

Reliable Estimation of Disparity Map in Textureless Region of Roadway

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Abstract— This study proposes a reliable disparity estimation method that plays an important role in stereo vision. Most of conventional disparity estimation algorithms have a critical weakness. They may generate erroneous results in monotonous or textureless areas such as roadways and hallways. To improve the reliability of estimated disparity in such areas, we select a textureless road area as a region of interest (ROI) and generate a synthetic disparity map which can be modelled by a simple gray-scaled gradation pattern according to the depth. Finally, we combine the conventional and synthetic disparity maps to generate a more reliable disparity map. Simulation results show that the disparity map constructed from the proposed algorithm is more reasonable and trustworthy.

Keywords— Stereo camera, Disparity estimation, Textureless region, Block Matching.

I. INTRODUCTION

Disparity has become very useful as stereo cameras are now employed in various applications such as the advanced driver assistance system (ADAS). A lot of disparity estimation methods are being actively studied [1, 2]. These methods can be divided into two major categories: local and global methods.

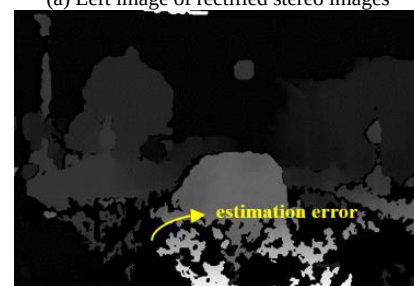
In general, global methods, which include graph cuts, dynamic programming, and belief propagation, usually show better performance than local ones. However, global methods have difficulty with real-time applications because of their high computational complexity. Therefore, local methods such as block matching and semi-global block matching (SGBM) are widely used in practical applications. However, the critical weakness of these methods is that the estimated disparity becomes unreliable in monotonous regions because these methods are based on correlations between texture parts. This problem can be easily identified in Figure 1. For convenience, we regard the left image as a reference and the stereo images are well rectified.

In fact, these problems have been previously discussed in many studies. And the majority of these studies has focused on correlation techniques to select an appropriate window size or window shape [3, 4]. However, the interest of this paper is not in stereo matching algorithms which is based on correlation. We present a new estimation method that is suitable for the textureless roadway environment. We use two disparity maps selectively. One is an ordinary disparity map by conventional method using fixed window size, and the other is a synthetic

disparity map by proposed method. Finally, we propose an algorithm to combine the two disparity maps and to generate a new trustworthy disparity map.



(a) Left image of rectified stereo images



(b) Disparity map using SGBM method

Figure 1. Estimation error in monotonous regions.

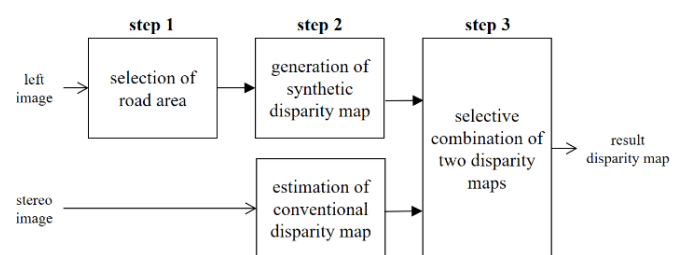


Figure 2. Block diagram of proposed disparity estimation method.

II. PROPOSED DISPARITY ESTIMATION METHOD

A block diagram of the proposed disparity estimation method is shown in Figure 2. The entire process consists of three steps. The first step is to select a region of interest (ROI) in the left image from which we extract straight lines in advance. In the second step, we generate both conventional and synthetic disparity maps. Finally, we selectively combine the two

disparity maps. The output of the entire process is also a disparity map that has a reliable disparity value inside the ROI.

In general, there is no pattern except the lane in a roadway. The road area in a captured image is even more monotonous due to the camera lens blur effect. We define this area as the ROI. To determine the ROI, we use lane detection algorithm (LDA). Many LDAs have been studied [5], and, the Hough transform and RANSAC are commonly used for fitting line. The LDA detects the various types of lane boundaries such as painted lane marks, road edges, concrete barriers, and guardrails. However, we do not have to extract all lane boundaries. Because the entire road area is ROI, we use only the two outermost lane boundaries to select ROI. Then, we can assume that the intersection of the two lines is a vanishing point. Based on this, we can finally select the ROI from the inner part of the two lanes below the vanishing point. A ROI is shown in Figure 3.

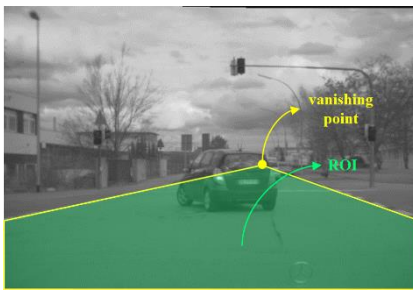


Figure 3. The ROI selected from the left image.

In this paper, two types of disparity maps are used. One is the conventional disparity map by SGBM method with a fixed window size. For convenience, we call this SGBM disparity map 'disp_map1'. Because the disp_map1 is based on the correlation between the left and right images, if the distinct features does not exist such as a road area, the reliability of the disparity value cannot be guaranteed as shown in Figure 1(b). Therefore, in order to improve the reliability of disparity values in the textureless area of the ROI, another disparity map is required. We generate a synthetic disparity map that looks like gray-scale gradation pattern. If we know disparity range related to the baseline of stereo camera, synthetic disparity map can be modelled by filling the ROI with linear gradation values in vertical direction. We call the synthetic disparity map, for convenience, 'disp_map2'. The disp_map2 can be obtained by (1)

$$disp_map2(x, y) = \frac{disparity\ range}{vertical\ range} \times (y - vp.y) \quad (1)$$

where *vertical range* is distance from the vanishing point to bottom line of the image. And *vp.y* is vertical position of the vanishing point. In addition, we equally apply the post-processing methods of disp_map1 such as blurring to minimize the heterogeneities when combining the two disparity maps. As shown in Figure 4, disp_map2 has more reliable disparity values than disp_map1 in the textureless area.

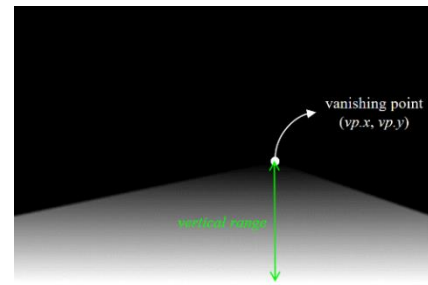


Figure 4. The synthetic disparity map.

The two disparity maps both have partially reliable disparity values in the flat ROI. On the other hand the disp_map1 has reliable disparity values on the object, the disp_map2 has more reliable disparity values than disp_map1 on the non-object area. Therefore, if the two disparity maps are combined selectively, a new dense disparity map can be generated. The key concept of the combination algorithm is to distinguish the object and non-object so we should select either the disparity value of disp_map1 or disp_map2 for each pixel. In our approach, the sum absolute difference (SAD) between disp_map1 and disp_map2 defined in (2) is calculated within a 3×3 pixels window as shown in Figure 5.

$$diff_{1,2} = \begin{cases} 0, & \text{if } disp_map1(i, j) = 0 \\ \sum_{(i,j) \in window} |disp_map1(i, j) - disp_map2(i, j)|, & \text{otherwise} \end{cases} \quad (2)$$

Here, the pixel in which disparity value of disp_map1 is zero should not be considered because the disparity value of the vanishing point is assumed to be zero in (1).

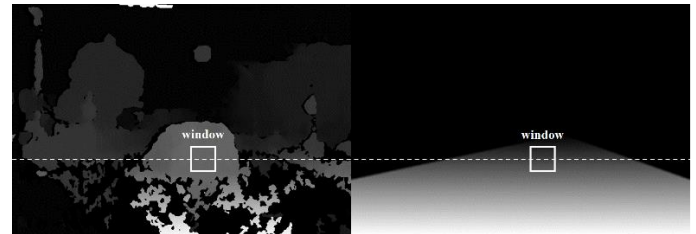


Figure 5. The SAD window between disp_map1 and disp_map2.

The SAD value of the object is greater than the non-object if the disp_map2 is modelled well. Therefore, the object and the non-object are distinguished and the final disparity map can be obtained by (3)

$$disp_final(x, y) = \begin{cases} disp_map1(x, y), & \text{if } diff_{1,2} > th \\ disp_map2(x, y), & \text{otherwise} \end{cases} \quad (3)$$

Figure 6 show the pattern map of the combined result. The yellow points represent the part assigned from disp_map1 and the dark green points represent the part assigned from disp_map2.



Figure 6. The pattern map of the synthesized result.

III. EXPERIMENTAL RESULTS

We used the Open CV library to implement our proposed algorithm. All images used in the simulation were provided by Daimler AG's Stereo Sequences taken using a calibrated stereo camera in a driving car [6]. The size of the pair of rectified stereo images was 640 x 480 (VGA resolution). The experimental results are shown in Figure 7. As shown in Figure 7, the proposed method can provide a reliable disparity map in the textureless region compared with Figure 1(b). Even though the non-object area is improved, the disparity values inside the object are well maintained.

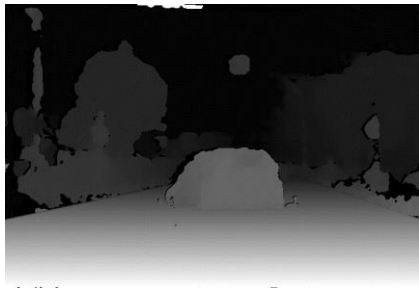


Figure 7. Experimental result by the proposed method.

Additionally, in order to demonstrate the validity of the result, from right image, we reconstructed the compensated left image by disparity map. As shown in the yellow circles of Figure 8, the compensated left image generated by the proposed method is more similar with original left image shown in Figure 1(a).



(a) Compensated left image by disp_map1



(b) Compensated left image by disp_final

Figure 8. Comparison of two compensated left images.

IV. CONCLUSIONS

In this paper, we proposed a combination algorithm to improve the reliability of a conventional disparity map, especially in monotonous regions. After a ROI is selected, a synthetic disparity map that looks like a gray-scale gradation pattern is generated. The key idea of the combination algorithm is to distinguish the object and the non-object in the ROI and to assign the conventional disparity value to the object and the synthetic disparity value to the non-object. The experimental results verified that the proposed algorithm could successfully improve the accuracy of the disparity in the textureless region while maintaining the original disparity of the object unchanged.

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