Expert Systems with Applications 39 (2012) 8356–8368

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

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

Advanced formation and delivery of traffic information in intelligent transportation systems ☆

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ARTICLE INFO

Keywords:
Intelligent transportation systems
Traffic parameters
Event Detection
WiMAX
WiFi

ABSTRACT

To meet the safety requirement for the increasing traffic densities nowadays, there exists a growing demand for advanced systems that can provide drivers essential traffic and travel information to improve road safety and traffic efficiency. In this paper, we combine the video analysis and multimedia networking technologies to present a highly integrated intelligent system that can achieve the above goals. For traffic information, the system presented in this paper collects traffic parameters and detects relevant events by analyzing traffic surveillance videos. Through robust tracking algorithms and reasoning logics, important traffic parameters and events are extracted from the surveillance videos accurately. Afterwards, summarized real-time traffic conditions and important events along with corresponding live traffic videos are formed into layers and multicasted through an integration of WiMAX infrastructure and vehicular ad hoc networks (VANET). By the support of adaptive modulation and coding in WiMAX, the radio resources can be optimally allocated when performing multicast so as to dynamically adjust the number of data layers received by users. In addition to multicast supported by WiMAX, we also design a knowledge propagation and information relay scheme by VANET. Through this relaying technology, about 80% of the mobile stations that were unable to subscribe additional layers of data due to insufficient downlink bandwidth from WiMAX could regain more than 90% of the data in the additional layers within tolerable buffering time.

1. Introduction

Intelligent transportation systems (ITS) integrate advanced electronics, communications, sensing and information technologies to design management strategies for streets, vehicles and people. Intelligent vehicles can be equipped with many kinds of sensors, powerful computing capabilities, sophisticated software systems, and large communication capacities (Chen, 2011; Wang, 2006). Connecting intelligent vehicles with one another and with their driving environment is a growing trend in ITS (Li, Song, Wang, Niehsen, & Zheng, 2005). With the increasing traffic density, a traffic and travel information multicasting system that provides real-time information to drivers can substantially improve road safety and traffic efficiency. In this paper, we combine the video analysis and multimedia networking technologies to present a highly integrated intelligent system that can achieve the above goal.

The system architecture for the proposed advanced traffic and travel information multicasting system is illustrated in Fig. 1. The roadside cameras capture the traffic surveillance videos of major intersections or highway sections and send the videos back to the local traffic service center, which is responsible for analyzing the received surveillance videos to obtain the desired traffic parameters and events. To accomplish the task, the system segments out the foreground objects from the surveillance videos and perform tracking on the objects. Traffic parameters are computed from the statistics of the tracking results, and events are detected either by establishing rule-based reasoning logic or training appropriate recognition models using training data. After the traffic parameters and the events are extracted, the information is multicasted through the wide-range wireless infrastructure. In the work proposed by Liu, Yoo, Jang, Choi, and Hwang (2005), scalable geo-referenced videos and geographic information are transmitted to GPS-guided vehicles. The feasibility of multicasting real-time traffic data to mobile stations is inspired by the work (Liu et al., 2005). In addition to the traffic conditions, the drivers

☆ This work is under the support of Ministry of Economic affairs, Taiwan.
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doi:10.1016/j.eswa.2012.01.184

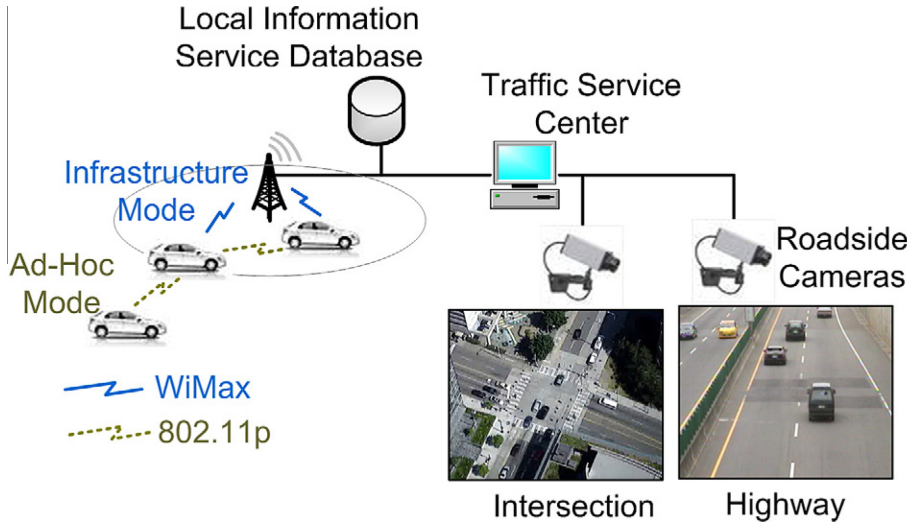

Fig. 1. System architecture.

can also choose to see the real-time streamed traffic surveillance videos of a certain location. Contents of local information services such as places of interest, hotels, restaurants, gas stations or parking lots can also be multicasted through the infrastructure. Under such circumstances, the multicast contents can include both pure text and multimedia data. In order to use the channel efficiently, the multicast contents are arranged into layers, and utility-based resource allocation is applied at WiMAX base station (BS). Users receive a certain number of layers of information according to their needs and real-time channel conditions. Furthermore, a complementary knowledge propagation and information relay mechanism is designed to support users that need more information but with unfavorable channel conditions.

We will review some related works on video processing techniques for traffic applications, as well as some works on vehicle-to-infrastructure and vehicle-to-vehicle communications in the next section. In the literature review, we also discuss the advantages of the proposed schemes over other existing works. Then, we elaborate the proposed traffic parameter extraction and event detection scheme via video analysis in Section 3. In Section 4, we discuss the information multicasting and relay through heterogeneous networks. The experimental results are reported and discussed in Section 5. Finally, conclusions are made in Section 6.

2. Related works

It has been an important topic to extract traffic parameters and report relevant events in real-time in ITS. Traditionally, traffic parameters are obtained via inductive loop or magnetic detectors. However, video-based systems have emerged in recent years (Fernández-Caballero, Gómez, & López-López, 2008; Hu, Tan, Wang, & Maybank, 2004; Kastrinaki, Zervakis, & Kalaitzakis, 2003; Vallejo, Albusac, Jimenez, Gonzalez, & Moreno, 2009). Video-based systems have many advantages over traditional sensing systems. First of all, video-based systems are able to capture a larger variety of information. Also, they are relatively inexpensive and easier to install, operate, and maintain. With massive deployment of surveillance cameras nowadays, there is a growing demand for intelligent systems that can replace human operators and analyze both unidirectional traffic on highways (Beymer, McLauchlan, Coifman, & Malik, 1997) and multi-directional traffic in intersections (Atev, Arumugam, Masoud, Janardan, & Papanikolopoulos, 2005; Kamijo, Matsushita, Ikeuchi, & Sakauchi, 2000; Veeraraghavan, Masoud, & Papanikolopoulos, 2003). Therefore, video processing techniques for traffic applications have received increasing attention of researchers. Video-based event or accident detection (Atev et al., 2005; Fu, Hu, & Tan, 2005; Hu et al., 2004; Kamijo et al., 2000) and traffic parameter extraction schemes (Fathy & Siyal, 1998; Hsu, Liao, Jeng, & Fan, 2004) have been designed based on the foundation of robust video tracking. Various tracking methods for video objects have been investigated. Classical filters such as Kalman Filters (KF) (Beymer et al., 1997; Melo, Naftel, Bernardino, & Santos-Victor, 2006; Veeraraghavan et al., 2003), Extended Kalman Filters (EKF) (Foresti, 1998; Foresti, 1999), and Particle Filters (PF) (Maggio & Cavallaro, 2005; Qu, Schonfeld, & Mohamed, 2007; Zhou, Chellappa, & Moghaddam, 2004) have been largely employed for the tracking purpose. Kalman filters assume linear models and Gaussian noises to obtain optimized closed-form formulation for prediction and update. Although extended Kalman filters and particle filters relax one or both of the assumptions for more flexible models, the main problem of video tracking remains in handling segmentation errors and occlusion. No matter what kind of filters are used, segmentation error and occlusion handling schemes still need to be explicitly designed in order to achieve robust tracking. In this paper, we utilize the measurement candidate selection procedure and a modified Probabilistic Data Association (PDA) approach (Cheng & Hwang, 2007; Cheng & Hwang, 2009) combined with Kalman filtering to perform robust tracking and thus obtain traffic parameters and relevant events accurately.

Traffic conditions, events and travel information can be multicasted through the infrastructure of either full-cover wireless technology such as 3G or WiMAX (Fig. 2(a)) or Dedicated Short Range Communications (DSRC) (Fig. 2(b)). Information can also be exchanged directly among vehicles via vehicular ad hoc networks (VANET). Guo, Ammar, and Zegura (2005) proposed a framework to provide a live video streaming service to drivers through vehicle-to-vehicle (V2V) networks. They used a store-carry-and-forward approach to transmit video data in a partitioned network environment and incorporated a signaling mechanism to continuously trigger video sources to send video data to receivers. Killat and Hartenstein (2007) discussed the design of an accident prevention application (APA) based on vehicular ad hoc networks and addressed how an APA could be designed and formalized with the help of Markov Reward Processes. It would be extremely costly and unnecessary for the deployment of DSRC base station to cover the entire roads in a large area. The VANET can alleviate the extensive DSRC base station deployment and maintenance cost (Fig. 2(b)). However, it is very