Stereo Vision for Visual Object Tracking and Distance Measurement Assessment

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ABSTRACT

The computer vision for binocular eyes system has many applications in robot applications and safety purposes. Based on the previous research, the combination of the area of sight of stereo vision will trigger the trigonometry intersection point for determine the distance of the objects from it baseline. The system programme codes is one of the issue need to confront consequent since there are various sorts of calculation that are in the same field, however has unmistakable of use. This project focuses on how to measure distances using binocular vision. The main objective is to evaluate the binocular vision system by calculating the distance of objects in real environment. Furthermore, the project proposes a new program algorithm for binocular vision system to work, in order to identify distance of an object with a basic equation has been derived and set in the designed algorithm. The setting environment are set to single and multi-objects measured, object in environment and changes of degree of bright light. Evaluation of the system shows the detected distances are consistence and the data were recorded. The value of the distances detected are then compared with the real environment distances. The result show distances measured moderate enough for proposed system to function and may facilitate improvements in computer vision system for industry.

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1 Introduction

Binocular vision alludes to the condition where the two eyes see a typical segment of visual space. In vertebrates, the measures of this cover extent from 0^0 to around 190^0 in humans. There could be a lot of things that use binocular vision as their sight type [1-2]. Robot vision that has associated with not calibrated environments [3] ordinarily have constrained situating and following abilities, if control errands cannot be suitably modified utilizing accessible elements as a part of the situations. In particular, to perform two and half dimensions (2.5D) trajectory taking over operations using binocular vision, it appears to be important to have need learning on point shrewd correspondence data between two picture planes. In any case, any suspicion cannot be made for any smooth 2.5D trajectory. This anticipates depicts how one may upgrade self-governing robotic vision for 2.5D taking over assignments utilizing eye-to-hand binocular visual. Taking over account of the novel encoded blunder, a picture-based criticism control law is proposed without expecting point shrewd binocular correspondence data that still can measure distances of an item [4].

The proposed control of the method has been to ensure errand accuracy by utilizing just an around to align binocular vision system. The objective of the given undertaking is to drive an instrument mounted concurrently the robotic vision to take after an outwardly decided smooth 2.5D target direction in identifying separation with exactness. The recommended control planned is reasonable for applications that need exact 2.5D situating and following in genuine situations. The methodology proposed in this project is effectively approved in a genuine undertaking environment by performing explores different avenues regarding a binocular vision that should be customized.

The goal is to build up the programming algorithm for the binocular eyes system to measure the distance from the cameras as shown in. Furthermore, the objective of this project is to test the ability of the binocular vision system in evaluating the distance of an object in certain circumstance. These targets can be accomplished by utilizing two cameras as the binocular eyes system and the programming algorithm to distinguish the distance of the object from the cameras furthermore known as depth of the video. In addition, programming algorithm have been designed to grasp the object in motion and also to test the ability of the algorithm in collective situation which reacting like real situation. A few parameters have been applied to where the experiment is done in a controlled environment and monocular eye system was used as the apparatus to capture the image with the plain colour background wall.

2 Methodology

Two high definition of web cameras were used as the eyes of this system. The two cameras with binocular vision in which binocular divergence gave by the two eyes distinctive positions on the head gives exact profundity discerning. By implementing this concept, 2.5D of sight can be obtain which will results to the trigonometric intersected point that can be used to detect distant as shown in Figure 1.

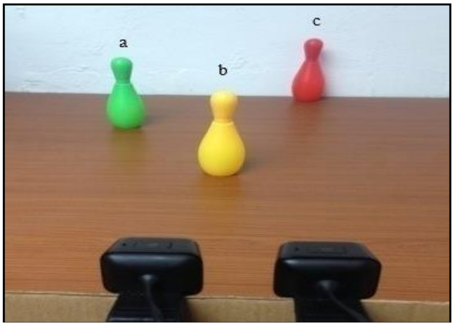


Figure 1. Pins and balls set up in environment.

In the other hand, a programming will estimate the distance of the object from the cameras. The product being utilized are Microsoft Visual Studio 2008 and OpenCV 2.1 by adding into calculation to make the vision having the capacity to calculate the distance as the output utilizing two cameras. The binocular eyes system which is two cameras as the device and attempted the figuring in genuine environment and adequate lighting are required.

As illustrated in pictures above, Figure 1 shows how the three pins are set up according to point a, b and c with a distance of 50cm, 40cm and 60cm respectively. Then the positions of the pins are changed according to the scope required.

Sum of. Absolute Differences (SAD) windows are utilized as a scoring technique for every pixel in the image based stereo matching on its environment. There are three stages of the square coordinating system that OpenCV utilizes; prefiltering, correspondence search, and post separating [5]. Amid this stage, the left and right images are standardized with the goal that they have the same lighting levels. A window of variable size is put over every pixel and the pixel is supplanted utilizing the accompanying as shown in Equation (1)

$$\min\,[\max\,(Ic - I\,, -Icap)\,, Icap] \tag{1}$$

In this formula, I is the normal power esteem in the window and *Icap* is a furthest farthest point which is preset. *Ic* is the force of the pixel that the window is focused over, the one that will change. Then the corresponding of the focuses on the left picture to those in the right picture is found. After amendment, the lines in the images are adjusted so that the relating focuses ought to hypothetically lie along the same line number in both pictures. A score is figured by setting the SAD window at the pixel in left picture. The calculation then searches the right picture beginning with the same direction as the left and moves to one side, along the x-axis, computing scores for every pixel area until it achieves the most extreme difference. Dissimilarity is the quantity of pixels balance from the underlying pixel that is being taken a gander at for a correspondence. The SAD worth is ascertained utilizing the accompanying condition as shown in Equation (2).

$$SAD(r,c) = \sum_{y=-w}^{y=w} \mathrm{x} \sum_{x=-w}^{x=w} |Right(y+r, x+c+d) - Left(y+r, x+c)| \tag{2}$$

According to the formula, *r,c* is the fact of the matter being search down a correspondence in the right picture, d is the divergence of the point in the right picture from the first point, and w is the measure of the window that is set over every point. From this condition, it is demonstrated that the scores are computed in view of the force estimations of the nearest pixels encompassing the point. The point in the right picture inside the pursuit range with the most reduced score is viewed as the best match for the point in the left picture. The counterbalance of this point from the first point in the left picture is taken as the dissimilarity for that correspondence and from that the conditions above are utilized to process the profundity.

Post separating is done to evacuate correspondences that are viewed as false matches. For this, OpenCV utilizes a uniqueness proportion and a surface edge. The uniqueness proportion is utilized to ensure that the worth that was ascertained for the coordinated point is the nearest score, as well as is an exceptional score where it is encompassed by scores that are a long way from being a match. The composition edge is set with the goal that clamour can be decreased amid the coordinating procedure, not score that is beneath the surface edge is considered.

The following parameter is the output dissimilarity picture, which is the uniqueness map containing the balance of a pixel in the left picture concerning its position in the privilege 32 pictures. OpenCV utilizes a 16-bit accuracy connection normal, implying that every pixel has 16 sub pixel areas to which the relationship of a point is checked. Because of this, the qualities put away in the output divergence picture are not the right uniqueness values and should be separated by 16 to get the best possible difference to re-projection and deciding profundity. The last parameter is the state of the parameters utilized by the relationship schedule. Furthermore, it holds the qualities for the quantity of incongruities to hunt and the uniqueness proportion down coordinated focuses to acknowledge.

The quantity of variations variable is utilized to decide the most extreme inquiry length of the relationship schedule. This quality will affect the connection schedule, where bringing down its gives a snappier relationship process, as it is looking through less potential matches for every pixel then if it was a higher value [6]. Expanding the quantity of incongruities builds the hunt territory, which moderates the procedure, additionally gives the likelihood of coordinating focuses that may have a correspondence that is outside of a lower range. This quality ought to be changed considering the situation of the scene that is introduced to the connection schedule.Once the program detects the distances, five data will be recorded for each experiment and the average is being calculated. The values are then being compared with the real distances. After comparing the distances and the errors are obtained, graphs are being plotted to see the behaviour of the data for each variable.

As for the detection on moving object, different programming algorithm has been integrated to obtain a binary mask image in the video frame. The mask will allow only the objects that belong to the foreground to be visible in the frame. The pixels in the current frame should be determined first to replace the foreground pixels. Last step is shadow detection, this process is very important to prevent moving shadows that exist being misclassified as moving objects in the frame. Shadows are the reason why two separate objects will be merged together. In this step, we can choose whether to enable shadow detection or eliminate, since the shadow are also considered moving object. Below is the main programming explanation to make an algorithm of the proposed method of moving object.

From the previous programming code, to count the object, we should set certain threshold before can count the moving object. The threshold is the recognise moving object must be intercept with the line that we make count no. of moving object. The moving object that has been recognised is marked with red colour in geometrical shape. After it has been mark with the red colour, the geometrical red colour will be inside the green rectangular shape. This green rectangular are intercept with the line that we have created. The interception between both lines that I make and rectangular shape will enable the counting process. Rectangle is consist of 4 lines, thus it is easier to say that it is actually line Intercept line, to insert the mathematical formula into programming, it has to be started with normal interception formula first. This is done using the two point form of the line. First we need to take two points to form the lines because in programming language the lines need to be built from the point. The equation (3) below two example of point in same of line

$$\frac{y-y_1}{x-x_1} = \frac{y_1-y_2}{x_1-x_2} \tag{3}$$

Then the equations (3) are rearranged and expand to get the equation (4) and multiplying by ($x_1 - x_2$) we can get equation (5)

$$y - y_1 = \frac{y_1 - y_2}{x_1 - x_2} x - \frac{y_1 - y_2}{x_1 - x_2} x_1 \tag{4}$$

$$(y_2 - y_1)x - (x_1 - x_2)y = (x_1 - x_2)\, y_1 - (y_2 - y_1)x_1 \tag{5}$$

Ideally, the lines should be in the form Ax + By = C but since we already stated before, it need to be program point first before can make the line. Now since we got the line build from the point we can change it into Ax + By = C form. Compare equation (5) to equation of lines Ax + By = C to get value in form of A, B and C.

$$\begin{gathered} A = y_2 - y_1 \\ B = x_1 - x_2 \\ C = B * y_1 + A * x_1 \end{gathered} \tag{6}$$

So, from 2 points we can now convert it into the lines equation (6), to make line interception with line we need to make another line, which are from the line in rectangle.

$A_1X + B_1Y = C_1$ (This is Line we form from points above)
$A_2X + B_2Y = C_2$ (The Second Line is from the Rectangle)

Now, we have several lines in the form Ax + By = C. So solving for intersection is just solving a set of equations, to solve it by multiply the first equation with B_2 and the second with B_1. Then you end up with equation (7) and equation (8):

$$A_1B_2X + B_1B_2Y = B_2C_1 \tag{7}$$
$$A_2B_1X + B_1B_2Y = B_1C_2 \tag{8}$$

Subtract the equation (7) with equation (8) the result is:

$$A_1B_2X - A_2B_1X = B_2C_1 - B_1C_2 \tag{9}$$

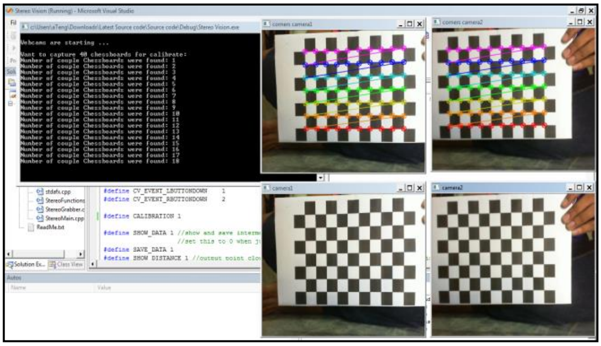
From the equation above it show the intersection happen and equation (10) is the result of x and y value that intercept.

$$X = \frac{B_2C_1 - B_1C_2}{A_1B_2 - A_2B_1} \quad \text{and} \quad Y = \frac{A_1C_2 - A_2C_1}{A_1B_2 - A_2B_1} \tag{10}$$

From equation (10) we get the idea to imply it in programming, which is the x and y below in the programming are not stated since it is the detected moving object value.

3 Results and Discussion

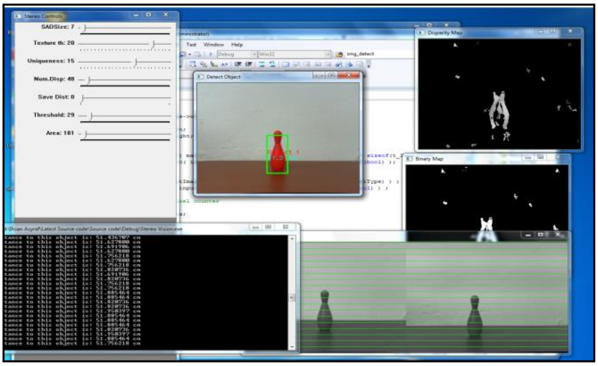
The experiments were conducted to evaluate the ability of the algorithm whether it can detect and recognize the colour of the object. The algorithm was set to distinguish the object of multiple colour scheme in motionless and in motion. It continues to capture object position accuracy in indoor environment where the light intensity had been controlled to condition of low light and normal light. In the other hand the fixed variable were the shape and the size of the object, background environment, angle of the cameras and light position.



```
Webcams are starting ...

Want to capture 40 chessboards for calibrate:
Number of couple Chessboards were found: 1
Number of couple Chessboards were found: 2
Number of couple Chessboards were found: 3
Number of couple Chessboards were found: 4
Number of couple Chessboards were found: 5
Number of couple Chessboards were found: 6
Number of couple Chessboards were found: 7
Number of couple Chessboards were found: 8
Number of couple Chessboards were found: 9
Number of couple Chessboards were found: 10
Number of couple Chessboards were found: 11
Number of couple Chessboards were found: 12
Number of couple Chessboards were found: 13
Number of couple Chessboards were found: 14
Number of couple Chessboards were found: 15
Number of couple Chessboards were found: 16
Number of couple Chessboards were found: 17
Number of couple Chessboards were found: 18
```

```
#define CV_EVENT_LBUTTONDOWN    1
#define CV_EVENT_RBUTTONDOWN    2

#define CALIBRATION 1

#define SHOW_DATA 1 //show and save interm
                    //set this to 0 when ju
#define SAVE_DATA 1
#define SHOW_DISTANCE 1 //output point clo
```

Figure 2. Successful camera calibration.



SADSize: 7
Texture th: 20
Uniqueness: 15
Num.Disp: 48
Save Dist: 0
Threshold: 29
Area: 181

```
tance to this object is: 51.436707 cm
tance to this object is: 51.627800 cm
tance to this object is: 51.691986 cm
tance to this object is: 51.627800 cm
tance to this object is: 51.756218 cm
tance to this object is: 51.627800 cm
tance to this object is: 51.756218 cm
tance to this object is: 51.820736 cm
tance to this object is: 51.691986 cm
tance to this object is: 51.820736 cm
tance to this object is: 51.756218 cm
tance to this object is: 51.756218 cm
tance to this object is: 51.885464 cm
tance to this object is: 51.885464 cm
tance to this object is: 51.820736 cm
tance to this object is: 51.820736 cm
tance to this object is: 51.950397 cm
tance to this object is: 51.885464 cm
tance to this object is: 51.885464 cm
tance to this object is: 51.885464 cm
tance to this object is: 51.820736 cm
tance to this object is: 51.950397 cm
tance to this object is: 51.885464 cm
tance to this object is: 51.756218 cm
```

Figure 3. Single red pin with distance of 60cm.

Figure 2 shows the successful method [7] camera calibration. If both images from left and right camera were quite similar, both images can easily have rectified and paired the points of the corner of the squares in between the both images. The result was determined by the colour produced from both images.

Figure 3 shows that single-red pin is used for the experiment. The pin is put 60cm from the camera and five data are recorded. Then the red pin is substitute with yellow and green pin respectively.

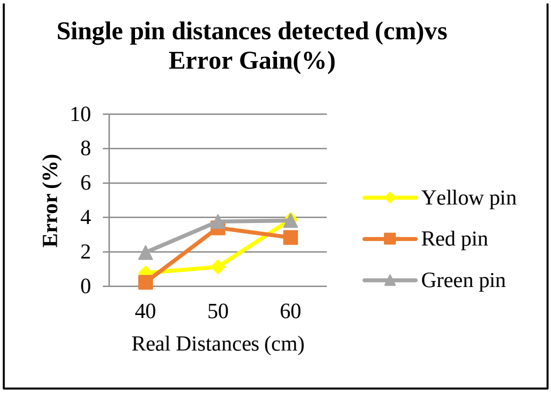


Figure 4. Result of single pin set up at different marks.

Figure 4 shows the result of single pin set up at different marks. For 40cm mark, the errors are 0.23%, 0.78% and 1.97% for red, yellow and green pin respectively. For 50cm mark, the errors are 3.4%, 1.1.2% and 3.76% for red, yellow and green respectively. Lastly for 60cm mark, the errors are 2.83% 3.88% and 3.82% for red, yellow and green respectively. This shows that at the mark of 40cm, the errors are the least among 50cm and 60cm mark. The hypothesis that has been stated for this project is the further the object, the less accuracy of the program to calculate the distance. However, all the errors are less than 5% which state that this algorithm is good for single object measurement.

Figure 5 shows that the behaviour of the graph for three pins in the environment is different from three pins without any environment. As for the three pins in the environment, the pattern of the graph line is totally different. It also has the biggest error among all the readings taken which is 3.7%. This shows that noisy environment can affect the calculation of distance within this algorithm.

Figure 6 shows the different degree of bright light. From the observation conducted during the experiment, the high intensity of light has the biggest error (30.7%) followed by low lux point (6.0%) and lastly followed by the smallest error which is normal lux point (0.8%) error. This shows that normal degree of bright light is the most suitable condition for measuring distances of an object. Although the sufficient intensity of light is needed, exceeding the normal range of bright light will make the program become more difficult to find the contour of the object thus harden the calculation of the distances.

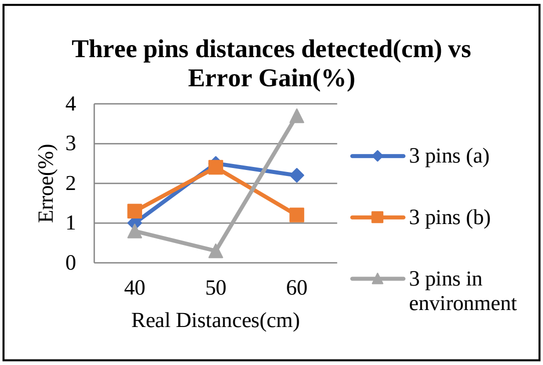


Figure 5. The behaviour of the graph for three pins in the different environments.

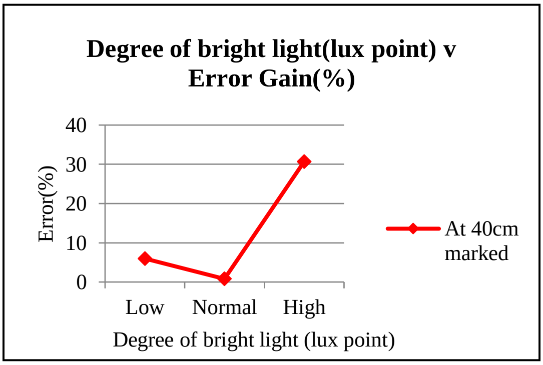
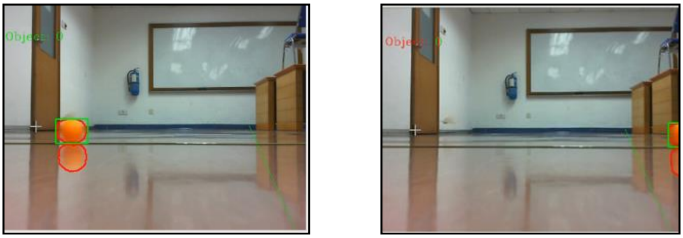


Figure 6. The different degree of bright light.

As for the detection for the moving object, the object will be mark in red colour if detected, then rectangle are created follow the red colour shape. Moreover, to justify the moving object fairly, the detected moving object must past green lines that have been created and the counter in object must increase as shown in Figure 7.



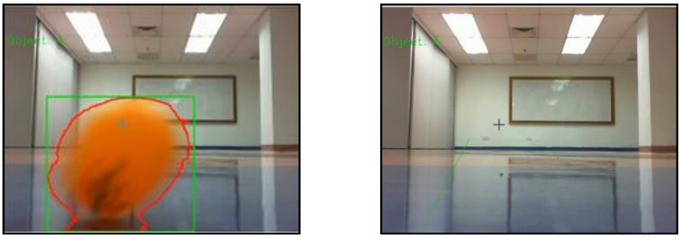
a) b)

Figure 7. a) The example of debug programming before moving object cross the green lines.
b) The example of debug programming after moving object cross the green lines.

Other than that, the count function can be used as benchmark, to detect the limit of the distance from the camera and speed of this programming.

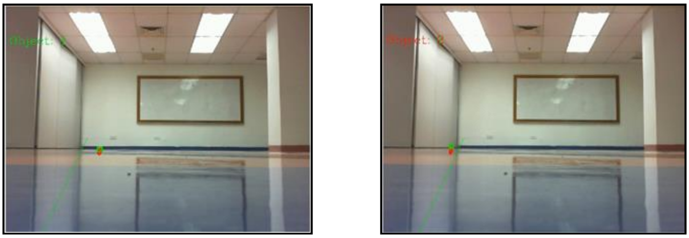
I. <u>Distance of moving object from webcam.</u>

By using the count function, the moving object must pass the green lines and count. It is to show the limitation distance of this program. The count function has been chosen as benchmark because, even the moving object far from the webcam, if the object counter still be counted, that mean the programming can still detecting the moving object as shown in Figure 8 and 11.



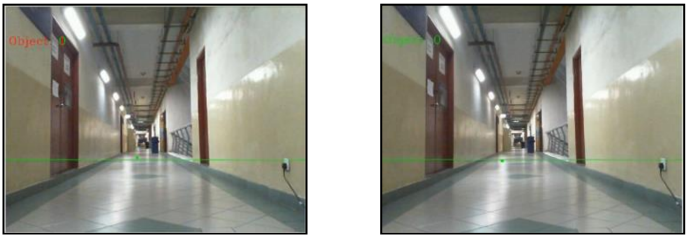
a) b)

Figure 8. a) Showing that the distance of moving object from webcam at 0.05 meter still fairly detected.
b) Prove the counter are been increase from 4 to 5 count, after the moving object cross the green line.



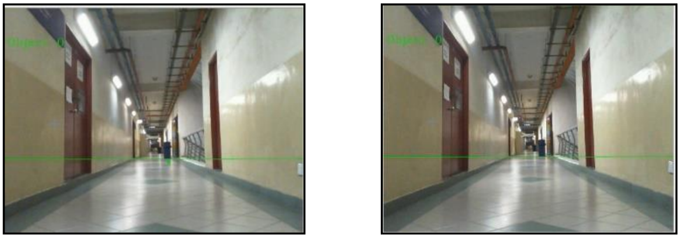
a) b)

Figure 9. a) At 10m, the moving object showing that it is fairly detected.
b) After the moving object crossed the green lines, the object is shown count from 1 to 2.



a) b)

Figure 10. a) The distance between moving object and web cam is 13meter, but the moving object detected.
b) The object count increase from 0 to 1 show it still detect at 13 meter distance.



a) b)

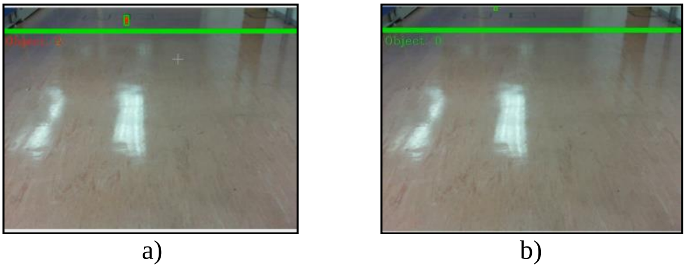
Figure 11. a) The moving object detected until 13meter distance from webcam
b) Show that moving object when reach 15meter distance are not detected, the object counter also does not increase

Since, the size of room is 10.2-meter length in Figure 9, the experiment cannot be carried out inside the room thus, we choose hallway outside to continue the experiment as shown in Figure 10.

From the result 13 meter is the limit of the detected moving object as shown in Figure 11. If the moving image is more than 13-meter distance, the moving object look too small, thus it considered no changes in the background image.

II. <u>Speed of Moving object.</u>

For moving object count function, the object must pass the green lines to be count.



a) b)

Figure 12. a) At 1.5m/s object speed, the object are still detected and the count is increase
b) At 3.0 m/s object speed show an example of detected moving object but not counted.

From the result the threshold of the object speed for moving object to be count is set to 1.5m/s. If the moving object speed is more than 1.5m/s, the object will not be count even the moving object been detected and mark as shown in Figure 12.

4 Conclusion

There are a lot of binocular vision types that can be used for the distance measurement purposes. The most common one is trigonometry method that used triangle as the main concept for the calculation. A less demanding technique for calibrating extensive standard vision system should be produced. Presently, the main techniques for doing this is by utilizing an expansive checkerboard or physically extricating focuses from a huge object with highlight purposes of known measurements. Nevertheless, there is an easier step that may be used which is by anticipating a system, where a highlight focuses can be removed effectively, onto the side of a building or floor and taking pictures for adjustment. According to the previous researches that have been done, detecting objects contour is commonly simpler object geometry such as straight lines, circle, square and rectangle [8][9]. This is because the objective itself is to measure the distance regardless the shape of the object [10].

As a conclusion, based on the data that have been obtained from this experiment, this project can be concluded that the colour of an object does not affect the depth map of the image. Although the colours are changed, the distances of the object detected are quite similar with each other. On the experimental analysis, the main factor that affects the distances that will be computed is the range of distances from the binocular eyes system source itself [11]. The further the objects from the camera, the higher percentage of errors will be recorded. Therefore, the calibration of the cameras is important in order to get the focus point from both images that act as the range precision. Other than that, the control windows that control the parameters of the object need to be detected are important too. It controls the program not to detect any other components that have no relation to the distances that wanted to be measured. The degree of light (lux point) is one of the critical parts of this experiment. The large amount of light will induce glare for the binocular vision. This will disturb the value of depth map that want to be calculated because the difficulty to find the blob contour of the images. In this project, the experiment that have been conducted conclude that the precision and accuracy of the distance detected is based on the result of calibrated cameras and the amount of light must be in the range of normal lux point otherwise new algorithm should be designed. On the experimental analysis for the moving object, it shows that the distance limit of the programming to detect moving object is more than 13meter. However, the result might not be obtained accurately due to the interference from the outside such as wind and dim lighting, hence, the objectives of this project are fulfilled.

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