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AI-Powered Smart Garbage Monitoring and Cleaning System

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***Abstract*— In this system the real VNC viewer software is used to operate the smart waste-bin by controlling from distance. When the bin becomes full, the operator starts the checking process by pressing the 'Q' key on the laptop. This operation turns on the camera, captures the images and present condition of the bin, and automatically sends a "Bin Full" signals to the selected telegram channel along with the bins location. Once the cleaning staff cleans the bin, they pushes the push button placed near the bin to confirm the work. Then the system sends a "Bin Cleaned" Message with the updated location details to telegram. If the operator presses the 'Q' key again after cleaning, the system sends a "Bin Normal" Message showing that the bin is in normal condition. At any time, if the manual push button is pressed, the system sends a "Manual Button Alert" to telegram, without considering the bin condition. This method provides continuous updates and allows real-time monitoring of the smart waste-bin system.**

***Index Terms*— Remote Monitoring, RealVNC Viewer, Camera-Based Detection, Manual Alert System, Telegram Alerts.**

I. INTRODUCTION

Municipal waste management is important to keep public places clean and hygienic, but regularly checking dustbins is still a big problem. Since many bins are placed across large areas, manual checking becomes difficult, time-consuming, and inefficient. When waste collection depends only on manual inspection, bins may overflow before anyone notices. This causes bad smells and unhygienic conditions, which attract insects and stray animals and can lead to health issues. Fixed monitoring systems installed in only a few locations are also not completely reliable. Problems like uneven waste and wrong readings are produced due to blocked sensors, leading to delays in detecting full bins and poor cleanliness management.

Because of unnecessary manual inspections, many cities faced issues such as overflowing dustbins, poorly planned cleaning schedules, and higher maintenance costs. These problems harms the environment, reduce public satisfaction, and the workload for workers in waste-collection also increases. So, there is a clear need for a real-time monitoring system that reduces human effort, prevents inspection from being missed and improves overall waste management efficiency.

To solve these problems, this paper introduces an intelligent waste-bin monitoring system that integrates a Raspberry Pi, camera-based detection, GPS location tracking, and real-time messaging services. Instead of depending only on manual inspections, the operator can monitor the bin remotely using the RealVNC Viewer.

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When the bin becomes full the operator presses the 'Q' key, which turns on the camera and captures the current condition of the bin. Then automatically send a "Bin Full" signal along with exact location and image to the municipal telegram channel. This instant alert helps authorities to send cleaning staff quickly and prevents delays in waste collection.

This system also provides a simple way to confirm that cleaning is completed. By pressing the push button fixed on the bin the cleaning staff confirms that the waste is removed. This action sends a "Bin Cleaned" message along with the updated images and location details. If needed, the operator can press the 'Q' key again to check the bin status and system updates it to "Bin Normal". To keep away from confusion and pass over status updates this verification process helps to complete this cycle.

Fig.1 shows that traditional manual inspection methods have caused a gradual grow in bin overflow cases over the years. On the other hand the prefer monitoring system reduces delays and increases response time by providing timely updates. By utilize real-time alerts, accurate location tracking, and camera-based verification, the system better the efficiency of municipal waste management and helps maintain public areas cleaner with fewer bin overflows.

In 2016, about 15 dustbin overflow cases were outline in one year. At that time, bins were inspected manually, so delays in inspection often caused overflow, especially in busy public areas.

In 2017, the number of overflow cases increased to around 18. At that time the inspection process continued to depend on manual checking, which caused many bins to reamain unchecked for long periods.

In 2018, the number of dustbin overflow incidents increased to around 22. The grow workload made it difficult for municipal workers to inspect all bins on time, leading to more waste being left uncollected.

In 2019, nearly 25 dustbin overflow cases were recorded. This steady increase showed that manual inspection was no longer effective for managing a growing number of dustbins in different locations.

In 2020, almost 30 dustbin overflow incidents were reported. Due the increase time gap between inspection and cleaning, causing many bins to overflow before action was taken.

In 2021, the number of dustbin overflow incidents increased to almost 35. The manual monitoring system faced difficulties due to the rapid increase in waste generation and large delays in waste collection increased due to absence of real-time monitoring.

In 2022, the number of dustbij overflow incidents increased to almost 38. This shows that manual checking became less effective, as workers could not visit all dustbin locations regularly, leading to more waste accumulation.

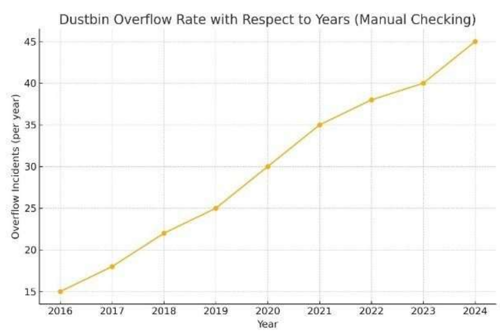

Fig.1 Annual Analysis of Dustbin Overflow Incidents Using Manual Checking

In 2023, almost 40 dustbin overflow incidents taken place. This increase clearly explains that technological assistance is very effective for waste management due to increase in depending on only manual inspection methods.

In 2024, almost 45 dustbin incidents taken place, highest recorded in the mean time. This trend shows that as the number of bins and waste increased, manual monitoring became completely inadequate, resulting in frequent overflows and poor waste management.

II. Literature Survey

- Chaudhary, Ritika, et al. "AI-Powered Smart Waste Management System: Optimizing Waste Collection and Recycling through Intelligent Automation." Available at SSRN 5241203 (2025).

- Raj, J. Relin Francis, et al. "AI-Powered Smart Waste Bins: Improving Hostel Mess Cleanliness with IoT and Machine Learning." 2024 2nd International Conference on Sustainable Computing and Smart Systems (ICSCSS). IEEE, 2024.
- Kumar, Vankadara Sampath, et al. "Smart Urban Waste Management System Powered by AI and IoT for Efficient Collection, Segregation, and Disposal." 2025 IEEE North-East India International Energy Conversion Conference and Exhibition (NE-IECCE). IEEE, 2025.
- Sinha, Aashna, et al. "Revolutionizing Waste Management AI-Powered Solutions for Electronic Waste in India." 2023 International Conference on Smart Devices (ICSD). IEEE, 2024.
- Tiwari, Vaibhav. "SmartGarb: An AI-Powered Application for Predicting Garbage Collection Vehicle Arrival Time in Small Cities with Office Commute Constraints." International Journal of Innovative Research in Technology and Science 12.2 (2024): 400-404.
- Nirmala, N., et al. "Role of Machine Learning and Artificial Intelligence in Smart Waste Management." Smart Waste and Wastewater Management by Biotechnological Approaches. Singapore: Springer Nature Singapore, 2025. 35-53.
- Doddamani, Dr Harshavardhana. "AI in Smart Waste Management: Tools and Applications." TechScholastic Press, Bengaluru 1 (2025): 1-103.
- Islam, Md Muhaiminul, et al. "Smart Waste Management Robot: Integrating IoT, Artificial Intelligence, SLAM, and CNN-Based Advanced Image Processing for Real-Time Trash Collection and Categorization." 2024 27th International Conference on Computer and Information Technology (ICCIT). IEEE, 2024.
- Raina, Arushi, et al. "IoT-Driven Smart Bins: Enhancing Waste Segregation and Its Impact on Public Health." Environmental Monitoring Technologies for Improving Global Human Health. IGI Global Scientific Publishing, 2025. 469-498.
- Das, Nivedita, et al. "Smart waste bin using AI, Big Data analytics and IoT." IoT-Based Smart Waste Management for Environmental Sustainability. CRC Press, 2022. 37-62.
- Arthur, Menaka Pushpa, S. Shoba, and Aru Pandey. "A survey of smart dustbin systems using the IoT and deep learning." Artificial Intelligence Review 57.3 (2024): 56.
- Reddy, Mani Kumar, et al. "Smart dustbin for real time waste segregation and monitoring." AIP Conference Proceedings. Vol. 2946. No. 1. AIP Publishing LLC, 2023.
- Barik, Sutanika, et al. "Machine learning-based smart waste management in urban area." International Conference on Advances and Applications of Artificial Intelligence and Machine Learning. Singapore: Springer Nature Singapore, 2022.
- Salodkar, Yash Ram, et al. "Iot-Based Smart Dustbin for Waste Level Monitoring and Segregation." 2024 IEEE Pune Section International Conference (PuneCon). IEEE, 2024.
- Chand, R. Prem, et al. "Arduino based smart dustbin for waste management during Covid-19." 2021 5th International Conference on Electronics, Communication and Aerospace Technology (ICECA). IEEE, 2021.

III. PROPOSED METHOD

A. Procedure For Inspection

Fig. 2 Block diagram of the monitoring process. The proposed method for monitoring the AI-powered smart garbage monitoring and cleaning system is based entirely on image processing, artificial intelligence, and GPS-enabled notifications, eliminating the need for traditional sensors.

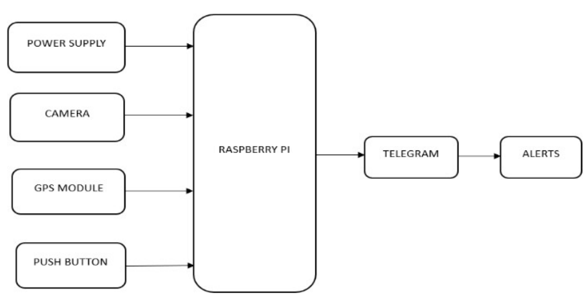

Fig.2. Block Diagram of Smart Garbage Monitoring and Cleaning System

Fig.3 in this system, cameras installed at specified locations on garbage bins to obtain pictures either at fixed time intervals or when enabled non- automatically through a control interconnection.

The acquired images are analysed using a deep learning driven artificial intelligence model that evaluates the fill percentage of the bin, detects overflow situations, and in certain cases classifies the category of waste. When the system identifies that a bin has reached capacity or is overflowing, it automatically generates a notification containing the bins location, visual data, and present condition, this notification is the. Transmitted to municipal officials and waste collection personnel via real time communication platforms such as telegram, facilitating prompt response and effective waste management.

Fig.3. Smart Dustbin Monitoring Process

The system stores all information about monitored waste bins in an electronic database and stores the historical data like fill-level patterns, high-demand time frames and overflow incidents frequency. By analyzing the collected data, better waste collection schedules can be planned by the authorities to reduce operational costs, and select efficient collection routes. The use of AI-based image analysis, GPS tracking, and automatic alerts helps maintain clean surroundings, lowers health risks caused by unmanaged waste, and frequent manual inspections can be reduced.

In addition, the software-based design reduces the requirement for many physical components, which decreases maintenance effort and cost. The system is easy to expand and can be implemented across different areas of a smart city. This proposed system shows how artificial intelligence and automation can enhance traditional waste management by making it smarter, more predictive, and more efficient.

B. RealVNC Viewer

RealVNC Viewer is a remote desktop application that allows operators to monitor and control the AI-based smart garbage monitoring and cleaning system from anywhere. It securely connects to the Raspberry Pi using Wi-Fi or the internet and provides real-time access to the system interface. With RealVNC Viewer, operators can view live camera footage, AI detection results, sensor data, and system logs without physically visiting the location. For checking waste levels, manage cleaning operations, identify technical problems, and perform maintenance this remote access is perfectly used. Overall, for improving control, flexibility, and efficient management of the smart garbage monitoring system RealVNC Viewer is used.

The smart garbage monitoring system utilize RealVNC Viewer to produce live remote surveillance of dustbin status. When a bin reaches its extent, the supervisor presses the Q key on the laptop, actuate the setup camera to document the present condition of the bin. The system instantly transmits a “Bin Full” notification to Telegram, along with accurate location information and captured images, enabling officials to respond promptly.

Once the bin is cleaned, the sanitation worker confirms the task by pressing the push button placed near the bin. This action automatically sends a “Bin Cleaned” message to Telegram along with updated location information and images, providing proper documentation. If required, the operator can press the Q key again after cleaning to verify the bin status. The system then sends a “Bin Normal” alert, indicating that the bin is clean and ready for use.

Moreover, whenever the push button is pressed, the system sends a “Manual Button Alert” to Telegram, even if the bin is not full. This feature helps improve safety and ensures proper monitoring of operations. By combining automatic alerts with manual confirmation, the system enables timely waste collection and reduces bin overflow issues. It also maintains a digital record of all monitoring and cleaning activities. Instant alerts, location information, and image evidence make the system reliable, transparent, and well suited for municipal waste management and smart city applications.

In the AI-based smart garbage monitoring and cleaning system, RealVNC Viewer plays an important role by providing remote access and control of the Raspberry Pi connected to the garbage bins. RealVNC Viewer is a remote desktop application that allows users to view and operate the Raspberry Pi screen from a laptop, desktop, or mobile device through a network connection. This feature is especially useful in smart waste management systems, as it enables continuous monitoring of multiple bins located in different areas. Using RealVNC Viewer, the operator can remotely view live camera footage and check stored images captured by the cameras installed on the bins.

When the AI system detects that a garbage bin is full or overflowing, it allows the operator to view the related images through RealVNC Viewer without visiting the location. This remote access helps in quickly verifying the condition of the bin and enables faster response. It also reduces the need for physical inspections, saving time and manpower. By combining RealVNC Viewer with AI-based image analysis and GPS alert systems, the system works smoothly and efficiently. Cameras capture images, the AI analyzes them to determine the bin status, and the results are displayed through RealVNC Viewer for real-time monitoring and decision-making. This integrated approach improves system efficiency, supports preventive waste management, and allows easy expansion across multiple urban areas.

The novelty of the proposed system lies in the integration of AI-based image analysis, GPS-enabled location tracking, RealVNC remote monitoring, and Telegram-based notification services into a single waste management platform. Unlike conventional systems that depend on ultrasonic sensors, the proposed approach utilizes image-based monitoring for waste-level assessment and incorporates cleaning confirmation through a push-button mechanism. This integrated framework improves monitoring accuracy, reduces maintenance requirements, and supports efficient waste collection operations.

IV. MEASURING SETUP

A. Ai-Powered Smart Garbage Monitoring Fabrication

Fig4. implies that the Raspberry Pi take action as the main processing unit of the system, control all key operations such as image capture, AI-based analysis, and alert communication.

The Raspberry Pi is a compact, low-cost, and energy-efficient single-board computer that offers adequate processing capacity to run deep learning models for real-time waste recognition and grouping. Cameras are connected to the Raspberry Pi constantly capture real time images of the garbage bins by clicking the Q key, which are then examine locally using AI algorithms to point out the fill level and find overflow conditions. When a bin is found to be full or overflowing, the Raspberry Pi spontaneously generates alerts consists the bin's location and processed images are sends to municipal authorities or cleaning staff through messaging platforms such as Telegram.

Fig.4. Raspberry pi

In inclusion, the system supports remote access and monitoring through tools such as RealVNC Viewer, allowing operators to view live camera feeds, carry out maintenance tasks, and modernize the system without being physically available at the site. The flexibility, small size, and strong processing capacity of the Raspberry Pi build it appropriate for implementing a scalable and intelligent smart garbage keep track of solution. By incorporate real-time AI analysis, self-operating alert communication, and data-driven waste handling functions

into a single programme, the system provide an well organized and practical perspective for latest urban environments.
Fig.5 implies that the significance of the GPS module in on condition that correct location instruction for each garbage bin. Moreover the system is basically based on image processing instead of physical level sensors, the GPS module make sure that every alert generated by the AI is linked to the command geographical position of the bin. When the camera captures images and the AI algorithm recognize a full or overflowing bin, the GPS module right away acquire the current complement and incorporate them in the alert message. This location particulars is then collective with municipal authorities or waste collection staff through platforms such as Telegram, authorize them to rapidly locate the bin that needs cleaning.
The GPS module in addition to helps diminish response time moreover supports greater arrangement of waste collection direction by clearly specify which bins are full and their expect locations. Over time, the location data collected through GPS allows dominance to study bin utilization trends in contrasting areas, recognize zones with high-rise waste generation, and determine where supplementary bins are needed. By integrating real-time location tracking with AI-based image inspection and automated alert systems, the GPS module enhance the accuracy, reliability, and overall efficiency of the smart garbage management system.

Fig.5.GPS Module

Fig. 6 shows the complete assembly of the AI-powered smart garbage bin, which collaborate intelligent software with necessary hardware components to design a compact and well organized system for automated waste monitoring and management. The Raspberry Pi acts as the central processing controller, synchronize all system functioning. A high-resolution camera is firmly secure to the bin to frequently detector the waste level or capture images when manually triggered. These images are sent to the Raspberry Pi, where a deep learning–based AI model inspects the bin condition to find out the fill level and recognize any overflow.
For accurate location identification, a GPS module is combined into the system so that the require coordinates of the bin are comprise in every alert. The whole system can be remotely retrieved and monitored using RealVNC Viewer, authorize operators to view live images, control system functions, and perform preservation without physically look in on the bin. All components are surround in a preservative housing mounted on the bin to secure durability, shielding from environmental conditions, and genuine cable organization.
When the AI discover that the bin is full, the system automatically coordinates with the captured image, GPS location, and bin current condition and sends an alert to municipal dominance or waste collection personnel through Telegram. This combined assembly results in a smart, self- monitoring garbage bin that utilize without physical level sensors, depends entirely on image-based intelligence, diminishes manual effort, enhance cleanliness, and improves the overall efficiency of waste collection operations.

Fig.6. Completed AI-powered smart garbage bin Assembly

V. RESULTS

Fig.7 shows that the process used by the system to find when a garbage bin becomes full. The operator continuously observes the bin and presses the Q key to examine the current condition of the bin. When this Q key is pressed, the camera placed on the bin captures an image that indicate the level of waste inside. This captured image is used to verify that the bin has reached its maximal capacity. After verification, the system straight away sends a “Bin Full” alert to the Telegram channel along with the bin’s GPS location. This knowledge allows the cleaning staff to the particular location which is comes along with the captured image, then the cleaning staff respond quickly, avoiding overflow and helping to keep a clean environment.

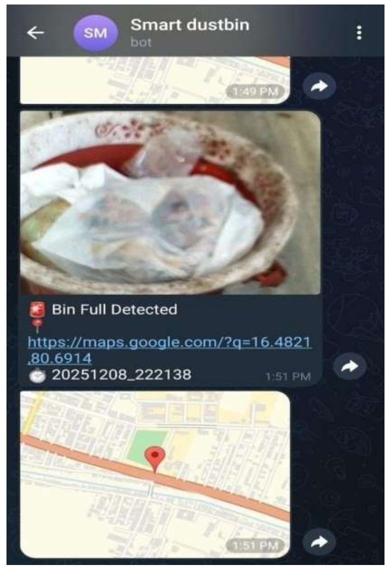

Fig.7. Bin Full Alert with GPS Notification

Fig. 8 shows that the cleaned garbage bin. If the waste is removed from the bin, the cleaning staff validate the completion of the task by pressing the manual push button placed near the garbage bin. This action implies a “Bin Cleaned” notification, which is sent to Telegram along with the updated location details. This confirmation make sure that the bin disinfect process has been decently completed and keeps all disturbed personnel informed. It also helps maintain correct records of disinfect activities, reduces the need for recurrent inspections, and make sure that the bin is ready for use afresh without any delay.

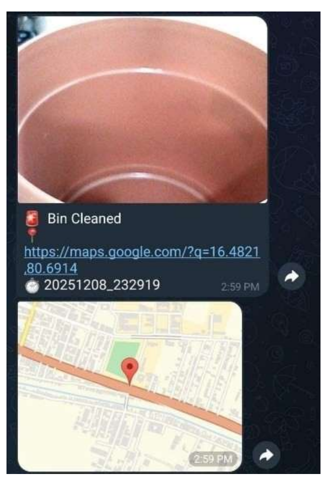

Fig.8.Bin Cleaned Status Update with GPS Notification

IV. CONCLUSION

Checking garbage overflow at the correct time is predominant for maintaining cleanliness in public and urban areas, and the amalgamation of camera-based monitoring with RealVNC Viewer provides an constructive solution. Rather than depending only on structured manual inspections, the system allows the operator to remotely give permission and detect dustbins through RealVNC Viewer from a single location. Whenever a bin needs to be inspect, the operator can activate image capture, and the system gives a clear visual affirmation of the bin's proper condition.

This cooperation between human direction using RealVNC Viewer and system-supported image conformation makes the observing process faster and simpler while diminish the chances of missed or delayed inspections. With the help of GPS tracking, bins spread over large areas can be easily recognize, authorize cleaning staff to come back quickly. Before taking any action, the operator can review the captured images, which helps prevent false alerts. In addition, the stored images and location data can be used later to analyze waste patterns and improve future planning and coordination.

Overall, this semi-automated system improves cleanliness, reduces bin overflow issues, increases operational efficiency, and supports effective municipal waste management.

REFERENCES

[1] M. Ali, S. M. Abbas, and F. Afzal, "IoT-Based Smart Waste Management System: A Practical Approach," Environmental Science and Pollution Research, vol. 27, no. 14, pp. 17861–17872, 2020.
[2] R. Prem Chand, S. Kumar, and R. Prasad, "Arduino Based Smart Dustbin for Waste Management During COVID-19," Proc. 5th Int. Conf. Electronics, Communication and Aerospace Technology (ICECA), IEEE, 2021.
[3] S. Barik, S. Nayak, and R. Dash, "Machine Learning-Based Smart Waste Management in Urban Area," Proc. Int. Conf. Advances and Applications of Artificial Intelligence and Machine Learning, Springer, 2022.
[4] N. Das, S. Dey, and P. Banerjee, "Smart Waste Bin Using AI, Big Data Analytics and IoT," in IoT-Based Smart Waste Management for Environmental Sustainability, CRC Press, 2022, pp. 37–62.
[5] R. P. Arthur, S. Shoba, and A. Pandey, "A Survey of Smart Dustbin Systems Using IoT and Deep Learning," Artificial Intelligence Review, vol. 57, no. 3, 2024.
[6] M. K. Reddy, S. R. Kumar, and V. S. Rao, "Smart Dustbin for Real-Time Waste Segregation and Monitoring," AIP Conference Proceedings, vol. 2946, no. 1, 2023.
[7] Y. R. Salodkar et al., "IoT-Based Smart Dustbin for Waste Level Monitoring and Segregation," Proc. IEEE Pune Section Int. Conf. (PuneCon), 2024.
[8] A. Raina, P. Gupta, and S. Malhotra, "IoT-Driven Smart Bins: Enhancing Waste Segregation and Its Impact on Public Health," IGI Global, pp. 469–498, 2024.
[9] M. M. Islam et al., "Smart Waste Management Robot Integrating IoT, Artificial Intelligence, SLAM, and CNN-Based Image Processing," Proc. 27th Int. Conf. Computer and Information Technology (ICCIT), IEEE, 2024.
[10] J. Relin Francis Raj et al., "AI-Powered Smart Waste Bins: Improving Hostel Mess Cleanliness with IoT and Machine Learning," Proc. 2nd Int. Conf. Sustainable Computing and Smart Systems (ICSCSS), IEEE, 2024.
[11] S. Doddamani, "AI in Smart Waste Management: Tools and Applications," TechScholastic Press, Bengaluru, 2024.
[12] T. Shelke, S. Patil, and B. Patil, "Real-Time Smart Garbage Monitoring and Management System," International Journal of Innovative Research in Engineering & Management, vol. 10, no. 4, 2023.
[13] A. Kumar and P. Singh, "IoT-Based Smart Garbage Monitoring System with Location Tracking," International Journal of Engineering Research & Technology (IJERT), vol. 10, no. 6, 2021.
[14] S. Patel and R. Shah, "Smart Waste Management Using Raspberry Pi and IoT," International Journal of Advanced Research in Computer Science, vol. 11, no. 5, 2020.
[15] N. K. Jain and A. Mishra, "Design of Smart Dustbin Using Image Processing and IoT," International Journal of Computer Applications, vol. 176, no. 28, 2020.