



# INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

## Implementation of Stereo Vision for Depth Calculation

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**Abstract**— The object detection using stereovision is a process to identify a specific object in sequence of different images. In many years it receives a much more attention due to huge number of applications like navigation, automated inspection, wildlife analysis etc. The detection of actual object with different shapes is a difficult task; due to some issues like external environment, fast movement of object, shadows, noises etc., so there is requirement to choose appropriate methods/algorithms with respect to it. So this paper specifies depth analysis with stereo vision using appropriate algorithm.

**Keywords**—Depth, stere, camera, Checkerboard, Distance.

### I. INTRODUCTION

The depth analysis is predominant tool to investigate various parameters like object detection, distance, size, shape and many other dimensions. Stereovision is a most versatile and flexible application which used in many applications such as detection, navigation, security, wild life analysis etc. Stereo vision systems can be ordinarily used in object detection whereas it generates depth information which detects a very small objects with accurate measurement of side and distance. The Stereovision system can be implemented using two cameras which provides disparity between two objects. The Object detection can be achieved by using various traditional methods like Background subtraction, frame differentiation etc. [1][2][3][4] But due to some limitations they are not satisfactory for real time applications. The camera calibration is primarily important step which use 3D computer vision to extract metric information for 2D images for object detection, which can be achieve by using various methods. Checker board method with black and white square pattern is one of the efficient and accurate method which can be used for camera calibration.[8] Firstly camera initiates too many distortions in image. Tangential and radial are the major distortions. In a checker board image, the lines are appeared as curved due to radial distortion whereas tangential distortion arises due to parallel misalignment of image plane and image. This distortions can be corrected by using appropriate scaling formulas. Another parameters such as intrinsic and extrinsic parameters which include focal length, optical centers, rotational and translational vectors etc. can be find using sample images of checker board

pattern. Distance, size and other dimensions can be estimated using various equations.

### II. LITERATURE SURVEY

#### A. Literature survey based on calibration methods

##### 1. Traditional camera calibration method

The traditional camera method is suitable for every type of camera which have high precision calibration which gives high accuracy. The given calibration of reference object is known in shape and size. The internal and external parameters of camera are determined by the mathematical transformations. But the algorithm of this method is comparatively complex than other calibration methods.

##### 2. Camera self calibration method

The camera calibration is done only by comparing relationship between the image of surrounding environment during the moving camera. Here the 'Kruppa' equations are introduced which determines internal and external parameters. The equations of Kruppa equations are complicated to solve so this method is unstable for the camera calibration.[5]

##### 3. Linear calibration method

The typical calibration method or direct linear transformation method was proposed by 'Abdul-Aziz' & 'Karara' in 1971. Here the parameters are defined while internal and external parameters of camera should be determined by linear equations without any iterative calculations. The precision in this method is inaccurate. [6]

##### 4. Tsai two step calibration method

This method was proposed in 1987, there was radial distortion although directly solving Kruppa equations can get internal and external parameters of camera. The matrix transform method was used firstly to determine camera parameters and then achieved as parameter's initial value, the distortion factor and use of optimization method improves the calibration and accuracy. Due to high calibration accuracy it reduces space dimension parameters. This method is not suitable for simplified calibration and it is difficult to obtain noncoplanar 3D points. [10]

#### 5. Zhang calibration method

'Zhang' calibration or 'planar pattern method' uses 2D checkerboard to calibrate camera without expensive calibration target. This requires shoot and calibrate template from more than two images with different angle. It doesn't need specific position and displacement information of planar template movement. The calibration process is complex. [7]

The outcome from all this survey is that, the planar pattern method is preferable for the stereo vision, than any other method. It gives a better result and accuracy. In this method process of calibration is complex, but it is easy to overcome this problem.

### B. Literature survey based on camera

#### 1. Logitech C170

The Logitech C170 is a basic camera with a 5 megapixel with a frame rate of 30 fps with resolutions of 1024 X 768 Pixels. It is easy to interface with applications. Passive 3D depth estimation is one of the limitations of this camera. The limitation of the logitech C170 is that, its poor resolution.

#### 2. Logitech C270

The Logitech C270 offers relatively high grade and HD quality image. The maximum resolution 1280 X 720 image capture. The USB 2.0 webcam provides the image. Among this it yields parameters setting such as white balance, exposure, brightness, gain and contrast. [8][9]

#### 3. IDS UI-1646 USB

It is a 1.3 MP colored pixel camera with compact and robust design. Camera can be easily mounted with various number of applications without any interfacing issue. It is a board level camera which supports the use of M12 S-mount lenses. The maximum resolutions are 1280 by 1024 with ability of 25 frames/ sec. [12]

#### 4. PB-MV13

PB-MV13 is 1.3 Mp camera, whose frame rate is 500 frames / second. Resolution of camera is 1280 X 1024 micrometer. 12 X 12 micrometer is a pixel size. Power consumption of this camera is high and it is also very expensive. [13][14][15]

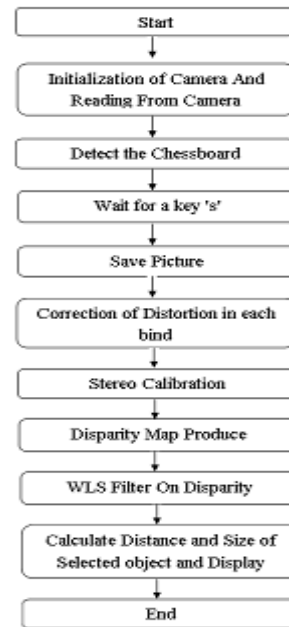
#### 5. HDCS-2020

It is a CMOS structured with very high resolution and less consuming power, which is available in two different types VGA and CIF. Pixel size is 7.4 X 7.4 micrometer. Storage is comparatively high around 6 GB. [11]

The Logitech C270 has a high resolutions and it fulfills all the featured and technical requirements. It provides high image

quality and better accuracy, so it is preferable for stereo vision system.

### III. Flow diagram



The flow diagram consist of several parameters. The parameters may divided into the two parts. The first part determines about images of checker board for calibration and second part describes about depth calculations and calibrations.

#### Part I

##### A. Initializaion of camera

Firstly initiates both cameras which are right and left cameras, after reading the captured video it store the frames in two variables named frames 'R' & frame 'L'. Convert the captured frames in gray for further operations and computations. [17][18]

##### B. Detect checker board

Take Chessboard of either 8x8 blocks (Playing Chessboard) or 10x7 blocks, and find the positions of internal corners of the chessboard. If chessboard corners are detected in both the cameras, 'cv2.cornerSubPix' instruction refines the corner locations. 'cv2.drawChessboardCorners' represents the detected chessboard corners. [17][18]

##### C. Save pictures

The detected images are saved by pressing 's' on keyboard. Minimum 200 images of the checkerboard are required for calibration (left-100 & right-100). Maximum number of images gives a better result of calibration. [17][18]

#### Part II

##### A. Stereo calibration

The stored database of Checker board images, stereo camera calibration is initiated and the locations of corners are again calculated. The function 'cv.calibrateCamera' determines the camera's intrinsic and extrinsic parameters from several views of a calibration pattern which determines various factors like camera matrices, the distortion coefficient, the rotation and translation vector. Calibrate stereo cameras use the function 'cv2.stereoCalibrate', these function estimates transformation between two cameras making a stereo pair. 'cv2.stereoRectify' calculates rectification transforms for each head of a calibrated stereo camera, where this function calculates rotation matrix for both camera (right, left), which makes image planes same (virtually). The function takes the matrices computed by

'cv2.stereoCalibrate' as input, and provides 2 rotational and 2 projection matrices as an output with new coordinates. To get horizontal stereo, both the cameras (left and right) shifted to each other along 'X' axis. In the rectified images, the corresponding 'epipolar' lines in the left and right cameras are horizontal and have the same y-coordinate. 'cv2.initUndistortRectifyMap' corrects the distortion and rectifies the transformation maps and represents the result in terms of map. 'StereoSGBM' used to obtain correlation between left and right camera. 'cv2.ximgproc.createRightMatcher' (stereo) creates the another stereo for right, but the result of this function is difficult to detect edge of the object because of noise. To remove this WLS filter is used. [18] [19]

### B. WLS filters on disparity

First, set a filter in initialization mode. It consist a lambda value, which can typically set at 8000, But if it is set at 80,000 it gives a better result. Another stereo object is created with 'cv2.ximgproc.createRightMatcher()' function. These two cases are used in WLS (Waited least square filter) to generate disparity map. So after starting both the cameras, read and store the frames and then applied 'cv2.remap' function to generate geometric transformation of the images. The result of 'cv2.remap' is then converted into gray image. Then gray images are converted in stereo image with the help of WLS filter. The values comes out from WLS filter are normalized with the help of 'cv2.normalize()' function. In disparity, the value contains a too much noise which can be removed by using morphological filter. The 'cv2.applyColorMap()' is used to convert a grey scale image into the 'colour

image. To identify the farther and nearer objects, the colour map command is used. The nearer object is specified by white ocean colour and farther object is specified by dark blue colour which shown in fig (f). [18] [19]

### C. Calculation of Distance

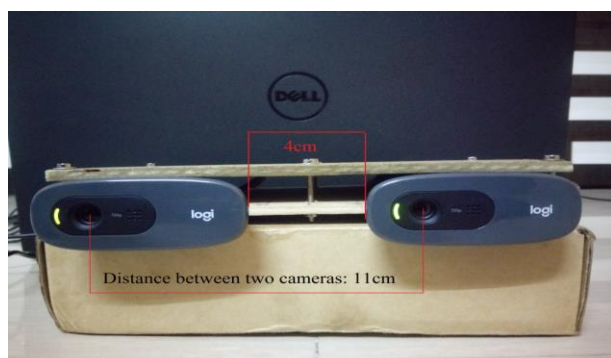
Once disparity generated, then distance must to determine. To determine appropriate distance, there is need to satisfy relation between distance and disparity, this can be achieved by 'regression'. In the regression, the disparity values are experimentally measured at several points which finally determine distance.

$$\text{Distance} = -593.97 * \text{average}^{**}(3) + 1506.8 * \text{average}^{**}(2) - 1373.1 * \text{average} + 522.06$$

The distance is measured by using above formula between the camera and the object.

## IV. Results and Discussion

The Stereo vision system implemented is based on two C270 cameras manufactured by Logitech. The camera contains CMOS color sensor with 5MP. Optical axis of two cameras are parallel with each other. From fig (a), the distance between two camera lenses is near 11cm.



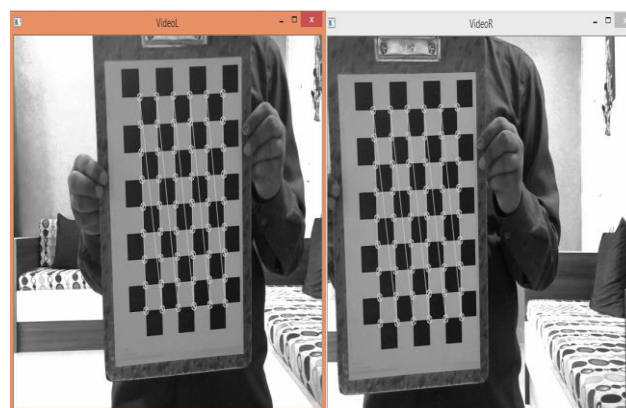
(a) Camera C270 setup

In order to find the disparity between objects, first need to detect the checker board. And need to find the positions of internal corners of the chessboard. After using a command



'cv2.cornerSubPix' then, it clarifies the corner locations as mentioned in flow description or algorithm and checker board pattern has been detected from fig.(b) and fig.(c).

(b). Detection of checker board

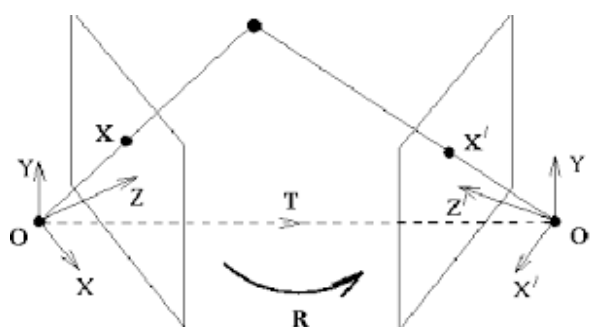


(c). Detection pattern of checker board

Detected pictures are saved and need to create a database of this pictures, like fig.(d) Database with maximum number of images gives better calibration result.

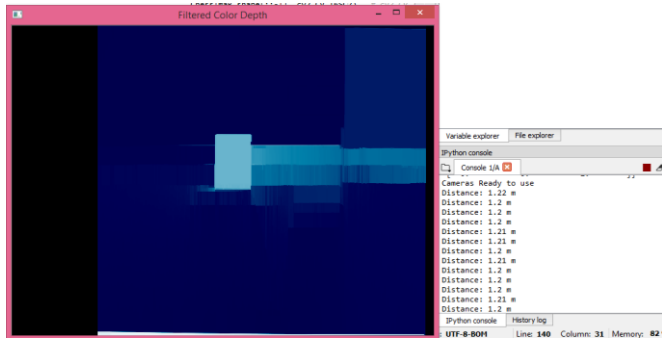
(d). Database of detected checker board

After determining intrinsic and extrinsic parameters from different views which specifies the different parameters such as camera matrices, the distortion coefficient, the rotation and translation vector. using function 'cv2.stereoCalibrate', the function estimates transformation between two cameras making a stereo pair. After rectification a camera planes are become virtually same. Then rotation matrices converted in another two rotation matrices and also two projection matrices with new coordinates. For horizontal stereo, both of the camera views are shifted relative to each other along 'X' axis with slight vertical shift. Both the cameras are epipolar to each other at both X & Y axis from fig.(e).

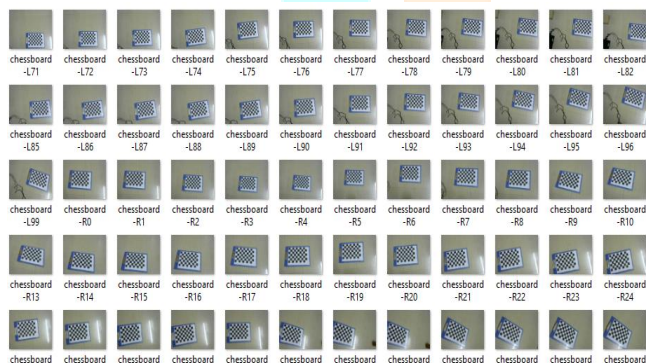


(e). Epipolar geometry plane of X & Y [16]

Undistortion and rectification transformation map are generated using command as mentioned in flow description. It is resulted in stereo correspondence images between both cameras. But result is hard to detect because of noise, which can be removed by using WLS filter. The values which comes from the filter are normalized using normalized command as mentioned in flow description .And disparity map has been generated, the other noises are removed by morphological filter. Disparity map shown in fig.(f), where ocn colour is nearer object while dark color shows farther views. Distance is calculated by using ‘regression’ which is relationship between disparity and distance.



(f). Disparity map image



The equation for distance is mentioned in flow description. Distance measurement is shown in a tabular form in fig.(g) and fig.(h) where for 8X8 checker board distance range from 68cm to 207cm and for 10X7 distance range is from 65cm to 190cm also the error range between computed and actual distance is mentioned in table for each checker board.

Sr No.	Computed Distance (cm)	Actual Distance (cm)	Error
1	65	68	3
2	70	73	3
3	76	76	0
4	82	84	2
5	90	91	1
6	137	137	0
7	174	173	-1
8	184	182	-1
9	190	192	2
10	200	203	3

(g).Result of 10x7 checker board

Sr No.	Computed Distance (cm)	Actual Distance (cm)	Error
1	68	70	2
2	73	75	3
3	78	80.4	2.4
4	87	84	-3
5	113	113	0
6	142	144	2
7	175	172	-3
8	189	189	0
9	1.94	1.93	-1
10	207	207	0

(h) Result with 8x8 checkerboard pattern

○ Limitations

- Large number of captured images (database) may lags down the system.
- Less number of captured images may affect the accuracy.
- With the use of Logitech C270, its work range is around 2 to 3 meters. With the use of better quality camera range can extended.
- A precision of measurement is around +/- 3cm.

V. Conclusion

The Stereo vision is a technique aimed to extract depth information from two camera images. The human eye can have natural perception of image detection, estimation etc. As like human eye, the stereo vision with calibration algorithm has achieved the depth perception using a two camera with calibration algorithm, and also achieved calculation of the distance, size and shape of the object without any disturbance. The stereovision system can detect a selected object and calculates its distance with the precision of +/-3cm in a range of 2 to 3 meters. The performance of this system can be further enhanced by using a good quality of camera.

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