The 'Camera Aided Topography Measurement System' has digital image processing as its backbone.

Image processing is any form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or, a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. Image processing usually refers to digital image processing, but optical and analog image processing are also possible.

Digital image processing is the use of computer algorithms to perform image processing on digital images. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing.

1.1 Aim of the Project

To determine the distance between a particular object and a camera (observer) with the help of digital image processing.

Problem Statement:

Calculation of distance between an object and camera (observer) based on the axial orientation of an object with respect to the camera axis.

1.2 Objectives

1. Real Time fetching of an image.
2. Processing it digitally, using MATLAB, for recognition of objects present in the image.
3. Computing distance between the recognized objects and the observer.
4. To produce the audio visual data analysis on the computer display.

1.3 Brief History and Recent Trends

There are many proposed methods for detection of object or obstacle and measurement of their respective distances.

The conventional methods are based on *SONAR*, reflection of *radiation* waves or *Photo-Devices*. But these methods have some limitations.

1. *Ultrasonic* based and *laser* based techniques depend on the nature of the reflective surface.
2. These methods fail in geometrical interpretation of the object.
3. These methods are less effective in categorization of the object.

Recent developments in the distance measurement technology using image processing are being developed. *Photonic mixer device (PMD)* and *Image based distance measuring system (IBDMS)* are some of them. PMD provides the real time distance in Two Dimensional images. But the major disadvantage is that; it has *low resolution* and limited *field of view*. Another approach was made in order to eliminate this discrepancy with a process called IBDMS. But this approach worked only for the objects which were perpendicular to the optical axis. Hence in order to remove these limitations, we are presenting 'Camera Aided Topography Measurement System'.

As mentioned earlier, Digital image processing is the use of computer algorithms to perform image processing on digital images. The first step we came across is the image pre-processing; which includes smoothening of the background texture, grayscale conversion, binarization and image enhancement; which is then used for object detection and distance analysis.

Image Preprocessing Fundamentals

2.1 Grayscale Conversion

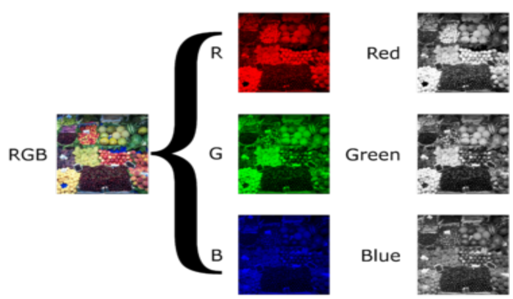


Figure 1(a) RGB to Grayscale Conversion

Figure 1(b) Original Image and its Grayscale

A grayscale digital image is an image in which the value of each pixel is a single sample, that is, it carries only intensity information. Images of this sort, also known as black-and-white, are composed exclusively of shades of gray, varying from black at the weakest intensity to white at the strongest.

Grayscale images are also called monochromatic, denoting the presence of only one (mono) color (chrome). Grayscale images are often the result of measuring the intensity of light at each pixel in a single band of the electromagnetic spectrum.

To convert any color to a grayscale representation of its luminance, first, one must obtain the values of its red, green, and blue (RGB) primaries in linear intensity encoding.
Grayscale images are commonly stored with 8 bits per sampled pixel, which allows 256 different intensities (i.e., shades of gray) to be recorded, typically on a non-linear scale.

The intensity of a pixel is expressed within a given range between a minimum and a maximum, inclusive. This range is represented in an abstract way as a range from 0 (total absence, black) and 1 (total presence, white), with any fractional values in between.

To convert a gray intensity value to RGB, simply set all the three primary color components red, green and blue to the gray value, correcting to a different gamma if necessary.

2.2 Binarization

Image binarization converts an image of up to 256 gray levels to a black and white image.

The simplest way to use image binarization is to choose a threshold value, and classify all pixels with values above this threshold as white, and all other pixels as black. The problem then is how to select the correct threshold. In many cases, finding one threshold compatible to the entire image is very difficult, and in many cases even impossible. Therefore, adaptive image binarization is needed where an optimal threshold is chosen for each image area.

Image binarization is a process which is very important in detection of object. The main purpose of binarization is conversion of an image into two sets that is foreground and background. Binarization can be of two types:

1. Global Binarization
2. Local Binarization.

Global Binarization is a technique in which the threshold is created on the basis of the whole image and using this threshold the image is converted into foreground and background.

Local Binarization is a process in which the threshold of the image is created based on the neighboring pixel values. Global binarization is a faster method than local binarization.ons.

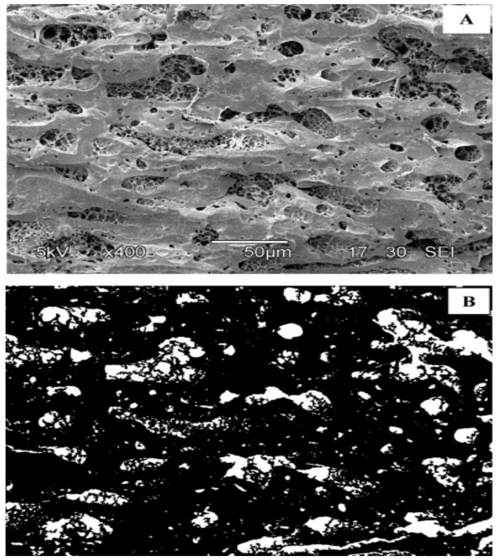


Figure 2 Original Image and its Binarized Image

2.3 Erosion and Dilation

Erosion and Dilation are two fundamental morphological operations. Dilation adds pixels to the boundaries of objects in an image, while Erosion removes pixels on object boundaries.

The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. The rule used to process the pixels defines the operation as dilation or erosion.

For dilation, the value of the output pixel is the maximum value of all the pixels in the input pixel's neighborhood. In a binary image, if any of the pixels is set to the value 1, the output pixel is set to 1.
For erosion, the value of the output pixel is the minimum value of all the pixels in the input pixel's neighborhood. In a binary image, if any of the pixels is set to 0, the output pixel is set to 0.

Figure 3(a) Original Image with its Dilated Image

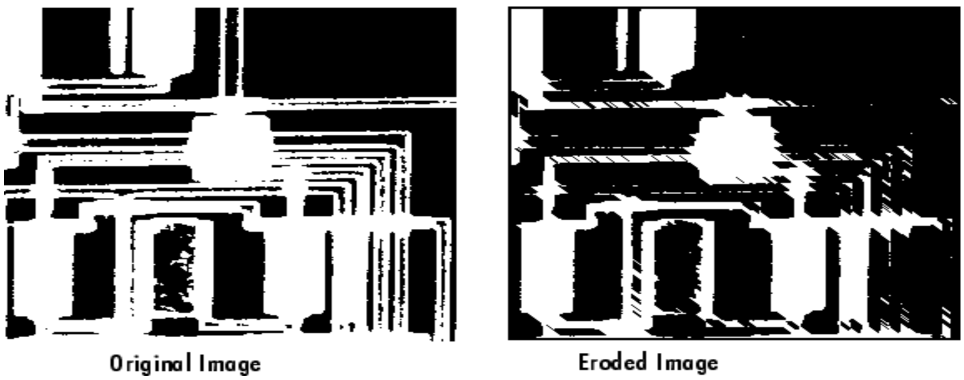


Figure 3(b) Original Image with its Eroded Image

Figure 3(c) Original Image - Dilated Image - Eroded Image

2.4 Image Enhancement

Image enhancement is the improvement of digital image quality, without knowledge about the source of degradation. If the source of degradation is known, one calls the process image restoration. It can be achieved by subtracting the Eroded Image through the Dilated Image.

Dilation, in layman's language, simply means *thickening* and Erosion means *thinning*. When thinned image is subtracted from the thickened image, we get the edge of the object.

2.5 Edge Detection:

Edge detection is one of the most commonly used operations in image analysis, and there are probably more algorithms in the literature for enhancing and detecting edges than any other single subject. The reason for this is that, edges form the outline of an object. Edge is a boundary between two homogeneous regions.
Edge detection refers to the process of identifying and locating sharp discontinuities in an image.

This means that if the edges in an image can be identified accurately, all of the objects can be located and basic properties such as area, perimeter, and shape can be measured. The purpose of detecting sharp changes in image brightness is to capture important events and changes, in the properties of the world.

Ideally, the result of applying an edge detector to an image, may lead to a set of connected curves that indicate the boundaries of objects, the boundaries of surface markings as well as curves that correspond to discontinuities in surface orientation.

2.5.1 Edge Detection Methods

Figure 4(a) Original Image

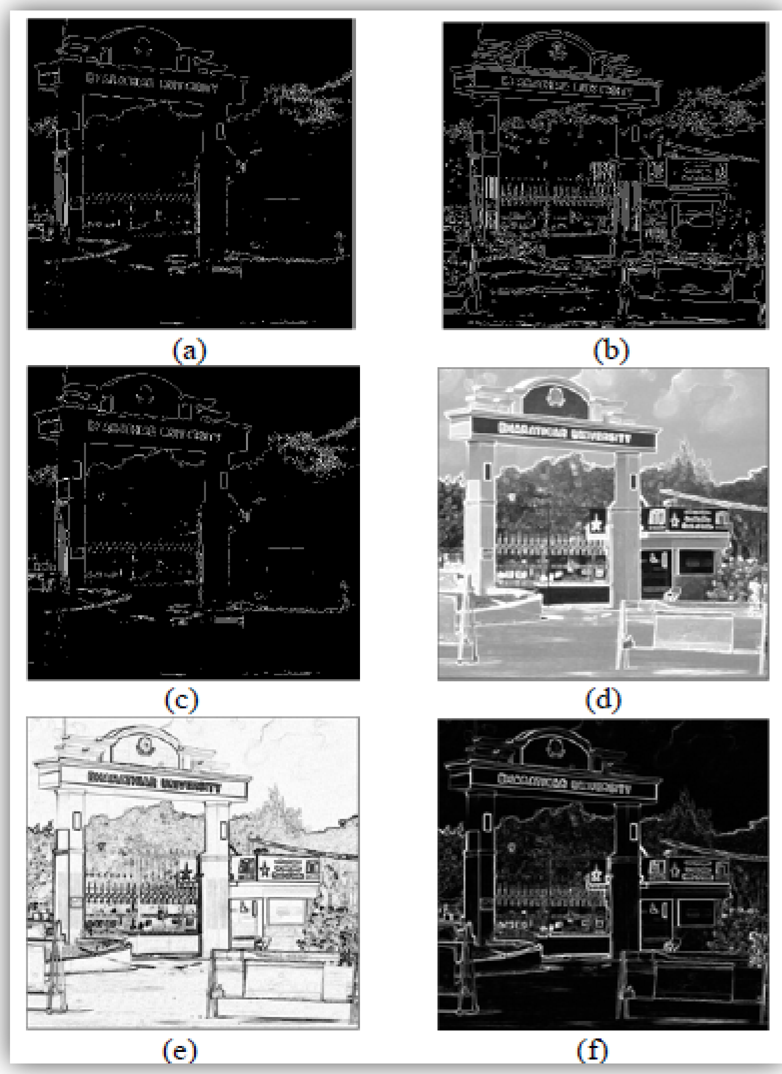


Figure 4(b) a. Prewitt Method b. Roberts Method c. Sobel Method d. Fuzzy Method e. Generic Method f. Neural Network Method

3.1 Block Diagram

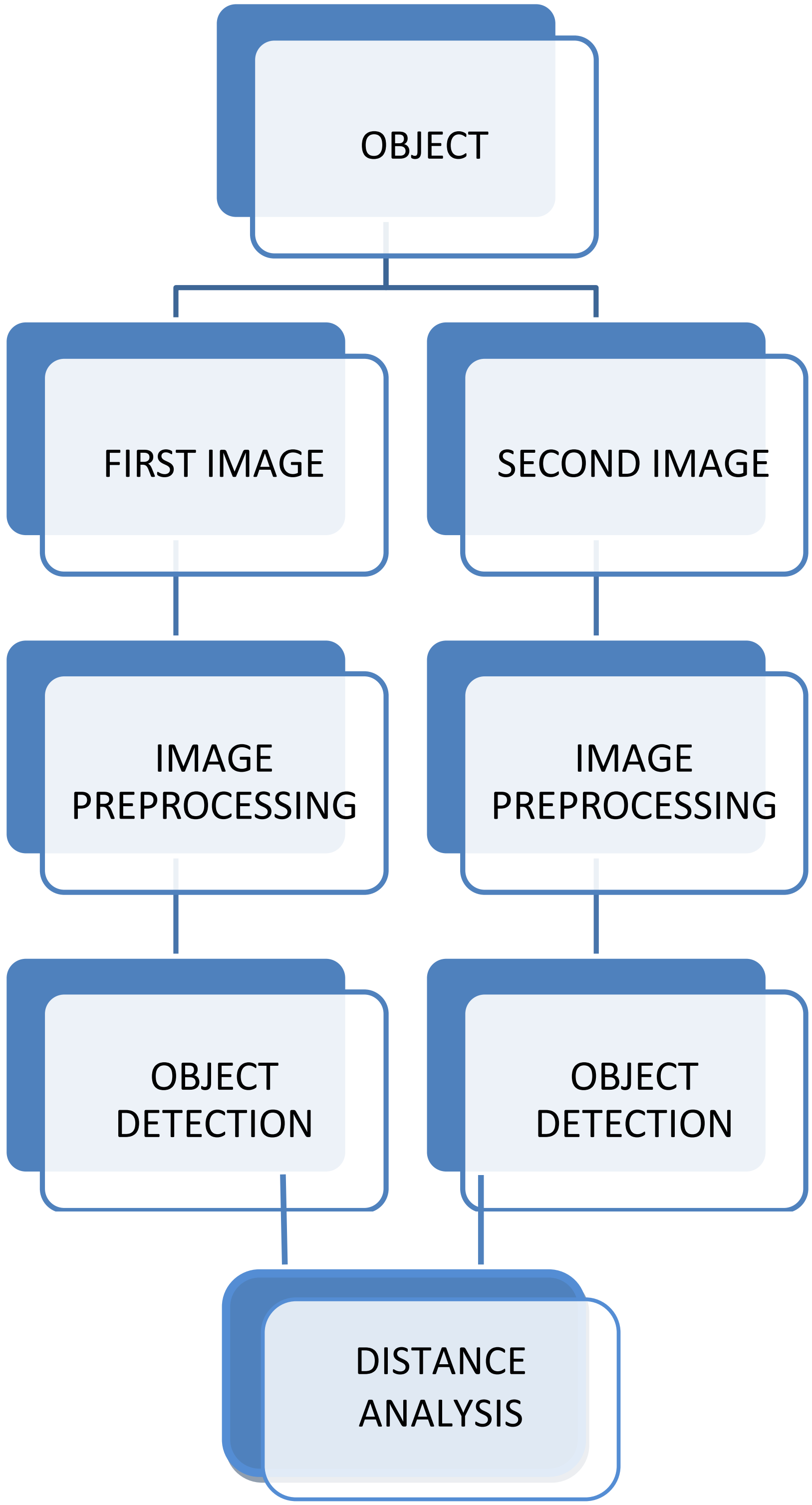


Figure 5 Block Diagram Representation

Earlier Approach

As soon as the idea strike our minds, we started searching for the literature and theory related to it.

We were first following the IEEE paper, HongZhang,LeiWang, Ruiming Jia,Image Processing Centre,Beihang University,Beijing, China,Junwei Li,National Key Laboratory on Optical Features of Environment and Target,"A Distance Measuring Method Using Visual Image Processing", Supported by the National Natural Science Foundation of China (Grant No. 60872079) and National Key Laboratory on Optical Feature ofEnvironment and Target Foundation (No. 9140C6105020805).

But we came across some limitations of this paper.
The major limitation was that it was efficient only for the plate type objects.

Hence after doing some survey, we found the new paper which is been used further as a base for our 'Camera Aided Topography Measurement System'.

3.2 Methodology

The scheme of the proposed method includes the following steps:

1. Image pre processing which includes;
   a. Grayscale Conversion of an image
   b. Image Binarization
   c. Image Erosion
   d. Image Dilation
   e. Image Enhancement
2. Object Detection
3. Distance Analysis

3.2.1. a Grayscale Conversion

An RGB image is converted to Grayscale i.e. Black-n-White image.
First an image is taken in MATLAB.

```
%Image reading and image display
image = imread(‘ path directory of a file ’);
imshow(image);

%Conversion to Grayscale
gray_image  = rgb2gray(image);
imshow(gray_image);
```

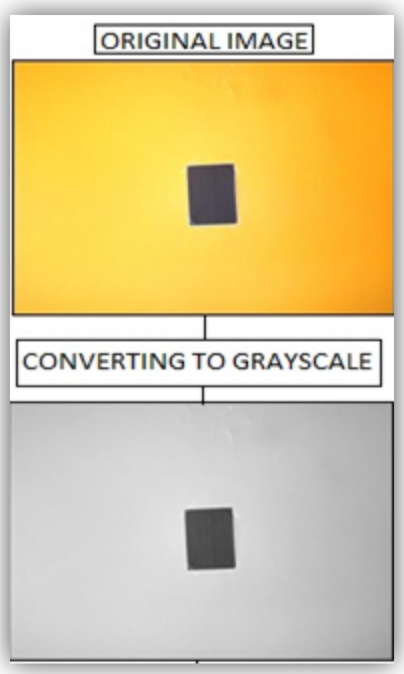
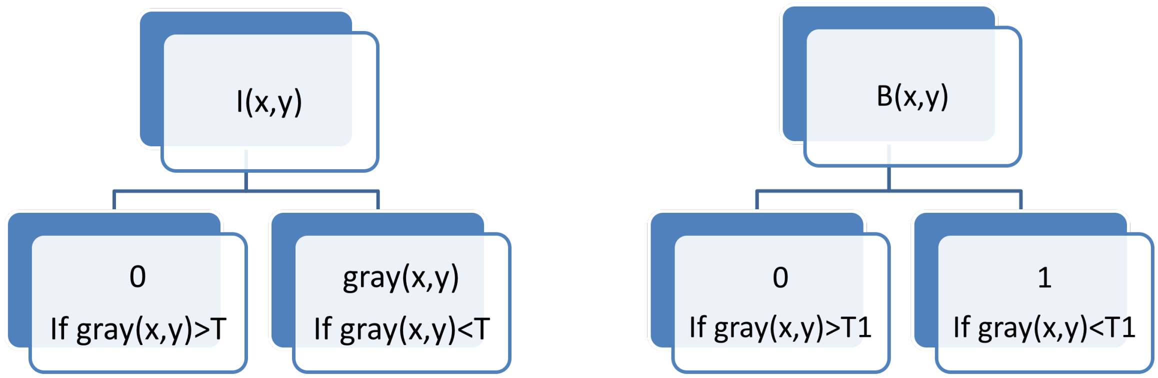


Figure 6 Process of Grayscale Conversion

3.2.1. b Image Binarization



- I(x,y) = Intermediate Image
- B(x,y) = Binarized Image
- T = Global Threshold
- T1 = Changed threshold

Figure 7 Process of Binarization

Grayscale images of unsigned integer (uint8) type contain intensity values ranging from 0 to 255 where 0 stands for black and 255 for white. For finalizing the image, a threshold is decided and then the image is converted into an array of ones and zeros based on this threshold.

The procedure consists of two steps:

i) Threshold detection
ii) Binarization of the image based on this threshold

Threshold detection is done by a procedure as mentioned below.
Global Binarization is a faster method than local binarization. Hence we have used here global binarization.

3.2.1.b.i Calculating global threshold of the image

The global threshold can be calculated by taking the average of the pixel values in the grayscale.

Equation 1

$$\mathrm{T} = \left\{ \sum_{(k,l)=(1,1)}^{(rows,cols)} \mathrm{gray}_{\mathrm{image(k,l)}} \right\} \div (rows * cols)$$

The image is then grouped by this threshold

$$I(x,y)=\begin{cases} 0 & \text{if } gray\_image(x,y) > T \\ gray\_image(x,y) & \text{if } gray\_image(x,y) < T \end{cases}$$

This image can also be called as an *'intermediate image'*.
The intermediate image which is obtained is again subjected to averaging operation but the averaging is done for only that value of pixels which are non zero and then the final threshold is calculated.
The threshold will change since the maximum background pixels are made 0.
Let the threshold be called T1.

3.2.1.b.ii Binarization of the image based on new threshold

The final Binarized image is obtained by the following method

$$B(x,y)=\begin{cases} 0 & \text{if } gray\_image(x,y) > T1 \\ 1 & \text{if } gray\_image(x,y) < T1 \end{cases}$$

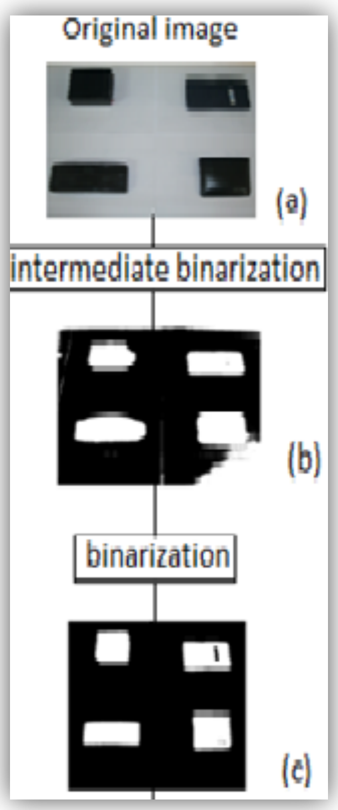


Figure 8 Binarization

3.2.1.c Image Erosion

The image obtained is then enhanced by a process of image erosion and dilation and then subtraction of those two images to obtain an enhanced image.

Let E(x,y) be the *'eroded image'*.
E(x,y) = imerode(B(x,y));

3.2.1.d Image Dilation

Let D(x,y) be the *'dilated image'*.
D(x,y) = imdilate(B(x,y));

3.2.1.e Image Enhancement

The enhanced image is obtained by subtracting the eroded image from the dilated one.

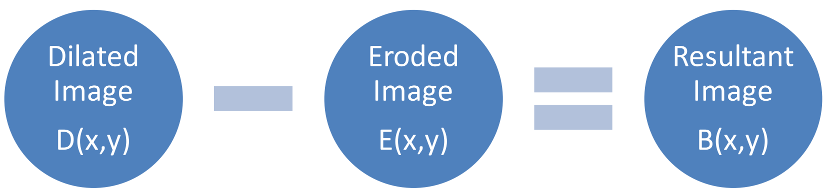


Figure 9 Process of Image Enhancement

B(x,y) = D(x,y) - E(x,y);
Where;
D(x,y) is the Dilated Image
E(x,y) is the Enhanced Image
While B(x,y) is the *'enhanced image'*.

This process will remove any redundancies which were not removed in Step a and b.

The finally *enhanced image* is further processed for object detection.

3.2.2 Object Detection

The final detection of object is carried out by the value of the pixels in the binary image. The *Bounding-Box Technique* is used further in order to find the maximum length and breadth of the object.

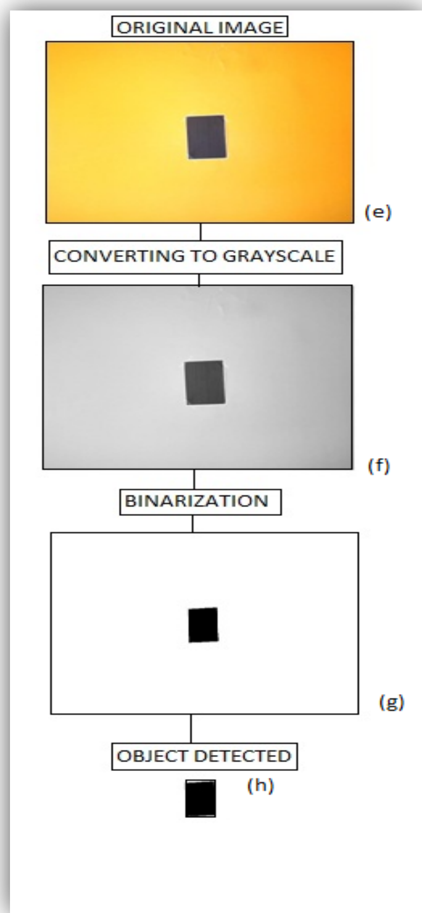


Figure 10 Final Object Detection

3.2.3 Distance Analysis

The final enhanced image is used for the object detection. There are three cases in distance analysis according to the orientation of the object with respect to the optical axis of the camera.

a. Object perpendicular to the camera axis
b. Object oblique to the camera axis
c. Two dimensional analysis of the object

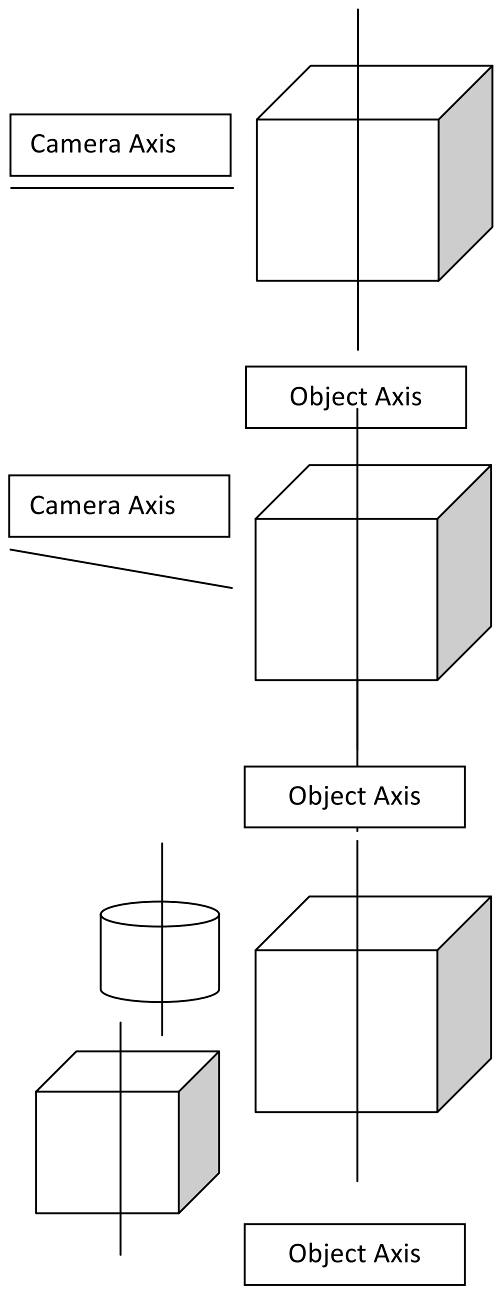


Figure 11 a. Object Perpendicular to the Camera Axis b. Object Oblique to the Camera Axis c. Two Dimensional Localization of the Object

All the mathematical formulae, equations and diagrams are taken from the Reference [1] Chen-Chien James Hsu, Member, IEEE, Ming-Chih Lu, and Yin-Yu Lu," Distance and Angle Measurement of Objects on an
Oblique Plane Based on Pixel Number
Variation of CCD Images", IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 60, NO. 5, MAY 2011

General procedure

An image is a two dimensional figure. So we cannot calculate the distance of the object from the camera with a single image and pixel count.

So we need to take at least two images and these two images should be shot by shifting the camera with a known shift in the lateral distance.

The distance by which the camera is shifted should be known. This distance is used in the formulae given below.

3.2.3.a Object perpendicular to the camera axis

Here an image is shot by taking the plane of the object exactly perpendicular to the plane of camera.
Another image is taken by shifting the camera towards or away from the object and the shift in position is also known.
Now by using the processes from 3.2.1.a to 3.2.4.b the horizontal length can be calculated. Let N1(L) be the length of the *Bounding-Box* obtained from 3.1.4 from first position image and N2(L) be the length from the second position.

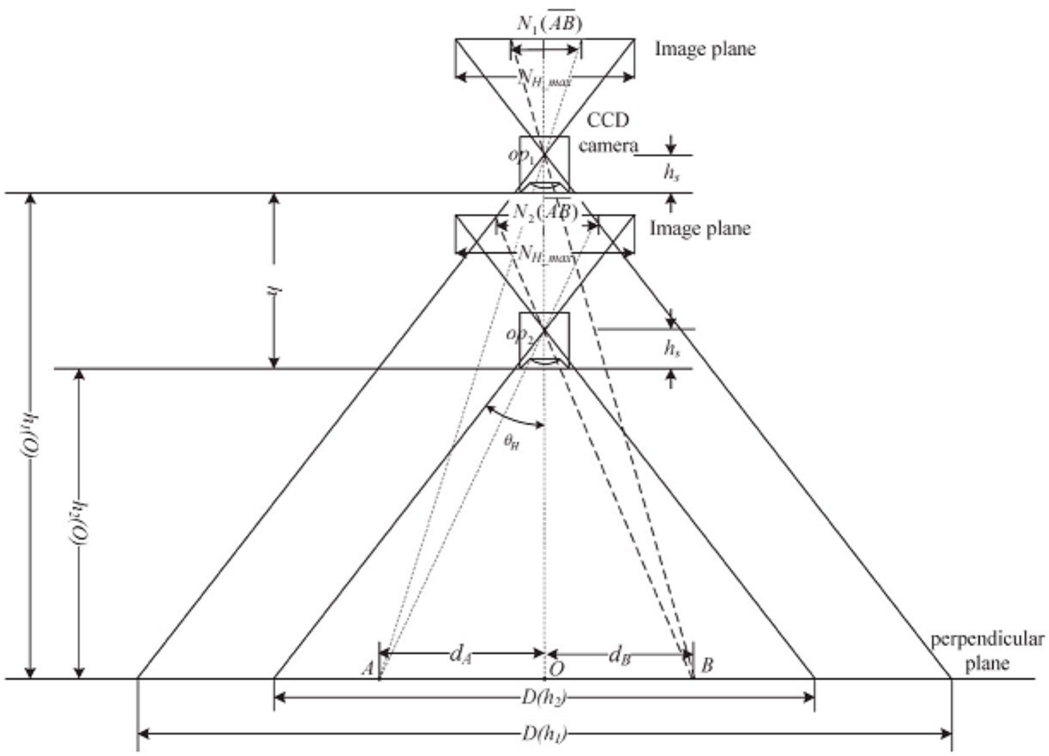


Figure 12 Schematic Diagram depicting the relationship between distance and variation of pixel counts at different photographic distances

$$N1(L) = N1(\overline{AB})$$
$$N2(L) = N2(\overline{AB})$$

The distance between the camera is calculated by the below formula

Equation 2

$$h1(O) = \frac{N2(L)}{N2(L) - N1(L)} \times (\Delta\mathrm{D} - hs)$$
$$h2(O) = \frac{N1(L)}{N2(L) - N1(L)} \times (\Delta\mathrm{D} - hs)$$

Here

h1(O) denotes the real-time distance of the object from the camera for position 1

h2(O) denotes the real-time distance of the object from the camera for position 2

ΔD is the known change in the position of the camera

hs is the distance between front end of the camera and optical centre of the camera

3.2.3.b Object Oblique to the Camera Axis

The procedure is similar to 3.2.3.a except the object's plane now is oblique to the optic axis of the camera.

Let the extremities of the object be denoted by point A and B.

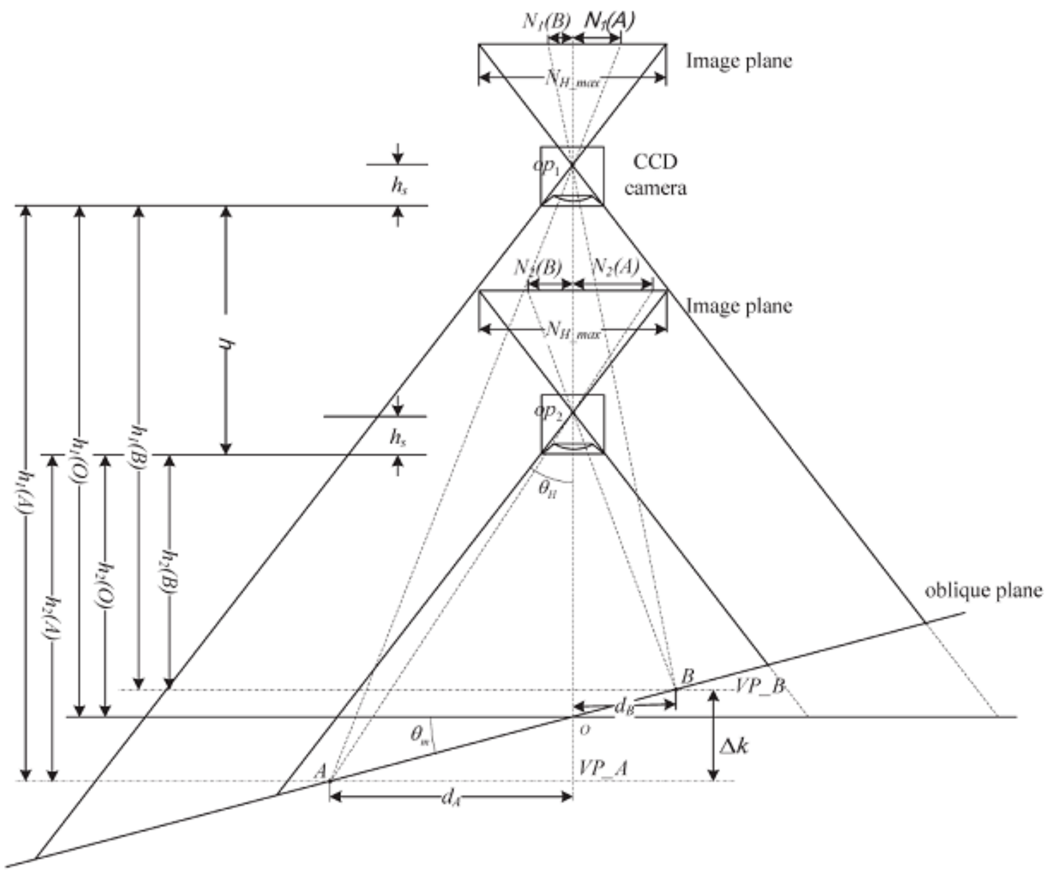


Figure 13 Configuration of the proposed image-based system for measuring objects on an oblique surface based on variation of pixel counts

The expression is

Equation 3

$$dA = \frac{2N1(A) \times N2(A)}{\big(N2(A) - N1(A)\big) \times NH_{max}h} \times tan\ \theta H \times \Delta \mathrm{D}$$

$$dB = \frac{2N1(B) \times N2(B)}{\big(N2(B) - N1(B)\big) \times NH_{max}h} \times tan\ \theta H. \times \Delta \mathrm{D}$$

Here;

$N1(A)$, $N1(B)$, are the number of pixels from the centre of the image to point A and B respectively.

Here dA is the distance of the point A from first position.

Here dB is the distance of the point A from first position.

$NH_{max}h$ is the maximum number of horizontal pixels in a row of an image.

θH is the half of maximum horizontal angle a camera can cover.

Thus, the photographic distances from the camera at positions 1 and 2 to point O which is the camera can be, respectively, expressed as

Equation 4

$$d1(O) = h1(A) - dA\ tan\ \theta m = h1(B) + dB\ tan\ \theta m$$

$$d2(O) = h2(A) - dA\ tan\ \theta m = h2(B) + dB\ tan\ \theta m.$$

$d1(O)$ and $d2(O)$ is the distance of the object's centre from the first position and second position respectively.

3.2.3.c Two Dimensional Localization of the Object

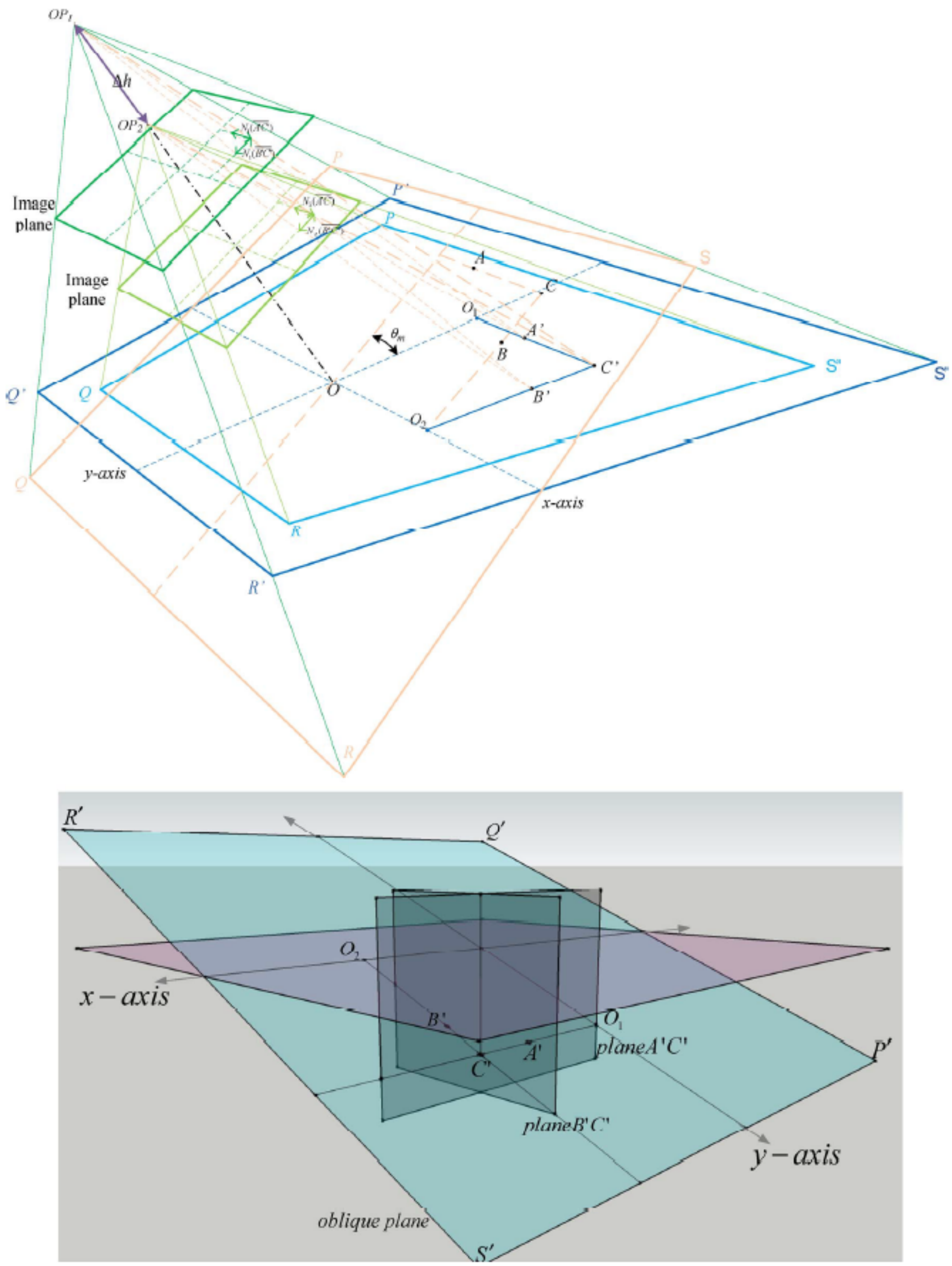


Figure 14 Perspective diagram showing the localization scheme using the proposed measurement method based on variation of pixel counts

The Two dimensional localization of the object is done whenever there are more number of objects in a plane and object is not at the centre of the plane or image.

The algorithm is as follows.

1. Divide the image into four quadrants.
2. Search for the pixel discontinuity in each quadrant and detect the object.
3. Then create a *Bounding-Box* around it; which gives the four corner points of the object.
4. Find out the mid-point of the concerned object.
5. Assume that point as C.
6. Use the row number of C and trace the object length on either left or right direction to get the end of the object, increment the count by 1.
7. Similarly use the column number of C and trace the object breadth wise on either up or down direction to get the end of the object, increment the count by 1.
8. Use these two count values for further calculation.
9. Let the horizontal count be N2(A'C') for second position image.
10. Let the horizontal count be N1(A'C') for first position image.

The distance of the object will be,

Equation 5

$$h1(A') = h1(C') = \frac{\mathrm{N2(A'C')}}{\mathrm{N2(A'C')} - \mathrm{N1(A'C')}}$$

where; *h1(A')* and *h1(C')* are the distance of the points A and C respectively.

In Chapter III, we have seen how we can go about the distance measurement. We used MATLAB R2011b for this processing.

1. For real time image fetching we are interfacing *HP Basic Starter Camera 'Supercomp' 1.3MP Resolution 640 x 480* web-camera.

   imaqtool is used for interfacing camera with the MATLAB and for acquiring images. %Image Acquisition Tool (Image Processing Toolbox)
   imread ( ) %Fetching an image from File System
   imwrite( ) %Writing image to the File System

2. For some image pre-processes, we have used inbuilt MATLAB functions such as;

   gray_image = rgb2gray( ); %Grayscale Conversion
   erode_image = imerode( ); %Image Erosion
   dilate_image = imdilate( ); %Image Dilation

   For image erosion and dilation we have used the *'Diamond Shaped'* structuring element.

3. Rest of the processes, including Object Detection and Distance Analysis, are done on the image pixel value matrix.

4. Front end is the elaborative, interactive yet simple *Graphical User Interface.*

4.1 Working Setup

4.2 GUI Screenshots along with the simulation

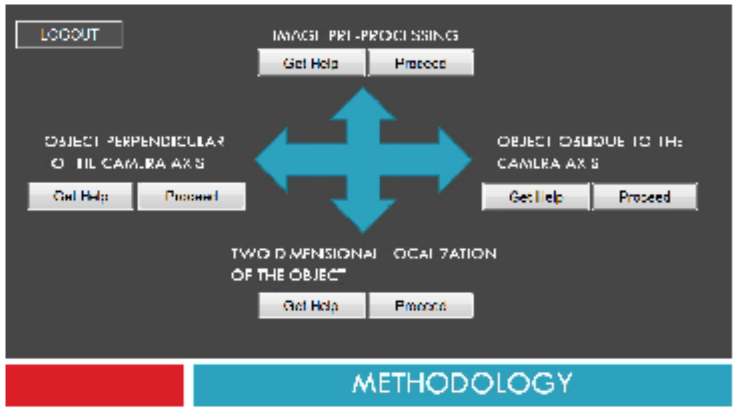


Figure 15(a) Main page GUI

The GUI shows a complete flow of the project. Each topic is provided with a separate help window.

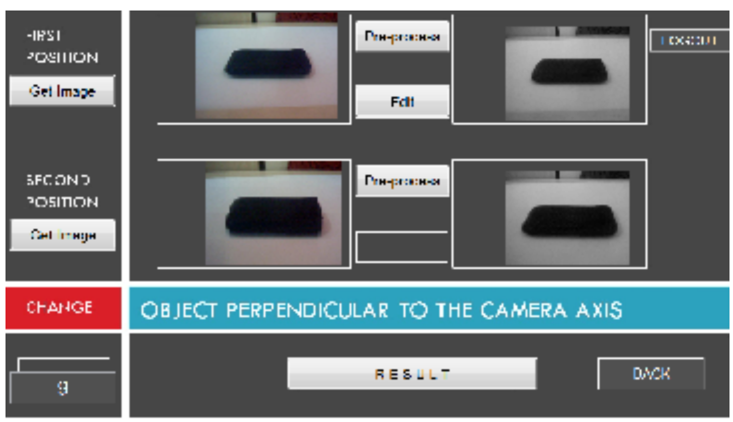


Figure 15(b) GUI for Object Perpendicular to the Camera Axis

The GUI is provided with the ‘Get Image’ button, which is helpful in a real time image fetching. It has four image displays. Two for originally captured images and rest of the two for showing preprocessed images. ‘Edit’ button opens the editor having all basic functions and processes such as brightness-contrast-color adjustment and various edge detection techniques.

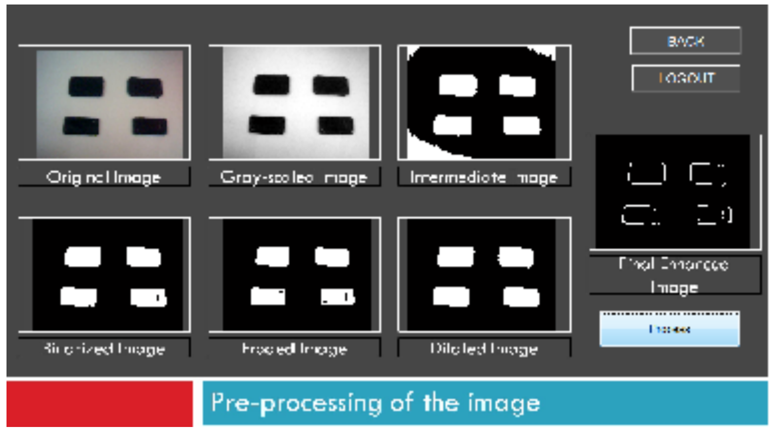


Figure 15(c) GUI for image preprocessing

The GUI has separate image showing windows each representing a different subprocess.

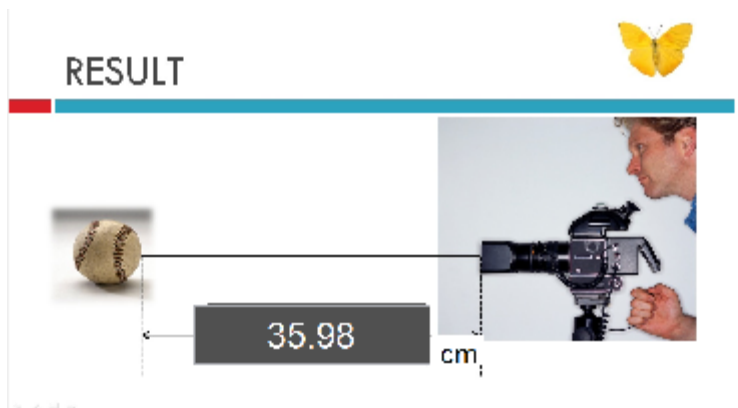


Figure 15(d) GUI for showing Final Result

The GUI has a text display which shows the output result. It is provided the audio feedback.

5.1 Results

Here are some of the experimental simulation results according to the cases.

5.1.a Object Perpendicular to the Camera Axis

Change in distance *(ΔD)* =10cm, *hs*=0.7

Table 1 Results: Object Perpendicular to the Camera Axis

Resolution	VGA	1536*2048	1944*2592
Actual distance	162cm	162cm	162cm
Measured distance	169.26cm	191cm	151cm
Error (%)	4.16	17.9	-6.21

5.1.b Object Oblique to the Camera Axis

The distance of the mobile from the camera was calculated

Table 2 Results: Object Oblique to the Camera Axis

Actual distance	30
Measured distance	28
Error (%)	6.66

5.1.c Two Dimensional Localization of the Object

Change in Distance (ΔD) =8cm, $hs = 0.7$

The distance of the lower left object is done.

Table 3 Results: Two Dimensional Localization of the Object

Actual distance	64
Measured distance	70.92
Error (%)	10.8

5.2 Error Analysis

i) Main cause of the error in the obtained readings is the *change in the angle* between the camera and the object while taking the images in two positions.
ii) Another cause of the error is error in *measurement of distance* between the two positions.
iii) Error in counting the *number of pixels* which mainly depends on the pre-processing of the image.
iv) The *resolution* of image also plays a very important role because more the resolution of an image more is the error amplified in measuring the number of pixels. Table 1 clearly explains this.

5.3 Future Scope

i) ***Car Collision Avoidance System:***
Device can be mounted on the cars which can calculate the distance between the device mounted car and the car in front by taking two shots. By knowing the distance and the time between the two shots, we can calculate the speed of the car and can predict about the collision whether it will take place or not.

ii) ***Visual Aid for Blind People:***
Device can detect objects and find out distances, so can guide a blind man to find his way out.

iii) ***Augmented Reality World:***
A virtual world can be created by creating virtual images of the surrounding.

Conclusion

An algorithmic approach for the image processes such as binarization, segmentation and object detection.

'Binarization' is independent of the illumination of the object.

'Bounding-Box Technique' is used for the object detection.

An easy, faster and more efficient way is produced for the 2D localization of the object.

References

[1] Chen-Chien James Hsu, Member, IEEE, Ming-Chih Lu, and Yin-Yu Lu," Distance and Angle Measurement of Objects on an Oblique Plane Based on Pixel Number Variation of CCD Images", IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 60, NO. 5, MAY 2011

[2]HongZhang,LeiWang,RuimingJia,Image Processing Centre,Beihang University,Beijing, China,Junwei Li,National Key Laboratory on Optical Features of Environment and Target,"A Distance Measuring Method Using Visual Image Processing", Supported by the National Natural Science Foundation of China (GrantNo. 60872079) and National Key Laboratory on Optical Feature of Environment and Target Foundation (No. 9140C6105020805)

[3] Digital Image Processing Using Matlab - Gonzalez Woods & Eddins

[4] MATLAB Official Website: http://www.mathworks.com