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Design and Implementation of a Mini Radar System

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Abstract - *The Mini RADAR System is an embedded systems project developed using the STM32 Blue Pill microcontroller, HC-SR04 ultrasonic sensor, SG90 servo motor, LCD display, LED, buzzer, and a Python-based radar visualization interface. The project was initially designed and simulated in Proteus software to verify system functionality and sensor interfacing before implementing the hardware prototype. The system operates by mounting the ultrasonic sensor on a servo motor that continuously scans the surrounding area from 0° to 180° and back. During scanning, the sensor measures the distance of nearby objects using ultrasonic waves. The STM32 microcontroller processes the measured distance and corresponding angular position, displaying the information on an LCD screen in real time. When an object is detected within a predefined threshold distance, visual and audible alerts are generated through an LED and buzzer. The angle and distance data are transmitted to a computer via UART communication using a CP2102 USB-to-TTL converter. A Python-based application receives the serial data and displays detected objects on a real-time radar interface, providing a graphical representation of the scanning process. The developed system is cost-effective, reliable, and suitable for obstacle detection, security monitoring, robotic navigation, and educational demonstrations, highlighting practical embedded system design and real-time visualization techniques.*

Key Words: Embedded Systems, HC-SR04 Ultrasonic Sensor, Mini Radar System, Servo Motor, STM32 Blue Pill.

1. INTRODUCTION

Radar (Radio Detection and Ranging) systems are widely used in defense, aviation, navigation, weather monitoring, robotics, and industrial automation for detecting and tracking objects. Conventional radar systems use electromagnetic waves to determine the position, distance, and movement of objects. However, such systems are often expensive and require complex hardware.

A Mini RADAR System can be developed using low-cost embedded system components to demonstrate the basic principles of object detection and tracking. In this project, an STM32 Blue Pill microcontroller is used as the main processing unit. An HC-SR04 ultrasonic sensor is mounted on an SG90 servo motor, allowing the sensor to scan the surrounding environment by rotating through different angles.

The ultrasonic sensor measures the distance of nearby objects, while the servo motor provides angular positioning. The measured distance and angle data are displayed on an LCD screen and simultaneously transmitted to a computer through UART communication using a CP2102 USB-to-TTL converter. A Python-based radar visualization program processes the received data and displays detected objects on a radar-like graphical interface. Additional alert mechanisms such as LEDs and a buzzer are used to indicate the presence of nearby obstacles.

This project demonstrates the practical application of embedded systems, sensor interfacing, serial communication, real-time data acquisition, and graphical visualization techniques.

Traditional radar systems are costly and complex, making them unsuitable for educational demonstrations and small-scale applications. There is a need for a low-cost and easy-to-implement radar system capable of detecting objects, measuring their distance, and displaying their location in real time. The proposed Mini RADAR System addresses this requirement by utilizing ultrasonic sensing, servo-based scanning, and computer-based visualization. The main objectives of the project are:

1. To design and develop a Mini RADAR System using the STM32 Blue Pill microcontroller.
2. To measure the distance of objects using the HC-SR04 ultrasonic sensor.
3. To rotate the sensor using an SG90 servo motor for environmental scanning.
4. To display angle and distance information on an LCD display.
5. To provide visual and audible alerts using LEDs and a buzzer.
6. To transmit radar data to a computer through UART communication.
7. To develop a Python-based radar visualization interface for real-time object tracking.

2. LITERATURE REVIEW

Qiu et al. (2022) presented a comprehensive review of ultrasonic ranging methods and discussed various pulse-echo distance measurement techniques, signal processing methods, and error compensation algorithms. The authors concluded that ultrasonic ranging provides an economical and reliable solution for short-range object detection in robotics and embedded systems. [1]

Utsha et al. (2021) developed an STM32 microcontroller-based ultrasonic radar system using the STM32F103, HC-SR04 ultrasonic sensor, SG90 servo motor, and graphical visualization software. Their work demonstrated that the STM32 platform provides higher processing speed, improved PWM control, and smoother radar scanning than conventional Arduino-based implementations. [2]

Xu (2025) proposed an ultrasonic detection system based on the STM32 microcontroller for real-time obstacle detection. The study utilized timer-based pulse measurement and embedded signal processing to improve distance measurement accuracy and demonstrated stable system performance under different operating conditions. [3]

Assem and Abdelmoneim (2025) presented a miniature radar system for critical mission applications. Their research focused on designing a compact radar platform capable of reliable object detection while reducing hardware complexity and system cost, making it suitable for embedded surveillance applications. [4]

Gupta et al. (2023) developed a portable ultrasonic radar using an ultrasonic sensor, servo motor, and embedded controller. The proposed system continuously scanned the surrounding environment and displayed detected objects on a radar interface, demonstrating reliable performance for obstacle detection and educational applications. [5]

Zapata (2025) investigated the calibration and performance analysis of the HC-SR04 ultrasonic sensor for radar-based distance measurement. The study reported that proper calibration significantly improves measurement accuracy while noting that environmental factors such as temperature and humidity influence ultrasonic sensor performance. [6]

The NIELIT Chennai project (2025) implemented an STM32-based ultrasonic radar system using the STM32 Blue Pill, HC-SR04 sensor, SG90 servo motor, UART communication, and Processing software. The project successfully demonstrated real-time environmental scanning, serial communication, and graphical radar visualization for educational and automation applications. [7]

A microcontroller-based ultrasonic radar project (2022) presented the implementation of a radar-like object detection system capable of measuring distance and scanning nearby obstacles using ultrasonic sensing. The authors concluded that embedded radar systems provide a cost-effective solution for robotics and surveillance applications. [8]

Simić et al. (2024) presented an ARM STM32-based parking assistance system that integrated ultrasonic sensing, motor control, and display modules for distance measurement. The study demonstrated that STM32 microcontrollers provide reliable real-time performance for embedded sensing and automotive assistance applications. [9]

Kumari et al. (2017) proposed an IEEE 802.11ad-based radar system for joint vehicular communication and radar sensing. Their work demonstrated the growing importance of radar technology in autonomous vehicles and highlighted future opportunities for integrating advanced radar systems with intelligent transportation applications. [10]

3. METHODOLOGY

The Mini RADAR System is designed to detect and track nearby objects using ultrasonic sensing and servo-based scanning. The system consists of an STM32 Blue Pill microcontroller, HC-SR04 ultrasonic sensor, SG90 servo motor, LCD display, LED indicator, buzzer, and a Python-based radar visualization interface. The flow chart of the system is shown in Fig.1.

The HC-SR04 ultrasonic sensor is mounted on the servo motor, which continuously rotates between 0° and 180°. During rotation, the ultrasonic sensor emits ultrasonic waves and receives the reflected signals from nearby objects. The STM32 microcontroller calculates the distance of the detected object based on the time taken for the echo signal to return.

The measured distance and corresponding angular position are displayed on the LCD screen and simultaneously transmitted to a computer through UART communication. A Python application running on the computer receives the data and displays it on a radar-like graphical interface. An LED and buzzer provide alert indications whenever an object is detected within a predefined distance range.

3.1 Working Principle of the Mini Radar System

The Mini Radar System is a microcontroller-based object detection and monitoring system that simulates the operation of a real radar using ultrasonic sensing technology. Instead of using radio waves like conventional radar systems, it uses ultrasonic sound waves to detect the presence, distance, and position of objects within its scanning range.

1. System Initialization

When the system is powered on, the STM32 microcontroller initializes all connected components, including the ultrasonic sensor, servo motor, and display interface. The servo motor is set to rotate within a predefined angular range, typically from 0° to 180°, enabling the sensor to scan the surrounding environment.

2. Ultrasonic Wave Transmission

The ultrasonic sensor (HC-SR04) consists of a transmitter and a receiver. The transmitter emits ultrasonic sound waves at a frequency of approximately 40 kHz, which is beyond the range of human hearing. These waves travel through the air until they encounter an object.

3. Echo Reception and Distance Measurement

When the emitted ultrasonic waves strike an object, they are reflected back toward the sensor. The receiver captures the reflected waves (echo). The STM32 measures the time interval between the transmission and reception of the ultrasonic pulse.

The distance to the object is calculated using the formula:

$$\text{Distance} = (\text{Speed of Sound} \times \text{Time}) / 2$$

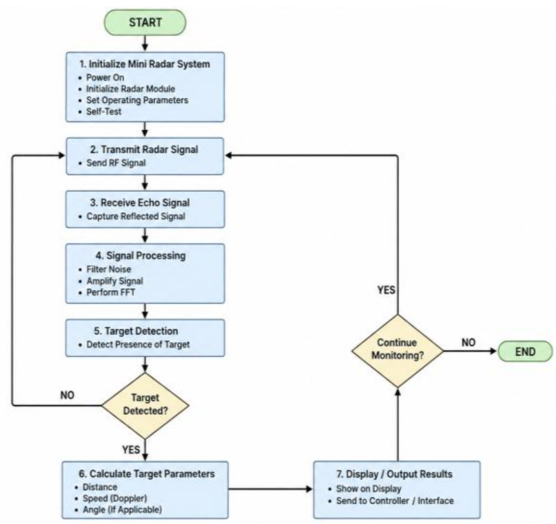

Fig -1: Flow chart of Mini Radar System

The division by 2 is necessary because the measured time represents the round-trip journey of the sound wave (from sensor to object and back).

Considering the speed of sound in air is approximately 343 m/s:

$$\text{Distance (cm)} = \text{Time } (\mu s) \times 0.0343 / 2$$

4. Scanning Mechanism

The ultrasonic sensor is mounted on a servo motor that rotates through a specified angle range. As the servo moves, the sensor continuously measures distances at different angular positions.

For example:

- 0° → Distance measurement taken
- 10° → Distance measurement taken
- 20° → Distance measurement taken
- 180° → Distance measurement taken

This process creates a two-dimensional scan of the surrounding area.

5. Data Processing by STM32

The STM32 collects two important parameters:

1. Angle of the servo motor
2. Distance measured by the ultrasonic sensor

These values are combined to determine the location of an object relative to the sensor. The STM32 continuously processes this information and sends it to a computer through serial communication.

6. Radar Visualization

A graphical interface developed using software such as Processing IDE receives the angle and distance data from the STM32. The software plots the detected objects on a radar-like display.

The display typically includes:

- A rotating scanning line
- Circular distance markers
- Angular reference lines
- Object indicators showing detected targets

As the sensor scans, objects appear on the screen at their corresponding positions, similar to the display of an actual radar system.

7. Continuous Real-Time Monitoring

1. The entire process is repeated continuously:
2. Servo rotates.
3. Ultrasonic sensor emits sound waves.
4. Echo is received.
5. Distance is calculated.
6. Data is processed by STM32.
7. Information is displayed on the radar screen.

This enables real-time monitoring of the environment and immediate detection of obstacles or moving objects.

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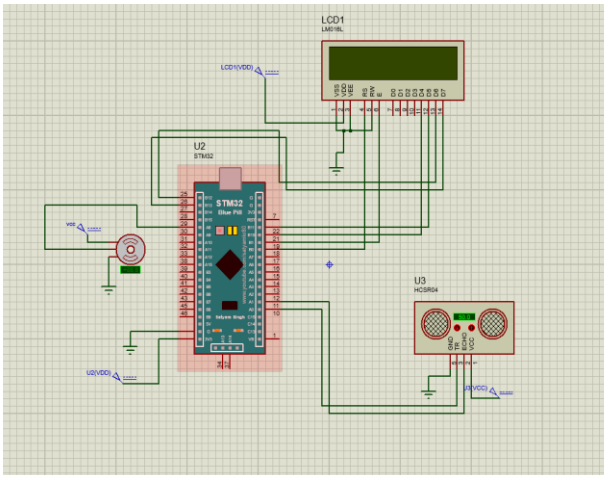

Fig -2: Proteus Implementation of Mini Radar System

3.2 Software and Hardware Implementation

The software implementation of the Mini Radar System is developed using Keil uVision 4 IDE with Embedded C programming for the STM32 Blue Pill (STM32F103C8T6) microcontroller is shown in Fig.2. The software is responsible for controlling the ultrasonic sensor, processing distance measurements, and displaying the results on the LCD module.

At the start of execution, the STM32 initializes the GPIO pins, timer modules, and LCD interface. The HC-SR04 ultrasonic sensor is used to detect objects by transmitting ultrasonic waves and receiving their reflected echoes. The microcontroller generates a trigger pulse to the sensor, which then emits ultrasonic waves toward nearby objects.

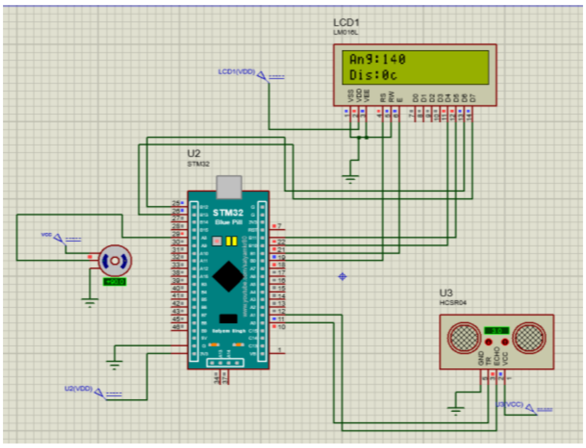

Fig -3: Proteus Output of Mini Radar System

from 0° to 180° and back. At each angular position, the STM32 triggers the ultrasonic sensor to transmit ultrasonic waves and measures the echo return time using its internal timer. Based on the measured echo time, the microcontroller calculates the distance to the detected object using the speed of sound.

When the transmitted waves hit an object, they are reflected back to the sensor. The echo signal is received by the STM32, and the timer module measures the time taken for the signal to return. Based on this time interval, the microcontroller calculates the distance between the sensor and the object using the speed of sound.

The calculated distance is continuously displayed on the 16×2 LCD (LM016L) connected to the STM32. The software repeatedly performs distance measurement and LCD updating, enabling real-time monitoring of objects within the sensing range.

In the implemented circuit, the STM32 Blue Pill serves as the central processing unit. The HC-SR04 ultrasonic sensor is interfaced with the microcontroller through Trigger and Echo pins. The 16×2 LCD is connected to the GPIO pins of the STM32 to display distance values. Whenever an object is detected, the measured distance is processed by the STM32 and instantly shown on the LCD, providing a simple and effective real-time object detection system.

The Hardware Implementation of Mini Radar System is implemented using the STM32 Blue Pill (STM32F103C8T6) microcontroller, an HC-SR04 ultrasonic sensor, an SG90 servo motor, a 16×2 LCD display, an LED, a buzzer, and a CP2102 USB-to-TTL converter. The STM32 Blue Pill acts as the central controller, managing the operation of all connected peripherals. The HC-SR04 ultrasonic sensor is mounted on the SG90 servo motor, allowing it to rotate and scan the surrounding area for objects.

During operation, the STM32 generates PWM signals to rotate the servo motor through a predefined angle, typically The calculated distance and the corresponding scanning angle are displayed on the 16×2 LCD in real time. If an object is detected within a predefined threshold distance, the LED and buzzer are activated to provide visual and audible alerts. Simultaneously, the STM32 transmits the angle and distance data to a computer through UART communication using the CP2102 USB-to-TTL converter.

A Python-based radar visualization interface running on the computer receives the serial data and displays the detected objects on a radar-like graphical screen in real time. This hardware implementation enables continuous environmental scanning, accurate short-range object detection, real-time visualization, and efficient monitoring using a compact and cost-effective embedded system.

3. PROPOSED OUTPUT

The developed Mini Radar System was tested under different indoor conditions to evaluate its performance in detecting nearby objects and displaying their positions in real time in proteus is shown in Fig.3. The system operated successfully, and all hardware and software components functioned as expected throughout the testing process. The HC-SR04 ultrasonic sensor accurately detected objects placed within its effective sensing range of approximately 2 cm to 400 cm.

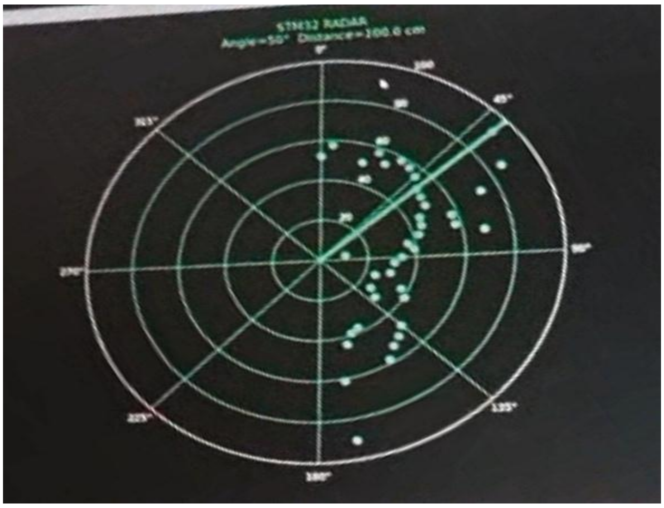

Fig -4: Real-Time Radar Visualization Output

The measured distances closely matched the actual distances, with only minor variations caused by environmental factors and the sensor's inherent tolerance. The STM32 Blue Pill microcontroller efficiently processed the echo signals and calculated the object distance using timer-based pulse measurement without any noticeable delay.

The SG90 servo motor rotated smoothly between 0° and 180°, allowing the ultrasonic sensor to scan the surrounding environment continuously. At each angular position, the STM32 triggered the ultrasonic sensor, measured the echo time, calculated the corresponding distance, and updated the system in real time. The scanning operation remained stable throughout repeated test cycles, providing consistent coverage of the monitored area.

The 16×2 LCD display successfully showed the current scanning angle and the measured distance, enabling users to monitor the detection process directly on the hardware. Whenever an object was detected within the predefined threshold distance, the LED indicator illuminated, and the buzzer generated an audible alert, confirming the presence of a nearby obstacle.

The measured angle and distance data were transmitted continuously from the STM32 to a computer through UART communication using the CP2102 USB-to-TTL converter. The communication remained reliable, with no significant data loss or transmission errors during testing.

The Python-based radar visualization interface successfully received the serial data and displayed the detected objects on a radar-like graphical interface in real time as shown in Fig.4. The rotating scan line synchronized correctly with the servo motor movement, and the detected objects appeared at their corresponding angular positions and distances on the radar screen. This provided a clear and intuitive visualization of the scanning process.

Overall, the Mini Radar System demonstrated stable, reliable, and continuous operation during multiple testing cycles. The integrated hardware and software successfully performed real-time object detection, distance measurement, serial communication, and graphical visualization, confirming that the proposed system met all the intended design objectives.

4. CONCLUSION

The Mini RADAR System was successfully designed and implemented using the STM32 Blue Pill microcontroller, ultrasonic sensor, servo motor, LCD display, LED, buzzer, and Python-based radar visualization interface.

The system was capable of detecting nearby objects, measuring their distance, and displaying their position in real time. The servo motor enabled continuous scanning of the surroundings, while the LCD display provided angle and distance information. The LED and buzzer generated alerts when objects were detected within a specified range. The Python radar interface successfully visualized the detected objects on a radar-like screen.

The project achieved all the objectives defined at the beginning of the work and demonstrated the practical application of embedded systems, sensor interfacing, serial communication, and real-time data visualization. The developed system is cost-effective, easy to implement, and suitable for educational, security, and short-range object detection applications.

5. FUTURE SCOPE

The mini radar system has considerable potential for future development and practical applications. By integrating advanced sensors such as LiDAR, infrared, or microwave radar modules, the system's detection range and accuracy can be significantly improved. The addition of wireless communication technologies like Wi-Fi, Bluetooth, or IoT modules would enable remote monitoring and real-time data sharing.

The system can also be enhanced with Artificial Intelligence (AI) and Machine Learning (ML) techniques for object recognition, obstacle classification, and intelligent decision-making. Furthermore, the radar display can be upgraded with more sophisticated graphical interfaces and data logging capabilities. Such improvements would make the system suitable for applications in autonomous vehicles, robotic navigation, security and surveillance systems, smart parking solutions, industrial automation, and disaster management. These advancements would transform the mini radar system from an educational prototype into a versatile and intelligent detection system for real-world use.

REFERENCES

[1] Z. Qiu, Y. Lu, and Z. Qiu, "Review of Ultrasonic Ranging Methods and Their Current Challenges," Micromachines, vol. 13, no. 4, Art. no. 520, 2022, doi: 10.3390/mi13040520.

[2] S. G. Utsha, M. S. Rahman, M. A. Hasan, and M. A. Hossain, "STM32 Microcontroller Based Ultrasonic Radar," Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology (BUET), Project Report, 2021.

[3] G. Xu, "Experimental Study on an Ultrasonic Detection System Based on the STM32 Microcontroller," Research Square (Preprint), Aug. 2025, doi: 10.21203/rs.3.rs-7380111/v1.

[4] M. Assem and F. Abdelmoneim, "A Miniature Radar for Critical Mission Application," in Proc. International Conference on Future Technologies for Artificial Intelligence (IC-FTAI), 2025, doi: 10.1109/IC-FTAI62324.2024.10950064.

[5] T. Gupta, B. P. Mishra, A. Dixit, and A. Kumar, "Portable Ultrasonic RADAR," International Journal of Novel Research and Development (IJNRD), vol. 8, no. 5, pp. d679–d683, May 2023.

[6] A. Zapata, "Speed Radar Using HC-SR04 and Arduino: Calibration and Data Analysis," arXiv preprint arXiv:2506.06314, 2025.

[7] "STM32 Microcontroller Based Ultrasonic Radar," NIELIT Chennai, Project Report, 2025.

[8] "Microcontroller Based Ultrasonic Radar," Department of Electrical and Electronic Engineering, Project Report, 2022.

[9] D. Simić, M. Mladenović, and M. Milojević, "Parking System Emulation Based on an ARM STM32 Microcontroller," in Proc. IEEE Student Conference (IEEESTEC), 2024, pp. 67–71.

[10] P. Kumari, J. Choi, N. Gonzalez-Prelcic, and R. W. Heath Jr., "IEEE 802.11ad-Based Radar: An Approach to Joint Vehicular Communication-Radar System," IEEE Transactions on Vehicular Technology, 2017.