Smart Traffic Management System for Anticipating Unexpected Road Incidents in Intelligent Transportation Systems

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ABSTRACT

This article describes how anticipating unforeseen road events reveal a serious problem in intelligent transportation systems. Due to the diversity of causes, road incidents do not require regular traffic conditions and accurate prediction of these incidents in real-time becomes a complicated task not defined so far. In this article, a smart traffic management system based cloud-assisted service is proposed to preserve the traffic safety by controlling the road segments and predicts the probability of incoming incidents. The proposed cloud-assisted service includes a predictive model based on logistic regression to predict the occurrence of unforeseen incidents. The sudden slowdown of vehicles speeds is the practical case of the article. The classification task of the predictive model incorporates four explained variables, including vehicle speed, the travel time and estimated delay time. The prediction accuracy is proved by checking the model relevance according to the quality of fit and the statistical significance of each explained variable.

KEYWORDS

Cloud-Assisted Service, Delay Time, Intelligent Traffic Management, Logistic Regression, Loop Detectors, Observed Travel Time, Observed Vehicles Speed, Predicted Travel Time, Unexpected Incident

INTRODUCTION

Despite the progress made in the development of smart cities, the exponential increase in road density and the adjustment of traffic flow management. The traffic safety still contributes significantly to disturb the interests of citizens, the transportation activities and the economy of the government services. Actually, many transportation communities are focusing their efforts on developing Intelligent Traffic Management Systems (ITMS) based Decision Support Systems (DSS) to control the traffic safety, the traffic network and providing sustainable mobility for all road users (vehicles, passengers, pedestrian, etc.). From their perspectives, the intelligent traffic management systems (ITMS) will use the smart cities as backbone to make the citizens lives much easy by solving inherent daily problems such as the traffic congestion and the carpooling. Additionally, the solutions offered by these systems will offer an advantage not only for the road users but also to the transportation centers and the other government sectors. In this course, the ITMS are supposed to interact with modern vehicles, the road detector technology (e.g., traffic light and the loop detectors) and pedestrian through mobile devices. The Connected Vehicles (CV) (Lu et al., 2014), the Autonomous Vehicles (AV) (Gerla et al., 2014) and mobile devices (Barbareschi et al., 2015) are most prevalent road objects in the smart

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cities. These objects are destined to be equipped by countless embedded systems to collaborate, sense the traffic data and delivers various functionality on the move, connect and communicate with other real-world objects. Wei et al. (2015) combine the concepts of the vehicular network with cloud technology to offer advanced applications in order to improve the traffic management and increase the traffic safety. Liu et al., (2017) propose a multilayered urban-traffic management architecture that converge the vehicular ad hoc networks to the next generation of the wireless networks. The architecture aims to mitigate the traffic congestion and improve the management tasks. The use cases of the architecture are essential for the rapid traffic accident occurrence and reducing the required time for rescue accidents. For better road traffic control, the vehicle mobility and the real traffic condition are two relevant factors to understand the behavior of the traffic safety (Eiza & Ni, 2013). Additionally, the traffic monitoring is the best way to control the traffic safety and estimate the traffic parameters (Mohana & Ashwathakumar, 2012). Besides, the context of this paper is destined to improve the traffic safety and ensure an effective prevention system in complex traffic conditions. Particularly, it predicts the occurrence of unexpected traffic incidents when a slowdown in vehicle speed is detected by loop detectors. In fact, the road incidents are one of the main causes of traffic congestion and it absorbed by little works in the literatures. According to Lee et al. (2002) the road incidents and its negative effects (e.g., crash) on the freeways can be predicted based on the real-time traffic factors such as the traffic flow, road density and the variation in the vehicles speed. Wu et al., (2013) aim to reduce the travel time of the vehicles under congested conditions by proposing dynamic path algorithm. The proposed algorithm uses traffic data provided by advanced traffic information systems such as Global Positioning System (GPS) and Geographic Information System (GIS). Chen et al. (2016) develop appropriate models to predict accurate information about the crash occurrence in complex driving environments. The proposed model incorporates the environmental conditions (e.g., weather conditions) and the traffic parameters stored in the traffic database. Yan et al. (2016) propose in-vehicle audio warning system able to read and prevent drivers about road limit speed where, achieved experiments demonstrate the effectiveness of the proposed audio warning on increasing traffic safety. Additionally, recurring bottleneck is a subclass of road incidents that presents a key factor that disrupts the vehicular traffic. Under these circumstances, bottlenecks can be detected when the loop detectors show a slow traffic speed. To avoid the bottleneck, various control strategies which have been proposed use the variable speed limit (VSL) control to improve the traffic safety, reduce the risk of the rear-end collision and adjust the speed of the traffic flow. Li et al. (2014) propose a control strategy of variable speed limits (VSLs) to reduce the risk of the rear end collision. The proposed control strategy is based mainly on specific crash risk prediction for the freeways and overcrows conditions. Jin et al. (2014) apply the variable speed limit (VSL) strategy to tackle the capacity of a lane-drop bottleneck that is caused by lane closures. The VSL control strategy is applied to adjust the traffic flow speed based on the estimated discharging traffic flow rate by proposing capacity drop model. Besides, various statistic strategies are used to predict the road incident based on exploring the relationship between the traffic variables. In which, Dong et al. (2014) describe a multivariate random-parameters zero-inflated negative binomial (MRZINB) model for jointly modeling crash counts. The objective of the applied regression model is to find a strong relationship between traffic crash frequencies, pavement conditions, traffic variables and the traffic network. The output of the regression model shows high correlation level between the inputs, which mean that the model is appropriate and the input factors contribute significantly to achieve a better goodness of fit. The applied logistic regression model by Michalaki et al. (2015) is to identify most relevant factors that affect the severity of accidents that occurred on motorways. In which, various factors are incorporated in the model. The evaluation results show that the number of vehicles, the rush hours and low visibility are high correlated and contribute significantly to increase the road severity. Abdelatif et al., (2016) adopt a data collection method which implements the Choquet integral operator to collect and aggregate raw observed data provided by the loop detectors to predictor traffic parameters. The proposed method is intended to bring more advantages for the
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