ARDUINO-BASED RADAR SYSTEM FOR SHORT-RANGE APPLICATIONS

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Abstract

The development of cost-effective and efficient radar systems has gained widespread attention due to their potential applications in surveillance, security, robotics, and automation. Traditional radar systems, which are based on radio frequency (RF) technology, tend to be expensive and complex to implement for short-range applications. This paper presents a low-cost, Arduino-based radar system designed for short-range object detection and tracking. The system utilizes an ultrasonic sensor (HC-SR04) to measure distances, a servo motor to scan the area, and an Arduino microcontroller to process and visualize data in real time. The proposed design offers a simple yet effective approach for applications such as obstacle detection, proximity sensing, and security monitoring. This study details the hardware and software implementation, working principles, and potential use cases of the system, along with possible improvements for future developments.

Keywords

Arduino, radar system, ultrasonic sensor, servo motor, real-time detection, object tracking, short-range applications

1. Introduction

Radar systems play a crucial role in modern technology, enabling the detection and tracking of objects over various distances. These systems have been widely used in military applications, air traffic control, weather monitoring, and automotive collision-avoidance technologies. However, conventional radar systems rely on complex RF technology, making them expensive and unsuitable for short-range applications where simpler and cost-effective solutions are required.

With advancements in embedded systems and microcontroller-based designs, low-cost radar alternatives have emerged for various applications, such as autonomous robotics, home security, and industrial automation. This paper introduces a radar system based on an Arduino microcontroller that uses ultrasonic technology instead of RF signals. The system operates by emitting ultrasonic pulses, detecting reflected signals, and visualizing the obtained distance data. By integrating an ultrasonic sensor with a rotating servo motor, the system is capable of scanning its surroundings and providing real-time object detection.

This study aims to explore the design, working principles, and implementation of an Arduino-based radar system. The project demonstrates how microcontrollers can be leveraged for real-time object detection with minimal hardware complexity and cost.

2. System Components and Architecture

2.1. Hardware Components

The proposed radar system consists of the following key components:

- **Arduino Uno** – The microcontroller that processes sensor data and controls the servo motor.
- **Ultrasonic Sensor (HC-SR04)** – A sensor used to measure distances by emitting ultrasonic waves and detecting their reflections.
- **Servo Motor (SG90 or MG995)** – Controls the rotational movement of the sensor for scanning the surrounding area.
- **LCD Display or PC Interface** – Displays the detected object positions and distance values in real time.
- **Power Supply** – Provides the required voltage to operate the microcontroller and sensors.

2.2. Working Principle

The Arduino-based radar system operates by continuously emitting ultrasonic pulses using the HC-SR04 sensor. When these pulses hit an object, they bounce back to the sensor, which then calculates the distance based on the time delay between transmission and reception. The servo motor rotates the sensor within a specified angle range, enabling the system to scan a wider area. The Arduino microcontroller processes this data and visualizes the detected objects on a display or computer screen, simulating a traditional radar interface.

The distance calculation follows the basic formula:

$$\text{Distance} = \frac{\text{Speed of Sound} \times \text{Time Delay}}{2}$$

where the speed of sound in air is approximately **343 m/s**.

3. System Implementation

3.1. Circuit Design

The circuit setup for the Arduino-based radar system involves connecting the HC-SR04 ultrasonic sensor to the Arduino board. The **Trigger** and **Echo** pins of the sensor are interfaced with digital I/O pins on the Arduino. The servo motor is connected to a PWM-enabled pin to control its rotation. A simple LCD module or a computer with serial communication can be used to display real-time data.

Connections:

- **HC-SR04 Sensor**:
    - VCC → 5V (Arduino)
    - GND → GND (Arduino)
    - Trigger → Digital Pin 9
    - Echo → Digital Pin 10
- **Servo Motor**:
    - VCC → 5V (Arduino)
    - GND → GND (Arduino)
    - Control Signal → Digital Pin 6

3.2. Software Development

The radar system is programmed using the Arduino IDE. The software is responsible for:

- Controlling the servo motor to rotate within a predefined angle range.
- Triggering the ultrasonic sensor and recording the time delay of reflected signals.
- Processing distance measurements and mapping them to angular positions.
- Sending the processed data to a computer for visualization.

A graphical user interface (GUI) can be developed using **Processing IDE**, MATLAB, or Python to represent the detected objects on a radar-like display.

Arduino Code Snippet:

```
#include <Servo.h>

Servo myServo;
const int trigPin = 9;
const int echoPin = 10;

void setup() {
  Serial.begin(9600);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
```

```
  myServo.attach(6);
}

void loop() {
  for(int angle = 0; angle <= 180; angle += 5) {
    myServo.write(angle);
    delay(200);

    digitalWrite(trigPin, LOW);
    delayMicroseconds(2);
    digitalWrite(trigPin, HIGH);
    delayMicroseconds(10);
    digitalWrite(trigPin, LOW);

    long duration = pulseIn(echoPin, HIGH);
    int distance = duration * 0.034 / 2;

    Serial.print(angle);
    Serial.print(",");
    Serial.println(distance);
  }
}
```

This script rotates the servo motor and measures distances at each step, sending data to the serial monitor for further processing.

4. Applications

The Arduino-based radar system has various applications in different fields:

- **Obstacle Detection** – Used in robotics for navigation and collision avoidance.
- **Security Systems** – Monitors restricted areas for unauthorized movements.
- **Industrial Automation** – Tracks object positions in warehouse and factory environments.
- **Smart Vehicles** – Can be integrated into parking assistance systems for real-time proximity detection.
- **Military Training Simulations** – Used in educational environments to demonstrate radar concepts.

5. Conclusion

This paper presented an Arduino-based radar system that utilizes an ultrasonic sensor and servo motor for short-range object detection. The system provides a cost-effective and efficient method for real-time distance measurement and visualization. The simplicity and affordability of the proposed design make it suitable for a wide range of applications, including security, robotics, and industrial automation.

Future enhancements could involve integrating wireless data transmission, improving graphical visualization, and incorporating machine learning algorithms for advanced object classification. Additionally, using LiDAR or infrared sensors may enhance the accuracy and range of detection.

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