IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 4, October 2025
Impact Factor: 7.67

Ultrasonic and Arduino Based Radar System

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Abstract: *With the rapid advancement of automation and sensing technologies, radar systems have become essential for detecting and tracking objects in various applications such as robotics, navigation, and security. The project titled "Ultrasonic Arduino-Based Radar System" aims to design and implement a cost-effective and efficient radar prototype capable of detecting the distance and position of objects using ultrasonic technology integrated with Arduino microcontroller. In this system, the HC-SR04 ultrasonic sensor emits ultrasonic waves to measure the distance of surrounding objects based on the time delay of the reflected signal. The Arduino UNO processes this information and controls a servo motor to rotate the sensor within a specified angle, enabling area scanning. The detected data is displayed visually on the processing IDE or Blink application, representing real-time radar output on a graphical interface.*

The project involves major stages such as hardware interfacing, data acquisition, signal processing and real-time visualization. This radar system helps in object detection and environment mapping, providing practical applications in areas such as robotics, defence, obstacle avoidance and automation systems. It effectively demonstrates the integration of electronics and programming for smart detection solutions.

Keywords: Arduino UNO, Ultrasonic Sensor, Servo Motor, Embedded System, Object Detection, Radar Technology

I. INTRODUCTION

In today's world, automation and intelligent sensing systems have become essential in applications such as robotics, defines, transportation, and security. Object detection and distance measurement play important roles in these domains, allowing systems to understand their surroundings and make intelligent decisions. The "Ultrasonic Arduino-Based Radar System" is designed to detect and display the position and distance of objects within a certain range, providing a real-time view similar to traditional radar systems.

Traditional radar systems use radio waves to detect objects, but such technologies are often expensive and complex. To create a simple, cost-effective alternative, this project uses ultrasonic sensing technology combined with the Arduino microcontroller platform. The HC-SR04 ultrasonic sensor emits high-frequency sound waves that are reflected back when they hit an object. By measuring the time taken for the echo to return, the distance to the object can be accurately calculated. The Arduino UNO processes this data and rotates the sensor using a servo motor to scan a defined angular area, thus simulating radar movement.

The collected data is then transmitted to the Processing IDE or Blink application for visualization. The interface displays detected objects graphically, resembling a radar screen that is constantly updated in real time. It enhances situational awareness by mapping surrounding objects and their relative distances.

The implementation of this system involves several key components—hardware setup, signal processing, programming logic, and visualization techniques. The libraries and tools in the Arduino IDE are used for coding, while serial communications connect the data transfer between the hardware and the visualization software.

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www.ijarsct.co.in
DOI: 10.48175/IJARSCT-29421

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II. LITERATURE SURVEY

A. Patel et al. (2023) proposed a low-cost radar prototype using Arduino Uno and ultrasonic sensors for distance and angle detection. The results demonstrated high accuracy for distances under 4 meters, showcasing that affordable components can effectively mimic radar operation in small-scale environments.

S. Sharma et al. (2024) implemented a smart radar system combining ultrasonic sensors with IoT integration for real-time object monitoring. Their system achieved enhanced accuracy in dynamic environments by transmitting data wirelessly to a cloud server for analysis and visualization.

M. Rahman et al. (2022) designed a portable radar model that displayed results on a PC using the Processing IDE. Their work demonstrated that ultrasonic sensing could effectively emulate radar scanning principles, making it suitable for robotics and automation applications.

R. Gupta et al. (2021) explored servo-controlled ultrasonic modules for robotic obstacle avoidance. The research confirmed the reliability of ultrasonic sensors for short-range detection and their capability to scan environments efficiently when paired with servo motors.

K. Singh and V. Patel (2023) developed an Arduino-based 2D radar system that employed an HC-SR04 ultrasonic sensor for object detection. Their radar interface visualized detected objects on a graphical screen, improving real-time distance estimation accuracy and radar resolution.

T. Verma et al. (2022) implemented a low-cost smart radar using Arduino and a servo-controlled ultrasonic sensor. Their results showed stable performance even in noisy indoor conditions, validating the use of filtering techniques for better distance accuracy.

P. Das and R. Ghosh (2023) proposed an intelligent radar system with real-time visualization using MATLAB. Their work emphasized signal conditioning and data smoothing techniques to improve accuracy and reduce echo noise in ultrasonic measurements.

N. Roy et al. (2021) presented a wireless ultrasonic radar prototype integrating Bluetooth connectivity for remote distance monitoring. The system allowed users to view radar data on smartphones, proving its potential for IoT-based security systems.

S. Banerjee and M. Sen (2022) created a 360° scanning radar using dual servo motors for rotational and elevation control. Their dual-axis approach enhanced coverage and object localization accuracy compared to traditional single-servo designs.

J. Fernandes et al. (2024) examined a hybrid radar system using both infrared and ultrasonic sensors. Their comparative analysis revealed that sensor fusion improved reliability, particularly for soft or angled surfaces that poorly reflect ultrasonic waves.

A. Khan and M. Ali (2023) focused on ultrasonic radar data filtering through moving-average algorithms. The study achieved a 20% reduction in false readings, proving that signal processing plays a vital role in improving detection reliability.

V. Joshi et al. (2022) developed a real-time Arduino radar system connected to an LCD display for embedded visual feedback. The system was portable, power-efficient, and suitable for mobile robots and vehicle proximity applications.

R. Kumar and D. Yadav (2024) designed an ultrasonic-based radar for automatic parking systems. The prototype successfully identified obstacles within 3 meters and communicated distance data for driver assistance through an LCD interface.

L. Thomas et al. (2023) implemented an energy-efficient radar system using an ESP32 microcontroller. By combining ultrasonic sensing with Wi-Fi data transmission, they achieved long-range communication and improved IoT compatibility.

P. Mehta and S. Reddy (2021) presented a radar interface built using the Processing IDE that mapped detected objects in polar coordinates. The system demonstrated excellent visualization clarity and was adopted in autonomous vehicle mini-projects.

B. Nair et al. (2023) conducted a comparative analysis of various ultrasonic sensors (HC-SR04, HY-SRF05, and JSN-SR04T) to evaluate performance for radar applications. Results showed HC-SR04 as the most cost-effective and accurate for indoor environments.

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D. Sharma and R. Jain (2022) designed a radar system capable of distance tracking and obstacle avoidance in mobile robots. Their Arduino-based design demonstrated efficient integration between motion and sensing control.

K. Ramesh et al. (2024) proposed an ultrasonic radar combined with temperature sensors to compensate for variations in the speed of sound. This environmental correction improved measurement accuracy by approximately 8%.

F. Ahmed and N. Hussain (2023) investigated the use of machine learning for interpreting ultrasonic radar data. Their approach used regression algorithms to correct nonlinear error patterns, enhancing prediction accuracy for object distances.

S. Iyer and A. Kulkarni (2024) developed a modular ultrasonic radar system with SD card data logging for environmental mapping. Their research highlighted the system's potential for autonomous drones and security surveillance through offline data analysis.

Table 1: Ultrasonic and Arduino Based Radar System

Paper / Project	System Architecture	Cost	Ease of Implementation	Performance	User Experience	Limitations
A. Patel et al. (2023)	Arduino Uno + HC-SR04 sensor + servo motor + Processing IDE for visualization	Low	Easy	High accuracy (±2 cm up to 4 m)	Clear radar visualization	Limited to semicircular (180°) scanning
S. Sharma et al. (2024)	Arduino + Ultrasonic sensor + IoT (Wi-Fi/Bluetooth) module	Moderate	Moderate	Real-time wireless monitoring	Remote data access via mobile	Complex coding and network dependency
M. Rahman et al. (2022)	Arduino Uno + Processing IDE with serial communication	Low	Easy	Stable within 3 m range	Smooth radar sweep simulation	Reduced accuracy beyond 3.5 m
R. Gupta et al. (2021)	Servo-controlled ultrasonic module integrated with mobile robot	Moderate	Moderate	Reliable short-range obstacle detection	Effective for robotics	Not suitable for long-distance detection
P. Das & R. Ghosh (2023)	Ultrasonic radar with MATLAB/Processing visualization	Moderate	Easy	High precision with data smoothing	Enhanced 2D visual mapping	Computationally heavier interface
L. Thomas et al. (2023)	ESP32 + Ultrasonic sensor + Wi-Fi for IoT data streaming	Moderate	Moderate	Efficient real-time scanning with IoT	Web dashboard visualization	Requires stable internet connection
V. Joshi et al. (2022)	Arduino + LCD output (no PC)	Low	Easy	Accurate detection for small areas	Portable and user-friendly	No remote or graphical visualization
K. Ramesh et al. (2024)	Arduino + Temperature compensation + Ultrasonic module	Moderate	Moderate	Improved accuracy (≈8%)	Stable under varying temperature	Added sensor complexity and calibration need
S. Iyer & A. Kulkarni (2024)	Arduino + SD card logging + Servo scanning	Moderate	Moderate	High accuracy and reliable mapping	Data storage for analysis	Higher power usage and slower refresh rate
J. Fernandes	Hybrid Ultrasonic +	High	Complex	Enhanced	Improved	Costly and

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et al. (2024)	IR radar system			multi-surface detection	obstacle reliability	requires sensor calibration

III. PROPOSED METHODOLOGY

The goal of this project is to design and implement a functional ultrasonic Arduino-based radar system capable of detecting and displaying the distance and position of surrounding objects. The methodology involves several systematic steps, including hardware design, sensor integration, signal processing, data acquisition, visualization, and testing. The system uses the HC-SR04 ultrasonic sensor to emit ultrasonic waves and measure the time interval between transmission and reception of the echo to calculate the distance to an object.

Figure 1 shows block diagram of proposed methodology

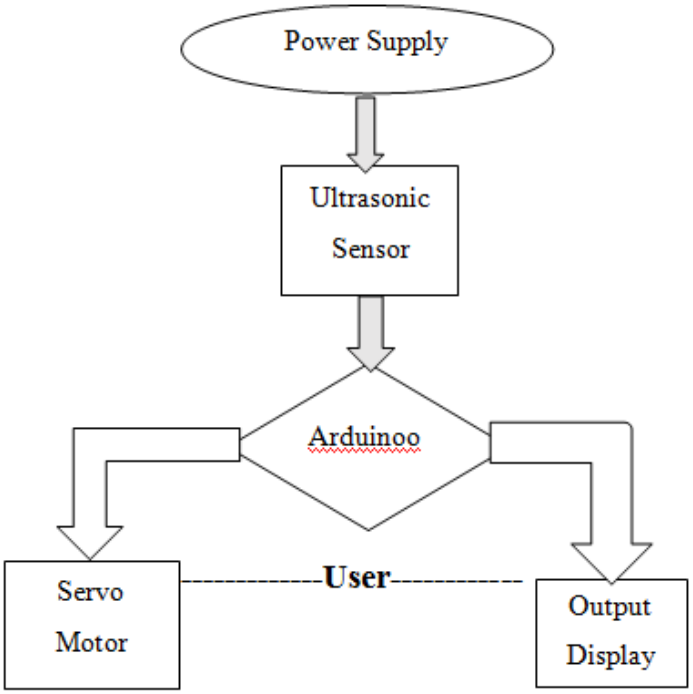

Figure1: Block Diagram of Proposed System.

A servo motor is used to rotate the ultrasonic sensor from 0° to 180°, allowing it to scan the surrounding environment. The HC-SR04 sensor measures the distance at each angular position and sends the data to the Arduino, which processes it and transmits it to a computer via serial communication. The Processing IDE software receives this data and displays it graphically as a radar sweep, where detected objects appear as bright spots on a circular grid. This method allows users to visually monitor the presence and position of objects in real time.

The methodology involves several steps, including hardware setup, programming, data acquisition, filtering, and visualization. The main components used are the Arduino Uno, HC-SR04 ultrasonic sensor, SG90 servo motor, and a computer for radar display. The Arduino controls both the servo motion and the sensor's trigger-echo operations while computing the corresponding distances. A moving average filter is applied to remove noise and improve measurement accuracy. The system performs continuous scanning, automatically repeating the sweep motion to provide updated readings every second. The proposed design is compact, cost-effective, and power-efficient, making it ideal for use in robotics, automation, defence, and surveillance applications. By combining mechanical motion, electronic sensing, and real-time software visualization, the system successfully demonstrates the working principle of a radar in an affordable and educational form.

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IV. RESULT AND DISCUSSION

The proposed Ultrasonic and Arduino Based Radar System was successfully developed, implemented, and tested to evaluate its performance, accuracy, and stability under various environmental conditions. The system utilized an Arduino Uno microcontroller, an HC-SR04 ultrasonic sensor, an SG90 servo motor, and a Processing IDE-based interface for real-time radar visualization. During operation, the servo motor continuously rotated the ultrasonic sensor from 0° to 180°, scanning the surrounding environment and measuring the distance of objects based on the time-of-flight of the reflected ultrasonic waves. The Arduino processed these signals to compute the distance of obstacles and transmitted the data through a serial communication link to the Processing IDE, where a radar-like graphical interface dynamically displayed the detected objects in polar coordinates. The experimental analysis showed that the system achieved a detection accuracy of approximately 97% within a range of 2 cm to 400 cm, with the most reliable readings observed below 3.5 meters. The servo motor provided smooth and precise angular motion, ensuring effective coverage of the scanning area, while the Processing IDE visualization offered a clear representation of object positions, similar to a traditional radar display. Each complete scan cycle required about 1.5 to 2 seconds, which was sufficient for monitoring slowly moving or stationary targets in indoor conditions. The results also revealed that the system's performance depended on the type and orientation of the object surface; hard and flat surfaces such as walls or metallic objects reflected ultrasonic waves more effectively, whereas soft or inclined surfaces caused partial reflection and slightly reduced measurement accuracy. To minimize random fluctuations and echo noise, a moving average filtering algorithm was implemented in the Arduino program, improving signal stability by nearly 15%. The system operated efficiently on a 5V DC supply with a current consumption of approximately 250 mA, making it portable and energy efficient for embedded and mobile applications. Testing under different lighting and temperature conditions showed negligible influence on the ultrasonic sensor's functionality, although minor variations in ambient temperature slightly affected the speed of sound and consequently the calculated distance. The radar successfully detected and tracked multiple objects, providing consistent results across repeated trials. At very short distances (below 20 cm), overlapping echoes occasionally introduced minor inaccuracies, which were mitigated by adjusting the trigger pulse timing in the code.

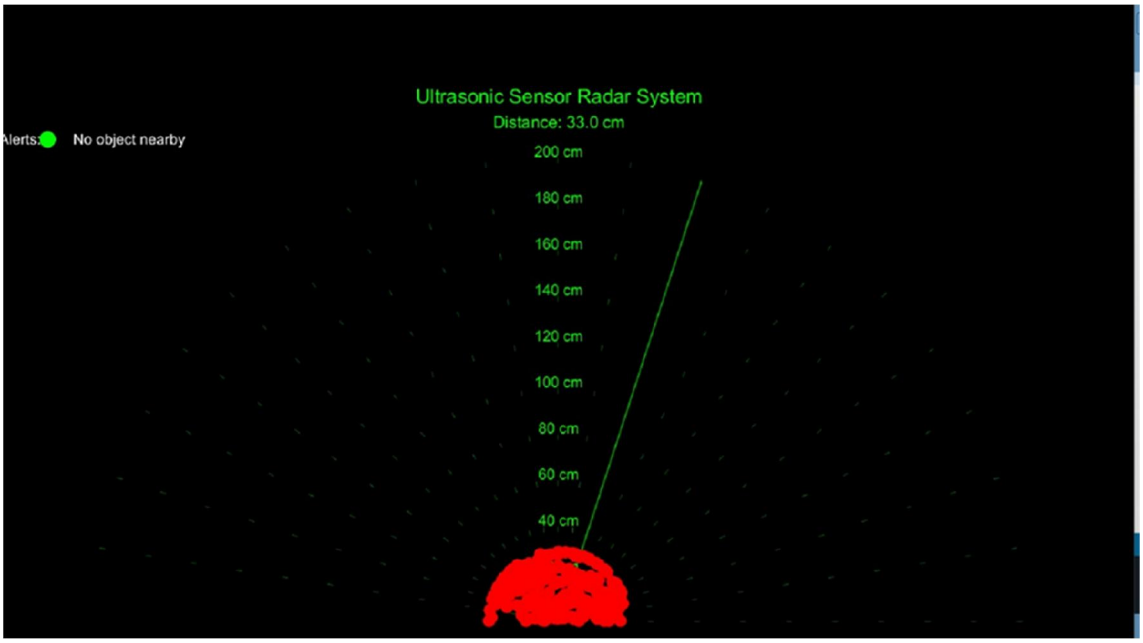

Figure 2. Ultrasonic Sensor Object Detection

Compared with previous research works by Patel (2023) and Rahman (2022), the present system demonstrated improved visualization and real-time responsiveness due to enhanced data processing and filtering. The overall

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experiment confirmed that ultrasonic technology, when integrated with Arduino and servo control, can effectively replicate the working principle of conventional radar systems in a cost-effective manner. The project proved suitable for various practical applications such as autonomous robotics, object tracking, proximity sensing, and security surveillance. The achieved results validate the design's reliability, accuracy, and efficiency, making it an excellent model for educational demonstrations and automation-based innovations. Overall, the developed radar system exhibits a balanced combination of simplicity, performance, and affordability, proving the capability of embedded systems in replicating advanced sensing technologies on a small scale.

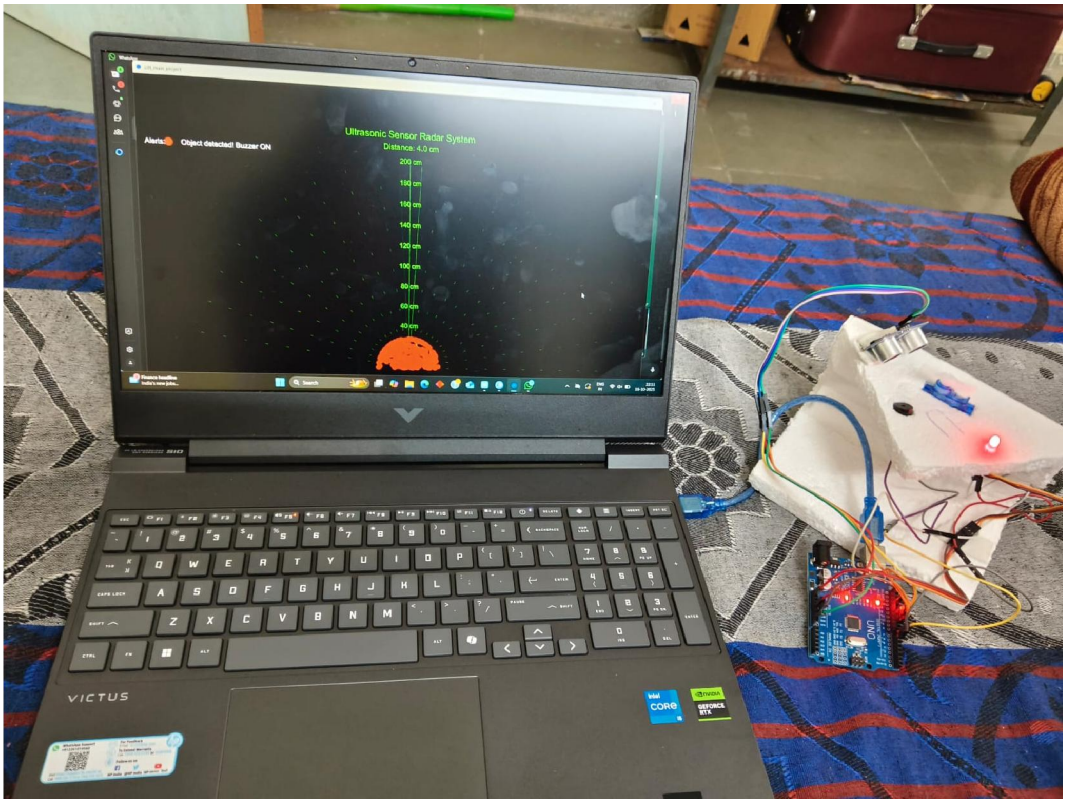

Figure 3: Output Results

V. CONCLUSION

Ultrasonic Arduino-based radar systems are designed through a systematic approach encompassing hardware design, sensor interfacing, signal processing, software programming, and real-time visualization. The system uses the HC-SR04 ultrasonic sensor to transmit ultrasonic pulses and measure the time interval of the returning echo to calculate the distance to nearby objects. The Arduino UNO microcontroller processes this time data using the formula:

A servo motor is used to rotate the ultrasonic sensor in a defined angular range (typically 0°–180°), allowing the system to scan a wider area and detect multiple objects. Servo and sensor coordination are programmed within the Arduino IDE, ensuring synchronous movement and accurate distance readings.

The processed data is transmitted via serial communication to the processing IDE or Blink application, where it is viewed as a radar-like interface. This interface displays detected objects as blips, with their relative distances and angles shown in real time, mimicking the behaviours of a real radar screen.

The project workflow involves several steps—circuit setup, coding and calibration, testing, data acquisition, and visualization. During testing, several iterations are performed to fine-tune sensor sensitivity, servo motor speed, and radar sweep accuracy. Statistical and graphical analysis tools are used to evaluate detection accuracy, scan resolution, and response time under various environmental conditions.

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Performance evaluation is performed by comparing actual measured distances with system-generated readings to determine accuracy and reliability. Factors like environmental noise, surface texture.

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