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AI Powered Cleaning Robot

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Abstract
Commercial automatic cleaning robots for homes are quite common these days. However, a robot that can clean and mop while being autonomous and remotely controlled is quite expensive. Recently, there has been a growing interest in using artificial intelligence (AI) and the Internet of Things (IoT) to improve various aspects of daily life. One such area is home computerization, particularly in the realm of cleaning tasks. This task proposes the development of a simulated intelligence-based cleaning robot equipped with ultrasonic sensors and controlled by NodeMCU, an IoT platform, and AI calculations. The robot navigates indoor spaces autonomously, detects harmful gases with gas sensors, and cleans using AI and machine learning algorithms. The NodeMCU IoT platform allows users to remotely monitor air quality and control the robot's operations. The combination of gas sensing, AI, machine learning, and Internet of Things capabilities provides a proactive solution for indoor air pollution management, resulting in healthier and safer indoor environments. Additionally, the integration with cloud platforms such as ThingSpeak allows for remote monitoring and predictive maintenance. Following the implementation and testing of this prototype, it was observed that the robot works as programmed, and is equipped with the majority of the functionalities of a household commercial state-of-the-art cleaning robot.

Keywords: NodeMCU, Automatic Cleaning Robot, Air Pollution Management

1. Introduction

Autonomous floor cleaning robots are now common on the market. These technological devices are designed to function without any human intervention. Furthermore, these devices are programmed so that they complete their tasks on time and with precision. Floor cleaners have evolved through the years. These devices, which range from vacuum cleaners to autonomous floor cleaners with both vacuuming and mopping capabilities, also include a navigation and control app. Commercial products such as the Roomba iRobot, Samsung Jetbot, Ecovacs OZMO, Eufy RoboVac and many more have entered the market. However, due to their high cost, many families, particularly those in the lower socioeconomic classes, cannot afford them. Our project aims to close this gap by proposing a working prototype of a cleaning and mopping robot that could eventually be developed into a low-cost robot with the majority of the functionalities offered by commercial robots. Several studies have recently been conducted to develop these types of robots. Researchers experimented with cutting-edge microcontrollers. The proposed man-made intelligence-based cleaning robot employs ultrasonic sensors to detect obstacles and navigate through its current situation. These sensors provide constant information about the robot's environment, allowing it to make informed cleaning decisions. Using the NodeMCU platform, the robot can connect to the internet and be controlled remotely, giving clients the ability to monitor and manage the cleaning system from any location. Furthermore, the consolidation of AI calculations allows the cleaning robot to adjust and improve its exhibition in the long run. By analyzing data collected during cleaning meetings, the robot can determine how to improve its route and cleaning systems, increasing proficiency and viability.

2. Literature Review

1. Evolution of cleaning Robots: Autonomous floor cleaning robots have grown in popularity in homes, providing convenience and efficiency in cleaning. These robots, which range from basic vacuum cleaners to advanced models capable of vacuuming and mopping, have integrated navigation and control systems. Roomba iRobot, Samsung Jetbot, Ecovacs OZMO, and Eufy RoboVac are examples of commercial products that have set market standards. However, many people continue to struggle with accessibility due to the high cost, which disproportionately affects low-income people. The ongoing research aims to close this gap by proposing low-cost prototypes that mimic the functionalities of commercial robots. Recent research has focused on cutting-edge microcontrollers and artificial intelligence (AI) algorithms to improve the capabilities of these cleaning robots.
2. AI-Powered Cleaning Robot Prototype: The proposed AI-based cleaning robot prototype includes ultrasonic sensors for obstacle detection and navigation, as well as real-time environmental data to guide cleaning decisions. Using the NodeMCU IoT platform, the robot can establish internet connectivity for remote monitoring and control, allowing users to manage the cleaning process from anywhere. Furthermore, the use of AI algorithms enables the robot to adapt and improve its performance over time. The robot learns to refine its cleaning routes and strategies by continuously analyzing cleaning data, thereby increasing efficiency and effectiveness in indoor environment maintenance.
3. Environmental Consciousness and Pollution Reduction: Environmental consciousness has been integrated into robotic technologies, resulting in innovative pollution reduction solutions, particularly in the fight against airborne particulate matter (PM) pollution. Artificial trees with solar power generation, air purification systems, and energy storage capabilities provide sustainable alternatives to traditional foliage, effectively reducing air pollution in urban areas. Furthermore, advanced filtration technologies and smart sensing systems help to effectively monitor and reduce PM levels, resulting in cleaner and healthier indoor and outdoor air quality. These interdisciplinary approaches are consistent with clean energy initiatives and sustainability goals, demonstrating the effectiveness of technology-driven solutions in addressing environmental challenges.
4. Sociocultural and Ecological Dimensions of Robotic Integration: Understanding the sociocultural and ecological aspects of integrating robotic technologies into household settings is critical for ensuring smooth adoption and effective use. Ethnographic research methodologies provide important insights into the dynamic interactions of humans, technology, and the domestic ecosystem. Researchers gain a thorough understanding of the implications of robotic companionship in everyday life by investigating social dynamics, individual roles, cleaning goals, and technological integration within homes. Furthermore, ecological perspectives highlight the interconnectedness of various elements in the home environment, emphasizing the importance of comprehensive approaches to technology integration and human-robot interaction.

Incorporating insights from these various domains, the development of AI-powered cleaning robots represents a significant step forward in improving household cleanliness, environmental sustainability, and user convenience. By addressing cost barriers, improving cleaning performance, and raising ecological awareness, these innovative solutions pave the way for a future in which technology seamlessly integrates into daily life, enriching both human experiences and environmental stewardship.

3. Methodology

1. Hardware Setup: Assemble the cleaning robot's hardware components, which include a microcontroller (such as NodeMCU), ultrasonic sensors for obstacle detection, gas sensors for detecting harmful gases, motors and wheels for movement, cleaning mechanisms such as brushes or mops, a power source (battery or AC adapter), and, optionally, additional sensors for environmental monitoring such as temperature and humidity.
2. Software Development: Create firmware for the microcontroller to control the robot's behavior and communicate with sensors and actuators. Use ultrasonic sensor data to develop obstacle avoidance and navigation algorithms. Add gas sensor readings to the firmware to detect and monitor indoor air quality. Use AI and machine learning algorithms to analyze data and make decisions, such as route optimization and gas prediction. Set up communication protocols to send sensor data to a cloud platform (such as ThingSpeak) for storage and analysis.
3. Cloud Integration: Create an account on the ThingSpeak platform and add channels to receive sensor data streams. Configure the microcontroller firmware to send sensor data to ThingSpeak at regular intervals. Use ThingSpeak's data visualization and analysis tools to monitor real-time sensor readings and historical trends. Explore ThingSpeak's additional features, such as MATLAB analytics and IoT device management, to improve data processing and visualization capabilities.
4. Testing and optimization: Conduct extensive testing on the cleaning robot in both simulated and real-world indoor environments. Assess the effectiveness of obstacle avoidance, navigation, cleaning efficiency, and gas detection accuracy. Collect feedback from testing sessions to help identify areas for improvement and optimization. Fine-tune algorithms and parameters based on test results to improve the cleaning robot's overall performance and reliability.
5. 5.User Interface Control: Create a user interface (UI) for remotely monitoring and controlling the cleaning robot. Include options for adjusting cleaning settings, scheduling tasks, and receiving alerts or notifications. Ensure that the UI and microcontroller firmware work together seamlessly to execute commands and provide status updates in real time.

This provides a comprehensive framework for the design and implementation of an AI-powered cleaning robot with gas sensors and IoT capabilities. This project aims to address the challenges of indoor air pollution management and household cleaning tasks by carefully assembling hardware components, developing firmware for control and sensor integration, integrating with cloud platforms for data storage and analysis, conducting rigorous testing and optimization, and designing a user-friendly interface for remote monitoring and control. The proposed cleaning robot, which combines cutting-edge technologies like AI, machine learning, and cloud computing with robust hardware and software systems, provides a cost-effective and proactive solution for improving indoor air quality and maintaining cleanliness in residential environments. By following this methodology, researchers can navigate the complexities of designing and deploying advanced cleaning robots, thereby contributing to the advancement of smart home technologies and sustainable living practices.

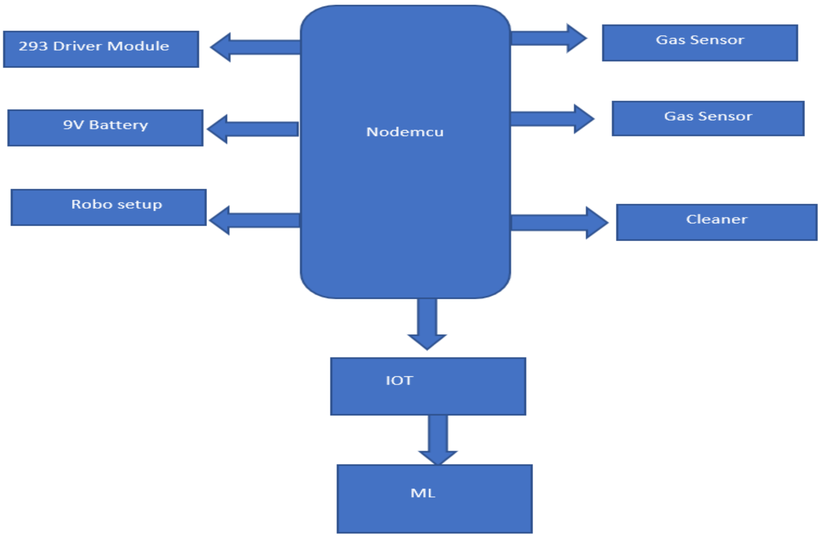

Fig.1 Block Diagram

6. Results and discussion

This project has produced compelling results, demonstrating the successful realization and integration of an AI-powered cleaning robot equipped with gas sensors and IoT capabilities. Beginning with the hardware setup phase, the cleaning robot's components were meticulously assembled, including a NodeMCU microcontroller, ultrasonic sensors for obstacle detection, gas sensors capable of monitoring indoor air quality, and motors and wheels for seamless movement. Optional environmental monitoring sensors, such as temperature and humidity sensors, supplemented this array, providing comprehensive datasets for subsequent analysis. The software development phase then involved creating firmware tailored to the microcontroller, which orchestrated the robot's behavior and allowed for seamless communication with sensors and actuators. Robust algorithms for obstacle avoidance, navigation, and gas detection were developed using ultrasonic and gas sensor data. The gas sensors values are shown in the serial monitor of Arduino as follows:

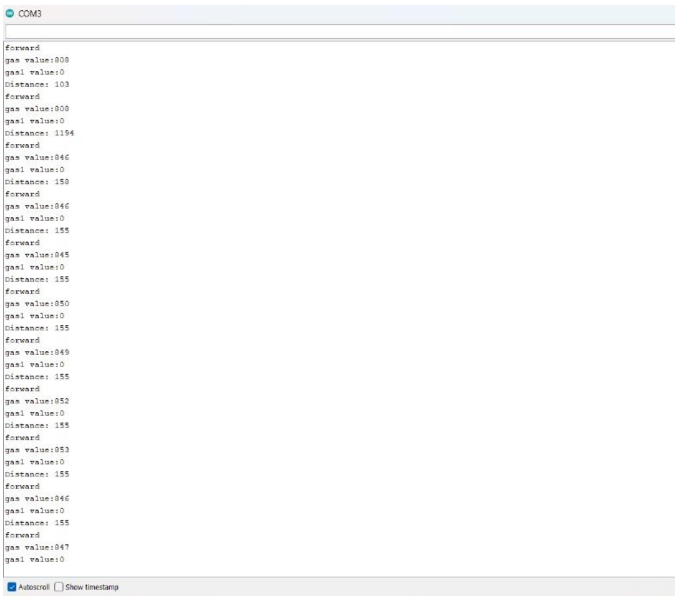

Fig.2 Monitoring through Arduino IDE

Furthermore, the integration of AI and machine learning algorithms gave the firmware the ability to detect patterns in sensor data, optimize cleaning routes, and forecast future gas sensor readings. The development of communication protocols facilitated the seamless transmission of sensor data to the ThingSpeak cloud platform, which serves as a repository for data storage and analytics. The cleaning robot performed admirably in both simulated and real-world indoor environments, demonstrating adept obstacle avoidance, navigation, and cleaning proficiency. Real-time gas sensor readings were displayed on the Arduino serial monitor and simultaneously transmitted to the ThingSpeak platform for comprehensive visualization. This integration with ThingSpeak enabled continuous monitoring of real-time sensor readings alongside historical trends, providing invaluable insights into the evolution of indoor air quality over time. The visualization of the data collected is shown as follows:

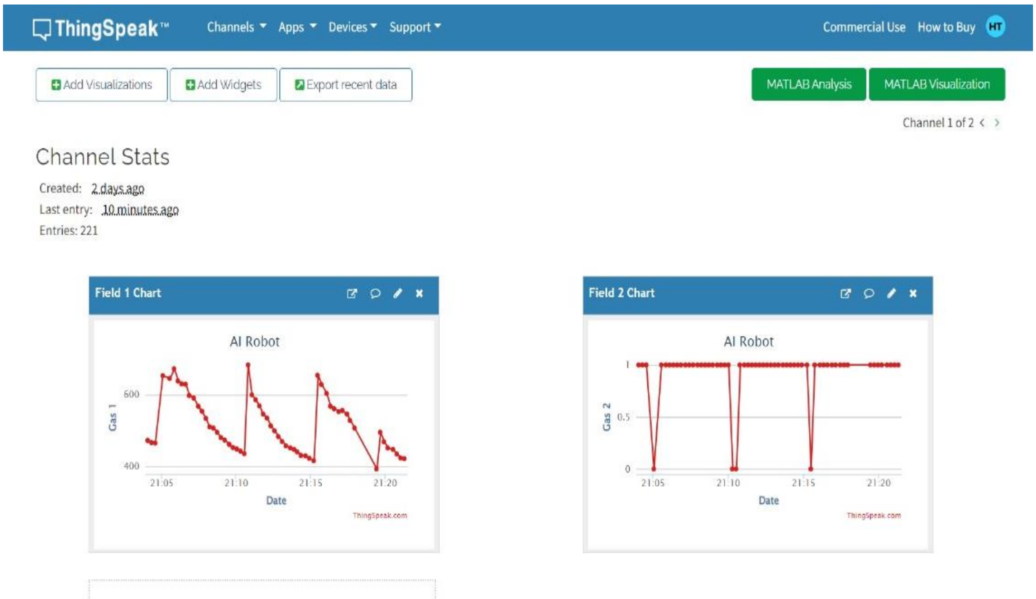

Fig.3 Data Visualisation using ThingSpeak

Furthermore, ThingSpeak's gas sensor data was used for predictive analysis by exporting it to a machine learning model which is, ARIMA model. Using the wealth of historical sensor data, the machine learning model accurately predicted future gas sensor readings, providing a proactive framework for maintaining indoor air quality and protecting occupants' well-being. The results of the forecasted values and also the Risk possibility details are shown as follows:

```
                    created_at  entry_id  gas_value  gas _2value  \
0   2024-03-11T13:10:46+00:00         1         78            1
1   2024-03-11T13:11:03+00:00         2         58            0
2   2024-03-11T13:11:19+00:00         3         70            1
3   2024-03-11T13:11:36+00:00         4         67            1
4   2024-03-11T13:11:52+00:00         5         62            1
..                        ...       ...        ...          ...
65  2024-03-11T13:51:46+00:00        66         43            1
66  2024-03-11T13:51:46+00:00        67         53            0
67  2024-03-11T13:52:46+00:00        68         35            1
68  2024-03-11T13:52:46+00:00        69         34            1
69  2024-03-11T13:52:46+00:00        70         33            0

        risk_possibility
0   Low Risk Possibility
1   Low Risk Possibility
2   Low Risk Possibility
3   Low Risk Possibility
4   Low Risk Possibility
..                   ...
65  Low Risk Possibility
66  Low Risk Possibility
67  Low Risk Possibility
68  Low Risk Possibility
69  Low Risk Possibility

[70 rows x 5 columns]
```

Fig.4 Dataset after preprocessing

```
Forecasted values: 70     38.911053
71     39.340686
72     36.507028
73     36.034731
74     36.608702
          ...
165    36.983357
166    36.983357
167    36.983357
168    36.983357
169    36.983357
Name: predicted_mean, Length: 100, dtype: float64
```

Fig.5 Forecasted Values

In addition to real-time monitoring of gas sensor data and historical trends, the project's machine learning component provides valuable insights into future risk scenarios related to indoor air quality. The addition of a bar chart visualization depicting high and low-risk scenarios improves the overall comprehensiveness of the results obtained. The cleaning robot's efficacy in proactively managing indoor air pollution is highlighted by comparing the predictive analysis of future gas sensor readings to the identified risk scenarios. This comprehensive approach to data analysis not only informs immediate decision-making, but also enables users to anticipate and mitigate potential risks, helping to create healthier indoor environments. The bar chart representation is as follows:

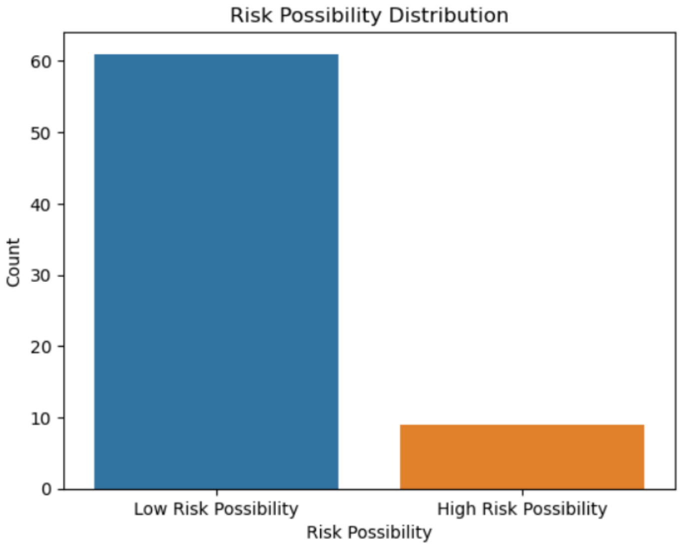

Fig.6 Bar Chart of Risk Possibility Distribution

This project's successful implementation demonstrates the transformative potential of AI-powered cleaning robots outfitted with gas sensors and IoT capabilities for proactively managing indoor air pollution while improving household cleanliness. Future research may focus on fine-tuning the cleaning robot's algorithms, expanding the range of environmental sensors, and incorporating additional AI-driven functionalities to improve performance and versatility. Furthermore, investigating the system's scalability to accommodate larger indoor spaces and commercial domains presents a promising avenue for broadening its beneficial impact on indoor air quality management. In conclusion, this project represents a significant step toward the realization of intelligent cleaning solutions designed for smart homes and conducive to sustainable living environments.

7. Conclusion

To summarize, the creation and integration of an AI-powered cleaning robot equipped with gas sensors and IoT capabilities represents a significant step forward in the field of smart home technologies. Through meticulous hardware assembly, firmware development, and cloud integration, the cleaning robot has demonstrated remarkable capabilities in navigating indoor spaces, detecting obstacles, monitoring indoor air quality, and performing cleaning tasks autonomously. This project's successful implementation demonstrates its potential to effectively manage indoor air pollution and improve household cleanliness, resulting in healthier and safer living environments. Moving forward, research and development efforts could concentrate on improving the robot's algorithms, expanding its sensor capabilities, and investigating commercialization and scalability options. Furthermore, investigating novel AI and machine learning applications in conjunction with IoT technologies may improve the functionality and versatility of cleaning robots, paving the way for widespread adoption in homes, offices, and public spaces. Overall, this project is a step toward the development of intelligent cleaning solutions that meet the changing needs of modern society.

8. Future Scope

The successful implementation of the AI-powered cleaning robot paves the way for a variety of future research and development opportunities. One potential direction is to refine and optimize the robot's algorithms to improve navigation, obstacle avoidance, and cleaning efficiency in complex indoor environments. Furthermore, further research into sensor technologies may result in the integration of additional environmental sensors for comprehensive indoor air quality monitoring, such as sensors for volatile organic compounds (VOCs), particulate matter (PM), and allergens. Furthermore, investigating the integration of advanced AI and machine learning techniques could allow the cleaning robot to adapt and learn from its surroundings, resulting in improved performance over time. Furthermore, exploring commercialization and scalability options could entail working with industry partners to bring the AI-powered cleaning robot to market and deploy it in a variety of settings, including homes, offices, hospitals, and public spaces. Overall, the project's future scope includes a wide range of opportunities for developing intelligent cleaning solutions and meeting the changing needs of modern living environments.

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