CHAPTER 1

INTRODUCTION

1.1 OBJECT DETECTION AND TRACKING

LIDAR has become an established method for collecting very dense and accurate elevation data across landscapes, shallow-water areas, and project sites. This active remote sensing technique is similar to radar but uses laser light pulses instead of radio waves. LIDAR is capable of producing extremely high accuracies and point densities, thus permitting the development of precise, realistic, three-dimensional representations.

The data given by these LIDAR sensors would be Point cloud data. A point cloud is a discrete set of data points in space. The points may represent a 3D shape or object. Each point position has its set of Cartesian coordinates (X, Y, Z) Point clouds are often aligned with 3D models or with other point clouds, a process known as point set registration.

1.2 SENSOR USED FOR OBJECT DETECTION

The basic concept of the electronic distance measurement system is adopted in many areas like aviation, navigation for linear positioning and motion control application. The commonly used technologies for object detection and distance measurement are,

1. Global Positioning System (GPS)
2. Sound Navigation and Ranging (SONAR)
3. Radio Detection and Ranging (RADAR)
4. Light Detection and Ranging (LIDAR)

GPS

It is well known that the ordinary Global Positioning System (GPS) fails to provide location and time information under water. The reason is that the electromagnetic signals from the orbiting satellites are heavily damped in water and hence can not be detected by the receiver in most cases of interest. Acoustic waves are the canonical alternative, and there exist a variety of acoustically based systems.

GPS Intelligent Buoys (GIBs) are portable tracking systems that include a network of surface buoys equipped with GPS receivers and submerged hydrophones. Each hydrophone receives acoustic signals transmitted by a synchronized pinger onboard an underwater target. The buoys communicate the times of arrival of the received signals to a central station, such as a local support vessel, where the position of the underwater target is estimated.

SONAR

Sonar (sound navigation and ranging or sonic navigation and ranging) is a technique that uses sound propagation (usually underwater, as in submarine navigation) to navigate, measure distances (ranging), communicate with or detect objects on or under the surface of the water, such as other vessels.

The two types of Sonar technology are (i) *passive* sonar which involves listening to the sound made by vessels and (ii) *active* sonar which emits pulses of sounds and listens for echoes. Acoustic location in air was used before the introduction of radar. Sonar may also be used for robot navigation, and SODAR (an upward-looking in-air sonar) is used for atmospheric investigations. The term *sonar* is also used for the equipment used to generate and receive the sound. The acoustic frequencies used in sonar systems vary from very low (infrasonic) to extremely high (ultrasonic). The study of underwater sound is known as underwater acoustics or hydroacoustics.

The major limitation of the SONAR technology is that it will be affected by the other sound waves outside the water and also a single sound wave cannot determine the distance of the object precisely. Sound from different directions is transmitted to the object which leads to loss.

RADAR

Radar (radio detection and ranging) is a detection system that uses radio waves to determine the distance (*ranging*), angle, and radial velocity of objects relative to the site.

A radar system consists of a transmitter producing electromagnetic waves in the radio or microwaves domain, a transmitting antenna, a receiving antenna (often the same antenna is used for transmitting and receiving using a duplexer) and a receiver and processor to determine properties of the objects.

One of the important and noticeable disadvantages of Radar is, external interference reduces its efficiency and accuracy. The Radar system is slower and hence it takes more time to detect an object.

LIDAR

LIDAR is a method for determining ranges (variable distance) by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver.

It can also be used to make digital 3D representations of areas on the Earth's surface and ocean bottom of the intertidal and near coastal zone by varying the wavelength of light.

Based on our literature survey, it is observed that LIDAR and Radar can both emit a stable and powerful modulated signal, which greatly increases the underwater detection range. The difference between these two technologies is mentioned in Table 1.1

LIDAR vs RADAR:

Table.1.1 LIDAR vs RADAR

LIDAR	RADAR
LIDAR sends and receives light waves to judge how far objects in their environment are.	RADARs use radio waves with much bigger wavelengths (100-300cm) and have lower attenuation.
LIDAR systems are crisper and much more detailed.	Images formed by RADAR are not much better.
LIDAR Provides high image clarity.	RADARs have different bands, but even the high-resolution RADARs fall short in image clarity.
Because of the nature of the laser pulses, LIDAR is mostly used to measure the exact distances of an object.	It does not allow the detection of smaller objects due to longer wavelengths.
LIDAR technology is capable of creating high-resolution images of an object at any surface.	It cannot provide an exact 3D image of the object due to the longer wavelength.

2D LIDAR

2D LIDAR is an active optical sensor, used to perform scanning and detection of surfaces surrounding the sensor.

These electronic sensors emit light on the horizontal plane, usually the

X-Y plane. Based on the captured reflected light, an accurate representation of the distance of the object is known.

3D LIDAR

A variation of 2D LIDAR, known as 3D LIDAR maps the three-dimensional space around the robot. That is, information is captured along the X,Y and Z axis thus adding another dimension to the scanning plane. The collected measurement data enables the detection of objects in three-dimensional space, even under extreme weather conditions and in undefined environments.

The differences between 2D and 3D LIDAR sensors as given in the Table 1.2

Table.1.2 Comparison of 2D and 3D LIDAR Sensors

2D LIDAR	3D LIDAR
The 2D LIDAR system is designed to spin as it emits only one beam of light towards a surface.	3D LIDAR one is designed to emit several beams of light to collect more detailed object data.
2D LIDAR intends to collect object data only on its X and Y axes, the beam of light is only shot along the object's horizontal plane.	3D LIDAR focuses its beam along its target's vertical plane to capture 3-dimensional data on the X, Y, and Z axes.
2D LIDAR sensors are not expensive.	3D LIDAR costs 100 times that of 2D LIDAR sensor.
2D LIDAR sensors are smaller in size.	3D LIDAR sensor are heavier in size and not easily portable

Table 1.2 shows that the cost of a 2D LIDAR sensor is very low. However they cannot provide the depth information regarding the object like 3D LIDAR sensor. In this project, we propose a cost effective technique using a fusion of 2D LIDAR and camera images to get the type of objects as well as the object distance underwater. We have enhanced the project further by fusing 1D LIDAR sensor data along with motor and camera to achieve the results of 3D LIDAR based system This Report is organized as follows.

1.3 ORGANIZATION OF THE REPORT

Chapter 1 focuses on the objective of the project and a brief introduction. Chapter 2 shows the Literature Review done for this project. Chapter 3 shows the design and specification of the hardware components used in the project. It also talks about the software that has been designed and implemented in the project. Chapter 4 presents the methodology used for designing this project. Chapter 5 presents the implementation and real time results of the project. Chapter 6 presents the conclusion and future scope of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

Research related to fusion based object detection using 2D LIDAR sensor and camera is very broad and comprehensive. The main challenge is to properly fuse the output of both sensor and camera to get the better result.

The many ways in which objects can be detected also creates challenges for developing experimental models to detect the different objects.

2.2 LITERATURE SURVEY

The authors of [1] give an overview of how to fuse the 2D LIDAR Sensor along with the camera. This paper provides some algorithms to detect an object using a camera and measuring the distance using a 2D LIDAR sensor. But the method proposed by this paper has a difficulty to accurately detect the edge of the object if the positional change between the sensors is large.The authors of [2] and [3] provide a simple object tracking method for land scenarios. The authors in [4,5,6] specify several go-to ML algorithms such as YOLOv4 for object detection and the distance measurement of an object.The model used in these papers are trained for normal data and not for point cloud data. Other indoor localization methods consider the amplitude of received signal from a LIDAR sensor [7,8,9]. In [10], an underwater self-localization approach based on pseudo-3D vision-inertia was reported. The developed method merged depth information with 2D optical images, and utilized a tightly-coupled nonlinear optimization algorithm to fuse the IMU data and the RGB images from the downward-looking camera. The experimental results illustrated that the proposed method can achieve continuous and robust localization under the changing underwater environment. In [13], which was based on particle swarm optimization (PSO) and the unscented FastSLAM algorithm. In the method, the PSO was adopted to solve the particles' degeneracy. The experiment's results revealed that the method had a better performance compared with FastSLAM Algorithm. An improved SLAM algorithm, based on (Oriented FAST and Rotated BRIEF) ORB features, was proposed in [12], and the nonlinear optimization method was utilized to optimize the scale of visual odometry and the AUV pose. The authors of [13,14,15] provide YOLO models for object detection using pattern recognition and computer vision. These localization strategies depend on pre-installed wireless hardware devices on the site and thus may not be applicable in noisy environments.

2.3 CONCLUSION

Based on our literature survey, we aim to design a 2D LIDAR based cost-effective object detection and distance measurement mechanism which would be flexible and user friendly without compromising on the accuracy as offered by 3D LIDAR based system .Accordingly, the objective of the project is derived as given below,

2.4 OBJECTIVE

The main objective of this project is to fuse the camera output and the 2D LIDAR sensor data to detect the type of object and to estimate the distance of that particular object. The specific objectives are as follows:

- ❖ To study the 2D LIDAR and 3D LIDAR sensors and draw calibration graphs.
- ❖ To design a hardware circuit to acquire data using 2D and 3D LIDAR sensors.

- ❖ To interface a camera and 2D LIDAR sensor with a microcontroller circuit and program it to capture image as well as LIDAR data.
- ❖ To develop an algorithm to fuse the image information and distance information to produce the required results about the object type and its distance from the host system and also display the distance within the object's bounding box.
- ❖ To send alert messages whenever the object comes within a given perimeter
- ❖ To compare the performance of the object detection and distance estimation system with that of the 3D LIDAR based system.

CHAPTER 3

DESIGN OF THE PROJECT SPECIFICATION

3.1 HARDWARE REQUIREMENTS

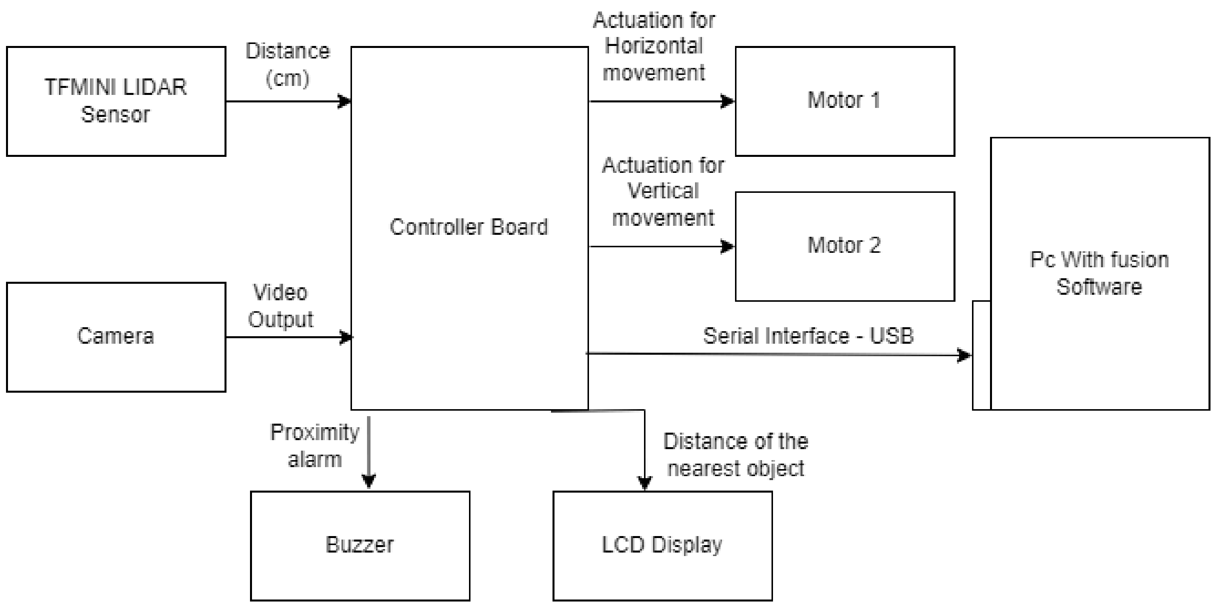


Fig.3.1 Block Diagram of the Proposed Fusion System

The materials required for the implementation of the project are:

1. 3D LIDAR Sensor (Ouster OS-128)
2. 2D LIDAR Sensor (TFMini 2D LIDAR Sensor)
3. Prototyping board (Raspberry Pi 3)
4. Camera (Raspberry Pi Camera Module)
5. Buzzer
6. LM016L LCD Display

3.1.1 3D LIDAR SENSOR (OUSTER OS-128)

The basic connection between the 3D LIDAR sensor and PC is given in Figure 3.1. There exists a control module which can be programmed through python in order to control the motor rotation speed, adjusting the angle of view, sampling time and so on. The sensor and PC will be connected via the control module using TCP/IP protocol and the sensor address would be given by the manufacturer. Users can enter those ip addresses to see the sensor configuration locally on their controlling device (PC) through the sensor dashboard.

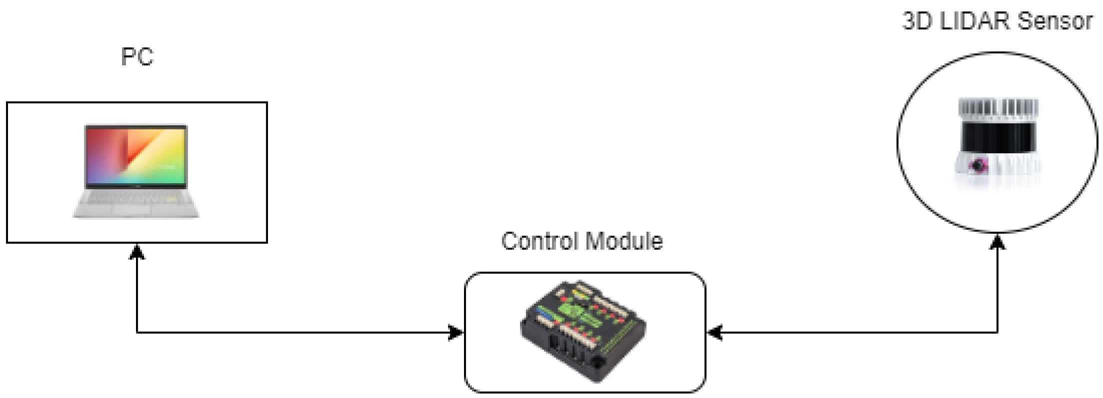


Fig.3.2 Schematic of 3D LIDAR based distance estimation system

3.1.2 2D LIDAR SENSOR (TFMini 2D LIDAR Sensor)

TFMini 2D LIDAR sensor is a compact, low-power, and affordable time-of-flight ranging sensor that is commonly used in robotics, drones, and IoT applications. It can measure distances up to 12 meters with an accuracy of ±5 cm and a scan rate of up to 1000 samples per second. The TFMini 2D LIDAR sensor uses infrared light to detect objects and can operate in various lighting conditions, including direct sunlight. It has a small form factor and can be easily integrated into a wide range of devices. The sensor is designed to be easy to use and comes with a UART interface, making it compatible with a wide range of microcontrollers and single-board computers.

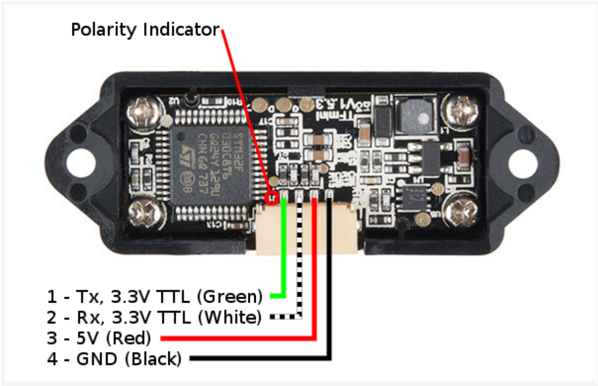


Fig.3.3 TFMini 2D LIDAR Sensor

3.1.3 PROTOTYPING BOARD(Raspberry Pi 3)

Prototyping boards of any type like Raspberry pi, Arduino can be used with their corresponding language. Raspberry Pi has been chosen for this process because of its reduced cost and easy to interface with PCs.

The Raspberry Pi processor is being used here to process all the data and interface the sensor. Any type of Raspberry Pi model that has an I2C interface can be used. In this project, a Raspberry Pi 3B model has been used.

The complete Specification of Raspberry Pi 3B model is given in the appendix section of this report.

3.1.4 CAMERA

The Raspberry Pi 5MP Camera Module is a small, lightweight camera designed specifically for use with the Raspberry Pi. It features a 5 megapixel OmniVision OV5647 sensor and can capture 2592 x 1944 resolution images and 1080p video at 30 frames per second. The camera module connects to the Raspberry Pi board via a ribbon cable and is controlled through the Raspberry Pi's camera software.

Fig.3.4 Raspberry Pi Camera Module

3.1.5 Buzzer

A buzzer is an electronic device that produces a loud, buzzing sound when an electrical signal is applied to it. It is typically used in electronic circuits to provide an audible alert or notification. A buzzer consists of a piezoelectric element or a magnetic coil that vibrates when an electrical signal is applied to it. The vibration produces sound waves, which are amplified by a resonant cavity to produce a loud buzzing sound.

Fig.3.5 Buzzer

3.1.5 LM016L LCD Display:

The LM016L is a commonly used 16x2 character LCD (Liquid Crystal Display) module. It is widely used in embedded systems and microcontroller-based projects for displaying text messages and other information. The module has a built-in HD44780 controller, which simplifies the interface between the module and the microcontroller.The display consists of two rows of 16 characters each, and each character is made up of a 5x8 dot matrix. It can display ASCII characters, symbols, and even custom characters that can be programmed by the user.

Fig.3.6 LM016L LCD Display

3.2 SOFTWARE REQUIREMENTS:

1. Image Processing Software
2. Integrated Development Environment

3.2.1 IMAGE PROCESSING SOFTWARE

Ouster Studio is software provided by Ouster to visualize, record, and analyze data from Ouster LIDAR sensors. Ouster Studio is cross-platform and we had used Ouster studio on the Windows platform. The software performs real-time visualization, processing, and recording of live 3D LIDAR data captured from Ouster LIDAR sensors. Ouster Studio is also able to replay stream data stored in .pcap files recorded from live streams directly within Ouster Studio.

3.2.2 INTEGRATED DEVELOPMENT ENVIRONMENT

PyCharm is a popular Integrated Development Environment (IDE) used for programming in Python. It is developed by JetBrains and provides a comprehensive set of tools for writing and debugging Python code.

PyCharm is available in both community and professional editions. The community edition is free and open source, while the professional edition is a paid version that includes additional features such as remote development capabilities and support for web development frameworks.

3.3 OVERVIEW OF THE PROPOSED FUSION SYSTEM DESIGN

The servo motors for horizontal and vertical rotation are controlled by a PWM signal from the Raspberry Pi. The signal is given is given in the form of duty cycle and converted into corresponding angle using eqn(1)

$$K = (\Theta / 18) + 2.5 \qquad \textbf{(1)}$$

Where,

K is Duty Cycle of the servo motor

Ө is the required angle to be rotated by the servo motor

The TFMini 2D LIDAR sensor is mounted on the setup that gives the horizontal rotation of 180° and vertical rotation of 90°. The data from the TFMini 2D LIDAR sensor is transmitted to Raspberry Pi via i2c protocol.

The camera module is connected to the camera module port of the Raspberry Pi 3 board. The raspistill is used to interface the camera output with raspberry pi

CIRCUIT DIAGRAM

For our project we have used the RXD (GPIO 15) and TXD(GPIO 14) pins on the Raspberry Pi 3B to receive the data from the sensor through I2C communication protocol. The corresponding pins on the TFMini sensor are thereby connected. Vin is connected to the 5V output on the pi and the GND pin is connected to the ground port.

The servo motor is powered up by the same 5V from the Raspberry PI. The PWM pins of the two servo motors are connected to GPIO 22 and GPIO 23 respectively in which PWM signals are given.

The camera module is connected directly to the camera module port of the Raspberry pi 3B model where it can be powered up also. The data from the camera is processed via opencv-python module

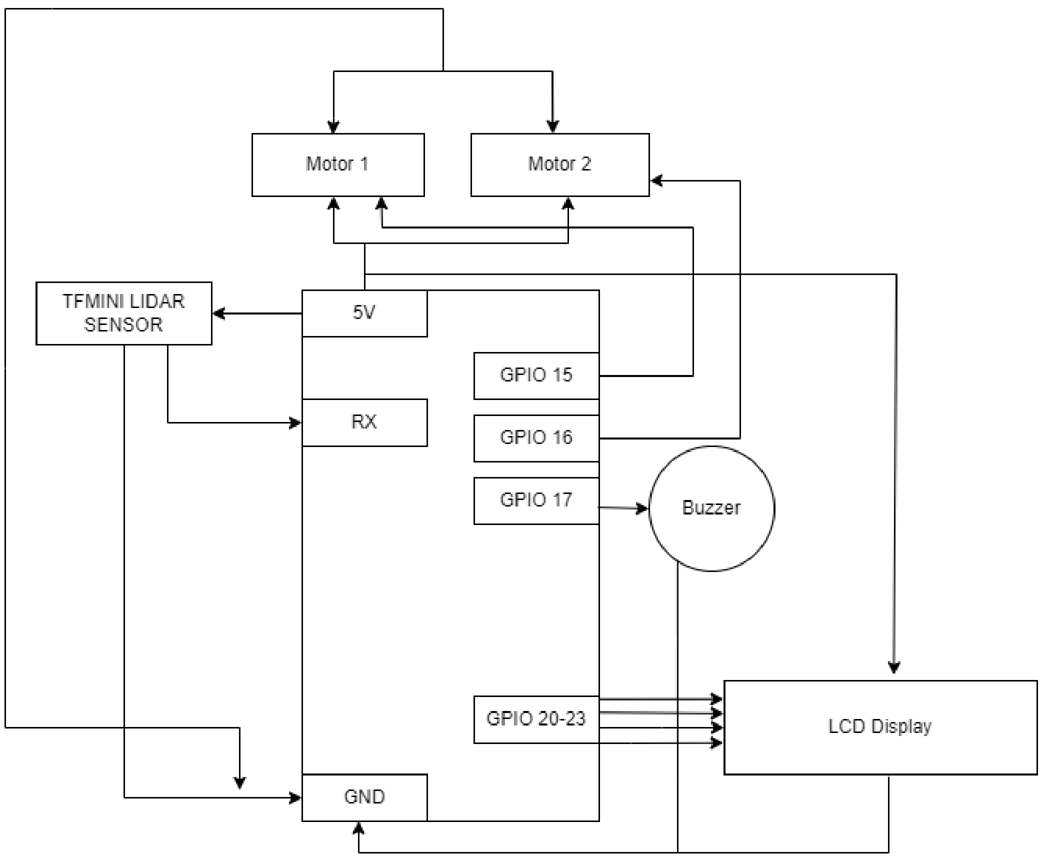


Fig.3.5 Circuit Connection for interfacing 2D LIDAR Sensor Module, camera, buzzer and LCD with Raspberry Pi

CHAPTER 4
METHODOLOGY

4.1 INTRODUCTION

The proposed methodology consists of detection of objects and estimating the distance using two systems. One based on 3D LIDAR sensor module and other cost effective system is fusing the 2D LIDAR sensor data with Camera data. The both system has been described below

4.2 CALIBRATION OF LIDAR SENSOR

1. First, mount the sensor in a stable position so that it is not moving or vibrating during the calibration process.
2. Connect the sensor to a computer using a USB cable after installing the necessary drivers and software to communicate with the sensor.
3. Set the baud rate of the sensor to the desired value using the TFMini Config software.
4. Set the scanning range of the sensor to the desired value using the TFMini Config software.
5. Set the data output format of the sensor to the desired value using the TFMini Config software.
6. Test the sensor by placing an object in front of it and verifying that the sensor is able to detect the object.
7. If necessary, adjust the position of the sensor to improve its performance. We can do this by moving the sensor closer or farther away from the object you want to detect.
8. Repeat steps 6 and 7 until the sensor's performance is satisfied.
9. Once the sensor's performance is satisfied, save the settings in the TFMini Config software.

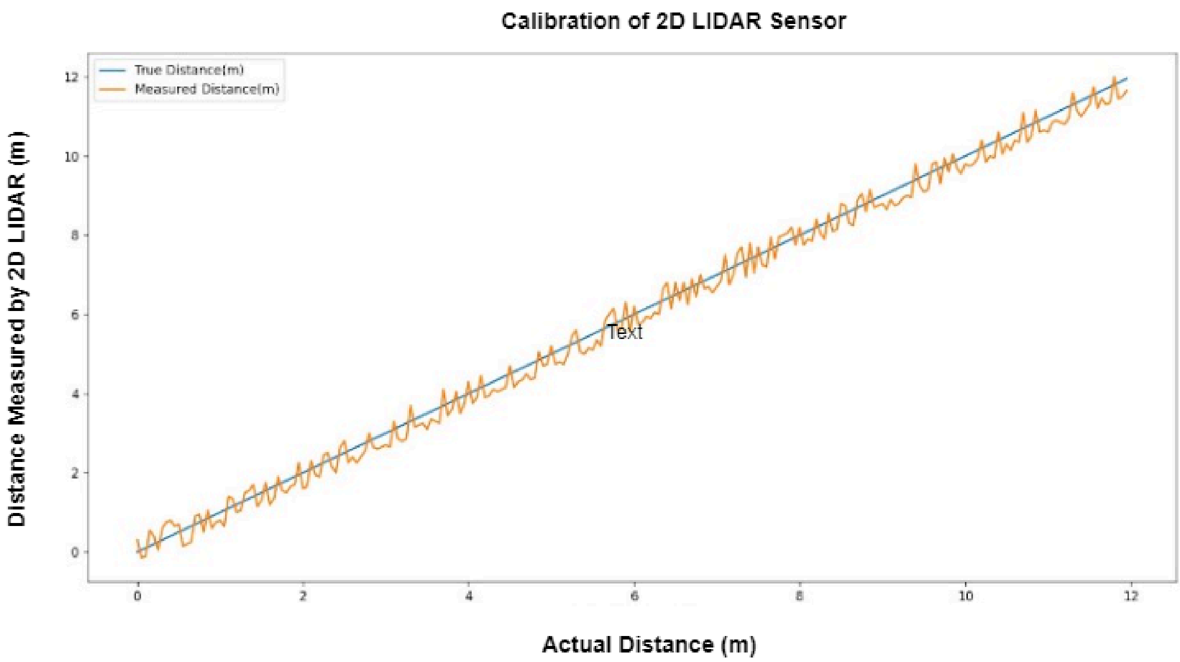


Fig.4.1 Calibration of the 2D LIDAR sensor

4.3 3D LIDAR BASED OBJECT DETECTION SYSTEM

The 3D LIDAR has inbuilt servo motors along with the camera and sensor attached to it. The rotation of the servo motor can be controlled via python programming. The sensor can also be calibrated for a particular range and accuracy. The main disadvantage of these types of 3D LIDAR sensors is that they are highly costly. Once the sensor has been programmed, it will automatically start to gather the data which includes the intensity of the laser received, angle, distance and also the point cloud data of the entire image. Next this point cloud data is given to the YOLOv5 algorithm to detect various objects.

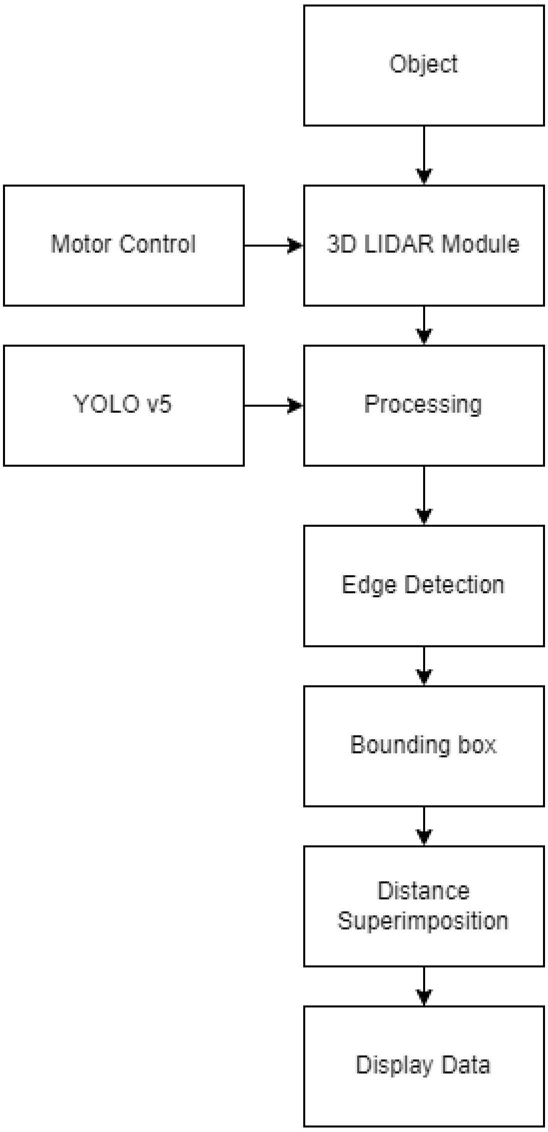


Fig.4.2 Flow Diagram for 3D LIDAR based object detection and distance estimation

4.3.1 ALGORITHM FOR THE 3D LIDAR BASED SYSTEM

- Set the speed of the motor as normal
- Get the point cloud data from sensor
- Set the object detected array and object distance array as empty
- Change the 3D coordinate to 2D
- Convert the video frames to grayscale
- Input the video frames to YOLOv5 model and detect the various object
- Update the array with the details of the object detected

- Display the processed video output

As mentioned earlier, YOLOv5 takes an image, video, webcam, or video stream, but it does not recognize PCAP files generated by Ouster LIDAR sensors. To feed Ouster data to YOLOv5, we need to transfer its data layers into images. The Ouster's Python SDK makes this task extremely easy. With the help of the SDK, we modified the detect.py file to run the inference on the reflectivity layer from the PCAP file.

In the detect_pcap.py file before sending the image into the YOLOv5 model, we took the point cloud data and tried to extract the image from those 3d points by the below procedure. In this Data Structure, each image will be represented by n points by (x,y,z) in the graph. In order to get the exact view of the Ouster sensor, we need to convert these (x,y,z) points from Cartesian to Polar Coordinates given in eqn(1) and eqn(2). This conversion is very useful for plotting the point in the Polar plot.

$$\Theta = tan^{-1}(y / x) \quad \textbf{(1)}$$

$$r = \sqrt{x^2 + y^2 + z^2} \quad \textbf{(2)}$$

Where,

Θ is the angle of deviation of the nearest point of the object from the center point

r is the radial distance of the object

x,y,z are the position in the cartesian coordinate

The distance of the object is estimated as follows,

$$d = (c \star t) / 2 \quad \textbf{(3)}$$

Where,

d is the distance of the object

c is the speed of light

t is round trip time taken by the laser

For a stepper motor used inside the 3D LIDAR sensor, the Steps per second can be calculated as,

$$s = RPM \times \psi \times 60 \quad \textbf{(4)}$$

Where,

s is the Steps per second

ψ is the step angle

$$\psi = (N_S - N_R)/(N_S \times N_R) \times 360 \quad \textbf{(5)}$$

Where

N_R is number of rotor

N_s is the number of stator

4.3.2 EXPERIMENTAL SETUP:

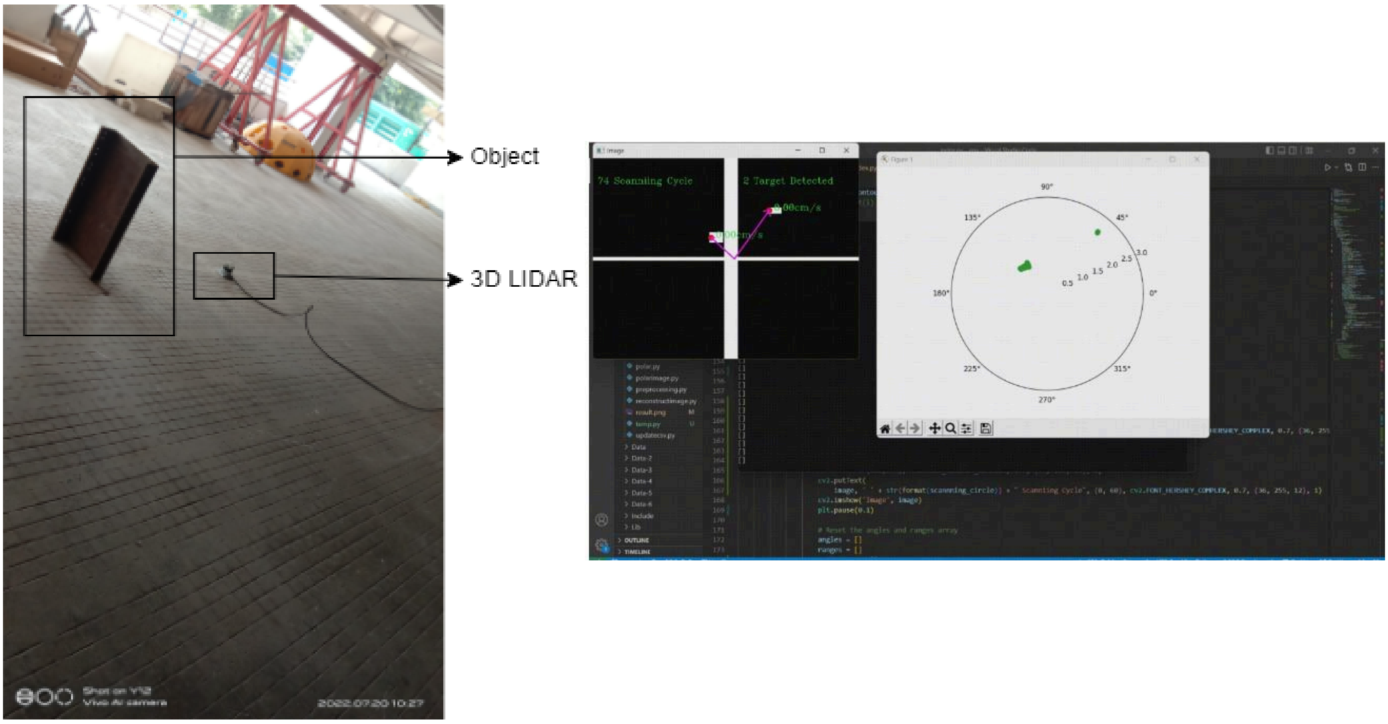


Fig.4.3 **Snapshot of the experimental setup with 3D LIDAR based sensing module**

4.4 PROPOSED FUSION BASED SYSTEM

The 2D LIDAR sensor and camera is placed in the field of view where we need to detect and estimate the distance of the object. The 2D LIDAR sensor will emit Laser and detect the reflected Laser and the distance is being calculated based on the time taken by Laser to return back. The camera will capture the image and give it to the ML Model to detect the object. Finally both data will be fused together. Fig 4.4 represents the flow of the 2D LIDAR working.

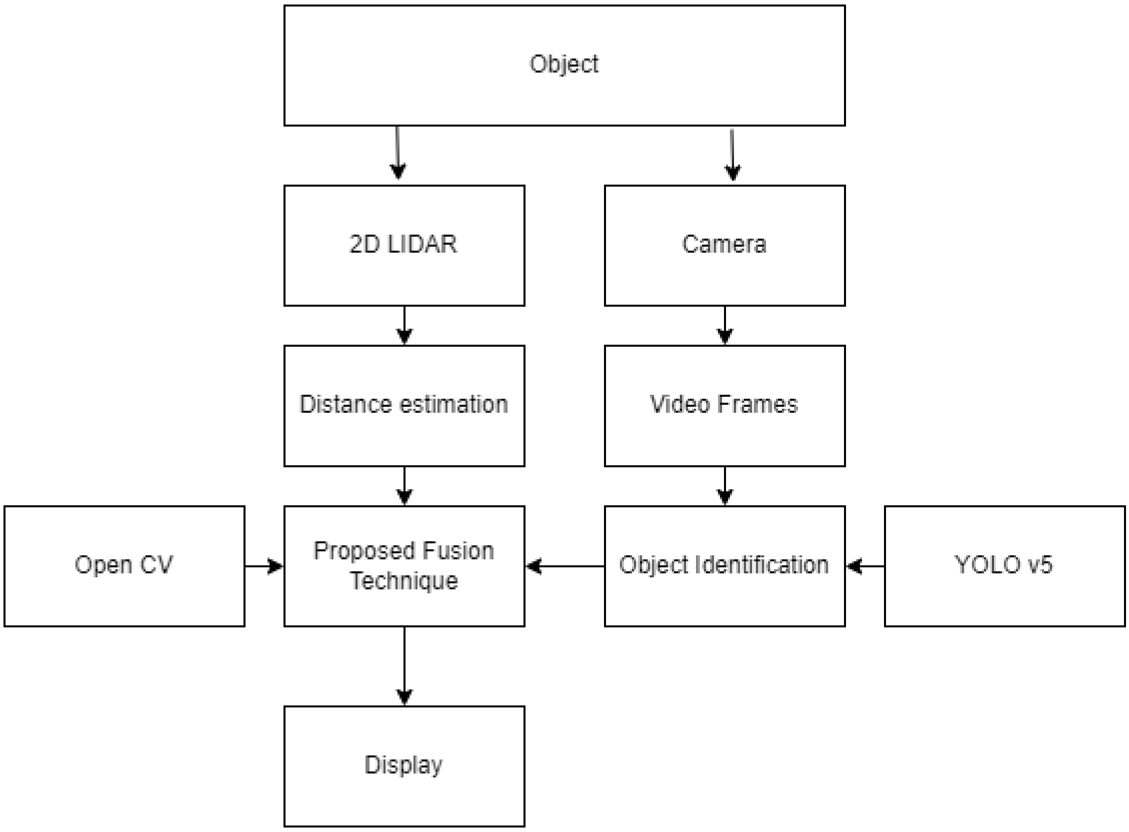


Fig.4.4 Flow Diagram for object detection and distance estimation using proposed fusion based system

4.4.1 ALGORITHM FOR THE SOFTWARE DESIGN

- To Detect the Object
    - Start the webcam
    - Set FPS = 30

- Capture the image using OpenCV
- Set detected object array as empty
- For I = 0 to 30
  - Get each frame
  - Give to OpenCV ML Algorithm to detect the object
  - Update the detected object array
  - Show the video output

- To Estimate the distance
  - Start the servo motor for horizontal rotation with 0°
  - Estimate the distance at that point
  - Increase the horizontal angle by ΔΘ
  - Repeat step 2 and 3 until the angle reaches 180°
  - Start the servo motor for vertical rotation with 0°
  - Repeat step 2-4 until the angle reaches 90°
  - Reset all the servo motors to the initial position

4.4.2 EXPERIMENTAL SETUP

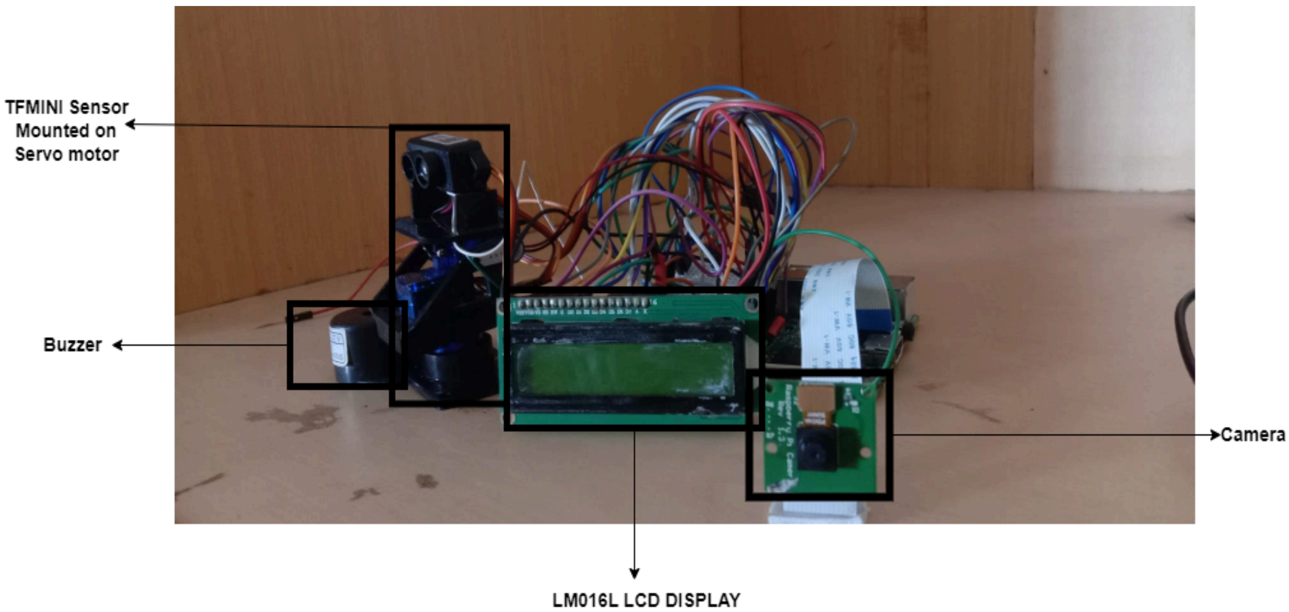
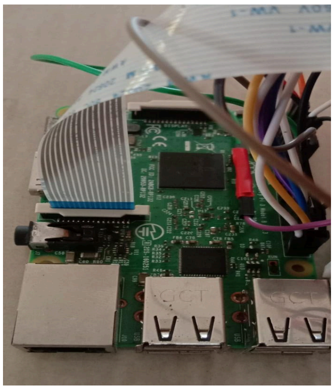
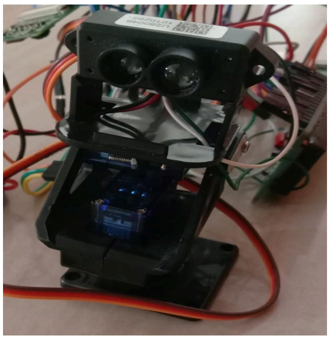
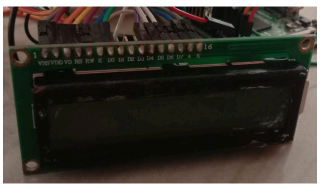


Fig.4.5 Snapshot of the 2D LIDAR based sensing module

Table.4.1 Components Used in the Project

	The Raspberry Pi 3 is a single-board computer that was released in 2016 by the Raspberry Pi Foundation. It is an upgraded version of its predecessor, the Raspberry Pi 2, and offers several improvements in terms of processing power, connectivity, and multimedia capabilities.
	The sensor is mounted on a setup where two servo motors are fixed. Servo motors are controlled using the PWM signal provided to them by Raspberry Pi. TFMini LIDAR sensor is a lightweight, affordable LIDAR sensor developed by benewake.
	The Raspberry Pi Camera Module is a popular accessory designed specifically for Raspberry Pi single-board computers. It provides a compact and affordable solution for capturing images and videos, making it ideal for various projects and applications.
	A buzzer is a small electronic component that is commonly used for generating sound or audible alerts in various devices and systems. It is a simple and versatile device that produces a buzzing or beeping sound when an electrical signal is applied
	The LM016L is a popular alphanumeric LCD (Liquid Crystal Display) module that is commonly used for displaying characters and simple graphics.

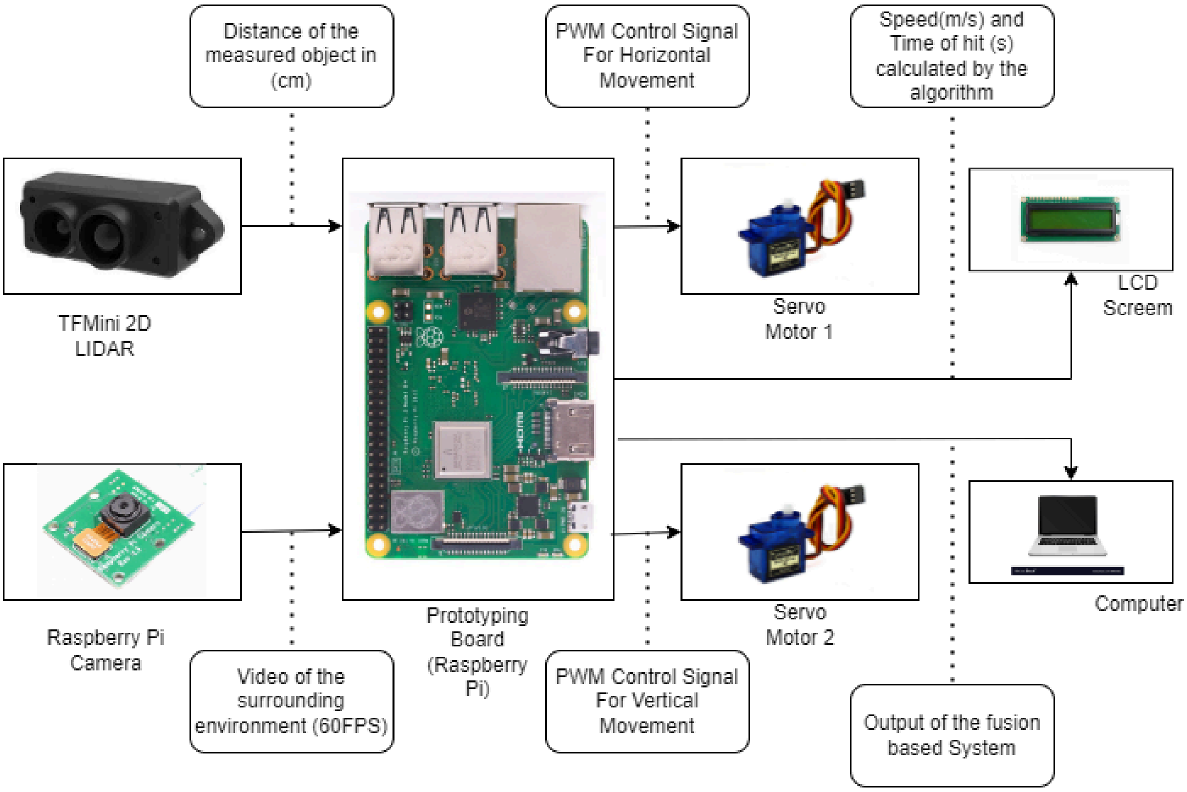


Fig.4.5 Schematic of the interfacing diagram for the 2D LIDAR based object detection and distance estimation

The figure 4.5 depicts the schematic of the proposed fusion system. There are two inputs given to the prototyping board being (i) the distance of the measured object in centimeters and the video of the surrounding environment. The outputs from the prototyping board are (i) the PWM control signal for horizontal and vertical movement, (ii) speed and time of hit calculated by the algorithm and (iii) the output of the fusion based system.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RANGING AND ACCURACY

The following image depicts the output from the 3D LIDAR sensor being plotted in the polar plot. There are two objects being detected and their corresponding velocities are being estimated. The python program is being run in the background to collect the point cloud data from the Ouster sensor

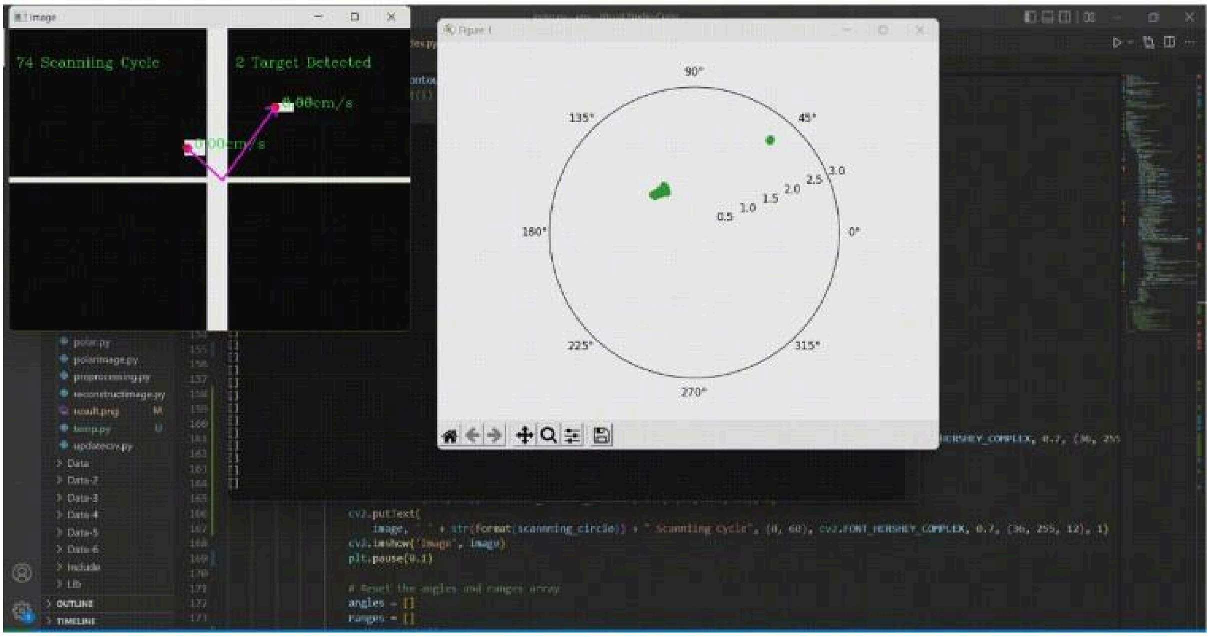


Fig.5.1 Output of 3D LIDAR Sensor module

The following image depicts the output from the python program. The YOLOv5 model predicts the objects from the point cloud data.The main challenge is detecting the person from the point cloud data. The ML model has been trained for Normal person detection and the model has been trained for the point cloud data. The accuracy of the model also has not changed much.

Fig.5.2 Output of the proposed fusion based system with bounding box for object, distance of the nearest object and it's approaching velocity

The green bounding lines are drawn from the point cloud data returned from the sensor. The distance is superimposed on the camera output by the fusion algorithm. This setup has been placed under various scenarios and graphs have been plotted against actual distance and measured distance and it is concluded that under the scenario where the path of the laser is interfered by bright flashlight, the deviation between the actual and the measured value is very high.

The following table 5.1 and 5.2 gives the performance of the proposed system under various environmental scenarios

Table.5.1 Performance of the proposed system under various environmental scenarios

(a) without any induced interference

Sl.No.	Experimental Scenario	Detection range (m)	Detection accuracy (%)
1	Indoor (Day time)	0.5-12	±1% - ±3%
2	Indoor (Night time)	0.5-12	±2% - ±4%
3	Indoor (dark room)	0.5-12	±2% - ±3%
4	Under water (dark)	0.5-12	±2% - ±5%
5	Under water (with light)	0.5-12	±4% - ±6%

(b) with induced interference

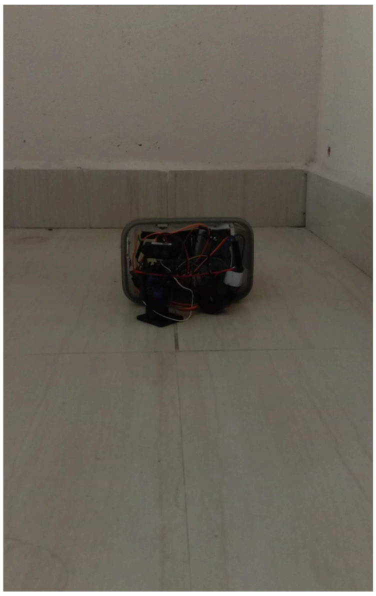
Sl.No.	Experimental Scenario	Interference induced	Detection range (m)	Detection accuracy (%)
1	Indoor (Day time)	Flash light	0.5-12	±3% - ±4%
2	Indoor (Night time)	Flash light	0.5-12	±3% - ±5%
3	Indoor (dark room)	Flash light	0.5-12	±2% - ±3%
4	Under water (dark)	Flash light	0.5-12	±4% - ±6%
5	Under water (with ambient light)	Flash light	0.5-12	±6% - ±8%

Fig.5.3.a Snapshot of our proposed system in daylight without induced interference

Fig.5.3.b Snapshot of our proposed system in daylight with induced interference

Fig.5.4.a Snapshot of our proposed system in night time without induced interference

Fig.5.3.b Snapshot of our proposed system in night time with induced interference



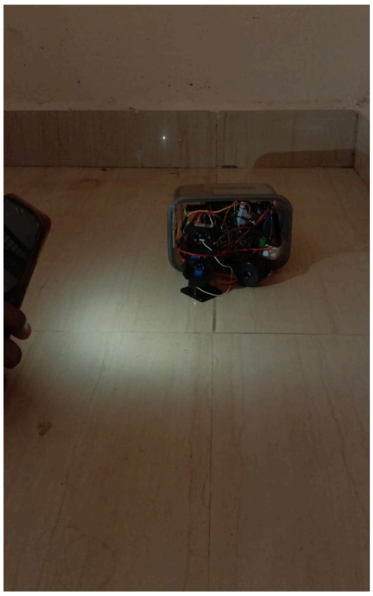


Fig.5.5.a Snapshot of our proposed system in dark room without induced interference

Fig.5.5.b Snapshot of our proposed system in dark room with induced interference

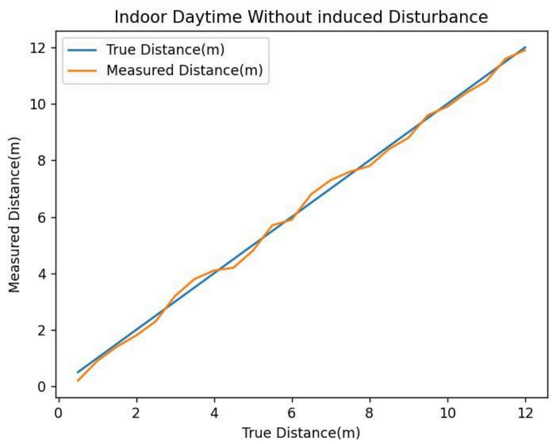


Fig 5.6a. Performance in daylight without induced interference

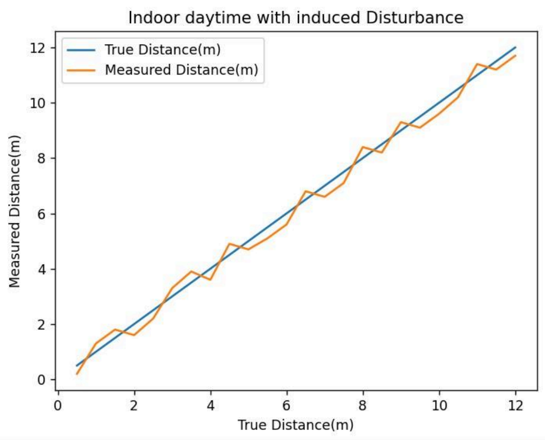


Fig 5.6b. Performance in daylight with induced interference

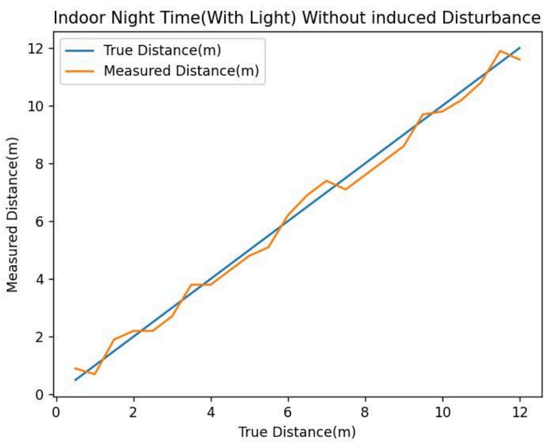


Fig 5.6.a. Performance in night time without induced interference

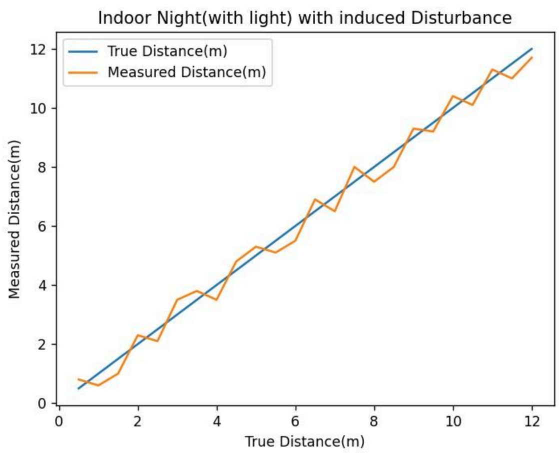


Fig 5.6.b. Performance in night time with induced interference

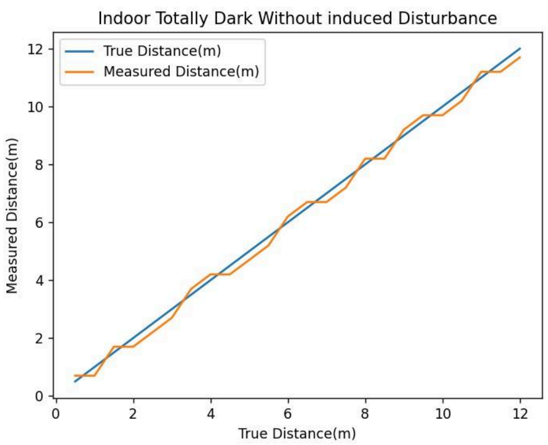


Fig 5.7.a. Performance in dark room without induced interference

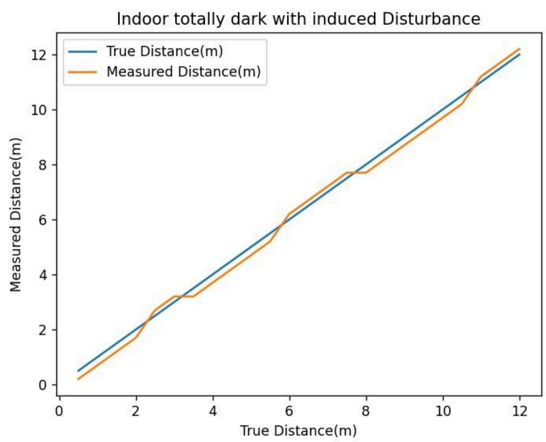


Fig 5.7.b. Performance in dark room with induced interference

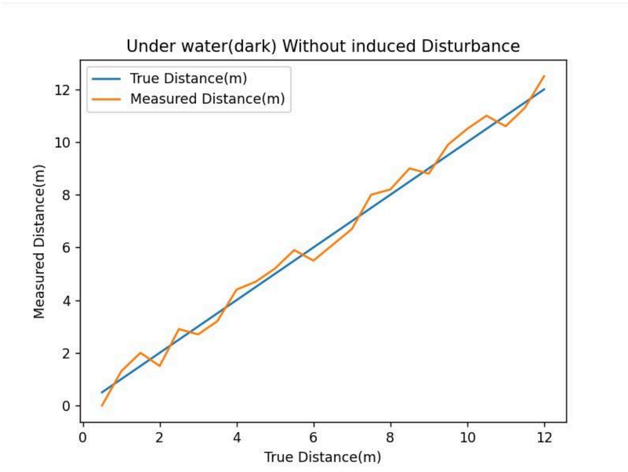


Fig 5.8.a. Performance in under water(dark) without induced interference

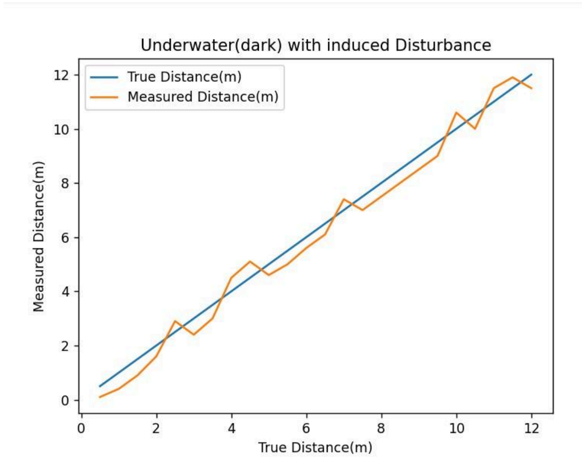


Fig 5.8.b. Performance in under water(dark) with induced interference

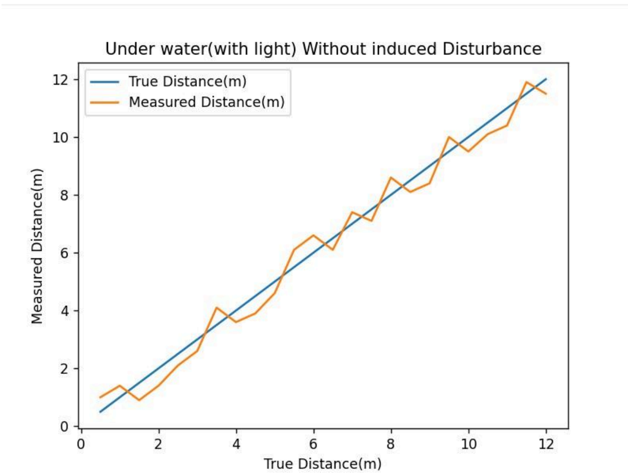


Fig 5.9.a. Performance in under underwater (light) without induced interference

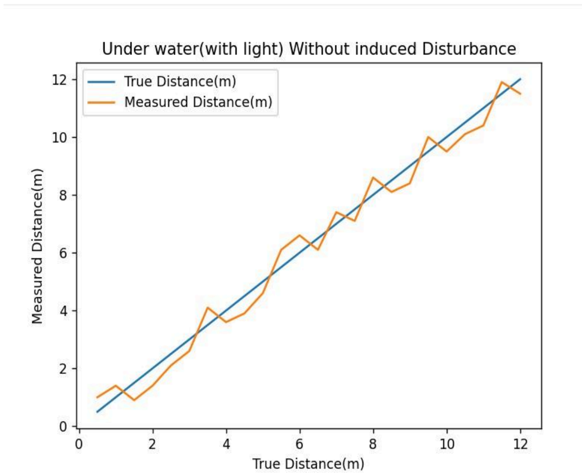


Fig 5.9.b. Performance in under underwater (light) with induced interference

5.2 TIME OF HIT ESTIMATION:

The time of hit is defined as the time taken by an object to hit the system in which our proposed system has been mounted. Our proposed system can calculate the time of hit of an object that is in minimum distance. To calculate the time taken to complete one scan cycle and the change in distance is required.

To calculate the time taken for one scan cycle, the following calculation is followed.

Horizontal angle is 0 to 180 degree with the increment of 9 degree

Hence 180 degree is divided into **21 times**

Each Horizontal scan time for 9 ° = **0.05 seconds**

Total steps traversed = 21

Total Horizontal scan time = 21 x 0.05 = **1.05 seconds**

The first horizontal scan is taken with the vertical angle set to 0°. This scan cycle is enough to estimate the velocity of the approaching vehicle.

Let the distance of an object be x,

After first scan, let the distance be x’

Time taken for single scan = **1.05s**

The change in distance of the target can be identified within a single horizontal scan time,

Hence speed = **(x’ - x) / 1.05** m/s

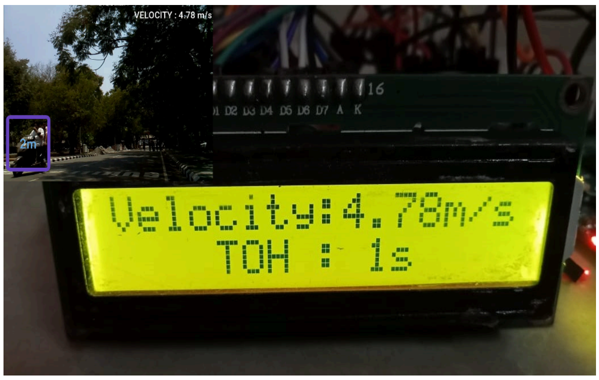


Fig.5.3 Snapshot of the LCD Display output

The above mentioned procedure is fair enough to estimate the velocity of the approaching target. To get the complete 3D model of the target, the system has to complete both horizontal and vertical scan cycles.

Total time for one scan cycle = 5.25 x 16 = T_H = **16 seconds**

Vertical angle is 70 to 100 (30) degree with the increment of 2 degree

Hence the total 30 degree is divided into **16 times**

Each Vertical scan time for 2° = **0.05 seconds**

Total steps traversed = 16

Total vertical scan time = 16 x 0.05 = T_V= **0.8 seconds**

Total no of time the module will come to its home position for one scan cycle = **16 times**

Total time taken = 16 x 0.1 = T_{HH} = **1.6 seconds** (Horizontal Home Position)

To bring back the module to vertical home position the time taken = **0.2 seconds**

Total time taken = 0.2 x 1 = T_{HV} = **0.2 seconds** (Vertical Home Position)

Total time for a scan cycle = $T_H + T_V + T_{HH} + T_{HV}$

Total time for a scan cycle = 16 + 0.8 + 1.6 + 0.2 = **18.6 seconds**

The 18.6 seconds is the time required to map the entire environment in point cloud data format. But this time is not necessary to calculate the approaching velocity and time of hit. The single horizontal scan in the crucial angle which is normal degree (0 degree) is enough to calculate both approaching velocity and time of hit.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

SUMMARY

The first step was calibrating the 2D LIDAR sensor and the sensor is interfaced with a prototyping board using the same I2C line. The distance is obtained from the serial monitor. The raspberry pi camera module is used to detect the object using the ML model. Then the output from the LIDAR sensor is fused with the detected object from the web camera.

CONCLUSION

From the table and graph, we may arrive at the conclusion that our proposed system works fine with all different scenarios except where a bright flashlight interferes with the path of the laser beam. The deviation from the actual distance to measured distance is high during this scenario. Hence, our proposed system fails in this scenario.

FUTURE SCOPE

The future scope of this project would be integration of 4 cameras with 4 sensors so that the complete 3D image of the surroundings can be captured. The number of cameras can also be reduced to one along with the stepper motor to rotate the single camera to capture the 3D environment.

The range can also be increased by using a high range 2D LIDAR sensor fitted in a stepper motor and made to rotate. The 2D LIDAR sensor along with a single camera can also fairly reduce the cost.

The fusion of 2D LIDAR sensors and cameras has the potential to improve the accuracy and robustness of many applications in fields such as autonomous vehicles, robotics and mapping. By combining the strengths of both sensors, a system can obtain a more complete understanding of its environment.

2D LIDAR sensors are able to generate highly accurate depth maps, but have difficulty detecting certain objects such as transparent or reflective surfaces. Cameras, on the other hand, can provide detailed visual information, but can struggle in low-light or highly reflective environments. By fusing data from both sensors, a system can overcome these limitations and improve its perfomanance.

One example of an application where the fusion of 2D LIDAR and cameras is beneficial is in the perception of autonomous vehicles. The LIDAR sensor can provide the vehicle with a precise understanding of the distances to objects in the environment, while the camera can provide visual information about the color, shape and texture of those objects. By combining this data the vehicle can improve its ability to detect and classify objects in the environment, and make more accurate decisions about how to navigate.

In addition to autonomous vehicles, the fusion of 2D LIDAR and cameras also has potential in areas such as robot navigation, object recognition and 3D mapping. Overall, the ability to combine the data from both types of sensors provides many opportunities to improve performance in a wide range of applications.

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