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EXPLOITING IMAGE PROCESSING TO MEASURE DIMENSION OF SHORT DISTANT OBJECTS

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ABSTRACT

This research work shows the utilization of image processing technique to calculate the distance and the size of an object. We call it LASERCAM, as it uses the laser beam technology. The proposed technique is based on the concept of image perspective in which one can observe that as the distance of an object from the observer increases, the observer feels that the object is shortening. The primary logic for using the laser spots is to make its projection on the required object so that when the image is captured, the two spots are also get captured in image frames so that the proposed method to calculate its distance and size can be implemented. The calculation of distance is based on the distance between the two spots at a specific distance. According to the theory of image perspective, there is an inverse relation between distance from object and distance between laser spots, which is observed during the study as the distance increases from object, the distance between two laser spots decreases. The calculation of size is based on the numbers of pixel present between laser spots. The proposed method determined the length of specific number of pixels between laser spots and the known length is used to calculate the size of the object.

Keywords: laser spots, remote sensing, distance, size, estimation and calculation, image processing.

1. INTRODUCTION

Nowadays, digital data is everywhere and images are the most important category among the openly available data. The use of image processing and smart applications is increasing day by day to perform necessary tasks by using different available efficient methods in many fields. Generally, for measuring distance of an object, there are two approaches: Contact and non-contact approaches. In contact distance measurement, there are several methods including measuring tape, meter ruler, or straight scale which need to be controlled by a user but there are many objects that can be corrosive and have an irregular path which is not easy to measure. On the other hand, there are several methods that are proposed for non-contact measurement, for example, laser reflection method (Osugi, 1999) Infrared (IR), and Ultrasonic for distance measurement methods (Tarek, 2009) that are based on reflection and the important part is reflectivity of the object. The accuracy of the measuring system varies and depends on the surface area and index of reflection. Novotny and Ferrier (1999) suggested that if the surface reflection is not good, the system may find difficulty between two arbitrary objects to measure the distance. Image distance measurement methods are based on pattern recognition and image signal analysis techniques (Yan, 2001). When a view is seen by human eyes, it is observed that as the distance from the observer increases, the objects in the view give a perspective that they are shortening. Furthermore, as the distance of an object from the observer increases, the observer feels that the object is shortening. The phenomenon is known as image perspective. This phenomenon can be observed on railway tracks during a journey. As shown in Figure-1, the distance between two (left and right) lines is constant throughout the view but due to the fact of image perspective, it is giving the perception that the distance between lines is shortening. In this research paper, a method is proposed to calculate the distance and size of an object in a given image where laser spots are present. This technique is time-efficient as compared to mentioned methods. It takes just a fraction of time to find the distance of an object. The study has been conducted on live image frames, which are acquired from live video. The laser spot propagating device is connected with the camera to capture those laser spots with the live image frame to calculate the distance of an object where laser spots are present. It requires less men power and time as compare to described methods. On the other hand, it will be able to contend with IR technique due to its low price and because of its dimension calculation function.

Figure-1. Image perspective phenomenon.

VOL. 16, NO. 13, JULY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

2. BACKGROUND AND RELATED WORK

Various techniques and solutions have already been proposed for distance measurement, size, and dimension calculation as presented by (Raza *et al*., 2018; Shan *et al*., 2018, Lau, 2017; Li *et al*., 2017; Murawski, 2015; Sharif, *et al*., 2013; Lazaro *et al*., 2009; Jungel *et al*., 2007; Wang *et al*., 2007; Lu *et al*., 2006). Some of these methods and proposed solutions are described below:

2.1 Distance Calculation using Ultrasonic and Infrared (IR) Sensors

In this method, Novotny and Ferrier (1999) measured the distance by using Ultrasonic and Infrared sensors. In this method, Phong Illumination Model is presented to determine the surface properties and distance to the surface calculation. Using ultrasonic and the IR transmitter, the rays (both ultrasonic and IR) are sent from the sensors, which after collision with any object during traveling path are reverse back and receive back at both receivers and hence the time difference is recorded (Figure-2). In this method, the amplitude response of ultrasonic and IR sensors depends on the object reflectivity in order to measure accurate distance.

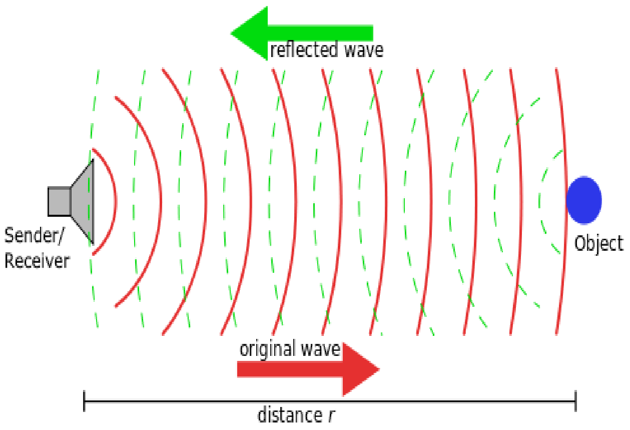

Figure-2. Ultrasonic and Infrared technique.

2.2 Using Triangular Method for Image Based Height Measuring System

Tarek M., (2009) used IR rays while Osugi K. *et al*., (1999) and Sharif *et al*., (2013) developed Laser based scanning system. An image-based height measurement system is proposed by (Miug *et al*., 2004 and Murawski K. 2015) for a liquid or a particle in a tank. Two laser projectors are fixed on the base to produce two projected brightest lasers spot and a vertical plane is defined on the material surface in the tank. Time is used instead of pixel counter for the distance measurement and an electronic circuit is used to count the number of clock pulses between two bright laser spots. As these two brightest laser spots form an isosceles triangle, the actual height of liquid can be calculated in the tank by using simple formula as shown in Figure-3.

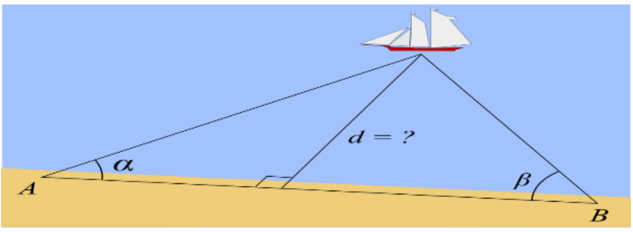

Figure-3. The triangulation method for image-based height measuring system.

2.3 The Human-Height Measurement Scheme Using Image Processing Techniques

Ming-Chih and Wang (2004) proposed a fixed laser point triangular distance measurement (FLPTDM) method for human height measurement. In this method, the combined use of a digital camera and a laser beam is proposed for an accurate distance measuring system. A laser beam is used for signal emission and the camera is used for signal detection. The offset compensation data is used to calculate the distance between laser beams projected image and center of the image, error calibration, and improvement of the measurement precision. Lu M.C. (2006) also proposed image based area and distance measurement technique.

2.4 Laser Range Distance Measurement and Beam Splitting Technique using camera to measure the distance of an Object

Pen *et al*., (2020) used a hand-held structured light vision system for boxes. This system measures dimension information through laser triangulation and deep learning using only two laser-box images from a camera and a cross-line laser projector. A system is proposed by (Chen *et al*., 2003) to calculate the distance between an object and the camera by using a laser range measuring device combining with a beam splitting device. The system takes the image of an object on the focal length of the lens and then analyzes its height and width on the image detector and computes the final distance of the object from the camera according to the geometrical optics. Another technique is presented by (Jernej and Vrancic, 2008) to measure the distance based on stereoscopic pictures. Khlief and Shnawa (2018), extracted image feature using MATLAB program and achieve image processing technique to get useful information from image and gained very close to real measurement.

2.5 Measuring Distance Using a Single Camera and a Rotating Mirror

Kim *et al.* (2005) proposed a new distance measurement technique with the use of a single camera and a rotating mirror.

ARPN Journal of Engineering and Applied Sciences

Figure-4. The two-laser spot method.

Several continuous reflected images are obtained from a camera in front of the rotating mirror. This technique presents a relationship between pixel speed and distance, in which movement of a pixel is calculated based on a sequence of images and the corresponding pixel of an element pointing at longer distance rotates at a higher speed. Whereas, Lau K.C. (2017) presented a novel multi-dimensional measuring system with 360-degree working range.

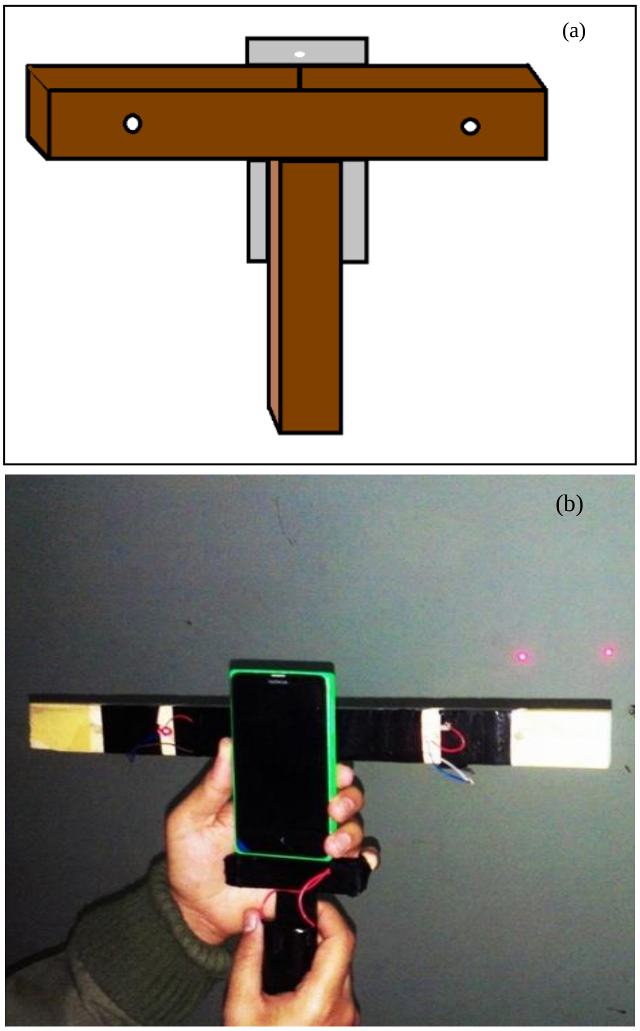

Figure-5. The LASERCAM, (a) The LASERCAM device armature, (b) The LASERCAM device with live laser spots and Mobile device.

3. DESIGN AND METHODOLOGY

3.1 Proposed Two Laser Spot Method

A new method is proposed and developed in the current research study which is based on two laser spot methods whcih is named as LASERCAM. The proposed idea is based on the principles of image perspective. According to the fact, as the distance increases, the number of pixels between two laser spots decreases. The phenomenon of image perspective can be seen by using two laser spots in Figure-4 which illustrate that as the distance increases, the number of pixels between two laser spots decreases and vice versa.

3.2 Development of LASERCAM Device

The LASERCAM device is made up of a wooden frame in which straight holes are present to support laser diodes as shown in Figure-5. This hardware is used to calculate the size of an object and also to measure the distance between an object and the LASERCAM device. The overall efficiency of this device depends upon the straightness of the laser diode because if the diode changes its position (change in the angle), the output will not be the same as required. The LASERCAM device consists of two laser lights which are fixed in hardware in such a way that the camera is present at the midpoint of laser lights. All the connections are also made for supplying the power to the laser diodes. The proposed technique has four parts, in which every part is composed of some steps to be performed. The details of every step are described in Figure-6.

Figure-6. Distance measurement flow.

3.2.1 Acquisition of image frames from video

There are three steps for acquiring an image frame from video, which are as follows:

a) Using a mobile camera to capture video,

b) Connecting mobile camera from MATLAB by using network and mobile IP, and

c) Getting image frames from MATLAB by using GUI.

3.2.2 Detection of red spots in image frame

After the acquisition of an image frame, the next task is to find the position of the red spot which is present in an image frame. The steps and detail for the detection of red spots in image frame are discussed in the following sections.

VOL. 16, NO. 13, JULY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

3.2.3 Applying red filter

The theory behind getting the position of red laser spot is to apply red filter on it so to get the brightest point at its position. After getting the position of the brightest spot, the main task is to find the number of pixels between these two spots.

3.2.4 Getting brightest point by threshold Technique

After the application of red filter our next task is to find the brightest pixel of red spot. To do this task, the threshold technique on red filtered image is performed.

3.2.5 Splitting image

The red laser spot is being present at the middle of the frame. The whole image frame is split into three parts and the middle one is used for further process because the whole information is present in the middle of the frame. Splitting the image frame is also beneficial in avoiding unnecessary information and to work on both laser spot separately. The black area in figure 7 shows the required area.

Figure-7. Movement of laser spots in medium.

3.2.6 Getting point from split image

This step involves getting required true pixel separately of both left and right split image.

3.2.7 Finding Central Pixel

Now finding central pixel to select one pixel among a group of pixels of brightest spot (Figure-8).

Figure-8. Applying red filter for finding the brightest spot in captured image.

3.3 Calculation of Distance from the Object

The first objective of this research work is to calculate the distance between the object where laser spots are present and LASERCAM device. For calculating the distance between LASERCAM device and object, a formula has been developed by generating a table which consists of total number of pixels between laser spots at a specific unit of distance. According to the theory of image perspective, as the distance from an object increases, the total no. of pixels between laser spots decreases. Now for calculating the distance from the object, a table is developed, and then graph by using the total numbers of pixels between laser spots at a specific distance is generated. For the calculation of the distance from the object, an observation table is plotted by using the total numbers of pixels between laser spots at a specific distance which is shown in Figure-10. The observation graph also suggests that as the distance from the object increases, the distance between laser spots decreases. This shows an inverse relation between the number of pixels and the object. Therefore, to calculate the distance by using the laser spots method, an equation is developed from inverse relation between the number of pixels and object distance and mentioned as equation 1 and equation 2.

$$\text{number of pixels} \propto \frac{1}{\text{distance}} \quad \text{--- (1)}$$

$$\text{number of pixels} = \frac{k}{\text{distance}} \quad \text{--- (2)}$$

here, k = 2.163 *10000 (in presented case)

3.4 Size Measurement of any Object where Laser Spots are Present in Image Frame

Built-in ruler of MATLAB is used here for size calculation. MATLAB ruler gives the distance in its own unit. The number of pixels of an object and the number of pixels between laser spots are counted by MATLAB ruler which are required for size calculation. The distance between spots is already known which is 7 inches.

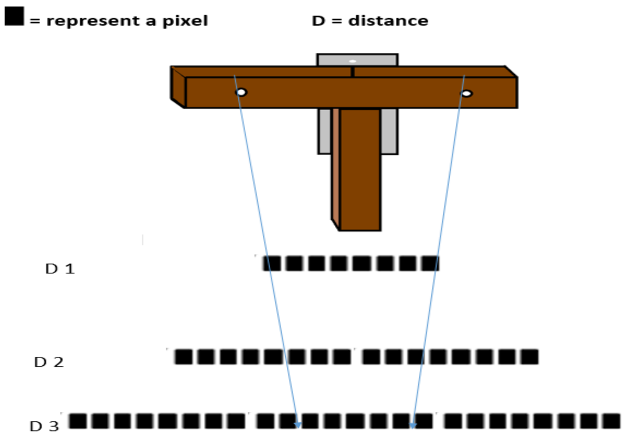

Figure-9. Distance calculation.

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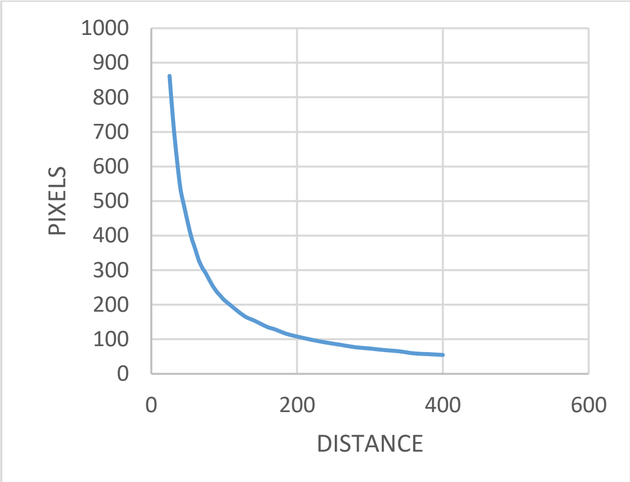

Figure-10. Relationship between pixels and distance.

Figure-11 shows the flow of steps to be carried out for size calculation. The size is calculated in such a way that we already know the number of pixels between laser spots and know the constant distance between laser spots 7 inches (17.7 cm). So, if we want to calculate the size of any object, we just have to divide the number of pixels of an object by the total number of pixels between laser spots and then multiply it by 17.7 CM or 7 inches.

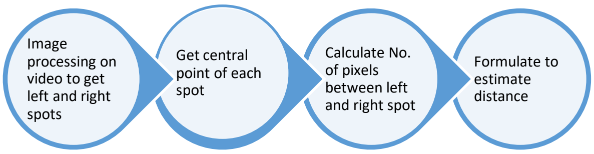

Figure-11. Size measurement flow.

$$\text{Size of Object} = \frac{\textit{No. of pixels of object}}{\textit{No.of pixels between laser spots}} \times \textit{distance between spots} \quad \text{--- (3)}$$

4. RESULTS

The size of an LED display has been measured by using the proposed method which can be seen in Figure-12 (a). The width of the LED display in our proposed method is 76.2264 cm and it is at the distance of 308.041 cm as shown in Figure-12 (b). Calculation of the width manually by measuring tape, as seen in Figure-12 (c), shows that the width of the LED display is 75 cm and the distance is 309 cm. The result from our proposed method shows that the width is 76.2264 cm and the distance is 308.041 cm.

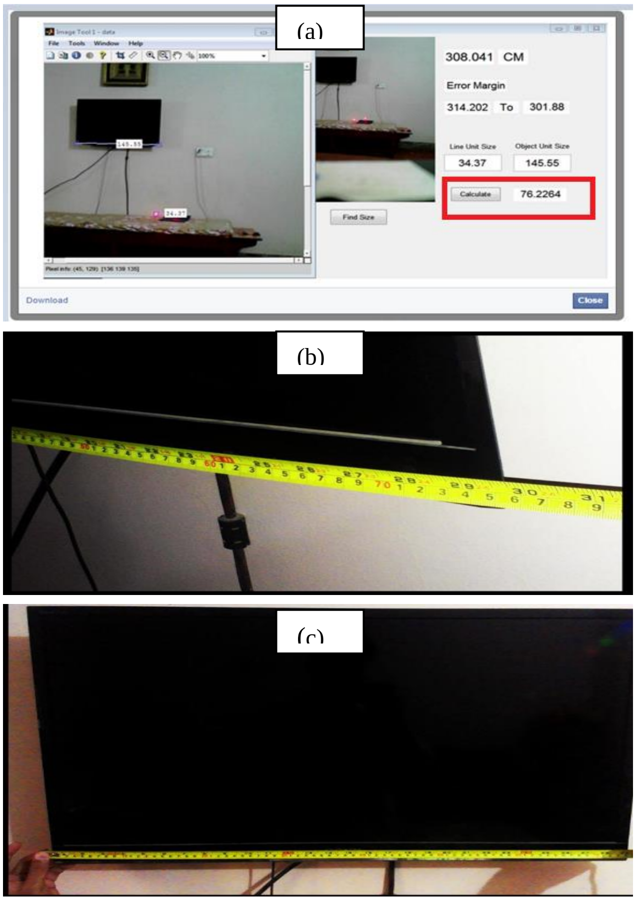

Figure-12. Measurment of objecs using LASERCAM and Manual method.

Table-1 shows the cost and range comparison of commonly used tools and techniques which makes LASERCAM very cost-effective as compared to other devices which are present in the market today. This proposed system can be used in many ways and conditions especially in highly pressurized and high temperature areas to perform the desired task without encountering these constraints. Table-2 shows the cost of manufacturing of LASERCAM system at a domestic level. Industrial production cost may definitely be more attractive.

Table-1. Cost and range comparison.

Tools and techniques	Max range in centimeters	Price in USD
Infrared	10 - 40 cm	14$
Ultrasonic	2 - 300 cm	30$
LASERCAM	25-400 cm	3$

Table-2. Cost of LASERCAM.

COMPONENT	PRICE (in PKR)
2 LASER DIODE	200
WOODEN FRAME	50
BATTERIES	20
WIRES	2
SWITCH	8
TOTAL	280

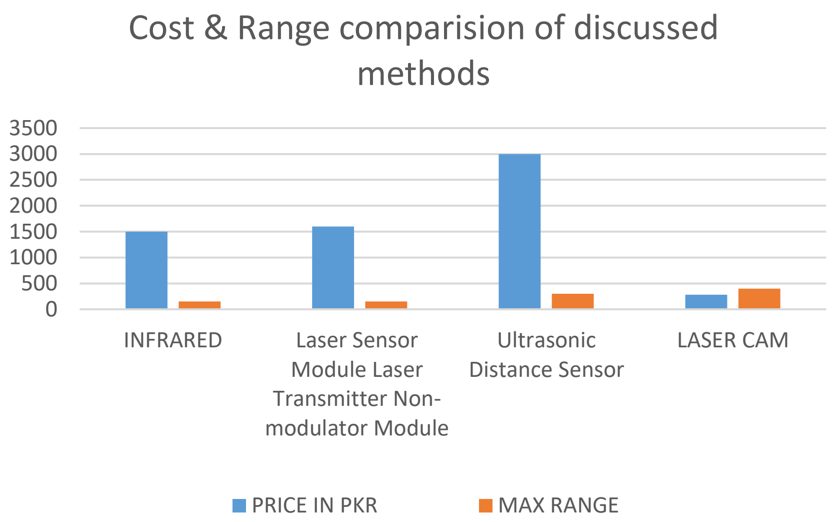

Figure-13. Cost and range comparison of discussed methods.

5. CONCLUSIONS

The proposed work provides a cost-effective and time-efficient method to measure the distance of an object (Figure-13) that doesn't need any high-speed expensive camera and complex image processing and pattern recognition techniques. Though the proposed method is comparatively based on a simple algorithm, the computed distance is quite accurate (with an error rate of 0% to 1.7%). This system can be useful in many real-time environments, for example, it can be utilized in a mobile robot navigation in the real environment. The system can also be used to measure the distances of live objects in real-time autonomous navigation and for automatic breaking system for self-driving and normal cars. In manufacturing industries, this can be used in sorting system materials based on size etc. The distance and size of the object can be easily calculated by using the proposed LASERCAM device, which shows the utilization of image processing and laser beam technology into a new way to perform similar tasks. This work shows how to make a cheap device which is very much cost-effective and time-efficient as compare to other devices which are present in the market today. Presented work is about the innovation and automation of a process of distance and size calculation to lower the labor cost and to make the overall process time-efficient. This system can be used in many ways and variant environmental conditions, especially in highly pressurized and in the high temperature areas without coming in contact with these constraints.

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