DESIGN AND DEVELOPMENT OF RIVER SURFACE CLEANING ROBOT USING IOT

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ABSTRACT

This project presents an IoT-based surface-cleaning robot designed to collect waste from water bodies. The robot uses a conveyor belt for debris collection and ultrasonic sensors for obstacle avoidance. Controlled remotely via Bluetooth or Wi-Fi, it ensures flexible and user-friendly operation. A bin-level detection system alerts the user when the waste container is full. The robot is battery-powered, compact, and portable, making it suitable for varied environments. It addresses limitations of existing cleaning methods by automating tasks, reducing human effort, and improving efficiency. Future enhancements may include GPS-based navigation, AI-based object detection, and solar charging. The project integrates robotics, IoT, and environmental management in a practical application. It offers a cost-effective, scalable solution to surface waste problems in public and industrial settings.

1. INTRODUCTION

In today's rapidly evolving world, automation and smart systems are becoming essential in reducing manual labor and increasing efficiency. This project presents a smart surface-cleaning robot equipped with a conveyor belt system, obstacle detection, and wireless control. Designed for both indoor and outdoor environments, the robot is capable of autonomously collecting waste or debris from surfaces while avoiding obstacles in its path.

One of the key features of this system is its intelligent obstacle avoidance — when it encounters an obstacle, it automatically reverses for 3 seconds and redirects its path. Additionally, the robot includes a bin status detection mechanism: when the waste bin is full, a visual or audible indicator notifies the user. The robot's operations, including movement and cleaning controls, can be managed remotely using a mobile phone via Bluetooth or Wi-Fi, providing ease of use and flexibility. This project not only aims to improve cleanliness and hygiene in various environments but also showcases the integration of automation, smart sensing, and remote control in a cost-effective and practical system.

2. LITERATURE SURVEY

- **Reliability**: The system must operate continuously without failure. It should be highly reliable in detecting falls or responding to manual emergency triggers. The system should have a low failure rate for hardware components (e.g., sensors, GSM module) and software functions.
- **Real-Time Performance**: The system must process fall detection and manual panic triggers immediately with minimal delay. The response time for detecting a fall and sending an SMS alert should not exceed 10-15 seconds.
- **Scalability**: The system should be scalable, allowing for the addition of more sensors or features (such as heart rate monitoring or environmental sensors) in the future. It should accommodate updates, expansions, or integration with other smart home or healthcare systems.
- **Security**: All sensitive data (e.g., location, user information) must be encrypted during transmission to protect user privacy. The system must implement secure communication methods (e.g., using secure APIs or protocols for sending SMS).
- **Device Connectivity & Integration**: The system should be able to support a variety of embedded devices (sensors, actuators, controllers) that communicate over common protocols like MQTT, HTTP, and Modbus. Devices should be able to send data to the central server or cloud platform for real-time analysis and control. The system should provide seamless integration with existing industrial control systems (ICS).
- **Real-Time Data Monitoring:** The system must include a panic button that the user can press manually if they feel unsafe or need help. Pressing the panic button should activate the same emergency response as a fall detection alert.
- **Location Tracking**: The system should integrate a GPS module to determine the user's location (latitude and longitude). Location data should be updated in real-time for accurate emergency response.
- **Emergency Communication**: The system should send an SMS message to predefined contacts (e.g., family members, caregivers, or emergency services) with the user’s location. The message should include a Google Maps link that displays the user’s location for easy navigation.
- **Real-Time Operation**: The system should continuously monitor for fall events and the manual panic button press without delays. All sensor readings (from the magnetometer and GPS) should be processed in **real-time**.
- **System Reset & Recovery**: After sending an alert, the system should automatically reset and resume fall detection and monitoring. It should recover from errors or communication failures, ensuring minimal downtime.

3. METHODOLOGY

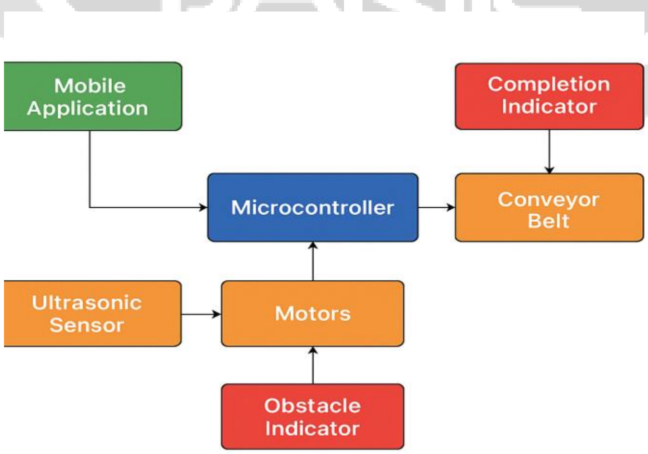

Fig 4.2 Block Diagram of the system module

The step-by-step process of the system begins with initialization, where the microcontroller **ESP32** activates the sensors (IR sensor & Ultra Sonic sensor), motors (DC and Gear motors), and other components once the system is powered on. At this stage, the boat remains idle, awaiting commands from the mobile application. When the user sends a command via the mobile app through Wi-Fi Module, the app communicates with the microcontroller to initiate the cleaning process. During operation, the ultrasonic sensor constantly scans for obstacles in the boat's path. If an obstacle is detected, the microcontroller halts or reverses the boat for three seconds to avoid a collision. In the absence of obstacles, the motors propel the boat forward while the surface cleaning mechanism and conveyor belt work simultaneously to collect and remove debris from the water. Upon completion of the cleaning operation, the boat sends a signal to the microcontroller, which activates a completion indicator By the IR sensor either on the mobile app or on the boat itself to notify the user. The boat then automatically navigates back to its starting position, guided by the microcontroller while avoiding any obstacles in the process.

3.1. Hardware and Software Requirements

Hardware Components:

i. **MICROCONTROLLER**: **ESP32:** The ESP32 is a powerful, cost-effective microcontroller with built-in Wi-Fi and Bluetooth, ideal for IoT and robotics. Its dual-core processor allows efficient multitasking, outperforming traditional boards like the Arduino Uno. It features multiple GPIO pins for connecting sensors and actuators. The ESP32 also supports key communication protocols like PWM, I2C, SPI, and UART.

ii. **MOTOR DRIVER:** A motor driver is a vital component that controls the speed and direction of DC motors, acting as an interface between the microcontroller and motors. Since microcontrollers like the ESP32 can't supply high current, motor drivers like the L298N are used to handle this load. The L298N can control two DC motors and supports PWM for speed control. It enables forward, reverse, and turning motions based on microcontroller signals. In this project, the motor driver powers both the wheels and conveyor belt for smooth operation **GPS Module**: **NEO-6M GPS Module**

iii. **ULTRASONIC SENSOR:** An ultrasonic sensor measures distance by emitting high-frequency sound waves and detecting their echo. The HC-SR04 is a popular module used for this purpose. In robotics, it's essential for obstacle detection and avoidance. In the cleaning robot project, the sensor continuously scans for obstacles ahead. When an object is detected, the microcontroller halts or reverses the robot to prevent collisions, ensuring safe and autonomous operation.

iv. **IR SENSOR:** An IR (Infrared) sensor detects objects or changes using infrared light, typically through a transmitter and receiver pair. It's widely used in robotics for object detection and proximity sensing. In the cleaning robot project, the IR sensor checks if the dustbin is full by detecting blocked signals. When waste is detected, it alerts the microcontroller, which triggers an LED or buzzer. This automates maintenance by notifying the user to empty the bin, ensuring efficient operation.

v. **RELAY MODULE:** A relay module is an electrically operated switch that lets low-power microcontrollers like the ESP32 control high-voltage devices. It uses an electromagnet to open or close circuits safely. In the cleaning robot project, it controls components like a high-power conveyor motor or a bin-full alert system. The relay provides isolation between the microcontroller and high-power devices, ensuring safety. Built-in features like flyback diodes and optocouplers make it reliable and easy to use in robotics.

vi. **BUZZER:** A buzzer is a low-power audio device used to give alerts or notifications in electronic projects. In the cleaning robot, it provides sound indications when the dustbin is full or an obstacle is detected. It is activated by a control signal from the microcontroller like the ESP32. Buzzers are compact and easy to integrate, enhancing user feedback. This makes the system more interactive and easier to monitor without constant visual attention

vii. **DC GEAR MOTORSP:** A DC gear motor combines a DC motor with a gearbox to reduce speed and increase torque, ideal for controlled movement in robotics. In the cleaning robot, it powers both the wheels and conveyor belt for waste collection. These motors are compact, energy-efficient, and capable of handling loads or small inclines. Speed can be adjusted using voltage or PWM via a motor driver. This allows the microcontroller to ensure smooth and precise robot movement

viii. **CONVEYOR BELT:** A conveyor belt is a motor-driven system that continuously moves objects using a flexible belt over rollers. In the cleaning robot, it collects surface waste and transports it into the onboard dustbin as the robot moves. Powered by a DC gear motor, it ensures steady and controlled operation. This enhances cleaning efficiency by gathering debris without stopping.

ix. **BUCK CONVERTER:** A buck converter efficiently reduces high DC voltage to a lower, stable level, ideal for battery-powered projects. It uses switching components to minimize energy loss, unlike heat-dissipating linear regulators. In the cleaning robot, it steps down 12V to 3.3V or 5V to safely power the microcontroller. This enables all components to run from one power source while preserving battery life.

x. **BATTERY:** The battery powers all electronics in the surface-cleaning robot, with a 12V lithium-ion pack being a reliable choice. A 3-cell (3S) Li-ion battery provides around 11.1V to 12.6V, balancing power, weight, and runtime. Higher capacity batteries extend operation time, and a protection circuit (BMS) prevents overcharging or deep discharge. A buck converter steps down voltage to safely power the microcontroller and sensors

xi. **Arduino UNO:** Arduino Uno collects data from various sensors (temperature, humidity, gas, soil moisture, TDS, laser) and processes it for improved accuracy and Embedded HTML, CSS, and JavaScript Languages were used here.

3.2 ACTIVITY DIAGRAM

3.2.1 Schematic Diagram

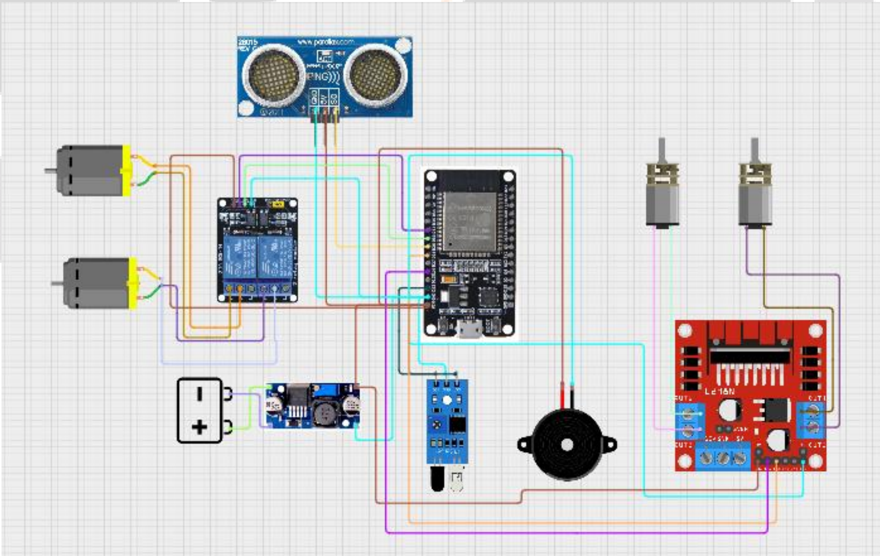

Fig 3.1. Schematic Diagram of the project

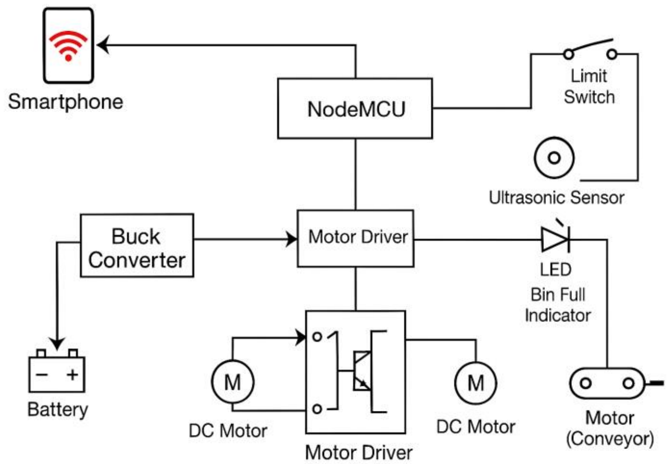

Fig 3.2. Activity diagram of the project

This comprehensive system diagram illustrates an automated control mechanism, likely for a bin or conveyor, centered around a NodeMCU microcontroller. Power is supplied by a battery, regulated by a buck converter to ensure stable voltage for all components. A smartphone provides wireless control and monitoring capabilities, communicating directly with the NodeMCU. The NodeMCU, acting as the system's brain, manages inputs from a limit switch, which provides positional feedback, and an ultrasonic sensor, crucial for distance measurement or bin fullness detection. It then processes this data to control multiple outputs, including two DC motors for primary mechanical actions and a dedicated motor for a conveyor system, both driven by appropriate motor drivers. Additionally, an LED serves as a clear "Bin Full Indicator," triggered by the NodeMCU based on sensor readings. This integrated design, encompassing power management, wireless communication, sensor-based feedback, and motor control, highlights a sophisticated automated solution capable of intelligent operation and user interaction. The system's modularity and distinct functional blocks suggest its applicability in various automated tasks such as material handling, smart waste management, or dispensing systems, emphasizing both automation and user-friendly control

4. RESULTS AND DISCUSSION

Fig 4.1. Final output of the project

The overall system of the cleaning robot operates through the coordinated interaction of several key modules. When the system powers on, the microcontroller—such as a Node MCU or ESP32—initializes all connected components to prepare for operation. The user then activates phone control, connecting to the robot via Wi-Fi or Bluetooth, depending on the module used. Through the mobile app, the user can remotely control the robot’s movement, including commands to move forward, backward, turn left or right, and turn the conveyor belt on or off. As the robot moves, the conveyor belt runs continuously to collect surface debris and transport it into the collection bin.

During operation, an ultrasonic sensor constantly scans ahead to detect obstacles within a preset distance, typically around 20 centimeters. If an obstacle is detected, the robot automatically stops to avoid collision, reverses for about three seconds, and then halts again to wait for further user commands. This obstacle detection feature enables the robot to navigate safely and autonomously in its environment. Inside the dustbin, a sensor—either an infrared (IR) sensor or a limit switch—monitors the bin’s fill level. When the bin reaches capacity, the sensor triggers an alert system that activates a visual indicator, such as an LED, or an audible buzzer to notify the user that the bin needs emptying.

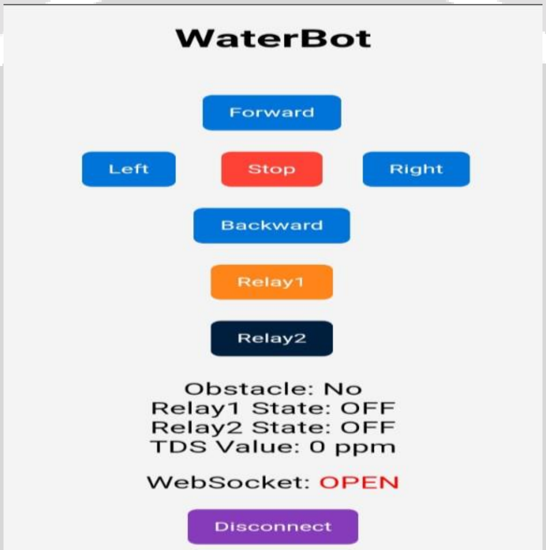

Fig4.2. Control notification received in the registered mobile phone

Once the user is informed, they can manually empty the bin and reset the system. The robot remains paused during this process to prevent overflow or malfunction. After the bin is cleared, cleaning operations can resume either automatically or under the user’s manual control via the phone app. This seamless integration of power management, remote control, obstacle avoidance, debris collection, and user notification ensures efficient, safe, and user-friendly cleaning performance in the robot. The design allows flexibility for user intervention while maintaining autonomous operation, enhancing the overall effectiveness of the cleaning process

5. FUTURE ENHANCEMENT

In the future, this surface cleaning robot can be enhanced with advanced features such as GPS-based autonomous navigation to allow it to clean predefined areas without manual control. Integration of solar panels can make the system more energy-efficient and environmentally friendly, especially for long-duration operations on water surfaces. Adding a camera with AI-based vision processing could enable object classification, allowing the robot to distinguish between waste and natural elements like leaves or floating logs. Furthermore, real-time data transmission to a mobile app or cloud server could enable remote monitoring, performance tracking, and automatic alerts. These enhancements would significantly improve the robot's efficiency, autonomy, and usefulness in larger-scale or commercial cleaning application.

6.CONCLUSION

In conclusion, the surface cleaning robot presents an innovative and practical solution for maintaining cleanliness on water or flat land surfaces. With its conveyor-based waste collection system, obstacle detection, and remote control via mobile devices, it offers a safe, efficient, and user-friendly approach to environmental cleaning. Though there are limitations such as battery dependency and limited payload, these can be addressed through future enhancements like solar integration and AI-based automation. Overall, this project contributes meaningfully toward sustainable waste management and showcases the potential of robotics and IoT in real-world applications. The IoT-based system allows for remote monitoring, control, and data analysis, enabling timely interventions and informed decision-making. Furthermore, its scalable and eco-friendly design makes it a promising solution for both urban and rural water bodies

7. REFERENCES

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