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# Distortion Correction for Corresponding Points Estimation Using General-Purpose Camera

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**Abstract:** In order to use the general-purpose camera for stereo vision, the correction for distortion is needed. In this study, a new technology to achieve the distortion correction is proposed. The proposed method is based on block matching method. In the proposed method, global and local estimations for two reference images are carried out and two vector maps which are used for estimating corresponding points are obtained. In this study, a new correction technology to need for acquisition depth information using the general-purpose camera is suggested. This is an extended research of the previous research. The proposed technique firstly obtains the vector map based on the block matching technology for solving the lens distortion and the distortion correction is achieved using the vector map. The proposed method is useful for simplified 3D information extraction than precise processing.

**Key words:** Stereo vision, disparity, block matching, distortion correction, depth image, vector

## INTRODUCTION

Stereo vision is widely used in various fields. Along with development of unmanned vehicle system recently, various sensors are used for detecting the existence of objects and obstacles in front of a vehicle. Especially, the image processing technology is being used widely for application of stereo vision (Furukawa and Ponce, 2010; Hiep *et al*., 2009). In applications of stereo vision technology, some fields such as face recognition require very accurate 3D shape information. A camera system with high performance is necessary to obtain accurate 3D shape information but it is very expensive. Meanwhile, there are also many application fields that require rough depth information, not precise information. For example, access sensing of entrance and exit and obstacle detection of unmanned ground vehicle are included in such application fields. This study aims to the latter, rough applications. In the stereo vision system, accurate calibration is very important. It's because the calibration result determines the relationship between 3D normal coordinate and 2D image coordinate. The ideal pinhole camera model leads to imaging of world lines as lines on the image plane (Hartley and Zisserman, 2000). However, most of real cameras have nonlinearities owing to lens distortion. The distortion parameters should be estimated for each camera (Unal *et al*., 2007). Many calibration techniques have been studied for minimizing several distortions. A popular method is a plumb line method (Devernay and Faugeras, 2001; Melegy and Farag, 2003). This mainly depends on optimization procedure for curved lines obtained from 3D line segments. Other techniques rely on point correspondences which are use epipolar and trilinear constraints (Fitzgibbon, 2001; Sawhney and Kumar, 1997). Another calibration method relies on 2D reference patterns. Tsai (1987) obtain images of flat board with check patterns from a different viewpoint. The calibration process is somewhat complicated and time-consuming. Li *et al*. (2013) improved this process and introduced fast and automated calibration methods. Also, Zhao *et al*. (2015) used the phase matching and bundle adjustment algorithm.

In this study, a new correction technology to need for acquisition depth information using the general- purpose camera is suggested. This is an extended research of the previous study (Dalmiya and Dharun, 2015). The proposed technique firstly obtains the vector map based on the block matching technology for solving the lens distortion and the distortion correction is achieved using the vector map.

## MATERIALS AND METHODS

### Block matching-based distortion correction

**Stereo vision and depth detection:** Triangles, $\Delta u_1 = O_1 o_1$ and $\Delta O_2 Sx$ have the same trigonometric ratio. The depth value from such triangles can be obtained as follows. In other words (Fig. 1):

$$Z = \frac{2hf}{u_2 - u_1} = \frac{bf}{u_2 - u_1} = \frac{bf}{D} \quad (1)$$

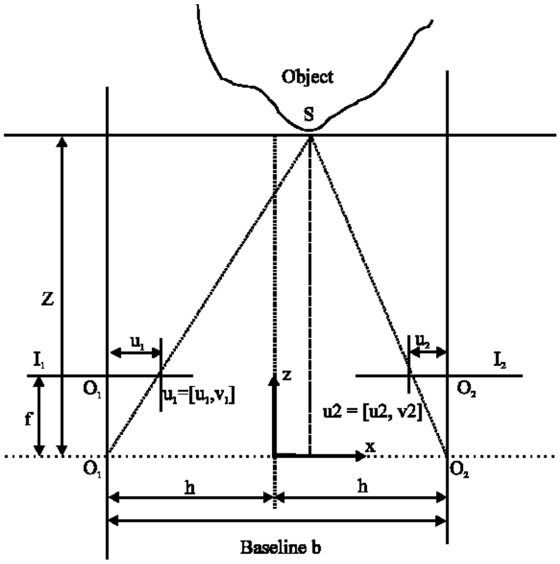



Fig. 1: Stereo vision coordinates

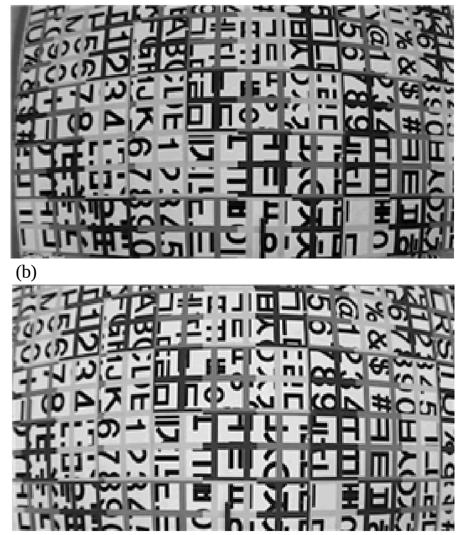
The other parameters of 3D space can be obtained as follows:

$$x = \frac{-b(u_1+u_2)}{zD},\ y\frac{bv}{D} \quad (2)$$

In Eq. 1, D = df/Z is called disparity. The distance to the object, depth is inversely proportional to disparity D. Also, disparity is directly proportional to baseline b in other words, the distance between the centers of two lenses. Therefore, the accuracy becomes higher as the baseline increases for determining the disparity. Unfortunately as the distance between cameras increases, the difference between two images becomes greater. In this case, some objects shown in one camera may be not seen in an image taken by the other camera. Also, the image is enlarged as the focal distance increases, so, the disparity is proportional to the focal distance f. Obtaining the depth which is the distance from the image plane to the object in 3D stereo is an important purpose and such value is obtained through Eq. 1. Also, it shows that it is possible to obtain this value by obtaining the disparity D. The vector map for correction of left and right stereo images is obtained using the reference images and these are used to correct input images. The most part of camera distortion can be solved through this procedure. This method is somewhat insufficient for obtaining a very precise result but it is enough for obtaining main characteristics only.

**Reference images for distortion correction:** The lens used in general-purpose camera is 45° generally but in this experiment, a lens with 90° or higher is used. Therefore, a higher distortion appears. Such distortion occurs when light is refracted through the lens and it is called barrel distortion. In barrel distortion an image appears to be bent outwards. Therefore when the same grid is placed and captured with a camera, the size of grid on the middle appears to be largest. Such barrel distortion is one of significant problems when applying the stereo vision technology. Therefore, it is necessary to correct the distortion using an appropriate method. The methods using the pattern of grid structure are being widely used for the distortion correction but the calculation process of such methods is complicated. In this study, it is intended to introduce the technology to correct distortion based on the block-matching algorithm which is widely used for motion estimation. In case of a pattern with repetitive grid structures, there is a difficulty in obtaining the best optimal value due to the repetition of the same pattern. Therefore, the following reference images are used in this study. In other words, in Fig. 2a, b are left and right images and these images are obtained from an object produced using various letters and line patterns by using two cameras.

(a)



(b)

Fig. 2: Reference images: a) Image-upper and b) Image-down, respectively)

**The flow of the proposed algorithm:** The flow diagram of algorithm suggested in this study is shown in Fig. 3. The algorithm can be divided into two parts including Part a and b and Part-A is the step to create vector map for distortion correction and Part-B is the step to detect an actual object or measure the depth. Each step can be explained as follows.

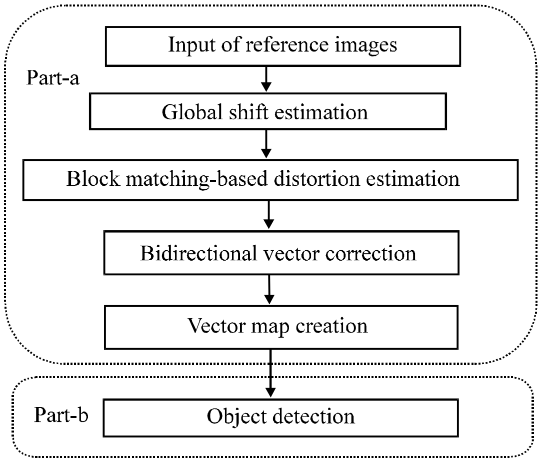



Fig. 3: Flow diagram of the proposed algorithm

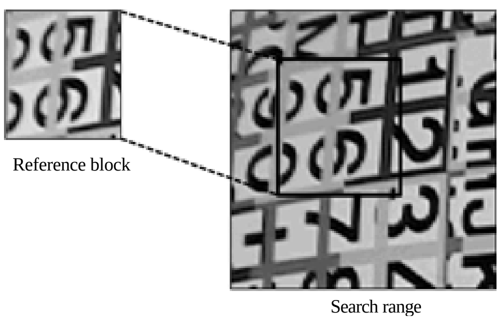



Fig. 4: Application of block matching algorithm

**Explanation of each step**

**Global shift estimation:** In case the baseline or epipolar line of two cameras is not aligned correctly, it is corrected in this step. For this, an image is regarded as one single block and the process to correct it to the position with the minimum error is carried out.

**Block matching-based distortion estimation:** In this step, the level of distortion between the left and right images is calculated and as a result, the vector map is obtained. The block matching technology has been used frequently for motion compensation when carrying out video compression in MPEG. It is intended to use such block matching technology in this study. In Fig. 4, a small image on the left indicates 8×8 block and an image on the right indicates an image in the search range to find the block which matches with the relevant block most. In Fig. 4, the reference block on the left indicates the block to estimate the distortion level and the search range on the right indicates the image in the search range of the corresponding image. The position where the block with the minimum error between two blocks appears while moving by pixel unit in the search range is the matching

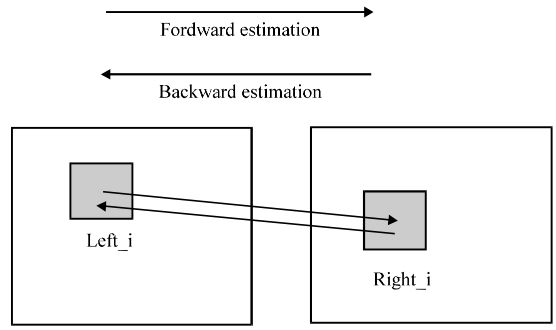



Fig. 5: Bidirectional block matching

position. The result value obtained at this time is displayed as a vector including moving distance and direction. It is necessary to set the search range properly according to the distortion level. In this step, the bi-directional vector map for the left and rig ht images is obtained. This is necessary for vector correction which will be carried out next.

**Bidirectional vector:** In generally the block matching algorithm is applied to one direction forward or backward to estimate motion of each block. Unfortunately, a few blocks may have mismatched results in estimation. In case the vector map obtained from the previous step, sometimes wrong vectors are obtained due to local minimum error in case of some blocks. In such case, the vector is corrected by back projection method (Fig. 5).

**Object detection:** The vector map obtained from the previous step is used for measuring the depth or detecting an object. This is the step to obtain disparity. There are various methods for detecting disparity from a stereo image such as pixel unit, block unit and area unit but in this study, it is detected in block unit. At this time, the size of block to be used is 8×8.

## RESULTS AND DISCUSSION

**Block matching-based distortion:** The size of block used for block matching is 16×16. Figure 6 shows the obtained block matching in a vector form. In other words, the positions of blocks matching with the time of each block were connected with a line. It is possible to find out the size and direction. As shown in the figure, the correction value for barrel distortion becomes larger outwards in comparison to the middle part. Also, the radial direction is shown.

**Object detection:** Based on the distortion correction information obtained through the reference image, the experiment to detect an object with actual depth was carried out. Figure 7a, b show left and right images when

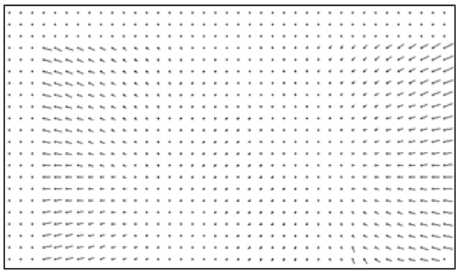


Fig. 6: Vector map


Fig. 7: Detected results: a) Left input image; b) Right input image; c) Changed blocks and d) Detected object blocks

the person stands on the side. A part shown in darker gray in Fig. 7c indicates the change area. Figure 7d shows the final result of detecting parts with depth from the change area.

## CONCLUSION

In this study, a new correction method based on the block matching technology was proposed in order to solve the lens distortion owing to using general-purpose cameras for stereo matching. Based on two reference images, the vector map was generated and the depth information was extracted. The proposed method is useful for simplified 3D information extraction than precise processing.

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