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Journey time estimator for assessment of road network performance under demand uncertainty

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ABSTRACT

This paper proposes a journey time estimator (JTE) to estimate the stochastic journey time of each path for performance assessment in road network with uncertainty due to day-to-day demand variations. The stochastic network framework is adopted in this paper, in which link flows and path journey times are modeled as random variables so as to fully utilize the first- and the second-order statistical properties of the partial data collected for the journey time estimation. The second-order statistical property is referred to the variance–covariance (var–cov) of the observed path journey times and link flows available for the estimation. In this paper, the proposed JTE is formulated as a bi-level optimization problem. The objective of the upper-level problem is a variant of the Least Squares function, which considers the mean and var–cov of the observed path journey times. In addition, the observed statistical distribution of the link flow is also used to formulate a chance constraint in the upper-level problem. The lower-level problem is the reliability-based stochastic user equilibrium traffic assignment problem in stochastic network, which explicitly considers the reliability-based path choice behaviors of the road users under demand uncertainty. A heuristic iterative estimation-assignment algorithm is employed to solve the proposed bi-level problem. Numerical examples are provided to demonstrate the applications of the JTE and efficiency of the proposed algorithm.

1. Introduction

1.1. Background

Journey time, travel time, or the time required to traverse a roadway between any two nodes (points) of interest, is a fundamental measure of system performance in road networks (Vanajakshi et al., 2009). Therefore, the estimation of journey times is of increasing concern for assessing the impacts of various transport policies and plans on network performance particularly under uncertainty in traffic demand. Recently, more attention has been given to the estimation of journey times in

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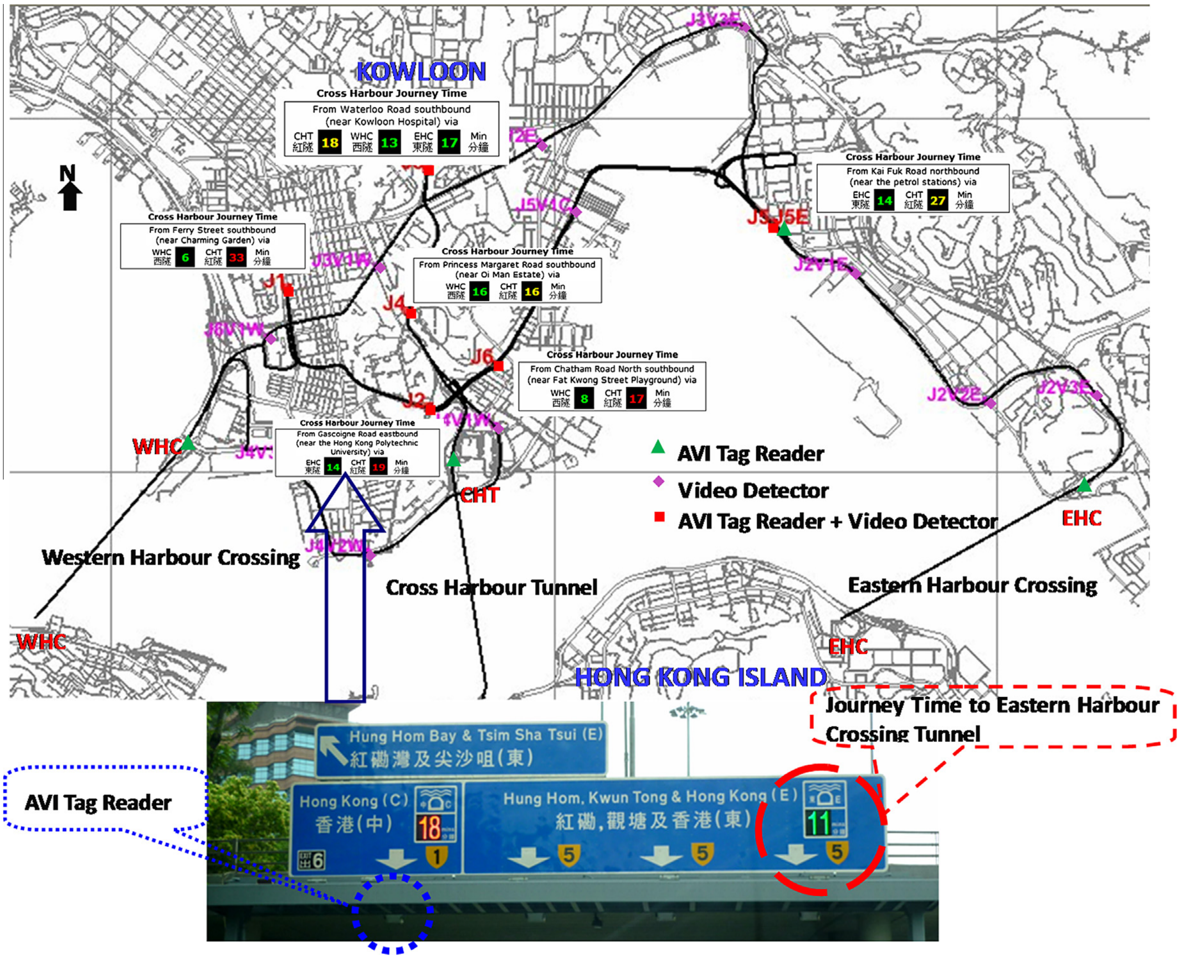

Fig. 1. Journey Time Indication System in Hong Kong.

road networks with the use of different traffic data collected by various technologies. These technologies include electronic distance-measuring instruments, electronic license plate matching, cellular phone tracking, automatic vehicle identification (AVI) (Tam and Lam, 2008), automatic vehicle location, Global Positioning System (GPS) (Bouchier, 2004; Taylor et al., 2000; Tong and Chen, 2004; Uno et al., 2009), probe vehicle (Hellinga and Fu, 2002), virtual probe vehicle (Liu and Ma, 2009; Liu et al., 2012), wireless magnetic sensors (Kwong et al., 2009) and so on.

In Hong Kong, the AVI tag readers can provide time stamps at which vehicles pass successive checkpoints. As such, the journey times between two checkpoints with AVI readers can be observed (Tam and Lam, 2008). Such journey time information is defined as the path segment journey time, which has been used in the Journey Time Indication System (JTIS) in Hong Kong as shown in Fig. 1 (see Hong Kong Transport Department website: http://tis.td.gov.hk/rtis/ttis/index/main_partial.jsp). The digital signs of JTIS display journey time in minutes from the location of the indicators to the exit of the respective road tunnels. The displayed digits are shown in three colors for different traffic conditions. Red[4] represents congestion, amber indicates slow traffic and green smooth traffic. It should be noted that vehicles may make stops or detour along the paths or path segment, it is necessary to filter out such outlier observations for journey time estimation. Since these vehicles would experience a journey time that is atypical, these observations should therefore be removed from the data set of valid observations to avoid producing erroneous observed journey times. There are several algorithms for filtering out outlier observations, such as TransGuide algorithm (Southwest Research Institute, 1998), TranStar algorithm (Houston TranStar, 2012), Transmit algorithm (Mouskos et al., 1998) and Real-time Traveler Information System (RTIS) algorithm (Tam and Lam, 2008). Among these algorithms, the RTIS algorithm is particularly designed and adapted to provide journey time observation using AVI data in Hong Kong. Therefore, the RTIS algorithm has been adopted in this paper to provide the observed path and path segment journey time information for journey time estimation.

[4] For interpretation of color in Fig. 1, the reader is referred to the web version of this article.