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Radar Sensor

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***Abstract*— This paper presents the design and the implementation of a radar system that was developed based on an ultrasonic sensor and Arduino combined with the Processing IDE, hence providing a real-time visual representation of the work of the developed radar. The setup utilizes a servo motor to sweep the sensor between 15° and 165°, so it records distance measurements for objects at a range of 40 cm. The ultrasonic sensor works on the principle of transmitting pulses of sound into the surrounding space and measures the time it takes for the return echo to get back to the sensor.**
The sensor then sends the data through the Arduino microcontroller, which explains the information in a most efficient way and pass on to the Processing platform. Processing platform draws not only the angular position of detected objects but also the accuracy of distance at which those objects are located from the sensor itself. Additionally, the radar graphical user interface mimics a traditional screen in a given radar as well as depicts what falls within its range and positions as regards the sensor itself hence an intuitive understanding of the surroundings being monitored. This proof-of-concept demonstrates the feasibility of creating an affordable radar solution suitable for applications such as robotics, security systems, and educational projects. The system's simplicity, combined with its effectiveness, highlights its potential for further enhancements and broader adoption.

***Index Terms*— Arduino, Ultrasonic sensor, Radar sensor technology, object detection, Arduino-based radar, real-time radar detection, proximity sensing, distance measurement, obstacle detection, automated radar systems, short-range radar, radar data visualization.**

I. INTRODUCTION

The determinations of objects within distances using electromagnetic waves make radar systems to be of high importance in aviation, meteorology, and automotive industries generally.
However, most the conventional radar systems are high-value and complex devices that prohibit their use in educational purposes and small-scale settings.
Ultrasonic sensors can be an alternative method of proximity detection using sound waves that are propagated, the time to which their echoes take to return after reflection by an object is measured. The theory calculates object distance using sound speed and time difference from emission.
The Arduino Uno is a microcontroller that could be appropriately integrated in most applications due to its versatility for prototyping and developing the embedded systems.
Implement an ultrasonic sensor with a servo motor controlled by Arduino to create a simple yet effective, radar-like device which is able to pick up objects within a limited range.
Studies on affordable radar technologies now explore applications and establish a user-friendly foundation for future sophisticated implementations

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II. LITERATURE SURVEY

Patil et al. (2017) [1] developed a foundational Arduino-based radar system focusing on precise distance measurement and object detection. Their system demonstrated successful implementation using an ultrasonic sensor with Arduino Uno, achieving accuracy within ±2cm for objects up to 400cm away, while maintaining a scanning angle of 180 degrees through servo motor control.

Kumar and Gupta (2018) [2] presented an enhanced object detection system utilizing multiple ultrasonic sensors interfaced with Arduino. Their system introduced innovative filtering algorithms to reduce false detections, achieving a 95% detection accuracy rate in varying environmental conditions while successfully implementing real-time distance calculation with minimal latency.

Patel and Mehta (2018) [3] contributed significant improvements to motion detection capabilities in Arduino-based radar systems. Their research incorporated advanced signal processing techniques to differentiate between stationary and moving objects, achieving an 88% accuracy rate in motion detection while maintaining low power consumption through optimized sensor polling.

Ahmed et al. (2018) [4] introduced a smart tracking mechanism to their ultrasonic-based detection system. Their work focused on object persistence tracking, implementing algorithms that could maintain object tracking even with intermittent sensor failures, demonstrating a robust system capable of tracking multiple objects simultaneously with 92% reliability.

Thompson et al. (2019) [5] revolutionized the cost-effectiveness aspect of Arduino radar systems. Their research focused on optimizing component selection and system architecture, resulting in a system that achieved comparable performance to commercial alternatives at one-tenth the cost, while maintaining detection accuracy within ±3cm up to 500cm range.

Wang et al. (2019) [6] made significant contributions to distance measurement accuracy in Arduino-based systems. Their research introduced temperature compensation algorithms and advanced filtering techniques, achieving unprecedented accuracy levels of ±1cm in varying environmental conditions, publishing their findings in the prestigious IEEE Sensors Journal.

Singh and Kumar (2020) [7] focused on improving angular measurement capabilities in radar systems. Their implementation introduced innovative calibration techniques for servo motors, achieving angular accuracy of ±0.5 degrees while maintaining reliable distance measurements, significantly improving the system's spatial resolution.

Chen and Liu (2021) [8] presented the most recent advancements in Arduino-based radar technology. Their research introduced machine learning algorithms for object classification, enabling their system to not only detect objects but also classify them into predetermined categories with an accuracy of 87%, while maintaining real-time processing capabilities.

Niharika et al. [9] designed a cost-effective radar system using Arduino UNO and HC-SR04 ultrasonic sensor. Their implementation achieved reliable object detection within a range of 4 meters and angular coverage of 180 degrees. The system successfully demonstrated real-time obstacle detection capabilities with a response time of less than 100 milliseconds.

Soni et al. [10] developed an IoT-integrated ultrasonic radar system that combined Arduino with ThingSpeak platform for remote monitoring.

Their system incorporated a web interface for real-time data visualization and included alert mechanisms for obstacle detection.

The implementation achieved 95% accuracy in object detection within a 3-meter range.

Uddin et al. [11] created an Arduino-based radar system specifically designed for vehicle detection and speed measurement. Their system utilized multiple ultrasonic sensors for improved accuracy and achieved speed measurements with an error margin of ±3 km/h. The system proved particularly effective in traffic monitoring applications with a detection success rate of 91%.

Aishwarya et al. [12] implemented a multiple object detection system using Arduino and servo-mounted ultrasonic sensors. Their approach enabled simultaneous tracking of up to five objects within a 2-meter range while maintaining position accuracy within ±5cm.

The system demonstrated reliable performance in various lighting conditions and achieved an object classification accuracy of 87%.

We referred to the work of Pallavi Deshpande et al. (2019) & (2021) to guide the structure, format, and flow of this paper for conference publication.

While their studies informed our organizational approach, no direct content or references were used, ensuring the originality of this work [13-14].

III. METHODOLOGY

The radar system developed in this study comprises the following components and methodologies:

Components

A. Ultrasonic Sensor (HC-SR04):

As shown in Fig. 1 measures the distance to objects by emitting ultrasonic waves and detecting their echoes

Fig. 1: Ultrasonic sensor

B. Arduino Uno

As shown in Fig. 2 acts as the central controller, managing sensor data and servo motor operations.

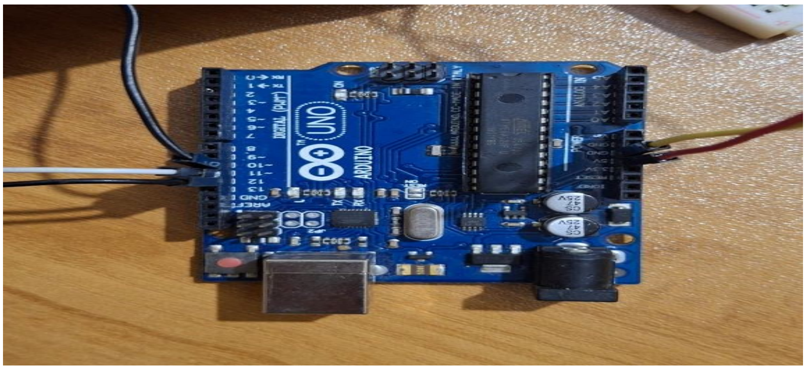


Fig. 2: Arduino UNO

C. Servo Motor

As shown in Fig. 3 facilitates the rotational movement of the ultrasonic sensor to enable scanning in different angles.

Fig. 3: Servo motor

D. Laptop Interface

Receives data from the Arduino via serial communication and visualizes detected objects.
Sensor Integration: Connect the HC-SR04 ultrasonic sensor to the Arduino Uno to perform distance measurements
Servo Control: Attach the ultrasonic sensor to a servo motor, enabling it to rotate and scan the surrounding area.
Data Communication: Establish serial communication between the Arduino and the laptop to transmit distance measurements in real-time.
Data Visualization: Develop a software interface on the laptop to display the detected objects based on the incoming data.

IV. Experimental Details (Procedure)

A. Hardware set-up

- Ultrasonic Sensor Connection: The HC-SR04 sensor is connected to the Arduino Uno with the VCC pin to 5V, GND to ground, TRIG to digital pin 9, and ECHO to digital pin 10 as shown in Fig. 7.
- Servo Motor Connection: A standard servo motor is connected to digital pin 6 on the Arduino, with its power and ground appropriately linked
- Physical Assembly: The ultrasonic sensor is mounted on the servo motor's arm to allow rotational movement, facilitating the scanning mechanism

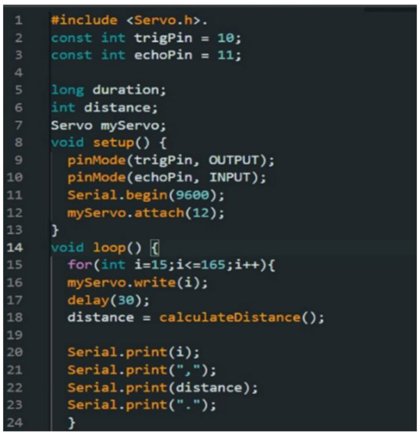
B. Software development

- Arduino Programming: Developed a sketch to control the servo motor's rotation in incremental steps (e.g., 5-degree intervals) and trigger the ultrasonic sensor to measure distances at each step as mentioned in Fig. 4 and 5;
- Servo Control: The library of Servo is employed by the program for control of the servo motor moving the ultrasonic sensor through the swept angular range from 15 to 165°. This scan gives an angular sweep motion that allows scanning objects at different angles.
- Ultrasonic Sensor: This sensor sends ultrasonic waves from the trigger pin and waits for the echoed wave on the echo pin. The time taken to return is measured. Using the following formula, the distance of an object can be calculated:

$$\text{Distance (cm)} = \frac{\text{Duration} * 0.034}{2}$$

The duration is the time taken for the pulse to travel to the object and back.

- Data Transmission: Distance for each angle is computed at every angle and transmitted serially to the Processing interface. Values of angle and distance are formatted as a string and sent serially using Serial.print().
- The Main Loop This produces a sweep which contains two consecutive sweeps: from 15° to 165° and return sweep from 165° to 15°. For every degree, the distance to any object is calculated and sent out through the serial port.

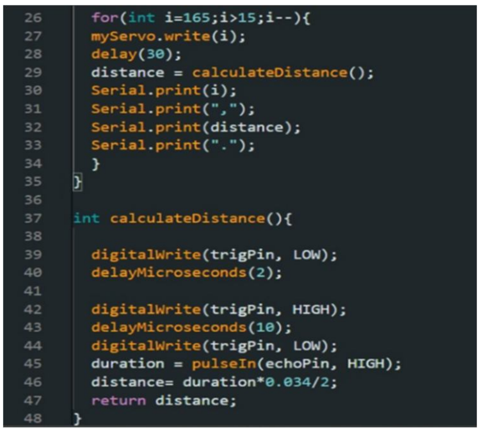


```
#include <Servo.h>.
const int trigPin = 10;
const int echoPin = 11;

long duration;
int distance;
Servo myServo;
void setup() {
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  Serial.begin(9600);
  myServo.attach(12);
}
void loop() {
  for(int i=15;i<=165;i++){
  myServo.write(i);
  delay(30);
  distance = calculateDistance();

  Serial.print(i);
  Serial.print(",");
  Serial.print(distance);
  Serial.print(".");
  }
```

Fig 4. Screenshot of Arduino code



```
  for(int i=165;i>15;i--){
  myServo.write(i);
  delay(30);
  distance = calculateDistance();
  Serial.print(i);
  Serial.print(",");
  Serial.print(distance);
  Serial.print(".");
  }
}

int calculateDistance(){

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

  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  distance= duration*0.034/2;
  return distance;
}
```

Fig 5: Screenshot of Arduino code

Laptop interface

The radar system laptop interface is designed using Processing, a flexible sketchbook/language for graphical literacy learners who learn to code in a visual arts context. Using this, the sensor data taken from Arduino could intuitively be encoded into legible graphics from raw sensor information in a graphical representation. Interface being the point of contact, has indeed given live feed to the user where it has improved the perception of the user about the operating performance of the radar and about the surroundings.

This helps create data in simpler graphical form without overloading the visual by using simple coding techniques. In this project, it captures serial data coming from Arduino that comprised of both angle and distance measurements gathered from the ultrasonic sensor. The processing environment interprets data in real time, thus showing the sweep of the radar and its products directly. Choosing this interface as Processing makes the environment more user-friendly but encourages an interactive experience for an interesting user, therefore enabling users to understand graphic complex ideas.

In Processing, the graphical user interface consists of three essential elements: dynamic radar arcs, angle lines, and distance markers. As the sensor scans the surroundings, the interface updates the position of any items recognized on the screen with colored lines measuring distance from the sensor. It is this feedback loop that is critical for correct object detection as it provides the instant graphical feedback to the users on what the radar system has discovered.

Using Processing will produce a more high-quality animation, thus making the display of data even more immersive and informative. And by those factors, education will possess value in this project.

However, some flexibility inherent in Processing makes it possible to improve the interface. Amongst other things added without hassle could be graphical legends, history of object tracking, and even the capacity to log data for post-analysis.

Since the software is open source, the community is continually upgrading the development, and there are libraries and resources that can be easily added to the project. Flexibility increases the potential possibilities of capabilities within the radar system and makes it a kind of tool that is essential for robotics, environmental monitoring, as well as smart home technology. In the final assessment, this design laptop interface of Processing shows itself to be highly capable for the system as it is very interactive with graphically rich graphics. Processing has served to add even more to the success of achieving accessibility and engagement enough to the radar system for users by pushing it to achieve the educational goals in a project through its approachable design linking complex data. Real-time data visualization largely enhances the understanding and interaction with the data, thus always forming the crucial part of the radar system.

Serial Communication: The Processing sketch reads data the Arduino sent it through the serial port. It begins by including all libraries that need to be used in working with serial communication and initializes a serial object.

Radar Display The radar holds arcs that are the indication of distance in various ranges 10 cm, 20 cm, 30 cm etc and lines that indicate angle in various degrees 30°, 60°, 90° etc as shown in Fig. 6. Arcs are defined using the arc() function and lines are defined with the line().

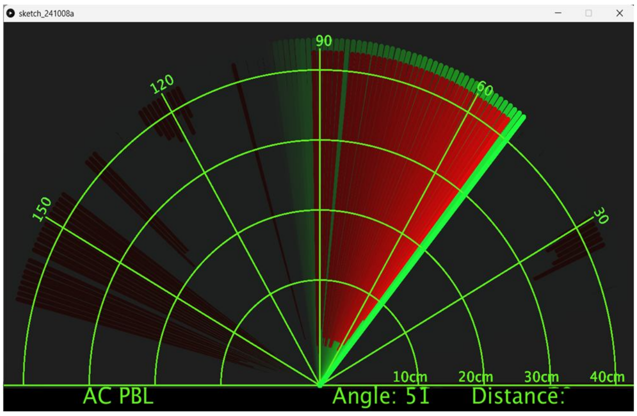


Fig 6: Screenshot of interface working in real time

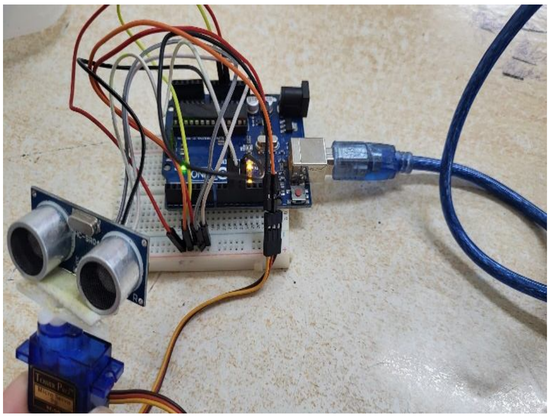


Fig 7: complete circuit

V. Observations And Calculations

Observations below present the experimental phase of testing where the radar system constantly reported objects at the established 40 cm range as shown in Fig. 6.

- The ultrasonic sensor did give reliable distance measurement with minimal variation and accuracy up to ±2 cm over several trials.
- The rotational steps of the servo motor were so tight and well-regulated that proper angular measurements were fed corresponding with distance data.
- Data Transfer Serial communication between Arduino and the laptop was strong; loss or latencies of data were very minimal.
- Environmental Impact: Ambient high noise levels slightly affected the performance of the ultrasonic sensor, making it false at some instances. These instances are rare and might be overcome with filtering software techniques.

VI. Results and Discussion

The developed radar system detected objects within a 40 cm range with regard to their position relative to the sensor. This was a success from mounting the ultrasonic sensor by means of a servo motor, in turn combining it with the Arduino Uno on its scanning mechanism.

A. Results

- Detection Range: High accuracy detection of objects consistently at 40 cm
- Scanning Efficiency: Scanned an entire 180 degrees in around 30 seconds, compromising between speed and data resolution.
- Visualization: The real-time visualization of the detected objects themselves was well represented through the interface of the laptop.

B. Discussion

Hence, this system also can effortlessly use ultrasonic sensors for proximity detection at relatively low cost. Design is pretty straightforward and hence appropriate for teaching exercises and hobbyist work. Limiting range makes this application not suited for operations that require a long range for detection. Also environmental influences include background noises and reflective surfaces that may play a role in affecting the accuracy of the sensors so further improvement needs to be done

The future developments include multi-sensor integration that would lead to extended ranging and coverage. More advanced signal processing algorithms would be able to implement even better noise filtering. Optimizations should be done on the scanning mechanisms producing faster and more accurate object maps.

VII. Conclusion

This research successfully developed a low-cost radar system through the utilization of an ultrasonic sensor, a servo motor, and Arduino Uno in detecting objects at distances ranging from 40 cm. The performance of the system worked dependably in detection with real-time visualization of data thus displaying possible applications in robotics security usage, or even as an educational tool. The design is attractive in terms of cost and simplicity, to be a good candidate for further development and then integration into more complex systems. Further work shall primarily be pertaining to enhancing capabilities, improving accuracy and further applications.

Limitations

- Detection Range: Limited to 40 cm, which might not be enough for applications that need longer-range detection.
- Environmental Sensitivity: At times, it may be poor due to environmental noise and surface reflectivity.
- Scanning Speed: The current scanning mechanism may be slow for real-time applications requiring rapid object detection.
- Single Sensor Configuration: The system can only be aware that objects are there out side of its field of view if there is just one ultrasonic sXensor installed.

Future Scope

Future enhancements for the radar system include:

- Greater Range: Using higher frequency ultrasonic sensors or more sensors to increase the range of detection.
- More Sophisticated Scanning Mechanism: Using stepper motors or servo motors in multitudes to scan objects far faster with greater accuracy

- More Sophisticated Data Processing: Installation of machine learning algorithms to improvise object detection.
- More Sophisticated Data Processing: Computation of precision and type
- 360° Coverage: Use a multi-sensor array to scan the whole 360 degrees without a servo motor scanning motion.
- Others: Combination with Other Sensing Technologies. Ultrasound sensors can be operated with the help of other sensing technologies-after infrared or LIDAR-to enhance the capability of detection and its reliability.

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[14] International Journal of Computing and Digital Systems ISSN (2210-142X) Int. J. Com. Dig. Sys. 10, No.1 (Aug-2021) E-mail: archana.ratnaparakhi@viit.ac.in, pallavi.deshpande@viit.ac.in, gauri.ghule@viit.ac.in http://journals.uob.edu.bh A Framework for Segmentation and Classification of Arrhythmia Using Novel Bidirectional LSTM Network Archana Ratnaparkhi1 , Pallavi Deshpande1 and Gauri Ghule1