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Room Measurement Based on Machine Vision

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ABSTRACT: The 3D imaging system consisted of a camera, a cross line laser, and a Raspberry Pi circuit was used for automation and supported by python image processing. The system was able to calculate the width, length, and height of the door or window hence able to estimate the door or window volumes. The use of cross line laser beam for laser triangulation methods gives easiness for measuring width and length of the door or window beside its function to measure the door or window depth or height hence makes the system potential to be used for logistics and courier small holder companies. The accuracy of length measurement will be improved by scanning mode (3D scanner) where the door or window placed in a motorized stage. This system also can be developed for irregular object without complex algorithm.

[Keywords: cross line laser python image processing, complex algorithm]

1. INTRODUCTION

Most current generation smartphones can only take static, two-dimensional images. But a 3D mapping camera can record the entire shape of an object or scene and Room measurement based on machine vision. That means it can see around or inside of things, creating real depth rather than just the illusion of depth.

This isn't a new technology; it's just been expensive until now. To use Smart Picture to measure an object, room, structure, window, door you'll first need to capture every angle using a 3D mapping-capable camera. Once the shot is captured, Smart Picture provides you with a set of tools that let you specify exactly what you'd like to measure. The app then delivers the measurements via cloud-based platform. Home improvement businesses may find a smart measurement service like Smart Pictures very useful to their day-to-day operations. Contractors would save lots of time measuring dimensions of a room or building by letting a Smart Picture-powered app do the heavy lifting. Or in some cases, home improvement businesses could even outsource a preliminary estimate for a job by letting customers take the measurements even if they don't have a 3D mapping camera.

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Now a day's every system is automated to face various challenges. In the present days automated systems have unmanned operations, flexibility, reliability, and accuracy. Due to this demand every field prefers automated control systems. Especially in the field of electronics automated systems are giving good performance. If we are talking about distance measurement, there are various methods which are as discussed based on literatures.

1.1 Vision Based Distance Measurement System Using Single Laser Pointer Design for Underwater Vehicle:

In 2009 Melioidotic A, Mohammad A Rashid, Saputo Adi N & Agus Buddymoon et al. [4] introduced a Vision based navigation has been investigated and an approach by using single laser pointer. UUV is usually equipped with camera as the eye of operator and camera supported by computer vision can also give some important information. The design of the system and algorithm to be used for calculating horizontal and vertical distance between an object and camera. Beside the camera, a laser pointer is used for the set up and computer is used for image processing and data calculation. There are two major works in designing this distance measurement system. First is obtaining a real time image processing algorithm need for laser spot /mark detection. Second is finding a scaling factor or formula that convert the object position (pixels) on the image into real world position (meters). This technique deals with underwater unmanned vehicle used for distance measurement using red laser pointer by making spot and Image processing algorithm. There are many well-known algorithms such as MSER, SIFT etc. to be used for object detection and recognition but it takes few hundred milliseconds up to few seconds for complex image per frame. Thus, it is difficult to be used as part of a real time control system. As image of laser spot is taken by camera which is kept inside water from experiment point of view it is difficult to achieve. Firstly, we must arrange shielding to protect camera and laser pointer than between camera and target there is a region of water so there is some refraction index which must affect the image information. The proposed idea is somewhat using the same thing as laser pointer and camera of eight mega pixel but medium is air in both indoor and outdoor region and experimentation is possible. There is no complexity in experiment.

1.2 Pixel Area Based Target Distance Estimating and Corresponding Target Hitting Force Calculating Autonomous Robot Using Single Video Device:

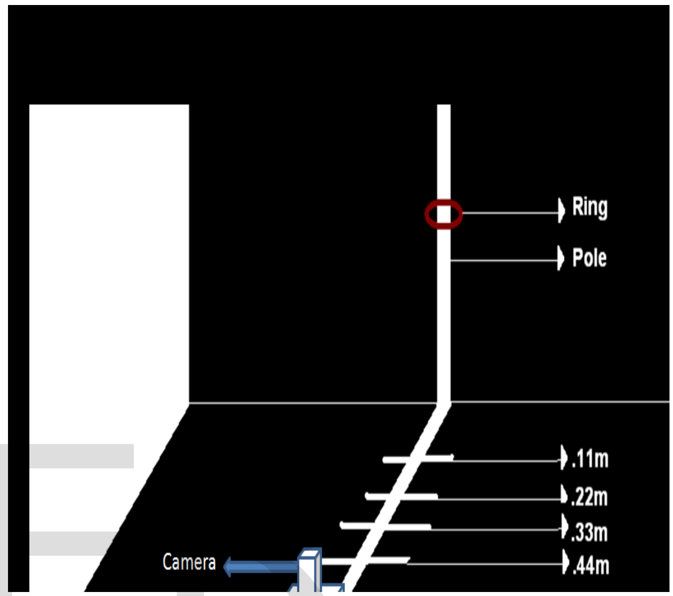
In 2011 by Astha Jain et. al. [1] developed robot works on an easier algorithmic to estimate the distance of associate object by using one camera. This paper presents a basketball playing robot works on white line algorithm estimates distance & calculating hitting force to basket the ball. Simply, When Robot is a basketball player and if there is a target to do goal by robot, so how robot will use its vision and mind to estimate distance of that basket to do goal.

Distance measurement term basically used here. So, on measuring distance, robot vision system uses orthodox White Line Tracing algorithm & for working of mind MATLAB programming is used .For White line Tracing algorithm we need to draw a broad white line or we have to use pole of white color in front of black background vertically and horizontally both and a normal camera is also needed because both methods depends on pixel counts so for pixel count image is compulsory and for image, camera is essential.

On the line, several discrete junctions are fixed. The user inputs the point, from which he wants the ball to be thrown, as achieved distance from using this algorithm basically performs a ball throwing mechanism as here robot is a basketball player.

The maximum distance considered for throwing the ball is 0.66 meter (from the pole) and minimum distance is 0.11 meter (from the pole). This distance range is measured on the straight white line starting from the base of the pole and aligned to it perpendicularly. There are five points fixed at 0.11m, 0.22m, 0.33m, 0.44 m and 0.66m from the pole. These points are identified as white junctions for better judgment. The robot can start from any point beyond 0.66m mark on the white line as in Its result basically shows in Fig 3-pixel area of pole verses distance graph, and this is totally indoor because in this experiment there is no discussion of light variation or natural light variation with respect to distance and time in image from which we are obtaining

Fig1. Distance range measurement



pixel count. There are some limitations in earlier paper that are: - 1) It was not able to measure distance more than 1 meter. 2) It was totally indoor.

1.3 A Review on Image Based Target Distance & Height Estimation Technique Using Laser Pointer and Single Video Camera for Robot Vision:

In 2015, Ms. Neha Shukla: This method, LBPA i.e., laser beam pixel area with Image based Distance Measurement Technique in Robot Applications presents a distance measurement method based on pixel count in images taken by 8mp cameras by referencing to two laser-projected spots in the object/target/wall using green laser pointer, to make this experiment less costly, commonly available camera of 8 megapixels and very commonly available green laser pointer will be experimental tools. Here camera is fixed from where images are taken of both laser projected spots, and this image is going through a program made in MATLAB using image processing toolbox which will be able to give us pixel count of that images as we have made our objective function as distance is a function of pixel count. By establishing a relationship between pixel counts and distance we get two different distances, through which we can measure height of the object, wall or target as these distances are base and hypotenuse of right-angle triangle. One of the advantages in using the proposed measuring approach is that it can make building height measuring instrument too. In this method hybridization of laser beam, camera, and image processing-based program for counting pixels is required. This experiment is useful in robot vision and separately it can be used as an instrument for measuring distance and height as well. In proposed work there are some Merits: -1) It can measure distance more than 1 meters. 2) Previous techniques were a hardware-based research of distance estimation, but this is semi hardware programming 3) It can be able to measure height of that object/wall. This alternative framework i.e., hybrid system of laser beam, camera, and image processing-based program for counting pixels of laser projected spots framework of this method is as shown in Figure below

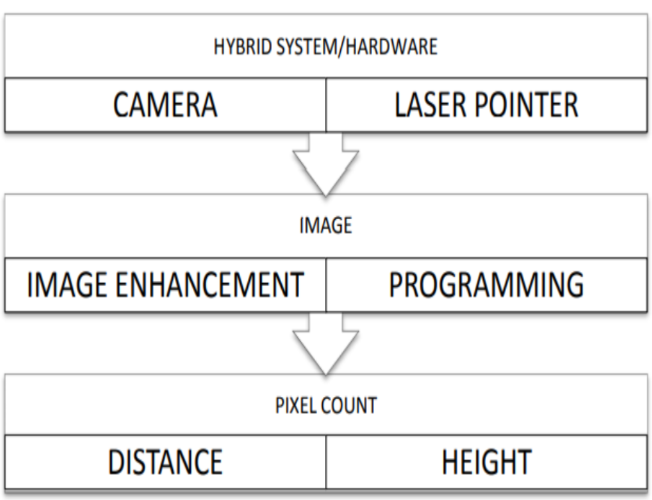


Fig2. Framework of the system

So, algorithm is based on distance= f (pixel count), which is our research objective. Our work is only concentrated in robot vision for making it efficient and more useful. The heart of this distance & height measurement technique for robot vision is MATLAB programming/coding, using image processing toolbox, which reads the image taken by camera. This methodology will go through experimentation and results with available stuff.

SUMMARY

This paper presents an introductory concept of various methodologies used to measure distance by ultrasonic based, laser based, image based, white line tracing-based algorithms for robot applications Laser beam pixel area Image based algorithm along with literature review of research work on distance measurement. The paper may help the new researchers expeditiously with a brief idea of distance measurement based on laser beam and image processing program and various paper studied may give a quick approach to the new researchers.

2. OBJECTIVE

- ✓ Real estate professionals (real estate agent, interior design decorator or designer, architect, topographer, energy adviser...): will help you make a floorplan of a house, apartment, a specific room of a flat.
- ✓ Construction workers can use it to quickly measure jobs: concreter, tile layer, carpet fitter, painter, drywall guy, plasterer, builder, carpenter, electrician, plumber, slater...
- ✓ For gardener, landscaper, swimming pool builders and maintenance, digger, earth-moving, navy: this app also works outside
- ✓ Cost estimation professionals: this length measure app can make pricing estimates; it will be a great

assistant for quantity surveyor, price studies technician, economist…

- ✓ Building industry: foreman, site manager or engineer can drop their tape measure and ruler to perform a quick measurement check

3. PROPOSED METHODOLOGY

The application of line laser and laser triangulation method can reduce the number of cameras and make the system simpler. The triangulation method was effectively used to measure concrete surface morphology

3.1 3D imaging using cross line laser

In this study, an automatic 3D imaging technique using laser triangulation method was used to estimate volume of door or window with different sizes. The system was constructed without moving stage and used a cross line laser. **Cross line laser beam offers more advantages than using one line laser beam or stripe structured light** in estimation door or window volume. Algorithms to extract two laser lines to find width, length, and height of the door or window are presented.

The 3D imaging setup is comprising of three main components which are:

- ✓ Camera with CMOS sensor of QSXGA 5 MP
- ✓ Cross line laser with 650 nm wavelength
- ✓ Raspberry Pi 3B+ 1GB, RAM quad-core 64-bit @ 1.4GHz.

Laser beam is illuminated onto the door or window surface, then reflected into the camera, the three components form a triangle. There are four configurations can be used for laser triangulation methods which depend on the camera and line laser position, each has benefit and drawback. The configuration is known as reverse geometry]. This configuration is simpler and robust, the line image is not disturbed hence no need complex algorithm to extract line information.

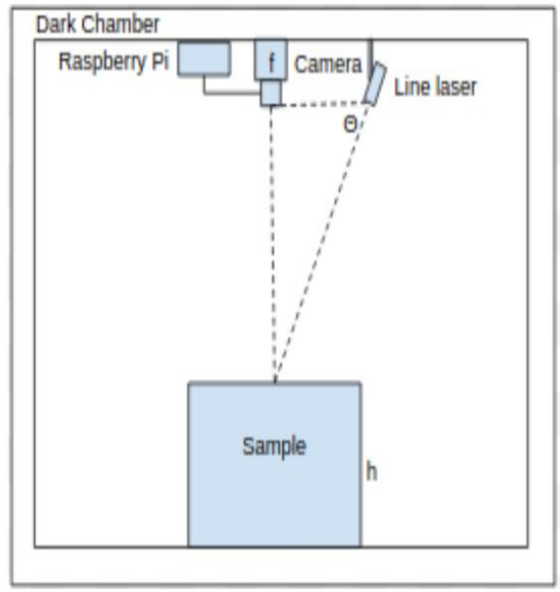


Fig3. 3D Imaging Setup (a)


```
#!/usr/bin/python
from time import sleep
from picamera import PiCamera
import sys

camera = PiCamera()
camera.resolution = (1024, 800)
camera.iso = 300
camera.start_preview()
sleep(5*12)
camera.capture(sys.argv[1])
```

Fig3. and Python Script for Door or window Image Acquisition (b)

Figure 1(b) shows the Python script of Door or window image acquisition driver. Each door or window image which is illuminated by cross line laser light was acquired by the camera. **The camera was connected to camera**

sensor interface (CSI) of Raspberry Pi board via USB 3.0 cable. The camera was set to ISO=300; resolution=1024x800 pixels. These parameters then were implemented using Pi Camera code listing shown in Fig. (a). **each door or window image then saved in the Raspberry Pi memory for further steps. The door or window image illuminated by the crossline laser light which is situated in the dark chamber. This image was taken using a cell phone** camera to demonstrate 3D imaging technique

Door or window Width and Length Estimation Algorithm

Door or window width and length estimation utilizes image processing technique. The algorithm for door or window width and length (area dimension) the first step of the length algorithm is to read the pixel values of the door or window image, the pixels in RGB domain then converted to grayscale. Next step is to extract the horizontal laser line from the image pixel, contouring algorithm then employed to extract the broken laser line. Later step is to sort the extracted contours from left to right, then, bounding door or window drawn to the third contour. Bounding door or window length then converted from pixel to cm. The conversion was done manually using an image of measuring tape placed on one of the door or window surfaces.

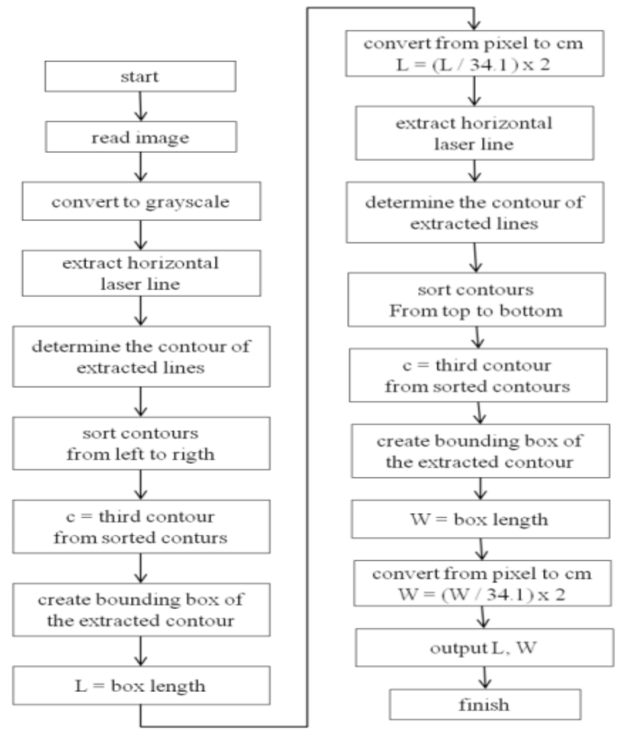


Fig4. Width and length line extraction algorithm

The steps for door or window width estimation are like the length estimation steps. The width of the door or window is represented by the vertical line of the image. Figure shows the algorithm for the width estimation. The first step is to extract the vertical laser line from the image pixel, contouring algorithm then employed to extract the broken laser line which represents the width of the door or window. The final step is to sort the extracted contours from top to bottom. Then, bounding door or window is drawn to the third contour. Bounding door or window length then converted from pixel to cm.

Door or window Height Estimation Algorithm

Door or window height estimation done by using laser triangulation techniques and image processing. When line laser projected to the door or window, line deviation will be formed. Line deviation point, laser line center point, and laser angle will be used as parameter for door or window height measurement. This algorithm then is implemented in Python program. Flowchart of the algorithm is shown in Figure below. Estimation of width, length, and height of each door or window was done automatically using Python acquirement and estimation program.

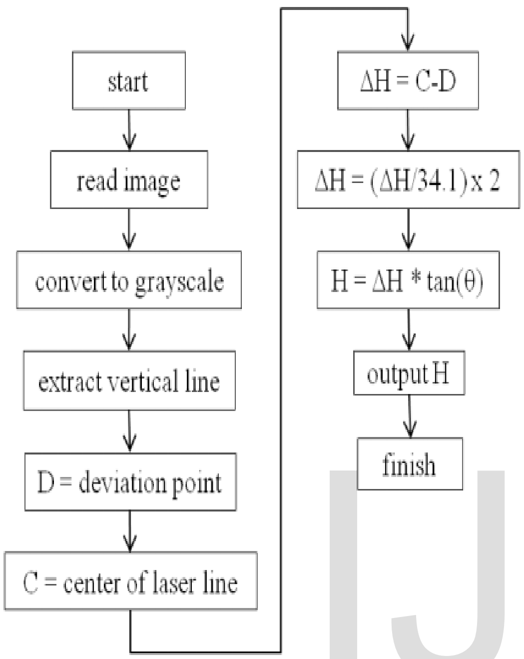


Fig5. Height extraction algorithm

3.2 Laser beam sources for 3D measuring and process control

Laser diode based light sources are widely used for high precision measurement and inspection systems

The laser sources shown in Figure combine a laser diode with refractive and sometimes diffractive optics to achieve the required beam shape. The form and shape of the beams reflect the broad variety of their application. Even within the basic groupings of laser line, laser spot or pattern, there are variants that differ widely in their physical characteristics.

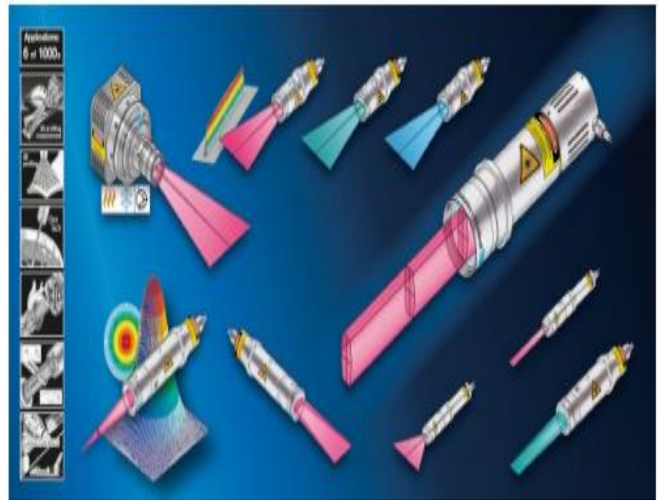


Fig6. Laser beam sources for 3D

Laser beam sources for 3D measuring and process control applications: laser lines are ideal for triangulation and laser light sectioning, telecentric beams predestined for laser diffraction and laser spots for particle counting and sizing.

Laser lines and laser spots are used for a large variety of applications, e.g., laser lines for 3D measurements. Depending on the prerequisites for depth of focus of the laser line, either micro lines with a high-power density and smaller depth of focus or macro lines with larger line width and increased depth of focus are appropriate. Special variants with low noise and reduced coherence length can improve the measurement results.

4. CALCULATION

4.1 Dimension Measurement Principle

We model doors as parallelepipeds in the present work, although real doors may present some bent edges, missing corners, and asymmetries. The dimension of a door can be computed from the 3D coordinates of these key points (Dot V1, V2, V3, V4, D1, D2, D3, D4 and O, as shown in Figure 6(b)) on the silhouette edges of the captured two laser-door

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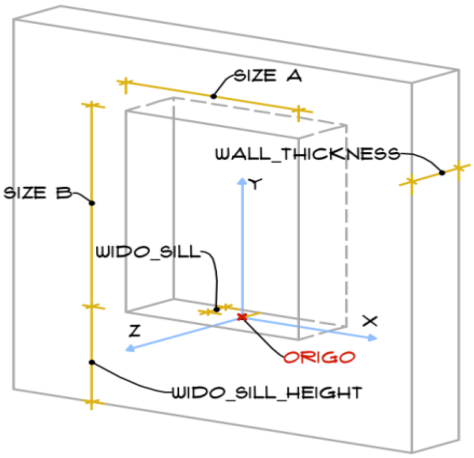
images. Thus, before the dimension of the measured door can be obtained, the door silhouettes



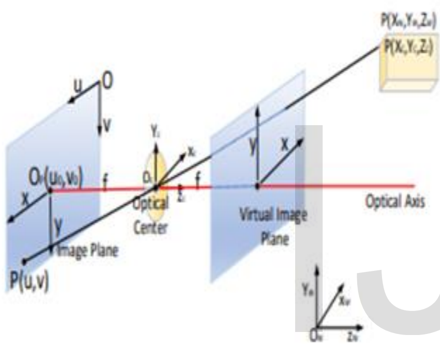


Fig7. (a) Perspective projection model of the visual sensor

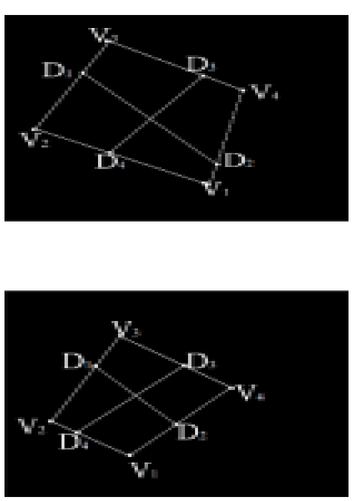


Fig7. (b) key points in the image

The camera and the crossline laser are used to acquire laser-door images of the measured door, forming a crossline laser strip line embedding the profile structured edge information of the door face, as shown in Figure (b). If the parameter equation of the laser plane and the camera is known, the equations of the door face can be computed by intersecting the image rays with the laser planes. Thus, the 3D coordinates of the key points can also be obtained easily. Here, we define the camera coordinate system as the fiducial coordinate system. The equation of the laser light planes that describe the location of the laser planes in the camera coordinate system is assumed as follows:

$$\begin{cases} a_1 x_c + b_1 y_c + c_1 z_c + 1 = 0 \\ a_2 x_c + b_2 y_c + c_2 z_c + 1 = 0 \end{cases}$$

Where ai, bi, and ci, (i=1,2) are the coefficients of the two laser planes in our system. Therefore, a camera is modeled via the usual pinhole model to describe the projection relation between the 3D object space and the 2D image [23]. Thus, as shown in Figure 6(a), four coordinate systems are established. These systems include the image pixel coordinate system (unit: pixel), the image physical coordinate system (unit: mm), the camera coordinate system (unit: mm), and the world coordinate system (unit: mm). The relationship between a 3D point P (Xw, Yw, Zw) and its image projection P (u, v) is given by:

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = A\left[R, t\right]\begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \text{with } A = \begin{bmatrix} \alpha & 0 & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1 \end{bmatrix}$$

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where s is an arbitrary scale factor, (R, t), called the extrinsic parameters, are the rotation matrix and translation vector, respectively, which relate the camera coordinate system to the world coordinate system, A is the camera intrinsic matrix, and (u0, v0) is the principal point in the image pixel coordinate system. α and β are the scale factors in image u and v axes, and γ is the parameter describing the skew of the two image axes. Equation (3) represents the transformation relationship of the point P between the camera coordinate system (Xc, Yc, Zc) and the image pixel coordinate system (u, v):

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = A \begin{bmatrix} X_c/Z_c \\ Y_c/Z_c \\ 1 \end{bmatrix}$$

Assuming the 3D coordinates (Xc, Yc, Zc) are also on the laser stripes and in the image pixel coordinate system, (u, v) could be derived from Equations (1) and (3):

$$X_c = Z_c \frac{(u-u_0)}{\alpha}$$

$$Y_c = Z_c \frac{(v-v_0)}{\beta}$$

$$Z_c = \frac{d_i}{a_i}\left(-\frac{c_i}{a_i}-\frac{(u-u_0)}{\alpha}-\frac{b_i}{a_i}\frac{(v-v_0)}{\beta}\right)^{-1}$$

Therefore, the 3D coordinates P (Xc, Yc, Zc) on the laser stripes in the camera coordinate system can be computed. Thus, all the 3D coordinates on the laser stripes in the camera coordinate system of the image can be obtained. Thus, with the 2D coordinates (Dot D1, D2, D3, D4, O) on the laser stripes of the door face, the door face plane equation can easily be fitted with the least-squares method in the camera coordinate system:

$$Ax_c+By_c+Cz_c+1=0$$

Where A, B, and C are the coefficients of the door face plane equation. Thus, the 3D coordinates of these key points (V1, V2, V3, and V4) on the silhouette edges of the laser-door image could be derived from Equations (3) and (7). We assume that the 3D coordinates of the vertices of a door face (Dot V1, V2, V3 and V4) are V1(xv1, yv1, zv1), V2(xv2, yv2, zv2), V3(xv3, yv3, zv3), and V4(xv4, yv4, zv4), respectively. The length and the width of the door face can be computed as follows:

$$\text{length} = 1/2\left(\sqrt{(x_{v1}-x_{v2})^2+(y_{v1}-y_{v2})^2+(z_{v1}-z_{v2})^2} + \sqrt{(x_{v4}-x_{v3})^2+(y_{v4}-y_{v3})^2+(z_{v4}-z_{v3})^2}\right)$$

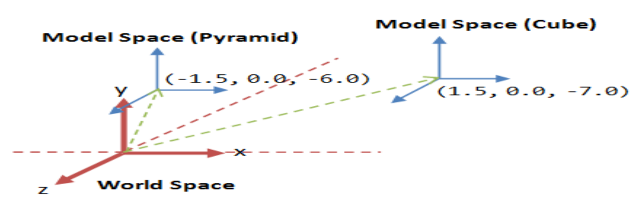
$$\text{width} = 1/2\left(\sqrt{(x_{v1}-x_{v4})^2+(y_{v1}-y_{v4})^2+(z_{v1}-z_{v4})^2} + \sqrt{(x_{v2}-x_{v3})^2+(y_{v2}-y_{v3})^2+(z_{c2}-z_{v3})^2}\right)$$

Through the same strategy, the length' and width' of the door face can be obtained by processing any adjacent face of the door. Therefore, the height of the measured door can be expressed as

$$\text{height} = \begin{cases} \text{width}'(\min[(\text{width}'-\text{width}),(\text{width}'-\text{length})] \\ \qquad < \min[(\text{length}'-\text{width}),(\text{length}'-\text{length})]) \\ \text{height}'(\min[(\text{width}'-\text{width}),(\text{width}'-\text{length})] \\ \qquad > \min[(\text{length}'-\text{width}),(\text{length}'-\text{length})]) \end{cases}$$

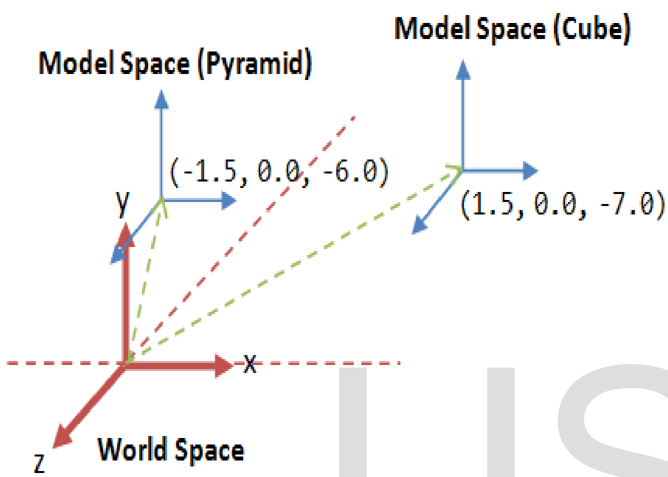
The door volume can be computed as follows:

V=width length height



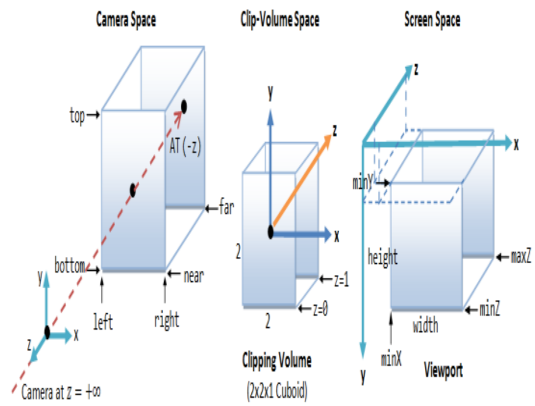
The objects are defined in their local spaces (model spaces). We need to transform them to the common world space, known as model transform.

To perform model transform, we need to operate on the so-called model-view matrix (OpenGL has a few transformation matrices), by setting the current matrix mode to model-view matrix:

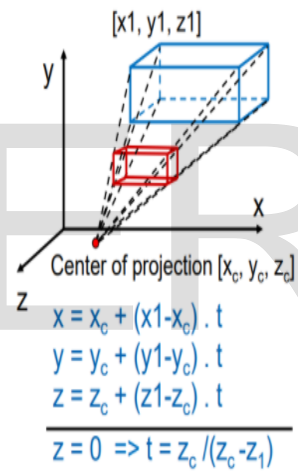


A camera has limited field of view. The projection models the view captured by the camera. There are two types of projection: perspective projection and orthographic projection. In perspective projection, object further to the camera appears smaller compared with object of the same size nearer to the camera. In orthographic projection, the objects appear the same regardless of the z-value. Orthographic projection is a special case of perspective projection where the camera is placed very far away. We shall discuss the orthographic projection in the later example.

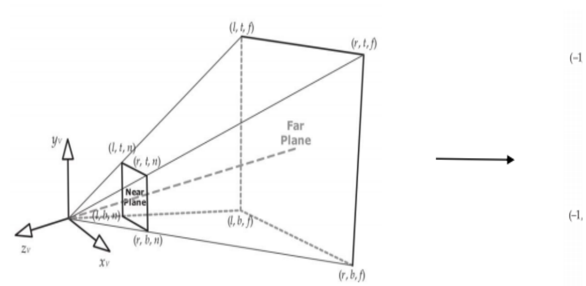
To set the projection, we need to operate on the projection matrix. (Recall that we operated on the model-view matrix in model transform.)



PERSPECTIVE PROJECTIONS



$$M = \begin{bmatrix} 1 & 0 & -\frac{X_c}{Z_c} & 0 \\ 0 & 1 & -\frac{Y_c}{Z_c} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & -\frac{1}{Z_c} & 1 \end{bmatrix}$$



camera / eye space

$$P=\begin{bmatrix} \frac{2n}{r-l} & 0 & \frac{r+l}{r-l} & 0 \\ 0 & \frac{2n}{t-b} & \frac{t+b}{t-b} & 0 \\ 0 & 0 & -\frac{f+n}{f-n} & -\frac{2nf}{f-n} \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

MODEL TRANSFORM

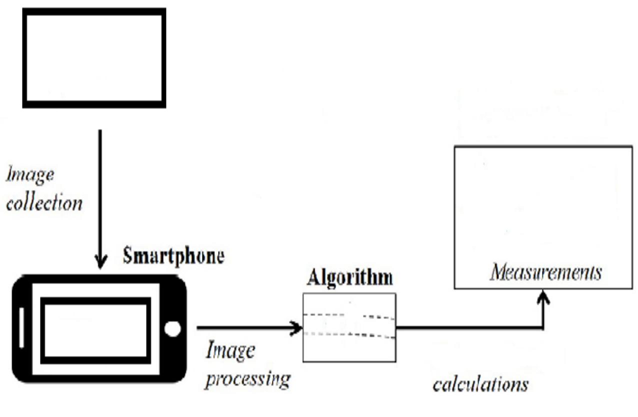


Fig8. Model Transform

4.2 Vision based distance measurement system using single laser pointer design

A calibration wall or surface to obtain some reference data had been formulated. All measurement were scaled to and calculated based on those data. The calibration process can be conducted in the air. The associated image captured by camera when laser beam hit the calibration wall according to Figure below shows the projection of a laser spot at the detected wall to the calibration wall. R is the distance between camera's center and the laser pointer's center as shown above. A' is the distance between camera lens and calibration wall. C is vertical distance between camera center and laser spot at detected wall.

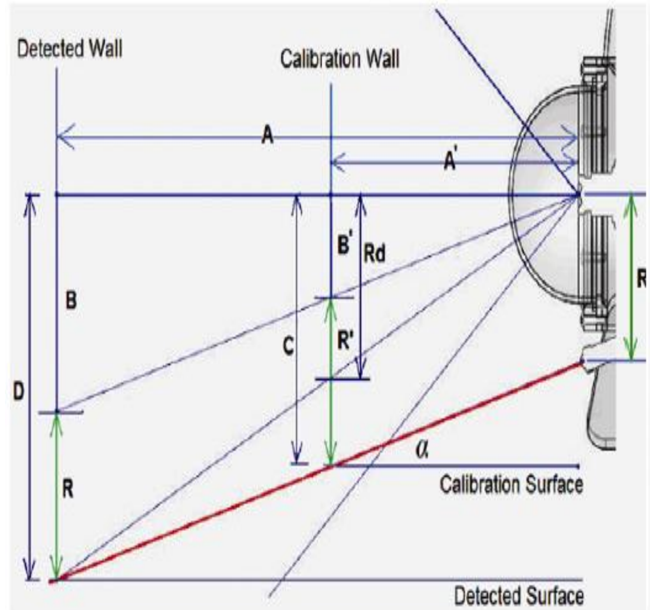


Fig9. Geometric Analysis

We will keep these values as reference data. What we want to find is A, the horizontal distance between camera and detected object. It is derived:

(B + R) / A = (B′ + R′) / A′

B/A + R/A = B′/A′ + R′/A′

R/A = R′/A′

A = A′ (R/R′) ……………………………………………. (1)

This equation can be solved by referring to Fig. above. (R/R′) in equation (1) will be seen on the image as

(Ri/Ri′). So, we can write:

(R/R′) = (Ri/Ri′)

Then equation (1) will be:

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$A = A'(Ri/Ri')$ …………………………………………… (2)

Where:

$Ri = Ci - Bi'$

$Ri' = Rdi - Bi'$

Ci and Rdi are measured directly based on image processing. Bi' is calculated by combining Figures below as follows:

$B'/C = Bi'/Ci$

$Bi' = Ci\,(B'/C)$ …………………………………………………. (3)

Where:

$B' = A' \tan$ _

$C = B' + R$

B' and C can also be measured directly from the calibration wall. Bi is a constant. This is a shift distance caused by tilt angle of the laser pointer. If the angle is zero, Bi' is zero as well. Finally, we calculate the vertical distance, D.

$D = B + R$

$D = A \tan \alpha + R$ ……………………………………………… (4)

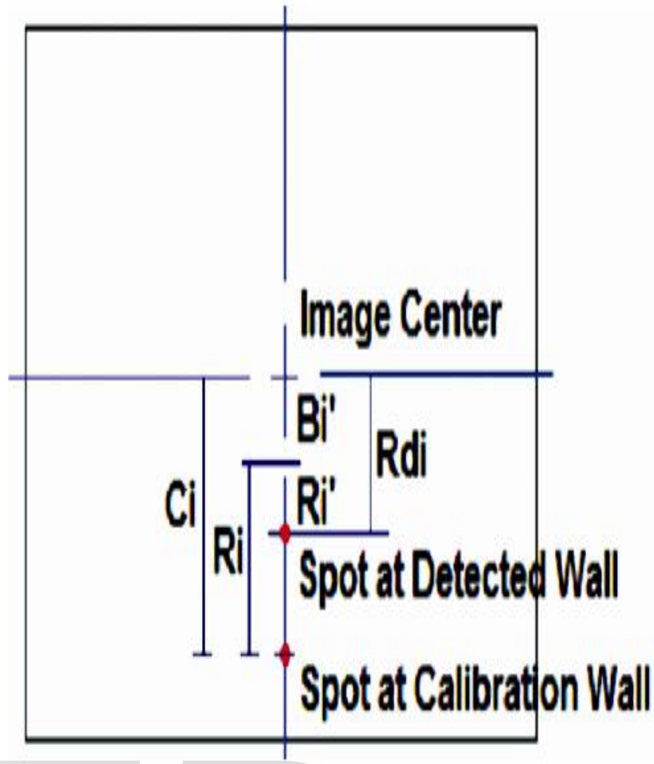

Fig10. Distance calibration

5. RESULTS AND DISCUSSION

The testing purpose was to verify distance measurement calculated by software with true measurement. In this testing we only conducted the horizontal measurement testing as depicted in Figure below.

First, we had to do a distance calibration. The purpose of the calibration is to find the linear scale of pixel to distance. We placed the camera 100 cm away from the wall as shown in Fig. 10. With this setup, the distance of the laser spot to the image center was 24 pixels. It meant that one pixel represents 24/100 cm. The measurement range of this testing was between 25 cm and 280 cm.

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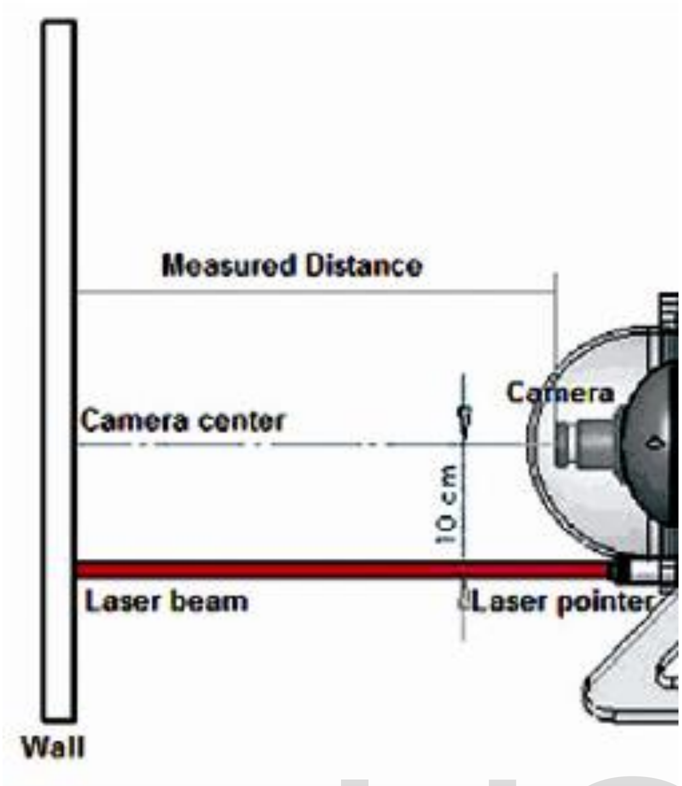

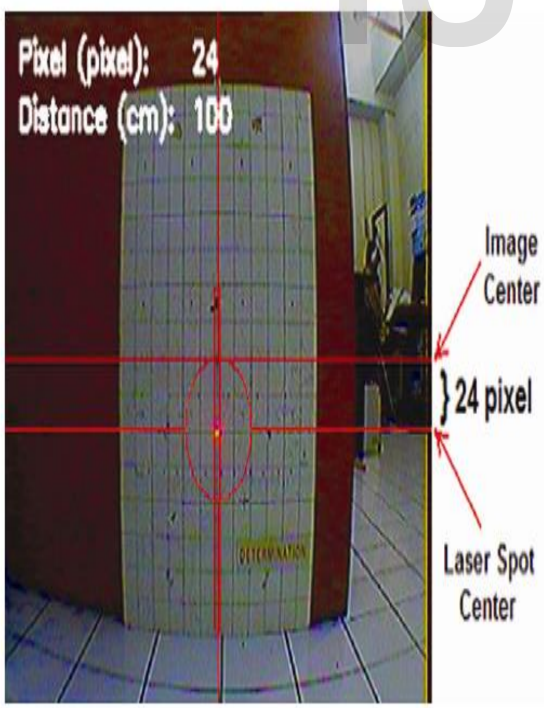

Fig11. Image of a laser spots wall. Parameters are measured in pixel

CONCLUSION

This paper presents an introductory concept of various methodologies used to measure distance by ultrasonic based, laser based, image based, white line tracing-based algorithms for mobile phone applications Laser beam pixel area Image based algorithm along with literature review of research work on distance measurement. The paper may help the new researchers expeditiously with a brief idea of distance measurement based on laser beam and image processing program and various paper studied may give a quick approach to the new researchers. If the detected points have higher accuracy, such as the precision of detecting the square corner points on the calibration plate, the measurement accuracy of the measurement model can be higher. The main factor affecting the measurement accuracy of the model is the error of the detected points on the ellipse, and the error is mainly affected by the surface roughness. Many calibration techniques for line-structured light vision sensors have been proposed over the past three decades and can be divided into two main categories according to how they obtain the 3D coordinates of the feature points (also known as calibration points) on the light plane. One is with the assistance of apparatus, such as a laser displacement sensor or robotic arms, that is hard to operate and unsuitable for on-site calibration. The other obtains the coordinates of calibration points using targets with a relative high accuracy geometric constraint, which is widely used in on-site calibration due to easy setup and simple operation. However, these techniques face several drawbacks that prevent them from achieving a higher accurate calibration.

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