# Pedestrian detection for intelligent transportation systems combining AdaBoost algorithm and support vector machine

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### A R T I C L E  I N F O

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### A B S T R A C T

Pedestrians are the vulnerable participants in transportation system when crashes happen. It is important to detect pedestrian efficiently and accurately in many computer vision applications, such as intelligent transportation systems (ITSs) and safety driving assistant systems (SDASs). This paper proposes a two-stage pedestrian detection method based on machine vision. In the first stage, AdaBoost algorithm and cascading method are adopted to segment pedestrian candidates from image. To confirm whether each candidate is pedestrian or not, a second stage is needed to eliminate some false positives. In this stage, a pedestrian recognizing classifier is trained with support vector machine (SVM). The input features used for SVM training are extracted from both the sample gray images and edge images. Finally, the performance of the proposed pedestrian detection method is tested with real-world data. Results show that the performance is better than conventional single-stage classifier, such as AdaBoost based or SVM based classifier.

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## 1. Introduction

Pedestrians are the vulnerable participants among all the objects involved in the transportation system when crashes happen, especially those in motion on streets and roads under urban traffic situations. Therefore, road traffic safety has received much concern by governments and social organizations in China, such as the developments associated with intelligent transportation system (ITS) and safety driving assistant system (SDAS) technologies. The object of these technologies is to enhance comfort and safety of driver and road user (Gandhi & Trivedi, 2007; Vallejo, Albusac, Jimenez, Gonzalez, & Moreno, 2009).

Among the factors that may contribute to traffic accidents, human error is one of the most important factors, such as driver's inattention and wrong decisions. A World Health Organization report described traffic accident as one of the major causes of death and injuries around the world, accounting for an estimated 1.2 million fatalities and 50 million injuries (Peden et al., 2004). Unfortunately, a large majority of such deaths were not vehicle occupants but road users, consisting of pedestrians, bicyclists, two wheelers, and other small vehicles. According to the National Highway Traffic Safety Administration report, there were an estimated 5,811,000 police-reported traffic crashes in 2008 in the United States. Among those accidents, there were 69,000 pedestrians injured and 4,378 pedestrians killed. The pedestrian deaths accounted for 11.7% of the total fatalities. Most pedestrian fatalities occurred in urban areas (72%) under normal weather conditions (89%).

In developing countries such as India, Brazil and China, the problem is much worse. Accidents and the fatalities on road are the result of reciprocity of a number of factors. Road users of those countries, especially in India, are multiplex in nature, ranging from pedestrians, bi-cycles, and tractor trolleys, to various categories of three wheelers, motor cars, buses, trucks, and multi-axle commercial vehicles etc. India has the second largest road network in the world with over 3 million km of roads, 46% of which are paved. As a result, there were 105,725 people killed in road traffic crashes in India in 2006, ranking the top of other countries (Mohan, Tsimhoni, Sivak, & Flannagan, 2009). Pedestrians, bicyclists and motorized two-wheelers riders constitute 60%–80% of all traffic fatalities in India (Mohan, 2002). Fortunately, facing the terrible traffic situation, India government has done something to improve pedestrian safety. A project named "Traffic calming strategies to improve pedestrian safety in India" has been initiated, which is aimed to produce a theoretical and practical background to produce guidelines for India on traffic calming measures.

As for China, the traffic status is not satisfactory, according to the report of China Ministry of Public Security. There were 327,209 road traffic accidents in 2007, resulted in 380,442 people injured and 81,649 people killed. Among those accidents, there were 69,000

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pedestrians injured and 21,106 pedestrians killed. Compared with developed countries, the number of accidents and fatalities is much higher and the traffic problem is much worse. The pedestrian deaths accounted for 25.9% of the total fatalities, compared to 11.4% in the United States in 2007. Therefore, the solutions for China to improve the safety of pedestrian are critical. Commonly, pedestrian safety improvements could be made by using targeted countermeasures based on scientific, system-wide understanding of vehicle surroundings. If there is a possible collision between vehicles and pedestrians, something has to be done to warn the driver. Obviously, drivers receive a good deal of visual information while driving a vehicle (Armingol et al., 2007). In similar way, machine vision plays an important role in enhancing traffic safety and provides plentiful information to the driver. This paper aims to propose a pedestrian protection method based on monocular vision, which can detect potentially dangerous situations involving pedestrians ahead of time. Unlike the conventional methods, two-stage classifiers have been trained to realize pedestrian detection. The features used to train the classifier during each stage are different in view of different strategies.

The reminder of this paper is organized as follows: Section 2 reviews relevant researches related to pedestrian detection problem. Section 3 presents the entire pedestrian detection system in detail, including pedestrian segmentation based on cascaded classifiers trained by AdaBoost and pedestrian recognition using SVM training with multi-features. The experiment results are shown in Section 4. Finally, Section 5 concludes the paper with some possible directions for future work.

## 2. Literature review

Pedestrian safety has received much concern in recent years and considerable researches have been conducted by various groups to enhance the safety and mobility of pedestrians.

Inspired by the fact that human visual system can extract abundant information from the scene in real time, the commonly used sensors for detecting pedestrians are imaging sensors in visible light or infrared radiation images. Papageorgiou and Poggio (2000) described a monocular pedestrian detector based on two degree polynomial SVM. The features used to train the classifier were Haar wavelets that capture significant information of pedestrian. The same architecture was used to realize face and car detection tasks. They stated that it is the first people detection system described in literature, which is purely a pattern classification system and does not rely on motion, tracking, background subtraction, or any assumptions on the scene structure. Mohan, Papageorgiou, and Poggio (2001) located people with four distinct example-based detectors. Those detectors were trained to separately find four components of human body: the head, legs, left arm and right arm. After ensuring that these components were present in the proper geometric configuration, a second example-based classifier was applied to classify a pattern as either a person or not. They performed better results than a full-body person detector designed along similar lines. Sabzmeydani and Mori (2007) built shape-let features selected from low-level features to discriminate between pedestrians and non-pedestrians. Those features were used to train the final pedestrian classifier with AdaBoost algorithm. Dalal and Triggs (2005) proposed the grids of histogram of oriented gradient (HOG) descriptors with a linear SVM classifier. Their results showed that their feature sets significantly outperformed existing feature sets for human detection. Cheng, Zheng, and Qin (2005) proposed a pedestrian representation approach based on Spare Gabor Filters and SVM. Alonso, Llorca, and Sotelo (2007) described a comprehensive combination of feature extraction methods for vision-based pedestrian detection. They used different feature extraction methods for different sub-regions in the image and then combined with a SVM based classifier. Their results showed that combination of feature extraction methods is an essential clue for enhanced detection performance. Szarvas, Sakai, and Ogata (2006) presented a pedestrian detection method based on convolutional neural network (CNN). It could automatically optimize the feature representation to the pedestrian detection task and regularize the neural network. Compared with SVM classifier, they concluded that the accuracy of SVM classifier using the features learnt by CNN is equivalent to the accuracy of CNN. Furthermore, the computational demand of CNN classifier is lower than that of the SVM. Llorca, Sotelo, Parra, Ocaña, and Bergasa (2010) presented an analytical study of the depth estimation error of a stereo vision-based pedestrian detection sensor. Pedestrians were detected by combining a 3D clustering method with SVM classification. Their results indicated that the sensor provides suitable measurements despite its inner accuracy constraints due to the quantization error. In addition to the individual research, there exist several recent remarkable surveys and comparisons on pedestrian detection systems based on vision. For example, Gerónimo, López, Sappa, and Graf (2010) stated the problems arising in the research of pedestrian protection systems, such as the lack of public benchmarks and the difficulty to compare many of the proposed methods. They presented a more convenient strategy to survey the different approaches by dividing the pedestrian detecting problem into different processing steps. Enzweiler and Gavrila (2009) performed an elaborate experimental study of monocular vision based pedestrian detection by comparing the use of various features and classifiers. Their objective is to provide an overview of the current state of the art from both methodological and experimental perspectives. Their results indicated that a clear advantage of HOG/ linSVM at higher image resolutions and lower processing speeds, and a superiority of the wavelet-based AdaBoost cascade approach at lower image resolutions and real-time processing speeds.

Although imaging sensors can provide abundant contents, they can not recover depth information, which is important for pedestrian collision avoidance application. To enhance the advantages of each sensor and overcome its limitations, there is a combination of different kinds of sensors that give complementary information. Bertozzi et al. (2008) introduced a system to detect and classify road obstacles fusing data of a camera, radar, and an inertial sensor. Vision was used to preliminary detect the presence of pedestrians in a specific region of interest. Results were merged with a set of regions of interest provided by a motion stereo technique. They stated that the vision based filtering provides an effective reduction of radar's false positives. Broggi et al. (2009a) triggered a non-reversible system by searching for pedestrians in specific areas with a laser scanner and a camera. As shown in detail in (Broggi, Cerri, Ghidoni, Grisleri, & Gi, 2009b), they focused on a specific urban scenario in which the detection of pedestrian is conducted, Their objective is to protect pedestrians who are hidden by parked vehicle or stopped bus, as well as those crossing the road between two stopped vehicles on the other side of the road. Scheunert, Cramer, Fardi, and Wanielik (2004) combined far infrared camera and laser scanner to obtain robust detection and accurate localization of pedestrians. Kalman filter based data fusion handled the combination of the outputs from laser scanner and far infrared camera. The European Union funded projects PROTECTOR and its successor SAVE-U were focused on reducing accidents involving vulnerable road users with fusion of different kinds of sensors (Michael & Andrzej, 2005). The California partners for advanced transit and highways (PATH) conducted research on transportation safety issues, including pedestrian protection, driver behavior modeling, and intersection collision prevention (Chan, Bu, & Steven, 2006). In their recent report on pedestrian detection, the performance and limitations of various products and technological approaches were investigated.