The DLI-Based Image Processing Algorithm for Preceding Vehicle Detection

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Abstract: This paper proposes an image processing algorithm for detecting obstacles on road-lane using DLI(disparity of lane-related information) that is generated by stereo images acquired from dual cameras mounted on a moving vehicle. The DLI is a disparity that is acquired using single lane information from road lane detection. For the purpose to reduce processing time, we use small blocks obtained by edge-histogram based blocking logic. This algorithm detects moving objects such as preceding vehicles and obstacles. The proposed algorithm has been implemented in a personal computer with the road image data of a typical highway. We successfully performed experiments under a wide variety of road conditions without changing parameter values or adding human intervention. Experimental results also showed that the proposed DLI is quite successful.

Keywords: DLI(disparity of lane-related information), obstacle detection, stereo matching, image processing

1. INTRODUCTION

Recently, a large amount of work on the image processing of road traffic scene has been done for intelligent safety vehicle(ISV), which is aiming at improving a vehicle's safety and may even provide for autonomous navigation. This paper proposes an image processing algorithm capable of recognizing obstacles by using a DLI(disparity of lane-related information).

The proposed algorithm is based on stereo the image processing. The DLI is a disparity that is acquired using a single lane boundary information from road-lane detection. The texture segmentation algorithm uses small blocks obtained by edge-histogram based blocking logic to reduce processing time. This algorithm detects moving objects such as preceding vehicles and obstacles.

The proposed algorithm has been implemented in real time on video data obtained from a test vehicle driven on a typical highway.

2. ALGORITHM OUTLINE

This paper presents a stereo algorithm that we have developed as part of an obstacle detection system that detects moving vehicles on the highway.

An algorithm in this paper is based on the following two assumptions about road lane boundaries and obstacles. One is that there are no abrupt changes in the direction and location of road lanes and obstacles. The other is that the intensity of road lane boundaries and obstacles differs from that of the background.

The proposed algorithm is organized as shown in Figure 1. First, road-lane detection was performed for input frame. We use a cumulative distributed function(CDF), which accumulates the edge magnitude along the edge orientation of the input image[1]. Second, the DLI was constructed by stereo processing. When we carefully look at the shape of the DLI we can decide whether obstacle is existence or not. Third, the searching window was selected for on-road obstacle detection. It is selected by the DLI graph. Fourth, the block window was constructed by blocking logic. Fifth, the texture extraction is performed for segmentation of the isolated obstacles.

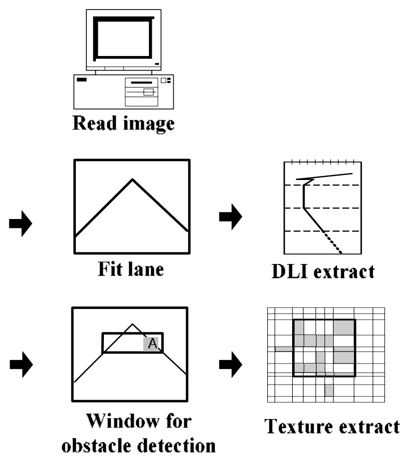


Fig. 1 Organization of the algorithm.

3. DLI

Stereo image processing uses two images taken simultaneously from a pair of cameras whose optical axes are parallel. For each pixel in the left image, a corresponding pixel is searched for in the right image. The disparity in location of the pixel in the two images is then used to triangulate the distance of the underlying point in space from the camera pair. The disparity of stereo images is usually obtained by using all pixel information of left and right images. But in this paper, it is obtained by using some pixel information of single lane boundary from road lane detection. The DLI means disparity of the lane related information. The DLI has the advantage of saving memory space and computation times, because the DLI uses some pixel information of the selected lane boundary, which is either of the extracted left lane marks or right lane marks. The DLI has characteristic that the obstacle such as preceding vehicles has large magnitude of the edge in road image. The DLI, which uses this characteristic, can analogize the position of obstacles and detect the existence of obstacles.

Figure 2 shows creation of the basis window for the DLI. In Figure 2, the line with a dot means the lane mark of the right image of stereo images. In Figure 2, the straight line means the lane mark of the left image of stereo images. The window for the DLI is created to focus on the right lane mark in the left image of stereo images.

The size of the basis window is 30×4 pixels. And the stereo matching is implemented to focus on the right lane mark in the left one of the stereo images. In Figure 2, for detecting the same region of the straight lane region and the line region with a dot, the basis window is shifted to the left.

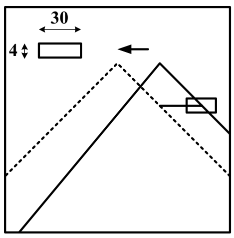


Fig. 2 DLI algorithm.

The equation (1) is the absolute distance (city block distance) that is used to compare the magnitude of edge in the left image and right one of stereo images.

$$C_n = \sum | L_i - R_{ni} | \quad (1)$$

The C_n means the absolute distance of the n-th window. If the left one of stereo images is set a standard, L_i means the magnitude of the edge in the i-th pixel of the basis window in the left one of stereo images. The R_{ni} means the magnitude of the edge in the i-th pixel of the n-th window in the right one of stereo images.

$$DLI = MIN(C_n), \ (1 \le n \le m) \quad (2)$$

The equation (2) represents the DLI. The DLI was divided into four regions as shown in Figure 3. In the DLI graph, the horizontal axis represents the DLI that is obtained by equation (2) and the vertical axis represents the row pixel of the input image. The DLI has four regions that are vanishing point region, obstacle region, road-lane region and occlusion region. If the objects are at near distance, the disparity has lager magnitude.

The region (a) is close to the vanishing point region. In the region, the DLI can not obtain an accurate and confidence magnitude of the edge. This paper does not handle region (a) because this region has no effect in proposed algorithm.

The region (b) is the obstacle region. In this region, the DLI maintains same magnitude. This means there are obstacles such as preceding vehicle in the lane. If there is the preceding vehicle within the lane, in the input image, this preceding vehicle appears to focus on the rear. The distance of between the vehicle and the rear of the preceding vehicle is the same. If there is the preceding vehicle, the magnitude of the edge in this place is larger than any other region. So the DLI is obtained by the disparity of this place.

The region (c) is the lane region. In this region, the DLI is increased as a regular ratio. The disparity of the lane, which is near the vehicle, is large. And the disparity of the lane, which is far from the vehicle, is small.

The region (d) is the occlusion region of stereo images. In the region, the DLI can not know an accurate magnitude.

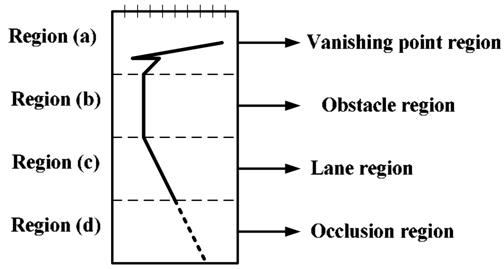
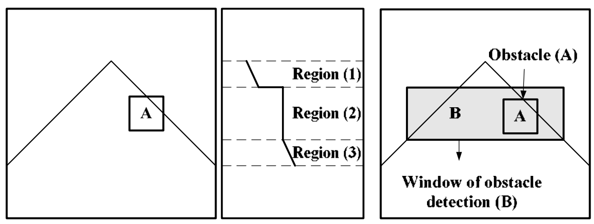


Fig. 3 Division of the DLI graph.

4. OBSTACLE DETECION

As a result of the DLI, obstacle region is identified. It is then necessary to perform obstacle segmentation. Obstacle segmentation can be regarded as a procedure to cluster similarly connected small block windows in a graph built by the DLI



(a) (b) (c)

Fig. 4 Selection of the searching window for the obstacle detection.

In Figure 4 (a), the rectangle denoted by “A” represents an obstacle in the traveling lane. Figure 4 (b) was formed by DLI of input images. The shadow rectangle denoted by “B” of Figure 4 (c) is the selected window for the obstacle detection. It is selected by region (2) of the DLI graph in Figure 4 (b). The reason why the region (2) is selected as the searching window for obstacle detection is the region (2) has a constant disparity value that correlates with an obstacle.

As shown in Figure 4, it can be supposed that the region (2) of DLI corresponds to the obstacle in a road lane. In order to recognize obstacle we need to construct a block window as shown in Figure 5. For this work, we use edge information defined by the gradient of an intensity function. The vertical and horizontal gradients are calculated as follows:

$$G_x = |\ (a_{13} + 2a_{23} + a_{33}) - (a_{11} + 2a_{21} + a_{31})\ | \tag{3}$$
$$G_y = |\ (a_{11} + 2a_{12} + a_{13}) - (a_{31} + 2a_{32} + a_{33})\ | .$$

Figure 5 shows construction of the block window for obstacle recognition. X and Y represent the number of vertical and horizontal pixels of the searching window, respectively. N is regular interval of X and Y. In Figure 5, small blocks obtained by edge-histogram based blocking logic. It is defined as follows:

$$C_v = MAX\left(\sum_{j=1}^{N} His_{Gx}(j)\right) \tag{4}$$
$$C_h = MAX\left(\sum_{i=1}^{N} His_{Gy}(i)\right),$$

where His_{Gx} and His_{Gy} are the histogram of vertical axis and horizontal axis.

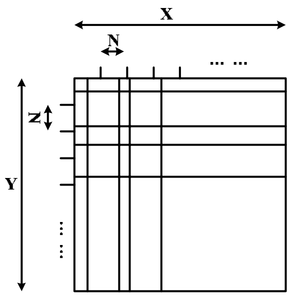


Fig. 5 Construction of the block window for obstacle segmentation.

We constructed ξ by collecting small blocks with the estimated texture for the obstacle detection as follows:

$$\xi = \begin{cases} 1, & if\ T_b > T_w \times Weight \\ 0, & otherwise \end{cases}, \tag{5}$$

where T_w is the mean value of the G_y in the searching window, and T_b is the mean value of the G_y in the block window.

As shown in Figure 6, the colored block windows show result of extracting texture for the obstacle segmentation.

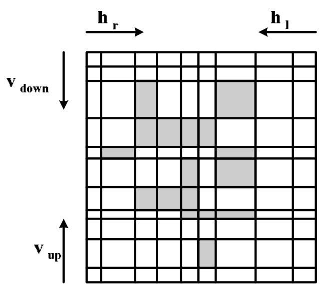


Fig. 6 Extraction of the texture for obstacle segmentation.

5. CONCLUSION

In this paper, we have presented an efficient method for obstacle detection on road-lane which consists of DLI. The points of our method are the utilization of disparity map generated by stereo matching. The proposed algorithm in this paper has been implemented in C++ on a commercial Pentium Ⅳ 1.4 GHz running under windows XP. The following illustrates the test results performed on highways. The whole process for detecting obstacle points and segmentation of isolated obstacles is performed. The results show that the proposed approach is quite practical and useful.

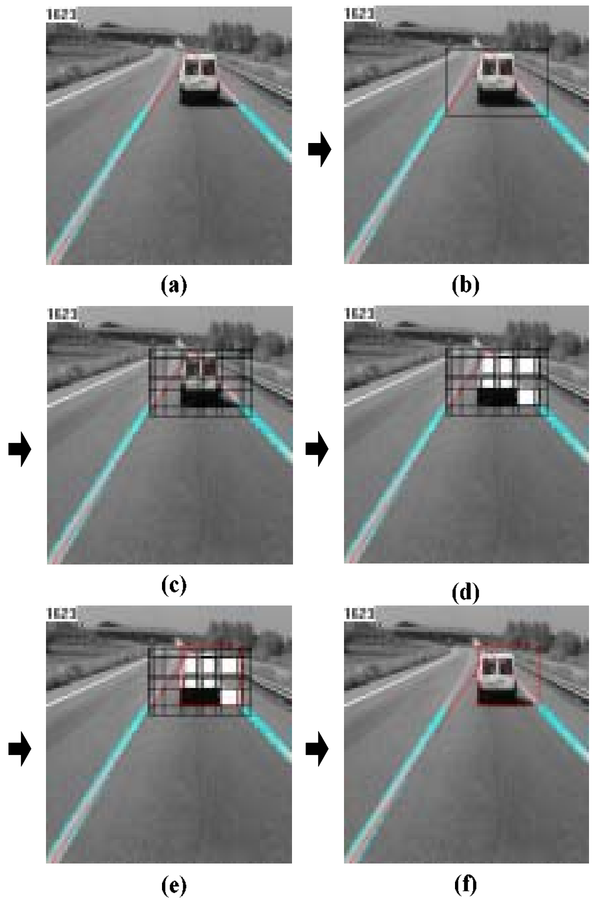


Fig. 7 Preceding vehicle detection based on DLI.

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