On-road Obstacle Detection by Comparing Present and Past In-vehicle Camera Images

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Abstract

We propose a method for detecting general obstacles on a road by subtracting present and past in-vehicle camera images. Compared to the existing learning-based methods that could detect only specific obstacles, the proposed method based on image-subtraction could detect any kind of obstacles. To achieve this, the proposed method first realizes a frame-by-frame correspondence between the present and the past in-vehicle camera image sequences, then performs a road surface registration between the corresponded frames. Obstacles are detected by using the di erence of the road surface regions. To demonstrate the e ectiveness of the proposed method, experiments were conducted using several image sequences captured by an actual in-vehicle camera. The experimental results showed that the proposed method could detect general obstacles accurately at a distance enough to safely avoid them.

1 Introduction

Research and commercialization of driving support technologies have become active research topics. We especially focus on a technique to detect forward obstacles from in-vehicle camera images. This technique is essential to realize a collision-warning system that could significantly reduce the number of traffic accidents. Accordingly, a number of technologies to detect forward obstacles have been developed. However, most of them could detect only specific obstacles such as pedestrians and cars. Detecting general obstacles that cannot be learned beforehand is a challenging task because in reality various obstacles exist on a road.

Recently, in-vehicle camera image database[1] is becoming popular. In addition, the speeding up of wireless telecommunications and the growth of storage capacity are remarkable. This would allow a system to collect and store in-vehicle camera images taken in the past, and use the information for driving supports.

In light of the above background, we propose a method for detecting general forward obstacles based on an image subtraction technique between present and past in-vehicle camera images that are captured at the same location.

This paper is organized as follows: Section 2 describes related work. Section 3 details the proposed method. Experimental results are shown and discussed in Section 4. Section 5 summarizes this paper.

2 Related Work

Various techniques for detecting obstacles on the road have been proposed such as [1]. They use various sensors including millimeter-wave radar, stereo or monocular camera, or infra-red camera. Currently, the millimeter-wave radars are installed only on expensive cars, and its spatial resolution is too low to detect a small obstacle. The stereo cameras still have some difficulties regarding their calibration [2] and the detection of point correspondences between images with satisfactory accuracy. The technologies using an infra-red camera are specialized only for pedestrian detection, which assists the visibility in night-time driving.

Researches with a monocular camera have been actively attempted. However, most of them detect only specific obstacles such as pedestrians and cars using an object learning-based method [3][4]. The proposed method also uses a monocular camera, but aims to detect general obstacles by comparing present and past in-vehicle camera images. Thus, there is no need to learn image features of the obstacles beforehand.

The proposed method needs a past in-vehicle camera image sequence including no obstacles that were captured along the road that the vehicle currently runs. There have been some techniques [5] for construction and updating a street image database that contains in-vehicle camera images corresponding to each road on a street map. We could obtain the past in-vehicle camera image sequence from such databases. Meanwhile, methods have been developed to remove obstacles from a street image database [6]. These techniques could be used to synthesize a past in-vehicle camera image sequence with no obstacles.

3 Detection of General Obstacles on a Road

[1] Google Street View, `http://maps.google.com/`

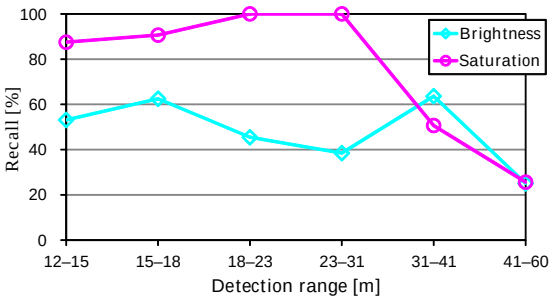

Figure 8. Recall rates of the obstacle detection.

these sequences, another one captured at the same road section including no obstacles was used as the past image sequence.

We evaluated the detection accuracy by the following criterion:

$$\text{Recall rate} = \#\text{ of true-positives} \;/\; \#\text{ of obstacles}\ .$$

Either the brightness image or the saturation image was used for the detection, and the recall rates were calculated with respect to the distance to the obstacles. Here, the thresholds for the detection were determined so that the average number of false-positives per frame should be less than 0.003.

4.2.2 Result and Discussion

The recall rate for each detection range is shown in Fig. 8. The examples of the detected result of distant obstacles are shown in Fig. 9.

Figure 8 indicates that the obstacles closer than 31 m were able to be detected accurately by using the saturation value. In addition, the proposed method could detect small obstacles such as a ball or a pylon at a distance of more than 31 m. The obstacles with low saturation such as a vehicle or a pedestrian were successfully detected by using the brightness value. Therefore, combining these two criteria may improve the detection accuracy.

From Fig. 9, it was confirmed that various distant obstacles could be detected by the proposed method. Especially, Fig. 9(d) demonstrates the remarkable ability of the proposed method. The proposed method successfully detected the ball with a diameter of 20 cm at a distance of 48 m. This means that small obstacles could be detected far enough to be avoided safely even when running at a speed of 60 km/h.

5 Summary

We proposed a method for detecting general obstacles on a road by subtracting present and past in-vehicle camera images. Compared to the existing learning-based methods that could detect only specific obstacles, the proposed method based on image-subtraction could detect any kind of obstacles. To achieve this, the frame by frame correspondences between the present and the past in-vehicle camera image sequences was obtained. Then the road surface registration between the corresponded frames was carried out. Finally, obstacles were detected by using the subtraction of the road surface regions.

To demonstrate the effectiveness of the proposed method, an obstacle detection experiment was carried out by applying the proposed method to several image