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CleanSight 2.0: An Autonomous Floor Cleaning Robot

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***Abstract*—Maintaining clean indoor floors is a fundamental hygiene requirement, yet doing so manually demands considerable time and physical effort. This paper presents CleanSight 2.0, a low-cost autonomous floor cleaning robot developed for scrubbing indoor surfaces without human involvement. The system is built around an ESP32 DevKit as the primary controller, an HC-SR04 ultrasonic sensor for real-time obstacle detection, an L298N dual H-bridge motor driver for independent wheel control, and a dedicated scrubber motor that keeps the cleaning brush in continuous rotation. Experimental evaluation on tile, marble, and cement floors demonstrated an average cleaning efficiency of 1.09 m²/min and approximately 1.9 hours of battery runtime under normal operating conditions. The proposed design proves that reliable autonomous cleaning can be achieved with accessible, low-cost components, making it viable for residential spaces, classrooms, and small commercial areas as well as an effective educational platform in robotics and embedded systems.**

***Index Terms*—Floor Cleaning Robot; ESP32; Autonomous Navigation; Ultrasonic Sensor; L298N Motor Driver; Obstacle Avoidance; Smart Cleaning System**

I. INTRODUCTION

A clean floor is one of the most basic requirements for a healthy and comfortable living environment. Dust, allergens, and fine particles that settle on floor surfaces over time degrade indoor air quality and pose health risks, particularly in enclosed spaces such as homes, classrooms, and offices. Despite being essential, floor cleaning is a repetitive, time-consuming task that most households and small institutions still carry out manually.

The steady growth of low-cost microcontrollers and sensor modules has made it increasingly practical to automate such domestic tasks at an affordable price. Autonomous floor cleaning robots have gained attention in recent years because they can carry out cleaning operations with little or no human involvement. However, most commercially available systems such as Roomba remain financially out of reach for average households and educational institutions. Student-level prototypes, on the other hand, often trade off reliability for affordability — many lack effective obstacle avoidance or a proper scrubbing mechanism.

This paper presents CleanSight 2.0, an autonomous floor cleaning robot designed to bridge that gap. The system integrates real-time obstacle detection, differential wheel navigation, and a continuously rotating scrubbing brush into a single compact and budget-friendly platform. The design targets smooth to moderately textured indoor surfaces and is intended to reduce manual cleaning effort while simultaneously serving as a hands-on learning tool for students in embedded systems and robotics.

The remainder of this paper is organized as follows. Section II reviews relevant prior work. Section III describes the system methodology and hardware components. Section IV covers the hardware and software design. Section V presents experimental results, and Section VI concludes with directions for future work.

FIG. 1. PHYSICAL ASSEMBLY OF THE FLOORBOT AUTONOMOUS FLOOR CLEANING ROBOT

II. LITERATURE REVIEW

A. ESP32-Based Cleaning Robots

Patil et al. [1] demonstrated how inexpensive hardware can be combined to automate floor cleaning using a microcontroller-based robot. Their work confirmed a meaningful reduction in manual effort, but the prototype relied on fixed movement patterns without real-time obstacle sensing and lacked a dedicated scrubbing mechanism. Faisal et al. [2] extended this concept by incorporating an ESP32 and an ultrasonic sensor, confirming the platform's dual-core capability and ease of sensor integration. Their system showed satisfactory obstacle avoidance but did not explore scrubbing in detail and experienced occasional delays caused by simultaneous motor control and sensor processing.

B. Sensor-Based Navigation

Borenstein and Koren [9] established ultrasonic sensing as a reliable, low-cost approach to indoor obstacle detection. Their analysis showed that time-of-flight distance measurement enables effective real-time navigation decisions, though accuracy degrades near highly reflective or steeply angled surfaces. Kim et al. [4] further demonstrated that sensor-guided navigation algorithms can substantially improve path coverage and cleaning efficiency, though at the cost of greater computational complexity that is difficult to replicate on low-cost hardware.

C. Cleaning Mechanisms and Control

Sharma and Singh [3] highlighted that continuous and consistent brush contact with the floor surface is critical for effective dirt removal. Their work identified uneven terrain as a key challenge for maintaining brush pressure. Fu, Gonzalez, and Lee [10] provided foundational principles for coordinating sensing, actuation, and decision-making within a robotic system, which informed the overall control architecture of CleanSight 2.0. Guo and Zhang [8] surveyed existing cleaning robots and noted persistent issues including inadequate scrubbing integration, weak corner coverage, and reduced sensor accuracy under humid conditions.

D. Research Gap

The reviewed literature shows that while multiple autonomous cleaning robots have been prototyped, low-cost ESP32-based systems that combine reliable obstacle avoidance with an integrated scrubbing mechanism remain underexplored. Table I summarizes the key papers reviewed and highlights this gap.

TABLE I. LITERATURE REVIEW COMPARISON SUMMARY

Ref.	Author(s)	Contribution	Limitation	Controller
[1]	Patil et al.	Low-cost floor cleaning robot	No real-time obstacle avoidance	Arduino
[2]	Faisal et al.	ESP32 + ultrasonic floor cleaner	No integrated scrubbing	ESP32
[3]	Sharma & Singh	Rotating brush mechanism	Inconsistent brush pressure	Arduino
[4]	Kim et al.	Autonomous mobile cleaning robot	Expensive, high complexity	Custom
[8]	Guo & Zhang	Survey of cleaning robots	No new implementation	N/A
[9]	Borenstein & Koren	Ultrasonic obstacle avoidance	Limited angular coverage	N/A

III. METHODOLOGY

CleanSight 2.0 operates through three coordinated functional stages: system initialization, autonomous navigation, and continuous floor scrubbing. These stages run concurrently under the management of the ESP32 DevKit, following established principles of coordinated robotic control [10].

A. System Initialization

On power-up, the ESP32 initializes all connected peripherals: the L298N motor driver, the HC-SR04 ultrasonic sensor, and the scrubber motor. A brief self-check confirms that every component is responsive before forward motion begins. The ESP32 was selected as the central controller because of its dual-core architecture running at up to 240 MHz, its built-in Wi-Fi and Bluetooth support, and its generous GPIO availability, which allows simultaneous control of multiple motors and real-time sensor reading [1].

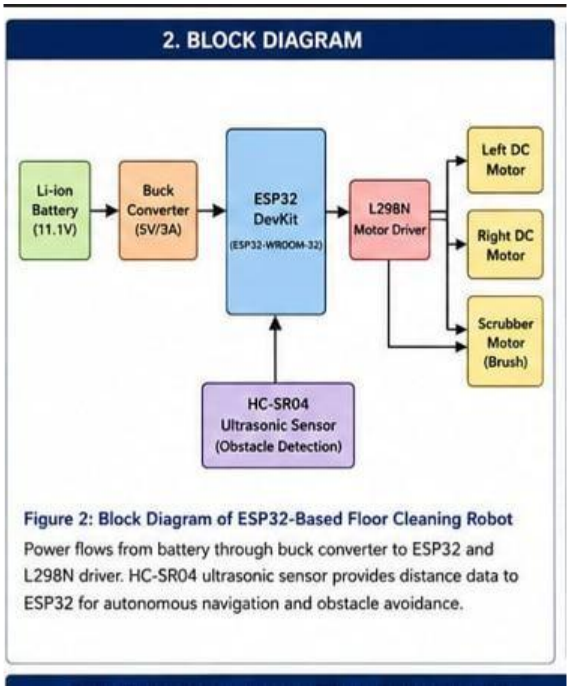


Fig. 2. Block diagram of the ESP32-based control architecture for the floor cleaning

B. Autonomous Navigation
Navigation relies on the HC-SR04 ultrasonic sensor, which emits short bursts of sound and measures the elapsed time until the echo returns. The ESP32 converts this time value into a distance reading. When an obstacle is detected within 20 cm, the controller instructs the L298N to stop the wheel motors and steer the robot in a new direction before resuming forward movement. This reactive avoidance strategy is consistent with widely validated ultrasonic-based navigation techniques for indoor robots [2], [9].

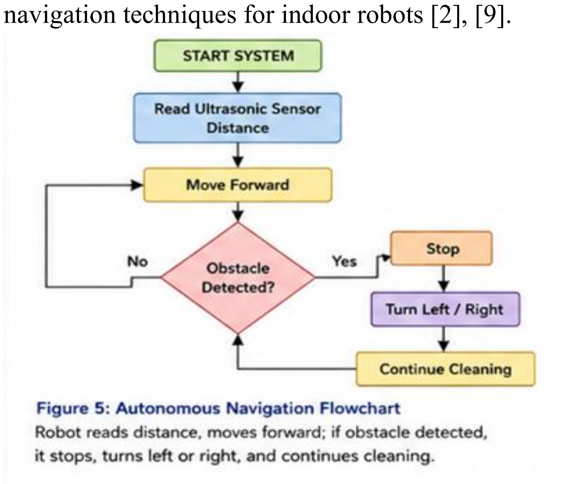


Fig. 3. Navigation and obstacle detection logic flowchart for the ESP32-based floor cleaning robot.

C. Integrated Cleaning Mechanism
The scrubber motor activates at start-up and runs continuously throughout the entire cleaning session. It drives a rotating brush mounted on the underside of the chassis, which loosens and removes dust and fine particles from the floor surface. The robot executes a repeating cycle: move forward while scrubbing, detect and avoid an obstacle if present, then continue. Maintaining consistent brush-to-floor contact is addressed through the mechanical mounting of the brush, a design decision informed by the findings of Sharma and Singh [3].

D. Hardware Components
All components were selected on the basis of cost, availability, and compatibility. The ESP32 DevKit serves as the main controller. The L298N dual H-bridge motor driver independently controls the two DC gear motors for differential steering; its onboard 5 V regulator also supplies power to low-current components. The HC-SR04 sensor provides obstacle sensing across a 2–400 cm range with a simple GPIO interface. A dedicated DC motor drives the scrubbing brush independent of the navigation state. A DC-DC buck converter stabilizes the supply voltage to the ESP32 and sensors despite variations in battery discharge level. The entire system is powered by a rechargeable Li-ion battery pack, chosen for its favorable energy density, light weight, and rechargeability.

IV. HARDWARE AND SOFTWARE DESIGN

A. System Architecture
The CleanSight 2.0 system comprises four functional blocks: power supply, sensing, control, and actuation. The Li-ion battery feeds all components through the buck converter. The HC-SR04 sensor delivers real-time distance data to the ESP32, which processes it and generates PWM control signals for the L298N motor driver. The wheel motors and scrubber motor constitute the actuation layer, with the scrubber motor connected through a separate control channel to ensure it operates independently of navigation state.

B. Circuit Design
The HC-SR04 trigger and echo pins connect to two GPIO pins on the ESP32. The L298N input pins are driven by ESP32 PWM-capable outputs to vary motor

speed and direction. All circuit nodes share a common ground reference. The buck converter output feeds the ESP32 3.3 V rail and the sensor supply line to maintain stable operation as battery voltage declines under load.

C. Control Algorithm

The firmware runs as a continuous real-time loop written in C/C++ using the Arduino IDE with the ESP32 board support package. Each iteration triggers the ultrasonic sensor and reads the echo duration via the pulseIn() function. If the calculated distance exceeds 20 cm, the wheel motors are driven forward at full PWM duty cycle. If the distance falls at or below 20 cm, the wheel motors are halted and the robot executes a timed turn before resuming forward travel. The scrubber motor output pin remains asserted high throughout all navigation states, ensuring uninterrupted cleaning. Motor direction and speed are controlled using digitalWrite() and analogWrite() calls on the L298N input and enable pins.

V. EXPERIMENTAL RESULTS AND ANALYSIS

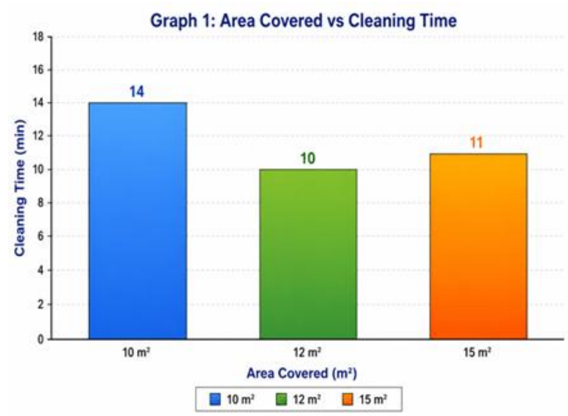
The CleanSight 2.0 prototype was tested in a real indoor environment to evaluate cleaning efficiency, navigation performance, battery life, and obstacle avoidance accuracy. Common household obstacles — walls, chairs, and plastic bottles — were randomly placed in the test area to simulate realistic indoor conditions. Tests were conducted on three floor types: tile, marble, and cement.

A. Cleaning Efficiency

Table II presents the area covered and time recorded for each floor type, along with the calculated average cleaning speed.

TABLE II. CLEANING AREA AND TIME ON DIFFERENT FLOOR TYPES

Floor Type	Area (m^2)	Time (min)	Speed (m^2/min)
Tile	12	10	1.20
Marble	15	11	1.36
Cement	10	14	0.71



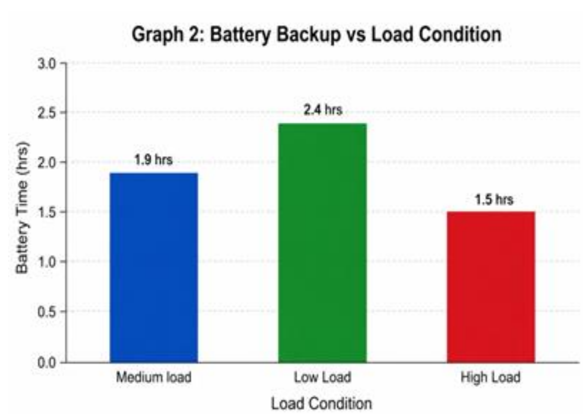
Performance was highest on marble (1.36 m^2/min) and tile (1.20 m^2/min) due to their smooth surfaces. Cement produced the lowest speed (0.71 m^2/min) because the rough texture increased wheel resistance and slowed the robot. Cleaning near corners was slightly reduced due to the robot's turning radius.

B. Battery Performance

Table III shows battery runtime measured under three load conditions. As motor current demand increased, runtime fell from 2.4 hours at idle to 1.5 hours under continuous heavy load. At the standard cleaning load, the robot operated for approximately 1.9 hours, adequate for small to medium-sized rooms.

TABLE III. BATTERY PERFORMANCE UNDER DIFFERENT LOAD CONDITIONS

Load Condition	Battery Runtime (hrs)
Idle	2.4
Normal Cleaning	1.9
Heavy Load (Continuous)	1.5



C. Obstacle Detection
Table IV summarizes detection outcomes for different obstacle types encountered during testing.

TABLE IV. OBSTACLE DETECTION RESULTS

Obstacle Type	Detection Result
Wall	Detected successfully
Plastic bottle	Detected successfully
Chair leg	Minor delay observed
Small thin object	Partial detection

Flat and solid obstacles were reliably detected. Narrow objects such as chair legs produced occasional brief delays because the ultrasonic beam may not fully intercept a thin surface at all approach angles. Very small objects were only partially detected, a known limitation of single-sensor ultrasonic systems [9]. Adding secondary sensors in future iterations would address this shortcoming.

D. Overall Performance
Across all test conditions, CleanSight 2.0 delivered an average cleaning efficiency of 1.09 m^2/min. The prototype successfully demonstrated stable autonomous operation on all three floor types, confirmed practical battery life for typical room sizes, and showed reliable avoidance of common household obstacles. These results validate the design concept and identify specific areas — corner coverage, thin-object detection, and extended battery life — for improvement in subsequent versions.

VI. CONCLUSIONS AND FUTURE WORK

This paper described the design, implementation, and experimental evaluation of CleanSight 2.0, an affordable autonomous floor cleaning robot built around the ESP32 DevKit. The system successfully integrates real-time obstacle avoidance via an HC-SR04 ultrasonic sensor, independent wheel navigation through an L298N motor driver, and a continuously rotating scrubbing mechanism into a single compact platform. Testing on tile, marble, and cement floors confirmed an average cleaning efficiency of 1.09 m^2/min and a practical battery runtime of 1.9 hours under normal conditions — sufficient for small to medium-sized indoor spaces.

The results demonstrate that effective autonomous floor cleaning is achievable with inexpensive, readily available components, making the platform well-suited for both household use and as an educational tool in robotics and embedded systems courses. Compared to manual cleaning and basic sweep-type robots, CleanSight 2.0 delivers more consistent and less labour-intensive cleaning.

Future work will focus on several enhancements. Integration of SLAM-based path planning will improve floor coverage by replacing the current reactive navigation with deliberate mapping. A multi-sensor configuration — combining infrared or camera-based detection with the existing ultrasonic module — will address detection gaps for narrow and small objects. The ESP32's built-in Wi-Fi will be exploited to enable IoT-based monitoring and remote control through a web dashboard or mobile application. Advanced battery management and power-saving modes will extend operational runtime. Finally, a water dispensing mechanism and a debris collection tray will be added to broaden cleaning capability across different surface conditions.

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REFERENCES

[1] S. R. Patil, A. S. Bhosale, and P. M. Jadhav, "Microcontroller-based autonomous floor cleaner robot," Int. J. Eng. Res. Technol., vol. 8, no. 6, pp. 1–4, 2019.
[2] M. R. Faisal, A. Nugroho, and D. Setiawan, "Automatic floor cleaning robot using ESP32 and ultrasonic sensor," J. Robot. Control, vol. 2, no. 1, pp. 1–6, 2021.
[3] R. K. Sharma and P. Singh, "Automated cleaning robot with smart navigation and control," J. Mechatron. Robot., vol. 3, no. 2, pp. 10–15, 2020.

[4] J. Kim, H. Lee, and S. Park, "Design of autonomous mobile robot for cleaning," Appl. Sci., vol. 11, no. 17, p. 8076, 2021.
[5] H. Choset et al., Principles of Robot Motion: Theory, Algorithms, and Implementations. Cambridge, MA, USA: MIT Press, 2005.
[6] S. Thrun, W. Burgard, and D. Fox, Probabilistic Robotics. Cambridge, MA, USA: MIT Press, 2005.
[7] R. Siegwart, I. R. Nourbakhsh, and D. Scaramuzza, Introduction to Autonomous Mobile Robots, 2nd ed. Cambridge, MA, USA: MIT Press, 2011.
[8] Y. Guo and L. Zhang, "A survey on cleaning robots," IEEE Trans. Syst., Man, Cybern., vol. 47, no. 5, pp. 1–15, 2017.
[9] J. Borenstein and Y. Koren, "Obstacle avoidance with ultrasonic sensors," IEEE J. Robot. Autom., vol. 4, no. 2, pp. 213–218, 1988.
[10] K. S. Fu, R. C. Gonzalez, and C. S. G. Lee, Robotics: Control, Sensing, Vision, and Intelligence. New York, NY, USA: McGraw-Hill, 1987.