Radar System: A Low-Cost Intelligent Prototype

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# ABSTRACT

This study explores the development of a cost-effective radar simulation system using an Arduino Uno, an HC- SR04 ultrasonic sensor, and an SG90 servo motor. The device detects and maps obstacles in real-time, providing graphical visualizations through the Processing IDE. Designed as an educational prototype, this system affordably illustrates core radar concepts, with detection capabilities ranging from 2 to 400 cm. It serves as a foundation for applications in robotics, surveillance, and future smart systems.

**KEYWORD-** Arduino Uno, Ultrasonic Sensor, Radar Simulation, Obstacle Detection, Real-Time Visualization.

# INTRODUCTION

In many domains, including meteorology, autonomous vehicles, aviation, and military defence, radar technologies are essential. These systems operate on the idea that waves are sent out and that their position, speed, and other properties are ascertained by examining the reflections of the waves off objects. Conventional radar installations present difficulties for educational institutions and small-scale research projects because they require sophisticated signal processing, intricate electronics, and a substantial financial outlay. With the increasing availability of inexpensive and accessible sensors and microcontrollers like Arduino, new possibilities for imitating radar operations have emerged. Because Arduino is open-source, versatile, and user- friendly, it's a great platform for creating affordable radar prototypes.

We discuss previous research, the rationale behind design choices, the development process, and performance evaluation, aiming to contribute a practical and scalable model for academic, industrial, and personal innovation. In many domains, including meteorology, autonomous vehicles, aviation, and military defence, radar technologies are essential. These systems operate on the idea that waves are sent out and that their position, speed, and other properties are ascertained by examining the reflections of the waves off objects. Conventional radar installations present difficulties for educational institutions and small-scale research projects because they require sophisticated signal processing, intricate electronics, and a substantial financial outlay.

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This study investigates the use of Arduino technology and the Processing IDE to build a low-cost ultrasonic radar system. In order to provide a cutting-edge teaching tool, the project combines hardware control, real-time data collecting, serial connection, and dynamic visualization. In addition to reproducing the fundamental features of commercial radar systems, it offers adaptability, scalability, and the possibility of growth into more intricate applications like environmental sensing based on the Internet of Things, robots navigation, and security monitoring.

In order to provide a useful and scalable paradigm for scholarly, commercial, and individual innovation, we go over previous studies, the justification for design decisions, the development process, and performance evaluation.

# METHODOLOGY

**Participants/volunteers:** There were no live volunteers in this study; solely electrical components were used.

**Study Design**: To create a working prototype that could measure distances and provide visual feedback, an experimental approach was used.

## Resources:

* The Arduino Uno board
* Ultrasonic sensor HC-SR04
* SG90 servo motor
* A breadboard and jumper wires
* 5V power source and USB interface
* IDE software for processing
* Red and Blue LEDs (for visual alerts)
* 16x2 LCD Display (for real-time distance and angle display)
* Buzzer (for audio alert)

## Utilized Software Libraries:

* To precisely regulate the servo motor angle, use **Servo.h.**
* To optimize distance estimates and handle ultrasonic sensor readings, use **NewPing.h**.
* Data acquisition and visualization using the Processing Serial Library.

## Hardware Assembling:

* Attached securely to the SG90 servo motor shaft was the HC-SR04 ultrasonic sensor.
* The Arduino Uno was connected to the servo motor so that it could rotate from 0° to 180°.
* Both red and blue LEDs were attached to digital pins; the blue LED denotes scanning, and the red LED signals the detection of an object in the vicinity.
* Readings of angle and distance in real time were shown on a 16x2 LCD display.
* To sound an alert anytime an object is identified within a critical distance range (less than 50 cm, for example), a buzzer was included.
* A breadboard was used to firmly assemble all of the parts.
* To prevent sensor readings from being impacted by USB power fluctuations, a steady 5V external power source was utilized.

## Data handling and programming:

* The servo motor's incremental movements were controlled by Arduino code, which also produced ultrasonic pings at each stage.
* Continuous comparisons between distance measurements and threshold values were made.
* The buzzer and LEDs were activated according on the detection distance.
* Both the current angle and the measured distance were shown in real time on the LCD.
* For graphical visualization, data was sent to the Processing IDE via serial communication at a baud rate of 9600.

## Procedure:

1. To reduce inaccuracy under typical room settings, the ultrasonic sensor was calibrated.
2. Initialization: The LEDs changed to scanning (blue), the LCD display was initialized, and the servo motor was set to 0°.
3. The servo motor was moved by the system in tiny steps during a continuous scanning cycle.
4. The buzzer was triggered and the red LED blinked if an object was found within a predetermined threshold.
5. Real-time angle and distance readings were simultaneously updated on the LCD.
6. Obstacles within the sensor's detectable range were indicated via visual radar sweeps.
7. To verify detection accuracy, a variety of objects made of metal, wood, and fabric were positioned at predetermined distances.
8. To evaluate the robustness of the system, environmental conditions including illumination and temperature were slightly changed.

## Testing Conditions:

* + indoor setting with typical lighting.
	+ Testing range: 5 cm to 350 cm.
	+ different target materials (hard, soft, rough, and smooth).
	+ Servo speed was modified to provide an optimal scan rate, such as a 15 ms step-to-step delay.
	+ The close-range object detection process confirmed the activation of the buzzer and LED.

# RESULTS

The created radar system was tested in an indoor setting with varying temperatures and lighting. Objects between 5 and 350 cm were reliably recognized by the system. The blue LED stayed on during scanning, indicating that

the radar sweep was underway. The buzzer issued an audible warning and the red LED began to blink when an object was spotted within 50 cm.

The 16x2 LCD screen provided a precise indication of the angular position and distance in real time. With little delay, usually less than 100 milliseconds, the Processing IDE radar visualization displayed the location of obstacles. Overall system performance stayed consistent, although testing with various object materials revealed a minor decrease in accuracy for soft and absorbent surfaces.

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| **Parameter** | **Observation** |
| Maximum Detection Range | Approximately 350 cm |
| Minimum Reliable Detection | 5 cm |
| Angular Coverage | 0° to 360° |
| Measurement Error | ±5 cm |
| System Reaction Time | <100 ms |
| LED and Buzzer Activation | ≤50 cm Distance |

# DISCUSSION

The radar system's usability was greatly improved by combining visual and audio alert methods. The red LED and buzzer ensured timely warning in critical proximity conditions, while real-time updates via the LCD display gave instant feedback regarding the distance and angle of identified objects.

The main goal of the research, which was to economically mimic radar capability, was accomplished. Additionally, by integrating several output modalities (LCD, LEDs, buzzer) without affecting overall responsiveness, the system showed scalability.

There were several restrictions noted. Environmental elements including humidity, air temperature, and the target surface's texture can all affect how sensitive ultrasonic sensors are. Detection accuracy was somewhat worse for soft materials like cloth than for hard surfaces like wood or metal.

## Future enhancements can consist of:

* + Bluetooth and Wi-Fi wireless communication modules for remote surveillance.
	+ Smarter obstacle detection by integration with sophisticated object categorization algorithms.
	+ To cover blind regions, several ultrasonic sensors are used.

All things considered, the Arduino-based radar system offers a very useful, instructive, and expandable prototype for applications involving intelligent obstacle identification.

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