PASSIVE DISTANCE MEASUREMENT USING LOW POWER LIGHT EMITTING DIODE

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PASSIVE DISTANCE MEASUREMENTS USING LOW POWER LIGHT EMITTING DIODE

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In the name of Allah the Most Beneficent and Most Merciful,

Abu Hurairah narrated that the Messenger of Allah said:
"Whoever is not grateful to the people, he is not grateful to Allah."
(Jami' at Tirmidhi, Book 27, Hadith 2008)

Alhamdulillah, all praises to Allah, the Almighty and the most Merciful for his blessing to complete this thesis and bachelor degree successfully. Not to forget, Peace and Prayer to the Prophet, Muhammad S.A.W.

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ABSTRAK

Terdapat pelbagai jenis sensor pengukuran jarak yang tersedia di pasaran yang digunakan dalam pelbagai aplikasi seperti dalam bidang robotik dan juga dalam industri perkilangan. Kos yang rendah dan ketepatan yang tinggi peranti adalah penting dalam kebayakan aplikasi yang membawa kepada pelbagai jenis kaedah pengukuran jarak. Selain itu, sebilangan besar literatur membuktikan bahawa mencari kaedah lain untuk mengukur jarak adalah disengajakan, terutamanya untuk aplikasi deria dan minat tinggi diperhatikan dalam teknik pengukuran tanpa sentuhan. Tesis ini adalah mengenai sistem pengukuran jarak menggunakan kos rendah dan kurang penggunaan kuasa diod pemancar cahaya (LED). Dalam projek ini, teknik pengukuran jarak pasif digunakan dan objek dengan permukaan rata dicipta dari sumber cahaya monokromatik dalam tahap pengcahayaan yang terkawal digunakan untuk pemprosesan imej.

ABSTRACT

There are many types of distance measurement sensor available in market that is used in various applications such as in robotics field and also in manufacturing industries. A low cost and high accuracy of the device are important in most of the applications lead to various types of distance measurement methods. Furthermore, a large number of literatures prove that searching for other methods of measuring distances is intentional, especially for sensory applications and a high interest is observed in non-contact measurement techniques. This thesis is about distance measurement system using a low cost and less power consumption of light emitting diode (LED). In this project, a passive distance measurement technique is applied and an object with flat surface is created from monochromatic light source in a controlled illumination level of surrounding that is used for image processing.

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LIST OF SYMBOLS

nm	Nanometre
Wf	Fermi Levels
eV	Electronvolt
mm	Millimeter

LIST OF ABBREVIATIONS

LED	Light Emitting Diode
LDR	Light Dependent Resistor
VLC	Visible Light Communication
THz	Terahertz
OWC	Optical Wireless Communication
TOF	Time of flight

CHAPTER 1

INTRODUCTION

1.1 Introduction

In this chapter, it will introduce an overview of distance measurement system via visible light communication. The background of study, objectives and the scope of the project are explained in this chapter.

1.2 Background of Study

Wireless communications is the transmission of information without wires, cable or any electrical conductors over a distance and the transmitted distance can be reaching up to hundred metres. This wireless communication is the fastest growing segment in the communications technology industry where the cellular phone haves experience this aggressive evolution over the last decades starting from the first invented telephone by Alexander Graham Bell in 1876 (Goldsmith, 2005). The cellular phone is advance rapidly and become a business tools in the most developed countries and they compete to each other in order to deliver the performance needed to support emerging applications.

Besides, the wireless communication system is not only occurs to the cellular phone yet there are many devices that use wireless system such as satellite television, wireless computer and Wi-Fi. The benefits from this technology are that data or information can be transmitted faster and it reduces the cost for the maintenance and installation purpose. It is also become convenient because it can be use anywhere. There are various types of wireless communication which are satellite communication, broadcast radio, microwave radio, Bluetooth, and infrared wireless communication that can be use to develop a new product in the future.

The next generation of wireless communication systems is expected to move ahead from being solely radio frequency to hybrid systems including optical wireless communication systems (Connor & York, n.d.). The visible light communication (VLC) is the optical wireless communication (OWC) that becoming an alternative choice for next generation wireless technology by offering low cost, unregulated bandwidth and ubiquitous infrastructures support (Sagotra & Aggarwal, 2013). Visible light is use for data transmission by modulating light in the visible spectrum (400-800 THz or 780–375 nm) that is particularly used for illumination. The VLC has experienced exponential growth with the growth of high power light emitting diode (LED) in the visible spectrum(Arnon, 2015). VLC systems take the advantage of the light emitting diodes (LEDs) which can be pulsed at very high speed without perceptible effect on the lighting output and human eye.

However, LED has dual functionality for illumination and communication which contributed to a sustainable and energy efficient approach (Uysal & Nouri, 2014). As light emitting diode (LED) is low in power consumption, minimal heat generation lighting and has a longer life-time compared to the fluorescent lamp system, many researchers are working on the development of light emitting diode (LED) (Komine & Nakagawa, 2004). The aim of this project is to investigate and develop a distance measurement system by using LED to produce a flat surface object with the support from the camera for image processing.

1.3 Problem Statement

There are various devices that use in distance measurement available in the market like ultrasonic, laser, capacitive sensors and others. Most of them give a very significant impact on process automation and factory automation parts of a product manufacturer. Today's distance measurement sensors are used in varying applications for automated systems, robotics, and safety systems. Because of its various applications, the demand for the sensor is growing steadily from time to time.

However, there are also many methods use in distance measurement system in order to obtain the accurate values. Many researches have been made to produce a distance measurement system from low cost materials, and also the device is low power consumptions. LED is known for its advantages which comply with the characteristics that researcher demand compare with other light system such as fluorescent lamp system. Therefore, the purpose of this project is to develop a distance measurements sensor by transmitting light from light emitting diode (LED) to the flat surface object.

1.4 Objectives

The objectives of this project are:

- To develop a light meter for illumination level measurement using light dependent resistor (LDR).
- To implement a new method of object distance measurement by using light emitting diode (LED) and image processing approach.

1.5 Scope of Study

The main focus of this study is to measure a distance between a camera and an object with flat surface created from monochromatic light sources in a low illumination environment. This project actually utilizes the advantage of light emitting diode (LED) as illumination. Besides, LED is also low power consumption, long life and low temperature generation.

The project begins with calibration of illumination level using a light dependent resistor (LDR) against a commercial light meter in a specific built bench top enclosure. This is to determine the illumination level of the bench top enclosure that is suitable in distance measurement system. Next is the camera calibration against simulated illuminated surface with known distance. And lastly is assessment of the distance between a camera and an object with the object diameter size produce by light emits from LED.

The measurements system is uses inexpensive and open source hardware and software packages. A webcam is use for image acquisition purpose. The object image acquire will be post processed using existing libraries of Processing 3 IDE from Processing Foundation and algorithms developed for fundamental relations in Euclidean geometry.

1.6 Summary

This chapter explains briefly about the project background and the aim of this project including the hardware and software use. The focus of this thesis is on the implementation of light emitting diode (LED) as signal transmission for object distance measurement. As discussed before, LED is one of the visible light communications that can be pulsed in a high speed without effecting the lighting output and human. To summarize about this project, the LEDs will emit the lights onto a flat surface and the webcam will capture the image form for image acquisition. All of this process occurs in a controlled illumination level surrounding.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In ancient times, people used their parts of the body as measuring devices. For example, people measured shorter distances on the ground with their feet. This is because people realized that the body can be ruled when it came to measuring. The length of a foot, the width of a finger, and distance of a step were all accepted measurements.

As time goes, people start to think an easy and better ways in measurement systems in order to obtain the more accurate measuring value and make the life much easier than before. A measuring standard was set to represent the same amount for everyone as different people measured the same items allowed different measurement value for example in length measurement, one foot is equivalent to twelve inches according to US customary systems of measurement before the invention of metric system. In the metric system, one meters is equal to 3.3 feet and this system has been used by all people around the world as measurement standard until today which is known as International System of Units (SI) (NIST, 2002).

Along with the evolution of measurement standard, there are various measuring devices that have been developed especially after researchers discover the nature of light. Many distance measurement products in the market nowadays, use the advantage from the light in developing the precise and accurate measuring devices. The general objective of this project is to develop an object distance measurement devices by using light emitting diode (LED). In order to achieve the objective, literature review was conducted in this chapter to get the better concept of measuring technique and the LEDs features.

2.2 LEDs

Light emitting diodes or known as LEDs are solid-state light emitting devices that emit less heat and last longer than other light source. LED has many advantages which it has a long operational life time compare to standard light and do not burn out and stop working but instead LED lower output levels over a very long period of time and become less bright. Besides, LED lightning features lead to better energy efficiency which estimated energy efficiency of 80%-90% when compared to traditional lightning and conventional light and it is also consume a low voltage power for LED illumination.

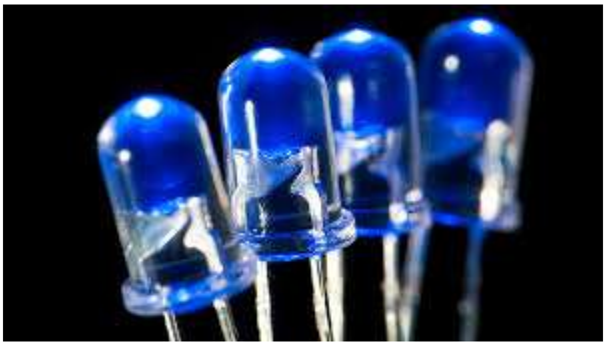
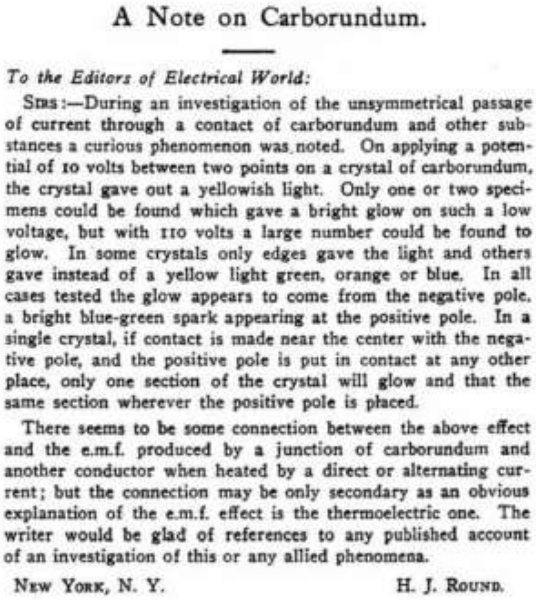


Figure 2.1: LEDs
Source: (whosgreenaz.com, 2015)

2.2.1 History of LED

Light emitting diode or LED is a semiconductor that is the major component of today’s technology. In 1907, Henry Joseph Round was the first to notice that a yellowish light is emitted when 10 volts is applied between two points on silicon carbide crystal (SiC) or called carborundum. However, Oleg Vladimirovich Losev from Russia was the first to investigate and propose a working theory in 1928 and also published a paper “Luminous carborundum detector and detection effect and oscillations with crystals”. He found that luminescence phenomenon occurred in some diode when biased in the reverse direction and in some diodes when biased in forward and reverse directions (Schubert, 2006).



A Note on Carborundum.

To the Editors of Electrical World:

SIRS:—During an investigation of the unsymmetrical passage of current through a contact of carborundum and other substances a curious phenomenon was noted. On applying a potential of 10 volts between two points on a crystal of carborundum, the crystal gave out a yellowish light. Only one or two specimens could be found which gave a bright glow on such a low voltage, but with 110 volts a large number could be found to glow. In some crystals only edges gave the light and others gave instead of a yellow light green, orange or blue. In all cases tested the glow appears to come from the negative pole, a bright blue-green spark appearing at the positive pole. In a single crystal, if contact is made near the center with the negative pole, and the positive pole is put in contact at any other place, only one section of the crystal will glow and that the same section wherever the positive pole is placed.

There seems to be some connection between the above effect and the e.m.f. produced by a junction of carborundum and another conductor when heated by a direct or alternating current; but the connection may be only secondary as an obvious explanation of the e.m.f. effect is the thermoelectric one. The writer would be glad of references to any published account of an investigation of this or any allied phenomena.

NEW YORK, N. Y. H. J. ROUND.

Figure 2.2: The first observation of electroluminescence from SiC (carborundum) light emitting diode.

Source:(Schubert, 2006)

In 1955, Rubin Braunstein of the Radio Corporation of America reported on infrared emission from gallium arsenide (GaAs) and other semiconductor alloys. Followed by Gary Pittman and Bob Biard from Texas Instruments who found that gallium arsenide gave off infrared radiation when electric current applied in 1961 and they also received the patent for infrared light emitting diode (LED). Nick Holonyak Jr. who worked at General Electric Company and later joined the University of Illinois developed in 1962 the first light emitting diode that emitted light in the visible spectrum of the frequency range and it was a red LED. He is known as the “father of the light emitting diode”. A graduated student of Holonyak, M. George Craford has invented the first yellow LED and a brighter red LED in 1972 while Thomas P. Pearsall developed high brightness light emitting diode in 1976 to use with fiber optics in telecommunications purpose.

Gallium nitride (GaN) was first investigated as a potential material for LEDs in the late 1960s by Paul Maruska and Jacques Pankove at the Radio Corporation of America. Shuji Nakamura and Takashi Mukai from Nichia Chemical Industries Corporation have made numerous contributions to the development of GaN growth, LEDs and lasers. The contributions included the demonstration of the first visible blue and green indium gallium nitride (InGaN) double heterostructure LED and the demonstration of first pulsed and InGaN/GaN current injection blue laser operating at room temperature (Schubert, 2006). Shuji Nakamura demonstrated the first high brightness blue LED based on InGaN and was awarded the 2006 Millennium Technology Prize for his invention (Nakamura, 2014). The common application of high brightness InGaN green LEDs is traffic signals.

The GaN revolution has since provided efficient UV, violet and blue light emitters. Due to these achievements, it is now possible to generate white light using GaN LEDs. There are different approaches to white LEDs as shown in Figure 2.2 a blue LED with yellow phosphors, a UV LED with blue and yellow phosphors (or red, green and blue phosphors), and a device that combines red, green and blue LEDs. However, the blue GaN LED with yellow phosphor dominates the white LED industry (Denbaars et al., 2013).

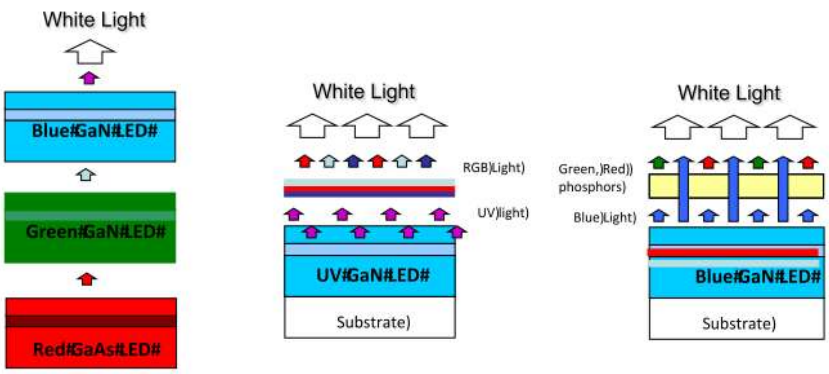


Figure 2.3: Three ways of generating white light from GaN LEDs
Source: (Denbaars et al., 2013)

According Shuji Nakamura, a white LED can be created by embedding phosphors in a plastic cap which surround as a blue LED as shown in Figure 2.3. Part of the blue light emitted from a blue LED is converted to lower energy colors, such as yellow, using a phosphor. The combination of blue and yellow light is perceived as white to the human eye. A higher quality of white light can also be created by mixing blue light with other colors as well including red and green (Nakamura, 2014).

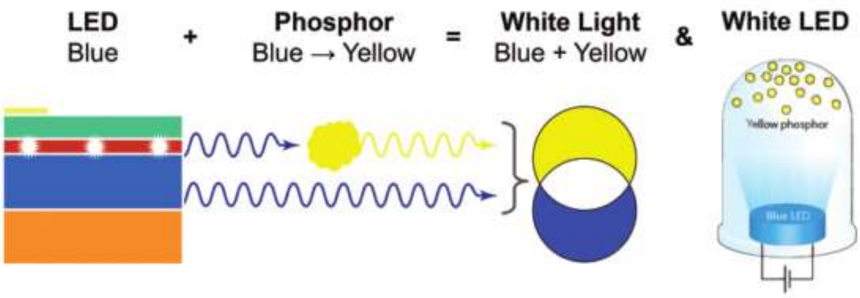


Figure 2.4: Combining a blue LED with embedded phosphors in the plastic cap creates a white LED.

Source: (Nakamura, 2014)

2.2.2 Theory of LED

A semiconductor is formed by P-type and N-type of materials. The Light emitting diode (LED) is a PN junction of semiconductor that emits light when forward biased releases the energy in the form of photons. This phenomenon is called electroluminescence. The LED is different from other diodes which its band-gap is designed for radiative recombination (Gujjari, 2012). This radiative recombination process occurs in competition with non-radiative recombination which the energy is converted to heat. When LED emits the light, the photon energy is equal to the band-gap energy. Most of the commercial LEDs are realized using a highly doped n and p junction.

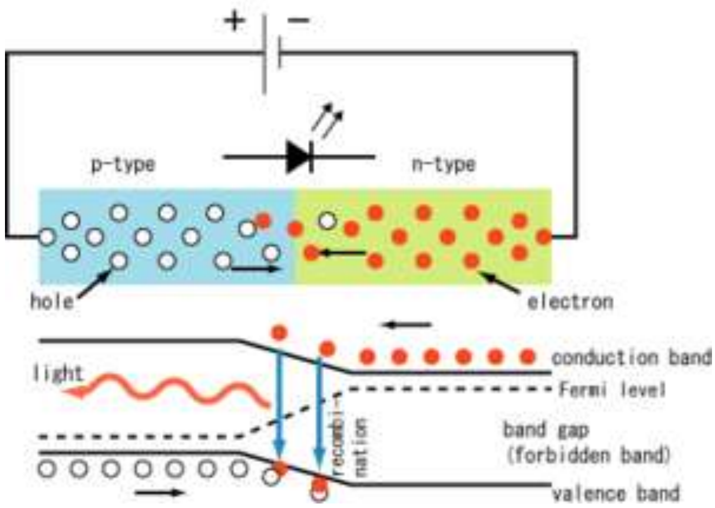


Figure 2.5: LED PN-junction biasing arrangement and the energy bands associated with the diode.
Source:(The LibreTexts libraries, 2015)

The Fermi levels (Wf) will be aligned and produce an energy barrier when joining the N-type and P-type materials even no external voltage is applied. There are two energy bands, the conduction band and valence band which are separated by forbidden region with the width of Wg. In the conduction band, electrons not bound to individual atoms are free to move. While in the valence band, unbound holes are mobile and have positive charge. The free electron in the N region cannot go up the barrier without external energy which is the same for the holes that cannot overcome the barrier until a sufficient energy (eV) is applied. When energy is supply, a free electron crosses the barrier, falls into the lower energy level and recombines with the hole and releasing the energy in the form of photons (Gujjari, 2012).

2.3 Distance Measurement

Determine the distance, size, or shape of an object is a great practical importance in everyday life. The main mechanism of humans and other organisms to nearly instantaneously obtain the object information that is depends on many variable is stereoscopic vision. As most of the people know that the eyes receive light from surrounding and producing retinal images that brain processes. This is an example of passive method. There is an example of an active method although it is not optical, it is the echolocation by bats. The short burst of sound emits by a bat is reflects from a target (echo) and detected by the bat's ears.

There are many practical applications in modern life from the accurate and quantitative determination of distance using light. Point-by-point measurements give 3D imagery important in, for example map making which is distance on the order of kilometer, assembly line quality control in meters, or microscopy in micrometers. Numerous active and passive techniques have been developed to obtain 3D imagery and there are classified in three main techniques which are geometrical, time of flight (TOF), or interferometry. A geometrical techniques example is triangulation relies in the spatial geometry between the source of light, target and detector. While the TOF method is depends on the finiteness of the speed of light and ability to measure the TOF directly with clocks (directly TOF) or indirectly (indirect TOF) by comparing the phase of the intensity-modulated emitted and reflected light. However, interferometry relies on the wave nature of light and the ability of the waves to interfere.

The flowchart of distance measurement methods is shown in figure 2.6. The methods involves optical (light) and non-optical (such as sonar). For the optical methods, it is divided into two categories which are passive an active method. The passive technique is the measurement system that does not illuminate the target but the light from the target is either reflected ambient light or the light produced by the target itself. In active technique, the measuring system does illuminate the target. Depending on the technique, the illumination may be a combination of monochromatic, polychromatic, continuous, pulsed, modulated, structured, polarized, coherent, or partly coherent light (Yadav & Mohite-Patil, 2012).

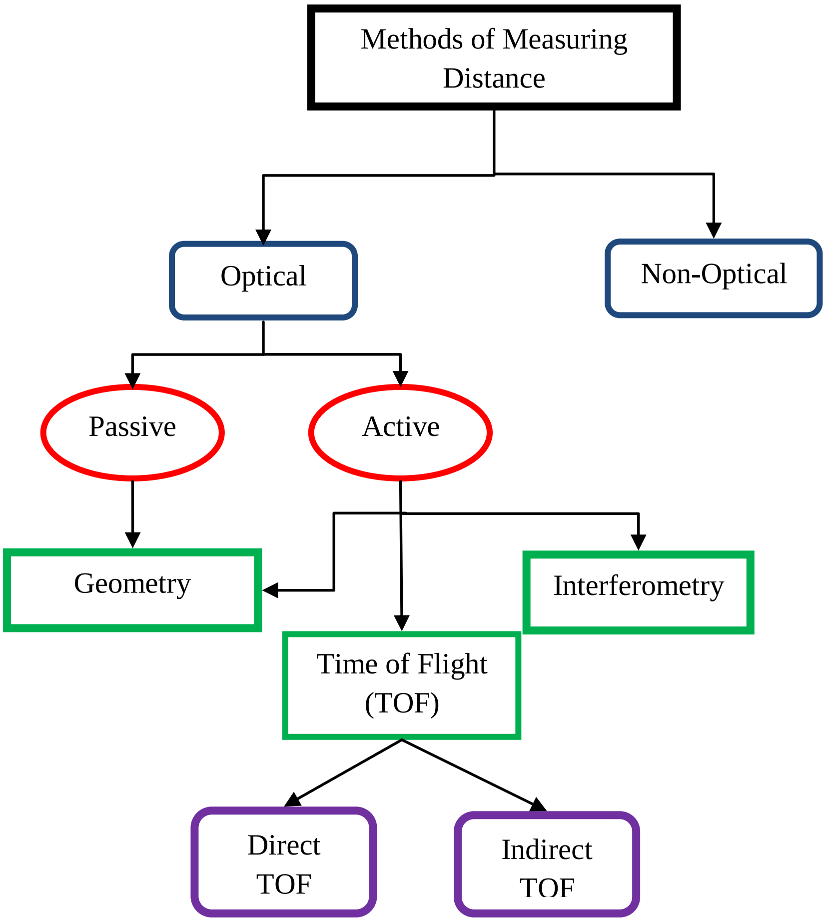


Figure 2.6: Flowchart of Distance Measurement Methods

2.3.1 Passive Method

Passive systems evaluate light coming from the target. Stereoscopy measuring method is one notable application of passive triangulation and geometrical technique which are used for recording and representing stereoscopic (3D) images. The two pictures taken are slightly different position creates an illusion of depth. There are two possible way in taking stereoscopic pictures either by using special two-lens stereo cameras or system with two single-lens stereo cameras joined together. The distance is calculated by taking the differences between the pictures and additional technical data like focal length and distance between cameras.

The stereoscopic picture is taken with a pair of camera which is similar to human eyes under some important restrictions as following (Yadav & Mohite-Patil, 2012):

Cameras should be horizontally aligned as shown in Figure 2.6.

The pictures should be taken at the same instant.

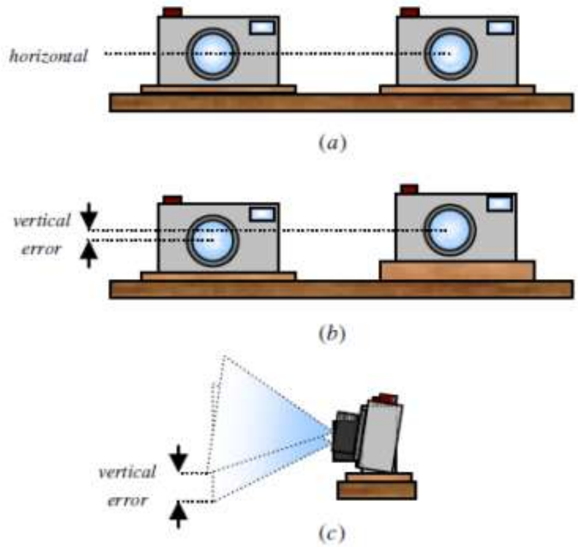


Figure 2.7: Proper alignment of cameras (a) and alignment with vertical error (b) and(c)
Source:(Yadav & Mohite-Patil, 2012)

From the stereoscopic pictures, the distance between the camera(s) and the chosen object within the picture can be calculated. Let the right picture taken in location SR and the left picture in location SL. B represent the distance between the cameras and φ_0 is camera's horizontal angle of view. The object's position, distance D can be calculated by doing some geometrical derivations.

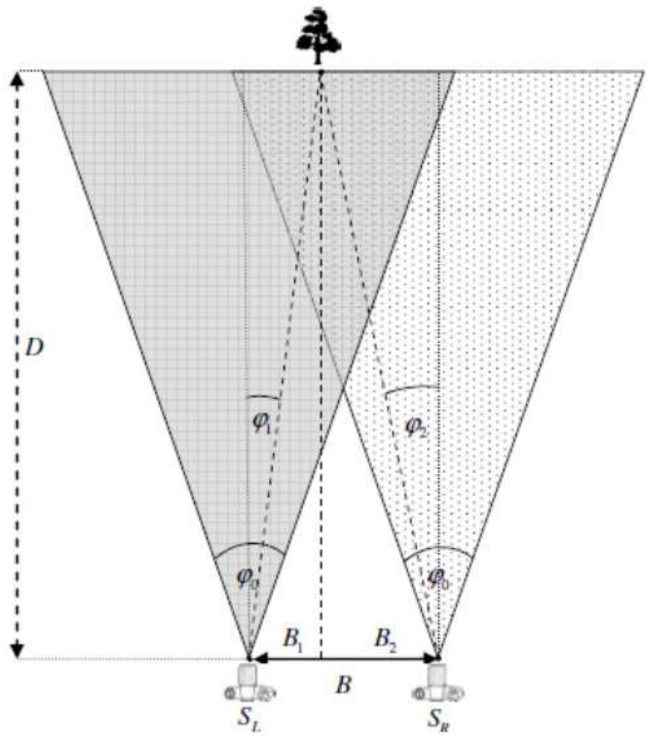


Figure 2.8: The picture of object taken with two cameras
Source:(Yadav & Mohite-Patil, 2012)

We can express distance B as a sum of distances B_1 and B_2 :

$$B = B_1 + B_2 = D \tan \varphi_1 + D \tan \varphi_2 \tag{2.1}$$

If the optical axes of the cameras are parallel, where φ_1 and φ_2 are angles between the optical axis of camera lens and the chosen object. Distance D is as follows:

$$D = B / \tan \varphi_1 + \tan \varphi_2 \tag{2.2}$$

2.3.2 Active Method

Active system employs a light source for illumination of the target. It is divided into three broad categories which are geometrical, TOF and interferometry. An image-based distance measuring system (IBDMS) is use in active distance measurement technique because it is very simple, consisting only a single CCD (charge coupled device) camera and two laser projectors formed in parallel besides the camera.

- Triangular Measuring Method

In Figure shows the triangular measuring method which D_{max} and H_{max} are the maximal horizontal distance and maximal photographing distance, respectively. By a triangular formula, the relationship is as follows (Yadav & Mohite-Patil, 2012):

$$\frac{D_k}{D_{max}} = \frac{H_k}{H_{max}} \tag{2.3}$$

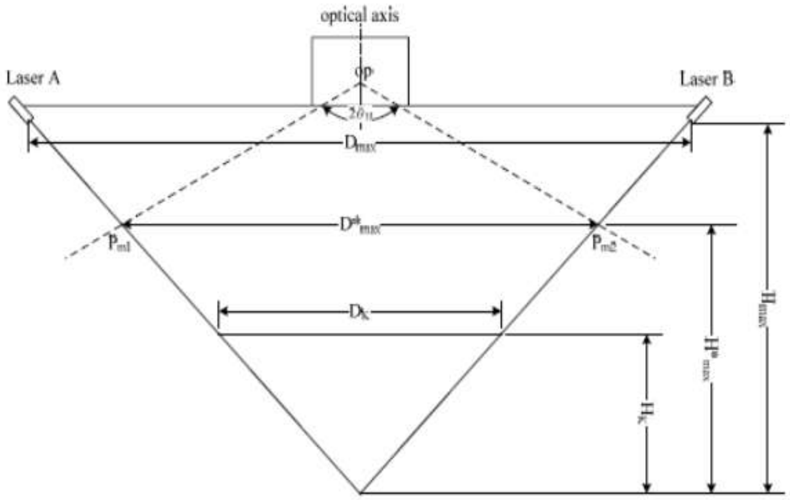


Figure 2.9: Schematic diagram illustrate triangle measuring method
Source:(Yadav & Mohite-Patil, 2012)

Because every CCD camera has a limited view angle 2θH as shown in Figure 2.9, the effective measuring range therefore lies between two dotted lines. Attempts in measuring objects lying in the invalid range between H*max and Hmax will result in fatal errors, because the projected spots will not appear on the image captured by the camera. Therefore, both maximal photographing distance (Hmax) and maximal horizontal distance (Dmax) must be suitably adjusted as H*max and D*max to prevent from lying in the ineffective zone outside the dotted lines. As a result, the equation of 2.3 has to be modified as follows:

$$\frac{D_k}{D *_{max}} = \frac{H_k}{H *_{max}} \tag{2.4}$$

Although redefining measuring range solves the problems of invalid measuring range, it is still difficult to make these two laser beams projected onto an identical position, which is extremely inconvenient for practical applications. That is why the parallel measuring method is proposed to remove the constraints on the triangular measuring method (Yadav & Mohite-Patil, 2012).

2.4 Brightness - Illumination Level

Illumination is the amount of light falling onto a surface area and it can be measured using a device such light meter which it measure the illumination level of surrounding in units lux. Illumination is important in daily life as it affect human routine for example in the night, a light bulb is use to illuminate the surrounding as there is no natural light from the sun.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the method to achieve the objective of this project is discussed. Research has been done for literature in Chapter 2 as reference in conducting this project. This project is consists of the calibration rig and experimental setup.

The calibration rig includes the calibration of illumination level of light dependent resistor against the commercial light meter and also camera calibration. An object image obtains from the webcam use for image processing purpose with the aid of Processing software. The distance between the camera and the object is related with the diameter size of the object.

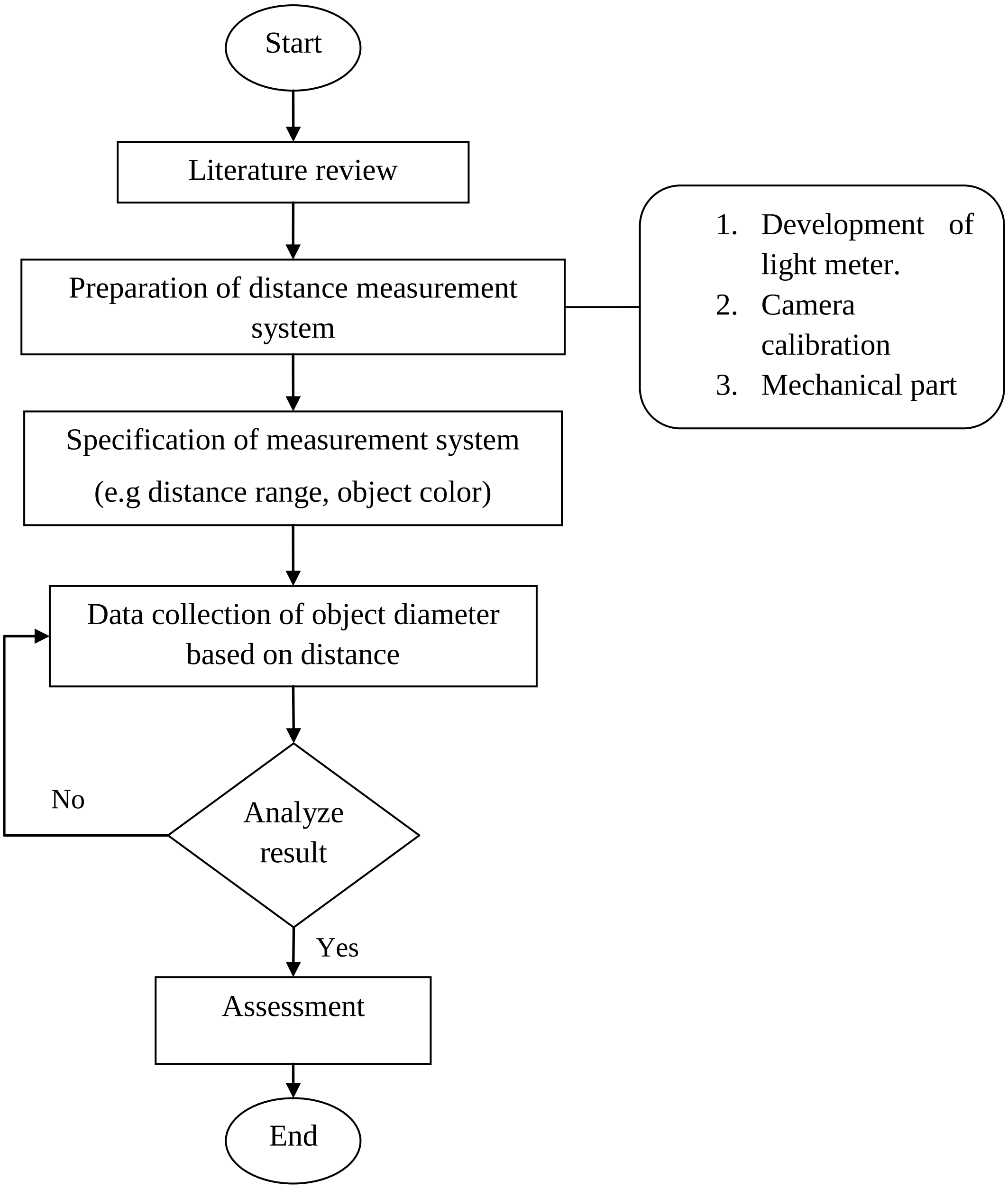


Figure 3.1: Project flowchart

3.2 Calibration rig

The calibration rig consists of the calibration of illumination level of light dependent resistor against the commercial light meter and also camera calibration. An object image obtains from the webcam use for image processing purpose with the aid of Processing software. There are two devices that are needed to calibrate which are light dependent resistor (LDR) against light meter for a low cost light meter development and camera calibration.

3.2.1 Calibration of Light Dependent Resistor

The calibration procedure consists of the arduino light dependent resistor (LDR) circuit, a commercial light meter (RS 180-7133) with unit measurement of lux which is the SI unit for illuminance and a specific built bench top enclosure or also called a control illumination chamber, a as shown in Figure 3.2. Illuminance is the measurement of the amount of light falling onto (illuminating) and spreading over a given surface area. The unit of the illuminance is lux which is equal to one lumen per square metre.

Figure 3.2: LDR, light meter and bench top enclosure

The flowchart of the calibration LDR against the commercial light meter is shown in Figure 3.3. The calibration start with the setup preparation as shown in Figure 3.4, the commercial light meter and the arduino LDR circuit is place at the centre of the bench top enclosure. The measurement value of arduino LDR circuit and light meter is taken at different angle of opening the bench top enclosure. The values obtain is use to formulate the calibration curve to produce a calibrated device.

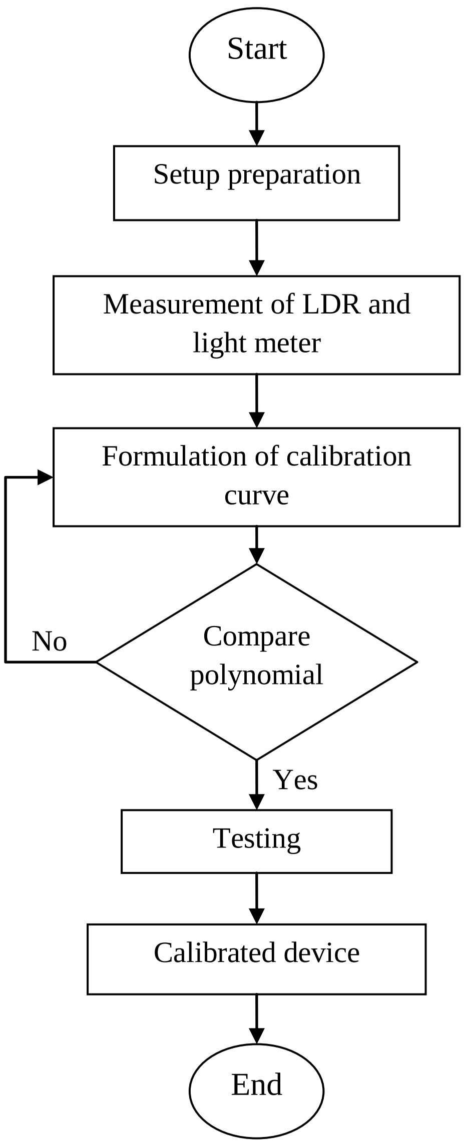


Figure 3.3: Light meter development flowchart

Figure 3.4: Position light meter and LDR inside the bench top enclosure

In order to measure the illumination levels inside the bench top enclosure, the opening angle of the bench top is taking into the consideration as the independent variable parameter by using the protractor as shown in Figure 3.5. While the LDR and light meter position as the controlled variable that should remain be constant throughout the calibration process.

Figure 3.5: Opening angle of bench top enclosure

3.2.2 Camera calibration

In-situ camera calibration is use the observation directly on the experiment to calibrate the camera in order to get the camera parameters. The camera is use to detect the light emits from the LED and also to get the best resolution of the image that is suitable to use in the distance measurement system. In this project, a webcam is use to capture the image of the object obtain and using the Processing software. The red LED light is use to create an object in this distance measurement system. Figure 3.6 below shows the camera view with 320 x 240 pixels resolution in Processing software.

Figure 3.6: Camera view from webcam using Processing software

The calibration procedure is consisting of traversing table of z-direction at a distance range within 100mm to 144mm. The object plane is also equipped with 2mmx2mm resolution of graph paper to obtain the actual object diameter in unit of millimetre.

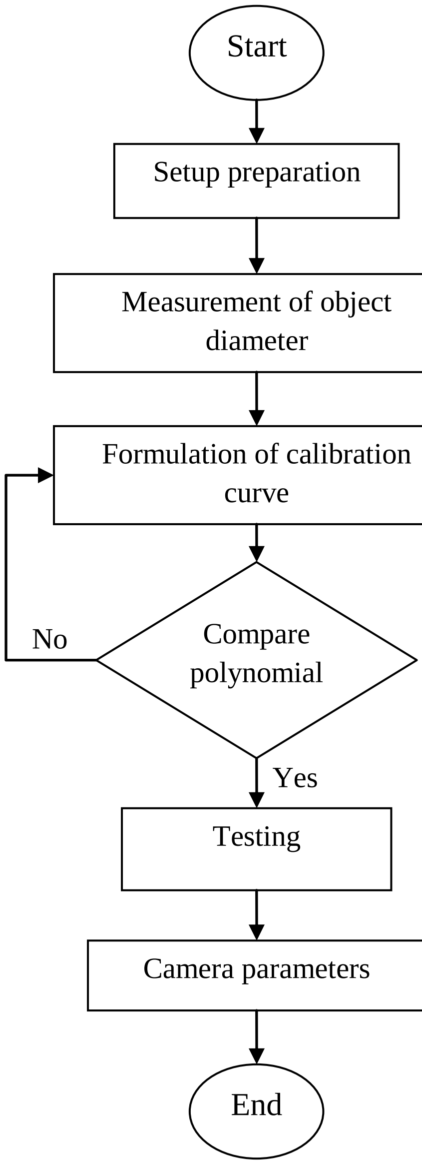


Figure 3.7: Flowchart of camera calibration

3.2.2.1 Searching algorithm

The processing software is use for the camera to detect the object within the distance range 100 mm to 144 mm. A black dot is acts as probe which gives information of its location in xy coordinates in 320x240 frame size which x is equal to width (320) of the frame while y is the height (240). The value of x and y obtain is use to calculate the diameter of the object in pixels and compare with the graph resolution based on the distance between the camera and the object plane.

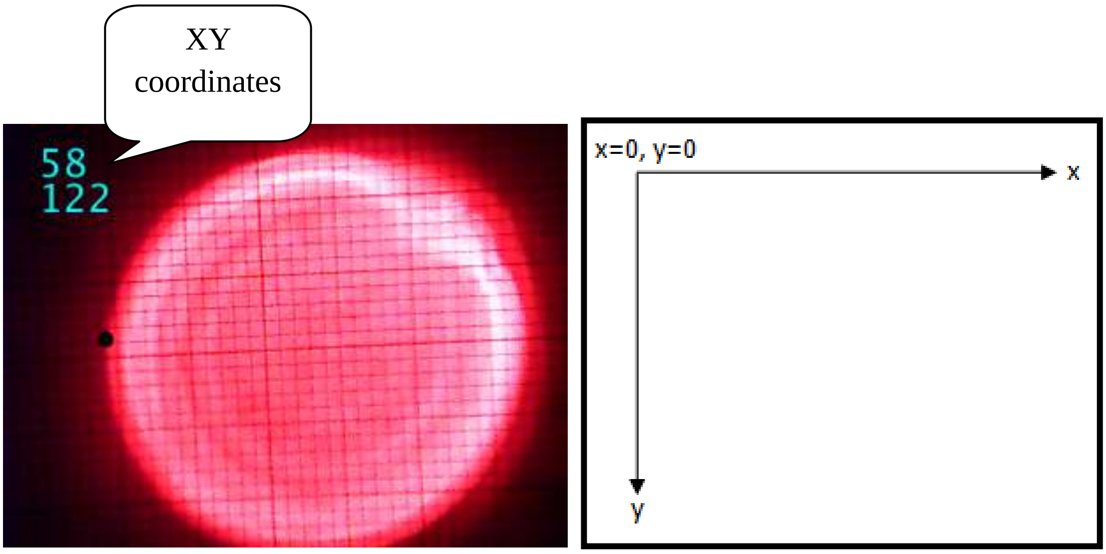


Figure 3.8: Object create from light emits by red LED

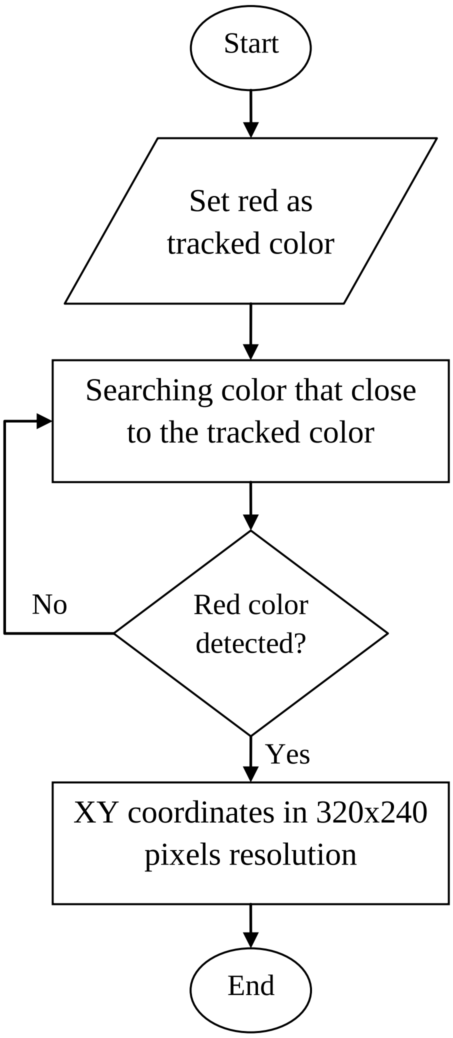


Figure 3.9: Searching algorithm

The diameter of the objects is acquire from the xy values of the black dot location as shown in figure below as it start read through every pixels from left to right where it detects the red color. By getting the maximum and minimum values of x value, the diameter of the object can be calculated.

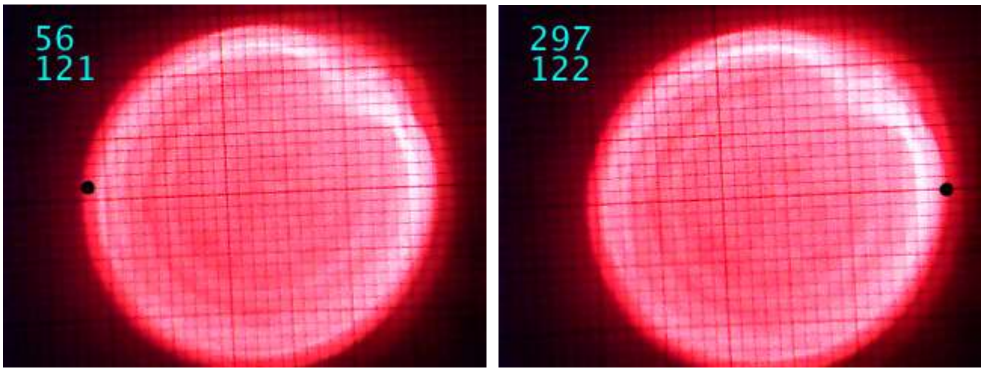


Figure 3.10: Minimum and maximum values of x

3.3 Experimental Setup

In the distance measurement system, a traversing system is need so that the object can move forward and backward from the camera. A slider rocker mechanism is use in the distance measurement system, which the movement is support by a servo motor. The traversing system is illustrate using inexpensive and open source software, OpenScad which is use in creating solid 3D CAD models. There are two important parts in distance measurement system design which is the sliding mechanism and the camera and LED holder. Figure below shows the sliding mechanism design.

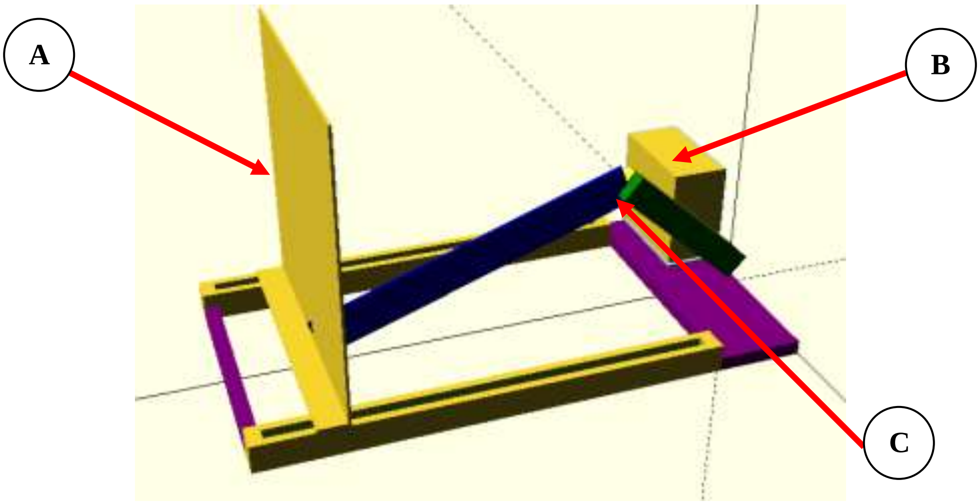


Figure 3.11: Sliding mechanism design using OpenScad

In the design, the main part includes:

- Flat surface where image create by light emits from LED
- Servo motor
- Slider rocker mechanism

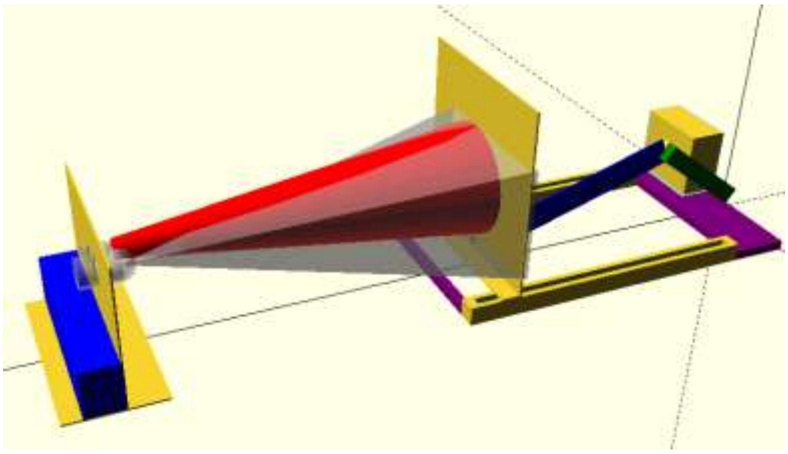


Figure 3.12: Distance measurement system design

An overall distance measurement system is also design using OpenScad as shown in Figure 3.9. It shows the location of the camera and LED which is place horizontally. This illustrates how to measure the distance between object form on the flat surface and camera.

The figure below shows the traversing table with slider rocker mechanism that includes the rotating parts and the flat surface which helps the image created on the flat surface move forward and backward. The materials use for this mechanism is thin plywood with the thickness of 2mm for easy handling.

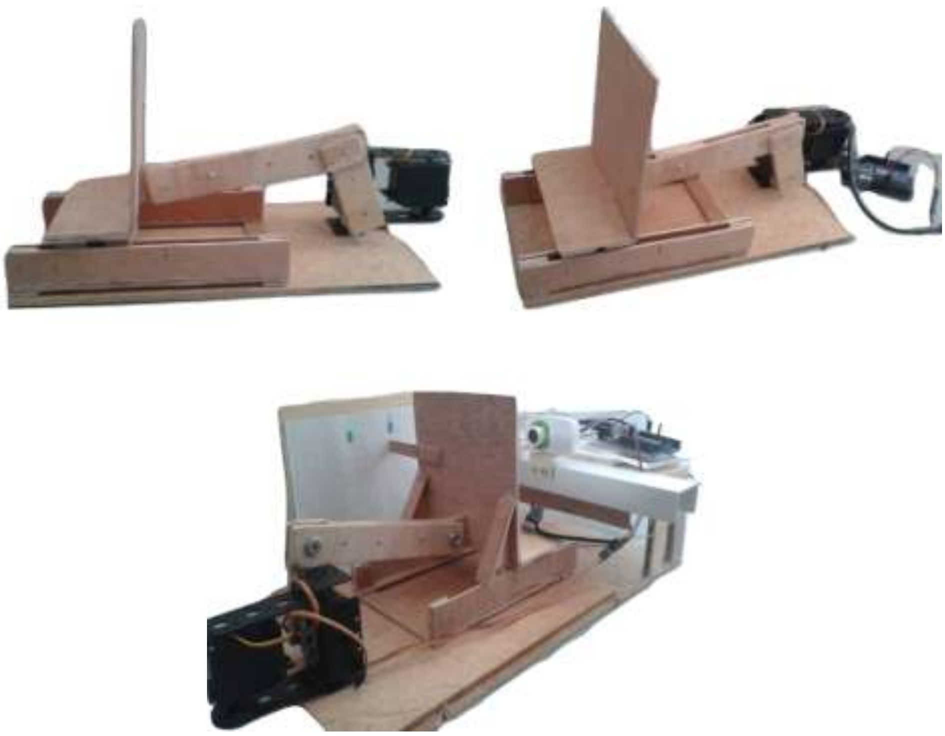


Figure 3.13: Traversing system

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results of the project are discussed in details. The results are based on the experiment that has been done. It consists of several parts that is need to be consider in order to achieve the main objective of the project and the results is analyse and discussed. By using Processing software, the information from the object image is obtained and measured. There two experimental results which are the development og light meter and distance between camera and object based on diameter of the object.

4.2 Development of light meter

The three set reading of light meter, LDR and the opening angle of bench top enclosure is taken for light dependent resistor (LDR) calibration against light meter. The graph shown in Figure 4.1 is use to produce the equation. Polynomial of 3^{rd} order is choose for formulation of the calibration curve as the percentage error is less than other polynomial orders. The equation obtain from the graph is then use to measure the LDR values against light meter with different opening angle of bench top enclosure.

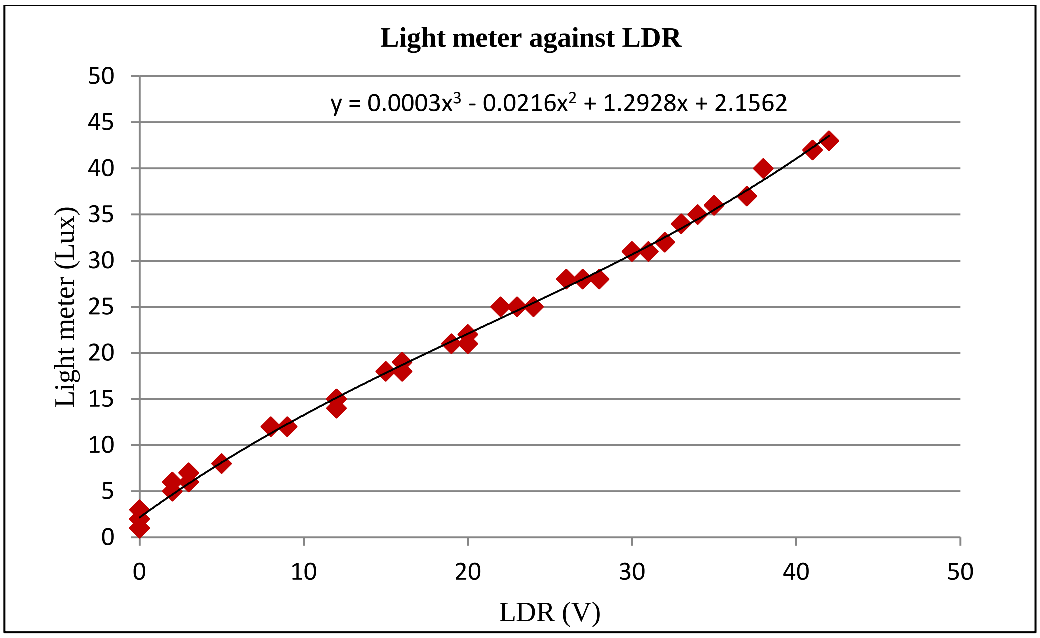


Figure 4.1: Calibration curve of light meter development

Light meter and LDR are used measure the illumination level inside the bench top at different angle. Figure 4.2 shows that the light meter measurement values are proportional to the LDR values.

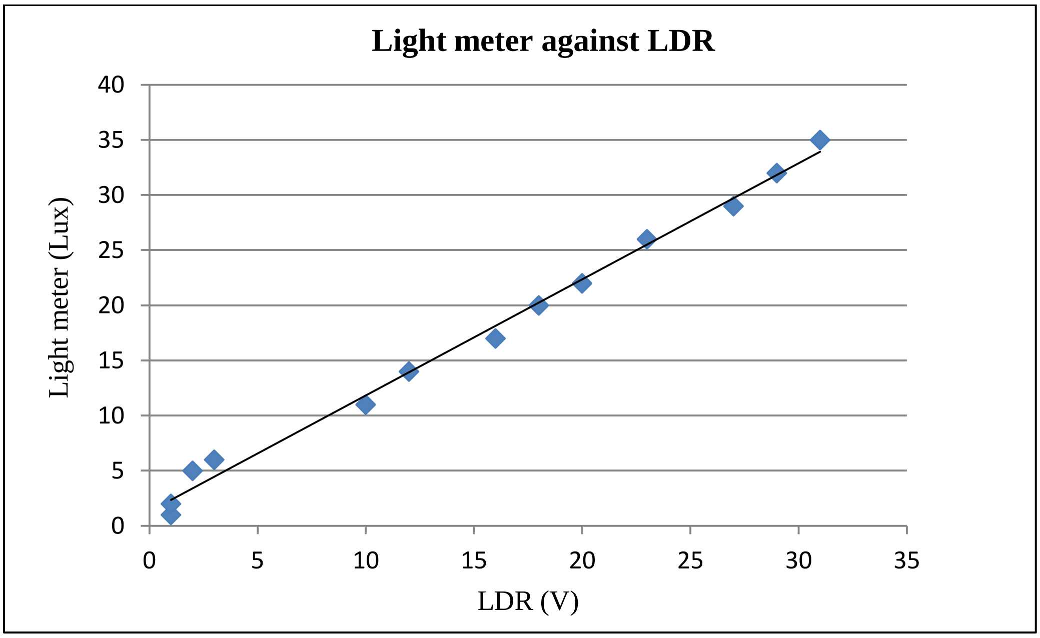


Figure 4.2: Light meter against LDR

The graph below shows the relationship between the opening angles of bench top enclosure with measurement values of light meter. As the opening angle increases, there is higher amount of light falling onto bench top enclosure. Therefore, the light meter measurement values increases.

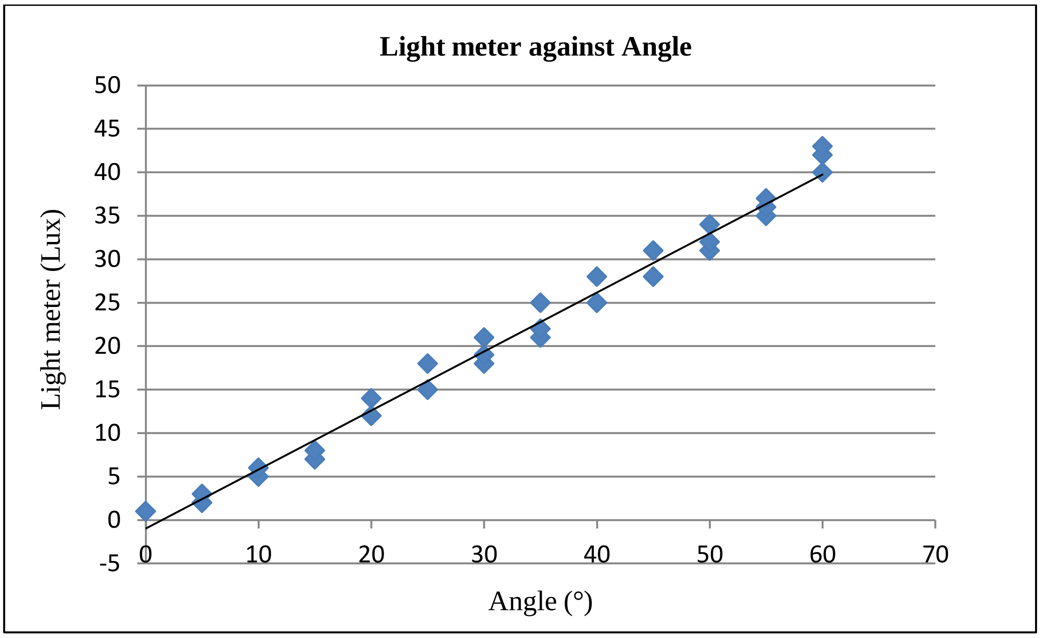


Figure 4.3: Relations between angle and light meter values

4.3 Distance measurement using object diameter

The diameter of the object is given by xy value in processing software and calculated using maximum and minimum values of x. The distance between the object plane and camera is measure by a graph paper with 2mmx2mm resolution. The calibration curve is plotted to form an equation to measure the distance with the diameter of object in pixels.

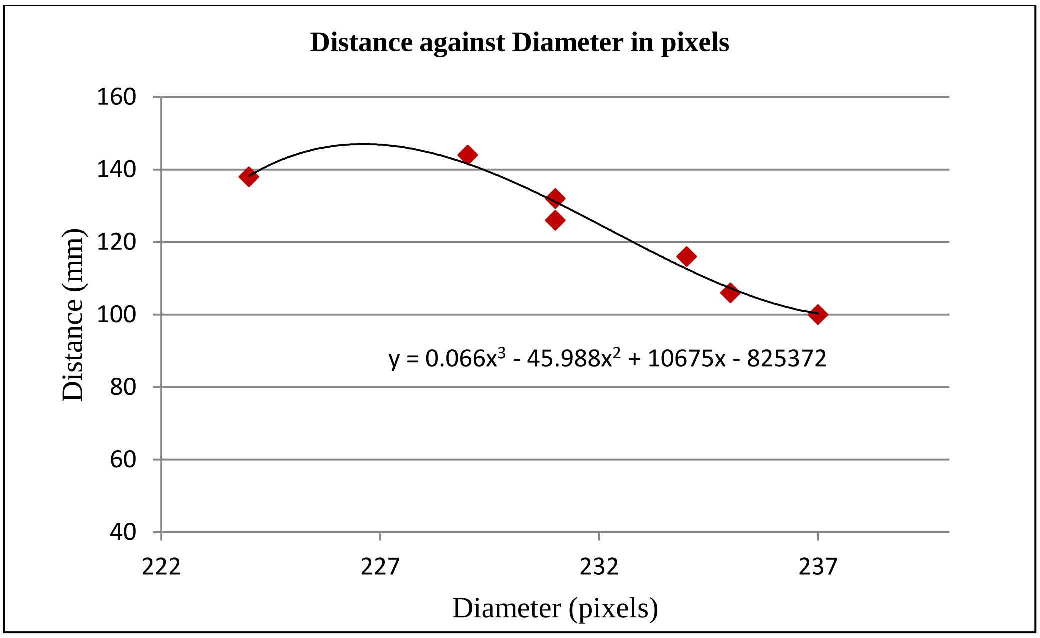


Figure 4.4: Calibration curve of distance against diameter object

The equation from the calibration curve is validate by taking the diameter of the object at unknown distance and calculated using the equation to get the distance between camera and object. The graph below shows that the distance is inversely proportional with the diameter of the object.

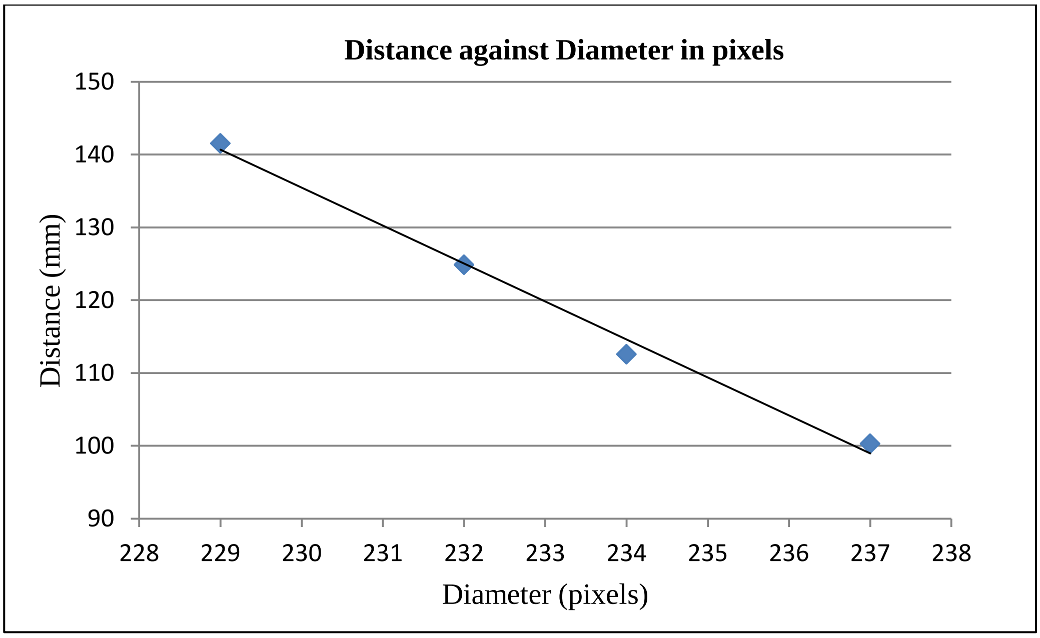


Figure 4.5: Distance in mm against diameter of object in pixels

The calibration curve below is use to obtain diameter in millimetre with the diameter in pixels. And the equation obtain with polynomial of 2nd order shows the correlation between the diameter of object in mm with diameter object in pixels as shown in figure 4.7. The graph shows that the diameter in mm is inversely proportional with diameter in pixels.

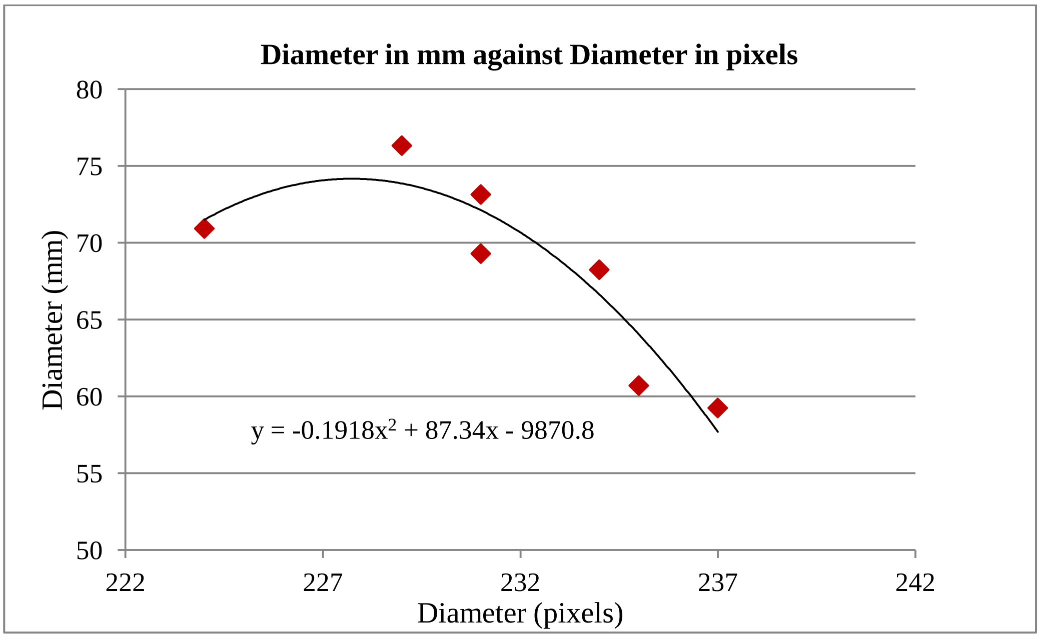


Figure 4.6: Calibration curve of diameter in mm against diameter in pixels

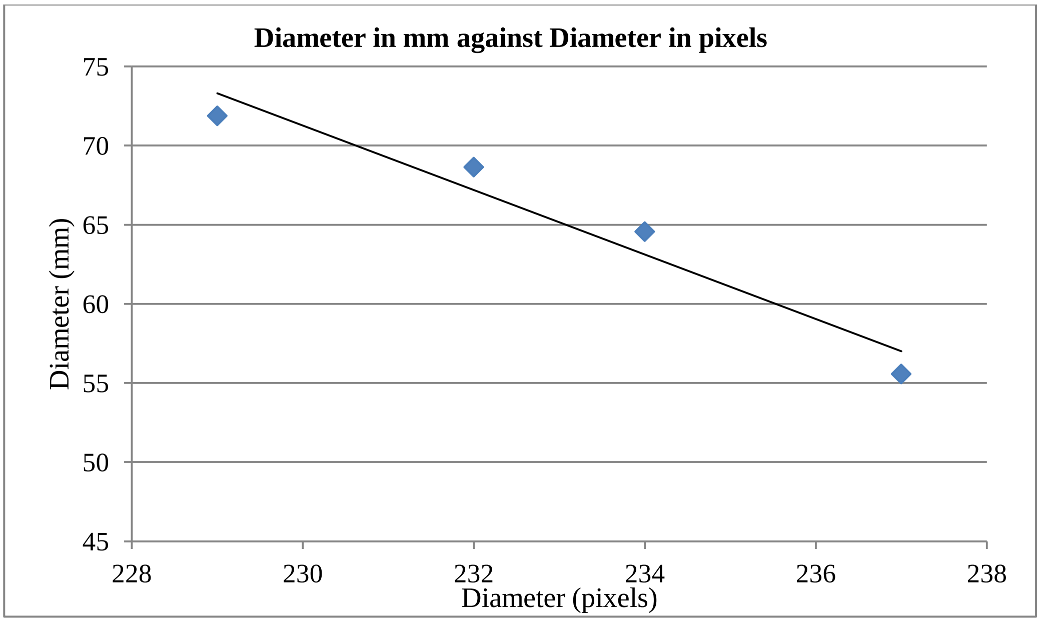


Figure 4.7: Relations between diameter in mm against diameter in pixels

Another calibration curve is obtained to form an equation for the distance with the object diameter in millimetre. The diameter of the object is calculated using graph paper with 2mmx2mm resolution. The figure 4.9 shows as the distance between camera and object increase; the diameter of object is also increase.

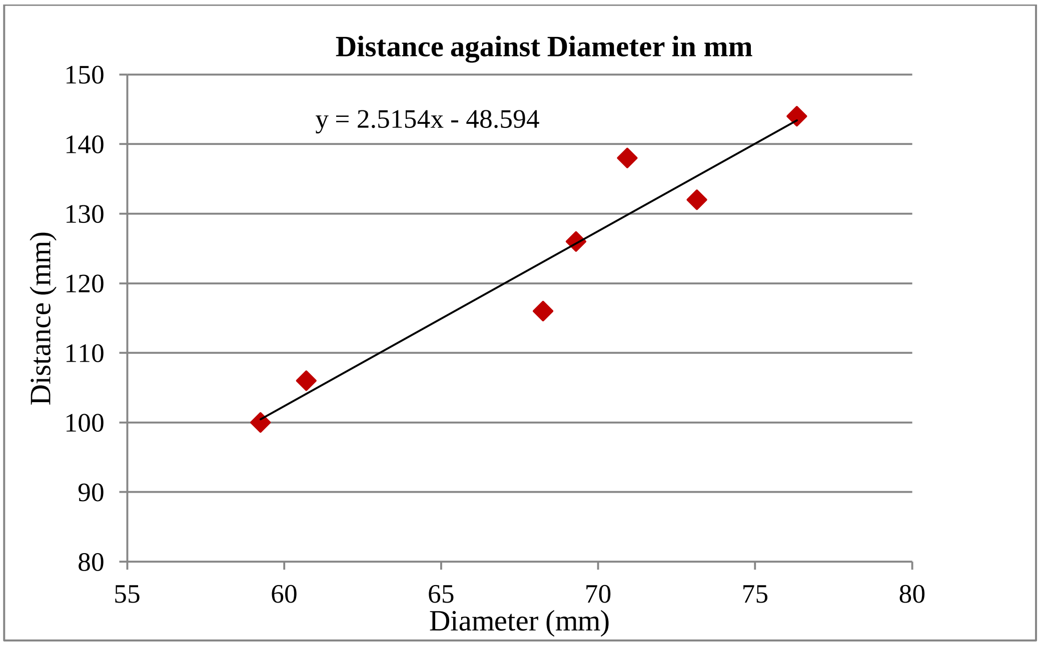


Figure 4.8: Calibration curve distance against diameter in mm

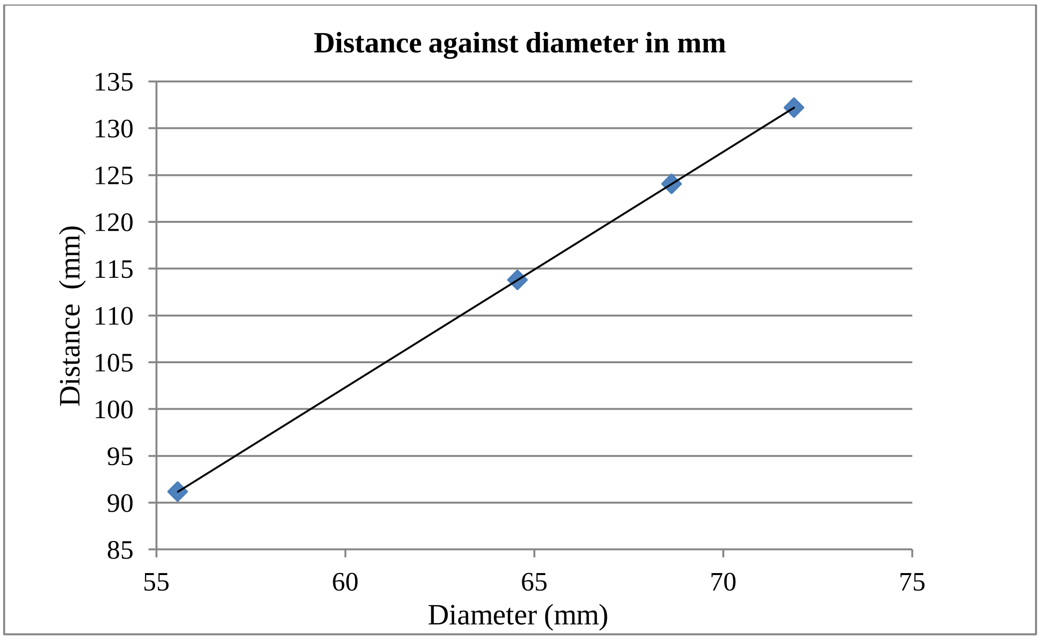


Figure 4.9: Distance against diameter in mm

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter will give short and briefly summary for overall of the project and also recommendation for future research.

5.2 Conclusion

As a conclusion, the main objectives of this project had been achieved. The light emitting diode (LED) can be use in passive distance measurement system which the camera receives the information about the object that created from light emits by LED.

The important parts of this project are successfully completed in order to achieve the objective especially the mechanical parts from designing using OpenScad to manufacturing process, it needs to consider the distance between camera and light emitting diode (LED) to get the best results during experiment. Besides, the ability of the camera to detect the object with red color and determine its diameter with the aid of Processing software. Moreover, the illumination level of the surrounding also affect in distance measurement experiment as the brightness color of LED is contribute in difficulty of object color detection.

Throughout this project, there are two main contributions which are:

- Traversing system

  The traversing system is use for the object plane motion from camera between ranges of 100 mm to 144 mm. The system is control by a servo motor with arduino as shown in figure below. The system was manufactured using only plywood.

Figure 5.1: Traversing system

- Low cost light meter

A low cost light meter is built by only using arduino LDR circuit. The measurement value of the LDR is in voltage unit. The LDR is calibrated against the commercial light meter with the unit of lux.

Figure 5.2: Low cost light meter

5.3 Recommendations

Although the use of LED and camera for measuring object distance can be achieved, but it still have several ways could be done to improve the result's accuracy. Several recommendations can be considered for the good of the future study.

This distance measurement system can only be measured in low illumination level surrounding. Besides, the diameter of the object is manually from the information of xy coordinates and also manually adjusted to a certain distance.

As a recommendation for further study or future work, the object searching algorithm can be improve so that the object diameter is directly measure in the Processing software without need to manually calculate. It will reduce time taken to calculate the diameter of object at a distance and also decrease man mistake during calculation by producing an algorithm. Moreover, the system can be fully automatic to reduce human intervention during measurement. This distance measurement system can be implement in a robot for example the wall following robot to replace the use of ultrasonic sensor.

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APPENDIX A

PROGRAMMING CODE

```
import processing.video.*;

// Variable for capture device

Capture video;

// A variable for the color we are searching for.

color trackColor;



void setup(){

//video size/ resolution

size(320, 240);

// one frame per second

frameRate (1);

// capture the video with size state

video = new Capture(this, width, height);

// start video

video.start();

// Start off tracking for red

trackColor = color(255, 0, 0);

}
```

```
// Read image from the camera

void captureEvent(Capture video) {

    video.read();  }


void draw() {

    video.loadPixels();

    // Draw the image to the screen at coordinate (0,0)

    image(video, 0, 0);

    // Before we begin searching, the "world record" for closest color is set to a high
number that is easy for the first pixel to beat.

    float worldRecord = 500;

    // XY coordinate of closest color

int closestX = 0;

    int closestY = 0;

    // Begin loop to walk through every pixel

for (int x = 0; x < video.width; x ++ ) {

for (int y =160-36; y < 161-36; y ++ ) {

int loc = x + y*video.width;

// What is current color

color currentColor = video.pixels[loc];
```

```
float r1 = red(currentColor);

float g1 = green(currentColor);

float b1 = blue(currentColor);

float r2 = red(trackColor);

float g2 = green(trackColor);

float b2 = blue(trackColor);
```

// Using euclidean distance to compare colors // We are using the dist( ) function to compare the current color with the color we are tracking.

```
float d = dist(r1, g1, b1, r2, g2, b2);
```

// If current color is more similar to tracked color than // closest color, save current location and current difference

```
if (d < worldRecord) {

worldRecord = d;

closestX = x;

closestY = y;}

}

}

strokeWeight(4.0);

stroke(0); // black dot

noFill();
```

```
ellipse(closestX, closestY, 5, 5);{

textSize(22);

text(closestX, 20, 30);

text(closestY, 20, 50);

fill(0, 250, 250);

println(" x1=",closestX, "y1=",closestY);

saveFrame("frame-##.png");}

    }
```

APPENDIX B

GANTT CHART

No.	Task Description		WEEK																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Receive project title	P																	
	Discussion with supervisor about the project	A																	
2	Development of light meter	P																	
	Working on introduction	A																	
3	Camera calibration	P																	
	Working on literature review	A																	
4	Mechanical parts	P																	
	Working on methodology	A																	
5	Distance measurement experiment	P																	
	Completing thesis report	A																	
6	Presentation	P																	
	Submission of thesis	A																	