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Radar System using Arduino

Prof. Nigade S.[1], Vishwakarma Kumar[2], Pawan Kumar[3], Kajal Kumari[4], Sweta Singh[5]
Professor, Department of Computer Science and Engineering[1]
Students, Department of Computer Science &Engineering[2,3,4,5]
Navsahyadri Education Society's Group of Institutions, Polytechnic, Pune, Maharashtra, India

Abstract: *This paper presents the design and implementation of a low-cost radar system using an Arduino microcontroller, an ultrasonic sensor (HC-SR04), and a servo motor to enable 2D object detection and distance measurement. The system emulates basic radar functionality by rotating the ultrasonic sensor in a predefined arc to detect obstacles within its range, capturing both angular and distance data. Real-time data visualization is achieved through serial communication with a host computer, where the detected points are plotted on a radar-like interface using Processing IDE. The proposed system demonstrates the feasibility of using inexpensive, off-the-shelf components to develop a functional and scalable radar prototype for educational and experimental applications. Experimental results validate the accuracy and responsiveness of the system, highlighting its potential in fields such as robotics, automation, and environmental mapping..*

Keywords: radar system

I. INTRODUCTION

Radar (Radio Detection and Ranging) systems have become an integral component in a wide range of applications, from defense and navigation to autonomous vehicles and industrial automation.

Traditional radar systems, however, are often complex, expensive, and inaccessible for educational or prototype-level implementations. With the growing availability of affordable microcontrollers and sensors, it is now possible to develop simplified radar-like systems for experimental and academic use. This paper explores the development of a low-cost radar system using an Arduino microcontroller, an ultrasonic distance sensor (HC-SR04), and a servo motor to simulate the scanning mechanism. The system mimics the fundamental principles of radar operation by transmitting ultrasonic pulses and measuring the time delay of echoes reflected from nearby objects. By rotating the sensor in a predefined angular range, the system collects spatial data that can be visualized to represent the surrounding environment.

II. ABOUT THE CIRCUIT

The radar system circuit is designed using minimal yet efficient components to ensure ease of implementation and cost-effectiveness. The primary elements include an Arduino Uno microcontroller, an HC-SR04 ultrasonic distance sensor, and an SG90 servo motor. The circuit facilitates angular scanning of the sensor to detect objects in the environment and measure their distance.

III. COMPONENTS REQUIREMENTS

- **Arduino Uno**: Acts as the central processing unit, handling sensor data acquisition, servo motor control, and communication with a computer for data visualization.
- **HC-SR04 Ultrasonic Sensor**: Used for distance measurement. It emits ultrasonic pulses and measures the time taken for the echo to return.
- **SG90 Servo Motor**: Rotates the ultrasonic sensor within a defined angle range (typically 0° to 180°) to simulate a scanning radar system.
- **Power Supply**: The entire system is powered via the Arduino's 5V output, connected either through
- USB or an external power source.

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3.1 WORKING

The Arduino sends control signals to the servo motor, rotating the ultrasonic sensor incrementally within the scanning arc. At each angle, the HC-SR04 sensor sends a pulse and listens for the echo. The Arduino calculates the distance based on the time delay and sends the angle-distance pair to a host computer via serial communication. This data is then visualized using Processing IDE or a similar tool to create a radar-like interface.

IV. LITERATURE OVERVIEW

Radar technology has seen extensive development since its inception, with modern systems offering high-resolution imaging, real-time tracking, and advanced object classification. Traditional radar systems utilize radio frequency (RF) signals and complex hardware to detect and track objects over long distances. While effective, these systems are generally cost-prohibitive for small-scale or educational projects. Consequently, researchers and hobbyists have explored alternative, low-cost methods to simulate radar-like functionality using microcontrollers and ultrasonic sensors.

Several studies have investigated the use of ultrasonic sensors as a viable substitute for RF-based radar in short-range applications. For instance, works such as [1] and [2] demonstrate the feasibility of using the HC-SR04 ultrasonic sensor in embedded systems for proximity detection and obstacle avoidance in robotics. These implementations focus on real-time data acquisition and are often limited to single- direction measurements.

To enhance spatial awareness, researchers have integrated servo motors with ultrasonic sensors to enable scanning-based object detection. Projects documented in [3] and [4] detail how servo-driven ultrasonic systems can be used to emulate radar scanning by rotating the sensor to capture distance data at various angles. These systems are commonly used in academic environments to teach sensor interfacing, embedded programming, and basic radar principles.

V. CIRCUIT CONNECTIONS

HC-SR04 Connections:

- VCC → Arduino 5V
- GND → Arduino GND
- TRIG → Arduino Digital Pin 9
- ECHO → Arduino Digital Pin 10

Servo Motor Connections:

- VCC (Red) → Arduino 5V
- GND (Brown/Black) → Arduino GND
- Signal (Orange/Yellow) → Arduino Digital Pin 11

VI. CONCLUSION

Radar (Radio Detection and Ranging) systems have become an integral component in a wide range of applications, from defense and navigation to autonomous vehicles and industrial automation.

Traditional radar systems, however, are often complex, expensive, and inaccessible for educational or prototype-level implementations. With the growing availability of affordable microcontrollers and sensors, it is now possible to develop simplified radar-like systems for experimental and academic use. This paper explores the development of a low-cost radar system using an Arduino microcontroller, an ultrasonic distance sensor (HC-SR04), and a servo motor to simulate the scanning mechanism. The system mimics the fundamental principles of radar operation by transmitting ultrasonic pulses and measuring the time delay of echoes reflected from nearby objects. By rotating the sensor in a predefined angular range, the system collects spatial data that can be visualized to represent the

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Problem Statement:

Traditional radar systems are complex, expensive, and require sophisticated hardware and signal processing capabilities, making them impractical for small-scale, educational, or low-budget applications. Furthermore, most commercial radar units are not easily customizable for experimental research or prototyping, especially in academic environments where accessibility and ease of use are essential.

There exists a gap in the availability of cost-effective radar-like systems that can be easily implemented using commonly available electronic components. While ultrasonic sensors offer a low- cost alternative for distance measurement, they typically operate in a fixed direction and do not provide comprehensive spatial awareness without additional mechanical control or software processing.

The main challenge addressed in this paper is the development of a simple, scalable, and affordable radar system that can:

Detect objects within a predefined angular range using an ultrasonic sensor. Provide real-time scanning and distance measurement.

Visually represent detected objects in a 2D radar-like interface.

Be easily implemented using open-source tools and hardware such as Arduino.

This project aims to bridge the gap by designing a basic radar system that leverages ultrasonic sensing, servo-based rotation, and Arduino-based control logic to create a functional and educational prototype. The system targets applications in robotics, obstacle detection, and environmental mapping, particularly in academic and research settings where affordability and simplicity are key.

VII. LITERATURE REVIEW

Several research studies and projects have been conducted in recent years to develop effective gas leakage detection systems using embedded technologies. Most commonly, gas sensors such as the MQ- 2, MQ-4, and MQ-6 have been used due to their high sensitivity to flammable gases like LPG, Methane, and Propane. These sensors are widely used in academic and industrial projects for real-time gas monitoring due to their affordability and ease of use.Studies have shown that integrating these sensors with microcontrollers like Arduino improves the responsiveness and accuracy of the system. Projects often involve interfacing additional components such as buzzers, GSM modules for alert messages, servo motors for automatic control of gas valves, and fans for ventilation. These systems have demonstrated significant effectiveness in preventing accidents caused by gas leaks.

Applications

- Educational demonstrations of radar principles.
- Obstacle detection in robotics.
- Short-range security systems.
- Indoor mapping and automation prototypes.

Strengths of the Project

- Cost-Effectiveness: The utilization of affordable components like the Arduino Uno, HC- SR04 ultrasonic sensor, and SG90 servo motor results in a low-cost radar system. This affordability makes it accessible for educational purposes and prototyping, allowing for widespread adoption in resource-constrained settings.
- Ease of Development and Flexibility: Arduino's open-source platform, coupled with extensive community support, facilitates easy development and customization. This flexibility enables rapid prototyping and adaptation to specific project requirements, making it suitable for a wide range of applications.
- Low Power Consumption: Compared to traditional radar systems, Arduino-based implementations consume less power, making them ideal for battery-operated or energy- efficient applications. This characteristic is particularly beneficial in remote or portable scenarios.

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- Real-Time Visualization: Integration with software like the Processing IDE allows for real- time graphical representation of detected objects. This feature enhances user interaction and understanding of the system's operation, providing immediate feedback and facilitating debugging and analysis.
- Educational Value: The simplicity and hands-on nature of building an Arduino-based radar system make it an excellent tool for educational settings. It aids in teaching fundamental concepts in electronics, programming, and sensor integration, fostering practical skills and innovation among students.
- Modularity and Scalability: The modular design allows for easy integration of additional components or sensors, enabling scalability and expansion of system capabilities. This adaptability supports the development of more complex systems, such as multi-sensor arrays or integration with wireless communication modules.
- Versatility in Applications:

Limitations of the Project

- Limited Detection Range: Ultrasonic sensors like the HC-SR04, commonly used in Arduino-based radar systems, typically have a maximum effective range of about 3 to 4 meters. This short-range detection is insufficient for applications requiring long-distance sensing, such as large-scale surveillance or automotive radar systems.
- Environmental Sensitivity: Ultrasonic sensors are susceptible to environmental factors. Soft or uneven surfaces can absorb sound waves, leading to inaccurate readings. Additionally, angled surfaces may deflect the waves away from the sensor, causing detection failures.
- Processing Power Constraints: Arduino microcontrollers, such as the Uno, operate at relatively low clock speeds and have limited memory. This restricts their ability to process complex algorithms or handle high-speed data acquisition, which are essential for advanced radar functionalities.
- Inadequate for RF Radar Implementations: Standard Arduino boards lack the capability to generate or process radio frequency (RF) signals required for traditional radar systems. Implementing RF radar would necessitate additional hardware and more powerful processing units.
- Limited Angular Resolution: The angular resolution of the system is constrained by the mechanical rotation speed of the servo motor and the sensor's beam width. This limitation affects the system's ability to distinguish between closely spaced objects.
- Real-Time Processing Limitations: Due to the processing constraints, Arduino-based radar systems may struggle with real-time data processing and visualization, especially when handling multiple targets or integrating with other systems.
- Scalability Issues: Expanding the system to cover larger areas or to integrate multiple sensors can be challenging due to the limited I/O ports and processing capabilities of standard Arduino boards

VIII. CONCLUSION

This project successfully demonstrates the development of a low-cost, Arduino-based radar system using an ultrasonic sensor for short-range object detection. The system efficiently integrates hardware components like the HC-SR04 sensor and SG90 servo motor with real-time data visualization, offering an intuitive and practical solution for learning and prototyping radar concepts.

Despite limitations such as limited detection range, environmental sensitivity, and constrained processing power, the system proves valuable in educational environments and for basic radar applications. Its modularity and flexibility make it suitable for further enhancements, including longer-range sensors, wireless communication modules, and advanced data processing techniques.

Overall, the Arduino-based radar system highlights the potential of open-source hardware platforms in democratizing access to radar technology and fostering innovation in embedded systems and sensor applications.