Wall Ease

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Abstract. *This paper presents the design and the development which enables it to autonomously navigate homes, offices, and commercial spaces without bumping into furniture, walls, or other objects, thus ensuring smooth, uninterrupted cleaning. Whether in small residential kitchens or large commercial areas, the bot can adapt to the layout and efficiently maintain clean and dry floors. Ultimately, this solution is designed to minimize safety hazards, especially for vulnerable populations such as children and the elderly, while improving hygiene standards. Additionally, by automating the process of spill detection and cleanup, the robot reduces manual labour, making it an efficient and practical tool for maintaining clean floors with minimal human intervention.*

machine learning for smarter navigation performance enhancements, are also explored. This project contributes to the growing field of home automation by providing a reliable solution for automated household cleaning, making it an ideal tool for modern residential environment.

The integration of smart technology allows users to control and monitor the robot remotely via mobile applications. the Wall Cleaning Robot represents a significant step forward in robotic automation, improving cleanliness standards.

Keywords: Compact design, ESP32, wall cleaning robot, home automation, robotics.

1. Introduction

Advances in Electrical and Electronic Engineering is a peer-reviewed periodical scientific journal aimed at publishing research results of the journal focus areas. The journal is published by the VSB–Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science, Czech Republic. The role of the journal is also to facilitate contacts between research centres and industry. The aim of the editors is to publish high quality scientific professional papers which may be presented by significant scientific teams, experienced authors as well as post graduate students and beginning researchers. All articles are subjected As urbanization and the demand for smart home technologies continue to grow, automation has become an integral part of everyday life. Among the most significant advancements in the home automation industry is the development of robotic cleaning systems. These devices aim to reduce the time and effort spent on household chores, offering users more convenience and enhanced efficiency. Traditional cleaning methods, although effective, require significant human intervention, which can be both time-consuming and physically demanding. In contrast, autonomous cleaning robots, such as wall cleaning bots, provide a smarter, more efficient solution by performing cleaning tasks autonomously with minimal human supervision.

Despite the growing popularity of robotic cleaning devices, several challenges remain in terms of affordability, navigation accuracy, and adaptability to different environments. Wall cleaning robots need to be compact yet effective, capable of navigating obstacles and varying floor types, while maintaining energy efficiency and cost-effectiveness. Additionally, the challenge of integrating advanced sensors, such as ultrasonic and infrared sensors, within a compact and low-cost design is one of the main hurdles in the development of reliable cleaning bots.

This paper introduces a *Compact wall Cleaning Bot* designed to address these challenges by integrating advanced navigation technologies, such as ultrasonic sensors, and an efficient control system based on the ESP32 microcontroller. The bot is designed to autonomously clean a variety of floor surfaces, while its compact size allows it to operate in tighter spaces where larger robots might struggle. The proposed system uses real-time obstacle detection and automated path planning to ensure thorough coverage, improved maneuverability, and higher cleaning efficiency. The aim of this research is to develop a cost-effective solution that meets the needs of modern consumers, without compromising on performance or reliability.

Through this research, we aim to contribute to the ongoing development of affordable, intelligent robotic cleaning solutions that can be implemented not only in households but also in commercial and industrial settings.

2. Components used

- ESP32 Microcontroller
- Ultrasonic Sensor
- Motors and Motor Driver
- Power Supply (Battery)
- Chassis and Wheels
- Brush Mechanism
- Software and Control System

3. Literature Survey

In recent years, the development of compact wall cleaning robots has become an area of significant research, with various studies focusing on the integration of sensors, efficient mobility, and cleaning performance.
Hwang and Kim (2018) highlighted the effectiveness of combining ultrasonic and infrared sensors for autonomous navigation, enabling robots to detect and avoid obstacles in real time. Tian et al. (2019) emphasized the importance of low-power, high-torque motors for improving the robot's mobility while maintaining energy efficiency, particularly in multi-floor environments. The software control systems, such as the ESP32 microcontroller, play a vital role in enhancing functionality. According to Smith et al. (2020), the use of microcontroller-based systems with Wi-Fi and Bluetooth capabilities allows for remote control and system updates, which greatly enhance the convenience of robot operation and maintenance. The cleaning mechanism, including the brush design, is also crucial for optimal performance. Jiang and Liu (2021) discussed adaptive brush systems that automatically adjust pressure according to floor types, enhancing cleaning efficiency without causing damage to sensitive surfaces. These advancements in sensor integration, mobility, and software control form the foundation for more autonomous and efficient floor cleaning robots.

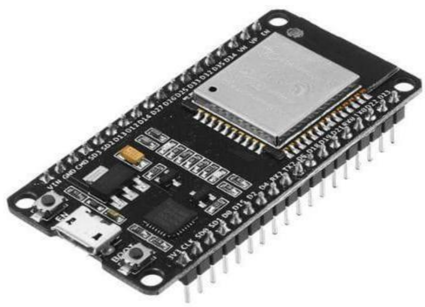
4. System design and Architecture

The system design and architecture of the Compact wall Cleaning Bot follow a structured, modular layout to integrate both hardware and software components seamlessly. The central control unit is the ESP32 microcontroller, which processes input signals from various sensors and manages the execution of motor control algorithms. The ultrasonic sensor is a critical part of the system, enabling real-time obstacle detection and navigation for efficient movement across the cleaning area. The motors, supported by a motor driver module, provide the necessary mobility to the wheels and drive the cleaning brush, ensuring effective debris removal.

The rechargeable battery powers the system, supplying energy to the microcontroller, motors, sensors, and other essential components. A sturdy chassis houses these elements, offering structural stability while facilitating smooth movement. The software component oversees navigation, cleaning patterns, and obstacle avoidance by processing data from the sensors and executing control commands. This comprehensive design ensures the bot is reliable, efficient, and adaptable to various cleaning environments, whether residential or commercial. The architecture allows for easy maintenance and upgrades, enhancing the bot's usability and performance over time.

5. Components description

- **ESP32 Microcontroller**

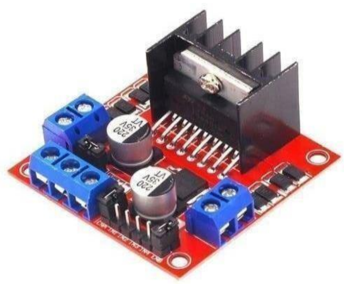


The ESP32 microcontroller is the brain of the robot. It handles all the logic for controlling the robot’s movement and decision-making. It processes inputs from the ultrasonic sensors to detect obstacles and also sends control signals to the motors through the motor driver. With its Wi-Fi capability, it allows for remote control and monitoring of the robot, making it adaptable to different environments.

- **Ultrasonic Sensor**

The ultrasonic sensor is crucial for autonomous navigation. It constantly measures the distance between the robot and objects in its path. When an obstacle is detected, the sensor sends data to the ESP32, which processes it and adjusts the robot’s movement to avoid collisions. This feature allows the bot to move efficiently without human intervention, ensuring it cleans the area effectively.

- **Motors and Motor Driver**



The motors provide the necessary movement to the robot, driving the wheels. The motor driver acts as an interface between the ESP32 and the motors, converting the signals from the microcontroller into physical motion. The driver controls the speed and direction of the motors, enabling the robot to move forward, backward, or turn based on the software’s commands. This allows for precise navigation during cleaning operations.

- **Power Supply (Battery)**

The robot operates on a rechargeable battery that serves as the primary power source for all its components, including the microcontroller, motors, sensors, and auxiliary circuits. This ensures the robot is completely autonomous, untethered from a power outlet, and capable of navigating freely across different areas. The battery is chosen based on the system's power requirements, ensuring it provides sufficient runtime for effective cleaning operations before requiring a recharge. Voltage regulation is implemented to supply stable and appropriate power levels to components with varying voltage needs, improving reliability and efficiency. Additionally, the compact and lightweight design of the battery complements the robot's portability, enabling smooth and agile movements. The inclusion of overcharge and discharge protection circuits ensures operational safety and extends the battery's lifespan.

- **Chassis and Wheels**

The chassis provides structural support, housing the various components such as the motors, microcontroller, and sensors. It is designed to be lightweight and durable, allowing the robot to move freely across different floor types. The wheels ensure smooth movement, with their design allowing the robot to traverse obstacles or rough surfaces while maintaining stability

- **Buck converter**

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 02 | Feb - 2025 SJIF Rating: 8.448 ISSN: 2582-3930

The buck converter in the Compact Floor Cleaning Bot project is used to efficiently step down the higher voltage from the power supply to a lower, stable voltage that powers the robot's components like the microcontroller and motors. By using the buck converter, power loss is minimized, which is crucial for battery-operated devices, ensuring longer battery life and reliable operation. The stable voltage output helps protect sensitive components, such as the microcontroller, from receiving excessive voltage, allowing the robot to run more efficiently and for a longer duration.

- **Relay module**

The relay module is used to control the high-power motors with low-power control signals from the ESP32 microcontroller. Since the ESP32 cannot directly drive the motors due to the high current and voltage they require, the relay module acts as a switch. When the ESP32 sends a control signal, the relay switches on or off the motors, allowing the robot to perform tasks like movement and cleaning. This setup protects the microcontroller from high current and ensures the robot can perform its functions without damaging the control system. The relay module is key for safe power management in the robot.

- **Brush Mechanism**

The brush mechanism is essential for cleaning debris on the floor. It typically consists of rotating or sweeping brushes that collect dirt, dust, and debris and push it toward the robot's collection area. Positioned at the robot's front or bottom, this mechanism is controlled by the microcontroller and works in tandem with the robot's movement to ensure efficient cleaning.

- **Software and Control System**

The software is the backbone of the robot's operations. It interprets inputs from the ultrasonic sensors and sends commands to the motors and brush mechanism. The control system allows for programmed cleaning paths, real-time obstacle avoidance, and the ability to change the robot's behavior based on its environment. Through this system, the robot can clean autonomously or be controlled remotely via the ESP32's Wi-Fi feature.

- **Bldc Motor**

A BLDC (Brushless DC) motor is an electric motor that operates without brushes, using an electronic controller to switch the current in the windings. This design eliminates friction and wear from brushes, leading to higher efficiency, longer lifespan, and less maintenance. BLDC motors provide precise control, making them ideal for applications such as drones, robotics, and electric vehicles.BLDC motors are typically more compact and lighter than their brushed counterparts, offering better power-to-weight ratios. They are also capable of operating at higher speeds and generating less heat due to the absence of friction from brushes.

6. Methodology

The methodology for developing the Compact Floor Cleaning Bot involves a systematic approach to integrate hardware and software components effectively. The process begins with hardware selection and assembly, prioritizing components that ensure functionality and efficiency. The ESP32 microcontroller serves as the central processing unit, coordinating data from ultrasonic sensors for obstacle detection and controlling the motors for movement. A rechargeable battery is selected to meet the power requirements, ensuring sufficient runtime for cleaning operations.

The chassis is designed to accommodate all components securely while supporting cleaning brushes and wheels for seamless floor navigation. Ultrasonic sensors are strategically positioned to provide comprehensive obstacle detection, feeding real-time data to the microcontroller.

In parallel, the software development process involves coding algorithms to interpret sensor data and control the bot's movement and cleaning actions. These algorithms are optimized to enhance cleaning patterns and ensure energy efficiency. .

Integration of hardware and software is followed by iterative testing and refinement, addressing issues such as sensor calibration, motor synchronization, and power management. The final design undergoes rigorous validation to ensure the bot operates reliably and efficiently, meeting the project's objectives. This structured methodology emphasizes precision and efficiency, resulting in a compact and functional cleaning solution.

7. Application

The Compact Wall Cleaning Bot has several applications in various environments such as homes, offices, and commercial spaces. It provides an automated solution for wall cleaning, offering convenience and time-saving benefits. By using ultrasonic sensors, the bot can detect obstacles and navigate around them, ensuring thorough coverage of the wall area while avoiding collisions with furniture or walls. The motors and motor driver allow for efficient movement and precise control of the robot's motion. Additionally, the integration of a buck converter helps in optimizing power consumption, ensuring the robot operates for longer periods with minimal battery drain. The relay module plays a crucial role in switching the high-power motors on and off safely using low-power control signals from the microcontroller. This makes the bot reliable and energy-efficient, providing users with an affordable and practical cleaning solution. The robot's application is especially useful in scenarios where manual cleaning is time-consuming, ensuring a clean and tidy space with minimal human intervention.

8. Advantages

The Compact Floor Cleaning Bot offers several significant advantages that revolutionize traditional cleaning methods. By incorporating automation, it significantly reduces human labour and time required for cleaning, offering a highly efficient alternative to manual floor cleaning. The system operates autonomously, allowing users to focus on other tasks while the bot ensures effective cleaning. Its compact design is a key feature, allowing it to access areas typically difficult to reach with conventional vacuums, such as under furniture, along edges, and in narrow spaces.

The integration of ultrasonic sensors plays a critical role in obstacle detection and avoidance, enhancing the bot's navigation capabilities. This sensor-based system allows it to detect obstacles in its path and prevent collisions, ensuring safe and smooth operation. Additionally, the bot's energy efficiency is a notable advantage. The power management system maximizes battery life, enabling longer cleaning sessions with a single charge and reducing the frequency of recharging, which contributes to the bot's overall efficiency.

Its ability to adapt to various floor types—tile, wood, and carpet—without losing performance makes it a versatile solution for both home and commercial environments. This adaptability ensures a consistent cleaning experience across different surface types, making it suitable for diverse settings. The minimal user intervention required further enhances its practicality, as the system works seamlessly with little to no input from the user

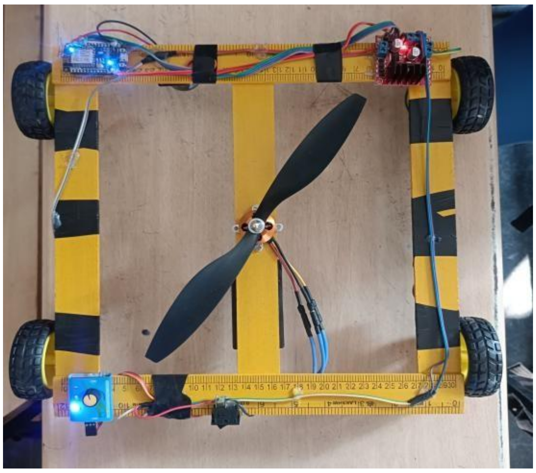
9. Programming

```
#include <ESP8266WiFi.h>
#include <ESP8266WebServer.h>
#include <ArduinoOTA.h

// connections for drive Motor FR & BR//
int enA = D3;
int in1 = 5;
int in2 = 4;
// connections for drive Motor FL & BLint
in3 = 0;
int in4 = 2;
//int enB = D6;
// const int buzPin = 16;

 // set digital pin D7 as buzzer pin (use active
buzzer)const int ledPin =1;

 // set digital pin D8 as LED pin (use super bright
LED)const int wifiLedPin = 3;

// set digital pin D0 as indication, the LED turn on if
NodeMCU connected to WiFi as STA mode


 //String command;
  // String to store app command state.int SPEED = 250;
 int speed_Coeff = 3;

 ESP8266WebServer server(80);
  // Create a webserver object that listens for HTTP
 request on port 80unsigned long previousMillis = 0;

// String sta_ssid = "";
  // set Wifi networks you want to connect to String
state_password = "";
  // set password for Wifi networks
```

```
}
// void setup() {
Serial.begin(115200);
 // set up Serial library at 115200 bps
Serial.println();
  Serial.println("WiFi Robot Remote
Control Mode - L298N 2A");
Serial.println(" --------- ");
// pinMode(buzPin, OUTPUT);
 // sets the buzzer pin as an Output
pinMode(ledPin, OUTPUT);
  // sets the LED pin as an Output
pinMode(wifiLedPin, OUTPUT);
 // sets the Wifi LED pin as an Output
digitalWrite(buzPin, LOW);
digitalWrite(ledPin, LOW);
digitalWrite(wifiLedPin, HIGH);

/ // Set all the motor control pins to
outputs  pinMode(in1, OUTPUT);
pinMode(in2, OUTPUT);
pinMode(in3, OUTPUT);
 pinMode(in4, OUTPUT);

  // // Turn off motors - Initial state
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);;

// set NodeMCU Wifi hostname based on chip
mac address  String chip_id =
String(ESP.getChipId(),HEX);
  int i = chip_id.length() - 4;
  chip_id = chip_id.substring(i);
 chip_id = "WiFi_RC_Car-" + chip_id; String
hostname(chip_id);
 Serial.println();
 Serial.println("Hostname: " + hostname);
  // first, set NodeMCU as STA mode to connect
with a Wifi network  WiFi.mode(WIFI_STA);
WiFi.begin(sta_ssid.c_str(), sta_password.c_str());
Serial.println("");
  Serial.print("Connecting to: ");
Serial.println(sta_ssid);
Serial.print("Password: ");
Serial.println(sta_password);;
}
```

```
//// try to connect with Wifi network about 10 seconds
unsigned long currentMillis = millis();  previousMillis =
currentMillis;
 while (WiFi.status() != WL_CONNECTED &&
currentMillis - previousMillis <= 10000)
 {    delay(500);
   Serial.print(".");     currentMillis = millis(); }  // if failed
to connect with Wifi network set NodeMCU as AP mode
if (WiFi.status() == WL_CONNECTED)
{    Serial.println("");    Serial.println("WiFi-STA-Mode");
Serial.print("IP: ");    Serial.println(WiFi.localIP());
digitalWrite(wifiLedPin, LOW);
  // Wifi LED on when connected to Wifi as STA mode
 delay(3000);
void loop() {  ArduinoOTA.handle();
  // listen for update OTA request from clients
server.handleClient();
  // listen for HTTP requests from clients  command =
server.arg("State");
  // check HTPP request, if has arguments "State" then
saved the value  if (command == "F") Forward();
 // check string then call a function or set a value  else if
(command == "B") Backward();
  else if (command == "L") TurnRight();  else if (command
== "R") TurnLeft();
  else if (command == "G") ForwardLeft();  else if
(command == "H") BackwardLeft();
  else if (command == "I") ForwardRight();  else if
(command == "J") BackwardRight();
el}se if (command == "S") Stop();
```

10. Demo picture



11. Conclusion

In conclusion, the compact wa l l cleaning bot is a cost-effective, efficient, and environmentally friendly solution for maintaining cleanliness in various environments. By integrating key components such as the ESP32 microcontroller, ultrasonic sensors, motors with a driver, and a brush mechanism, the robot effectively automates the cleaning process. The rechargeable battery provides the necessary power for autonomous operation, while its intelligent control system ensures precise navigation and obstacle avoidance.

This project demonstrates the potential of leveraging robotics and IoT technologies to create versatile cleaning solutions tailored to both domestic and commercial needs. Its modular design allows for scalability and customization, making it adaptable for specific applications. The bot's efficiency in resource utilization, combined with its low-budget construction, makes it an accessible innovation for broader adoption. Future enhancements, such as incorporating AI for more intelligent decision-making or adding advanced sensors, could further elevate its performance and utility.

12. Future scope

The future of the Compact Floor Cleaning Bot holds significant potential for enhancing its functionality and user experience. Key areas of development include:

1. **AI and Machine Learning Integration:** Advanced AI can enable the bot to adapt to its environment, optimize cleaning patterns, and improve over time. Machine learning algorithms can help the bot recognize different floor types and adjust its cleaning approach accordingly, enhancing both efficiency and precision.
2. **Smart Home Integration:** The bot can be made compatible with smart home systems, allowing for voice control and remote operation through platforms like Amazon Alexa or Google Home. A mobile app can provide real-time updates, cleaning schedules, and remote control functionalities, making it easier for users to interact with the bot.
3. **Improved Battery Technology:** Longer battery life, faster charging capabilities, and more energy-efficient batteries will increase the bot's operational time and reduce downtime. A longer-lasting battery means more extensive cleaning sessions and less frequent recharging, improving user convenience.
4. **Advanced Sensors:** The integration of lidar sensors and enhanced object recognition technology will provide the bot with better navigation capabilities, ensuring it can map complex environments and avoid obstacles with greater accuracy. This will result in more effective cleaning in diverse spaces.
5. **Additional Functionalities:** Expanding the bot's functionality to include dust removing or even UV light for sanitizing floors will provide a more comprehensive cleaning solution. Such innovations will make the bot suitable for a wider range of cleaning tasks, especially in hygienic environments like healthcare facilities.

By incorporating these advancements, the Compact wall Cleaning Bot will evolve into a highly efficient, versatile, and user-friendly tool for both residential and commercial use.

13. Acknowledgements

We would like to express our sincere gratitude to Sri Shakthi Institute of Engineering and Technology for providing the resources and support necessary for the development and execution of this project. Special thanks to our project guide and mentors for their invaluable guidance, encouragement, and expertise throughout the research and development phase. We also appreciate the contributions of the team members who helped in data collection, system design, and testing, ensuring the successful completion of this project.

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