Obstacle detection using trinocular stereo cameras without a disparity map

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Abstract**—***We propose an obstacle detection method based on trinocular stereo vision which consist of vertical and horizontal stereo cameras. Vertical edges and horizontal edges are extracted from horizontal stereo images and vertical stereo images. Then the edges are used to generate U-V-disparity maps. A rectangular obstacle has a characteristic that it is represented as a vertical line in V-disparity map and horizontal line in U-disparity map. Therefore an obstacle can be detected by analyzing line shapes in the U-V-disparity maps. Unlike conventional methods, the proposed method does not need to generate a disparity map which requires expensive computational cost. Therefore, the proposed method can operate in real-time.*

Keywords: obstacle detection, stereo vision, U-V-disparity maps, trinocular stereo cameras

1. Introduction

Stereo vision based obstacle detection have been developed in several ways. There are disparity map based methods [1], [2], U-V-disparity maps based method [3] and trinocular stereo based method [4]. Conventional stereo-based obstacle detection methods need an accurate disparity map. However, it is hard to generate an accurate one because of repeating or no texture resulting in matching ambiguities. Also, computational complexity is fairly high in generating an accurate disparity map using refinement techniques. Trinocular stereo based methods may eliminate ambiguity problems discussed above using an additional camera for vertical stereo. However, since trinocular stereo needs two accurate dispatity maps, those methods need higher computational complexity than conventional stereo cameras. Therefore, conventional stereo based or trinocular based obstacle detection method is difficult to implement for in real-time applications.

We propose simple obstacle detection method using trinocular stereo cameras. The trinocular stereo cameras consist of vertical pair of stereo cameras and horizontal pair of stereo cameras. Vertical edges are extracted from the horizontal pair and horizontal edges are extracted from the vertical pair. U-disparity and V-disparity maps are generated by the edge information. An obstacle is detected by analyzing U-V-disparity maps. The proposed method does not need to generate an ordinary 2D disparity map. Thus the proposed method can operate in real-time.

2. Proposed method

2.1 Trinocular Stereo cameras

The trinocular stereo cameras used in our system consist of three cameras: top, left and bottom cameras. The top and the bottom right becomes a vertical pair while the left and the bottom one become the pair for horizontal stereo as illustrated in Fig. 1.

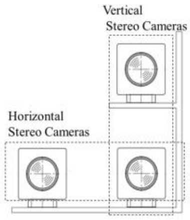


Figure 1. Trinocular stereo cameras.

The horizontal pair captures left two images Fig. 2(a) and (b), while the top camera captures an image Fig. 2(c).

Figure 2. Images captured by trinocular stereo cameras.

2.2 U-V-disaprity maps from trinocular stereo cameras

In the proposed method, U-V-disparity maps are generated using edge images. Noisy edges may cause wrong information about obstacles in U-V disparity maps. Gaussian filter to make image blurred and hairy edges are removed before generating U-V-disparity maps. Edges are extracted by Sobel edge operator. Vertical edges are extracted from a left-bottom image and a right-bottom image, and horizontal edges are extracted from the top and the bottom image. The edge images are used to generate U-V-disparity maps. Conventional obstacle detection methods using U-V-disparity maps need a whole disparity map. However, getting an accurate disparity map from a stereo camera is not only hard but requires expensive computational cost. We use edge images to generate U-V-disparity maps that do not need expensive computational cost. Thus the proposed method can operate in real-time. V-

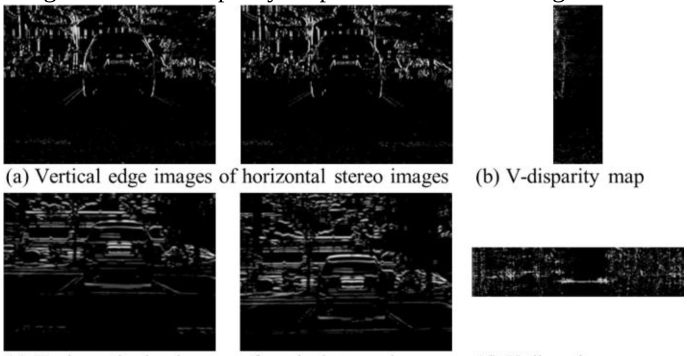
“This paper is being submitted as a poster for IPCV” disparity map is generated by calculating the row correlation of horizontal stereo image pair. The row correlation is computed as:

$$V_{disp}(d)=\sum_{d=0}^{Maxdisp} Row_r(d)Row_l(x+d). \tag{1}$$

where Row_r and Row_l are row indices of right and left images, respectively, and d is a disparity value. V-disparity map is generated by applying this equation to all rows. Similarly, U-disparity map is also generated by column correlation operation to whole columns of vertical stereo image pair, and the column correlation is computed as:

$$U_{disp}(d)=\sum_{d=0}^{Maxdisp} Col_t(d)Col_b(y+d). \tag{2}$$

where Col_t and Col_b are column indices of top and bottom images, respectively, and d is a disparity value. The edge images and U-V-disparity maps are illustrated in Fig. 3.



(a) Vertical edge images of horizontal stereo images (b) V-disparity map

(c) Horizontal edge images of vertical stereo images (d) U-disparity map

Figure 3. Edge Images and U-V-disparity maps of Fig. 2.

2.3 Obstacle Detection

As illustrated in Fig. 4, when an obstacle with height(h) and width(w) is found in an image, the vertical and horizontal edges of obstacle is contributes to form a vertical line at the same height in V-disparity map, and horizontal line at the same width in U- disparity map, respectively. Hough transform is used to extract the position of the line in Zhencheng [3]. Instead of the Hough transform, simple analysis of the horizontal and vertical projections of each disparity map allows to detect the rectangular object in an image as an obstacle.

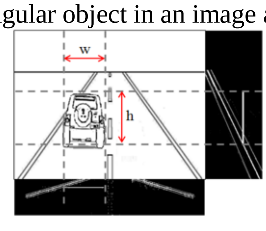
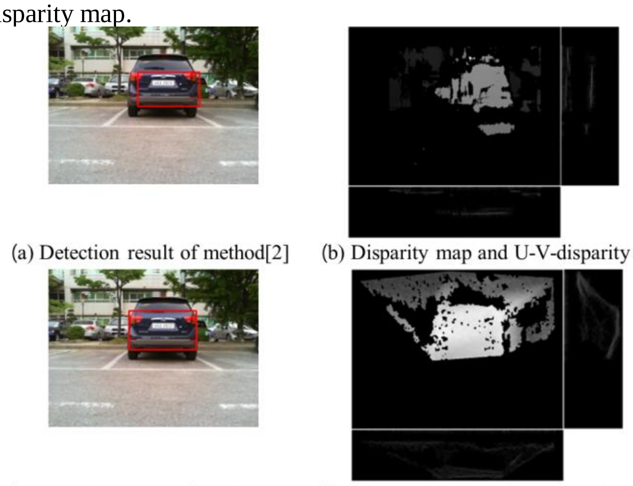


Figure 4. Analyzing U-V-disparity maps.

3. Experimental result

The experiments were conducted with images whose resolution is 320x240, captured by trinocular stereo cameras. We tested on an Intel Core2Quad 2.4Ghz personal computer, and compared the performance with conventional methods using disparity map. Fig. 5(a) represents the result of Konolige's method [1]. The method operates in real-time. However, the result is not accurate enough for detecting vehicles. Fig. 5(b) represents the result of Geiger's method [2] which was more accurate but took 58ms to generate the disparity map.



(a) Detection result of method[2] (b) Disparity map and U-V-disparity

(c) Detection result of method[3] (d) Disparity map and U-V-disparity

Figure 5. Results of conventional methods.

Figure 6. Detection result of Fig. 2.

The result of our proposed method is shown in Fig. 6. Our method detected an object more accurately and took only 32ms - much faster than conventional methods.

4. Conclusion

We proposed an obstacle detection method using horizontal and vertical stereo cameras. Vertical and horizontal edge images from the trinocular stereo cameras are used to generate U-V-disparity maps. An obstacle can be detected more accurately and faster by analyzing the U-V-disparity maps. Since the proposed method does not need the whole disparity map that requires heavy computation, it can be a good candidate for real time application for detecting obstacles in real-time on the road.

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