Computer Vision Based Distance Measurement System using Stereo Camera View

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***Abstract*— In recent years, especially in industrial automation systems, in order for robots to understand their distances and positions according to the target, close to human vision, computer vision systems are needed. Computer vision close to human vision can only be created using stereo cameras. In this study, a computer vision system is developed using the stereo camera system for measuring object distances. In the study, first of all, for the distance measurement, the distance of the face images obtained from the stereo camera system to the screen is calculated. In measuring the distances of the face images to screen, the disparity maps are first extracted and the face region is detected. Afterwards, the distance measurements are performed on the obtained images in the stereo camera system on account of calculating the shifts between the frames. In the experimental studies, the actual distance values such as 71, 74, 75, 79, 110, 125, and 115 of the face to the screen are measured as 70, 72, 73, 77, 97, 120, 132 cm by proposed system, respectively. When the experimental results are examined, we can say that the proposed computer vision system is successful in distance measurement using stereo camera view.**

Keywords*— Distance measurement, image processing, computer vision, stereo camera, disparity maps

I. Introduction

Computer vision systems which provide vision and simulation via computers are used in many fields in daily life [1]. The vision action can be performed by single, stereo or multiple camera systems. Stereo systems can realize computer vision event using doubled or multi-camera systems. Stereo vision systems are the visualization techniques which enable point coordinates to be reproduced in a 3D space on images obtained from two different cameras. Stereo vision systems which are mostly dual and based on multiple vision. These vision systems are utilized in many fields such as portable autonomous robotic systems, 3D measurements, object tracking, film industry, augmented reality and object recognition [2].

Obtaining disparity (difference) maps is one of the remarkable problems that need to be solved in stereo vision systems. Various methods are used to obtain disparity maps. The method that is based on stage geometry which is provided by matching pixels between two images is commonly preferred [3].

It is seen about literature that there are few in the number of practical applications which are performed by calibrated stereo vision systems. Huh et al. (2008) suggested an obstacle recognition system by utilizing stereo vision sensors. In a related system, first of all, the starting is determined; then the system finds potential obstacles [4]. Özüağ et al. (2012) established a stereo system including three cameras to detect face geometry as 3D in just a single pose via light sources [3]. Bhowmick et al. (2011) developed a stereo vision system that perceives pedestrians and determines how far away they are from the vehicle [5]. Lai et al. (2012) designed a stereo vision system to measure distance information of mobile robots [6]. Ross et al. (2012) proposed a stereo vision method to help mobile robots to find direction without camera calibration for depth estimation [7]. Soyaslan (2016) conducted a study and provided to determine the depth of different objects by the stereo camera system [8].

In this study, we developed a computer vision system for measuring object distances using stereo camera view. In the study, firstly, distances of face images obtained using stereo camera view to the screen were computed for measuring object distances. Then, the distances of the face images to screen were determined using disparity maps. In the last stage, the performance of the system was tested by comparing the measured distance values with the proposed computer vision system and the actual distance values. The following sections of the study are organized as follows. In the section II, the parts such as stereo vision system, depth, and disparity relationship methods are explained. The section III mentions about developed application that measures the distance between human faces and system using stereo camera system. Discussion of results can be seen at the final section.

II. Materials and Method

Figure 1 shows the block diagram of a stereo vision system designed within the scope of the research. In the system, after obtaining images from two different cameras (one of them is the reference camera and the other is the side camera), visible patterns on images are matched. In this study, 2 Logitech C310 USB WebCam was used for distance measurement. Distance measurement of a person is performed via cameras with the computer after preparing disparity maps from the visible patterns.

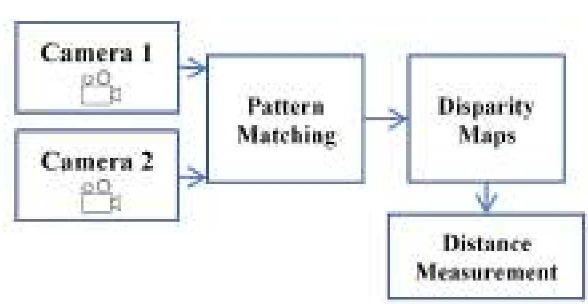

Fig. 1. Block diagram of the developed stereo vision system

A. *Stereo Vision System*

Figure 2 shows the components of a standard stereo vision system. It can be seen that axes and image planes are composed of a parallel system when a stereo-camera whose camera planes are properly aligned and lens disturbances are completely removed is analyzed [8].

Methods which are used for measuring distances between objects as almost certain are generally established by stereo camera systems. One of the cameras is used as the reference and the other one is accepted as the side camera in systems which are designed in this way. A stereo matching algorithm matches related patterns in another image of the side camera with the visible patterns of the reference camera. The difference in locations of the same patterns in these two images generates a disparity. Thus, the set of inequality related to the same image forms the disparity map. A disparity map can be turned into a deep map. Value of the depth is described as the value of the disparity. Depths which are obtained by inequalities necessitate obtaining parameters such as distances between cameras and lens length of cameras [9].

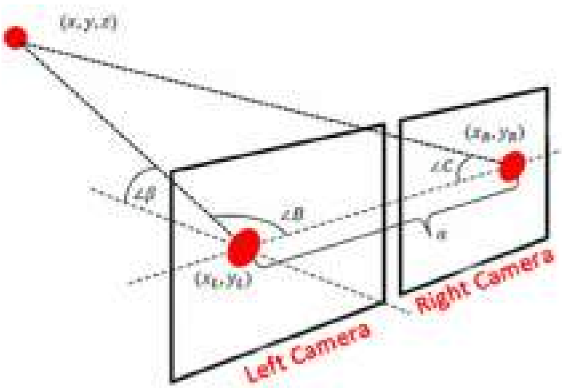

Fig. 2. A Standard Stereo Vision System [10]

Stereo vision is a 3D data acquisition process by multi 2D views [11]. Equality (1), Equality (2) and Equality (3) can be used to compute x, y, z coordinates in Figure 2 of any point that reflects from a surface obstacle [12].

$$x = a\,\frac{Sin\ C * Sin\ B}{Sin\ (B+C)} \tag{1}$$

$$y = a\left(\frac{1}{2} - \frac{Sin\ C * Cos\ B}{Sin\ (B+C)}\right) \tag{2}$$

$$z = a\left(\frac{Sin\ C * Sin\ B * Sin\beta}{Sin\ (B+C)}\right) \tag{3}$$

B, C, and β are the fixed angles in Figure 2 and Equality (1), Equality (2) and Equality (3); is the fixed distance between two cameras.

B. *Disparity (Difference) Maps*

The output of the stereo matching algorithm in stereo vision systems gives the disparity (difference) maps. Values of disparity maps are proportionately reverse to the depth on related pixel points. Values of disparity maps in computer vision are calculated by the distance between two neighboring pixels in images of right and left camera systems [13]. As is seen in Equality (4), disparity is found by x1-x2. Hereby, b, f and Z respectively are the focal length, baseline, and the depth.

$$D = x1 - x2 = \frac{b.f}{Z} \tag{4}$$

Depth and disparity are inversely proportional to each other. There also is a nonlinear relationship between these values. There occurs a sea change in depth if disparity decreases. However, the same situation is not valid for disparity; we do not see a sea change in depth value if disparity increases. So, depths of objects near to cameras are higher in stereo vision systems [8]. Computing the difference between two points on disparity maps is represented in Figure 3.

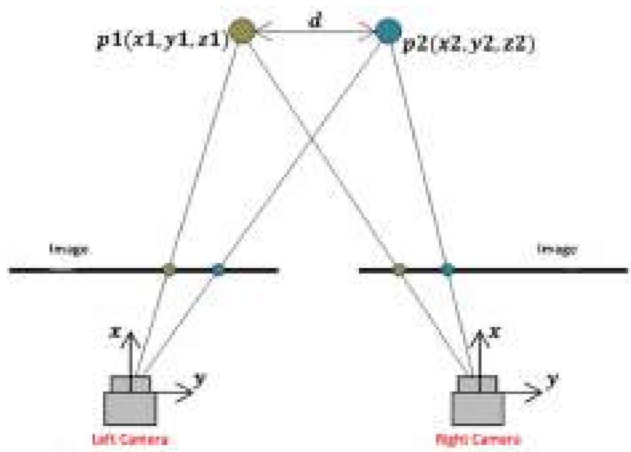

Fig. 3. Computing inequality between two points on disparity maps [10]

III. The Developed Application For Distance Measurement

An application was developed in this study to measure the distance between the system and human faces using stereo camera system. An interface was designed to calculate distances. Figure 4 shows the main form of developed application for distance measurement using the stereo vision system.

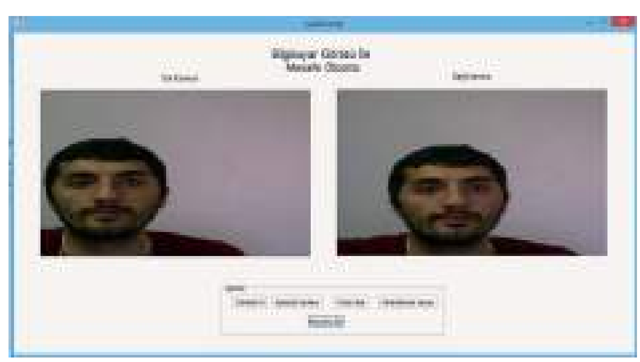

Fig. 4. The main form of application developed for distance measurement by the stereo vision system.

Camera calibration was performed for measuring distances at first. In literature, the calibration process can generally be conducted using OpenCV and Matlab.

Calibration of the system was realized in the Matlab environment. The standard chessboard is 8x8 square, but the boards used in stereo camera calibrations are usually arranged as 9x7, 8x7, 7x5. The chessboard used in this study was adapted so as to be 8x7. 8 pairs of 8x7 chessboard image were taken for the calibration process. As is seen in Figure 5, the calibration of the application was performed via these images. In the developed application, the images are calibrated after insertion and the calibration result of the desired image pair can be used. Calibration is a significant step for application success. Calibration success directly affects system success.

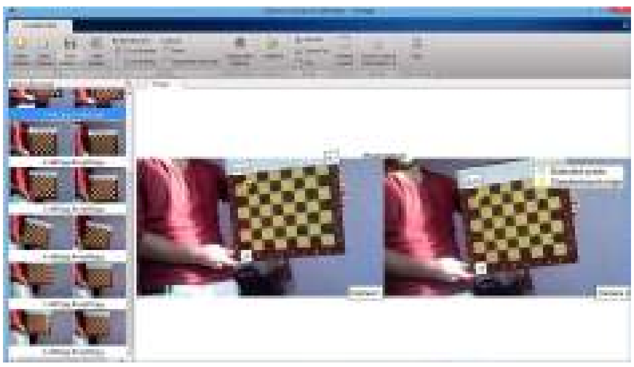

Fig. 5. Adjusting camera calibrations using Matlab application

After the calibration process is completed, the mat extension file containing the calibration settings is stored for use in the system as shown in Figure 6. This file contains the relationship of the cameras to each other and is used for distance measurement. The first time the application is started, it takes this setting file and displays the images from the stereo cameras on the screen. The received images are also recorded in the background.

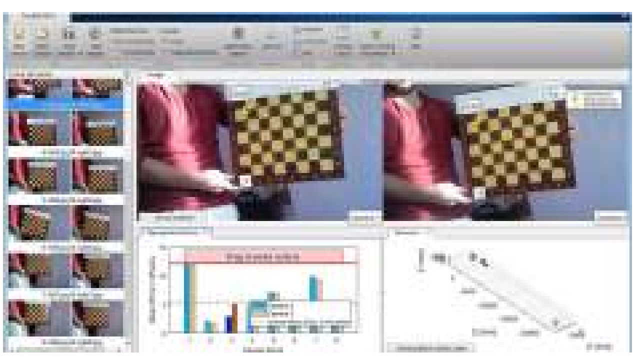

Fig. 6. Performance measurement of camera calibrations

The application can show the images of disparity map which are used to compute the distances to the user if required. Distance and disparity values are inversely proportional to each other. The screenshots of disparity maps is shown in Figure 7.

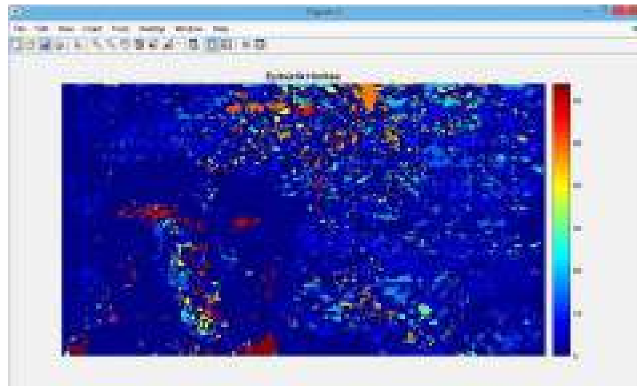

Fig. 7. Disparity map result of the image

The process to find the faces which are the starting step is essential to measure the distances. Distance measurement may start by finding correct faces. FaceDetector function of Matlab was utilized for this function. Faces whose location was determined in the image as the result of the function were marked as is seen in Figure 8.

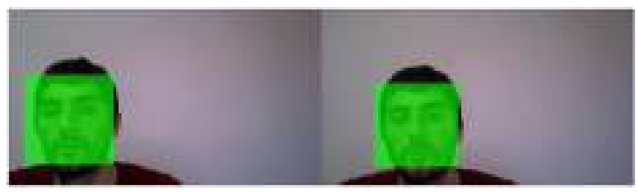

Fig. 8. Detection faces from image using FaceDetector function

Since the distance measurement is performed by stereo camera system, there may occur slidings between two images. Sliding differences in the application were measured to avoid potential slidings. This process was conducted by determining specific points in the images. Sliding and image distances were found as seen in Figure 9.

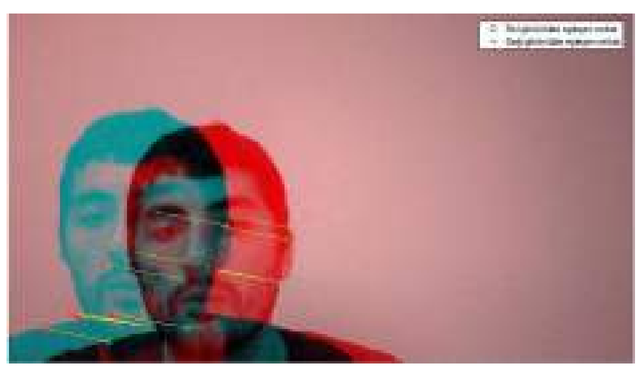

Fig. 9. Determining sliding distances in images

The developed application uses the stereo images to measure and record distance using all data. The measured distance for each frame of image is shown on the screen as shown in Figure 10. As can be seen from this image, the same measurement result was obtained from both cameras.

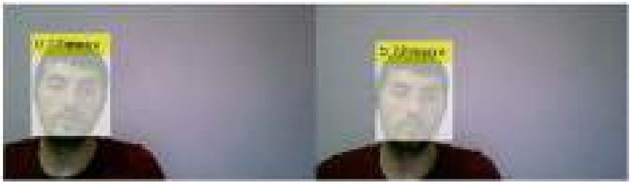

Fig. 10. Distance values measurement screen

As is observed in Figure 10, images from physically determined distances were measured in the application at the test stage of the application. This measurement values and physical measurement results were compared. As is seen in Figure 11, seven different test values were obtained for such as 70, 72, 73, 77, 97, 120, 132, respectively. On the other hand, physical measurement values were calculated such as 71, 74, 75, 79, 110, 125, 115 using proposed system, respectively. Figure 11 shows the relationship between the measured values found by the application and the physical actual measured values. As a result of, it is seen that the actual distance values and the proposed system are close to each other.

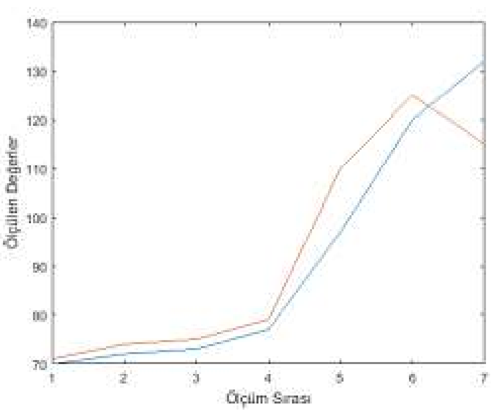

Fig. 11. The test measurement results of the system

IV. CONCLUSIONS

This study aimed to measure the distance of human faces to the system via a stereo camera using computer vision system. As is mentioned in the literature, similar stereo camera systems are commonly utilized. Several tests were performed in this study and the best results were obtained in 60 cm and 120 cm range. The differences of these distances gradually increase. Since calibration images were taken in the home environment, the error rate of values of different environments changes. It is seen that the differences decreases in case of making calibration adjustment by images in environments planned.

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