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Laser Guided Real Time Object Measurement and Distance Calculation System

M. SHARIF++, M. HASSAN, M. H. KHAN, M. RAZA, A. U. KHAN

Department of Computer Sciences, COMSATS Institute of Information Technology, Wah Cantt-Pakistan

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Abstract: This research paper explores the use of image processing and laser technologies for distance calculation and dimension measurement. The proposed techniques for distance calculation between the object and proposed CCLC (Computer Controlled Laser mounted Camera combo) and dimensions measurement are based on the pixels correspondence method, which calculates the distance between two red laser spots based on the number of pixels between these spots. The correspondence relations of these pixels are then used as reference for dimension measurement and distance calculation between the object and CCLC.

Keywords: Dimension measurement, CCLC, Video acquisition, laser transmitters, distance calculation.

1. INTRODUCTION

The use of image processing techniques is increasing day by day in many fields for different purposes and for performing important tasks. Traditionally, several systems and methods are being proposed for distance measurement and dimensions calculation. Various solutions for distance measurement have been proposed in (Hyongsuk *et. al*., 2005), (Tarek *et. al*.,2009), (Chih *et. al*.,2003), (Miug *et. al*., 2004), (Nleya *et. al*., 1998), (Wei *et. al*., 2007), (Ming *et. al*.,2006), (Matthias *et. al*., 2007), (Michele *et. al*., 2007), (Oberhauser *et. al*., 2006), (Jernej *et. al*., 2008), (Chen *et. al*., 2009), (José *et. al*., 2009) and for dimensions calculation they are discussed in (Ming *et. al*.,2006), (Chih *et. al*.,2007), (Fabiana *et. al*.,2006), (Hsu *et. al*., 2009). Some of these systems and methods are described as follows.

1.1. Distance measurement through a single camera and a rotating mirror

In camera and rotating mirror are used for distance measurement (Hyongsuk *et. al*., 2005). A sequence of reflected images is captured for distance information. As this technique is based on pixels of an object, hence pixel group movement is investigated. Moreover, equivalent points from two images are taken and numerous calculations have been done in order to enhance the physical limit and finding out the average.

1.2. Distance measurement through Ultrasonic and IR sensors

Another technique for measuring distance makes use of Ultrasonic and IR sensors in (Tarek *et. al*.,2009). The basic purpose of the combined use of these sensors is to develop a system that is capable of measuring the accurate distance. In this method the ultrasonic rays and IR rays from sensors are sent out with the help of ultrasonic transmitter and IR transmitter. In case these rays collide with any hurdle in their traveling path, they reverse back and are received by ultrasonic and IR receivers noticing the time and based on this time different methods are designed for distance measurement or distance calculation between transmitter and object.

1.3. Camera for Measuring the Distance to an Object using Laser Range Measuring Device and Beam Splitting Technique

A system is proposed in (Chih *et. al*., 2003) in which laser range measuring device with beam splitting technique is used to determine the distance from camera to an object. The system first takes the image of the object and then measures the distance between camera and the object. An image detector is used to analyze the focal length of the lens, the width and height of the image. By analyzing this parameter on the image detector, it is then possible to compute the width and height of the object according to the geometrical optics. Finally with the help of image detector, laser range measuring device and beam splitting technique, the distance from camera to object is determined.

1.4. Image Based Height Measuring System (Distance Measurement through Triangular Measuring Method)

A height measurement system is proposed in (Miug *et. al*., 2004) for liquid or particle materials in tank. Two laser projectors are set on a base, a vertical plane is defined and two brightest laser spots are projected on the surface of material in the tank. A timer instead of pixel counter is being used for measurement of distance. Also a circuit is used to calculate the number of clock pulses between two brightest laser spots projected on the surface of material of tank in

++Corresponding author. M. SHARIF, E-mail muhammadsharifmalik@yahoo.com,

video images. This height measurement system utilizes triangular measuring method. A CCD camera is used to visualize the image. The two laser projectors form an isosceles triangle and by using simple relationship between actual measured height and the distance of two laser spots, the actual height of liquid in tank can be calculated.

1.5. Image-Based Distance and Area Measuring System

A measuring system using scan-counter method via a CCD camera and laser is proposed in (Ming *et. al*.,2006). This system is based on the parallel measuring concept to calculate the distance between a CCD camera and an object. It also measures the projected area of the object with the help of pulse oscillators. This method does not need to store huge amounts of image data or using any pattern recognition approach. It quickly calculates the distance and the projected area using simple circuits and formulas. For distance calculation, two laser projectors are set on either side of a CCD camera and this system is kept in a box generating two parallel rays which project two bright spots on the object ROI. An external clock which is generated by an extra oscillator is used to measure the time interval between the two bright spots as the CCD scans the image. A circuit for counting the number of external clock pulses between the two bright spots is employed to calculate the interval between them in the video image. Due to the parallel setup of distance measuring system, a linear relationship exists between the actual distance and the interval of the two bright spots. Therefore, the actual distance from the CCD camera to the object can be calculated using a simple formula. For area measurement, circuits count the number of external clock pulses of the horizontal scan lines covering the projected area of the object. Then this projected area is calculated from simple algebraic formulas.

In this research paper a new technique is introduced to measure the dimensions of an object and also the distance between object and **CCLC.** The proposed technique employs the solution in four parts with each part containing some tasks to be performed. First part includes video capturing with the help of a wireless analog camera and extraction of frames which are still images. These frames include the image of laser spots which were generated by the laser transmitters attached on the left and right sides of camera. Second part detects the red laser spots as well as their positions in the image. Third part consists of distance calculation between an object and **CCLC**. For the purpose, the number of pixels between the two laser dots is calculated from the image and a correspondence between number of pixels and the distance is established. The distance between the object and **CCLC** is calculated, through this correspondence. Fourth major part of the technique is related with dimensions measurement of an object. For this, the proposed method finds the total numbers of pixels occupied by the object by calibrating the object boundary. Finally the dimensions are calculated by the use of mathematical process on length per pixel and total number of pixels between two calibrating points.

2. MATERIAL AND METHODS

Computer controlled laser mounted camera combo device is used to calculate dimensions of an object and also measuring the distance between object and laser cam device. The proposed method is used to calculate the distance between camera and object with the help of laser transmitter. The figure of proposed system i.e., CCLC is shown in **(Fig. 1).**

Fig. 1 Computer Controlled Laser mounted Camera(CCLC)

In this method a laser beam is used to calculate the distance between camera and object. A laser transmitter is attached on both the left and right sides of camera. Our technique consists of four parts with each part containing some tasks to be performed. The Flow Chart of the proposed system is shown in **(Fig 2).**

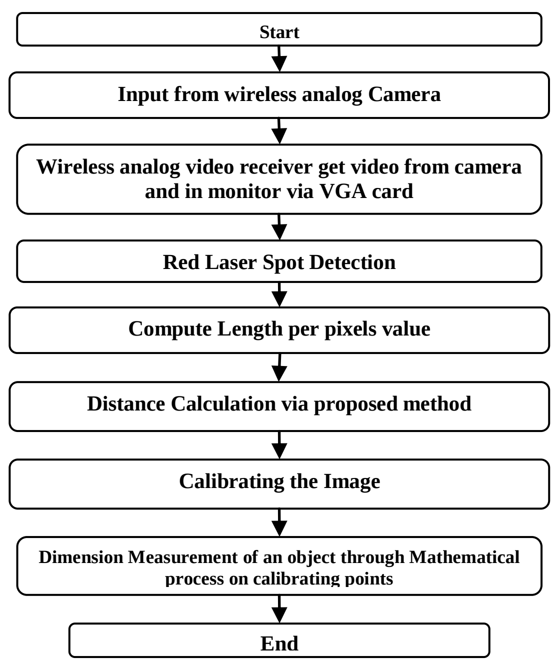


Fig 2. Block Diagram of Computer Controlled Laser mounted Camera combo

2.1. Video Acquisition from the Camera

When camera stores the video of object, the red spots of laser transmitters also get stored in the video. After this the proposed method divides the video into frames. The technique used for division can create 25 frames per second depending upon the video card as shown in **(Fig. 3).** After the completion of division process, each frame acts just like a still image.

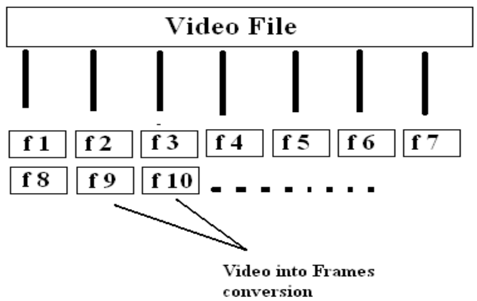


Fig 3. Video into Frames Conversion

2.2. Red Laser Spot Detection Method

In this part the main methodology is to find the position of red laser spots in an image by assuming them as the brightest spots in the image. For the identification and accurate detection of red laser spots a red filter is fitted with the wireless analog camera. The idea of using the red filter has been taken from the literature regarding laser spots detection in (Atul *et. al*., 2009). **(Fig. 4)** illustrates the detection of red laser spots without the red filter and using the red filter for accurate detection of these spots.

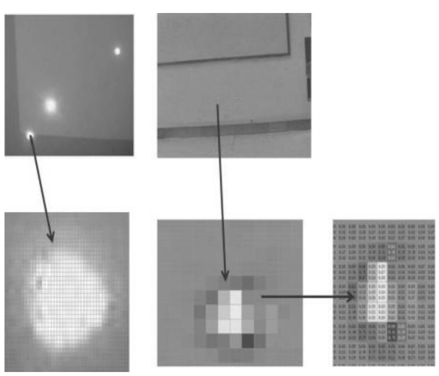


Fig 4. Detection of red laser spots without red filter and using the red filter

As it is known that laser spot intensity is very high because of which red laser spots are seen as white spots, therefore, red filter is being used for the accurate detection of these red laser spots. The use of this filter reduces the problem related to white spots region and making the region red. Illustration of red filter fitted with CCLC is shown in **(Fig. 5).**

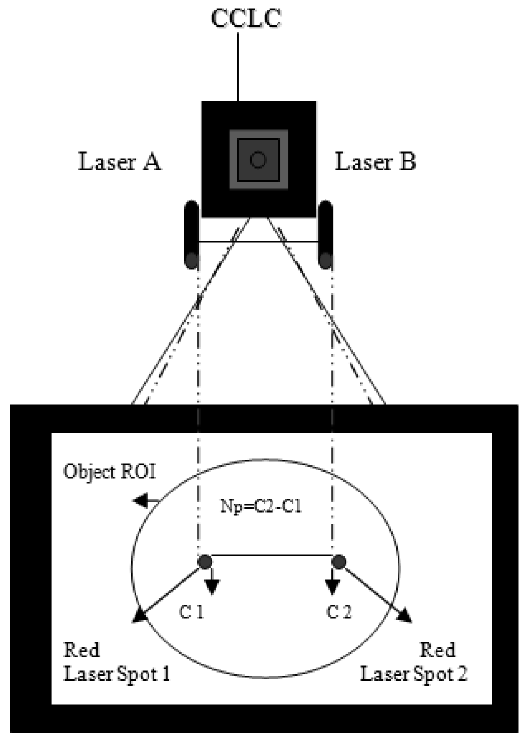


Fig 5Red filter with CCLC

In Fig. 5, Np is no. of pixels between two red laser spots and C1, C2 are the centroid of two correspondents' red laser transmitters. Now in order to find the position of red laser spots the method first takes the red, green and blue bands from original image of each pixel. Then it takes out the histogram of all the three bands. After this, the range of threshold value for laser intensity is calculated. Then it applies mask on the red, green, blue values after which it removes the unwanted objects from the original image. Finally the empty spaces are filled in image and mask is again applied on original image and on red laser spots to refine the image for clear vision of laser spots. **(Fig. 6)** illustrates the red spots detection method.

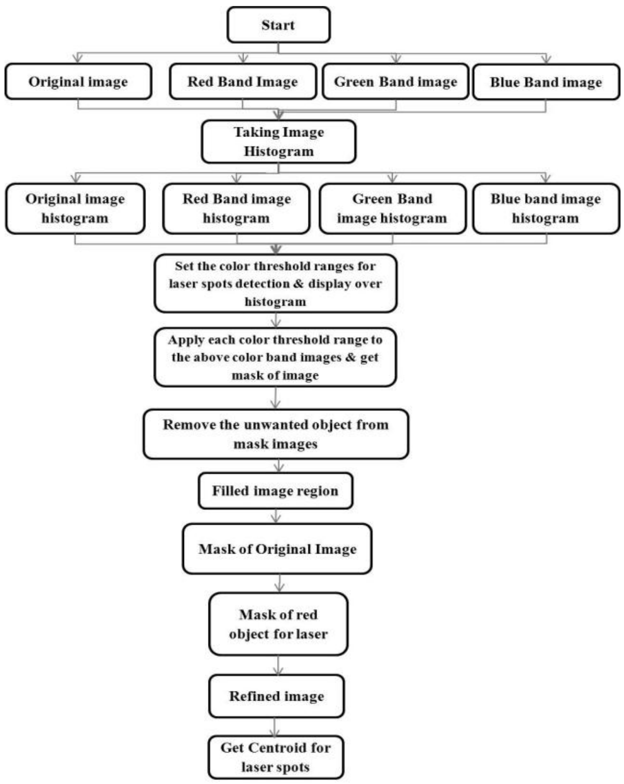


Fig. 6 Red Laser Spot detection method

2.3. Distance Measuring Between CCLC and Object

The third part of the research paper is related with calculation of distance between object and CCLC. For this purpose, the correspondence is made between total number of pixels and distance between CCLC and object. First of all a particular distance, starting and ending points are chosen. Then the distance between CCLC and object from starting point is calculated manually and a relation is made on the basis of this particular distance. This relation gives the number of pixels covered by red laser spots. The process continues till the ending point. We make the relation here just to develop a formula and take the particular distance in feet because we aim to develop the distance calculation formula in feet which is easily convertible into meter keeping in view the measurement of distance in daily life which is in one of these units. After making the relation the proposed method makes a lookup table in which it stores the value of the above iteration. After performing the above steps we get a base for developing a generic algorithm that will automatically calculate the distance between CCLC and object in feet. Then for further calculation, the lookup table is used to calculate the approximate distance between CCLC and object in feet. **(Fig. 7)** illustrates the calculation of distance between object and CCLC using the proposed method. As the laser lights are parallel, the actual distance between points A and B, C and D and E and F is same, but the camera sees these points converging as the distance H increases. Hence the camera view says that the distance between points A and B is more than the distance between points C and D.

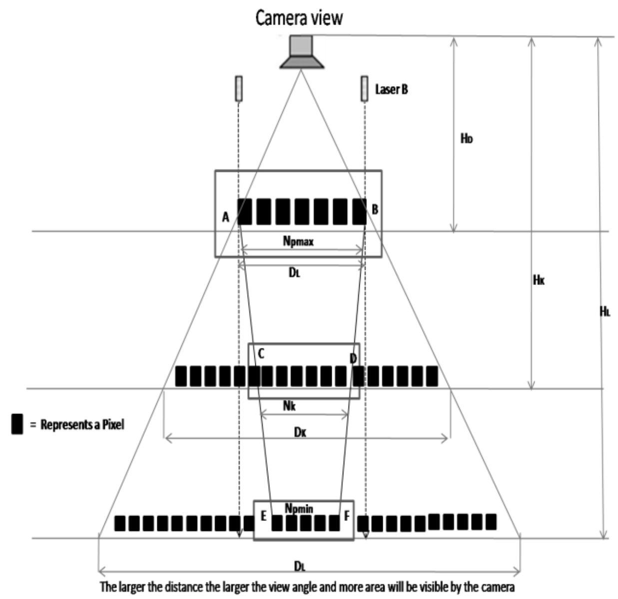


Fig 7 Proposed method for distance calculation

In Figure 7, D_L is the fixed length between two laser transmitters, N_{pmax} is the maximum number of pixels between two spots at points A & B at a distanceH_D, which is the distance between two spots at points A & B. N_{pmin} is the minimum number of pixels between two spots at points E & F. $H_{\max}$ is the maximum distance we would like to measure. H_K is the distance from the two projected spots at points C & D to the apex of the triangle. D_K & D_v are the lengths of the bases of triangles formed by the field of view of wireless analog camera particularly at points CD & EF. N_K is the number of pixels between the points C & D. The black square boxes represent the pixels. As there are two isosceles triangles in Figure 9, hence the ratio of D_K & D_L from the triangle relationship is equal to N_K & $N_{p\max}$.

$$D_L \propto \frac{1}{N_{p\max}} \rightarrow (1)$$

$$D_K \propto \frac{1}{N_K} \rightarrow (2)$$

By equating 1 and 2 and then dividing equation 1 by equation 2 we get,

$$\frac{D_L}{D_K} = \frac{N_K}{N_{p\max}} \rightarrow (3)$$

Now by cross multiplication the D_K will be

$$D_K = \frac{N_{p\max} * D_L}{N_K} \rightarrow (4)$$

If $N_{p\max}$ and D_L are given then D_K can be easily calculated by N_K. Once D_K is known, we can use triangle relationship formula (3) to get distance H_K. Now again by triangle relationship the ratio of D_K and D_L is equal to H_K and $H_{\max}$.

$$D_K \propto H_K \rightarrow (5)$$

$$D_V \propto H_{\max} \rightarrow (6)$$

By equating 5 and 6 and then dividing equation 5 by equation 6 we get,

$$\frac{D_K}{D_V} = \frac{H_K}{H_{\max}} \rightarrow (7)$$

Now by cross multiplication the H_K will be

$$H_K = \frac{H_{\max} * D_K}{D_V} \rightarrow (8)$$

Now for D_V we use again triangle relationship formula.

$$D_K \propto \frac{1}{N_K} \rightarrow (9)$$

$$D_V \propto \frac{1}{N_{p\min}} \rightarrow (10)$$

By equating 9 and 10 and then dividing equation 9 by equation 10 we get,

$$\frac{D_K}{D_V} = \frac{N_{p\min}}{N_K} \rightarrow (11)$$

Now by cross multiplication the D_V will be

$$D_V = \frac{N_K * D_K}{N_{p\min}} \rightarrow (12)$$

By putting the value of D_V in 8 we get H_K.

$$H_K = \frac{H_{\max} * D_K}{D_V} \rightarrow (13)$$

By performing an experiment we developed our general formula of distance calculation based upon pixels correspondence. This general formula is given below.

$$\psi = N/\alpha \rightarrow (14)$$

Where ψ is Lppx or Fppx and N represents the particular point across which we take the correspondence pixels value of two laser spots.

$$\alpha = f(x) - g(x) \rightarrow (15)$$

here, α represents the correspondence pixels difference, $f(x)$ & $g(x)$ represent the Upper bound pixels value and Lower bound pixels value respectively.

$$A = \sqrt{(z(x) - f(x))^2} \rightarrow (16)$$

Here A represents the Difference value, $z(x)$ represents the Actual pixels count & $f(x)$ shows the Upper bound pixels value.

$$B = A * \psi + \lambda \rightarrow (17)$$

Here B is the calculated distance between object and CCLC, A is the Difference value, ψ is Lppx or Fppx and λ shows the Upper Bound Scale value.

The low resolution camera with resolution 176*144=25,344 pixels, operating frequency of 2.4 GHz and 30 meter range of video capturing was used for experiments. The results regarding Distance Calculation are described later in Section 4.

2.4. Dimensions calculation of an object in Image

For dimensions calculation the proposed method first calculates the distance between two red laser spots present in the captured image. Then it finds the number of pixels between these laser spots. **(Fig. 8)** illustrates the procedure of taking dimensions of an object.

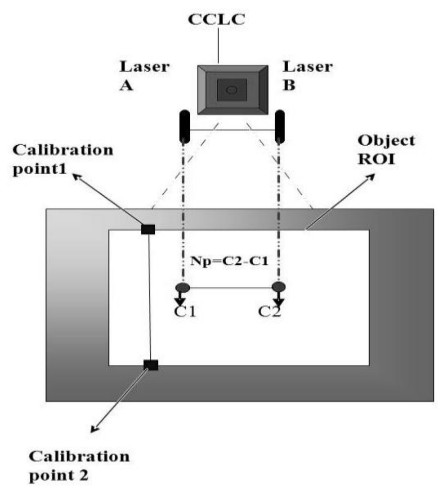


Fig 8 Procedure for taking dimensions of an object.

After finding out the total number of pixels between two red laser spots, the proposed method next finds out the length per pixel (of each pixel) between these spots. Then two calibration points are taken according to the need and total number of pixels is found out between these points. Then we multiply this total number of pixels with the current length per pixel calculated value using some mathematical process. As a result the proposed method will find out the height of object in image. Finally this whole process is repeated width wise to calculate width of the object in image and hence the proposed method will find out the complete dimensions (length, width, height) of object in an image. Sample images regarding Dimensions Calculation of different objects are shown below. For this we first target the lasers on the object ROI and then calculate the number of pixels between two red spots. These red laser spots are used as reference points. Then we calculate the length per pixel value. After this we set two calibrating points on the boundary of the object ROI which gives us the number of pixels between these points. Then we multiply this number of pixels with length per pixel value and get width of the object ROI. **(Fig. 9)** illustrates the width calculation process of object. As P_1 and P_2 are pixels, so

$$P_1 = (x_1, y_1) \ \& \ P_2 = (x_2, y_2)$$

$$P_G = \sqrt{((x_2 - x_1)^2 + (y_2 - y_1)^2)} \rightarrow (18)$$

Now the number of pixels that lie between two calibrating points is calculated and represented by P_G. P_G is then multiplied with ψ to get the final value i.e.,

$$C = P_G * \psi \rightarrow (19)$$

where C represents the calculated width or height by CCLC.

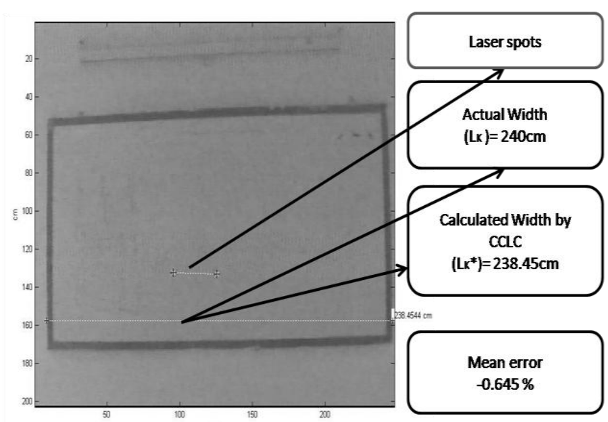


Fig 9 Illustration for calculating the width of object

Similarly, **(Fig 10)** illustrates the height calculation of object.

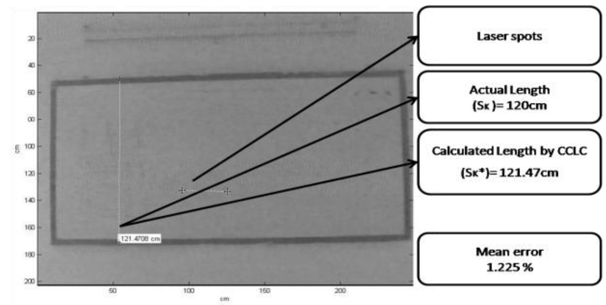


Fig 10 Illustration for calculating the height of object

(Fig 11) illustrates the caliper (length) calculation between two objects.

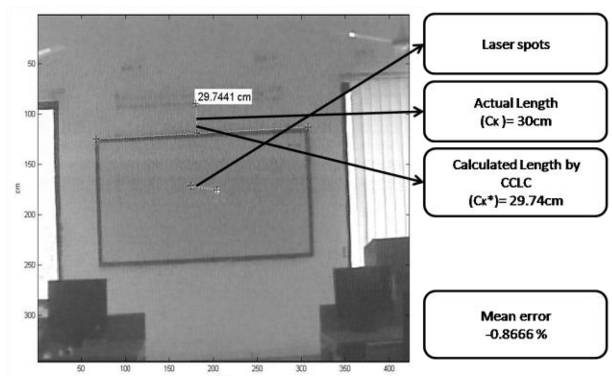


Fig.11. Illustration for calculating the caliper (length) between two objects

(Fig 12) illustrates the Radius calculation of object. Here, we set a calibrated circle around the object ROI. Now by some mathematical process we calculate number of pixels across the calibrated circle.

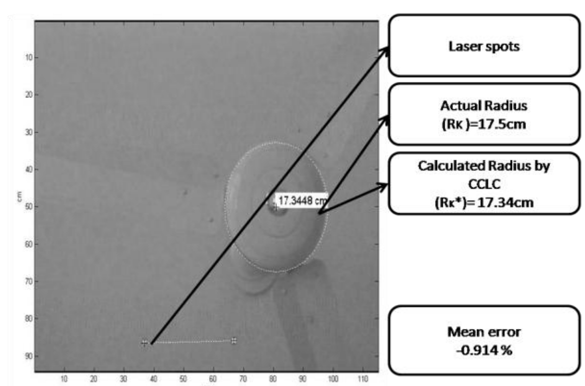


Fig 12 Illustration for calculating the Radius of an object

We also take human as an object and calculate the dimensions in order to analyze the efficiency of our proposed system. **(Fig. 13)** illustrates the height calculation of object (Human).

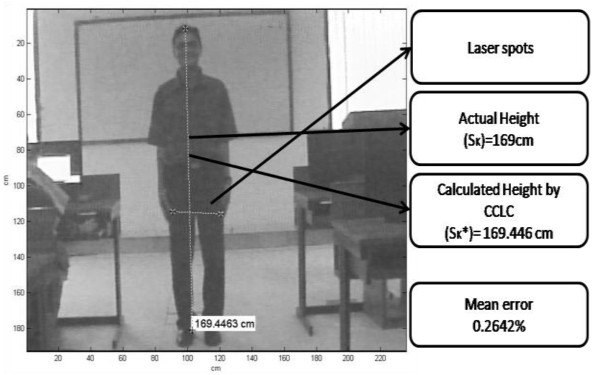


Fig 13 Illustration for calculating the height of a Human

(Fig. 14) illustrates the width calculation of object (Human).

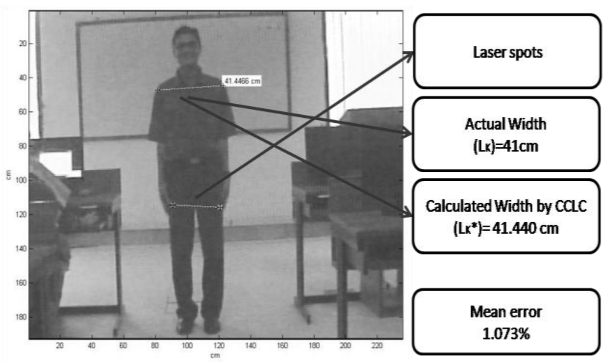


Fig 14. Illustration for calculating the width of a Human

3. RESULTS AND DISCUSSION

In this section, we present experimental results regarding distance and dimensions measurement to determine the effectiveness of our proposed system. **(Table 1)** gives the measurement results of a distant object at various photographing distances with DL=30cm. HK is the real distance and HK* is the distance calculated by our proposed system CCLC.

Table 1. Experimental results regarding distance measurement through CCLC.

Real Distance (Hk) cm	Distance Calculated by CCLC (Hk*) cm	Mean Error (%)
6 ft=183 cm	6.028ft=184.18 cm	0.466%
12 ft =366 cm	12.026 ft =366.79 cm	0.217%
15 ft =457.5 cm	15.068 ft =459.57 cm	0.453%
21 ft =640.5 cm	21.09 ft =643.24 cm	0.428%
27 ft =823.5 cm	27.23 ft =830.51 cm	0.851%
42 ft =1281 cm	42.31 ft =1290.45 cm	0.738%

Now we compare the distance measurement results of our system with the results of distance measurement in (Ming *et. al.*, 2006) and (Hsu *et. al.*, 2009) **(Table 2)**.

Table 2. Experimental results regarding distance measurement by our proposed system in comparison of the results in (Ming *et. al.*,2006) & (Hsu *et. al.*, 2009).

HK (cm)	IBDAMS [7]		DMBLCI [8]		Proposed System CCLC	
	HK* (cm)	**Error %**	**HK* (cm)**	**Error %**	**HK* (cm)**	**Error %**
180	176.07	-2.183	178.54	-0.811	178.73	-0.705
170	166.88	-1.835	168.33	-0.982	171.10	0.647
140	143.39	2.421	138.68	-0.943	141.21	0.864
130	130.43	0.331	128.93	-0.823	130.41	0.315
100	100.44	0.440	99.18	-0.820	100.43	0.430
90	92.61	2.900	89.22	-0.867	89.27	-0.807
60	61.19	1.983	59.50	-0.833	60.45	0.750

Apparently, significant improvements of distance measuring performance have been achieved through our proposed system CCLC in contrast to results demonstrated in (Ming *et. al*.,2006) & (Hsu *et. al*., 2009). Graph regarding experimental results of distance calculation in Table 2 is shown below in **(Fig. 15).**

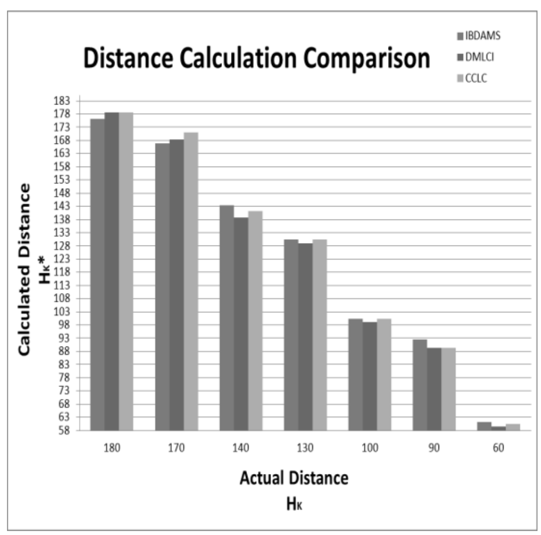


Fig 15 Illustration of Distance calculation comparison in Table 2.

The graph regarding experimental results of mean error comparison is shown in **(Fig. 16).**

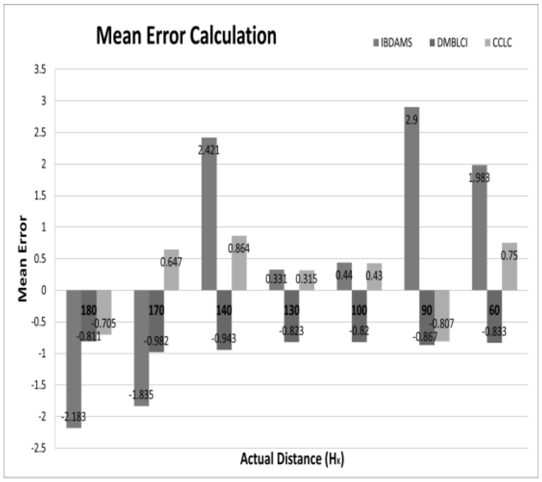


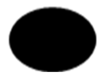
Fig 16 Illustration of Mean error comparison in Table 2.

The dimensions calculation results of some object in section D are mentioned earlier. Here we also present the experimental results regarding dimensions calculation of different objects in comparison with the measuring tape results and via our proposed system **(Table. 3,4).**. Here S_K and L_K are actual height and width while $S_K *$ and $L_K *$ are calculated height and width through CCLC.

Table 3. Experimental results regarding dimensions calculation from measuring tape.

No.	Types	Height Sk	Width Lk	Area Ak (cm sq)
1		38 cm	57 cm	2166
2		46 cm	23 cm	1661.06
3		S1=57 cm S2=60 cm	48 cm	1440
4		36 cm	46 cm	1656
5		37 cm	61 cm	1771.7
6		34 cm	50 cm	850

Table 4. Experimental results regarding dimensions calculation from CCLC.

No	Types	Height Sk*	Width Lk*	Area Ak* (cm sq)	Mean Error % Sk*	Mean Error % Lk*	Mean Error % Ak*
1		37.72	56.97	2148.90	-0.742	-0.05	-0.78
2		46.37	23.22	1692.98	0.804	0.95	1.92
3		S1= 57.11 cm S2= 60.39 cm	48.11	1452.68	0.192 0.650	0.22	0.880
4		36.21	45.68	1654.07	0.58	-0.69	-0.1165
5		37.29	61.5	1799.78	0.783	0.81	1.58
6		34.33	49.55	850.52	0.971	-0.90	0.061

4. <u>AREAS OF APPLICATION</u>

The proposed device is useful in many real time environments some of them are discussed as below.

Civil Engineering: Computer controlled laser mounted camera combo device is used in civil engineering field. It is useful in taking the measurement of roads, bridges etc.

Oil & Gas: Computer controlled laser mounted camera combo device is also being used in Oil & Gas field. It is useful in taking the measurement of oil & gas pipes and calculating their radius & length.

Forest Exploration: Computer controlled laser mounted camera combo device is also being used in forest exploration field. It is useful in wild life study & measurements of animals, plants, trees etc.

Mining Field: Computer controlled laser mounted camera combo device is also being used in mining field. It is useful in taking the measurement of caves and rocks.

5. <u>CONCLUSION</u>

In this paper, laser guided measuring system is proposed which is used to calculate the distance between CCLC and object. Our proposed system also measures the dimensions of an object. We use pixel based parallel measuring method to overcome the geometric distortion by camera lenses. The proposed system does not use expensive high speed DSP microprocessors and complex pattern recognition methods. Instead it performs the distance and dimensions measurement of an object using simple hardware components to reduce complexity. Our proposed measuring system is useful to reduce labor extensive work because of taking measurements automatically. It is also helpful to measure dimensions of objects located at inaccessible places.

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