Design and Development of an Embedded Autonomous Defense Robotic System

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***Abstract*—The increasing need for unmanned robotic systems that can work in hazardous and unknown environments has driven the development of intelligent obstacle detection and autonomous navigation technologies. This paper presents the design and development of an autonomous defense surveillance and obstacle avoiding robotic system based on Arduino with radar based environmental scanning, real time monitoring and inbuilt alert systems. To achieve continuous ambient scanning with radar-like capabilities in different directions, the engineered robotic platform has two ultrasonic sensors mounted on servo motors. The ultrasonic sensing system continuously measures the obstacle distance and sends the sensing data to the Arduino controller for immediate processing and to control autonomous navigation. The robotic platform autonomously plans collision-free trajectories and performs complex navigation manoeuvres such as forward movement, left and right turns, reverse movement and obstacle avoidance depending on obstacle positions and environment factors. The implemented navigation algorithm allows for efficient operation in unknown and dynamic environments suitable for surveillance applications. The robotic system consists of an I2C LCD module to observe the obstacle distance, navigation status and alert messages in real time. The system incorporates a buzzer based alert system to warn immediately if surrounding obstacles are detected within defined safety thresholds.**

***Index Terms*—Autonomous Robot Defense Surveillance, Obstacle Avoidance, Ultrasonic Sensor, Radar Scanning System, Arduino UNO, Embedded Systems, Internet of Things, Autonomous Navigation, Servo Motor, LCD Monitoring, Buzzer Alert System, Robotics, Embedded Programming, Intelligent Surveillance System.**

I. INTRODUCTION

Recent advances in embedded systems, autonomous robotics, intelligent sensing technologies and surveillance systems have profoundly changed the existing scenario of robotic applications. Autonomous robots are used in defense surveillance, industrial automation, border security, hazardous environment inspection, rescue operations and intelligent transportation systems [1,5] because of their ability to perform efficiently with minimum human intervention. The demand for intelligent robotic platforms that can make autonomous decisions and monitor environments is increasing and thus, a significant amount of research on obstacle detection, navigation control, and design of embedded robotic systems has been carried out. A good obstacle avoidance system allows a robot to sense nearby objects, to evaluate environmental elements and to manoeuvres safely without collisions [1, 8,10].

The intelligent robotic systems having the ability of autonomous navigation and environmental sensing are becoming more and more important for modern surveillance and monitoring applications. Ultrasonic sensing has been proved to be a good solution for object detection and distance measurement because of its low cost, small size, easy interface and reliable performance. Ultrasonic sensors work by transmitting ultrasound waves towards an object and using the reflected echo signal to find the distance to the obstacle. These sensors are widely used in autonomous robots, radar monitoring systems, intelligent vehicles, and embedded navigation

platforms [6,11,12]. Servo motor-based radar scanning systems enable multi-directional scanning and surveillance of objects, thus broadening the environmental sensing capabilities of autonomous robots [11,13]. Ultrasonic sensors mounted on servo motors are used to continuously rotate the sensors to the left, centre and right in order to detect any obstacles in the vicinity and to determine the safe passage in radar based robotic systems. This radar-like scanning system complements its autonomous decision-making and further improves the robot's capability of performing effectively in complex environments. This paper discusses the design and development of an Arduino based autonomous defence surveillance and obstacle avoiding robotic system. The system consists of radar based environmental scanning, real time monitoring and embedded alert system. The high-tech robotic platform employs two ultrasonic sensors mounted on servo motors to scan the environment continuously and detect obstacles in different directions. The sensing data received is sent to the Arduino controller to process and self-govern the navigation in real time. The system continuously senses the environment around it and automatically decides a collision free trajectory taking into account the available space on the left, right and front. The robot can move forward autonomously, turn left and right, move backwards and perform intelligent obstacle avoidance manoeuvres [2,4,10] using the evaluated distance and obstacle position. The implemented navigation algorithm allows the robotic platform to work efficiently in unknown, unstructured environments suited for surveillance applications. To improve the monitoring capabilities and interaction between the human and the machine, an I2C LCD display module is embedded into the robotic system to provide real time visualization of object distance, status of navigation and warning messages [20]. The buzzer alert system is used to produce sound signals when obstacles are detected in a specific safety range [21].

Feature	Description
Navigation Type	Autonomous
Obstacle Detection	Ultrasonic sensing
Environmental Monitoring	Radar-based scanning
Monitoring System	I2C LCD display
Alert Mechanism	Buzzer indication
Controller	Arduino UNO
PCB Design	Autodesk EAGLE
PCB Fabrication	In-house fabricated
Surveillance Capability	Real-time monitoring

Table 1 Proposed Defense Surveillance Robotic Platform

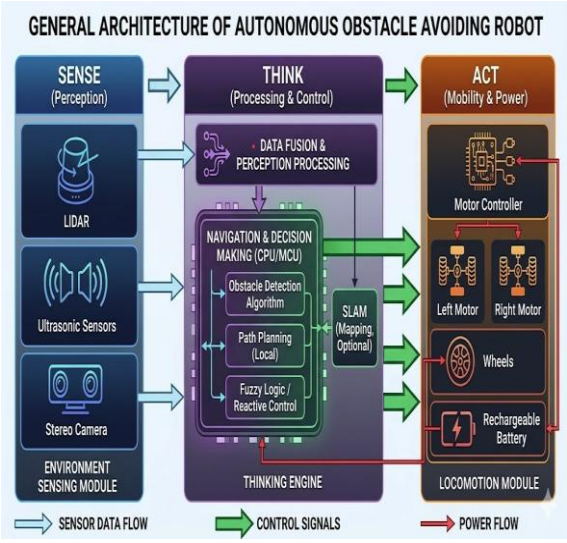


Figure 1General Architecture of Autonomous

The system is designed to use ultrasonic sensors, radar scanning of the environment, real time monitoring on LCD, buzzer alert and in-house PCB manufacturing. The engineered robotic platform is designed for autonomous navigation and surveillance in unknown cluttered environments. The system of advanced robotic device monitoring is based on radar enhanced ultrasonic environmental scanning. Two ultrasonic sensors are mounted on servo motors to scan the environment in the left, center and right directions to sense the surrounding objects and track the position of obstacles [11,13]. The ultrasonic sensing system uses the ultrasonic echo reflection principle to continuously measure the proximity of surrounding objects and transmits the collected data to the Arduino controller for instant processing and informed decision making. The radar based scanning operation allows the robotic platform to identify collision free travel pathways and operate independently in dynamic situations. When the system sees an obstacle ahead of it, it looks to the space on the left and the right and chooses the safer side to pass through. The robot is more efficient at surveillance and monitoring tasks with the enhanced

navigation system. The overall operational framework of the proposed defense surveillance robotic platform is as follows:
Environmental → scan → Detect obstacles → Analyze distances → Choose path → Navigate

The robotic platform uses an I2C LCD display module [20] to monitor in real-time the object distance, scanning direction and navigation status. The LCD constantly shows important operating data such as distance to obstacle, direction to obstacle, warning conditions and navigation options. This monitoring system enhances operator awareness and surveillance efficiency.

II. LITERATURE REVIEW

Literature review is an important part of research. It provides a complete knowledge of previous studies, existing methodology, technical innovations, limitations and research gaps related to the current research [1-5]. A detailed literature review helps the researchers in identifying the contemporary trends in autonomous robots, obstacle detection systems, radar-based environment scanning, embedded monitoring systems and defense surveillance technologies.
In recent years, autonomous robotic systems have attracted great attention in defense surveillance, industrial automation, hazardous environment inspection, border security, and intelligent navigation applications due to their ability to operate with minimum human interaction [1,5]. Researchers have investigated many technologies related to obstacle avoidance, ultrasonic sensing, autonomous navigation, radar scanning, embedded monitoring systems and PCB based robotic implementation [1,21].
Existing Work on Autonomous Navigation System- Autonomous navigation systems are crucial to intelligent robotic applications, as they enable a robot to independently evaluate the conditions of the environment, and to plan safe paths for its movements [2,4,10].

1. Ameen and Vokhidov [4] have suggested an autonomous mobile robotic navigation system for intelligent tracking and navigation applications.
2. Shahi et al. [5] developed a low-cost intelligent robotic platform with PID based navigation control and ultrasonic obstacle detection
3. Kumar and Singh [10] proposed a navigation system to monitor the environment and avoid obstacles using ultrasonic sensors

Current research on radar based environmental scanning systems- Radar-based environmental scanning is a promising approach to improve environmental awareness and obstacle localization in autonomous robotic systems [11,13].

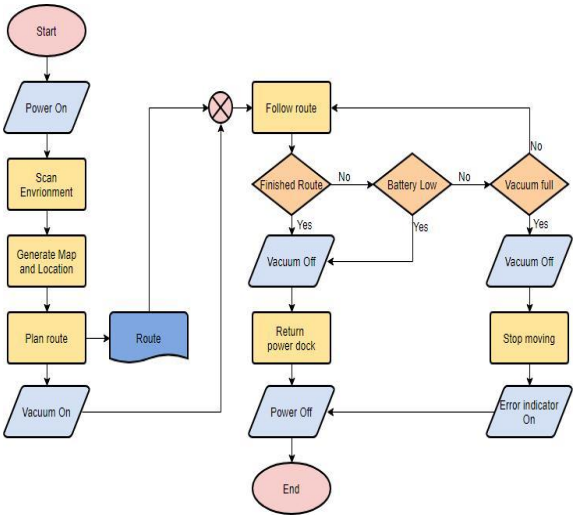
1. Patel and Shah [11] proposed an ultrasonic radar scanning system with a servo motor-controlled sensing architecture for the environmental monitoring
2. Chen et al. [12] proposed a real time ultrasonic scanning method for autonomous robotic systems.
3. Khan and Ali [13] developed a radar scanning system with servos motors for intelligent surveillance applications.

III. METHODOLOGY

The complete methodology and working of proposed Arduino based autonomous defense surveillance and obstacle avoiding robotic system is described in this chapter. The methodology mainly emphasizes on ultrasonic obstacle detection, radar-based environment sensing, autonomous navigation, environment monitoring, LCD surveillance operation, buzzer alarm mechanism and embedded control architecture of the developed robotic platform [1,21]. The proposed system continuously scans its environment, detects nearby obstacles, conducts radar-based environmental evaluations, detects safe navigation routes and autonomously manoeuvres robots without constant human supervision. The robot system uses a hybrid sensing and navigation architecture in which the ultrasonic sensors continuously scan the nearby objects and provide information about the environment to the Arduino controller. The controller analyses obstacle distance data, environmental assessments, and determines safe moving trajectories and regulates robotic navigation operations accordingly. The methodology integrates sensor technologies, radar scanning mechanisms, autonomous movement control and embedded monitoring architecture into an intelligent robotic

system for defense surveillance and hazardous environment applications. The robotic platform always executes environmental scanning based on radar exploiting a servo motor assisted ultrasonic sensor architecture [11,13]. When obstacles are detected in front, the controller makes an independent judgment to the distances of left or right obstacles and chooses the safest way to go through. The integrated LCD monitoring system continuously displays the ambient sensing data and navigation status. The buzzer alert mechanism generates warning signals when it senses close impediments within defined safety parameters [20, 21]. The proven approach significantly improves:

- Environmental monitoring capabilities
- Obstacle localization performance
- Autonomous Navigation Intelligence
- Ability to avoid collisions
- Monitoring of surveillance efficiency
- Dependability of embedded systems



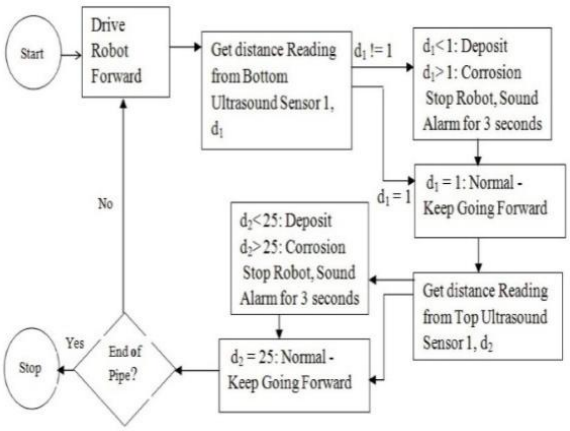


Figure 2 Full Methodology of the Proposed Robotic System.

Embedded Programming Methodology- The ultrasonic sensors are constantly detecting obstacles around it and sending the environmental sensing data to the Arduino controller. The controller processes the data of obstacle distance and does the radar based environmental scanning by servo motor control algorithms. The radar scanning system uses the rotating ultrasonic sensors in left, center and right directions for environment monitoring and obstacle detection tasks. The controller computes safe directions of motion for navigation independently by analyzing the environment and computing the distance to obstacles. The inbuilt software controls

the robot's movement and the LCD surveillance monitoring and buzzer alert functions. The LCD display constantly indicates obstacle distance, navigation direction and warning conditions and the buzzer provides alerts when close obstacles are detected within the set safety parameters.

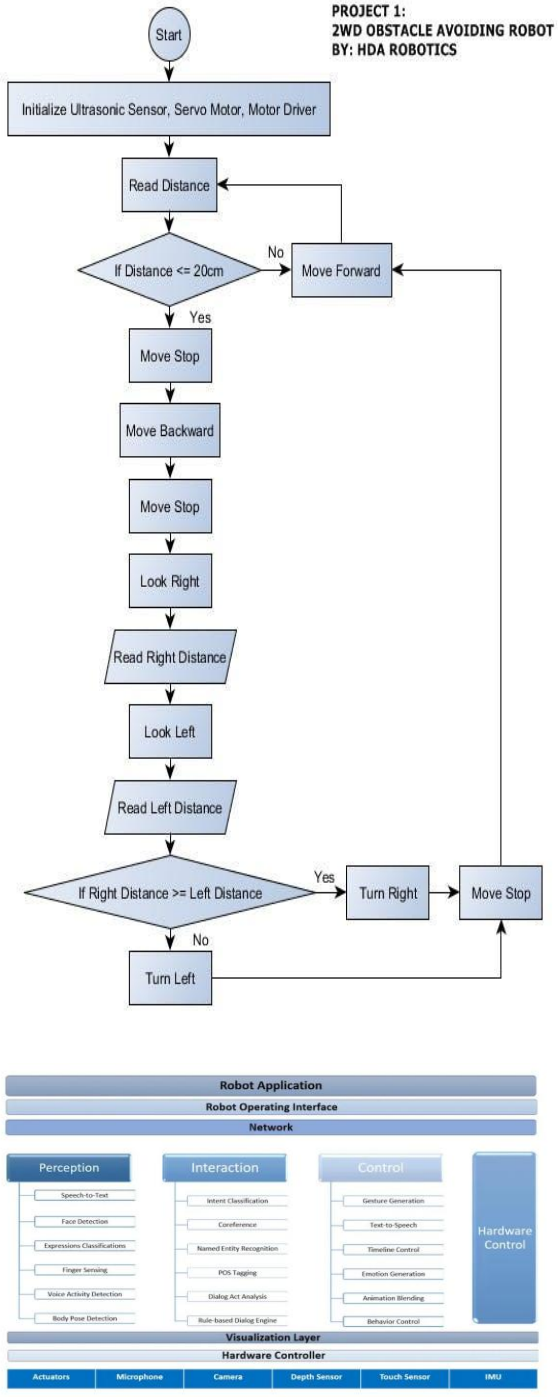


Figure 3 Flow chart of embedded programming

IV. RESULT

This chapter presents the experimental evaluation, performance analysis and operational results of the proposed Arduino based autonomous defensive surveillance and obstacle avoiding robotic system. The designed robot platform was experimentally tested under different environmental conditions for obstacle detection, environment scanning by radar, autonomous navigation, surveillance monitoring with LCD, buzzer alert, embedded software and PCB hardware reliability [1-21]. In practical testing conditions, the robotic platform was able to successfully show autonomous obstacle detection; radar enhanced environmental monitoring, intelligent path selection, collision free navigation, LCD surveillance monitoring, and buzzer alert functionality and embedded PCB hardware implementation. The experimental results confirm that the proposed robotic system can perform reliable autonomous operation, and is suitable for defense surveillance and hazardous environment monitoring applications.

The designed robotic platform was tested in real time obstacle detection environment in laboratory. The ultrasonic sensors regularly identified obstacles in the proximity during the testing period and the radar scanning system with the servo motor performed environmental scans left-center-right. The Arduino controller analyzed the ambient sensing data for autonomous navigation and movement control tasks

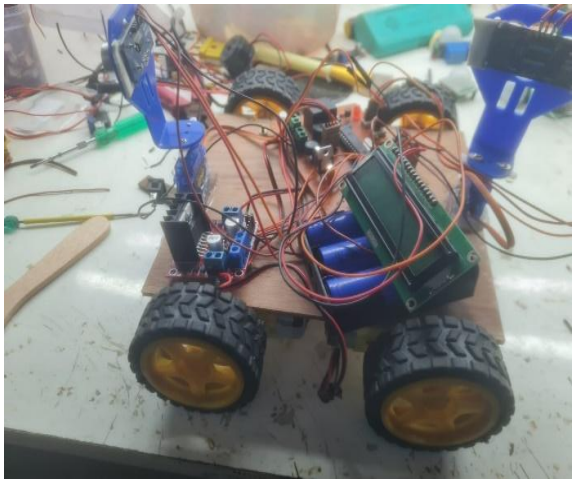
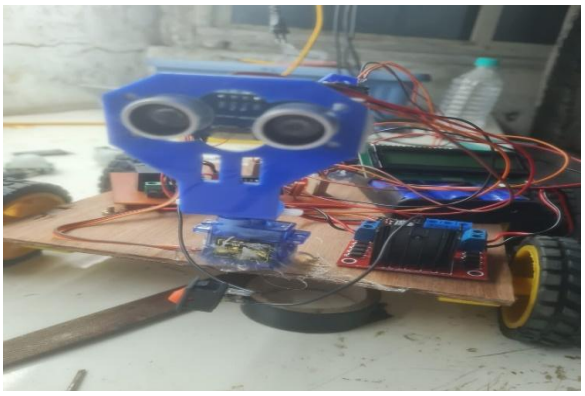


Figure 4 Fully Developed Robotic Platform



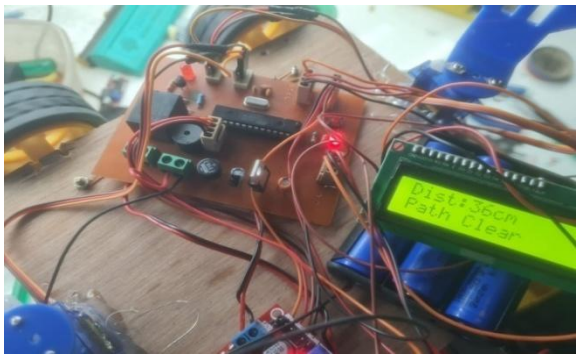


Figure 5 Experimental Evaluation of Developed Robotic Platform

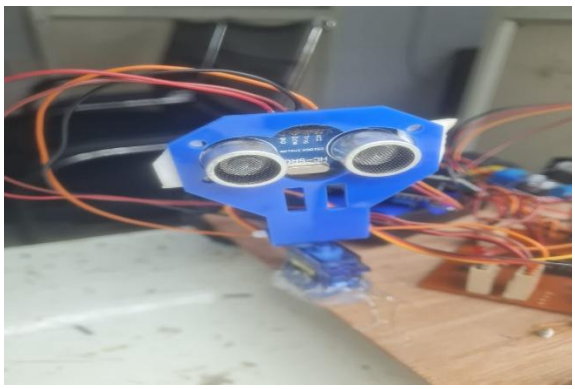


Figure 6 Ultrasonic Sensor Test for Obstacle Detection

Figure 7 Programming Development of a Finalized Task

V. FUTURE SCOPE

The applications and future improvements of the proposed Arduino-based autonomous defensive surveillance and obstacle-avoiding robotic system are described in this chapter. The robotic platform is designed with the use of ultrasonic sensors, radar scanning system, autonomous navigation, LCD monitoring system, buzzer alarm mechanism and PCB based hardware architecture for intelligent robotic functionality. The intelligent obstacle detection and autonomous navigation of the advanced robotic system can be applied in defense surveillance, industrial monitoring, hazardous environment inspection and educational research.

VI. CONCLUSION

This research work has successfully developed and implemented autonomous defense surveillance and obstacle avoiding robotic system using Arduino with

ultrasonic sensing technology, radar based environmental scanning, autonomous navigation architecture, LCD surveillance monitoring system, buzzer alert mechanism and PCB based embedded hardware implementation. The sophisticated robotic platform showed the ability to sense the environment, navigate successfully, avoid obstacles and operate autonomously during the testing trials. The proposed robotic system consists of a servo motor driven radar scanning system, which continuously scans the surroundings, along with two HC-SR04 ultrasonic sensors. The radar based environmental scanning architecture greatly enhanced the environmental awareness, obstacle localization capabilities and the autonomous navigation intelligence of the robotic platform. The robotic system was able to detect any nearby obstacles and find safe routes to navigate on its own during the operational man oeuvres. The designed robotic platform was able to successfully:

- Identification of obstacles
- Measuring distance
- Radar makes ecological monitoring easier
- Search yourself
- No crash
- Surveillance monitoring of LCD
- Activation of buzzer alarm
- Integrated motor controller
- Under real-world test conditions.

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