Distance Measurement System Using Binocular Stereo Vision Approach

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***Abstract*: Stereoscopy is a technique used for recording and representing stereoscopic (3D) images. It can create an illusion of depth using two pictures taken at two or more slightly different positions. There are two possible way of taking stereoscopic pictures: by using special two-lens stereo cameras or systems with two single-lens cameras joined together. Stereoscopic pictures allow us to calculate the distance from the camera(s) to the chosen object within the picture. The model of stereo camera imaging is established using traditional camera calibration method. The internal and external parameters of cameras are calculated and optimized. Then the suitable algorithm for matching the object from left to right image is developed on MATLAB. After that based on centroid of desired object disparity is estimated and the distance of the object is calculated using the epipolar triangulation method. The accuracy of the position depends on picture resolution, optical distortions and distance between the cameras. The results showed that the calculated distance to the subject is relatively accurate.**

Keywords-Distance; binocular stereo vision; disparity; matching; camera calibration; measurement

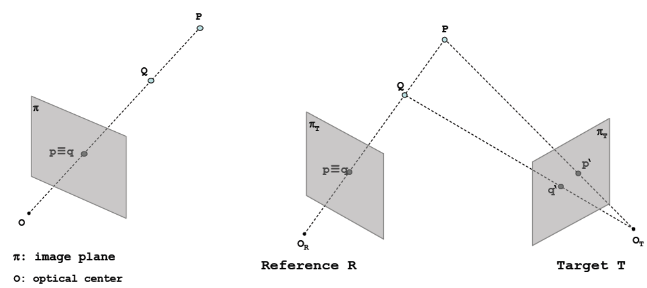
I. INTRODUCTION

There are many approach of measuring the distance of the object. The most commonly used approaches are LASER range finder, Ultrasonic measurement etc. These approaches are active & provide good accuracy but it needs continuous human assistance and many times it is not possible in application like industrial automation, navigation etc. By using passive approach like stereo vision for the distance measurement we can make it automatic detect and determine the object distance as well as object geometry.[1]

The paper shows implementation of such algorithm within program package Matlab and gives results of experiments based on some stereoscopic pictures taken in various locations in space.

II. STEREOSCOPIC MEASUREMENT METHOD

Stereoscopy is a technique used for recording and representing stereoscopic (3D) images. It can create an illusion of depth using two pictures taken at slightly different positions. In 1838, British scientist Charles Wheatstone invented stereoscopic pictures and viewing devices. 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[5]



(a) (b)

Figure 1. (a) single camera (b) stereo camera

As we can observe in image from the single camera that all the point into the same projection line are same image point. In fig 1(a) Both real points (P and Q) project into the same image point (p ≡q) This occurs for each point along the same line of sight and useful for creating optical illusion. With two (or more) cameras we can infer depth, by means of triangulation, if we are able to find corresponding (homologous) points in the two images shown in fig 1(b).

A stereo camera is a type of camera with two or more lenses with a separate image sensor or film frame for each lens. This allows the camera to simulate human binocular vision, and therefore gives it the ability to capture three-dimensional images, a process known as stereo photography. Stereo cameras may be used for making stereo views and 3D pictures for movies, or for range imaging. The distance between the lenses in a typical stereo camera (the intra-axial distance) is about the distance between one's eyes (known as the intra-ocular distance) and is about 6.35 cm, though a longer base line (greater inter-camera distance) produces more extreme 3-dimensionality. Stereo camera can be created by mounting two cameras having same configuration on the common base. The most important restrictions in taking a pair of stereoscopic pictures are the following:

- Cameras should be horizontally aligned ,
- The pictures should be taken at the same instant

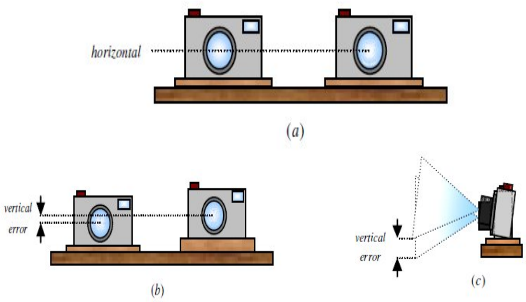


Figure 2. Proper alignment of the cameras (a) and alignments with vertical errors (b) and (c).

A. *Epipolar geometry*

It is the geometry of stereo vision. When two cameras view a 3D scene from two distinct positions, there are a number of geometric relations between the 3D points and their projections onto the 2D images that lead to constraints between the image points.

Figure (3) shows the schematic diagram of the system. The distance of two cameras' optical center is b. The optical axes of the two cameras are parallel. They have the same focal length f. A is the point with the vertical distance from the cameras of L. Its images on the two cameras are A_1 and A_2. x = x1 + x2 is the parallax.[2]

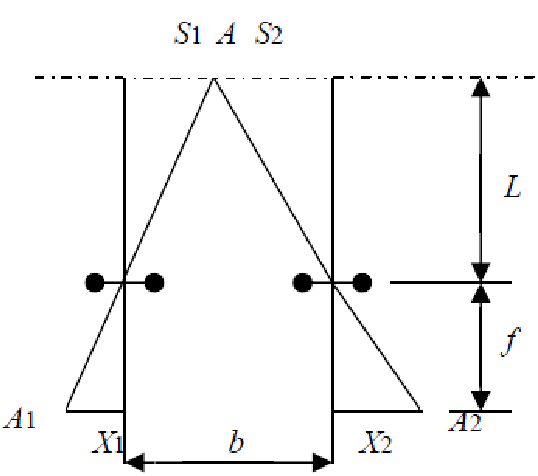


Figure 3. The schematic diagram of the system

According to the principle of similar triangle, we know,

$$\frac{S1}{x1} = \frac{L}{f} \qquad (1)$$

$$\frac{S2}{x2} = \frac{L}{f} \qquad (2)$$

$$b = S1 + S2 \qquad (3)$$

$$L = \frac{b * f}{x1 + x2} \qquad (4)$$

$$x = x1 + x2 \qquad (5)$$

$$L = \frac{b * f}{x} \qquad (6)$$

That is, when the two cameras' optical center distance b and focal length f are determined, the measured distance L is inversely proportional to the parallax x.

III. SYSTEM OVERVIEW AND ALGORITHM

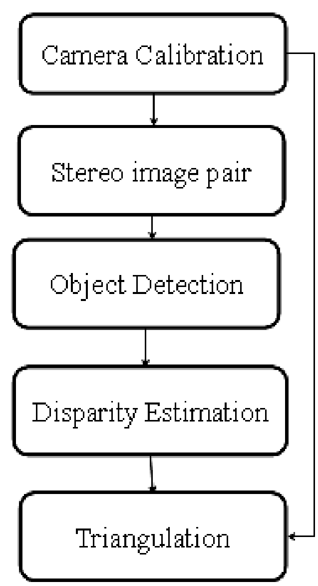


Figure 4. Overview of a stereo vision system

A. *Camera Calibration*

In geometrical camera calibration the objective is to determine a set of camera parameters that describe the mapping between 3-D reference coordinates and 2-D image coordinates. It include finding the quantities internal to the camera that affect the imaging process **(1)**Position of image center in the image (It is typically not at (width/2, height/2) of image)**(2)**Focal length**(3)**Different scaling factors for row pixels and column pixels **(4)**Skew factor **(5)**Lens distortion (pin-cushion effect).

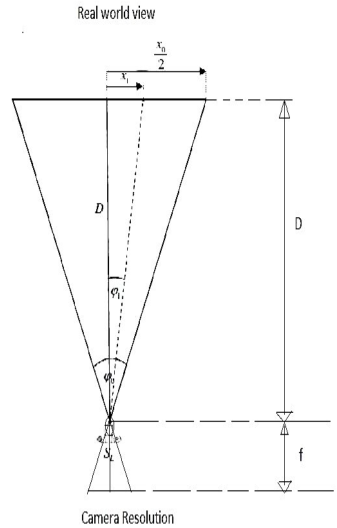


Figure 5. Focal length measurements

Focal length is primary parameter that is required for stereo vision system. In figure (5) X_0 is Full length of scale or object which completely fitted in camera's resolution, θ_0 is View angle, f is Focal length of camera.

$$L = \frac{Camera\_Resolution}{2 * \tan(\frac{\theta}{2})} \quad (7)$$

B. *Algorithm for stereo vision system*

For the positioning technology of binocular stereo vision, the key technology of calculating the coordinates is to accurately extract the binocular parallax. It requires high precision image matching technology. Therefore, solving the image matching problem is the main target of this system's software design

Image processing steps are followed as described in algorithm on the matlab platform. Initialize the stereo camera model. Capture the image pair with the both cameras at same time. Extract the object from the image based on colour or shape. In our case object is extracted from the image on the based on the colour of the object. Original image is converted into grey scale image & colour channel image. Then grey image is subtracted from the colour channel image. Then using hole filling & thresholding object region is extracted. Apply the Median filtering for noise removing & morphological operation like opening & closing to locate the boundary of the object. Calculate the centroid of the located object in both left & right image. Take subtraction of x coordinate of centroid in both images to calculate disparity. Applying the triangulation measure the object distance.

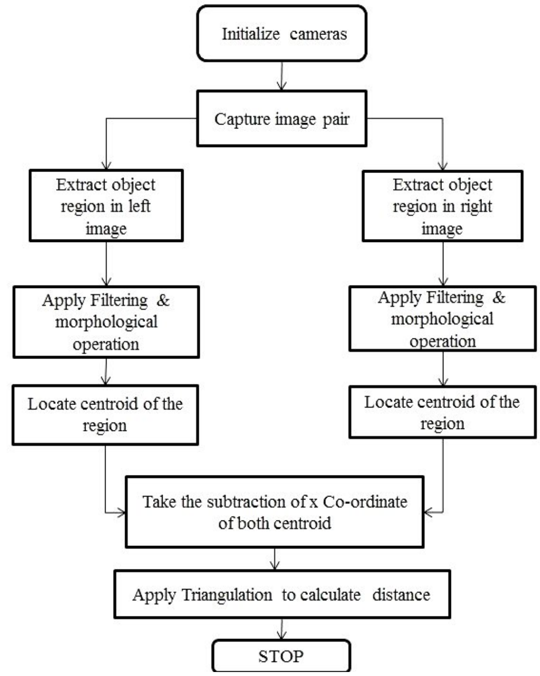


Figure 6. Algorithm for Distance measurement

IV. EXPERIMENTAL RESULTS

A. *Stereo Image pair*

This is stereo image pair captured through stereo camera model when object is placed at 1m from model

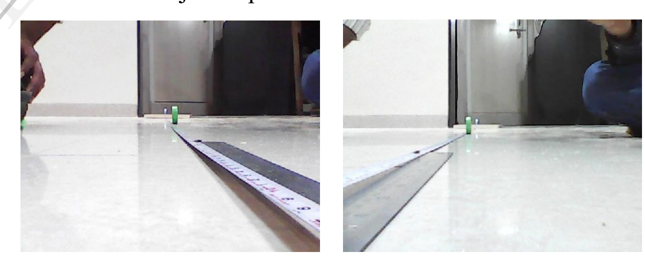


Figure 7. Image pair object at 1m

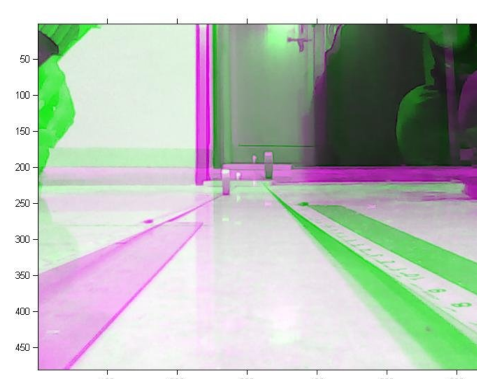


Figure 8. Dual channel image

B. Detected object

Detected object through described algorithm

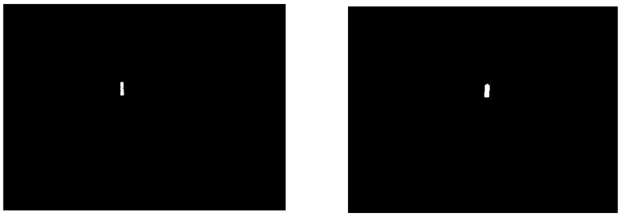


Figure 9. Detected object in both image

C. Observation Table

TABLE I. OBJECT X-COORDINATES IN LEFT AND RIGHT IMAGES WITH DISPARITY ANDDISTANCES OF THE TARGET OBJECT FOR FOUR TESTS

No	X1 (Pixcel)	X2 (Pixcel)	Disparity	D (cm)	D (ref)	Error (%)
1	60.1467	588.4624	528.3157	12.34	12	2.833333
2	148.5081	504.9913	356.4833	18.28	18	1.555556
3	192.2794	549.9943	267.7149	24.35	24	1.458333
4	223.901	436.7514	212.8503	30.629	30	2.096667
5	215.6579	393.0208	177.3629	36.75	36	2.083333
6	224.3746	382.2418	157.8672	41.2968	40	3.242
7	238.2039	363.6989	125.4959	51.9495	50	3.899
8	269.6119	331.7563	62.144	104.907	100	4.907
9	313.1025	381.9386	48.8361	134.196	130	3.227692
10	352.2678	396.4329	44.1651	147.615	150	-1.590

D. Distance vs Disparity

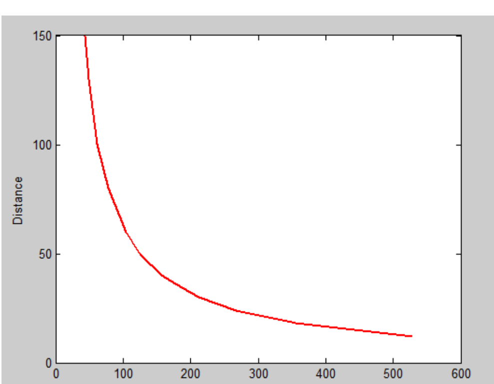


Figure10 Distance vs Disparity

E. Error Analysis

Measurement error of the system is mainly from image match error and optical sensor error. Image match error is the problem of programs. To reduce the error, we should find a more efficient way of image match. Optical sensor error comes from the unparallel of optical axis, cameras' focal length error, baseline error, and so on . To reduce the optical sensor error, it is necessary to select high-quality optical equipments, adjust carefully in experiment process, and fixed the equipments firmly after adjusting.

V. CONCLUSION AND FUTURE WORK

In this Paper, we have studied the binocular stereo vision distance measurement system based on parallax principle, introduce and analyzed the key algorithm. Distance of the particular color object from the scene is calculated with very good accuracy. In future the system is optimized by algorithm which support general object and make the system real-time.

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