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Automated Intrusion Mapper

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Abstract

This project exhibits the working of an electronic, long-range, LiDAR-based, automated intrusion-detection system prototype, which detects intrusion by utilizing LiDAR technology based on the principle of Time-of-Flight (TOF). It is a compact, secure, robust, user-friendly, and reliable intrusion-detection system. It operates at only 5V, which makes this a power efficient device. A long-range LiDAR sensor, mounted on a 2-Axis servo pan-tilt assembly, rotating to-and-fro (from 0^{o} to 180^{o}) detects intrusion when safe distance (that is user-defined) is breached by a trespasser. A high noise buzzer starts beeping whilst the safe distance is being breached. A 2-D real time mapping is visible to the user, who can assess any incoming threat by observing changes in it, accompanied by the safe distance breach alert.

Keywords: LiDAR, Sensor, Time-of-Flight, TOF, Intrusion-detection, Safe-distance

1. Introduction

Conventional security systems, such as cameras, radars, CCTVs are delicate, sophisticated systems possessing different sensors, input and output peripherals which serve a distinct purpose. Even though these systems are robust in nature, it is still very much prone to system shutdowns due to various reasons, such as:

- Faulty wires
- Bugs arising in the security software, messing with video, audio recordings, wrong timestamps, etc. This could lead to serious issues, since these could be used as evidence in stopping potential crimes, or in court.
- Accumulation of dust over the system, which is why deep-cleaning is required from time-to-time.
- Weather conditions posing a challenge.
- Power Supply rendered useless.
- High maintenance and installation expenditure.

Considering these risk factors, it could compromise the monitoring, reliability, safety and security of the place or object. Ongoing research in robust security solutions are concerned in overcoming the issuances mentioned above.

Light Detection and Ranging, LiDAR in short, is a remarkable tool which has great potential in providing reliable, hassle-free security solutions. LiDAR is proficient in mapping and creating 3D images, possessing high resolution fidelity. It does so by pinpointing the position, direction, speed, and size of the object in its FOV (Field of View). It can be combined with different sensors to provide a definitive overview over a protected space. LiDAR works profusely in ambient lighting, night time, and favourable atmospheric conditions. It has the potential to utilize real-time tracking as well. Therefore, LiDAR has incredible prospects in providing affordable, reliable, and robust security applications.

Automated Intrusion Mapper (A.I.M.) has the potential to be a reliable, compact, affordable, and robust system which can detect intrusion via precise and accurate 3D imaging by utilizing LiDAR's Time-of-Flight capability.

2. System Description

2.1. TFmini-S LiDAR Sensor

TFmini-S, as shown in Fig. 1, is an upgrade project based on the Tfmini. It is a miniaturized, single-point ranging product. Based on the TOF (time of flight) principle, it is designed with unique optics, electricity, and algorithms to achieve stability, precision, sensitivity and high-speed distance measurement function.

In addition to the low-cost, small-size, and long-ranging of the TFmini, the product itself has higher distance measurement accuracy. It is more adaptable to different outdoor environments such as strong light, different temperatures, and different reflectances. It has lower power consumption and more flexible detection frequency. The product is compatible with both the UART and I2C interface. Different interfaces can be switched by commands.

Figure 1: TFmini-S LiDAR Sensor

Working Principle of Tfmini-S LiDAR Sensor

TFmini-S, as mentioned before, utilizes the Time-of-Flight (TOF) principle. The LiDAR sensor produces near-infrared ray modulation wave periodically, which is reflected after hitting the target. Tfmini-S calculates the TOF by determining total phase difference, followed by calculation of proportional distance between the sensor and the target, as shown in Fig. 2.

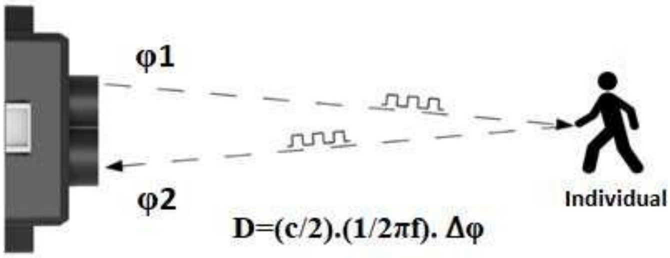

Figure 2: Schematic of TOF Principle

Table 1: Elucidation of TFmini-s's connection layout and its functions

NO.	COLOUR	FUNCTION	DETAILS
1.	Black	GND	Ground
2.	Red	+5 V	Power Supply
3.	White	RXD/SDA	Receiving/Data
4.	Green	TXD/SCL	Transmitting/Clock

2.2. Arduino UNO R3

Arduino UNO R3 shown in Fig. 3 has 14 digital input/output pins which are accessed by using functions such as pinMode(), digitalRead(), and digitalWrite() via Arduino programming [5]. Due to the onboard voltage regulator, it converts the voltage supplied to it to 5 volts. Therefore, the pins run on 5V. They can either receive or provide a maximum of 40mA current.

Figure 3: Arduino UNO

2.3. ARDUINO IDE

Arduino IDE stands for Integrated Development Environment. It is an open-source programming software, invented, engineered, and powered by Arduino. It is an intelligible language, which utilizes a combination of C, C++, and Java. It has devoted libraries for distinct peripherals. It is usually downloaded via the Library Manager, Arduino IDE. The programming written in this environment is well-suited with all the diverse versions of Arduino boards such as, Arduino nano, Arduino Leonardo, Arduino UNO etc. The IDE is affable for creation of open-source developments. Thus, it is favoured by researchers, engineers, students, and people from non-software disciplines. This is one of the most endearing factors of the Arduino IDE in fields of research, development and teaching. The version that it going to be used: ARDUINO 1.8.9.

2.4. Processing Software

Processing is a software which combines coding and visual arts. Processing is an incredible tool for creating art, technical prototypes, etc. Processing is based on the Java language, with custom built-in classes. Its highly intuitive GUI simplifies compiling the written program, and during its runtime. The Arduino IDE is based on Processing itself.

3. Working Principle:

Since TFmini-S is a single point ranging sensor, it is mounted on a 2-axis servo pan-tilt assembly, and, is prepared to move and scan from left to right (horizontally. The Arduino UNO steps the servo motor 1^{o} at a time, then it takes distance measurements with the LiDAR detector. The Arduino UNO is responsible for calculation of the X-Y coordinates of the points in two-dimensional space [from the distance measurements]. It then proceeds to output the data serially on a computer, or PC. After that, a Processing sketch is started on the computer. The Processing sketch then receives the 2D coordinates of the points, thus displaying it graphically. A block diagram of the entire process is given in Fig. 4. An additional servo motor (Servo Y) is also present if the user wants to scan the room vertically.

There are three programs, or *sketches*. The 'ToI2C' sketch is used to make the Lidar sensor I2C interface compatible. The 'MySketch2' sketch calculates the X-Y coordinates of the points in 2D space. The 'MySketchPDE2' sketch displays it graphically.

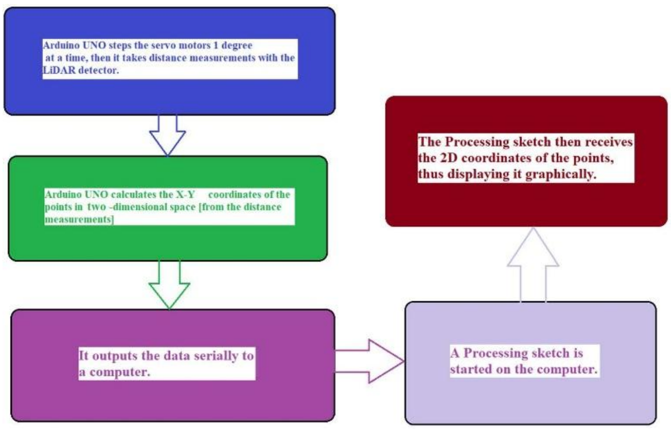

Figure 4: Block Diagram of Automated Intrusion Mapper.

4. Methodology:

The TX (Green Wire) and RX (White Wire) wire of the Tfmini-S Lidar sensor is connected to Digital Pin 2 and Digital Pin 3 of the Arduino UNO respectively. The red wire and the black wire of the Lidar sensor is connected to the analog 5V pin and the analog GND of the Arduino UNO. 'ToI2C' sketch is uploaded to the UNO to activate the I2C mode of the Lidar sensor. Following successful uploading of the said sketch, the TX and RX wires are now connected to SCL pin and SDA pin of the UNO respectively. Next, the 'MySketch2' is uploaded to the UNO. With the help of this sketch, Arduino UNO calculates the X-Y coordinates of the points in 2D space by using the distance measurements performed by the Lidar Sensor. After this, the *processing* software is turned ON. The 'MySketchPDE2' sketch is started. This enables the processing sketch to receive the polar coordinates from Arduino UNO via serial communication. It is then converted to cartesian coordinates, and displayed graphically in 2D, in real time. All the pins of Tfmini-S Lidar sensor, servo motors, Power supply board, Buzzer are properly connected as per their respective pin configuration as shown in, Table 2, 3, 4 and 5. A 1000 µF is added to smoothen the movement of the servo motor. The schematic diagram of the overall circuit diagram of the prototype is shown in Fig. 5.

Table 2: Tfmini-S LiDAR Sensor

Pin	Connection
TX	SDA Pin / Pin A5 (UNO)
RX	SCL Pin / Pin A4 (UNO)
VCC	5V Pin (UNO)
GND	GND (UNO)

Table 3: MGS90 Servo X

Wire	Connection
Brown	GND (UNO)
Red	Power Supply Board
Orange	Digital Pin 9 (UNO)

Table 4: Power Supply Board

Pin	Connection
VCC	Red Wire (Servo)
GND	GND (Servo and UNO)

Table 5: Buzzer

Wire	Connection
Red	Digital Pin 4 (UNO)
Black	GND (UNO)

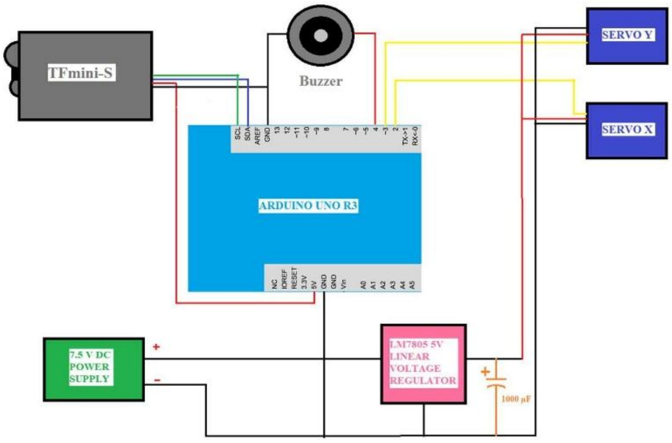

Figure 4: The schematic Diagram of the Automated Intrusion Mapper.

5. Experimental Results:

The system is designed, as shown in Fig. 5. Arduino UNO and 7.5V power supply is turned ON. When the processing sketch starts, it checks whether there are any errors in the sketch and then proceeds to open a pop-up window. The Arduino UNO restarts the already uploaded program accordingly. The Lidar sensor takes two seconds to calibrate (checks for internal errors) and then starts calculating distances of objects from it by using Time-Of-Flight (TOF) principle. The power supply, which has already been provided to the servo motor, starts rotating from 0^o to 180^o and back to 0^o continuously. A 15 ms delay is given after the servo angle increases by 1^o. The delay can be decreased to increase the speed of rotation of the servo motor. When the servo rotates from 0^o to 180^o, and, from 180^o to 0^o, it maps the surroundings it covers in 2D, which is displayed on the pop- up window in real time, as shown in Fig. 6.

In Fig. 6(a), one can observe that the Lidar sensor detected objects during its rotation in real time, which has been pointed out with red circles, as shown in Fig. 6(b).

Thus, a visual representation helps the observer assess the protected perimeter in real time. When the user-defined safe distance is breached, a high pitch buzzer goes off and alerts the observer and concerned individuals in its immediate vicinity.

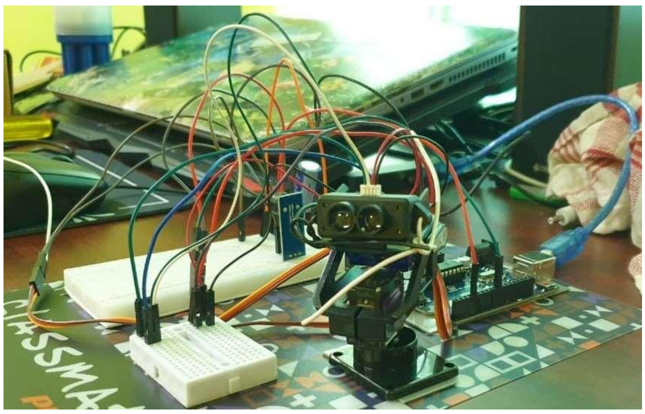

Figure 5: The experimental setup of "Automated Intrusion Mapper"

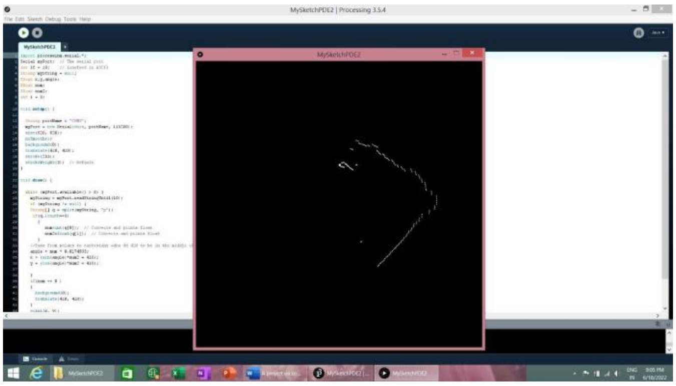

Figure 6(a): Lidar sensor mapping one side of the room, from 0° to 180° (to-and-fro)

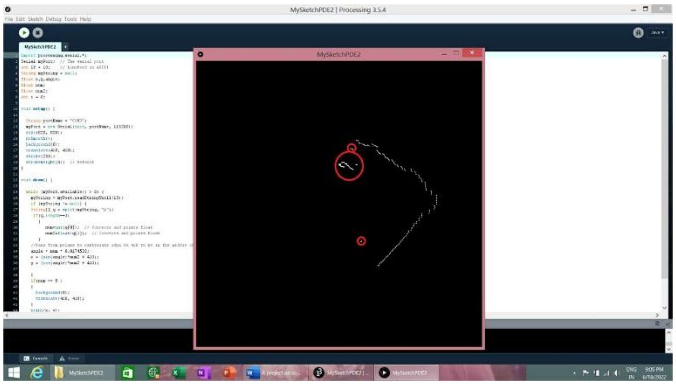

Figure 6(b): Objects detected by Lidar sensor pointed out by red circles.

6. Conclusion:

I have developed a secure, robust, user friendly, cost effective, automated electronic, long-range, LiDAR-based intrusion-detection system prototype, which detects intrusion along with 2D Perimeter-Mapping (180° capture) by utilizing LiDAR technology based on the principle of Time-of-Flight (TOF).

Limitations:

a) Intrusion Detection and 2D Perimeter-Mapping limited to 180°.
b) The servo motor may get damaged due to repeated rotations for longer periods of time. Thus, it might need to be changed frequently.

Future work:

a) Upgrading Intrusion Detection and 2D Perimeter-Mapping to 3D mapping and 360° capture.
b) Creating a custom servo motor which is resistant to wear-and-tear when subjected to longer periods of time.

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