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AN ULTRASONIC SENSORY-BASED DEVICE FOR REAL-TIME DETECTION OF TERRORIST THREATS USING ARDUINO-UNO

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Abstract

In recent times, the Boko Haram sect and bandits have been ambushing people more often, inflicting mayhem to their victims. Detecting these

Keywords: Arduino Uno, Bandits, Radar, Ultrasonic Sensor, Ambush, Object Detection, Servo Motor

INTRODUCTION

Background to Study

An ambush by armed bandits in Nigeria has cost lost of several lives and properties. So many other mayhems have been caused by these armed men. This catastrophe could be avoided by putting in place a check that can detect the presence of terrorists and bandits. Radar systems were developed covertly in many countries before and during World War II (WWII). The quick invention and triumph of contemporary radar during WWII in 1939 were vital to the Allies' victory in the conflict's conclusion. Scientists and inventors started investigating the non-military applications of radar toward the end of WWII. An antenna emits radio waves, which are energy beams. As radio waves collide with atmospheric particles, they disperse everywhere, and some of the scattered waves are reflected and collected by radar. The number of waves that were reflected to the radar criminals before the strike will go a long way to resolving some of the atrocities caused. An Arduino UNO board assembles the servo motor and the ultrasonic sensor using the C++ programming IDE software. The interaction of the Arduino using AT Mega microchip helps in coordinating and controlling the rotation of the servo motor, which aids the scanning of a target via an ultrasonic sensor from 0˚ to 180˚. This work was fashioned with an ultrasonic sensor mounted on a servo motor to give the 180˚ rotational scanning for targets. It was observed that the outcome of the tested result is about 98% accurate over a targeted radius ranging from 0m to 200m.

Increases with object size (Thomas et al., 2014). Compared to infrared sensors, ultrasonic sensors have several benefits, chief among them being their increased object detection range and interference resistance. By using sound waves, ultrasonic sensors can identify objects of any substance, colour, or transparency.

Statement of Problem

The military personnel lose their lives every day to armed bandits, as the unsuspecting criminals take them unawares. Efforts had been made to curb this situation, but so many had been abortive. This mayhem has led to the loss of lives of so many breadwinners of families, leading to a poor standard of living for the families they have left behind. There is a drastic drop in the figurative strength of our security operatives. This sudden drop in manpower could be controlled with the help of a deployed object detection system as proposed in this work.

Aim and Objectives

The research aims to design and implement a radar development system using an ultrasonic sensor. Specifically, it seeks to:

i. Design a circuitry that detects objects using an arguing Uno microcontroller.
ii. Program the Arduino Uno using C++ programming language.
iii. Test the system for evaluation.
iv. Assess the system's performance under various environmental conditions and at different distances.

Literature Review

Conceptual Framework

The radar system transmits pulses of radio waves via an antenna which strikes objects along its path and reflects a significant portion of the wave to the receiver that is in line of sight. The technology has continued to grow since it was discovered (Bendimerad & Boukern, 2019). Exploring infrared rays gives a simpler solution, thus, the simplicity leads to a short range of distance covered and significant error in precision (Thomas et al., 2014).

Principle of Radio Wave Radar

At the onset of the discovery of radar systems, their mode of operation had to do with the generation of electromagnetic signals in the transmitter that radiate into space via an antenna and collect the reflected signal via a receiver. The object's location and presence are detected by processing the reflected signal (Emmanuel Onoja, 2017). The radar equations link a radar's properties of the transmitter, antenna, and target. The range of an item is determined by timing how long it takes the radar signal to reach its target and return to the receiver.

Radars and the power density at a distance R from the radar are equivalent if the transmitter power Pt is transmitted via an isotropic antenna.

$$P_D = \frac{P_t}{4\pi R^2} \qquad 1$$

Considering that the gain of an antenna is the measure of an increased radiated power density and (1) is rewritten as represented in (2):

$$P_D = \frac{P_t G}{4\pi R^2} \qquad 2$$

The radar cross-section (σ) of the target defines the power density reflected by the radar for a specific power density incident on the target. The target reflects the intercepted signal in several directions.

$$R = \frac{P_t G}{4\pi R^2} \cdot \frac{\sigma}{4\pi R^2} \qquad 3$$

The product of the incoming power density and the effective area,A_e of the receiving antenna yields the power received by the radar. The physical area A and the effective area are related by:

$$A_e = \rho_a . A \qquad 4$$

The received signal is then given by (5):

$$P_r = \frac{P_t G}{4\pi R^2} \cdot \frac{\sigma}{4\pi R^2} . A_e \qquad 5$$

The distance at which a radar target cannot be spotted is known as its maximum range. This happens when the least detectable signal is just equal to the received signal power$P$.

$$R_{max} = \left[\frac{P_t G A \sigma}{(4\pi)^2 Smin}\right]\frac{1}{4} \qquad 6$$

Principle of Sound Wave Radar

The idea is to use sound waves to develop an object detection system that can detect items in real-time. The process of emitting an ultrasonic wave, detecting an item, and reflecting the echo, which the receiver receives based on the magnitude of the reflected signal. Shown in Fig. 1 describes how bat could select their path through sounds the make (Mehta & Tiwari, 2018).

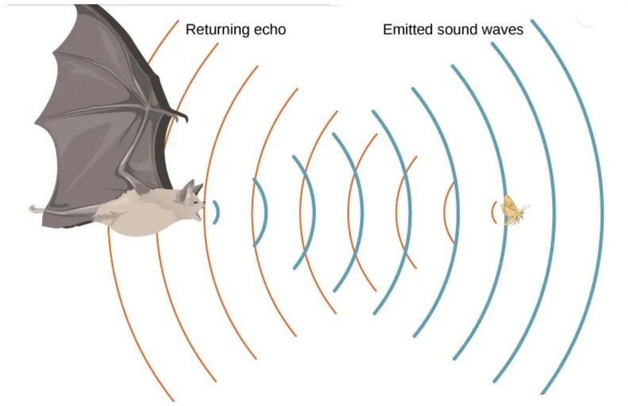

Fig. 1: Ultrasonic sound signal explored by bats in natural habitats (Mehta & Tiwari, 2018)

The formulae for calculating the Distance of sound travel are given in the echo equations as represented in (7) and (8),

$$Distance = Speed * Time \quad 7$$

Where the speed of the sound wave is 343m/s

$$The\ average\ Distance\ of\ an\ echoed\ sound = \frac{343 * time\ of\ echo}{2} \quad 8$$

The total distance is divided by 2 because the signal travels from the sensor to the object and back to the sensor.

Review of Related Studies

Ashwini *et. al.* (2020) in their work attempt to create a radar system with seven ultrasonic sensors attached to a servo motor for mapping applications driven by an Arduino Mega at380. Each sensor will detect and provide a signal to the Arduino for processing. This implementation offered a limited resolution of the servomotor's defect and the dispersed ultrasonic sensors (Ashwini et al., 2020).

Ikpenyi *et al.* (2022) worked on the sensors that produced overlapping echoes. The authors conducted a study to investigate the ultrasonic signal's Time-of-Flight between striking the target object and reflecting the ultrasonic transducer, as well as its amplitude, to study and interpret signal processing when confronted with overlapping echoes, which is important for distance measurement and map reconstruction applications while scanning a room corner. The study gave room for the examination of the ultrasonic response created by a pair of sensors in the transmitter-receiver configuration, as well as the pulse-echo technique for recognising surfaces that generate several echo responses (OE Ikpenyi et al., 2022).

In 'Abandoned Object Detection and Classification Using Deep Embedded Vision' by (Qasim et al., 2024), In their work, a novel two-stage strategy for locating and recognizing stationary objects in public spaces is proposed. To identify possible abandoned items in the monitored region and record temporal information, the first stage employs a sequential approach.

The authors (Lu et al., 2022) worked on 'Infrared Small UAV Target Detection Algorithm Based on Enhanced Adaptive Feature Pyramid Networks', For infrared small UAV target recognition, their work suggests a novel DEAX method called the enhanced adaptive feature pyramid networks-based Target recognition method.

The authors worked on (Fariñas et al., 2024), in 'Origin, Development, and Applications of Air-Coupled Broadband Ultrasounds for the Study of Tissues and Water Relations in Plant Leaves: A Review', The basis, evolution, and application of air-coupled ultrasonic techniques for the investigation of plant leaf tissues and their water relations were reviewed by the authors. Here are the two methods that have been suggested thus far: Non-Resonant Time Domain Transmittance and Non-Contact Resonant Ultrasound Spectroscopy.

Pandey (2016) in the research "A Review on Ultrasonic Radar Sensor for Security System" exploits ultrasonic sensing capability in home security. The ultrasonic sensor is mounted on a servo motor for a full rotation of 360˚, so that the sensor may detect an intruder in all directions. The device automatically makes a beeping sound. Using a GSM module, an intruder is detected and an SMS message is sent to the homeowner informing him of an intruder in the house (Pandey, 2016).

Varghese (Varghese et al., 2014) developed a system that allows vehicle drivers to quickly negotiate blind spots in traffic by attaching an ultrasonic sensor at the back of the car and a Light Emitting Diode (LED) on the dashboard to signal the proximity of other vehicles following behind. The light on the dashboard will flash anytime an incoming car gets closer.

Thomas's research (Thomas et al., 2014) focused on sensors with overlapping echoes. They conducted a study to investigate the ultrasonic signal's Time-of-Flight between hitting the targeted object and reflecting the ultrasonic transducer, as well as amplitude, to study and interpret signal processing when confronted with overlapping echoes, which is important for distance measurement and map reconstruction applications while scanning a corner of a room. The authors work on wall-corner classification using sonar, and in their experiment, they attempt to overcome the limits of the ultrasonic sonar system by measuring the corners of a wall. The results reveal an improvement in categorisation rates when geometric characteristics of an environment are taken into account. Ultrasonic sensors have a wide range of uses, including automatic parking systems, accident prevention systems, and aircraft flight control systems. Robots employ ultrasonic sensors to detect, identify, and, if necessary, avoid objects.

A navigational application was created for the visually handicapped. The device was made up of an embedded circuit that detected nearby obstructions and an Arduino IDE that gave the user spoken instructions. The embedded circuit employs an ultrasonic sensor to identify nearby impediments such as cars, walls, and so on. When an obstruction is discovered, the ultrasonic sensor sends a signal to the Arduino, which makes suitable decisions based on the incoming signal and informs the user accordingly (Olarewaju Iyapo et al., 2018).

A remote monitoring system was devised and built to avoid obstacles using ultrasonic sensors. The system is made up of two stations: a remote station (the robot) and a base station (the user), which can send commands to the remote station via teleoperation. The remote station consists of a GPS device, a GSM module, an ultrasonic sensor-based obstacle avoidance system, and a web-enabled camera for remote monitoring (Lee et al., 2022). Based on the incoming data from the obstacle avoidance system, GPS, and camera, the user can send commands to the remote station to change the route or otherwise (Emmanuel Onoja, 2017).

How to Program Arduino

After completing the circuit on the breadboard, upload the sketch (program) to the Arduino. An Arduino module can only save and execute one program at once. The Integrated Development Environment (IDE) is the software needed to create Arduino sketches. The IDE is developed in Java, however, the Arduino only accepts applications written in C (Ahmed, n.d.).

Processing is a high-level programming language with an integrated development environment (IDE) designed for the electronic arts, new media art, and graphic design communities. It teaches the principles of computer programming in a visual setting and serves as the basis for electronic sketchbooks. Casey Reas and Benjamin Fry, who had previously worked at the MIT Media Lab's Aesthetics and Computation Group, started the project in 2001. One of Processing's declared goals is to serve as a tool for non-programmers to learn programming by providing quick pleasure in the form of visual feedback. The language is based on Java but with reduced syntax and graphics programming concepts (Hameed & Rashid, 2019).

Choice of Ultrasonic over Infrared

Conversely, infrared sensors use reflected infrared light, which is influenced by a variety of elements, including surface characteristics, illumination, and the presence of dust or smoke.

Common uses for ultrasonic and infrared (IR) sensors include automation, object detection, and distance measuring. While both have advantages, in some situations ultrasonic sensors are superior to infrared sensors for several reasons (Benedito et al., 2024):

a) **Better Performance in Poor Lighting Conditions-** Despite infrared efficiency can deteriorate in bright sunshine or extremely reflecting surroundings, ultrasonic is unaffected by ambient light or total darkness (Lee et al., 2022).
b) **Material and Colour Independence-** The ultrasonic Although Infrared Detection can be affected by an object's colour and reflectivity (e.g., dark or translucent items may be harder to detect), it can identify objects regardless of colour, transparency, or surface polish (Lee et al., 2022).
c) **Greater Range and Accuracy in Distance Measurement-** Although infrared often has a shorter effective range and less precision at greater distances,

ultrasonic usually delivers more accurate range detection (e.g., 2 cm to several meters) on a variety of surfaces.

d) **Better at Handling Dust, Smoke, and Fog-** While infrared light-based sensors have trouble in smoky, dusty, or foggy environments, ultrasonic sound waves may pass through these materials rather well.

e) **Wider Detection Area-** While infrared often has a more focused and narrow beam, ultrasonic can have a conical detection zone that allows it to detect objects across a larger region.

When to Use Ultrasonic Over Infrared

The following are the reasons to choose ultrasonic over infrared.

a) In dark, dusty, or smoky/poor lite and unclear environments.
b) When dealing with objects of varying colours or transparency.
c) When longer range and more consistent object detection are required.

Ultrasonic Sensor

An ultrasonic sensor estimates distance by emitting a sound wave at a frequency higher than the human audible frequency (ranging from 20 kHz to several gigahertz) and listening for it to reflect (Benedito et al., 2024). By measuring the duration between the sound wave being produced and the sound wave reflecting, the distance between the sensor and the object may be calculated using the formula in equation 2.1. Ultrasonic waves have a universal speed of 330 m/s in room settings. The circuitry integrated into the module will calculate the time it takes for the sound wave to reflect and switch on the echo pin high for that exact length of time.

$$Distance = Speed \times Time \qquad 9$$

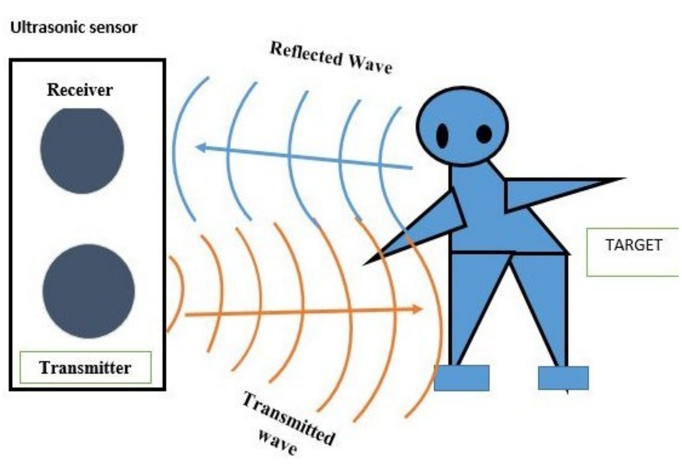

Fig. 2: Detection of a Target(Muftah et al., 2020)

The ultrasonic module has two eye-like projects in the front that form the Ultrasonic transmitter (transmits a sound wave, which travels in space and is reflected toward the sensor when any object obstructs it) and the Receiver (the Ultrasonic receiver observes the reflected wave) (see Fig. 3 A, B).

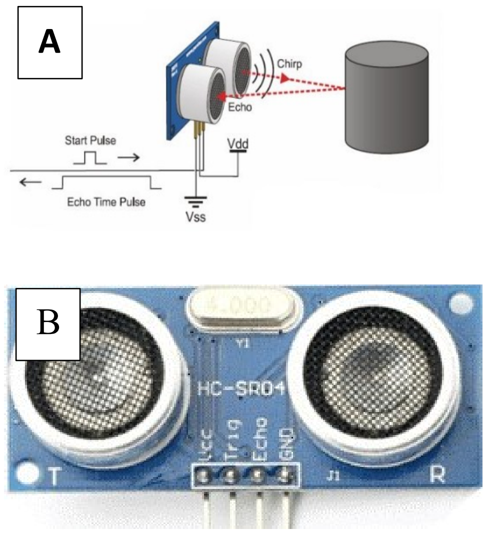

Fig. 3 A: Ultrasonic Sensor Pulse (Savitra et al., 2022) B: Ultrasonic Sensor (Pixabay.com)

Servo Motor

A servo motor is a mechanical instrument that uses electrical input to control the position of its armature. As shown in Fig. 4, it is made up of four components: a standard DC motor, a gear reduction unit, a position-sensing device, and a control circuit. Servo motors are mostly utilised in the robotics sector and radio-controlled vehicles. Servo motors provide precision control over angular position, acceleration, and velocity (Haidar, 2013).

Fig. 4: Servo motor (Kelvin Benjamin et al., 2020)

Research Methodology

Research Design

In this section, we described the design and implementation stages, which comprise hardware components (Arduino Uno, ultrasonic sensor, and servo motor) and software components (C++ Programming which aids the programming of the Arduino-Uno micro-controller). This work utilises an ultrasonic sensor to detect an intrusion, it does so by sending ultrasonic sound which is received by the receiving end of the sensor. We employ a servo motor to rotate the ultrasonic sensor via the axis of about 0˚ to 180˚. The system has the potential of detecting objects within the range of angle 0˚ to 180˚. The block diagram of the radar system is shown in Fig. 5.

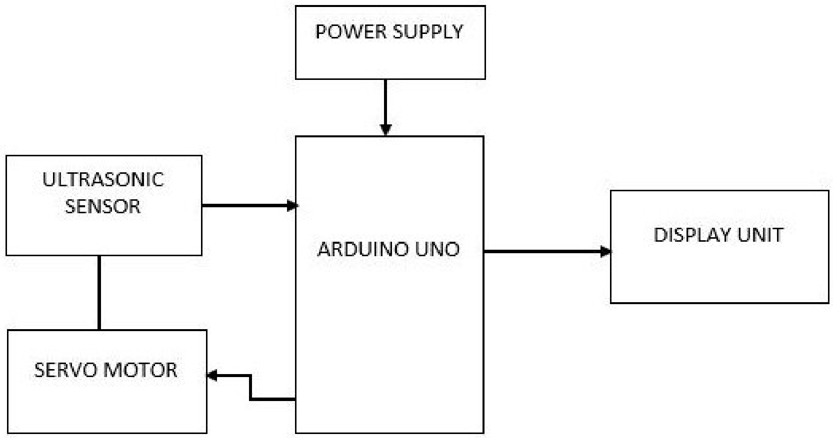

Fig. 5: Block working diagram of the sensory system

The circuit diagram of the radar system is shown in Fig. 6.

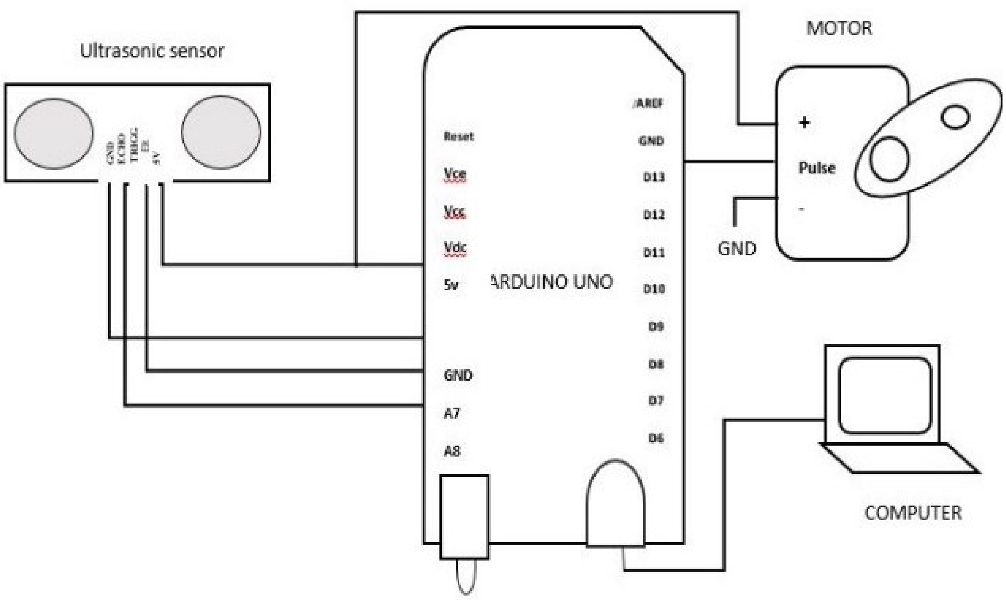

Fig. 6: Circuit Diagram of the Proposed Model

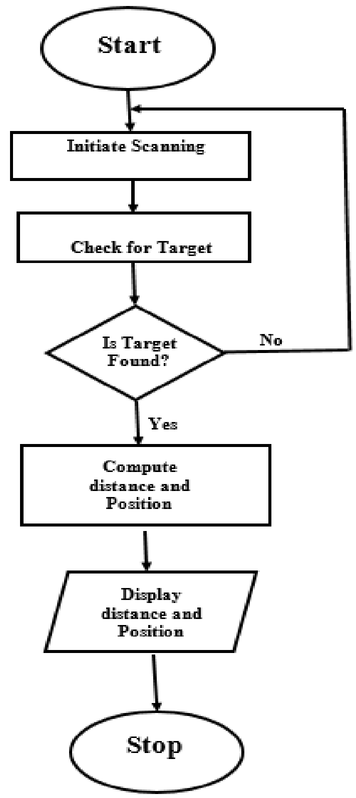

Fig. 7: Flowchart for a precise target of an object.

Fig. 7 is the flowchart that describes how a targeted object is been measured and classified. As the survey system scans to detect the presence of an intruder, hence checks for a target. If a target is found, it computes the proximity and position of the target which is displayed on the display unit; otherwise, the process is looped for re-scanning.

Hardware System Design

The Hardware design consists of an Arduino, an Ultrasonic sensor, a Servo motor, and a Display Monitor. Fig. 8: Connection of Components to the Arduino board. Here, both the servo motor and the ultrasonic sensor are connected to the Arduino board. The ultrasonic sensor is only mounted physically on the servo, not electronically. The servo motor aids the ultrasonic sensor to move via an angular degree of 180˚. Fig. 8 is the interconnection of the components (Benedito et al., 2024).

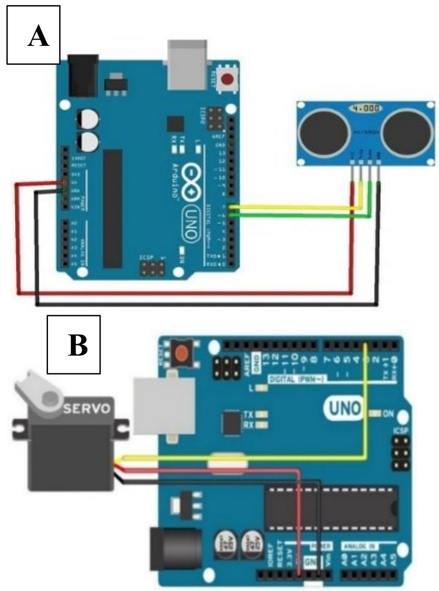

Fig. 8: Connection of Components to Arduino board A. Shows the connection ultrasonic sensor to the board. B. The connection of the Servo motor to the board

Software System Design

The software components involve programming Arduino IDE using the C++ Language to program the Arduino Uno. The program assembles the servo motor, LCD and the ultrasonic sensor (Izumi, 2024).

Justification of Method

The approach taken in this research is outlined in the block diagram in Fig. 5. The Arduino Uno board was programmed using the Arduino IDE to operate the Ultrasonic sensor and servo motor for distance measurement and position determination, utilising servo motor angle rotation values. The Ultrasonic sensor is attached to the servo motor. The Arduino will then transfer the angular position and object distance to a computer linked to the Arduino board's serial port. Processing software will be used to stimulate and analyse the plan position display of the angle and distance of the object on the laptop monitor.

Data Presentation

The parts of the project were constructed and tested for short/open circuits. The 9V power supply was confirmed to be within current specifications, and the external components functioned normally. The C++ code was a trial run for debugging; the application accurately calculates and determines distance and location.

Data Analysis and Results

The analysis involves the testing of the project's accuracy, range, and sensing capabilities. The following is the result analysis of the project:-

Accuracy

The accuracy of the project was compared with the actual distance measurement using a class II European tape meter; the sensor was placed facing the target while moving away at every 25cm for an effective distance of 200cm. Table 1 shows the maximum Deviation for each distance value. Fig. 9 also shows the graphical representation of the Deviation.

Table 1: The Maximum Deviation for each distance value

Distance (cm)	Sensor Measurement (cm)	Deviation
25	24.88	0.12
50	49.1	0.9
75	74	1
100	98.02	1.98
125	123.39	1.61
150	148.16	1.84
175	173.06	1.94
200	198.17	1.83

Table 2: Result of accuracy of the system from a distance of 130cm

Angle of Target (˚)	False Alarm Rate (%)	Precision (%)
0	10	90
30	5	95
45	1	99
60	2	98
90	2	98
120	2	98
135	0	100
150	7	93
180	2	98

Table 2 displays the results of the experiment to determine false alarm and precision, and it indicates that the best angle of precision was at 135˚ with an accuracy of 100% and the least to occur at an angle of 0˚ with an accuracy of 90%.

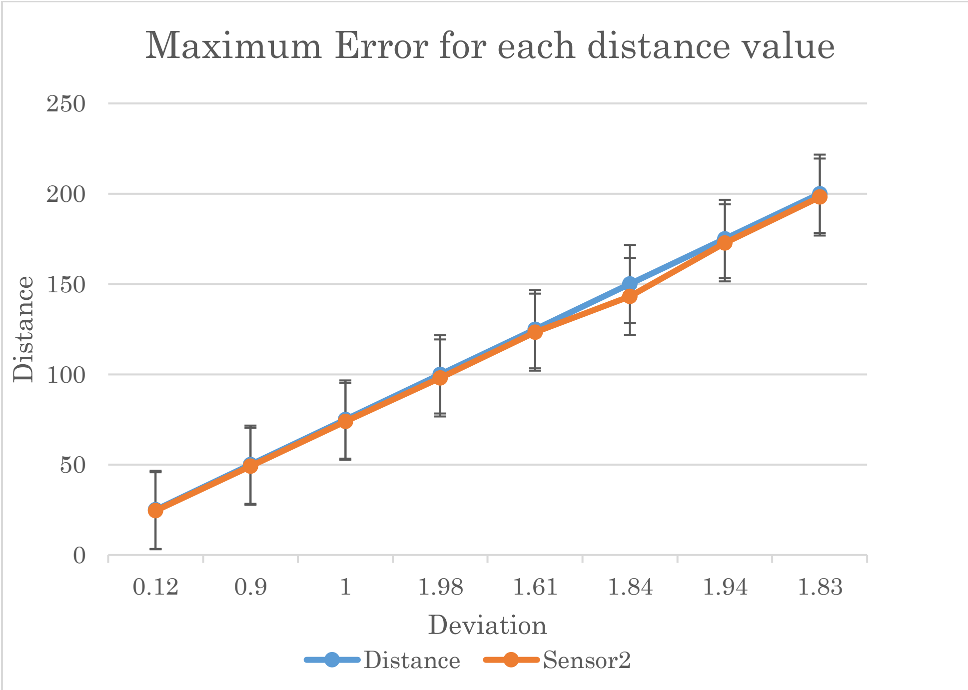

Fig. 9: Maximum Error for each distance value

Range

The project was tested with the actual distance measurement using a class II European tape meter, the sensor was placed facing the target while moving away at every 50cm for an effective distance of 200cm in detecting a target and represented in Table 3 which shows that targets cannot be detected at distances beyond 200 cm.

Table 3: Results of Range testing

S/N	Distance (cm)	Detect A Target
1	50	Yes
2	100	Yes
3	150	Yes
4	200	Yes
5	250	No

Sensing Capabilities

The project is capable of detecting targets of different sizes and shapes. The precision is about 99% in a target.

Project Prototype Showcased

Fig. 10 – 12 is a pictorial display of the constructed model from the inner circuit to the operational stage.

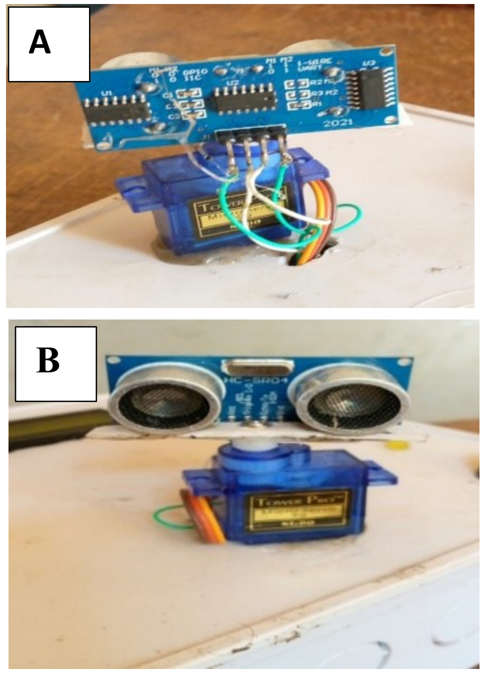

Fig. 10: A- Rear view of Ultrasonic Sensor Mounted on the Servo Motor. *B* - Front view of the Ultrasonic sensor mounted on the Servo Motor

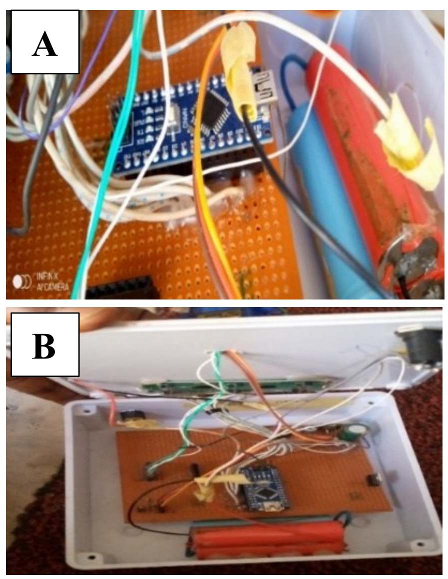

Fig. 11: *A* - Fixing of Microcontroller. B - Connecting Components to the Microcontroller

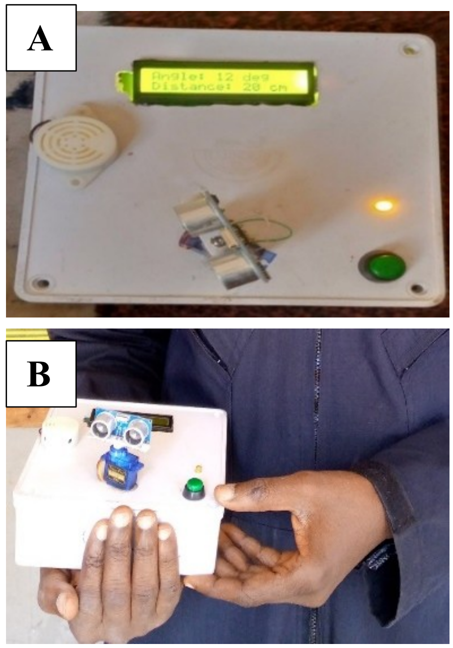

Fig. 12: A- Complete prototype during testing. B – Author showcasing the prototype of the detection machine.

Discussions of Finding

The hardware components were fabricated, and the Arduino UNO microcontroller was programmed. The servo motor was capable of rotating at an angle of 180^0. The ultrasonic sensor sent pulses via the trigger while the servo motor was running, and the echo picked up the vibrations. Arduino estimates the target's distance to the system determined by the transit time sensed by the echo, as well as the target's angular position. The LCD shows the distance and position of the target. The results can also be simulated on a laptop.

Conclusion

The research addresses the issue of identifying individuals remotely, even before arriving at their location. This identification could contribute towards the early detection of bandits' location, thereby reducing the risk of ambush on military personnel. Implementation, prototype development, testing, and evaluation were completed with a satisfactory throughput. The use of an ultrasonic sensor and a microprocessor offers a low-cost, effective solution for detecting a target under a variety of environmental circumstances. This work provides an inexpensive, real-time detection of a target. The system's accuracy, range, and sensitivity were analysed to determine its performance and effectiveness. The use of Arduino Uno with an ultrasonic sensor makes the system handy and easy to deploy, reducing the danger of radiation in the case of the electromagnetic-based radar system. The LCD shows the distance and position of the object being detected.

The system could be relied on in detecting as its accuracy of the target falls within the range of 90% to 100%.

Recommendations

The following recommendations can be made to improve the performance of the proposed system:

i. Use high-quality ultrasonic sensors to ensure accurate and reliable detection of targets.
ii. Regular monitoring of the project performance to maintain expected functionality.
iii. Smarter systems should be trained using machine learning algorithms to differentiate between human beings, animals, and wind based on the concept of object detection.
iv. We recommend that this model be compared with already existing methods, like infrared and artificial intelligence methods.

References

Ahmed, S. (n.d.). *Introduction to Arduino and C Programming*.

Ashwini, P., Kumar, M. M., Priyanka, V., Gangabhavani, V., Ram, B., Venkata, M., & Adama, R. (2020). *ULTRASONIC RADAR USING ARDUINO*. *7*(2), 8–13.

Bendimerad, Y., & Boukern, D. (2019). *Radar Prototype System For Target Detection and Tracking*. *November*.

Benedito, J., Álvarez-arenas, T. E. G., & García-perez, J. V. (2024). *Air-Coupled Ultrasonic Inspection of Foods : A Review*. *4*(July). https://doi.org/10.1109/OJUFFC.2024.3457503

Emmanuel Onoja, A. (2017). Embedded System Based Radio Detection and Ranging (RADAR) System Using Arduino and Ultra-Sonic Sensor. *American Journal of Embedded Systems and Applications*, *5*(1), 7. https://doi.org/10.11648/j.ajesa.20170501.12

Fariñas, L., Sancho-Knapik, D., Peguero-Pina, J. J., Gil-Pelegrín, E., & Álvarez-Arenas, T. E. G. (2024). Origin, Development, and Applications of Air-Coupled Broadband Ultrasounds for the Study of Tissues and Water Relations in Plant Leaves: A Review. *IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control*, *4*(June), 77–88. https://doi.org/10.1109/ojuffc.2024.3433316

Haidar, A. M. (2013). *Software interfacing of servo motor with microcontroller*.

Hameed, S., & Rashid, D. (2019). Arduino based radar system. *3C Tecnología_Glosas de Innovación Aplicadas a La Pyme*, *7*(4), 157–166. https://doi.org/10.17993/3ctecno.2019.specialissue.14

Izumi, S. (2024). 3-D Object Reconstruction From Outdoor Ultrasonic Image and Variation Autoencoder. *IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control*, *4*(June), 140–149. https://doi.org/10.1109/OJUFFC.2024.3466090

Kelvin Benjamin, A., Kenneth Ainah, P., & Ariebi John, B. (2020). Design and Implementation of a Low-Cost Ultrasonic Radar System using an Arduino Microcontroller. *International Journal of Scientific Research and Engineering Development*, *3*(July).

Lee, M. L., Chen, S. M., Jhang, J. J., Lu, L. S., Yang, S. T., Chiu, P. E., Tsai, Y. S., Wu, Y. S., Cheng, C. C., Chen, H., & Han, J. (2022). Fabrication and Characterizations of PbZrxTi1-xO3(PZT) Ultrasonic Sensing Chips. *IEEE Access*, *10*, 32453–32460. https://doi.org/10.1109/ACCESS.2022.3158740

Lu, Z., Yueping, P., Zecong, Y., Rongqi, J., & Tongtong, Z. (2022). Infrared Small UAV Target Detection Algorithm Based on Enhanced Adaptive Feature Pyramid Networks. *IEEE Access*, *10*(November), 115988–115995. https://doi.org/10.1109/ACCESS.2022.3219089

Mehta, S., & Tiwari, S. (2018). Radar System Using Arduino and Ultrasonic Sensor. *International Journal of Novel Research and Development (www.Ijnrd.Org)*, *3*(1), 14.

Muftah, M. N., Ali, I. S., & Omarabdalla, A. (2020). *A Short-Range Radar System Using Arduino*. *7*(8), 41–48.

OE Ikpenyi, OE Abumere, & JA Amusan. (2022). Construction of GSM based home security alert system using passive infrared sensor. *World Journal of Advanced Research and Reviews*, *14*(2), 648–657. https://doi.org/10.30574/wjarr.2022.14.2.0447

Olarewaju Iyapo, K., Michael Fasunla, O., Alaba Egbuwalo, S., James Akinbobola, A., & Temitope Oni, O. (2018). Design and Implementation of Motion Detection Alarm and Security System. *International Journal of Engineering and Advanced Technology Studies*, *6*(1), 2053–2202.

Pandey, G. (2016). *A Review on Ultrasonic-based Security System*. *2*(11), 476–480.

Qasim, A. M., Abbas, N., Ali, A., & Al-Ghamdi, B. A. A. R. (2024). Abandoned Object Detection and Classification Using Deep Embedded Vision. *IEEE Access*, *12*(March), 35539–35551. https://doi.org/10.1109/ACCESS.2024.3369233

Savitra, C. T., Anu, P., Sumathi, K., & Varshini, C. U. (2022). *Design of an Arduino Based Radar System*. *10*(11), 287–289.

Thomas, R. P., Jithin, K. K., Hareesh, K. S., Habeeburahman, C. A., & Abraham, J. (2014). Range Detection based on Ultrasonic Principle. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, *3*(2), 7638–7642.

Varghese, B., Jacob, R. T., Kamar, F., & Saifudeen, R. A. (2014). *Collision Avoidance System in Heavy Traffic and Blind Spot Assist Using Ultrasonic Sensor*. *2*(1), 93–96.