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“Design, Analysis and Implementation of an Ultrasonic Radar System for proximity Detection and Object tracking”

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Declaration

We hereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researchers are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

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Abstract

Radars are electronic systems that detect the presence of an obstacle (distance, location, speed and sometimes shape) by hitting and returning the radio waves it sends to an obstacle. Radars are still on the world agenda today. In this project, we will have designed a system that facilitates human life depending on the purpose of use. This project aims to adapt the radar to today's technology by designing an ultrasonic radar system. It may also use a variety of and range applications, including military installations, commercial applications, and distance, speed, location, range, direction, and size. Thanks to Arduino uno's rich library and easy design, I realized my ultrasonic radar system project. In short, as the working principle of my project, it is a device that can monitor the environment with movement and creates an image on the screen depending on the distance of the object detected by this sensor. It is used to detect objects in the environment by using the ultrasonic distance sensor we place on the servo motor which moves the radar itself. With the processing interface program I designed this project, we observe where the objects are.

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1 Introduction

We know everything produces sound wave just by existence and effect flow of air around them with their natural frequency. These frequencies are beyond hearing range of humans. Wave of frequency range of 40000hz and thereabouts are called ultra-sonic wave and these waves can be detected by an ultrasonic sensor which helps us to get various knowledge. An Ultrasonic detector usually has a transducer which convert sound energy into electrical energy and electrical energy into sound energy. They are used for measuring object position and orientation, collision avoidance system, surveillance system etc. Ultrasonic technology provide relief from problem such as linear measurement problem, as it allows user to get non-contact measurements in this way distance between object and its speed can me easily measured. Speed of travel of sound wave depends upon square root of ratio between medium density and stiffness. Also, property of speed of sound can also be changed by natural environment condition like temperature. So basically, an ultrasonic sensor sends ultrasonic waves which travels in air and gets reflected after striking any object. By studying the property of reflected wave, we can get knowledge about objects distance, position, speed etc. A processing software and an Arduino software is used with hardware system for detection of objects various parameters. One of the most common application of ultra-sonic sensor is range finding. It is also called as sonar which is same as radar in which ultrasonic sound is directed at a particular direction and if there is any object in its path it strikes it and gets reflected back and after calculation time taken to come back we can determine distance of object.in real life this method is used by bats.

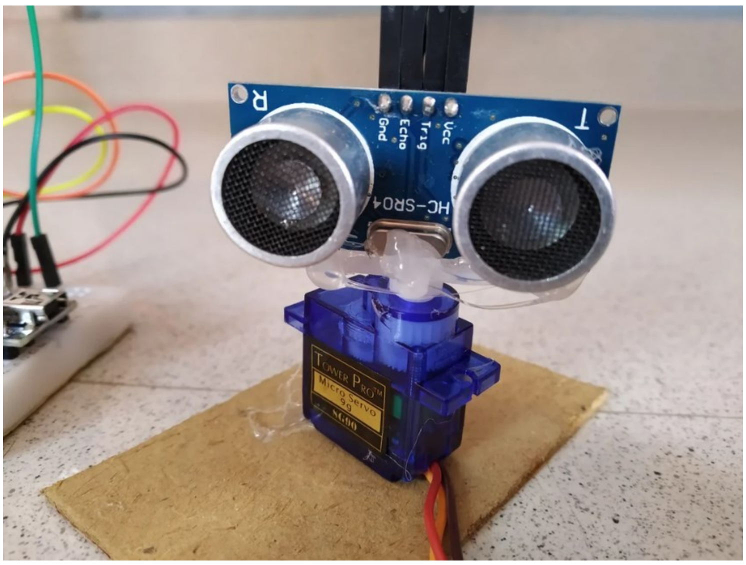

Figure 1: Ultrasonic Radar With Servo Motor

Equipment's details:

Arduino Uno:

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital Input /Output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16MHz ceramic resonator, USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 programmed as a USB-to-serial converter. Changes in Uno R3: 1. Pin out: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the reset pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible with both the board that uses the AVR, which operates with 5v and with the Arduino due that operates with 3.3v. 2. Stronger RESET circuit. 3. ATmega16U2 replace the 8U2. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino Boards.

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Figure 2: Arduino UNO

Ultrasonic sensor :

The working principle of this module is simple. It sends an ultrasonic pulse out at 40 kHz, which travels through the air, and if there is an obstacle or object, it will bounce back to the ultrasonic sensor. By calculating the travel time and the speed of sound, the distance can be calculated. Ultrasonic sensors are a great solution for the detection of clear objects. For liquid level measurement, applications that use infrared sensors, for instance, struggle with this particular use case because of target translucence. For presence detection, ultrasonic sensors detect objects regardless of color, surface, or material (unless the material is very soft, like wool, as it would absorb sound). To detect transparent and other items where optical technologies may fail, ultrasonic sensors are a reliable choice.

Figure 3: Ultrasonic Sensor

Servo motor:

A servo motor is a rotary actuator that allows for precise control of angular position velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servo motors. Servomotors are not a different class of motor, on the basis of fundamental operating principle, but uses servomechanism to achieve closed loop control with a generic open loop motor. Servo motors are used in applications such as robotics, CNC machinery or automated manufacturing.

Figure 4: Servo Motor

Liquid Crystal LCD I2C:

I2C, or Inter Integrated Circuit, is a half-duplex hardware protocol that uses two conductors, one clock (SCL) and one data (SDA) line, to connect two or more devices. One device, designated the master, uses the clock signal to synchronize data transfer to one, or multiple, slave devices at speeds up to 400 Kbps.

Figure 5: Liquid Crystal I2C

Breadboard:

Breadboards are one of the most fundamental pieces when learning how to build circuits. In this tutorial, you will learn a little bit about what breadboards are, why they are called breadboards, and how to use one. Once you are done you should have a basic understanding of how breadboards work and be able to build a basic circuit on a breadboard.

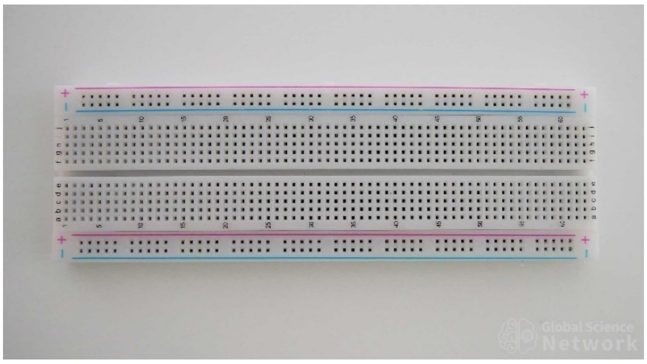

Figure 6: Breadboard

Buzzer:

When the power supply is switched on, the audio signal current generated by the oscillator passes through the solenoid coil, which generates a magnetic field. The vibration diaphragm periodically vibrates and sounds under the interaction of the solenoid coil and the magnet.

Figure 7: Buzzer

HC-SR04 Ultrasonic Sensor sine wave:

The HC-SR04 Ultrasonic Sensor measures the distance between two objects. It sends out a 40 000 Hz (40 kHz) ultrasound that circulates intermittently through the air and returns to the module if it encounters an object or obstruction. The length of the wave and the speed of the sound can be used to compute the distance.

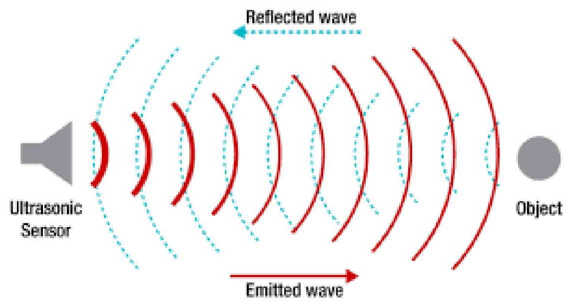

Figure 8: Ultrasonic Sensor Sine Wave

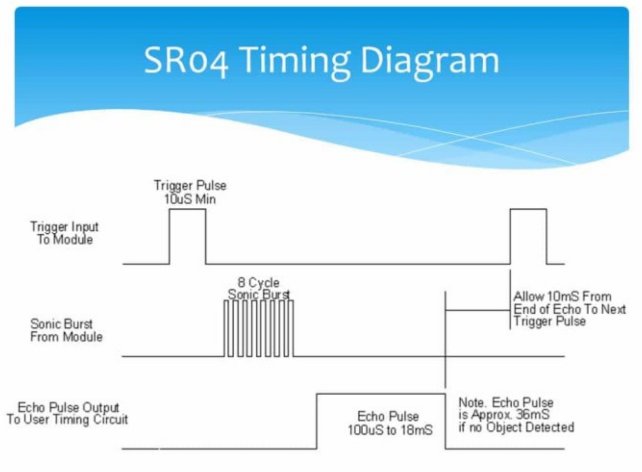

Figure 9: Ultrasonic sensor timing diagram

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

Performance comparison:

Ultrasonic radar, often used in applications like obstacle detection, parking assistance, and level sensing, can be compared to other radar technologies based on various performance metrics:

1. Range and Resolution Ultrasonic Radar: Typically operates within a range of 1 to 5 meters, with good resolution for close-range applications.

Microwave Radar: Has a much greater range (up to several kilometers) and better resolution at longer distances.

2. Frequency Ultrasonic: Operates in the range of 40 kHz to several hundred kHz.

Microwave: Operates in the GHz range, allowing for higher bandwidth and better resolution.

3. Environmental Sensitivity

Ultrasonic: Performance can be affected by temperature, humidity, and wind, as sound waves travel differently in varying conditions.
Microwave: Generally, more robust against environmental factors, though heavy rain and snow can impact performance.

4. Cost Ultrasonic: Typically, lower cost, making it suitable for consumer-grade applications. Microwave: More expensive due to complexity and capability but offers advanced features.
5. Applications Ultrasonic: Best for short-range applications like parking sensors and water level detection, Microwave: Used for long-range applications like automotive radar systems and weather monitoring.
6. Size and Integration Ultrasonic: Generally smaller and easier to integrate into compact systems. Microwave: Larger components may require more complex integration.

2 Literature Review

According to my research, I compared the ultrasonic sensor with many radar projects. In this project, which I took as an example, it is aimed to design an electronic circuit in order to make the lives of people with visual impairment easier, with the help of an ultrasonic distance sensor, to detect objects in front of the person and to give an audible warning to prevent them from hitting or snagging on objects.

The sensor was an ultrasonic sensor, and the microcontroller was an Arduino uno. The Arduino IDE was used to complete the programming portion of the project, as it serves as a code editor and compiler, as well as the process of uploading the developed software to the card. Arduino receives the distance information obtained through the use of sensors. The electronic circuit is connected to the Arduino outputs. The arduino sensed the objects with the ultrasonic distance sensor and issued an auditory warning with the buzzer speaker, therefore the desired target was reached. Similar commercial projects have proved that Bluetooth connection in mobile applications can remotely open and lock the door at a specified distance as a result of research. Furthermore, the results revealed that the ultrasonic sensor inaccuracy was used between the prototype and the actual and measured sensor distance. As a result, the nearest distance point of the measured distance may have a reduced percentage of error rate. Finally, he demonstrated in this work that he could use ultrasonic distance to track or track the position and angle of an object within a specified range. This technology is used by the Turkish army, navy, and air force in a variety of applications, including border security systems, marine radars to find landmarks and other ships, ocean surveillance systems, and aircraft anti-collision systems, among others. This system can serve a wide range of applications without requiring additional manpower**.**

3 Methodology

DESIGN IMPLEMENTATION OF RADAR SYSTEM The figure shown below shows the development life cycle of Radar project which involves various step such as design of different components, their testing, their implementation and implementation of entire system and their testing.

These steps can be enumerated into following stages

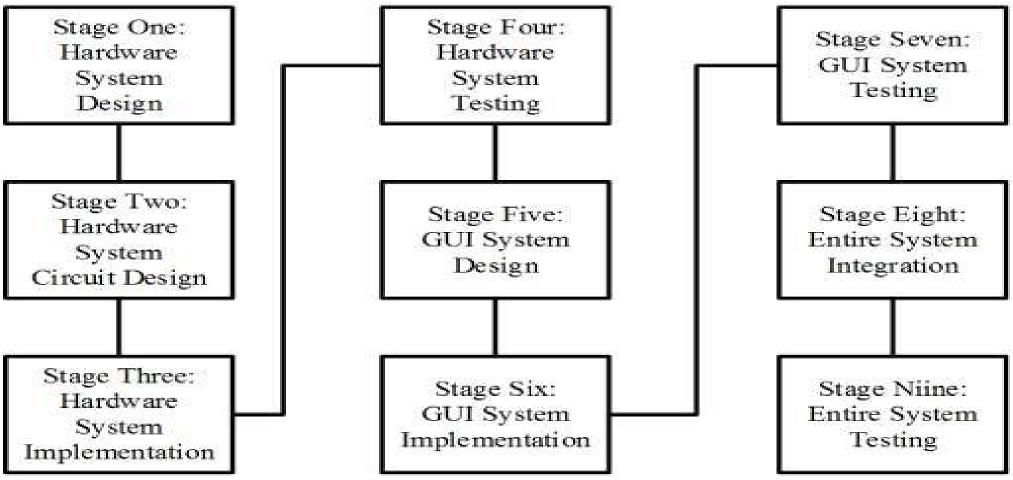

Figure 10: Development Life Cycle of Radar system

Hardware System Design: Hardware system consists of mainly 3 components named as Arduino, servo-motor, and ultra-sonic sensor. Ultrasonic sensor is mounded upon a servo motor which helps it to move and provide it a turning mechanism. Both ultrasonic sensor and servo motor are controlled and powered by Arduino. As given in above figure we can see both ultrasonic sensor and servo motor is powered by Arduino.

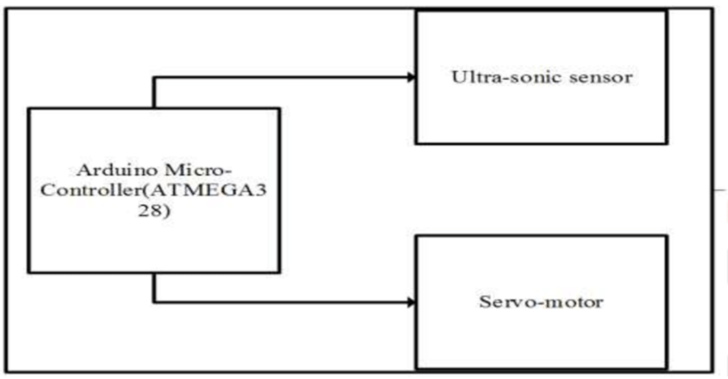

Figure 11: Hardware System Design of Radar System

<u>Hardware System Circuit Design:</u> Arduino board sends a signal of +5V to the trig pin of Ultrasonic Sensor HC-SR04 which triggers the sensor. Then it provides rotational action at the servo motor mechanically fitted along with ultrasonic Sensor HC-SR04 so that it can detect the moving objects and locate within 180degrees.The Arduino sends a HIGH pulse width of (10 S) on the TRIGGER pin of the sensor to regenerate a series of ultrasonic waves that propagate through the air until it touches an obstacle and returns in the opposite direction towards the sensor pin ECHO. The sensor detects the width of the pulse to calculate the distance.The signal on pin ECHO the sensor remains at the HIGH position during transmission, thereby measuring the duration of the round trip of ultrasound and thus determine the distance.

The LCD display displays the calculated distance and the angle of rotation. The buzzer is an additional component, it rings when there is a detection (Tone1 and Tone2) along with LEDs. Both LEDs along with the buzzer determine the field where the object is located (near or distant).Figure shows hardware system design which was designed using fritzing environment. It shows the connection of different electronics components. In the figure triggering pins of ultrasonic sensor is connected to Trigger pin D7and Echo pin D8 of Arduino, control line of servo motor is connected to D6 pin of Arduino. VCC pins of servo motor and ultrasonic sensor is connected to 5V pin of Arduino while ground pin of Arduino is connected to ground pin of both servo motor and ultra-sonic sensor.

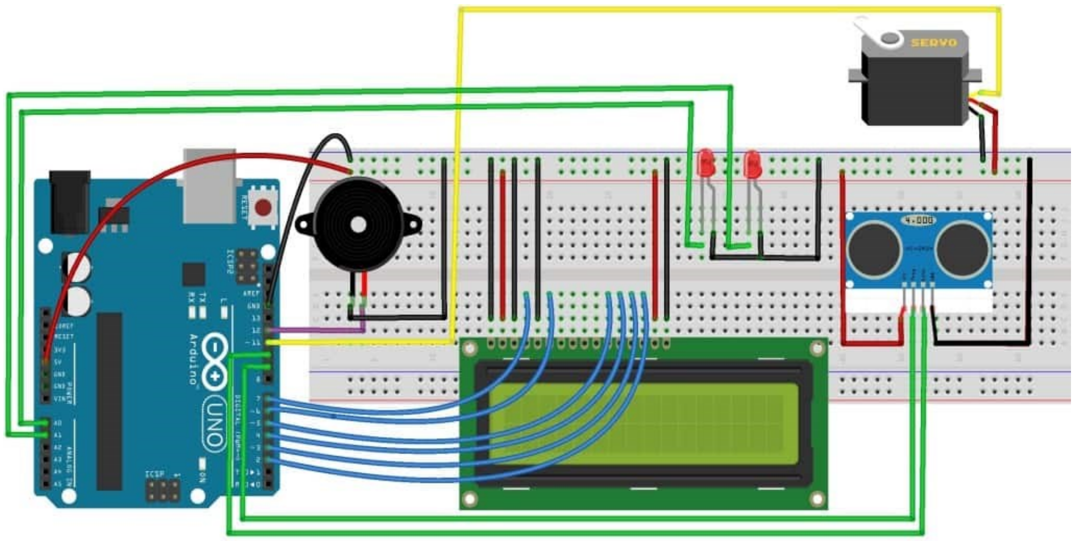

Figure 12: Hardware System Circuit Design

Hardware System Implementation: The below figure shows complete implementation of hardware system. It can be seen that ultrasonic servomotor is placed upon a servo motor and it is placed above bread board. Arduino is placed in breadboard in other side of the breadboard and entire connection is made between them. Arduino and servo motor are stick to breadboard to stop it from tripping over when servomotor moves. Arduino IDE was used to write code and upload it in Arduino. Arduino code reads position of servo motor and calculate distance of nearest object in the path.

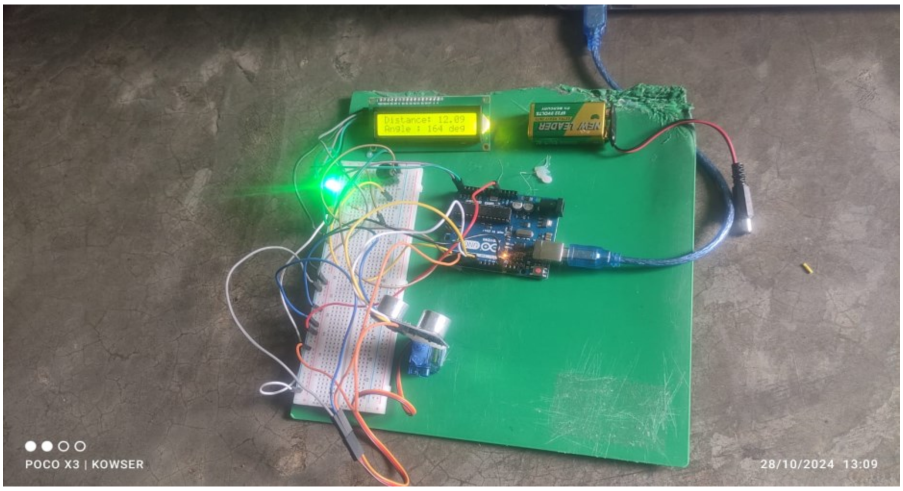

Figure 13: Breadboard of the hardware system implementation

Hardware System Testing: A cable was used for connecting Arduino to develop developing machine. From Arduino IDE helped us to obtain result in serial monitor.

GUI System Design and Implementation: GUI was build in JAVA program language and it has 2 classes that are given in below–

Object class of radar project represent object that it encounters such as distance, target/range and angle/direction of position of object. Distance () method (), angle () method, location () method takes the required value such as distance, angle and makes them on GUI to do simulation.

WORKING: The aim of this project is to calculate the distance position and speed of the object placed at some distance from the sensor. Ultrasonic sensor sends the ultrasonic wave in different directions by rotating with help of servo motor. This wave travels in air and gets reflected back after striking some object. This wave is again sensed by the sensor and its characteristics is analysed and output is displayed in screen showing parameters such as distance and position of object. Arduino IDE is used to write code and upload coding in Arduino and helps us to sense position of servo motor and posting it to the serial port along with the distance of the nearest object in its path. The output of sensor is displayed with the help of Arduino software to give final output in display screen

Figure 14: LCD Display Output

GUI System Testing: Graphical User Interface Testing (GUI) Testing is the process for ensuring proper functionality of the graphical user interface (GUI) for a specific application. GUI testing generally evaluates a design of elements such as layout, colors and also fonts, font sizes, labels, text boxes, text formatting, captions, buttons, lists, icons, links, and content. GUI testing processes may be either manual or automatic and are often performed by third-party companies, rather than developers or end users.

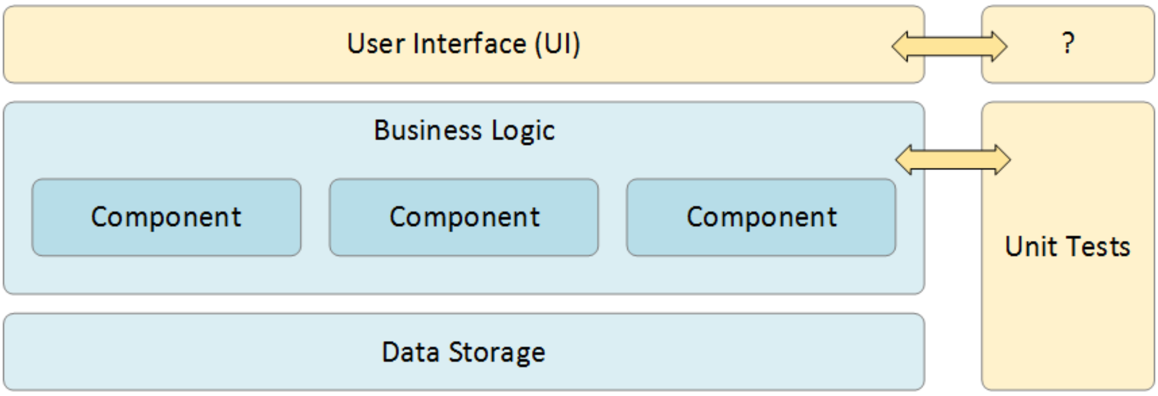

Figure 15: GUI System Testing

Software Design Implementation: The programming language was required for the construction of this system. The Arduino IDE software was used to program the microcontroller. The Arduino IDE software is a free, open-source program that allows you to edit, develop, and upload Arduino code. The Arduino IDE software is free and open-source, and it is used to compile programs for microcontrollers. The C programming language was used to write the code for this app. The void setup (), which is identified as program preparation and runs only once, is the most important section of the coding. Another component is a void loop (), which serves as the program's execution. Figure depicts the Arduino IDE interface, where all codes are typed and subsequently uploaded after compilation.

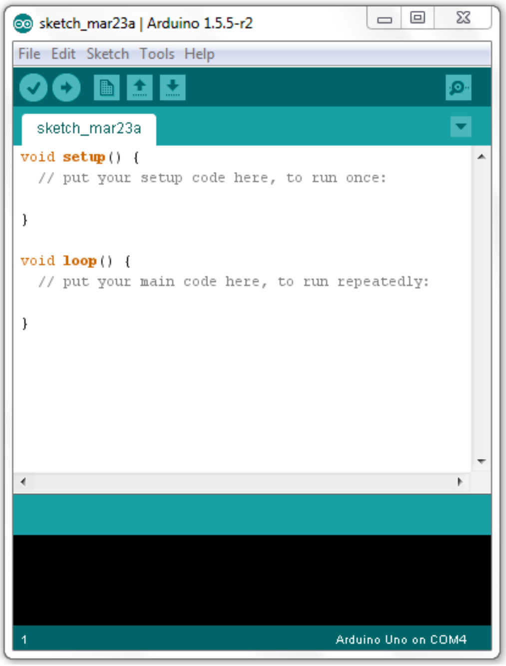

Figure 16: Arduino IDE interface

4 Results and Discussion

During the implementation of the experiment, the serial monitor continuously produced data. There were in total of 7 data sets collected for evaluation and validation checking, as shown in Table 1. The result shows whether the object is static or moving. If the object is moving towards the radar then it produces a negative value and vice versa. If the object is static, then the speed is zero. With this, the system is able to locate a moving object. Table 1 shows the results of a non-metal square 3D object. Object distance was increased with various speed to observe the validity of algorithm. The serial monitor output shows the four important parameters speed, distance, angle and pulse duration.

OBSERVATION OF OBJECT IN DIFFERENT ANGLE, DISTANCE

Angle (degree)	Distance (cm)	Travelling time (Microseconds)
42	6	383
62	9	551
63	10	597
81	12	740
79	13	777
86	14	835
22	15	904

TABLE 1

RANGE DETECTION OF PROPOSED RADAR SYSTEM AT DIFFERENT ENVIRONMENT

Range criteria for Ultrasonic sensor (HC-SR04)	Environment	Range
Maximum range	Inside the room	366cm
Maximum range	Inside the room	2cm
Maximum range	Outside the room	251cm

TABLE 2

Table 2 shows the range detection capacity in changed environments. For the same setup, it showed different values when it was inside the room and when it was outside the room. It is important to explore maximum and minimum range of proposed radar system in different environments.

ACCURACY MEASUREMENT OF DIRECTION OR ANGLE (DEGREE)

Actual direction (degree)	Servo indicated direction (degree)	Efficiency (%)
10	23	98.70%
40	53	99.68%
50	59	99.82%
85	86	99.99%
95	90	100%
110	109	100%
130	129	100%

TABLE 3

Table 3 is constructed from the data taken from servo reading and the actual value of the measured angle for the square metal object. Efficiency is also calculated for each data set to see the nature of response.

RADAR SYSTEM PERFORMANCE EVALUATION AGAINST DIFFERENT SHAPE OF OBJECTS

Object type	Ultrasonic distance	Actual distance	Efficiency
Square shape object (height=14cm, length =7.5cm)	18 cm 1046 cm	18 cm 1 cm	100% Undefined
Cylindrical metal object	19cm	18cm	94.44%
Square shape (height=4.5cm, length=2.5cm)	18cm 19cm	18cm 18.5cm	100% 97%
Square shape (height=3.4cm, length=1.5cm)	18cm	18cm	100%

TABLE 4

Table 4 evaluates the object direction and the angle error distortion. Table 4 is important to show the performance of the radar against different shapes and sizes. Small object, medium object and large object were used in this experiment. Table 4 shows that the proposed radar system was unable to detect small objects and the accuracy decreases with the decrement of size and shape.

Visual outcome observation: Figure was taken in the movement of the radar when the started to move by the servo motor. Where radar finds an obstacle, and an object is detected. By using coding, arc line and distance line were drawn. The code continuously took the value from a serial port. If there was no object detected. At the bottom of the screen, it is showed that angle was 164 degree and distance was 12.09 cm. The sketch was done for 0 degree to 180 degrees.

Figure 17: The result of system is represented by LCD Display, short distance, angle view

Discussion: Ultrasonic sensor is mostly used to find distances, but the current paper aims to measure three parameters (distance, speed and direction) at the same time. The radar's performance is also evaluated against different objects' shapes and sizes. In Table 4, the novelty and effectiveness of the work can be evaluated by looking at the comparison results of the current study with those of the previous ones. Cost, complexity, efficiency, decremental value of error and simplicity are the key success factors. The proposed system can detect moving object with the speed of 3.00 cm/s as shown in Table 1, which is similar to what has been done in previous research. In Table 2, what makes differences in the maximum range inside (366 cm) and outside of the room (251 cm) is the soundwave's speed as influenced by the environment parameter. For the same ultrasonic distance of 5 cm, a metal object shows 88.88% efficiency and a non-metal object shows 75% efficiency. That means this radar system provides better efficiency for metal objects compared to the non-metal objects. The results in Table 4 are identical to other works with a new numerical analysis done for different shape of objects. Table 4 to show that ultrasonic radar responds better to a square-shaped object than a cylindrical-shaped object. When a cylindrical object is very close to the sensor, it fails to detect it. The best identification is when the object is big. The accuracy of small object and cylindrical object identification started to decrease after 8 cm distance and totally fails to detect when the distance reaches 10 cm. The radar is unable to detect small objects like LEDs in any distances. The connection setup also fails to differentiate between two different objects; and detect object size of unknown object. Future studies will benefit from examining these areas.

Application:

1. Obstacle Detection and Avoidance: Ultrasonic radar systems can be used in autonomous robots or drones to detect obstacles and avoid collisions.
2. Security and Surveillance: These systems can be deployed as intrusion detection systems, scanning for motion or objects in a restricted area.
3. Automotive Parking Systems: Ultrasonic sensors are widely used in cars for proximity detection to assist in parking.
4. Home Automation: Motion detection for lighting control or alarm systems.
5. Medical Field: Similar technology can be applied in medical imaging systems (though using higher frequencies for more precision).
6. Water Level Monitoring: Ultrasonic sensors are used to monitor the level of liquids in tanks or reservoirs by measuring the time it takes for sound waves to bounce back from the surface of the liquid.
7. Robotics: Robots use ultrasonic sensors for navigation and collision avoidance, enabling them to see their environment through sound waves.

5 Comparison

When comparing ultrasonic radar projects, it's helpful to evaluate different aspects such as functionality, design, cost, complexity, and potential applications. Below is a comparison framework for several key types of ultrasonic radar or ranging systems, each with different capabilities.

<u>Basic Ultrasonic Distance Measurement (Simple Radar):</u>

- ✓ Purpose: Measure the distance to an object using ultrasonic waves.
- ✓ Components: Ultrasonic sensor (e.g., HC-SR04), microcontroller (e.g., Arduino, Raspberry Pi).
- ✓ Principle: The sensor sends out a high-frequency sound wave and measures the time it takes for the wave to bounce back from the object.
- ✓ Pros:
  a. Low cost
  b. Easy to implement and program
  c. Ideal for basic distance sensing and obstacle detection
- ✓ Cons:
  a. Limited range (typically up to 4-5 meters)
  b. Low accuracy at long distances
  c. Limited angular coverage (typically just one direction)
- ✓ Applications: Obstacle avoidance in robotics, simple object detection, level sensing in tanks, or distance measurement in short-range environments.

<u>Multiple Sensor Array Ultrasonic Radar:</u>

- ✓ Purpose: Measure distance and detect objects in a broader area by using multiple ultrasonic sensors.
- ✓ Components: Multiple ultrasonic sensors, microcontroller, servo motors (for rotating sensors), software for data fusion.
- ✓ Principle: An array of ultrasonic sensors is placed to cover different angles. The system can detect the distance and position of objects in a broader area (e.g., 180° or 360° field of view).
- ✓ Pros:
  a. Broader area coverage (more sensors = wider detection field)
  b. Can create rudimentary 2D radar maps
  c. Improved object localization by triangulation or data fusion
- ✓ Cons:
  a. Higher complexity in design and programming
  b. Increased cost due to multiple sensors
  c. Possible interference between sensors (cross-talk)
- ✓ Applications: Robotic navigation, parking assistance systems, 2D mapping for autonomous systems, security systems.

Rotating Ultrasonic Radar System:

- ✓ Purpose: Create a dynamic radar system with a rotating sensor to provide full 360° coverage.
- ✓ Components: A single ultrasonic sensor mounted on a rotating platform (e.g., servo or stepper motor), microcontroller, software to rotate the sensor and process data.
- ✓ Principle: The ultrasonic sensor rotates, sending out waves in all directions. It measures distance to objects around it, and the rotating motion allows for full coverage.
- ✓ Pros:

  a. 360° detection coverage

  b. More effective at mapping an area or detecting moving objects

  c. Can track objects in real-time if combined with motion processing
- ✓ Cons:

  a. Mechanical parts introduce wear and tear, leading to potential reliability issues

  b. Slower detection time due to rotational movement

  c. Requires a complex control system to handle rotation and distance calculation
- ✓ Applications: Autonomous vehicle systems, surveillance, area scanning, search-and-rescue missions.

3D Ultrasonic Radar System (Advanced):

- ✓ Purpose: Create a more sophisticated radar system capable of generating 3D maps of the environment using multiple sensors.
- ✓ Components: Multiple ultrasonic sensors, rotating or fixed sensors in a grid, microcontroller or a powerful processor, software for 3D data processing.
- ✓ Principle: Multiple sensors are arranged in a grid or a configuration that allows for full 3D coverage. These sensors can be fixed or rotating, and the distance data from all sensors are combined to form a 3D representation of the environment.
- ✓ Pros:

  a. High accuracy and resolution in 3D space

  b. Suitable for complex environments and advanced robotic systems

  c. Provides real-time environmental mapping
- ✓ Cons:

  a. Very high complexity

  b. Expensive due to multiple sensors and advanced processing power

  c. Difficult to implement without advanced algorithms for data fusion
- ✓ Applications: Advanced robotics, autonomous vehicles, industrial inspection, and 3D scanning of environments.

Ultrasonic Radar with Signal Processing (Noise Filtering):

- ✓ Purpose: Enhance the basic ultrasonic radar system with advanced signal processing techniques to improve reliability and accuracy.
- ✓ Components: Standard ultrasonic sensors, microcontroller or signal processor, software algorithms for noise filtering (e.g., Kalman filters, FFT).
- ✓ Principle: Standard ultrasonic distance measuring techniques are combined with advanced software to filter out background noise or signal interference, improving accuracy and stability.
- ✓ Pros:
  a. Better performance in noisy environments
  b. Higher accuracy and robustness in varying conditions
- ✓ Cons:
  a. Increased computational overhead
  b. May still struggle with extreme interference or poor signal propagation
- ✓ Applications: High-accuracy systems, noise-sensitive environments, autonomous robots in complex settings.

Summary Comparison:

Feature	Basic Ultrasonic Radar	Multiple Sensor Array	Rotating Ultrasonic Radar
Cost	Low	Medium	Medium to High
Range	Short (2cm to 4m)	Medium (up to 10m)	Medium (up to 10m)
Resolution	Low	Medium	Medium to High
Complexity	Simple	Medium	Medium
Durability	High	High	Moderate (moving parts)
Application Examples	Obstacle detection, distance measurement	Mapping sonar	360-degree scanning sonar

6 Conclusions

Radar is a remarkable invention from various perspective, including measuring velocity and calculating distance. The proposed radar system had only small error when calculating distances and can predict velocity accurately. When the object is static, the serial-monitor of the radar system shows the speed is 0 cm/s. When the object moves, the number goes along with it. Direction of the object was also observed with the best efficiency. The radar system detected the square and large cylindrical objects more precisely than small objects. The object size and distance are important variables in the shape analysis. Overall, the system can provide 100% efficiency unless of the distance is less than one centimeter and the size is extremely small. However, it important to note that the experiment was done in a constant environment.

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Appendix A

The Arduino code for the system is highlighted below;

```
#include < Servo. h>
#include <LiquidCrystal_I2C.h>

Servo my servo;
LiquidCrystal_I2C lcd(0x27,16,2); // Creates an LCD object. Parameters: (rs, enable, d4, d5, d6, d7)

int pos = 0;
const int trig Pin = 7;
const int echo Pin = 8;
const int motor = 6;
const int buzzer = 2;
const int ledPin1 = 3;
const int ledPin2 = 4;
float distance Cm, Distance Sec, duration;

void setup () {
my servo. attach(motor); // attach le Servo motor a la pin number 11
lcd. Begin (); //
pin Mode (trig Pin, OUTPUT);
pin Mode (echo Pin, INPUT);
pin Mode (buzzer, OUTPUT);
pin Mode (ledPin1, OUTPUT);
pin Mode (ledPin2, OUTPUT);
Distance Sec=20;

}

void loop () {
for (pos = 0; pos <= 180; pos += 1)
My servo. write(pos);
Digital Write (trig Pin, LOW);
```

```
Delay Microseconds (2);
Digital Write (trig Pin, HIGH);
Delay Microseconds (10);
Digital Write (trig Pin, LOW);

duration = pulse In (echo Pin, HIGH);
distance Cm= duration*0.034/2;
if (distance Cm <= Distance Sec)
{

If (distance Cm <= Distance Sec/2)
{

Tone (buzzer, 100); // Send 1KHz sound signal...
Digital Write (ledPin1, LOW);
Digital Write (ledPin2, HIGH);
Delay (700);
No Tone(buzzer); // Stop sound...
Lcd. set Cursor (0,0);
Lcd .print ("Distance: ");
Lcd .print (distance Cm);
Lcd .print (" cm ");
Delay (10);
Lcd. Set Cursor (0,1);
lcd. Print ("Angle: ");
lcd. Print (pos);
lcd .print (" deg ");
delay (2000);
}
else
{
Digital Write (buzzer, HIGH);
Digital Write (ledPin2, LOW);
Digital Write (ledPin1, HIGH);
Delay (100);
Digital Write (buzzer, LOW);
lcd. Set Cursor (0,0);
```

```
lcd. Print ("Distance: ");
lcd. Prin t(distance Cm);
lcd. Print (" cm ");
delay (10);
lcd. Set Cursor (0,1);
lcd .print ("Angle: ");
lcd. Print (pos);
lcd.  Print (" deg ");
delay (2000);
}
}
Else {
digital Write (buzzer, LOW);
digital Write (ledPin1, LOW);
digital Write (ledPin2, LOW);
}

lcd. Set Cursor (0,0);
lcd. Print ("Distance: ");
lcd. Print (distance Cm);
lcd. Print (" cm ");
delay (10);
lcd. set Cursor (0,1);
lcd. Print ("Angle: ");
lcd. Print (pos);
lcd. Print (" deg ");
delay (80);

}
for (pos = 180; pos >= 0; pos -= 1)
digital Write (trig Pin, LOW);
delay Microseconds (2);
digital Write (trig Pin, HIGH);
delay Microseconds (10);
digital Write (trig Pin, LOW);

duration = pulse In (echo Pin, HIGH);
```

```
distance Cm= duration*0.034/2;
if (distance Cm <= Distance Sec)
if (distance Cm <= Distance Sec/2)
{
Tone (buzzer, 100); // Send 1KHz sound signal...
Digital Write (ledPin1, LOW);
Digital Write (ledPin2, HIGH);
Delay (700);
No Tone (buzzer); // Stop sound...
lcd. Set Cursor (0,0);
lcd. Print ("Distance: ");
lcd. print (distance Cm);
lcd. Print (" cm ");
delay (10);
lcd. Set Cursor (0,1);
lcd. Print ("Angle: ");
lcd. Print (pos);
lcd. Print (" deg ");
delay (2000);
}
else
{
Digital Write (buzzer, HIGH);
Digital Write (ledPin2, LOW);
Digital Write (ledPin1, HIGH);
Delay (100);
Digital Write (buzzer, LOW);
Lcd. Set Cursor (0,0);
Lcd .print ("Distance: ");
lcd. Print (distance Cm);
lcd. Print (" cm ");
delay (10);
lcd. Set Cursor (0,1);
lcd. Print ("Angle: ");
lcd. Print(pos);
lcd. Print (" deg ");
delay (2000);
```

```
}
}
Else {
Digital Write (buzzer, LOW);
Digital Write (ledPin1, LOW);
Digital Write (ledPin2, LOW);
}

lcd. Set Cursor (0,0); //
lcd. Print ("Distance: "); //
lcd. Print (distance Cm); //
lcd. Print (" cm ");
delay (10);
lcd. Set Cursor (0,1);
lcd. Print ("Angle: ");
lcd. Print (pos);
lcd. Print (" deg ");
delay (80);
}
```