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Incident Detection Methods Using Probe Vehicles with On-board GPS Equipment

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Abstract

Mobile communication instruments have made detecting traffic incidents possible by using floating traffic data. This paper studies the properties of traffic flow dynamics during incidents and proposes incident detection methods using floating data collected by probe vehicles equipped with on-board global positioning system (GPS) equipment. The proposed algorithms predict the time and location of traffic congestion caused by an incident. The detection rate and false rate of the models are examined using a traffic flow simulator, and the performance measures of the proposed methods are compared with those of previous methods.

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Keywords: traffic incident detection; probe vehicles; GPS; urban expressway

1. Introduction

Effective management of limited resources is essential in our modern society; time, in particular is one of the most valuable and coveted resources. Managing travel time has increased the need for more accurate and reliable travel services for road traffic. Estimating the time and location of recurring traffic congestion has been made possible by advanced statistical methods and a large scale database of traffic flows. The accuracy of travel information provisions continues to improve for ordinary traffic conditions.

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A traffic incident is defined as a sudden event in traffic flow that is accompanied by an extraordinary drop in capacity and increased congestion. Traffic accidents are impossible to predict before they actually occur; such unpredictability can cause transport systems to fail, which greatly inconveniences our modern lifestyle. Prompt and accurate detection of traffic incidents is one of the most important actions for achieving reliable travel services.

Roadside traffic detectors have been installed to monitor traffic flows. Flow rate, spot speed, and time occupancy at a certain location are automatically observed for a given period of time. Observed traffic flow data has been used to study a wide variety of incident detection methods over the years. Dudek et al. (1974) developed the standard normal deviation (SND) algorithm. Dudek used past accumulated traffic data to estimate probability distributions; the probability of current, observed traffic volumes was examined to detect the occurrence of an incident. Payne (1976) developed the California algorithm, in which the space-time variation of time occupancy was compared to a threshold value estimated using past accumulated data. Lin and Daganzo (1997) proposed the University of California, Berkeley (UCB) algorithm. In this method, statistical fluctuations of time occupancy are recognized as random walks, and values that are out of range, are indicative of traffic incidents. Recently, Jeong et al. (2011) proposed a wavelet-based, freeway incident detection algorithm that combines the multi-resolution property of wavelet transforms with varying threshold values. Jeong et al. also introduced a new feature selection technique to select features that discriminate between normal and incident traffic conditions.

Performance of incident detection methods, based on traffic detectors, depends on the position of roadside equipment. If densely allocated traffic detectors are available, and data collection intervals are short enough, incident detection methods with fixed point observations are very effective. Ideal environments, such as this is, are limited, however; one example is urban expressways in Japan with supersonic traffic detectors installed every 200-300 meters. On the other hand, sparsely located detectors and longer data collection intervals may result in a failure or delay in identifying incidents.

The SND, California, and UCB algorithms are all examples of algorithms that are used by fixed observation systems. Nowadays, in addition to the traditional fixed point observation systems, mobile communication instruments have become available for road traffic monitoring. Vehicle trajectories can be observed by probe vehicles equipped with on-board GPS equipment and communication devices. Traffic incidents are detected using these floating traffic data. A small number of studies have been conducted to compare fixed-detector-based incident detection methods to traffic incident detection using probe vehicles.

Sermos and Koppleman (1996) proposed a dynamic measurement algorithm based on the ADVANCE project, in which both travel time and spatial location data are used.

Petty et al. (1997) proposed the Probe-UCB algorithm, which utilizes the acceleration and deceleration of an individual vehicle. After a probe vehicle passes through a congested area of traffic, its speed will increase until it reaches the free flow speed. An incident is detected when the acceleration and speed of the probe exceeds threshold values. Only a single probe vehicle is necessary to detect the occurrence of an incident; detection time is also minimized. Determining whether traffic congestion was caused by a traffic incident or not is difficult; thus, detection rates may be relatively low.

Chue et al. (2002) developed a mobile sensor and sample-based algorithm (MOSES) to detect incidents on freeways. MOSES is based on the statistical difference in the mean section travel time from two sets of probe vehicle samples before and during an incident. Algorithm performance depends on the percentage of probe vehicles; more than 50% of vehicles should be sampled as probes.

Li and McDonald (2005) developed a bivariate analysis model (BEAM) using two variables: the average travel times of probe vehicles and the travel time differences between adjacent time intervals. The magnitudes of increases in link travel time were compared for incident and non-incident conditions. An incident is identified by an increase in magnitude of travel time. This method uses the aggregated link travel times observed by several probe vehicles in a time interval.

Zhu et al. (2009) applied an outlier mining method to incident detection, which is based on probe vehicle data on urban arterial roads. Zhu et al. used changes of vehicle speed in space time dimensions. The speed differences between adjacent sections and adjacent time intervals were selected as feature vectors. Distance-based outlier detection was applied to distinguish incidents from non-incidents.

Recently, Kinoshita et al. (2014) have focused their attention on an anomaly detection method of traffic incidents by discovering abnormal car movements, and distinguished such movements from those occurring in spontaneous