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An IoT-Integrated Road Cleaning Machine for Enhanced Urban Hygiene

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Abstract: The rapid advancement of science and technology has given rise to a multitude of new inventions and innovations. Among these, the Internet of Things (IoT) stands out as a promising avenue for addressing the growing demand for highly automated systems with exceptional efficiency. This study is focused on the design and fabrication of an automated road cleaning machine, which will be thoroughly evaluated for its real-time performance. The road cleaning IoT machine has been purposefully engineered to efficiently and effectively clean roads through the application of IoT technologies. The machine is equipped with a powerful vacuum cleaner capable of effectively removing debris, such as tree leaves, papers, and sand dusts, from the road surface. One of the key features of this device is the integration of IoT sensors and cameras, enabling real-time monitoring and control of the machine's performance. Through this advanced system, operators can closely monitor its operations and make necessary adjustments as needed. The road cleaning machine represents a significant and noteworthy innovation in the realm of road cleaning, offering an effective, safe, and environmentally friendly solution for keeping roads clean and safe. By leveraging cutting-edge technology, this machine aims to revolutionize the way roads are maintained, providing a cleaner and safer environment for everyone.

Keywords: Internet of Things (IoT); automated systems; Road cleaning machine; Debris removal; Vacuum cleaner

1. Introduction

The road cleaning IoT machine represents an innovative and highly efficient device designed to meticulously clean and maintain the tidiness of roads and other paved surfaces. Its role in ensuring the overall cleanliness and hygiene of urban areas, highways, parking lots, and industrial sites cannot be overstated. With advanced features and capabilities, the road cleaning IoT machines are specifically engineered to tackle a wide range of debris, including dust, dirt, leaves, litter, and other waste materials that tend to accumulate on roads. The machine is equipped with powerful suction systems, acting like a high-performance vacuum cleaner, effectively collecting the debris from the surface. As we move forward, there are plans to introduce additional models that will incorporate water spraying mechanisms, further facilitating the removal of stubborn stains and sticky substances. The integration of Internet of Things (IoT) technologies allows for seamless communication and real-time monitoring of the road cleaning operations, optimizing efficiency and ensuring timely maintenance. These intelligent machines are set to revolutionize the road cleaning process, offering an environmentally friendly solution that contributes to cleaner and safer surroundings for the community.

Regularly cleaning a house becomes a challenging task, especially with children around. However, advancements in digital technology have simplified human life. This paper presents a smart street cleaning robot that efficiently cleans roads through remote control. The robot operates autonomously and manually, with additional features like scheduled cleaning and auto-dirt removal, ultimately enhancing human life and lifestyle [1].

The road cleaning vehicle is an efficient cleaning equipment that combines road cleaning, garbage recycling, and removal. This paper provides a brief overview of the research background and highlights representative products in the market. The current technology development includes multifunctional cleaning cars with features like suction and sweeping combination, dust suppression, and advanced technologies such as automatic driving and intelligent identification. The future of road cleaning vehicles is predicted to focus on intelligence and environmental friendliness [2].

Dust on the road causes uncleanliness and contributes to 33% of air pollution in India, leading to health and accident issues for road users. Therefore, it is vital to maintain clean roads. To develop a cost-effective dust cleaning machine that utilizes a scrubber brush and vacuum dust collector to clean dust from road dividers, replacing manual methods. Effective cleaning and sanitizing are essential for human health and wellbeing. Cleaning roads manually is both challenging and hazardous due to littered plastics, vegetable and fruit wastes, and papers. To alleviate the burden on humans, cost-efficient and eco-friendly road cleaning machines are proposed. This paper discusses the design, calculations, material selection, and cost estimation of the mechanically operated machine, which was modelled using Solid works [3, 4].

Research focuses on the design and development of an efficient, manually operated, and pollution-free road cleaner to maintain cleanliness and freshness while walking on streets. Unlike modern technology-based devices that cause pollution and are difficult to maintain, this eco-friendly and cost-effective prototype aims to spread the idea of an improved road cleaning machine. The machine utilizes easily available and low-cost materials, making it a user-friendly and practical alternative to conventional models, particularly in areas with power shortages [5-7].Pollution on railway tracks poses significant environmental and human health problems, mainly caused by passenger wastages. Manual collection of these wastes is both hazardous and challenging. The fabrication of a simple and innovative waste-collecting vehicle to efficiently clean railway tracks without manual effort. The cost-effective design allows for easy track cleaning and can also be adapted for home or road cleaning purposes [8].

An environment serves as a habitat for humans, plants, and animals, making cleanliness essential in our daily routine. A clean environment promotes a healthy society and prevents the spread of diseases. While conventional pulling machines are used for road cleaning, they pose risks during pandemics when direct human involvement can lead to infections. To address this, a remote-controlled cleaner with a sanitizer and cleaner is proposed, allowing sanitation workers to safely clean roads and public places, reducing the risk of disease transmission. The paper focuses on designing and building this innovative solution to ensure a hygienic environment for everyone [9].

The multipurpose road and floor cleaning machine has versatile applications, suitable for both rural and urban roads. Operating on mechanical design principles, this project aims to create a floor cleaning machine that utilizes manual and solar energy, equipped with motors and brushes. This portable and lightweight machine is effective in cleaning floors and rough roads, applicable in various settings such as houses, hospitals, auditoriums, shops, and computer centers. Addressing cleanliness issues in India, this road cleaner efficiently tackles dusty roads and removes metal particles. The study emphasizes achieving cleanliness with minimal resource utilization [10].

The primary objective of the road cleaning machine is to provide a cutting-edge, IoT-driven solution that ensures cleaner and safer roads while contributing to a more sustainable and environmentally conscious approach to road maintenance.

2. Methodology

To develop an efficient and eco-friendly road cleaning machine that utilizes IoT technologies to promote cleaner and safer roadways. The methodology followed in the design of IoT based road cleaning machine are designed as follows,

2.1 Component Selection and Integration:

The initial phase involves selecting and integrating the necessary components for the road cleaning IoT machine. Two DC motors are chosen to power the machine's movements, and a 24V rechargeable battery is selected, which is charged using a solar panel. To regulate the charging process and prevent overcharging and discharging, a solar panel controller is integrated into the system. A voltage regulator is used to step down the voltage from 24V DC to 5V DC to power the vacuum cleaner, ESP32cam, and ESP8266 Wi-Fi modules.

2.2 Hardware Development

The hardware development stage includes the assembly and construction of the road cleaning machine. The DC motors are connected to the wheels to enable movements, such as forward, reverse, left, and right. The vacuum cleaner is integrated into the machine to effectively remove debris from the road surface. The ESP8266 module is responsible for controlling the movements of the machine based on instructions received from the Android application via Wi-Fi.

2.3 Software Development

In this phase, the software components are developed to ensure seamless communication and control of the road cleaning machine. A customized

Android application is created, allowing the user to control the machine's operations remotely. The Android application communicates with the ESP8266 module using the IP address to send commands for movements and other functions.

2.4 Testing and Optimization

The road cleaning machine undergoes extensive testing to ensure its functionality, efficiency, and reliability. The movements, vacuum cleaner operation, and communication between the Android application and the machine are thoroughly evaluated under various conditions. Any issues identified during testing are addressed to optimize the machine's performance.

2.5 Real –time Monitoring and Control

The integration of the ESP32cam module allows for real-time monitoring of the road cleaning process. The module captures images and videos of the road surface, which can be accessed remotely through the Android application. This feature enables the user to monitor the machine's performance and assess the cleanliness of the road.

2.6 Safety and Security

Safety measures are implemented to ensure the machine operates securely and without risk to operators or pedestrians. The customized Android application includes safety protocols to halt the machine's movements in case of emergencies or obstacles.

2.7 Environmental Considerations

The use of solar-powered rechargeable batteries aligns with the environmentally friendly nature of the road cleaning machine. By harnessing solar energy, the machine reduces its carbon footprint and promotes sustainable practices.

2.8 Pilot Implementation and Feedback

A pilot implementation of the IoT-based road cleaning machine is carried out in a controlled environment, such as a designated road section. During this phase, feedback from users and stakeholders is collected to evaluate the machine's practicality and effectiveness. Any suggestions for improvement are taken into account for future enhancements.

2.9 Deployment and Maintenance

After successful testing and pilot implementation, the IoT-based road cleaning machine is ready for full-scale deployment. Regular maintenance schedules are established to ensure optimal performance and the longevity of the machine. Continuous monitoring and feedback from users contribute to ongoing improvements and updates.

The figure 1 presents a detailed illustration of the proposed IoT-based road cleaning machine, showcasing its advanced features and eco-friendly design. The drawing provides an overhead view of the machine, allowing a comprehensive understanding of its components and functionality

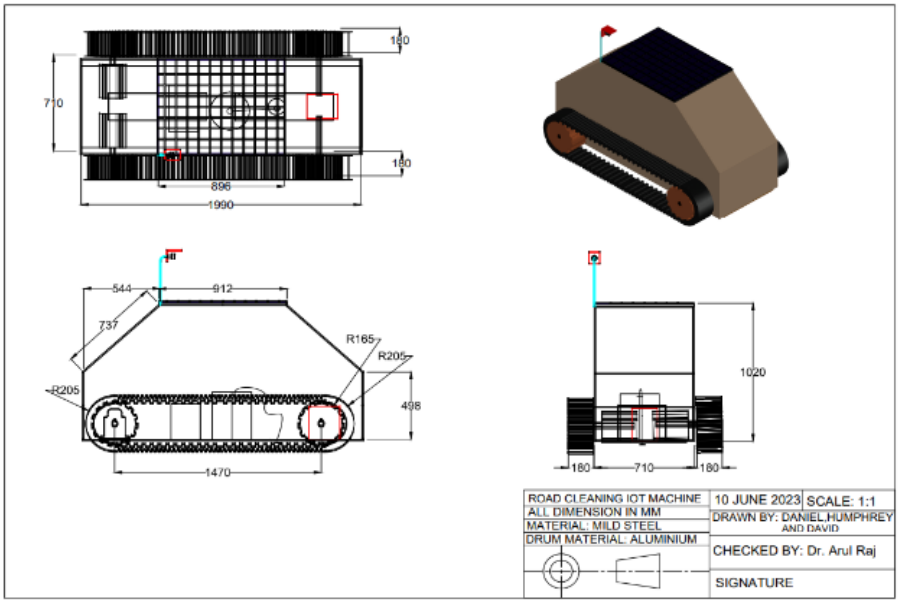

Figure 1 Proposed Model Design Drawing

Results and Discussion

The developed IoT-based road cleaning machine demonstrated promising results in efficiently cleaning and maintaining road surfaces. The integration of two DC motors powered by a solar-powered 24V rechargeable battery provided sufficient energy for the machine's movements, enabling it to move forward, reverse, turn left, and right. The use of a solar panel controller effectively regulated the battery charging process during the day and prevented discharging overnight, ensuring optimal battery performance and longevity. The voltage regulator played a crucial role in stepping down the voltage from 24V DC to 5V DC, facilitating the power supply to the vacuum cleaner, ESP32cam, and ESP8266 Wi-Fi modules. The vacuum cleaner efficiently removed debris, such as tree leaves, papers, and sand dust, from the road surface, ensuring thorough cleaning. The ESP8266 module effectively controlled the machine's movements, receiving commands from the customized Android application via Wi-Fi. This seamless communication allowed remote monitoring and control, enhancing user convenience and flexibility. The real-time monitoring feature, facilitated by the integration of the ESP32cam module, provided the user with visual feedback on the road cleaning process, allowing for quick assessment of the road's cleanliness.

Safety and security considerations were successfully addressed through the implementation of safety protocols in the Android application. In cases of emergencies or obstacles, the application enabled users to halt the machine's movements promptly, mitigating potential risks to operators and pedestrians. Environmental considerations were also taken into account with the use of solar-powered rechargeable batteries. By harnessing solar energy, the road cleaning machine reduced its environmental impact and contributed to more sustainable road maintenance practices. During the pilot implementation, the road cleaning machine showcased its effectiveness in cleaning designated road sections. User feedback indicated a high level of satisfaction with the machine's performance and convenience of remote control through the Android application. The real-time monitoring feature was particularly appreciated, as it provided visual confirmation of the cleaning process's efficiency.

Conclusion

The development of the IoT-based road cleaning machine marks a significant stride in the ever-evolving landscape of science and technology. The emergence of IoT has opened up a promising avenue for the creation of highly automated systems that excel in efficiency and performance. Our study has focused on the design and fabrication of an innovative road cleaning machine, which addresses the pressing need for effective and environmentally friendly solutions to maintain clean and safe roads. The road cleaning IoT machine is designed with meticulous attention to detail, encompassing a powerful vacuum cleaner that adeptly removes debris of various sizes, from small papers to sand dust, from road surfaces. The integration of IoT sensors and cameras allows for real-time monitoring and precise control, enabling the machine to adapt swiftly to changing road conditions and optimize its cleaning strategies. Looking ahead, future iterations of the road cleaning IoT machine will introduce additional models with water spraying mechanisms, enhancing their ability to combat stubborn stains and sticky substances on roads. This continuous improvement will only bolster the machine's performance and make it even more indispensable in maintaining the cleanliness and safety of our roadways.

References

1. B. Balaji and S. Nivedha, “Remote Controlled Road Cleaning Vehicle,” Journal of Physics: Conference Series, vol. 1717, 012014, 2021.
2. H. Xu, J. Xiao and Y. Feng, “Development and Research Status of Road Cleaning Vehicle,” Journal of Physics: Conference Series, vol. 1626, 012153, 2020.
3. R. Bisen, A. Ukey, M. Manohare, Y. Bharti, K. Burande and S.R. Bobde, “Design and Development of Dust Cleaning Machine for Cleaning Of Dust beside the Road Divider,” International Research Journal of Engineering and Technology (IRJET), vol. 07, no. 05, pp. 01-05, May 2020.
4. V.K. Tripathi, P. Saha, S. Jena, J.V. Raju and P. Rohith, “Design of Eco-Friendly Road Cleaning Machine,” in Proceedings of 7th ASRES International Conference on Intelligent Technologies. ICIT 2022, K.V. Arya, V.K. Tripathi, C. Rodriguez and E. Yusuf (eds.), Lecture Notes in Networks and

Systems, vol 685, Springer, Singapore, 2023, pp. 267-276.

5. S.R. Deokar, A.L. Gaikwad, O.B. Dange and G.H. Bhoge, “Ecofriendly Road Cleaning Machine,” International Research Journal of Modernization in Engineering Technology and Science, vol. 05, no. 04, pp. 01-05, April 2023.
6. S. Jha, “Eco-friendly Manually Operated Floor Dust and Road Cleaning Machine,” International Journal of Mechanics and Design, vol. 7, no. 2, 2021.
7. R. Kumar, M.A. Quadri, G. Prasad, G. Upadhyay, A. Kumar and R. Singh, “Design of mechanically operated floor cleaning machine,” International Journal of Research in Engineering and Innovation (IJREI), vol. 6, no. 3, pp. 199-202, 2022.
8. S. SenthilMurugan, S. BaluMahandiran, M. Vigneshkumar, P. AshokaVarthanan, M.K. Naveen and R. Mohammed Saliek, “Design and development of automated railway track cleaning machine,” in Proceedings of the International Conference on Advancements in Materials and Manufacturing Engineering – ICAMME 2021: ICAMME 2021, vol. 2527, no. 1, October 14 2022.
9. M. Sivachitra, S. Dinesh, B. Gowtham, K.S. Vinothraja and S. Eraianbu, “Remote-Controlled Multipurpose Road Cleaner,” in 2022 2nd Asian Conference on Innovation in Technology (ASIANCON), Ravet, India, 2022, pp. 1-5, doi: 10.1109/ASIANCON55314.2022.9908934.
10. P. Surendra et al., “Eco-Friendly Road Cleaner (Semi-Automatic),” International Journal of Advances in Engineering and Management (IJAEM), vol. 5, no. 4, pp. 147-153, April 2023.