IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 4, June 2025
Impact Factor: 7.67

RF Remote Operated Railway Track Cleaning Robot

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Abstract: *This paper aims to design and develop a prototype for a cost efficient Railway track cleaning machine which would prove to be an alternative to the current system in place if implemented and optimized. As we see many problems of uncleanness due to waste on track, it is a human responsibility and at the same time the government has to look at the track to clean the garbage. In India, it is common for every track in which state or which station there is problem, as we have admitted that it is problem which contributes to our effort to solve or reduce to some extent. The prototype will be design having similarities to original railways. The proposed prototype is designed to clean the track, as in India as we see a very less effort is made for cleaning purpose. We are designing a machine which is automated by using radio frequency so that it can be operated in both static and dynamic conditions. Human safety is our priority; hence, project is fully automated and will be easy to Operated. The robot is manually controlled via a remote allowing operators to clean tracks from a safe distance without the need for physical presence on the tracks. Equipped with advanced sensors and collection mechanisms, the robot can navigate the tracks autonomously, ensuring a thorough and consistent cleaning process..*

Keywords: Automation, Railway Track Cleaning, RF remote, Robotics, Wireless Technology

I. INTRODUCTION

The cleanliness and maintenance of railway tracks are of paramount importance for ensuring the safety, reliability, and efficiency of train operations. Railway tracks are constantly exposed to environmental elements and human activities, leading to the accumulation of dirt, debris, plastic, paper, and other solid waste. If left unchecked, these contaminants can obstruct the tracks, reduce traction, and even cause derailments, posing significant risks to both passengers and cargo. Another important point is of cleanliness and contamination. Since the railway platform is surrounded by people, there is always risk of virus and hygiene. This may cause serious health issue. Regular and thorough cleaning of railway tracks is, therefore, essential to maintain the smooth and safe operation of trains and also for health of people around.

Traditional methods of track cleaning, which rely on manual labor, are often labor-intensive, time-consuming, and fraught with safety hazards. Workers must operate in dangerous conditions, including extreme weather and the proximity of moving trains, making the task physically demanding and risky. Manual cleaning is also inconsistent, as it may fail to completely remove smaller debris or contaminants that can accumulate over time and lead to significant operational issues. The need for frequent maintenance and track closures further complicates the cleaning process, leading to disruptions in train schedules and increased operational costs.

To address these challenges, this project introduces a remote-operated railway track cleaning robot, designed to efficiently collect dirt, paper, plastic, and other solid waste from the tracks. The robot is manually controlled via remote, allowing operators to clean tracks from a safe distance without the need for physical presence on the tracks. Equipped with advanced sensors and collection mechanisms, the robot can navigate the tracks autonomously, ensuring a thorough and consistent cleaning process.

This innovative solution not only enhances the safety and efficiency of track maintenance but also reduces the need for manual labor, lowering the risks associated with traditional cleaning methods. By automating the cleaning process, the robot helps to maintain the integrity of the railway infrastructure, ensuring a safer, cleaner, and more reliable railway network.

DOI: 10.48175/568

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Need of Project:

The cleanliness of railway tracks on platforms is especially critical due to the accumulation of waste material, such as paper, plastic, and other debris discarded by passengers. These materials can pose significant safety hazards if not regularly removed. For instance, plastic bags and other lightweight debris can become entangled in the tracks or obstruct the track switches, potentially leading to operational failures or even accidents. Additionally, the presence of litter on the tracks can attract pests, contribute to pollution, and create an unsightly environment that detracts from the overall passenger experience. Regular cleaning of railway tracks on platforms is essential to maintain the safety, efficiency, and aesthetic appeal of the station, ensuring a cleaner and safer environment for both passengers and train operations.

Traditional methods of track cleaning, which rely on manual labor, are often labor-intensive, time-consuming, and fraught with safety hazards. Workers must operate in dangerous conditions, including extreme weather and the proximity of moving trains, making the task physically demanding and risky. Manual cleaning is also inconsistent, as it may fail to completely remove smaller debris or contaminants that can accumulate over time and lead to significant operational issues. The need for frequent maintenance and track closures further complicates the cleaning process, leading to disruptions in train schedules and increased operational costs.

II. LITERATURE SURVEY

Here we refer to P. Vamsi Krishna and Dr. S. Prakash [1]. Indian Railways may be the country's largest mobile source of environmental pollution. Indian Railways is perhaps becoming the biggest mobile source of environmental pollution in the country. And of course, this kind of round-the clock disposal of vast quantity of human waste in open environments to keep the trains clean is not at all healthy and advisable. The garbage from pantry cars and tray loads of hot mealson station and in train are also thrown off through the doors and windows of bogeys onto the tracks polluting the stations and places all along the train's way. The existing cleaning process of the tracks and the railway platforms is manual, which is tedious and far from the desired level of sanitation or cleanliness. Manual scavenging deals with maintenance of hygienic conditions through services such as collection and disposal of solid and liquid waste using basic tools like thin boards and buckets or baskets lined with sacking and carried on the head. By virtue of the job, many of the workers develop serious health problems in course of time. The health hazards include exposure to harmful gases such as methane and hydrogen sulphide, cardiovascular degeneration, musculoskeletal disorders, infections, respiratory system failure, etc.

1) Railway Track Cleaning Robot[1] uses centrifugal force to collects all light weight waste on track. But since its running continuously without driver, it ay face accident when train coming on track,

2) Design modelling and fabrication of railway track cleaning bot [2] uses rollers to collect waste. With the adjustable roller heights, waste collection may easy. But since the railway track height is always same, this feature has no significant impact. Also With only brush, its difficult to collect all waste.

3) Intelligent track cleaning robot [3] uses PIC microcontroller based system for four-wheel running robot with a suction unit. But without brushes to centralize waste, it needs more power.

4) Internet of things-based floor cleaning robot [4] presents floor cleaning robot mechanism controllable trhough WiFi and IOT using blick app. But lack of sensors makes impossible to detect obstacles

So from above study, a design must occupy with brushes with vacuum, sensors to detect obstacle and robot driving mechanism to operate it.

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III. SYSTEM DESIGN

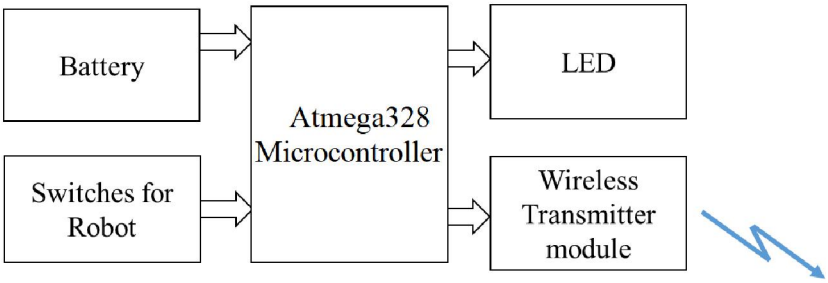

Fig. 1. Transmitter Section

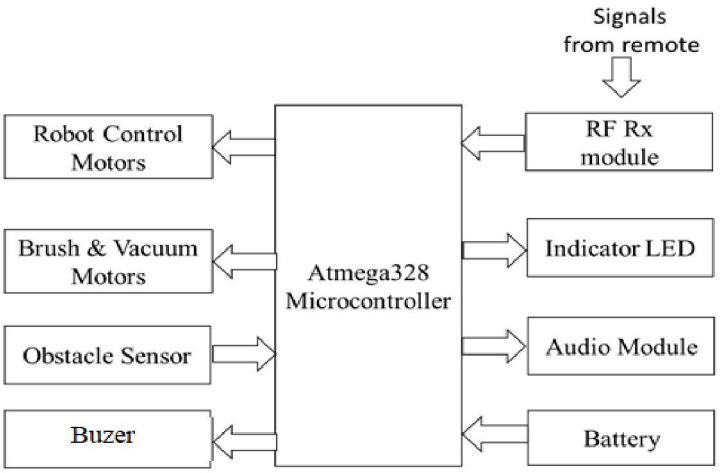

Fig. 2. Receiver Section

When Here Atmega328 microcontroller will be the main processing unit of remote control. It will send the RF signal to robot using RF transmitter module. Switches are connected to Atmega328 microcontroller. LED is used to provide indication when switch is pressed. Switches give signal to Atmega328 microcontroller. Then Atmega328 microcontroller sends corresponding control signal to wireless RF transmitter. Transmitter transmits the signal in the form of RF waves to the robot. Complete remote is powered by battery.

Here, RF signal received by RF receiver are given to Atmega328 microcontroller. Then Atmega328 microcontroller decodes that signal and identifies the switch pressed on remote. According to pressed switch, Atmega328 microcontroller gives signal to robot control motors or cleaning motors. LED is used to provide indication when signal is received. Ultrasonic sensor is used to detect obstacles. On detection on any obstacle, an audio record will be played. Complete robot is powered by battery.

IV. METHODOLOGY

Component Description

A. ATmega328 Microcontroller

The A microcontroller is a heart of every automation system. It is a small, low cost and self-contained on chip computer. Microcontrollers usually must have low-power requirements since many devices they control are battery-operated.

As per our requirements, microcontroller ATMEGA328P matches perfectly. Features of ATMEGA328P microcontroller are as follows:

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Features:

- 28 pin IC with 20 GPIO pins
- Inbuilt 6 channel ADC
- 2kb SRAM, 1kb EEPROM
- 32 General purpose registers
- Works on 5V
- Low power Sleep mode
- Multiple software tool support

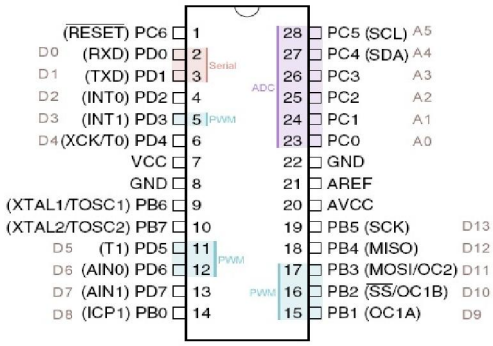

Fig. 3. Atmega328 Pinout

B. nRF-2401 Trans-Receiver Module

Its great little solution's for wireless control capable of up to 2Mbps communication with a range from 40 to 100 meter. Has on board antenna. The nRF24L01 is a single chip 2.4GHz trans-receiver with an embedded baseband protocol engine (Enhanced ShockBurst™), designed for ultra-low power wireless applications. The nRF24L01 is designed for operation in the world wide ISM frequency band at 2.400 - 2.4835GHz. The nRF24L01 is configured and operated through a Serial Peripheral Interface (SPI.)

Specifications:

- Operating voltage: +3.3V
- Nominal current 50mA
- Range: 50 to 200 feet
- Speed: 250kbps
- Channel Range: 125 Nodes

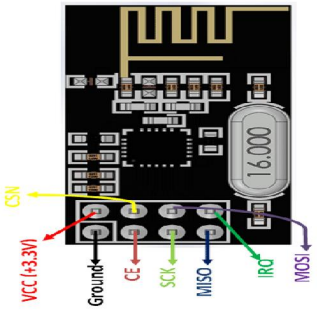

Fig. 4. nRF-2401 Trans-Receiver Module

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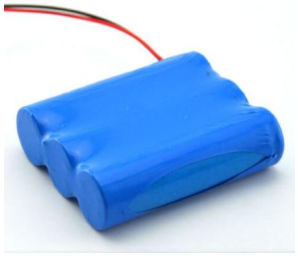

C. Battery Pack

This battery pack supplies power to the entire robot and electronics system. Lithium-ion batteries store energy through electrochemical reactions and release it when connected to a circuit.

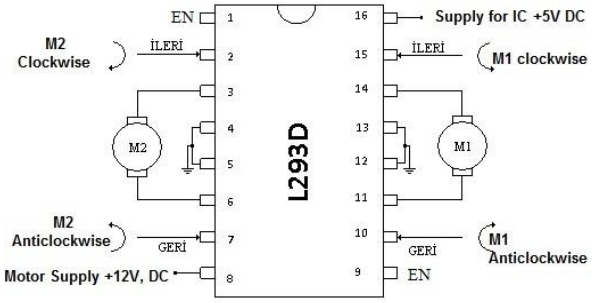

Fig. 5. Battery Pack

Specifications:

- Type: Lithium-Ion
- Rated Voltage: 11.1V
- Full Charge Voltage: ~12V
- Capacity: 2Ahr
- Cell Configuration: 3Series
- Inbuilt BMS for stable charging and protection
- Discharge Current: Up to 10A
- Charging Supply Required: 12V DC.

D. DC Motor

These motors are simple DC Motors featuring gears for the shaft for obtaining the optimal performance characteristics. They are known as Center Shaft DC Geared Motors because their shaft extends through the center of their gear box assembly. These standard size DC Motors are very easy to use. This DC Motor – 100RPM – 12Volts can be used in all-terrain robots and a variety of robotic applications. These motors have a 3 mm threaded drill hole in the middle of the shaft thus making it simple to connect it to the wheels or any other mechanical assembly. Nut and threads on the shaft to easily connect and internally threaded shaft for easily connecting it to the wheels. These DC Geared motors with robust metal/Plastic gearbox for heavy-duty applications, available in the wide RPM range and ideally suited for robotics and industrial applications.

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Fig. 6. DC Motor

E. L293D Motor Driver IC

The L293D is quadruple high-current half-H drivers. The L293NE is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. This device is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications. All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled, and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

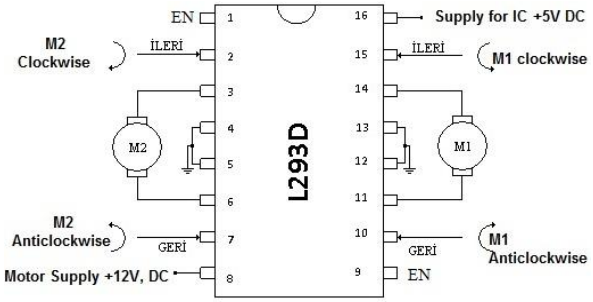

Fig. 7. L293D Motor Driver

F. Ultrasonic Sensor

HC-SR04 Ultrasonic sensor is a 4 pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like projects in the front which forms the Ultrasonic transmitter and Receiver. The sensor works with the simple high school formula that

Distance = Speed × Time

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected back toward the sensor this reflected wave is observed by the Ultrasonic receiver module After measuring the time taken by the wave to receive back, distance is calculated by above formula.

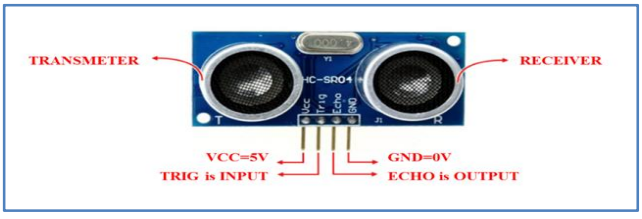

Fig. 8. Ultrasonic Sensor

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G. Vacuum Pump

This portable small size vacuum cleaner assembly is used with high power 3000RPM DC motor with 3.7V single cell power supply. This pointed nose structures centralized the suction capacity and the filter isolates the waste collected from motor assembly. Separately used high power DC motor offers powerful suction and make effective combination under low budget. This vacuum supply will be controlled by microcontroller through the SPDT relay along with cleaning motors.

Specifications:

- Voltage Range: 3V - 5V
- Current Rating: 2-2.5Amp
- RPM: 3000 RPM
- Suction inlet: 3cm

Fig. 9. Vacuum Pump

V. RESULT

Railway Track Cleaning Robot was successfully implemented and tested, achieving the following results:

- Efficient Cleaning: The brush and vacuum system effectively removed waste from the tracks, improving cleanliness.
- Reliable Remote Operation: The RF-based control system demonstrated a stable communication range of approximately 10 meters, allowing safe remote operation.
- Effective Obstacle Detection: The ultrasonic sensor accurately detected obstacles and triggered the audio alert system, preventing collisions.
- Accurate Waste Monitoring: The IR sensor successfully detected waste accumulation and provided timely alerts.
- Battery Efficiency: The system was able to operate continuously for approximately 20 minutes hours on a full charge, meeting expectations for real-world deployment.
- Enhanced Safety: The remote-controlled operation eliminated the need for manual track cleaning, reducing safety risks for workers.

Important observations of the project are as bellow:

1. Robot can drive in forward and reverse directions using remote
2. Range of wireless remote control: 15 ft line of sight
3. Power source required: 12V, 2Amp
4. Battery backup time: 20 Minutes.
5. Waste collection accuracy: 80%

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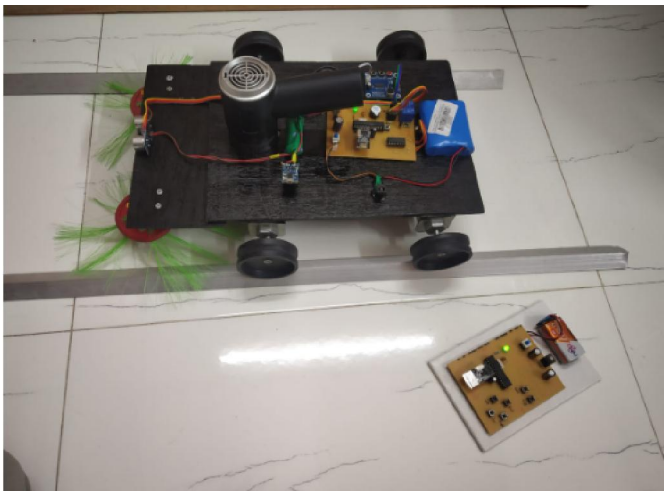

Fig. 10. Photograph of Module

VI. CONCLUSION

The development of a remote-operated railway track cleaning robot represents a significant advancement in maintaining railway infrastructure while prioritizing worker safety. This robot efficiently collects dirt, paper, plastic, and other waste from the tracks, ensuring a clean and safe environment for train operations. By combining advanced sensors for obstacle detection with an effective cleaning mechanism that utilizes brushes and a vacuum, the robot can autonomously navigate tracks and execute thorough cleaning tasks.

Additionally, battery power not only enhances the operational efficiency of the robot but also aims to reduce cleaning costs while ensuring reliable performance. Ultimately, this project demonstrates the potential for innovative solutions that promote cleanliness on railway tracks while safeguarding the health and safety of maintenance personnel. The proposed robot sets a new standard for automation in railway maintenance, offering a low-cost, effective approach to one of the industry's ongoing challenge.

VII. FUTURE SCOPE

One major future scope for this project is the integration of an AI-based autonomous navigation system. Since the current prototype has low efficiency due to manual remote operation, AI and machine learning algorithms can be implemented to enhance autonomous movement and obstacle detection. By using GPS and advanced sensors like LiDAR, the robot can navigate and clean railway tracks with minimal human intervention, significantly improving operational efficiency and reducing dependency on remote operators.

ACKNOWLEDGMENT

It gives us great pleasure in presenting the paper on “RF Remote Operated Railway Track Cleaning Robot”. We would like to take this opportunity to thank our guide, Mr. Mayur Ingale, Professor, Department of ETC Engineering, Sandip Institute of Technology & Research Centre , Nashik, for giving us all the help and guidance we needed. We are grateful to him for his kind support, and valuable suggestions were very helpful.

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