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Implementation of Microcontroller-Based Home Security System Using TF-Luna LiDAR

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Abstract

Insecurity is a major concern in homes and human inhabited facilities today. The need to fortify this facility and homes is key to solve the insecurity issues. This work is aimed at designing and implementing a home security system that utilizes a TF-Luna Light Detection and Ranging (LiDAR) sensor incorporated with an Arduino Uno R3 microcontroller. The main objective of this system is to enhance perimeter security and intrusion detection in various applications such as home security, industrial facilities, and critical infrastructure protection. The Integrated TF-Luna LiDAR sensor is known for two essential indices such as precision and reliability and the microcontroller unit creates a non-contact detection and ranging mechanism capable of accurately measuring object invasion distances. The Arduino Uno R3 microcontroller platform processes the collected LiDAR sensed data in real time and uses advanced algorithms for target detection, tracking, and anomaly identification. The system's key components include an intuitive user interface for control and monitoring, alarm generation, and data logging. The system provides real-time alerts and notifications to security personnel and home users through various communication channels. After been tested, evaluated and validated, it demonstrates its ability to detect and respond to intrusions accurately, even in adverse environmental conditions. The integration of a TF-Luna LiDAR sensor with a microcontroller offers a cost-effective and versatile solution for improving security and surveillance performance. This project showcases a promising approach to enhancing security systems by incorporating LiDAR technology, providing a foundation for further research and deployment in real-world security applications and ecosystem.

Keywords: *TF-Luna LiDAR, Security System, Arduino Uno R3 Microcontroller, Object Distance Measurement, Detection and Ranging.*

1. Introduction

The need for security system is a basic necessity for any individual in an invasion prone environment. But in this unsafe world, where crime, terror, and threats are at their peak, one can attain some sense of security using this technology. The TF-Luna Light Detection and Ranging (LiDAR) security system is an advanced technology designed to detect and respond to potential security threats or breaches in residential, commercial, or industrial facility. It comprises a combination of sensors, control panels, and alarm components working together to provide enhanced security measures. LiDAR is an effective and reliable intrusion detection with alarm system solution provisioning. This work focuses on developing an alarm system that utilizes TF-Luna LiDAR sensing technology for perimeter intrusion and motion detection. LiDAR security system is an active remote sensing technique and a measurement technology that consists of a laser emitter that emits short pulses of laser light. These laser pulses can be in the form of infrared, visible, or ultraviolet light, depending on the specific LiDAR. LiDAR system measures the time the emitted laser pulse travels to the object and returns to the receiver. This time measurement is based on the speed of light, allowing the system to calculate the distance between the LiDAR sensor and the objects in view. The data collected is further processed and analyzed to extract needed information about the detected objects. Microcontrollers and LiDAR sensors are combined to detect intruders. They're small computers on a single circuit are programmed for specific tasks. Despite the numerous advantages of LiDAR technology in security applications, certain challenges and limitations need to be addressed for its effective integration with a microcontroller-based system. The problem is to overcome these challenges and develop a robust solution that maximizes the potential of LiDAR for accurate and reliable intrusion detection in a security alarm system. The objectives are: Identifying intrusions or unwanted entry into the affected facility. This work is limited to the implementation of LiDAR based security system for home use.

2. Review of Related Works

Men and women face daily risks, including infiltrations that can lead to sacrifice in protecting our environment. By using breakthroughs, we can enhance security, reduce threats to our lives and protect our territorial integrity. Intelligent technologies can analyze data, identify patterns, and assist in countering emerging threats. We can monitor vast expanses of territory, detect intrusions in real time, and respond swiftly. We can accelerate the development of state-of-the-art security solutions by promoting innovation and knowledge exchange. (Akhilesh et al., 2020). The life of every human being is precious and safety is a challenge for us. But safety can be achieved by the use of various technological applications that do exist in this modern world. One of the techniques is the deployment of the sensor network. (Khan et al., 2017).

The development of security systems in the early 20th century involved the use of electrical circuits, telegraph wires, and bells to detect and alert people to potential threats. As technology improved, security automation and surveillance became more advanced with the incorporation of computerized controls and real-time video surveillance. Today, security systems consist of biometric access controls, motion sensors, CCTV cameras, intruder detection systems, and smart home security options. The history of security systems dates back to the creation of the first human habitations. The innovation and development of security systems show the amazing advancement from antiquated techniques to modern sophisticated security solutions, giving home owners unmatched control and peace of mind. (Lloyd security, 2021).

Microcontrollers, such as the Arduino, are becoming increasingly important in system applications and control methods due to their adaptability, cost-effectiveness, and ease of integration. Arduino boards provide a user-friendly environment for programming and linking components during the development process, offering a versatile platform for prototyping and developing electronic systems. The affordability and flexibility of microcontroller modules have democratized access to powerful control and automation abilities, allowing people from all walks of life to turn their ideas into reality. (Orlando et al., 2021). The use of automated systems has increased in the rapidly evolving world of technology, as people strive for productivity. Microcontrollers like Arduino are an essential part of this development, offering rapid and efficient automation that integrates seamlessly into everyday life. As technology advances, the demand for automated systems and microcontrollers is predicted to grow, empowering humans to realize the full potential of modern technology. Microcontrollers, like Arduino, play a critical role in transforming the way people live, work, and interact with technology. (Ramiz & Salama, 2022). A microcontroller as an embedded system obtains information through the sensors and adequately impacts the outside world after sensor data processing (Kelemen et al., 2020).

A sonar system would consist of a transmitter and a receiver. The transmitter will transmit the sonar signal to an object in front of it and will reflect once the signal reaches the object. The reflected signal (echo) will be sent to the receiver. The system evaluates the echo to determine the presence of the object (Kamaludin et al., 2015).

The sound speed in the air depends on the temperature. In the air the ultrasound speed is approximately 345 m/s, in water 1500 m/s and in a bar of steel, 5000 m/s (Paulet et al. 2016).

The sensor module uses ultrasonic waves to calculate an object's length to estimate distance using the SONAR or RADAR principle (Raghul, et al., 2023). Ultrasonic sensor is a measurement device that consist of two transducers one for transmitting an ultrasonic wave and the other for receiving the reflective wave. We use HC-SR04 ultrasonic sensor can detect lower range from 1cm to 2.5 meter with precession about 0.1 cm and frequency up to 40Khz. The target must be proper orientation and perpendicular to the direction propagation of pulse. The amplitude of receive signal decrease depend on the medium and the distance between transmitter and the target. The transmitter converts electrostatic energy from a vibrating membrane to an ultrasonic waveform whilst the receiver converts the reflected ultrasonic waveform back into electrical energy. This electrical energy combined with motor servo to see the angle of sweeping and ultrasonic waveform using Arduino Atmega 2560 then be interpreted by a computer display in two dimension for measurement angle and distance of object (Sansury, 2019). The HC-SR04 sensor sends an ultrasonic wave when triggered, being able to signal when the sent pulse is received. The distance can be determined, as the speed of sound propagating through the air is known (343.40 m s^{-1} at 20 °C), and the sound traveled twice the distance between the sensor and the object (Theodoro et al., 2023).

An ultrasonic or SONAR sensor is an electrical device that determines the distance between an object in front of it and itself by emitting small ultrasonic waves and using the time required for the waves to reflect off of the object and return to the sensor to determine the distance (Hunter, 2023). RADAR uses radio waves to detect objects' range, altitude, direction, and speed. It's employed for security measures in nuclear facilities, aviation, and long-range surveillance. The term RADAR was coined by the US Navy in 1940 as an acronym for Radio Detection and Ranging. (Anas & Adamu, 2020). RADAR and telescopes share a limited range of views. Telescopes use landscape elements for locating objects, while RADAR uses electromagnetic energy. A precise reference system is required for RADAR to detect and locate objects accurately. (Alzuwaid & Qabazrd, 2021). The ultrasonic sensor is used to measure the distance between the radar and any object-based non-contact technology. This system is controlled through Arduino. Arduino UNO board is sufficed to control ultrasonic sensor and also to interface the sensor and display device. Whereas, the movement of the sensor is controlled by using a small servo motor. This radar is controlled using the Arduino Uno board as a microcontroller. Ultra-sonic sensor is attached to the servo motor it rotates about 180 degrees and gives visual representation on the software (Bharathy et al., 2021).

Object detection is carried out continuously until an object is found. The Radar system operates tirelessly, ensuring that no objects of interest go unnoticed. The visual representation of the Radar is achieved through function codes, which include specific instructions that form the circular shape of the Radar display. These arcs serve as the foundation of the radar's visual representation, allowing other features to be added. (Nandnihi et al., 2020). To evaluate the performance of the proposed radar system, a visual was created (Biswas et al., 2020). The sensor displayed a red segment indicating the distance and angle of objects. The system measured the first object at 32cm instead of 30.5cm and the second object at 21cm instead of 20cm. Efficiency calculated at 95%. (Hameed & Rashid, 2019). Radar systems can easily obtain targets' ranges, speeds, and angles (Peng & Li, 2019).

LiDAR is an optical device that calculates the time for light to travel and bounce off a target surface. It evolved from calculating distances between satellites to accurately recording elevation data in various settings. LiDAR uses laser light pulses to measure distance, similar to radar. It achieves impressive accuracy and precision despite low pulse energy, which saves energy, extends range, and doesn't compromise data quality or reliability. (Pramod & Akshay, 2022).

The information flow goes between microcontroller, portable interface, and Lidar sensors. The communication between the micro-controller and LiDAR sensors is conducted through a portable interface that is designed in this project. The microcontroller unit will initialize the communication by setting up the appropriate configurations of the Lidar sensors (e.g., the data rate). After the initialization, the microcontroller unit will request the data of distance and angles from the Lidar sensors and those data will be sent through the portable interface. After receiving the data information, the microcontroller unit will determine whether the information from the Lidar should be displayed on LCD or stored in a memory stick. Then the microcontroller unit will process the information of the distance and angles to determine whether the distance is below a specified safe threshold. If the safety threshold is violated, then the microcontroller will disclose the message of safety warning or obstacle detected on LCD. If the safety threshold is not violated, the data of distance and angles will be kept in the memory stick that is also connected to the microcontroller through the portable interface (Hu et al., 2019).

Different technologies detect objects in various applications, with range, resolution, and interference determining suitability. LiDAR is for close to medium-range applications with high spatial resolution, sensitive to weather that scatters or absorbs laser light. RADAR offers long-range capabilities, low spatial resolution, and less weather sensitivity due to longer wavelengths. SONAR is effective for underwater imaging and mapping with moderate spatial resolution and is influenced by water conditions and noise sources.

While RADAR finds usefulness in Air Traffic Control (ATC) Radar is employed throughout the world for the purpose of safely controlling air traffic, en-route and in the vicinity of airports and Surveillance Radar is used for the detection and location of hostile targets for the purpose of taking proper military actions (Bakare et al., 2022). SONAR is used for object detection in water and Track and inspection of submarine telecommunication cables (Sun et al., 2021). The application of LiDAR is in Atmospheric Remote Sensing: Lidar excels at detailing aerosol profiles and types, while polarimetry offer constraints on overall aerosol abundance, absorption, and microphysical properties and in Ocean Remote Sensing: Polarized light originating beneath the ocean surface contains valuable microphysical details about hydrosols, including their shape, composition, and attenuation. Retrieving such information is challenging, if not impossible, using traditional scalar remote sensing methods alone. (Liu et al., 2023)

There are number of related works focusing on the surveillance system using sensors networks, the issue with such sensor systems is the degree to which they are vulnerable. This work explores the types of attack that could be successful and proposes defense that could be put in place to circumvent or minimize the effect of an attack. According to Hameed & Rashid (2019), The system measured the first object at 32cm instead of 30.5cm and the second object at 21cm instead of 20cm.The effective distance being measured using the TF-Luna LIDAR is 300cm.

According to Maeda et al. (2016), the RADAR is technically demanding and there is uncertainty is relatively medium. But the LiDAR which is quite technically demanding but the uncertainty is low to medium. As stated, the basic application is to comfort and ease in life of general public as it can be installed in almost all places with low-cost and operation facilities.

The project evaluated a microcontroller-based security system using a TF-mini LiDAR sensor in different environmental conditions. The system performed well in low light and adverse weather, but the presence of obstacles may affect accuracy. Compared to RADAR and SONAR technologies, TF-mini LiDAR has a shorter detection range than RADAR but higher object resolution than both. Integrating TF-mini LIDAR with a microcontroller offers a promising solution for enhancing security systems in various applications. Using affordable sensors and simplifying the system design can reduce costs and increase scalability. The work aims to optimize energy efficiency and extend battery life in microcontroller-based security systems with TF-mini LIDAR, particularly in portable or remote deployments.

3 Materials and Methods.

The following components will be used to ensure the success of the aim and objectives of this work. The Microcontroller-based security system to be designed comprises the hardware and the software section. The hardware consists of the construction and implementation. Arduino Uno R3, Connecting wires, Light Emitting Diode (Red), 9V Hi Watt Battery, Voltage resistor, 9V battery connector, TF-Luna LIDAR sensor, Buzzer, Resistor, Voltage regulator (7805), BC 547 Transistor, Capacitor, Diodes, and Power switch. Other Necessary Tools and Machines are: Soldering Iron, 1x Hot Glue Gun, Hot Glue as required, Arduino IDE (Integrated Development

Environment), Vero board, Benewake software, Laser cutting kit, CAD software (Fusion 360), Measuring Tape and Soldering Lead (generic).

Methods

Constructing a microcontroller-based security system using the TF-Luna LiDAR involves several methods and components to ensure accurate and reliable object detection and security monitoring. Here are the key methods typically used; Microcontroller Selection; Choose an appropriate microcontroller platform (e.g., Arduino) capable of interfacing with the TF-Luna LiDAR and executing control and monitoring tasks. TF-Luna LiDAR Integration; Connect the TF-Luna LiDAR sensor to the selected microcontroller using the appropriate communication interface (e.g., UART or I2C). Develop or utilize libraries and drivers to interface with the LiDAR sensor and retrieve distance measurements. Power Supply; Provide a stable power supply to the TF-Luna LiDAR and the microcontroller to ensure continuous operation. Data Processing; Implement algorithms for processing LiDAR data, such as object detection, distance calculations, and obstacle recognition. Object Detection and Security Logic; Set threshold distances or patterns to trigger security alerts. Alert Mechanisms; Integrate alert mechanisms, such as sirens, lights, to notify users of security breaches or suspicious activities. Testing and Calibration; thoroughly test the system, including calibration of the LiDAR sensor, to ensure accurate and reliable detection and minimize false alarms.

Hardware Implementation

Each component will be explained below along with their circuital representation as used in building the system security system. The software implementation is included in the microcontroller phase.

Given below is the general block diagram of the entire system in Fig. 3.1:

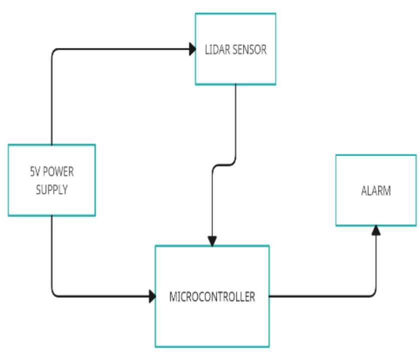

Figure 3.1- Block diagram of a Security system using LiDAR

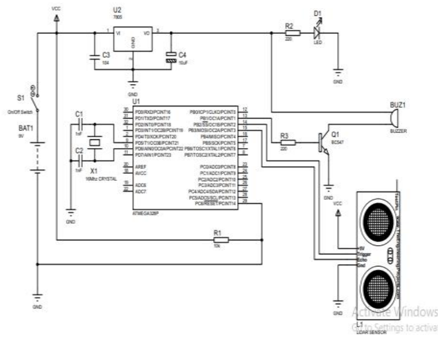

Figure 3.2 - Schematic diagram

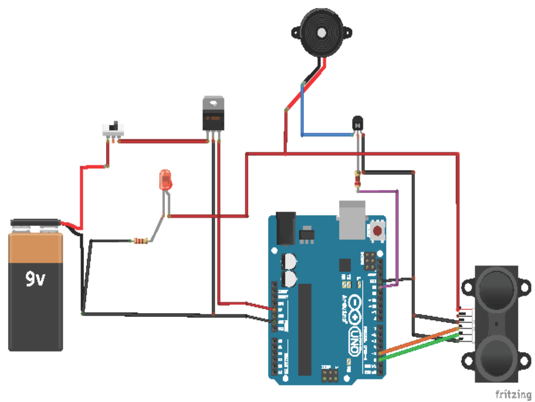

Figure 3.3 - Circuit diagram

The schematic and circuit diagram is shown in Fig,3,2 and Fig 3.3. It is built using only a few components to detect perimeter intrusion. The circuit works with a 12v power supply; the heart of the circuit is the TF-Luna LiDAR. The switch is used to turn ON/OFF the system, when power enters the system, the linear voltage regulator controls the amount of power entering the system and its output is connected to the power pin (5v) of the Arduino Uno. The resistor is connected to the power source to control the flow of power, also it is connected to the Arduino Uno (Vin) and also to the light-emitting diode. The BC 541 transistor has three terminals, one terminal (collector) is connected to the negative terminal of the buzzer the base is connected to the Arduino Uno pin (12) and the LIDAR sensor, the black pin (GND), the LED is also connected to the LIDAR sensor, red pin (5v power supply).

The LiDAR sensor which is used to detect the intrusion is connected to the green pin (TX-RX) and the white pin (RX-TX) of the microcontroller, LED and buzzer. The microcontroller reads and processes the sensor value, and therefore the system is housed in a box.

Description of Materials

Arduino Uno shown in Fig 3.4 is an open-source platform used to create electronic projects. Arduino consists of both a physically programmable circuit board (often called a microcontroller) and software or Integrated development environment (IDE) that runs on the computer and is used to write computer codes and load them onto the physical card. The Arduino platform has become very popular with those new to electronics, and for good reason. Unlike most previous programmable circuits, the Arduino does not require a separate hardware component (called a programmer) to load new code onto the board, you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making learning programming easier. Finally, Arduino offers a standard shape factor that divides the microcontroller functions into a more accessible package.

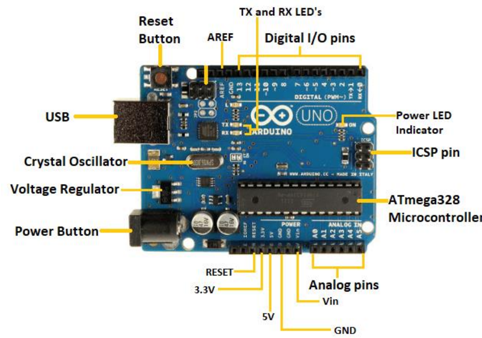

Figure 3.4 - Arduino Uno R3 board (Image Source: Arduino Uno R3,2023)

Jumper wires in Fig 3.5 are electrical wires with terminal pins on each end. They are used to connect two points in a circuit without soldering. You can use jumper wires to modify a circuit or diagnose problems in a circuit. Plug-to-socket jumper wires for connecting standard 2.54mm header pins and also for repacking connectors on various types of development boards. The pack consists of 40 pieces in different colors as shown below. Typically, it's a low-voltage and low-current electronic projects, such as those using Arduino, are designed to work with currents in the milli ampere (mA) range.

Plate 3.5 - Connecting wires

An LED is a two-lead semiconductor light source that emits light when forward-biased. It has a p-type and n-type semiconductor junction that allows electrons and holes to combine and release photons when activated. The color of the light emitted is determined by the energy band gap of the semiconductor material. The LED is often small in area (less than I mm2) and integrated optical components may be used to shape its radiation pattern. Standard indicator LEDs commonly used in electronics typically consume between 1 milliwatt (mW) to 100 mW (mW).

The LED (Red) in Fig 3.6, has a wavelength of 610 – 760 mm, the LED's forward voltage (Vf) is the voltage at which it starts to conduct and emit light. LEDs have specific Vf ratings, typically ranging from 1.5V to 3.5V or more, depending on the LED type and colour.

Figure 3.6 - Light Emitting Diodes (Image Source: Hackster, 2023)

An audio signaling device used in this work is shown in Fig 3.7, is a beeper or buzzer of an electromechanical piezoelectric or mechanical type. It converts the signal from audio to sound. Generally, it is powered through DC voltage (3V to 24V DC). Based on the various designs, it can generate different sounds like alarms, music, bells & sirens. The frequency range is 3,300Hz, Operating Temperature ranges from – 20° C to +60°C. The pin configuration of the buzzer includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal, the terminal is powered through 6Volts whereas the negative terminal is represented with the '-' symbol or short terminal and it is connected to the GND terminal. Buzzer durations are typically determined by the circuit design and the control provided by the microcontroller or other electronic components.

Figure 3.7 - Buzzer (Indiamart, 2023)

An electric battery in Fig 3.8, is a device consisting of two or more electrochemical cells that convert stored

Chemical energy into electrical energy. It is an electric battery that supplies a nominal voltage of 9 volts. Actual voltage measures 7.2 to 9.6 volts, depending on battery chemistry. The 9V (nine volts) battery is a rectangular dry cell battery but use a carbon-zinc chemistry, classified by Length

- 26. 5mm, Height - 48. 5mm, Width - 17. 5mm (Max) connector-style attachment terminals. It holds capacity upwards of 3000mAH. (3000 milli amps per hour) and were often used in radios but today are used more for smoke detectors, house alarms etc. Understanding the battery's rating helps ensure that it can provide the necessary voltage to power the system reliably.

Figure 3.8 - 9V Hi-Watt Battery (Hi-Watt, 2022)

The main function of the battery connector in Fig 3.9, is to hold the battery securely and firmly in place while the power is transferred from the batteries to the device in question. It has two matching snaps, a male and a female snap connector. To insert the battery, it will be lined at about 30° angle and then simultaneously pressed in and down. The external connections on the battery connector are often made via pin contact, solder lugs, or a set of lead wires.

Figure 3.9 - Battery connector (Image Source: Solarbotics, 2023)

The BC547 in Fig 3.10, is a widely used general-purpose bipolar junction transistor (BJT) with an NPN configuration, meaning it has a negatively charged layer between positively charged layers. It belongs to the BC family of transistors. This configuration allows it to be used as an amplifier or a switch. It is a top pick for low-power applications, such as illuminating LEDs, amplifying sensor signals etc. choosing the right transistor for an Arduino project is essential for ensuring proper electrical characteristics, reliability, safety, and cost-effectiveness, the maximum direct current gain of BC 547 is 800A.

Figure 3.10 - BC 547 Transistor (Image Source: Microscale, 2023)

A resistor in Fig 3.11 is a fundamental electronic component that opposes the flow of electric current in a circuit. It is commonly used to control the current, divide voltage, and limit the flow of electrical energy in electronic circuits. The primary function of a resistor is to regulate the flow of current and create specific voltage drops. Resistors are often color-coded to indicate their resistance value. The color bands on the resistor body represent specific digits and a multiplier that together determine the resistance value.

Figure 3.11- Resistor (Image Source: Techtarget, 2023)

TF-Luna LiDAR

The TF-Luna LIDAR is a Time-of-Flight (T.o.F) based LIDAR sensor, LIDAR stands for Light Detection and Ranging, and it is a remote sensing technology that uses light pulses to measure distances to objects or surfaces. The TF-Luna LIDAR is specifically designed for distance measurement applications and provides precise and reliable distance data. It emits laser pulses towards the target object and measures the time taken for the laser light to reflect to the sensor, the short high-power impulse is safe and does not damage the human eye. By knowing the speed of light, the sensor can accurately calculate the distance to the target. The TF-Luna LIDAR typically has a narrow field of view, allowing it to focus on specific targets. The operating voltage of the TF Luna LIDAR typically ranges from 5V to 12V, depending on the specific model, the range of the TF-Luna LIDAR is 8m.

The LiDAR sensor obtains Time of Flight (T.o.F) by measuring the alternating phase difference, and then calculating the relative distance between the sensor and the detected object.

$$ToF = \frac{nT + \phi}{2\pi \times T} \qquad (1)$$

Equation (1) is a formula for calculating Time of Flight (T.o.F) based on the phase difference (∏) between the transmitted wave and the reflected wave from an object, where 'n' is the number of full waves and 'T' is the time required for light to travel one wavelength. Fig. 3.12 depicts the scheme of Time of Flight (T.o.F) principles.

$$D = \frac{C \times T.o.F}{2} \qquad (2)$$

Aziz & Zakarijah, (2022) Equation (2) once the Time of Flight (T.o.F) value is determined, the distance (D) can be calculated. Equation (2) is a formula for calculating the distance based on known Time of Flight (T.o.F), where C is the value of the light speed (3×10^8)

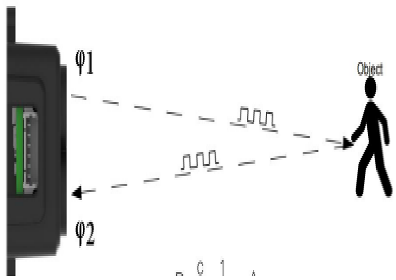

Figure 3.12 Time of flight principle (Image Source: Benewake, 2023)

Efficiency and error calculations for a TF Luna LiDAR system involve several factors, including the LiDAR's specifications and the environmental conditions in which it operates.

Efficiency Calculation:

Efficiency is the ratio of successful measurements to the total number of emitted laser pulses. It's usually expressed as a percentage.

Formula:

$$\text{Efficiency (\%)} = (\text{Successful Measurements} / \text{Total Emitted Pulses}) \times 100 \qquad (3)$$

Where:

Successful Measurements: The number of laser pulses that were reflected back to the LiDAR sensor.

Total Emitted Pulses: The total number of laser pulses emitted by the LiDAR during a specific time period or scan.

Error Calculation:

Error in LiDAR measurements can be quantified using various metrics, such as Mean Absolute Error (MAE) and Root Mean Square Error (RMSE).

a. Mean Absolute Error (MAE):

MAE measures the average absolute difference between LiDAR measurements and ground truth measurements.

Formula:

$$\text{MAE} = \Sigma\, |\text{LiDAR Measurement - Ground Truth}| / n \qquad (4)$$

Where:

Σ denotes the summation over all data points.

|LiDAR Measurement - Ground Truth| represents the absolute difference between a LiDAR measurement and the corresponding ground truth value, n is the total number of data points.
Root Mean Square Error (RMSE): RMSE quantifies the square root of the average of the squared differences between LiDAR measurements and ground truth measurements. It penalizes larger errors more than MAE.
Formula:

RMSE = sqrt(Σ (LiDAR Measurement - Ground Truth) ^2 / n) (5)

Where:
Σ denotes the summation over all data points.
(LiDAR Measurement - Ground Truth) ^2 represents the squared difference between a LiDAR measurement and the corresponding ground truth value.
n is the total number of data points. These formulas provide a basic framework for calculating efficiency and error in LiDAR measurements.

Table 3. 2 - Technical Specifications and Parameters

Description		Parameter value
Product performance	Operating range	0.2m~8m(90%reflectivity) [1]
	Accuracy	±6cm@(0.2m-3m)[2] ±2%@(3m-8m)
	Distance resolution	1cm
	Frame rate	1-250Hz[3]
	Ambient light immunity	70Klux
	Operation temperature	-10℃~60℃
	Enclose rating	/
Optical parameters	Light source	VCSEL
	Central wavelength	850nm
	Photobiological safety	Class1 (IEC60825)
	FOV	2°[4]
Electrical parameters	Supply voltage	3.7V-5.2V
	Average current	≤70mA
	Power consumption	≤0.35W
	Peak current	150mA
	Communication level	LVTTL(3.3V)
	Communication interface	UART / I2C
Others	Dimension	35mm*21.25mm*12.5mm (L*W*H)
	Housing	ABS+PC
	Storage temperature	-20℃~75℃
	Weight	<5g

Figure 3.13 TF-Luna’s PINs (Image Source: Evelta, 2023)

Table 3.2 - The Function and Connection Description of each pin

No.	Function	Description
1	+5V	Power supply
2	RXD/SDA	Receiving/Data
3	TXD/SCL	Transmitting/Clock
4	GND	Ground
5	Configuration Input	Ground: I2C mode /3.3V: Serial port Communications mode
6	Multiplexing output	Default: on/off mode output I2C mode: Data availability signal on but not switching value mode

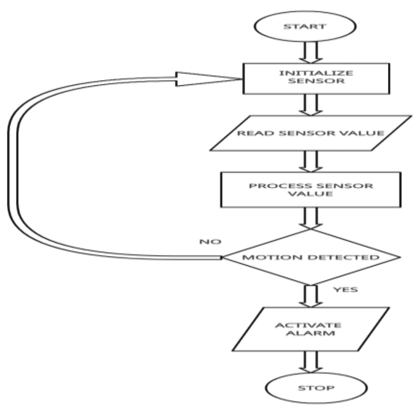

Figure 3.14 – Representing the work in flowchart

The above flow chart in Fig 3.14, explains the working and the decision flow of this framework. As can be seen, the system starts with an input i.e. when the TF-Luna LIDAR detects an object or does not detect any object, at any condition the encoder feeds the information in the controller while the servo keeps constantly rotating. As soon as any obstacle/object is detected by the ultrasonic sensor the data is immediately processed by the controller and is fed to the IDE which shows it on the display screen. Here the process ends with an estimated distance of the object from the system with the angle at which it is placed.

4. Results and Discussions

Testing the Power Section

This section comprises mainly the 9v battery, battery connector, switch, capacitor and voltage regulator. The battery is connected to a switch which is further connected to the Arduino microcontroller. The ground and 9-volt terminals of the battery are connected to the GND and VCC pins on the microcontroller. It is responsible for supplying the power needed to run the components connected to it. This is shown in Fig 4.1.

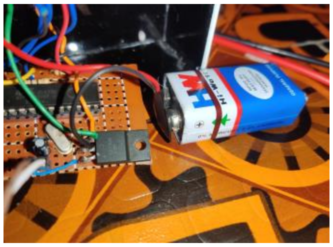

Plate 4.1 - Picture showing the battery

The Sensing Section

The TF-Luna LiDAR (Light Detection and Ranging) sensor is shown in Fig 4.2, and is a distance measurement sensor that uses laser light to determine the distance from the sensor to an object or surface. The sensing section is essential, as it allows the system to interact with its surroundings, respond to changes, and make decisions based on the collected data can be processed and used to make decisions or control actions, making it a valuable component. It is connected to the microcontroller, light-emitting diode and buzzer. A fully functional LiDAR system is made of four major subsystems namely; laser rangefinder, beam deflection, power management, and master controller units

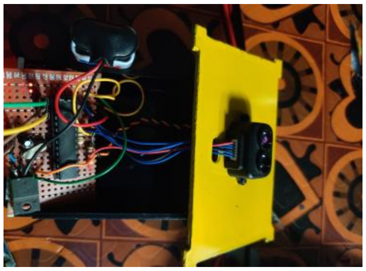

Plate 4.2 - The Sensing section

The Control Section

It involves defining the logic and rules that govern how the project operates. The microcontroller is the heart of the Arduino project, which is responsible for executing the programmed instructions and coordinating all the components and functions within the project. As in Fig 4.3

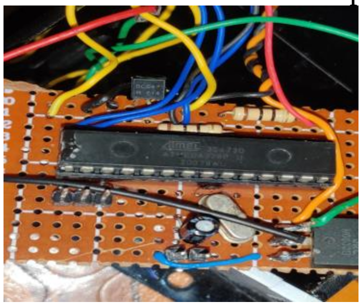

Plate 4.3 - The Control section

Testing the LiDAR Sensor (Code Serial Monitor)

It refers to a tool or feature provided by an integrated development environment (IDE), which allows the user to communicate with a microcontroller (send and receive data), such as an Arduino board, through a serial connection (usually USB). Object distance was increased with various speed to observe the validity of algorithm. The serial monitor output shows the important parameters that is the distance. As shown in Fig 4.4.

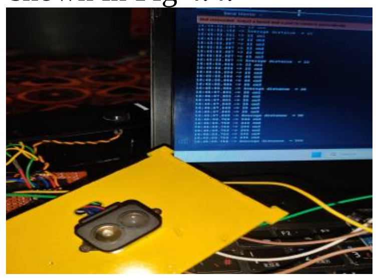

Plate 4.4 - Code serial monitor

Testing the LiDAR Sensor

The images below show readings from the LiDAR TF-Luna at varying distances from the object being measured. A tape measure is placed on the floor to show the distance between the object and the sensor which gives different sounds. From range 0cm to 100cm the system outputs a high-frequency beeping sound. From the range of 100cm to 200cm the system outputs from the buzzer a low-frequency beeping sound while from the range 200cm to 300cm, the system outputs a slow beeping sound. Also, all sensor readings above 300cm are ignored hence the system measurement range is between 0cm to 300cm. The setup worked properly as expected. The system was able to experimentally detect metal, non-metal and a still and moving human. As shown in Figures 4.5, 4.6, 4.7, and 4.8.

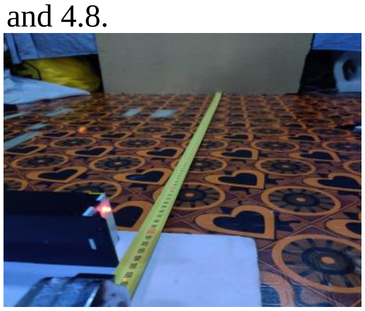

Plate 4.5 - At 100 cm (Front view)

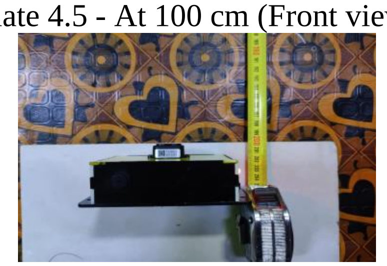

Plate 4.6 - At 200 cm (Top view)

Plate 4.7 - At 300 cm (Front view)

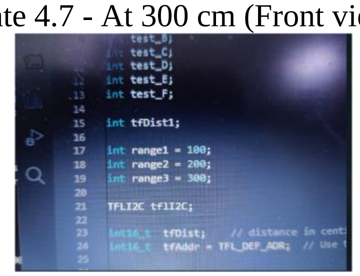

Plate 4.8 - Different sounds for different ranges (in centimeters) as set in the code.

Enclosure Modeling (Designing)

Enclosure modelling is critical as it protects the components from physical damage, dust, and moisture while providing a clean and professional appearance.

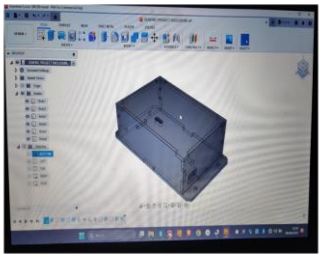

Plate 4.9- Enclosure modeling using Fusion 360

Enclosure Modeling (Laser cutting)

Laser cutting provides a precise and clean way to create custom enclosures for the project.

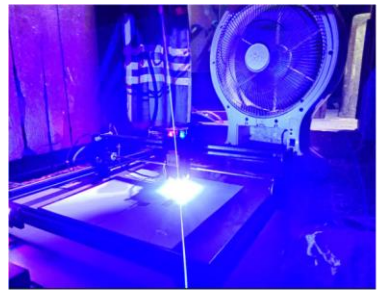

Plate 4.10 - Laser cutting

Testing Chart Range of Detection

Based on the sensitivity of TF-Luna LiDAR sensor, the detected ranges of the system are measured. The obtained measurement data are shown in the table below.

Table 4.1 - Table of values of the detection range

Distance (cm)	**Possibility of detection**
25	YES
50	YES
75	YES
100	YES
125	YES
150	YES
175	YES
200	YES
225	YES
250	YES
300	YES
325	NO
350	NO

.

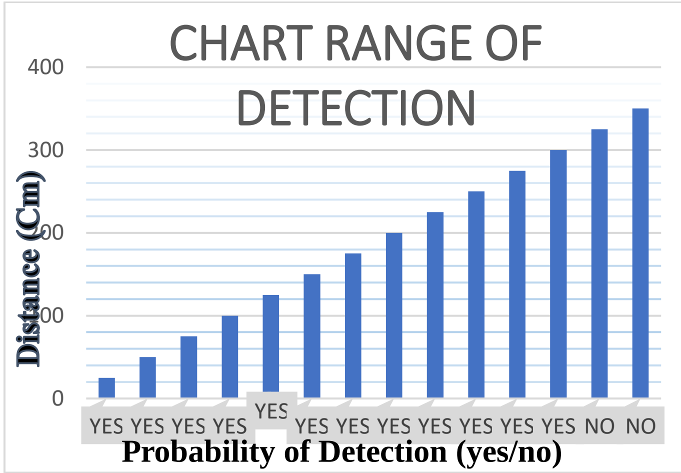

Figure 4.11 - Chart range of detection

The X-axis indicates the probability of detection and Y-axis indicates the value of the measured distances.

Conclusion

Taking the objectives into account, it can be stated that this project has been completed. Looking at this project individually, it can be seen that the first objective was to detect intrusion was achieved. The aim of the project was also achieved and the work was set out on the simplest and user friendly security system design, having the security of lives and properties in mind. The design was carefully out to eliminate such major problems that could arise in the future due to adoption of complicated design. The Light Detection and Ranging (LiDAR) security system in this construction serves its purpose perfectly. Therefore, efforts were made to ensure that a more simplified and less complicated design was achieved. In any application, the Light Detection and Ranging (LiDAR) security system is ultimately determined by the balance between performance and cost, also taking into account the power rating and the acceptable value of the various forms of risks. The construction was done in such a way that it makes maintenance and repairs an easy task and affordable for users, should there be any breakdown.

Recommendation

The battery is the least reliable part of the designed LiDAR security system. Nevertheless, the security design can influence the reliability of the components. The battery which is not rechargeable, should be replaced when dead. The TF-Luna LiDAR, which is 1-Dimensional, to extend the dimensionality and field of view (FOV) to 2D LiDAR, since weight is no longer an issue using electromechanical drive (servomotor). On top of that, custom made gear trains are utilized to extend the rotation of the servo motor to up to 360 degrees. The security system is indoor because it can't withstand harsh weather conditions, it can cover water resistant protective body.

Limitations

The effective range of the security system is 3 meters, the LIDAR security system is 1D (1-Dimension), and the protective body is not water resistant.

Conflict of interest: There is no conflict of interest.

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