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Smart Cleaning and Monitoring Robot

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Abstract: *With the advancement in robotics and automation, cleaning robots are gaining importance in domestic and industrial applications. This paper presents the design and development of a smart cleaning robot using Raspberry Pi. The proposed robot works in both autonomous and manual modes. It uses sensors such as ultrasonic sensors for obstacle detection and a motor-driven cleaning mechanism for efficient cleaning. Raspberry Pi is used for real-time control,provides intelligent processing and decision-making. The system is cost-effective, energy-efficient, and suitable for indoor environments.*

Keywords: Cleaning Robot, , Raspberry Pi, Autonomous System

I. INTRODUCTION

In recent years, the rapid growth of automation and robotics technologies has significantly transformed various industrial and domestic applications. Smart robotic systems are increasingly being adopted to reduce human effort, improve efficiency, and provide intelligent solutions for repetitive tasks. Among these applications, automated floor cleaning systems have gained considerable attention due to their ability to perform cleaning operations with minimal human intervention.

Traditional cleaning methods require significant manual labor, consume time, and may not always ensure efficient cleaning in large indoor environments. To overcome these limitations, autonomous cleaning robots have emerged as an advanced solution capable of performing cleaning operations automatically using sensors, embedded controllers, and intelligent navigation techniques. These robots are designed to detect obstacles, monitor environmental conditions, and navigate efficiently while cleaning the surface.

The proposed system, "Smart Cleaning Robot Using Arduino," focuses on developing a low-cost, energy-efficient, and intelligent robotic cleaning system suitable for indoor environments. The system integrates Arduino and Raspberry Pi technologies for real-time sensing, control, and decision-making processes. Arduino is responsible for handling sensor inputs and motor control operations, while Raspberry Pi performs higher-level processing and system coordination.

The robot utilizes multiple sensors such as ultrasonic sensors for obstacle detection, MQ-2 gas sensors for environmental safety monitoring, and DHT11 sensors for temperature and humidity analysis. A DC vacuum motor is employed to provide suction force for collecting dust particles, while geared DC motors enable smooth robotic movement. The system is powered using a portable power bank, ensuring cordless and mobile operation.

The primary objective of this research is to design and implement an autonomous robotic cleaning system that improves cleaning efficiency while reducing human effort and operational cost. The proposed robot can be effectively used in homes, offices, laboratories, hospitals, and other indoor spaces. Additionally, the system can be further enhanced in the future by integrating IoT-based monitoring, mobile application control, machine learning algorithms, and advanced navigation techniques for smart automation applications.

This research contributes toward the development of affordable and intelligent cleaning solutions by combining embedded systems, robotics, and automation technologies into a compact and efficient robotic platform.

II. PROBLEM STATEMENT

Traditional cleaning methods in domestic and industrial settings rely heavily on manual labor, making them time-consuming, physically demanding, and inconsistent in quality. Cleaning large indoor environments such as hospitals,

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offices, and warehouses requires significant human effort and often leads to incomplete or inefficient cleaning. Additionally, manual systems lack the ability to monitor environmental conditions such as air quality, temperature, and humidity during operation. Existing robotic cleaning solutions are often expensive, not easily customizable, and lack integration with environmental monitoring capabilities. Therefore, there is a need for a cost-effective, autonomous, and intelligent cleaning robot that can perform cleaning tasks efficiently while simultaneously monitoring environmental parameters, reducing human intervention and operational cost.

III. OBJECTIVES

- To design and develop a smart cleaning robot using Arduino and Raspberry Pi for indoor environments.
- To implement autonomous navigation with real-time obstacle detection using ultrasonic sensors.
- To integrate environmental monitoring sensors (MQ-2, DHT11) for air quality and temperature-humidity tracking.
- To develop a cost-effective and energy-efficient robotic cleaning system suitable for homes, offices, and hospitals.
- To enable both autonomous and manual operating modes for flexible deployment.

Comparison Table

Paper Title	Authors	Key Contribution	Limitations
Mobile Controlled Floor Cleaning Robot Using Raspberry Pi	Sunil Lendave et al.	Dry & wet cleaning with autonomous + mobile control	No environmental monitoring
Arduino Based Cleaner Robot	Shubham Tiwari et al.	Low-cost robot with obstacle detection	Limited sensor integration
Development of an Autonomous Vacuum Cleaner Robot	Ahmad Suharjo Marinda	Long battery life and dust detection	No intelligent decision-making
Autonomous Robotic Vacuum Cleaner	Swati Patil et al.	Autonomous indoor cleaning robot	Lacks scalability and higher processing

IV. WORKING OF SYSTEM

System Initialization

The robot is powered ON, the Raspberry Pi boots, and all GPIO pins, sensors, and relay modules are initialized for operation.

Web Server and Dashboard Setup

A Flask web server starts and connects to Wi-Fi, allowing the user to access the web dashboard for monitoring and control.

Command Processing

The system receives commands from the dashboard and checks whether the command is for robot movement or relay operation.

Robot and Relay Control

Movement commands control the motors through the L298N Motor Driver, while relay commands switch external devices like pumps or lights ON/OFF.

Sensor Monitoring

The robot continuously reads data from the DHT11, MQ2 Gas Sensor, and HC-SR04 sensors and displays the values on the dashboard.

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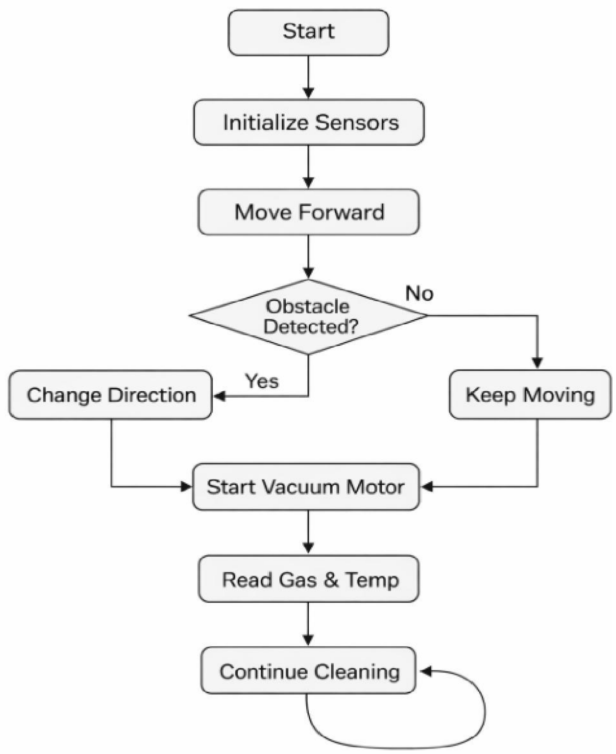

Fig. 2. Simple Flow Diagram of Methodology

Obstacle Detection and Continuous Operation

The system checks for obstacles using the HC-SR04 sensor. If an object is detected within 20 cm, the robot stops immediately; otherwise, it continues operation in a continuous loop.

V. SYSTEM DESIGN

1. System Overview

The proposed Smart Cleaning and Monitoring Robot is an IoT-based intelligent robotic system designed for automated cleaning, environmental monitoring, and remote operation using Raspberry Pi technology. The system integrates multiple sensors, motor drivers, relay modules, and a web-based control interface to create a smart robotic platform capable of real-time monitoring and obstacle avoidance.The robot uses a Raspberry Pi 4 Model B as the central processing unit, which controls all sensors, motors, and communication processes. A Flask-based web server hosted on the Raspberry Pi provides a browser-accessible dashboard through which users can remotely control robot movement and monitor live sensor data using any Wi-Fi-connected device.The system is equipped with a DHT11 for real-time temperature monitoring, an MQ2 Gas Sensor for smoke and gas detection, and an HC-SR04 for obstacle detection and automatic stopping functionality. These sensors continuously collect environmental data and improve the safety and intelligence of the robot.Robot movement is achieved using DC gear motors controlled through the L298N Motor Driver. The robot can move in forward, reverse, left, right, and stop directions according to commands received from the web dashboard. Relay modules are also integrated to control external devices such as spray motors, vacuum systems, cutters, or lighting systems.The ultrasonic obstacle detection system continuously measures the distance between the robot and nearby objects. If an obstacle is detected within 20 cm, the robot automatically stops to prevent collisions and ensure safe operation. The integration of IoT, web-based control, environmental monitoring, and automated cleaning creates a smart, cost-effective, and user-friendly robotic system suitable for applications such as industrial monitoring, smart cleaning, warehouse automation, educational robotics, and indoor surveillance.

2. Temperature Monitoring Module

This module monitors the surrounding environmental temperature using the DHT11 temperature sensor connected to the Raspberry Pi. The sensor continuously provides real-time temperature data to the system and displays it on the web dashboard.

Functions:

- Measures real-time temperature
- Provides environmental monitoring
- Displays temperature on web dashboard

Smoke and Gas Detection Module

The MQ2 Gas Sensor is used to detect smoke and harmful gases such as LPG, methane, and carbon monoxide. The sensor continuously monitors air quality and alerts the user when gas concentration exceeds the threshold level.

Functions:

- Detects smoke and harmful gases
- Improves safety monitoring
- Provides real-time gas status

Obstacle Detection Module

This module uses the HC-SR04 ultrasonic sensor to detect nearby obstacles and measure distance. The robot automatically stops when an object is detected within 20 cm to prevent collisions.

Functions:

- Measures obstacle distance
- Prevents collision automatically
- Improves robot safety

5. Motor Control Module

The L298N motor driver module controls the DC gear motors responsible for robot movement. The system receives movement commands from the web dashboard and controls the robot direction accordingly.

Functions:

- Controls forward and reverse movement
- Controls left and right turning
- Stops robot movement safely

6. Relay Control Module

The relay module acts as an electronic switching interface between the Raspberry Pi and external electrical devices such as spray motors, vacuum systems, cutters, or lights.

Functions:

- Controls external electrical devices
- Provides isolated switching operation

- Supports automation functions

7. Web Server and Dashboard Module

A Flask-based web server creates a browser-accessible dashboard for remote robot control and monitoring. Users can control the robot and monitor live sensor data through smartphones or laptops connected over Wi-Fi.

Functions:

- Provides remote robot control
- Displays live sensor readings
- Supports wireless communication

8. Cleaning Mechanism Module

The cleaning mechanism uses vacuum or suction motors integrated inside the robot chassis for cleaning operations. The system can activate cleaning devices through relay switching.

Functions:

- Performs automated cleaning
- Controls vacuum/suction motors
- Improves cleaning efficiency

9. Power Management Module

The power supply module distributes regulated power to the Raspberry Pi, sensors, motors, and relay modules to ensure stable and reliable operation of the robot.

Functions:

- Supplies regulated power
- Maintains system stability
- Supports continuous operation

10. Integrated Smart Robot Operation

All modules work together to create a fully automated smart robotic system capable of cleaning, monitoring environmental conditions, obstacle avoidance, and remote wireless operation.

Functions:

- Combines monitoring and cleaning operations
- Reduces manual effort
- Supports smart automation systems

VI. RESULTS

The Smart Cleaning and Monitoring Robot was successfully designed, developed, and tested for automated cleaning, environmental monitoring, and remote wireless control applications. The system effectively integrated Raspberry Pi, sensors, motor drivers, relay modules, and a Flask-based web dashboard to perform real-time monitoring and robot control operations.

The robot successfully performed directional movements including forward, reverse, left, right, and stop operations through commands received from the web dashboard over a Wi-Fi network. The L298N motor driver provided stable motor control and smooth robot navigation during testing.

The DHT11 temperature sensor successfully monitored real-time environmental temperature and continuously displayed the readings on the web dashboard. The MQ2 gas sensor effectively detected smoke and harmful gases, providing reliable environmental safety monitoring and alert generation.

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The HC-SR04 ultrasonic sensor accurately detected nearby obstacles and automatically stopped the robot when an object was detected within 20 cm. This obstacle avoidance functionality improved the safety and reliability of robot operation.

The Flask-based web interface successfully provided wireless monitoring and control functionality through smartphones and laptops connected to the same network. Sensor data was updated in real time, and robot response to user commands was fast and stable during operation.

The relay module successfully controlled external electrical devices such as vacuum motors, spray systems, and lighting loads through GPIO-based switching operations. The relay switching mechanism operated safely and efficiently during testing.

Overall, the proposed system demonstrated reliable performance, low-cost implementation, efficient environmental monitoring, obstacle avoidance capability, and user-friendly wireless control, making it suitable for smart cleaning, industrial monitoring, warehouse automation, and educational robotics applications.

VII. CONCLUSION

The Smart Cleaning and Monitoring Robot was successfully designed and implemented using Raspberry Pi, IoT technology, sensors, motor drivers, relay modules, and a Flask-based web interface. The system effectively performed automated cleaning, environmental monitoring, obstacle detection, and wireless robot control through a browser-based dashboard.

The integration of the DHT11 temperature sensor, MQ2 gas sensor, and HC-SR04 ultrasonic sensor enabled real-time monitoring of environmental conditions and improved the safety and intelligence of the robot. The obstacle detection mechanism successfully prevented collisions by automatically stopping the robot when objects were detected within a predefined distance.

The L298N motor driver provided reliable control of DC motors for robot movement in different directions, while the relay module efficiently controlled external electrical devices such as vacuum motors, spray systems, and lighting loads. The Flask web server enabled smooth remote operation and real-time sensor monitoring using smartphones and laptops connected over Wi-Fi.

The developed system demonstrated reliable performance, low-cost implementation, ease of operation, and flexibility for various smart automation applications. The project successfully achieved its objectives of creating an intelligent IoT-based robotic system capable of cleaning, monitoring, and remote wireless control. The proposed robot can be effectively used in industrial monitoring, warehouse automation, smart cleaning systems, educational robotics, and indoor surveillance applications.

VIII. FUTURE SCOPE

The Smart Cleaning and Monitoring Robot can be further improved by integrating advanced technologies and intelligent automation features. Future enhancements may include camera modules and computer vision techniques for real-time monitoring, object detection, and autonomous navigation. Artificial Intelligence and Machine Learning algorithms can also be added for intelligent decision-making and improved robot performance.

The system can be upgraded with cloud-based IoT platforms and mobile application support for remote monitoring and control from any location. Additional sensors such as humidity, fire detection, and air quality sensors can be integrated to enhance environmental monitoring capabilities.

Autonomous navigation techniques such as SLAM and path planning algorithms can enable self-navigation without human intervention. The cleaning mechanism can also be enhanced with advanced vacuum systems, water spraying units, and automatic waste collection features for improved cleaning efficiency.

These future improvements can make the system more intelligent, fully autonomous, energy-efficient, and suitable for industrial automation, smart cleaning, warehouse monitoring, and smart city applications..

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