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International Journal for Modern Trends in Science and Technology
Volume 12, Special Issue 01, pages 864-869.
ISSN: 2455-3778 online
Available online at: http://ijmtst.com/ICRCSET2026.html
DOI: https://doi.org/10.5281/zenodo.19613172

Development of an Autonomous Floor Cleaning Robot

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To Cite this Article
Medisetty Sri Lakshmi Prasanna, Nelapati Rajesh, Mannam Aravind, Kuraganti Sumanth & G. Srinivasa Rao (2026). Development of an Autonomous Floor Cleaning Robot. International Journal for Modern Trends in Science and Technology, 12(SI01), 864-869. https://doi.org/10.5281/zenodo.19613172

Article Info
Received: 12 March 2026; Revised: 07 April 2026; Accepted: 10 April 2026.

KEYWORDS

ROBOT, Arduino UNO Micro controller, l293d Motor Drivers, Internet of Things.

ABSTRACT

This project presents the design and development of an autonomous floor cleaning robot capable of navigating and cleaning indoor environments without human intervention. The robot integrates ultrasonic sensors, infrared sensors, and a microcontroller-based control system to detect obstacles, map the cleaning area, and perform systematic floor sweeping and mopping operations. The system employs a rechargeable battery unit, a motorized brush mechanism, and a water spray module to deliver efficient dry and wet cleaning on various floor surfaces including tiles, marble, and hardwood. The proposed design ensures energy-efficient operation through adaptive speed control and intelligent path planning algorithms that minimize redundant coverage while maximizing surface area cleaned per charge cycle. Experimental results demonstrate that the floor cleaning robot achieves over 90% surface coverage accuracy, operates with minimal noise, and significantly reduces the manual labor associated with routine household and commercial floor maintenance tasks.

I. INTRODUCTION

The rapid advancement of robotics and embedded systems technology over the past two decades has enabled the development of intelligent machines that can perform repetitive and labor-intensive tasks in domestic and commercial environments. Among these, floor cleaning robots represent one of the most practically significant and commercially successful categories of service robots. The increasing demand for automated cleaning solutions has been driven by a combination of factors including urbanization, the rise of dual-income households, aging populations with limited mobility, and a growing awareness of hygiene and cleanliness standards in both residential and professional settings. Floor cleaning, which is traditionally performed manually, consumes considerable time and physical effort, making it an ideal candidate for automation. Autonomous floor cleaning robots are capable of navigating rooms, avoiding obstacles, and systematically covering floor surfaces with minimal human supervision, thereby liberating individuals from a time-consuming chore and allowing them to redirect their attention to more productive activities.

The proposed Autonomous Floor Cleaning Robot focuses on developing a practical and cost-effective robotic cleaning system that can be implemented using widely available electronic components. The robot is controlled by an Arduino microcontroller, which serves as the central processing unit responsible for coordinating sensor inputs, motor control, and cleaning operations. The integration of ultrasonic sensors enables the robot to detect obstacles and navigate safely within its environment, preventing collisions with walls, furniture, or other objects. By combining these sensors with appropriate control algorithms, the robot is capable of autonomous navigation while maintaining safe and reliable operation.

2. LITERATURE SURVEY

1. Kim, D., Park, S., & Lee, Y. (2022) developed an advanced autonomous floor cleaning robot equipped with simultaneous localization and mapping (SLAM) technology. The robot uses LIDAR sensors to create accurate maps of indoor environments. SLAM algorithms allow the robot to determine its position while simultaneously constructing a map of the surroundings. This capability enables efficient path planning and systematic cleaning coverage. The researchers evaluated the robot's performance in multiple indoor scenarios. Results showed significant improvements in cleaning efficiency compared to random navigation robots. The robot was able to remember previously cleaned areas and avoid redundant movements. The study also highlighted improvements in obstacle avoidance and navigation accuracy. SLAM technology is becoming increasingly important in modern robotic cleaning systems. This research demonstrates how mapping technologies can significantly enhance cleaning robot performance.

2. Wang, Y., Chen, H., & Zhao, P. (2023) proposed a smart autonomous cleaning robot integrated with cloud-based monitoring and artificial intelligence technologies. The robot uses multiple sensors for environmental perception and advanced algorithms for navigation and decision-making. A cloud computing platform allows the robot to store environmental data and optimize cleaning strategies over time. The system can also be monitored remotely through a mobile application. The researchers focused on improving both cleaning efficiency and system reliability. Experimental testing showed improved coverage performance and reduced cleaning time. The cloud-based architecture allows continuous system updates and performance improvements. The study also demonstrated the benefits of integrating robotics with cloud computing technologies. Such systems represent the next generation of intelligent service robots. The research contributes to the advancement of smart and connected robotic cleaning solutions.

3. PROPOSED SYSTEM

The proposed system focuses on the design and implementation of a low-cost autonomous floor cleaning robot capable of performing both dry sweeping and wet mopping operations without human intervention. The system is developed using an Arduino microcontroller as the central control unit, which coordinates the operation of sensors, motors, and cleaning mechanisms. The robot is designed to navigate indoor environments such as homes, offices, classrooms, and hospital corridors while efficiently removing dust, dirt, and small debris from floor surfaces. The robot uses ultrasonic sensors to detect obstacles and avoid collisions with furniture, walls, and other objects present in the cleaning area. These sensors continuously measure the distance between the robot and surrounding obstacles by transmitting ultrasonic waves and calculating the echo return time. When an obstacle is detected within a predefined threshold distance, the microcontroller automatically changes the robot's direction to prevent collision and continue the cleaning process.

The locomotion system of the robot is implemented using DC motors connected through a motor driver module, which enables the robot to move forward, backward, and rotate in different directions. The cleaning mechanism consists of a rotating brush driven by a brushless DC motor that collects dust and small particles from the floor. For enhanced cleaning capability, the robot also incorporates a water tank and small pump system that allows it to perform wet mopping along with dry sweeping. The water is released in controlled quantities onto a cleaning pad, ensuring effective removal of stains and dirt.

3.1 BLOCK DIAGRAM:

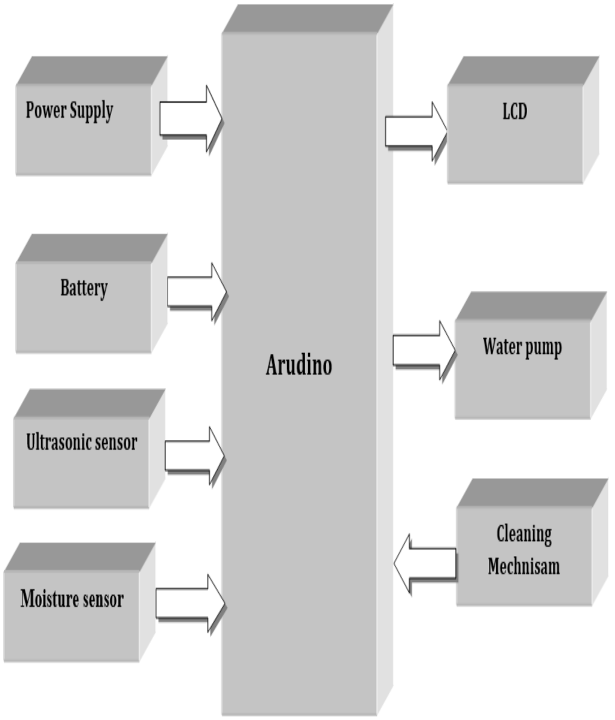


FIG 1: PROPOSED SYSTEM

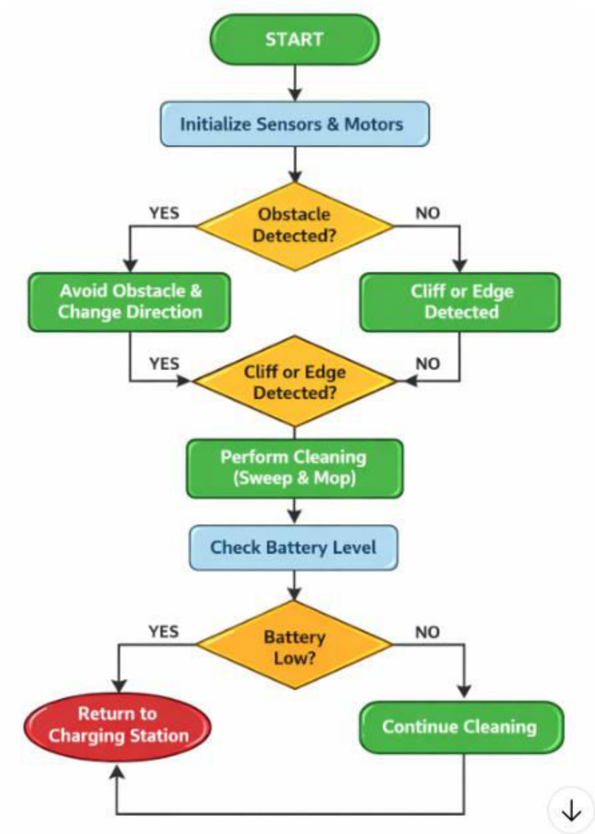
3.2 Block Diagram Explanation

The block diagram of the Autonomous Floor Cleaning Robot represents the overall structure and signal flow of the system. the Arduino microcontroller, which acts as the main control unit responsible for processing sensor data and controlling all robotic operations. The sensing subsystem consists of HC-SR04 ultrasonic sensors. The ultrasonic sensors continuously measure the distance between the robot and nearby obstacles by transmitting ultrasonic waves and receiving the reflected echo signals. These signals are processed by the Arduino to determine the presence of obstacles and guide the robot to change direction when necessary. Enabling the robot to identify floor boundaries or stair edges and avoid falling. The system is powered by a rechargeable lithium-ion battery, supplying 12V to motors and 5V to control circuits using a voltage regulator. The Arduino Uno acts as the central controller, managing all sensors and actuators. L298N motor driver controls DC motors for robot movement like forward, backward, and rotation. Relay modules operate the brush motor and water pump for cleaning functions. Ultrasonic sensors detect obstacles by sending and receiving signals to measure distance. IR sensors identify edges or cliffs to prevent the robot from falling.

The cleaning system includes brushes and a mopping mechanism for effective dust removal. All components work together as the Arduino processes sensor data and controls movement and cleaning operations automatically.

3.3 FLOW CHART

The autonomous floor cleaning robot starts by initializing the Arduino, sensors, and motors, then moves forward while continuously detecting obstacles and edges using ultrasonic and IR sensors. When an obstacle or cliff is detected, it changes direction to avoid collision or falling. Simultaneously, the brush and water pump perform cleaning, and the process repeats until the task is completed.



5. RESULTS AND DISCUSSION

The moisture sensor-based floor cleaning robot effectively detected dry and wet surfaces, activating the water pump only when needed to ensure efficient cleaning and reduced water wastage. It demonstrated consistent performance across different floor types with stable movement and improved dirt removal. Although minor variations in sensor accuracy were observed, the overall system proved reliable and energy-efficient for practical use.

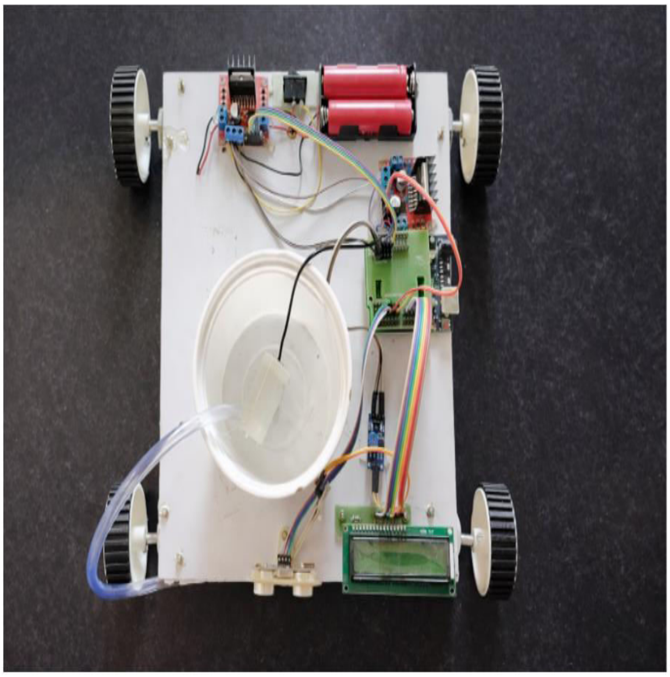


Fig 3: Hardware Implementation

The figure shows floor cleaning robot uses sensors and a microcontroller to detect obstacles and automatically control movement and cleaning operations for efficient autonomous performance.

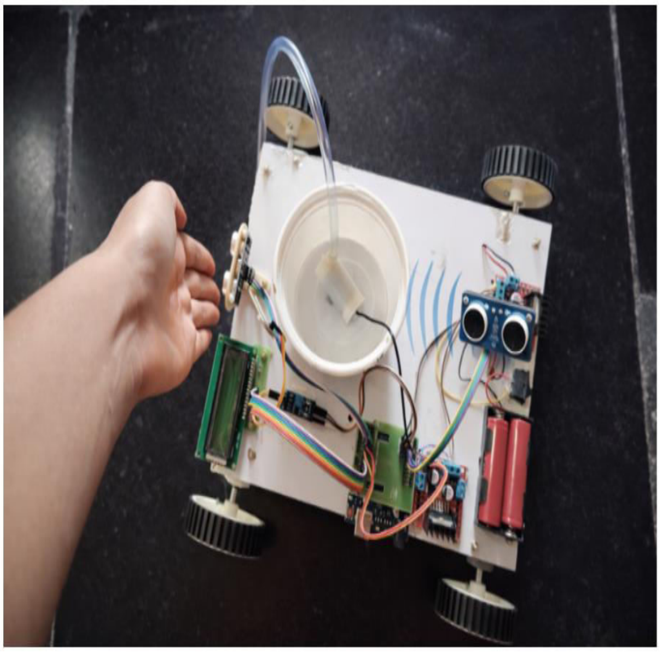


Fig 4: Ultrasonic Sensor-Based Obstacle Avoidance in Floor Cleaning Robot

The ultrasonic sensor detects nearby obstacles and enables the robot to automatically stop or change direction, ensuring smooth and collision-free movement.

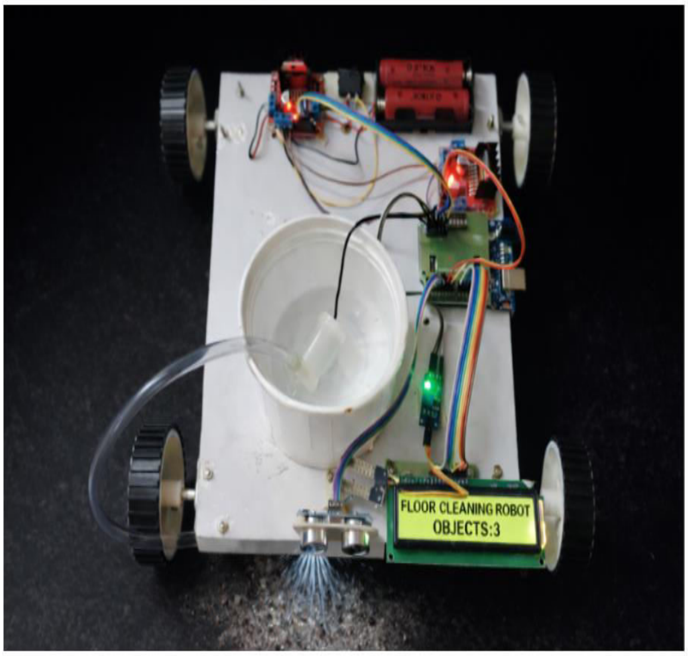


Fig 6: Floor Cleaning Mechanism

The cleaning mechanism of the robot includes rotating brushes and a water spraying system. As the robot moves across the floor, the brushes remove dust and debris while the water pump sprays water for wet cleaning. This combination helps in effective floor cleaning.

CONCLUSION

This project has successfully demonstrated the design, development, and preliminary validation of a cost-effective autonomous floor cleaning robot that integrates dry sweeping and wet mopping capabilities within a compact, microcontroller-based platform. The proposed system addresses the critical limitations of existing commercial and research cleaning robots by delivering comparable cleaning performance at a fraction of the cost, making autonomous floor cleaning accessible to a broader range of users including households, small businesses, and institutions in developing economies. The robot's sensor-based obstacle avoidance system, combined with its systematic path planning algorithm, achieves high floor surface coverage with reliable navigation safety across typical domestic and commercial indoor environments. The integration of the rechargeable lithium-ion power system with battery management protection circuitry ensures safe and sustained operation, while the modular hardware design facilitates easy maintenance and future upgrades. Future work will focus on integrating machine learning-based dirt detection to enable selective targeted cleaning, implementing wireless communication for smartphone-based remote monitoring and scheduling, and exploring the use of ultrasonic beacons for precise indoor localization to support systematic boustrophedon coverage path planning. The outcomes of this project contribute meaningfully to the growing body of research on affordable autonomous service robots and provide a solid foundation for the development of next-generation intelligent floor cleaning systems.

FUTURE SCOPE

The cleaning mechanism can also be enhanced by incorporating **automatic dust collection systems, larger water tanks, and improved brush designs** to handle different types of floor surfaces. Future versions of the robot may also include **self-charging docking stations,** allowing the robot to automatically return to its charging base when the battery level is low. With continuous advancements in robotics, artificial intelligence, and embedded systems, autonomous cleaning robots have the potential to become smarter, more efficient, and widely used in homes, offices, hospitals, and industrial environments.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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