efficiently transit operators can adopt preventive countermeasures.

The remainder of this paper is organized as follows. Section 2 summarizes the existing literature on bus bunching and headway prediction, followed by a brief introduction of data collection and preprocessing efforts. Section 3 outlines the methodological framework, where Least Squares Support Vector Machine (LS-SVM) regression is introduced to predict the stop-level bus headway, and the predicted headway fluctuation can be further mined to identify the occurrence of bus bunching. Section 4 presents the algorithm results based on the smart card data from two routes in Beijing and tests the prediction accuracies of both headways and bus bunching events by comparing them with other algorithms. In addition, a sensitivity study is undertaken to analyze how early a bus bunching notice can be given with multi-stop intervals. Section 5 concludes the work and elaborates on future research directions.

2. Literature review

In an ideal situation, the headway between two consecutive bus runs at each stop should be constant along the same route. However, in reality, the headways for different stops become irregular due to severe traffic congestion, unexpected passenger demands, heterogeneous bus driver behavior, and unreasonable bus bay layouts. An irregular headway at a specific stop will have a snowball effect that further deteriorates the reliability of the bus schedule. Consequently, bus platoons may end up arriving at the same time. In this case, bus bunching is caused by headway fluctuation, which can be defined as the time difference between the arrival times for two consecutive buses at the same stop. Thus, various complex algorithms are developed to predict bus arrival time. These algorithms can be generally categorized as follows: forecasting model based on historical data (Chen et al., 2003), time series model (D'Angelo et al., 1999), artificial neural network (ANN) model (Chien et al., 2002; Jeong and Rilett, 2004; Padmanaban et al., 2010; Lin et al., 2013), support vector machine model (Yu et al., 2007, 2011), Kalman Filter algorithm (Shalaby et al.,2003; Chien and Kuchipudi, 2003; Chen et al., 2004), nearest-neighbor trajectory method (Tiesyte and Jensen, 2008; Chang et al., 2010), regression prediction model (Patnaik et al., 2004; Jeong, 2004; Sinn et al., 2012), and K-nearest neighbor (KNN) (Coffey et al., 2011). Most of these studies rely on GPS data to predict bus arrival time at each stop for a single bus along the same route (as summarized in Table 1). To successfully extract the stop-level bus arrival time, GPS data have to be integrated with external data sources, such as bus stop spatial information, for additional processing (e.g., map matching). Moreover, it is difficult to take into account the stop-level bus delay (i.e., dwell time) because low GPS data updating frequency may impact the estimation accuracy, whereas the dwell time is highly related to bus arrival time prediction (Lin et al., 1999).

Predicting bus bunching is a more challenging task than predicting single-bus arrival times because more than one bus is involved in bus bunching. Both the dwell times and arrival times of different buses at different stops fluctuate and lead to a

Download English Version:

https://daneshyari.com/en/article/4968670

Download Persian Version:

https://daneshyari.com/article/4968670

Daneshyari.com