DISTANCE MEASUREMENT WITH A STEREO CAMERA

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DISTANCE MEASUREMENT WITH A STEREO CAMERA

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Abstract-- A research on measuring the distance of an object from an observer using a stereo camera has been carried out. The stages involved include camera calibration, image rectifying, disparity calculation, and three dimensional reconstruction. Distance of an object is determined using the central point of an object in a segemented bounding box. This distance is measured using the Euclidian distance measurement method to figure out the shortest distance from the center of the bounding box to both cameras. Results show that objects located 3 to 6 meters away are properly measured for their distances, with an average error of 4%.

Keywords: object measurement, stereo camera,rectifying, disparity, euclidian distance.

I. INTRODUCTION

Object distance measurement against certain references, such as an observer, is of great necessity, especially in the fields of monitoring and security, industry, navigation, robotics, and even for many applications in smart vehicles [1]. In general, there are two ways of object distance measurement: active and passive. Active measurement means that distance to an object is measured by sending signals to it. This includes methods such as radar, infrared, radio signal, ultrasonic sound, laser, and so on [2]. This active method is really prone to environmental conditions such as temperature, fog, and noises, like wave interference in a room. Other than that, this method only yields distance to an object, not necessarily the geometry of the object itself [3]. The second method is passive measurement, in which information is gathered from an object without sending any signal to it. This information is usually in the form of light intensity [2]. This is now made possible with the advent of computer vision that makes use of visual images of objects. This research attempts to calculate the distance of an object by using visual information gained from a pair of images taken by two cameras, which is known as stereo image. Using trigonometry, correlations between object positions from right and left tells the distance between the object and an observer this is the core concept of stereo vision and triangulation [3].

II. THEORY

Stereo vision is a discipline related to determining the 3 dimensional structure of a scene made of two or more digital images taken from different angles [4].

A stereo camera is two cameras of the same type and specification set on a straight line against either the vertical or horizontal plane. Distance to an object can be measured when the object is on the overlapping viewing point of the two observing cameras. Figure 1 depicts the coordinate system of a stereo camera, which is taken as at the central point between the camera on the left and the one on the right. With the congruence of $\Delta\ PC_LC_R$ and $\Delta\ P_LP_R$ triangles in Figure 1, the stereo coordinate system for both cameras can be written as in Equations 1 and 2.

$$\frac{b}{z} = \frac{(b + x_r) - x_l}{z - f} \quad (1)$$

$$z = \frac{b*f}{x_l - x_r} = \frac{b*f}{d} \quad (2)$$

Where $d = (x_l - x_r)$ is disparity, x_l is coordinate x on the left image, x_r is coordinate x on the right image, b is the length of the base line (distance between the optical axes of both cameras), and f is the focal length of the camera. Equation (2) shows that depth z is inversely proportional to disparity. The more the disparity is, the closer the object to the base line of the camera. This also goes the other way around, the less the disparity is, the father the object to the baseline [5].

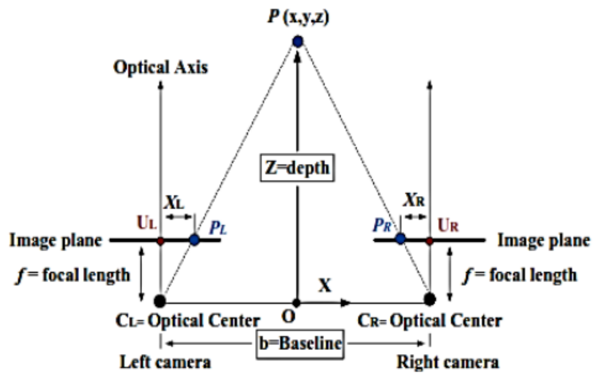

Figure 1. Epipolar geometry with parallel optical axes

III. METHOD

Distance measurement in this research is carried out in some stages. These include image rectifying, disparity determination, 3 dimensional image reconstructions, and distance calculation.

Camera Calibration

Camera calibration results in both intrinsic and extrinsic parameters of both cameras. The extrinsic parameters explain orientation and translation of the right camera against the left camera. Meanwhile, the intrinsic parameters reveal the transformation of point mapping from camera to pixel coordinates, from each camera and some internals parameters in the camera. Both of these parameters are used in the process of image rectifying and its subsequent 3 dimensional reconstruction. The data obtained in this research are given in Table 1.

Table1. Parameters of Camera Calibration

No	Parameter	Camera	
		Right	Left
1	Resolution	640 x 480	640 x 480
2	Duration	16 seconds	16 seconds
3	Total frame	160	160
4	Frame rate	10 fps	10 fps
5	Intensity	340 lux	340 lux
6	Camera distance from one another	12 cm	12 cm

Image Rectifying

Initially, images taken from both the left and right cameras are of 480x640x3 pixels and 8 bits dimensions. Once they are merged, these dimensions are reduced and are represented by a matrix of 408x553x3 size. Figure 2 depicts original and rectified images.

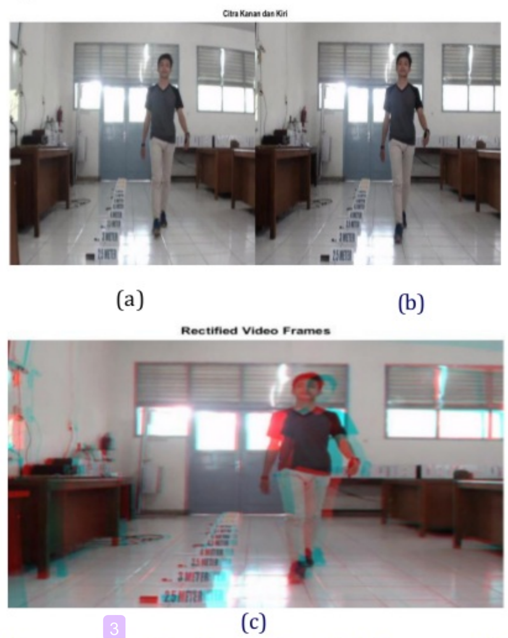

Figure 2. Original and rectified images; (a) original image from the left camera, (b) original image from the right camera, and (c) rectified image.

Both video images can be properly rectified. It can be observed that there are colors of red and blue both sides of the object. They are actually the color thickness that will be used as information on depth to determine the distance of the object.

Depth Information

Disparity is combination of two image rectifying results in a difference of the corresponding point at both the left and the right images. Disparity map in stereo vision represents the depth of an object. Disparity is inversely proportional to depth. Higher disparity means that the object is closer to the baseline of the camera. Inversely, lower disparity indicates that the object is farther from the camera baseline. Figure 3 shows a disparity map.

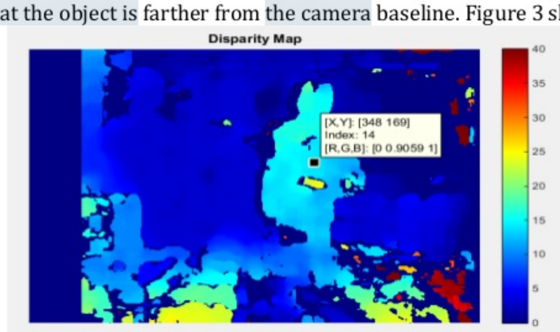

Figure 3. Disparity map

Three Dimensional Reconstruction

The three dimensional reconstruction processes makes use of disparity and camera calibration parameters. Three dimensional coordinates that match the pixels serve as input for disparity map. Three dimensional coordinates relative to the optical center of the left camera are based on the fundamental and essential matrices. Figure 4 represents a three dimensional reconstruction of the disparity map.

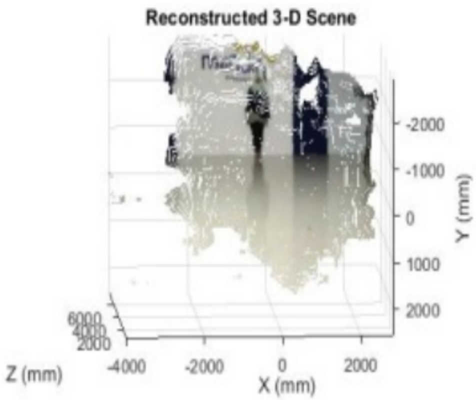

Figure 4. 3D reconstruction

IV.RESULT AND DISCUSSION

The distance of a human object moving toward the cameras has been successfully measured. This measured distance is compared to the distance measured with a roll-meter on the floor. Table 2 lists the distances measured.

Table 2. Measured distances

No	Actual distance (m)	Measured distance (m)	*Error* (%)
1	6.67	6.44	3.45
2	6.07	6.12	0.82
3	5.47	5.39	1.46
4	4.87	4.68	3.90
5	4.27	4.2	1.64
6	3.67	3.44	6.27
7	3.07	3.33	8.47

It can be seen from the table that distance measurement using a video camera is possible, despite the errors. These errors are 4% on average. The main factor to this is slow processing speed, that during video image acquisition, both cameras do not start and stop at the same time. This lack of coherence requires manual frame cutting, which means some frames may not be matched properly.

V.CONCLUSION

Results of this research show that the method proposed is capable of producing distance measurements with minimum error. Research in the future should employ video cameras with better processing performance that manual frame cutting is not required, and hence, minimize flaws in matching video frames. Further methods should also be developed, which may enable measurements of all kinds objects, either in motion or stationary. The other future possibility is applying a real-time method that will help speed up this distance measurement method for the fields of robotics, auto-cars, or even industry.

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