Waste Collector and Disposing WALL-E Robot

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***Abstract*—Rapid urbanization has intensified waste management challenges, resulting in environmental and public health concerns. This paper presents the design and implementation of an autonomous waste-collecting robot inspired by WALL-E. The system integrates Raspberry Pi and Arduino platforms, combining AI-based vision with embedded control. The Raspberry Pi performs waste detection using a lightweight deep learning model, while the Arduino manages navigation, sensor inputs, and actuation. Ultrasonic sensors enable obstacle avoidance, servo-driven claws handle waste collection, and a load-cell mechanism monitors bin capacity for automatic disposal. Experimental results demonstrate reliable autonomous operation with over 85% detection accuracy and approximately one hour of runtime per charge, offering a scalable and cost-effective solution for smart waste management.**

***Index Terms*—Autonomous robot, waste management, computer vision, embedded systems, Raspberry Pi, Arduino.**

I. INTRODUCTION

Rapid urbanization has led to a significant increase in solid waste generation, creating serious challenges in waste collection and disposal. Conventional waste management systems rely heavily on manual labor, exposing workers to health risks and inefficiencies. Advances in robotics and artificial intelligence enable automation of waste detection, collection, and disposal processes. This work aims to develop an autonomous robot capable of identifying, collecting, and disposing of waste using computer vision, embedded control, and real-time sensor feedback.

II. LITERATURE REVIEW

The integration of robotics and artificial intelligence (AI) into waste management has gained significant momentum due to increasing urbanization, labor safety concerns, and the need for sustainable environmental solutions. Existing research in this domain can be broadly categorized into AI-based waste detection, autonomous waste-collecting robotic systems, swarm robotics for large-scale cleanup, navigation and obstacle avoidance techniques, and robotic gripper and actuation mechanisms.

A. AI-Based Waste Detection and Classification

Recent studies emphasize the effectiveness of deep learning–based computer vision techniques for waste detection and classification. Abo-Zahhad et al. demonstrated a lightweight YOLO-based garbage detection model optimized for edge devices, achieving real-time performance on resource-constrained platforms such as Raspberry Pi fileciteturn0file0. Similarly, Wahyutama et al. proposed a YOLO-powered smart bin capable of automatically identifying and sorting waste, highlighting the feasibility of deploying AI vision models in embedded environments.

Advancements in YOLO architectures have further im-proved detection accuracy and efficiency. Alfattah Atalarais et al. explored YOLOv8 for automatic waste-type detection, reporting higher precision and faster inference suitable for smart recycling systems. Tran et al. optimized a ResNet-based deep learning model for Raspberry Pi 4, demonstrating that compact neural networks can still deliver robust trash classification performance. These studies collectively validate the choice of lightweight AI models for real-time waste detection in mobile robotic platforms.

B. Autonomous Waste-Collecting Robots

Early autonomous waste-collecting robots primarily focused on basic navigation and manual or semi-automated waste handling. Sivasankar and Priya developed a simple autonomous trash-collecting robot using ultrasonic sensors for navigation, proving the concept but lacking advanced perception and decision-making capabilities. More recent systems, such as the Outdoor Autonomous Trash-Collecting Robot (OATCR) proposed by Kulshreshtha et al., integrated YOLOv4-Tiny with ultrasonic sensors to enable outdoor litter detection and collection. While these systems demonstrated improved autonomy, many were limited to either detection or collection and did not provide a fully integrated end-to-end solution.

C. Swarm Robotics for Waste Management

To address scalability, swarm robotics has been explored as a potential solution for large-area waste collection. Alfeo's MIT research introduced the concept of urban swarms, where multiple low-cost robots collaborate to clean public spaces efficiently. Although swarm-based approaches offer redundancy and scalability, they introduce complexities in coordination, communication, and cost, making single-robot autonomous systems more practical for small- to medium-scale deployments.

D. Navigation and Obstacle Avoidance

Reliable navigation is a critical requirement for autonomous robots operating in dynamic environments. Classical obstacle avoidance techniques using ultrasonic and proximity sensors have been well documented by Borenstein et al., whose work remains foundational in mobile robotics. Many modern waste-collecting robots continue to rely on ultrasonic sensors due to their simplicity, low cost, and reliability for short-range obstacle detection, especially in indoor and semi-structured environments.

E. Robotic Grippers and Actuation Mechanisms

Efficient waste pickup requires adaptable and cost-effective gripper mechanisms. Hernandez et al. provided a comprehensive review of robotic grippers, discussing design trade-offs between mechanical complexity, adaptability, and cost. Ruo et al. further explored low-cost 3D-printed and electromagnetic grippers specifically designed for waste collection robots, emphasizing affordability and ease of fabrication. These studies informed the selection of a servo-driven claw mechanism in this project, balancing functionality with simplicity.

F. Research Gap and Motivation

Despite significant progress in individual areas such as AI-based detection, navigation, and robotic manipulation, most existing systems address these components in isolation. There is a noticeable lack of compact, cost-effective robots that seamlessly integrate waste detection, autonomous navigation, physical collection, capacity monitoring, and disposal within a single platform.

III. SYSTEM DESIGN AND METHODOLOGY

The system employs a dual-controller architecture in which the Raspberry Pi handles image processing and decision-making, while the Arduino manages motion control and sensor interfacing. The robot uses ultrasonic sensors for obstacle detection, servo motors for waste pickup, and a load-cell sensor to monitor bin capacity. A camera mounted on the chassis provides real-time visual input to the AI model for waste detection.

IV. IMPLEMENTATION AND RESULTS

A prototype was fabricated using a two-layer chassis integrating all electronic and mechanical components. The robot was tested under indoor conditions with varying lighting. The system achieved approximately 85% detection accuracy for

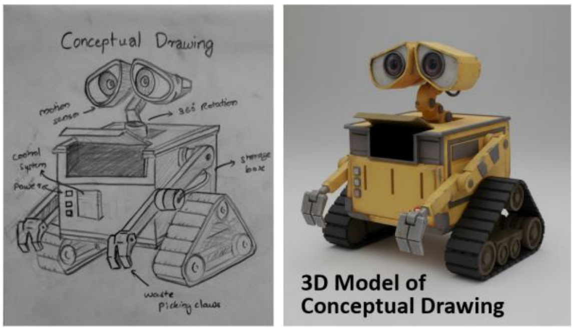

Fig. 1. Design Concept of the WALL-E Robot

common waste items and demonstrated reliable obstacle avoid-ance within a 30 cm range. The servo-driven claw operated smoothly, and the automatic disposal mechanism functioned as intended. The robot operated for nearly one hour on a single battery charge, with a total system cost under Rs. 30,000.

V. CONCLUSION

This paper presented an autonomous AI-driven waste col-lection robot integrating vision, sensing, and actuation. Experimental validation confirms its effectiveness and scalability for smart waste management applications. Future enhancements include IoT-based monitoring, solar-assisted charging, and improved mobility for outdoor environments.

REFERENCES

[1] M. Abo-Zahhad, A. Abdel-Aziz, and S. Kamel, “Lightweight real-time garbage detection using YOLO for edge devices,” Journal of Smart Systems and Applications, vol. 14, no. 2, pp. 112–125, 2025.

[2] W. Wahyutama, D. A. Nugroho, and A. Rahmadani, “Smart bin using YOLO for automatic waste sorting,” International Journal of Advanced Computer Science and Applications, vol. 13, no. 9, pp. 178–186, 2022.

[3] M. A. Atalarais, S. Yuliana, and R. D. Putra, “Automatic waste type detection using YOLOv8 for smart recycling systems,” Journal of Artificial Intelligence Research, vol. 32, no. 1, pp. 87–101, 2025.

[4] G. Sivasankar and R. Priya, “Autonomous trash collecting robot,” International Journal of Engineering Research and Technology, vol. 6, no. 8, pp. 1–5, 2017.

[5] M. Kulshreshtha, R. Sharma, and V. Mehta, “OATCR: Outdoor autonomous trash-collecting robot using YOLOv4-Tiny,” IEEE Robotics and Automation Letters, vol. 8, no. 5, pp. 2445–2453, 2023.

[6] J. Borenstein, H. R. Everett, and L. Feng, “Navigating mobile robots: Sensors and techniques for obstacle avoidance,” IEEE Trans. Robotics and Automation, vol. 7, no. 5, pp. 578–594, 1991.

[7] L. Hernandez, M. Cho, and A. Singh, “A review of robotic grippers,” Robotics Review, vol. 18, no. 2, pp. 95–110, 2023.

[8] J. Ruo, E. Tan, and Y. Lim, “Low-cost 3D-printed grippers for autonomous waste collection robots,” Journal of Robotics and Mechatron-ics, vol. 37, no. 1, pp. 56–70, 2025.

[9] A. Alfeo, M. Cimino, N. De Francesco, and G. Vaglini, “Urban swarm robotics: A novel approach for autonomous waste collection,” IEEE Access, vol. 8, pp. 196798–196811, 2020.

[10] S. Thrun, W. Burgard, and D. Fox, *Probabilistic Robotics*, Cambridge, MA, USA: MIT Press, 2005.

[11] R. Siegwart, I. R. Nourbakhsh, and D. Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd ed. Cambridge, MA, USA: MIT Press, 2011.

[12] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, “Internet of Things for smart cities,” IEEE Internet of Things Journal, vol. 1, no. 1, pp. 22–32, Feb. 2014.