Obstacle Detection using Heterogeneous Sensors for Intelligent Transportation Systems

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Abstract

The growing interest in Intelligent Transportation Systems (ITS) has motivated many of researchers to develop new technologies, such as Advanced Driver Assistance Systems (ADAS) and Advanced Smart Cruise Control (ASCC). Despite those efforts, various technical challenges still remain to assure the safety of the driver and the pedestrian. In this paper, we introduce several obstacle detection techniques, which are one of the most important aspects to ensure the transportation safety, using camera and LiDAR based on our survey results. We also present our indoor test-bed and platforms, which will be used to evaluate and compare surveyed techniques.

Ⅰ. Introduction

Obstacle detection has always been an important issue in Intelligent Transportation Systems (ITS) since it is closely related to the safety of the driver. For example, drivers might change their lane without checking the blind spot, where neighboring vehicles might be present. Such actions are likely to cause accidents that lead to fatalities. Despite the amount of efforts and resources invested to avoid collisions using various technologies, an incidence of such accidents does not seem to decrease [1]. According to the report from World Health Organization in 2013 [1], 0.62 million victims, which include pedestrians, motorcyclists and cyclists, are caused by the vehicle collisions.

In fact, many researchers are investing much effort to increase the accuracy of obstacle detection systems by employing heterogeneous sensors such as cameras and LiDAR [2], [3]. By accurately detecting the neighboring vehicles in advance, we can alert the driver to avoid the collisions.

The rest of this paper is organized as follows. We first introduce the obstacle detection techniques based on vision features and LiDAR in section Ⅱ. Section Ⅲ presents our indoor test-bed, which provides a risk-free environment to evaluate and compare various obstacle techniques. Section Ⅳ concludes this paper and discusses future work.

Ⅱ. Obstacle Detection Techniques

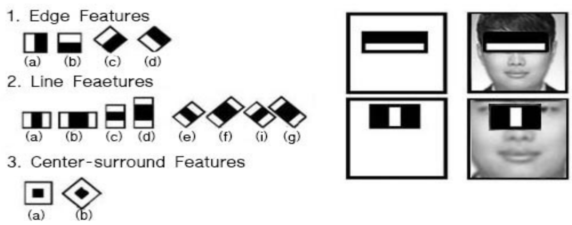
Using heterogeneous sensors for obstacle detection improves the reliability of collision avoidance systems. For example, Zhang et al. [4] proposed the use of LiDAR and camera- based features to achieve great detection accuracies. In this approach, a camera is used to classify the obstacles by extracting the surface and color information of the objects ahead, while LiDAR measures the distance between vehicles and classifies objects using the laser. In this section, we are going to discuss various features that can be extracted by using the camera and LiDAR. These features can be fused in different ways to improve the detection accuracy.

A. Vision-Based Techniques

In order to classify the obstacles, various features are extracted based on the images obtained from a camera. These features include Histograms of Oriented Gradients (HOG) [5], Haar-like [6], Local Binary Pattern (LBP) [7] and edge feature [8].

When classifying the obstacles, such as vehicles and humans, many researchers favor HOG because of its high accuracy. For example, [9] classified walking pedestrians by analyzing their leg motions. Furthermore, Dalal and Tiggs [10] experimentally showed that HOG significantly outperforms the other features when targeted objects are composed of simple silhouette patterns like vehicles and humans.

On the other hand, Haar feature represents the difference of pixel intensities in different regions of captured images. By combining the Haar elementary features shown in Figure 1, one can define the characteristics of target obstacles. For example, Viola and Jones [11] introduced the Haar-like feature combined with AdaBoost algorithm as a classifier for the pedestrian detection, which showed high detection accuracies.



<**Figure 1.** Elementary features of Haar-like>

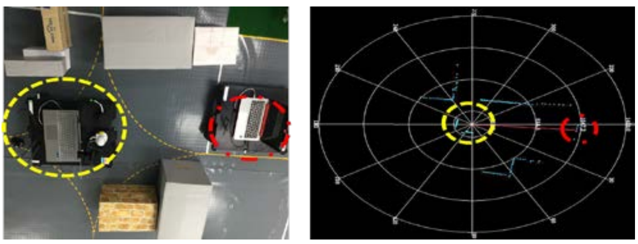
B. LiDAR-Based Techniques

Once camera-based features classify detected obstacles, LiDAR is used to complement the results by providing the distance measurements between objects. For example, Zhang et al. [4] showed that the points of LiDAR on the surface of detected objects could be used to estimate its shapes. In addition, Gong et al. [12] proposed a novel and convenient method to address the extrinsic calibration problem between LiDAR and camera features.

Ⅲ. Experimental Environment

To evaluate the aforementioned techniques, we have constructed the indoor test-bed as shown in Figure 2. Such an environment is designed to provide safe and cost-effective evaluation scenarios compared to the real field deployments. Ultrasonic sensors can detect objects on the roads and measure the distance between the vehicles and its surrounding obstacles within 6m with radiation angle of 50 degree. However, solely relying on the ultrasonic sensors still has many problems, such as limitations of radiation angle and inaccurate values. Due to the reason, we use LiDAR that emits modulated infrared laser signal to improve the accuracy of measured distance. The laser signal is reflected by the object to be detected and performs the localization of vehicles in test-bed via an environmental mapping as shown in Figure 3. Furthermore, the camera processes the stream of images to classify the obstacles on the road. Using the fused data from heterogeneous sensors, we expect to obtain more accurate information to detect obstacles on the road. The information, such as properties of the obstacles and the distance between the obstacle and the vehicle, can be used for enhanced detection mechanism.

<**Figure 2.** Experimental Environment and Platform>



<**Figure 3.** LiDAR operating in Experimental Environment>

Ⅳ. Conclusion & Future Work

In this paper, we surveyed the obstacle detection techniques based on a camera and LiDAR to implement on our test-bed. To process the image obtained from a camera, we will use several features discussed in the previous sections, and also simultaneously use a camera and LiDAR to obtain more accurate information since LiDAR provides the distance rage. We plan to implement our approach described in Section Ⅲ, and also investigate how to integrate Vehicle-to-Anything (V2X) with our obstacle detection approach to improve the accuracy of the detection even further.

ACKNOWLEDGMENT

This research was supported in part by Global Research Laboratory Program (2013K1A1A2A02078326) through NRF and Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No. B0101-15-0557, Resilient Cyber-Physical Systems Research).

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