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Object Distance Measurement by Stereo VISION

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ABSTRACT

The 3D camera consists of two cameras of parallel optical axes and separated horizontally from each other by a small distance and these two cameras are combined together in a single frame. The 3D camera is used to produce two stereoscopic pictures for a given object. The distance between the cameras and the object can be measured depending upon the distance between the positions of the objects in both pictures, the focal lengths of both cameras as well as the distance. Triangulation is used to relate those mentioned dimensions with each other. Image processing is used to determine relations between the pictures of the object in the images formed by left and right camera through the technique of template matching. Template matching is used to find similarity between parts of the two images containing the object picture, which lead to find the amount of disparity in the object position coordinates. The distance of the object varies inversely with disparity and the accuracy of distance measurements depends on resolution of the camera pictures, lens optical properties and separation between the optical axes of both cameras. Throughout this work a 3D webcam is used and a matlab code was written to find the object distance. Four tests were executed and the measured object distances were 18.7654 cm,46.3146 cm, 66.7480 cm, and 100.8809 cm. The measured distances were compared with those measured at the same time by a digital laser range finder and there were good agreement between them with percentage error ranged from 1.13% to -2.05%

Key words: Distance, stereo vision, template matching, webcam.

INTRODUCTION

There are many methods used to determine the distance to objects (targets) or obstacles. Some of these methods are active by sending some signals to the object such as laser range finder, ultrasonic range finder, radio waves, microwaves, infrared, etc. Some others are passive that only receive information about the target position. Among passive ones, the most popular are those relying on stereoscopic measuring method. The main characteristic of the method is to use two cameras[1,2].

Stereo vision is a technique for building a three dimensional description of a scene observed from several viewpoints. It is considered passive if no additional lighting of the scene, for instance by laser beam, is required. So defined, passive stereo vision happens to be very attractive for many applications in robotics, including 3-D object recognition and localization as well as 3-D navigation of mobile robots [3].

Most of the research on passive stereo vision has been devoted to binocular vision for which two cameras are observing the same scene from two slightly different viewpoints. As soon as two image points are matched, i.e., identified as corresponding to the same physical point, it is possible to compute the three-dimensional coordinates of this physical point.[3]

This paper shows finding of the distance of an object according to the principles of stereo vision making use of two webcams as sensing elements. Image processing is used through template matching and Matlab code is written to execute these procedures.

BASIC DISPARITY EQUATION:

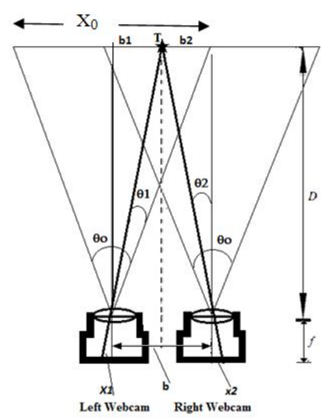

Fig. (1): Schematic diagram of an object pictured by two horizontally aligned cameras separated by small distance.

The schematic diagram of fig. (1) shows two webcams, left webcam and right webcam aligned so that their optical axes parallel and at a distance b from each other. The two webcams have the same parameters, i.e. the same focal length f and the same view angle θ_0. Image of the target T will be at distance x_1 in the left camera and at a distance x_2 in the right camera. Applying basic triangulation will lead to:

$$\frac{b_1}{D} = \frac{-x_1}{f} \quad , \quad \frac{b_2}{D} = \frac{x_2}{f}$$

Since b= b_1+ b_2, then,

$$b = \frac{D}{f}\left(x_2 - x_1\right)$$

$$D = \frac{bf}{x_2 - x_1}$$

$$\tan\left(\frac{\theta_0}{2}\right) = \frac{x_0}{D} = \frac{x_1}{f}$$

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$$f = \frac{x_0}{2\tan\left(\frac{\theta_0}{2}\right)}$$

$$D = \frac{bx_0}{2\tan\left(\frac{\theta_0}{2}\right)(x_2 - x_1)} \quad \text{------- (1)}$$

In equation (1) above, x_0 is the width of the image in pixels, x_2-x_1 is the disparity between the two images in pixels. Since the distance between both webcams b, the webcam angle view θ_0 and image width are constant for 3D webcam, then it seems that the distance D is inversely proportional todisparity (x_2-x_1). In order to compensate alignment errors, the view angle must be corrected by adding another term ϕ within the tangent in equation (1)[4] as follows:

$$D = \frac{bx_0}{2\tan\left(\frac{\theta_0}{2} + \phi\right)(x_2 - x_1)} \quad \text{--- (2)}$$

The alignment compensation term ϕ must be found experimentally. Therefore, equation (2) can be written as a power relation:

$$D = k.x^z \text{ --- (3)}$$

where k is constant given by,

$$k = \frac{bx_0}{2\tan\left(\frac{\theta_0}{2} + \phi\right)}$$

x= $x_2 - x_1$, and z is a constant to be found experimentally.

TEMPLATE MATCHING

In order to find the distance D of the target T from the two webcams (i.e. 3D webcam), two images were taken for the same scene containing the target by both webcams. A suitable format is selected for both cameras. The snapshots were converted from RGB into grayscale images. Those images were also enhanced by using histogram equalization in order to distribute the images intensity to the whole image instead of leaving it concentrated in specific narrow region. Template T(x,y) is made by selecting a small part of the left camera image f_L(x,y). The template must include the target whose distance to be determined. Care must be taken in the selection of the template. The coordinates (x,y) of the center of the template in the left image f_L(x,y) represent the coordinates of the target T in that image. This template will be matched withtemplate that represents the target is pointed interactively and its center coordinates are found from the program. This theright webcam image f_R(x,y) in order to measure similarity Sum of Squared Differences [5] technique is used within a Matlab program written to achieve this procedure. The between them. Fast Matching Using Cross Correlation Based template with its selected dimensions is cropped from the left image, and by using the template matching technique mentioned above, its similarity is measured with f_R(x,y) making use of the features of the image. The center coordinates of the target will be found in the f_R(x,y) shifted by the amount of disparity. The disparity (x=x_2-x_1) will be found from the difference between the x-axis of the target coordinates in the right and left webcams images respectively. Making use of equation (2), and by substituting for the constant values, the distance D can be found as a function of the amount of disparity x.

RESULTS AND DISCUSSION

In order to find the values of k and z in equation (3), the disparity x is found for a range of distances D of a target from the 3D webcam. The disparity corresponding to each distance is found by the Fast Matching Using Cross Correlation Based Sum of Squared Differences as mentioned above, while distance is measured by using a digital laser range finder. The distance D is plotted against disparity x in fig. (2) by using Excel program and the following empirical power relation is deduced:

D(cm) =15314[x(pix)]$^{-1.2}$-- (4)

Comparing the last empirical relation with equation (3) mentioned above, it can be found that the values of constants k and z are (15314) and (-1.2) respectively. This empirical relation is implemented in the Matlab code to calculate the distance to the target for each value of disparity extracted from template matching.

To examine the final code, four tests were made to find the distance of a target object. The selected target in these tests is the (small coffee pot). In all four tests, the center of a small red spot in the front part of the target is pointed to be within the center of the template. When the code runs and the spot is pointed interactively through mouse click, the program will automatically draw a green rectangle around the center of the template in the left camera image and a red rectangle around the new calculated template center in the right camera image. Also the program will display object x-coordinates (x_1), (x_2) in left and right camera images respectively. Besides, the program will also display the amount of disparity x in pixels and the distance D in centimeters.

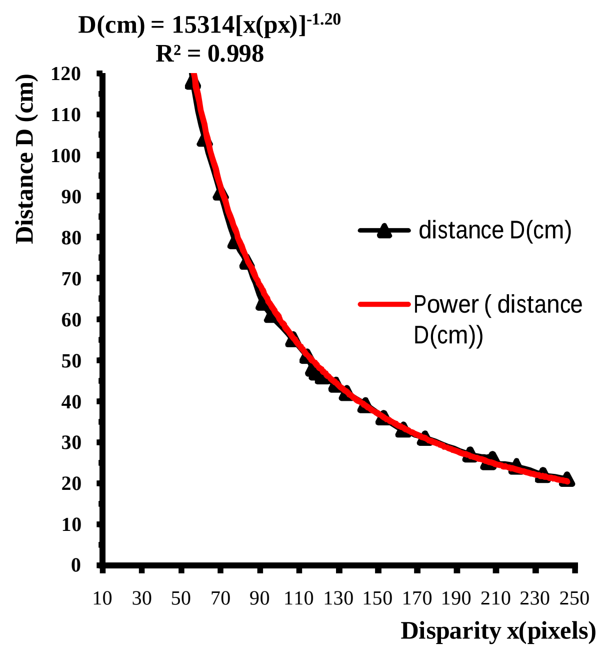

Fig.(2): Dependence of object distance on disparity

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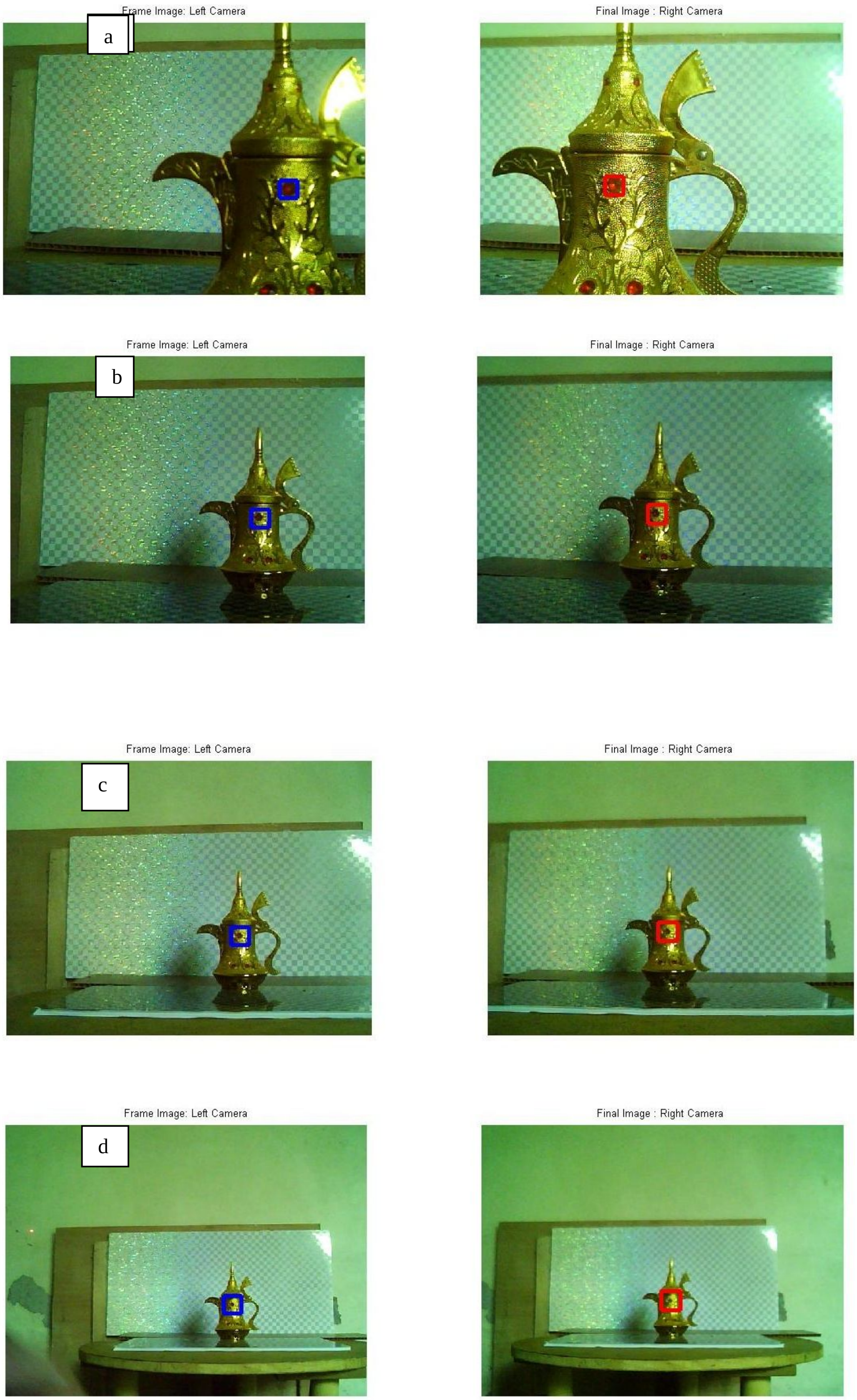

Fig.(3): The position of the target shown in left and right camera images for a) Test-1, b)Test-2, c)Test-3, and d)Test-4.

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Table (1) shows the results of the four tests while fig. (3) a,b,c, and d show the four images of the target showing the position of the target during Test-1, Test-2, Test-3, and Test-4 that are abbreviated in table (1). Besides finding the object distance D that are tabulated in table (1) by the algorithm above, it is also measured by the laser range finder which are values of D_{rf}that are also tabulated in table (1). The resolution of laser range finder was ± 0.5. The table also contains the percentage error between the two values of the distance. The error is small for small distances and it increases slightly as distance increases. Nevertheless, the error is not large and the results can be considered accurate.

Table (1): Object x-coordinates in left and right images with disparity anddistances of the target object for four tests

Test #	X_1 (pixel)	X2 (pixel)	X (pixel)	D (cm)	D_{rf} (cm)	%error
1	503.9573	237	266.9573	18.7654	19	-1.23
2	450.7407	325	125.7407	46.3146	46	0.68
3	408.7276	316	92.7276	66.7480	66	1.13
4	401.7254	336	65.7254	100.880 9	103	-2.05

CONCLUSION

In this research, object distance was measured through four tests using a 3D webcam and template matching technique. The measured distances were, 18.7654 cm,46.3146 cm, 66.7480 cm, and 100.8809 cm. These results were compared with object distances that were measured by digital laser range finder and showed almost good agreements. Relative errors were ranged from 1.13% to -2.05%.

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