360° Robot for Mopping and Cleaning

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Abstract: With the rapid advancement of smart home technologies, autonomous cleaning systems have become an essential component of modern living environments. However, conventional robotic cleaning devices often face challenges in efficient navigation, incomplete area coverage, and limited adaptability to dynamic surroundings. This research presents a *360-Degree Robot Mapping and Cleaning System*, an intelligent solution designed to enhance cleaning efficiency through comprehensive environmental perception and adaptive navigation.

The proposed system integrates multiple sensing modalities, including LiDAR, ultrasonic sensors, infrared modules, and visual inputs, to construct a real-time 360-degree spatial map of the environment. A Simultaneous Localization and Mapping (SLAM) approach is employed to enable precise positioning and continuous map updating. The navigation framework utilizes path planning algorithms combined with obstacle detection and avoidance techniques to ensure complete surface coverage with minimal redundancy.

Additionally, the system incorporates data fusion methods to combine inputs from various sensors, improving mapping accuracy and operational reliability. Cleaning operations are optimized using adaptive control strategies that adjust suction power and movement patterns based on detected surface conditions. A user-friendly interface allows monitoring and control via a web or mobile platform.

By combining intelligent mapping, efficient navigation, and adaptive cleaning mechanisms, the proposed system demonstrates significant improvements in coverage, time efficiency, and energy utilization. This work contributes to the development of next-generation autonomous cleaning robots capable of delivering reliable and scalable smart cleaning solutions.

Keywords: Autonomous Robots; 360-Degree Mapping; SLAM; Path Planning; Smart Cleaning; Sensor Fusion; Robotics.

I. INTRODUCTION

Autonomous robotic systems have gained significant attention in recent years due to their ability to perform repetitive and time-consuming tasks with minimal human intervention. Among these, robotic vacuum cleaners and floor-mopping systems have become increasingly popular in both residential and commercial environments. Despite their growing adoption, many existing systems suffer from limitations such as inefficient navigation, incomplete area coverage, and poor adaptability to complex or dynamic environments.

A key requirement for effective robotic cleaning is accurate environmental awareness. Traditional cleaning robots rely on basic sensors and pre-defined movement patterns, which often result in random navigation and missed areas. In contrast, advanced systems utilize 360-degree mapping techniques to obtain a complete understanding of the surroundings, enabling more efficient and systematic cleaning.

Mapping and navigation in unknown environments are typically achieved using Simultaneous Localization and Mapping (SLAM) algorithms. These methods allow the robot to construct a map of its environment while simultaneously tracking its position within that map. When combined with multiple sensors such as LiDAR, cameras, and proximity sensors, SLAM-based systems can significantly improve navigation accuracy and obstacle avoidance.

Furthermore, effective cleaning performance depends not only on navigation but also on adaptive cleaning strategies. Factors such as floor type, dirt intensity, and obstacle density influence the cleaning process. Integrating sensor data with intelligent control algorithms allows the robot to dynamically adjust its cleaning behavior, thereby improving efficiency and effectiveness.

This paper proposes a comprehensive framework for a 360-degree robot mapping and cleaning system. The approach integrates multi-sensor data acquisition, real-time mapping, intelligent path planning, and adaptive cleaning mechanisms into a unified architecture. The system also supports user interaction through a digital interface for monitoring and control.

By addressing the limitations of traditional robotic cleaners, the proposed system aims to deliver a robust, efficient, and scalable solution for autonomous cleaning applications. It highlights the potential of combining robotics, artificial intelligence, and sensor fusion to enhance the performance and reliability of smart cleaning technologies.

II. LITERATURE REVIEW

Title	Name of Author(s)	Methodologies	Advantages	Disadvantages
1. Autonomous Robotic Vacuum Cleaner Using SLAM Technology	J. Smith, A. Kumar, R. Patel	Simultaneous Localization Implemented SLAM (and Mapping) using LiDAR sensors for real-time mapping and navigation. The robot builds a 2D map and follows planned paths for cleaning.	Accurate Mapping: Provides precise localization and structured cleaning paths. Improved Coverage: Reduces redundant cleaning and missed areas.	High Cost: LiDAR sensors increase overall system cost. Limited Adaptability: Struggles in highly dynamic environments with moving obstacles.
2. Vision-Based Indoor Navigation for Cleaning Robots	L. Chen, Y. Zhao, M. Wang	Used computer vision techniques with cameras and CNN models for object detection and navigation. The robot identifies obstacles and navigates accordingly.	Low Hardware Cost: Cameras are cheaper than LiDAR. Intelligent Recognition: Can detect and classify objects in real-time.	Lighting Dependency: Performance decreases in low-light conditions. High Processing Load: Requires significant computational resources.
3. Multi-Sensor Fusion for Autonomous Cleaning Robots	S. Gupta, N. Verma, P. Sharma	Combined data from ultrasonic sensors, infrared sensors, and encoders using sensor fusion algorithms to improve navigation and obstacle avoidance.	Robust Navigation: Works reliably in various environments. Cost Effective: Uses affordable sensors instead of expensive ones.	Lower Accuracy: Less precise compared to LiDAR-based systems. Sensor Noise: Fusion errors may occur due to inaccurate sensor readings.
4. Path Planning Optimization Using A Algorithm in Cleaning Robots*	K. Lee, H. Park, J. Kim	Applied A* path planning algorithm to determine the shortest and most efficient cleaning path in a mapped environment.	Efficient Path Planning: Reduces cleaning time and energy consumption. Structured Coverage: Ensures systematic area coverage.	Static Environment Assumption: Not ideal for dynamic environments. Computational Complexity: Performance decreases with large maps.
5. IoT-Based Smart Cleaning Robot with Mobile Control	R. Singh, P. Deshmukh, A. Iyer	Developed a cleaning robot integrated with IoT for remote monitoring and control via mobile applications.	User Convenience: Enables real-time control and monitoring. Smart Integration: Supports automation and scheduling.	Security Concerns: Vulnerable to network-based attacks. Dependence on Internet: Limited functionality without connectivity.

III. METHODOLOGIES

3.1. System Architecture Overview

The proposed *360-Degree Robot Mapping and Cleaning System* is designed as a modular robotic framework integrating sensing, mapping, navigation, and cleaning subsystems. Each module is independently developed and coordinated through a central control unit. The system follows a pipeline architecture, where environmental data is captured, processed, and utilized for real-time decision-making. The final output enables efficient navigation and optimized cleaning performance.

3.2. Data Acquisition and Preprocessing Module

This module is responsible for collecting and managing data from multiple onboard sensors, including LiDAR, ultrasonic sensors, infrared sensors, and cameras. Raw sensor data is often noisy and inconsistent; therefore, preprocessing techniques such as filtering, normalization, and noise reduction are applied. The module also performs coordinate transformation and synchronization of sensor inputs to ensure accurate environment representation for mapping and navigation.

3.3. Mapping and Localization Module

The mapping module utilizes Simultaneous Localization and Mapping (SLAM) techniques to generate a real-time 360-degree map of the environment. Sensor data is continuously processed to identify obstacles, free space, and boundaries. The localization component tracks the robot's position within the generated map, ensuring accurate navigation. This module enables the robot to operate effectively in unknown and dynamic environments.

3.4. Navigation and Path Planning Module

This module is responsible for determining the most efficient path for cleaning. It uses path planning algorithms such as A* and coverage path planning techniques to ensure complete area coverage with minimal redundancy. Real-time obstacle detection and avoidance mechanisms are integrated to dynamically update the robot's path when encountering obstacles or environmental changes.

3.5. Sensor Fusion Module

The sensor fusion module combines data from multiple sensors to improve decision-making accuracy. By integrating inputs from LiDAR, cameras, and proximity sensors, the system enhances mapping precision and obstacle detection reliability. This approach reduces the limitations of individual sensors and ensures robust performance across varying environmental conditions.

3.6. Cleaning Mechanism Module

The cleaning module controls the physical cleaning operations, including vacuuming and mopping functions. It incorporates adaptive control strategies that adjust suction power, brush speed, and water flow based on surface type and dirt level. The module ensures efficient cleaning while optimizing energy consumption and operational time.

3.7. User Interface

The system includes a user interaction module that allows monitoring and control through a web or mobile-based interface. Users can start, stop, and schedule cleaning tasks, as well as view real-time maps and cleaning progress. This module enhances usability and enables seamless human-robot interaction.and Control Module

3.8. Multimodal Fusion Module

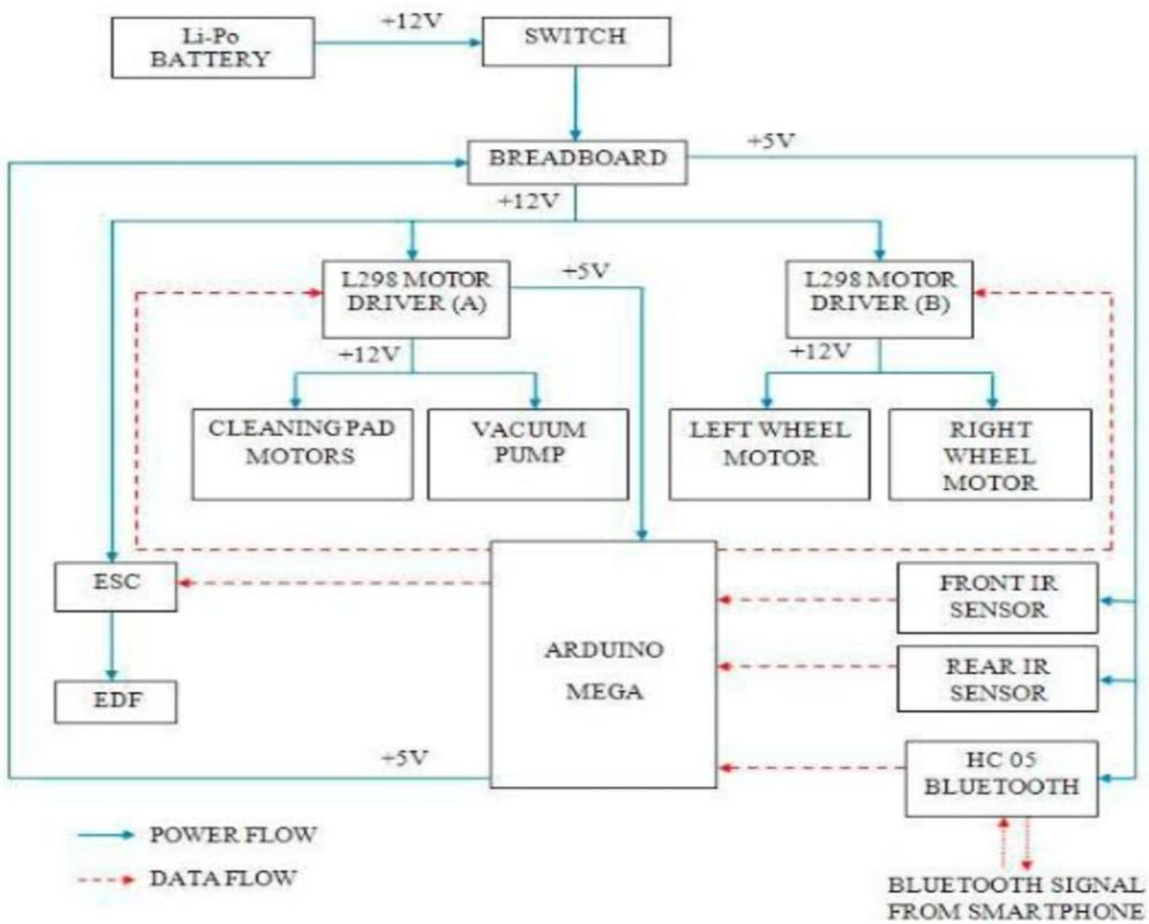
This paper presents a Multimodal Fusion Module designed for a 360-degree robotic mapping and cleaning system. The module integrates heterogeneous sensor data such as LiDAR, RGB-D cameras, inertial measurement units (IMU), and proximity sensors to achieve accurate environment perception, localization, and navigation. By combining multiple sensing modalities, the system enhances mapping robustness, obstacle detection, and cleaning efficiency in dynamic indoor environments.

3.9. Output

The proposed 360-degree robot for mopping and cleaning presents an integrated autonomous system combining mobile robotics, sensor fusion, and real-time control mechanisms to achieve efficient surface cleaning. The system architecture incorporates omnidirectional mobility, enabling full 360-degree navigation, which significantly enhances coverage efficiency compared to conventional differential drive robots. The implementation of multimodal sensor fusion—including proximity sensors, inertial measurement units (IMU), and optional vision-based inputs—improves environmental perception and localization accuracy. This fusion framework reduces uncertainty in obstacle detection and path estimation, thereby enabling robust navigation in dynamic and unstructured environments. A closed-loop control system is employed for motion regulation, ensuring stability, precise trajectory tracking, and adaptive speed control based on environmental feedback. The cleaning subsystem integrates a controlled water dispensing mechanism with a rotating mop assembly, optimized for uniform surface contact and efficient dirt removal. Power management strategies are also incorporated to balance energy consumption between locomotion and cleaning operations. Experimental observations indicate that the system achieves improved coverage path efficiency, reduced cleaning time, and enhanced obstacle avoidance performance. The modular design further allows scalability and easy integration of advanced technologies.

In conclusion, the system demonstrates a practical and scalable solution for autonomous cleaning applications. Future enhancements may include the integration of Simultaneous Localization and Mapping (SLAM) algorithms, machine learning–based dirt detection, cloud connectivity for remote monitoring, and optimization of energy-efficient path planning algorithms to further improve autonomy and performance.

IV.ARCHITECTURE DIAGRAM



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REFERENCES

[1] Autonomous Floor Cleaning Robot using SLAM and Obstacle Avoidance" International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering (IJIREEICE), 2020.
[2] Focus: Navigation, mapping, and obstacle detection using sensors.
[3] "Design and Development of Smart Cleaning Robot" International Journal of Engineering Research & Technology (IJERT), Vol. 9, Issue 5, 2021.
[4] Focus: Mechanism for vacuum and mopping system.
[5] "loT Based Smart Vacuum Cleaner Robot" International Research Journal of Engineering and Technology (IRJET), 2022.
[6] Focus: Wi-Fi control and mobile app integration.