Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

AI Waste Sorting using Transfer Learning with PyTorch

Dr. Shailaja S
Associate Professor, Department of Computer Science and Engineering, Poojya Doddappa Appa College of Engineering, Kalaburagi, Karnataka, India.

Sneha S Keralli, Surabhi, Manoj
Student, Department of Computer Science and Engineering, Poojya Doddappa Appa College of Engineering, Kalaburagi, Karnataka, India.

Abstract - With rapid urbanization and population growth, the amount of solid waste generated has significantly increased, leading to overflowing bins and unhealthy environments in cities. Manual segregation of waste poses serious health risks to workers and is time-consuming. To address this, an Automatic Waste Segregation System is proposed that categorizes waste into three types: wet, dry, and metallic. The system is cost-effective, improves waste handling efficiency, and reduces human involvement. Different sensors detect respective waste types and automatically place them in designated bins. Additionally, disposal information is continuously updated to a remote server for monitoring and management.

Keywords - Deep Learning, Waste Classification, Image Processing, Transfer Learning, Computer Vision

I. INTRODUCTION

The rapid increase in population has resulted in improper waste handling and disposal. Solid waste management requires considerable time, workforce, and resources. Currently, most waste is dumped into landfills without proper separation, leading to water pollution, foul odor, and serious health hazards. In India, ragpickers play a major role in recycling, but prolonged exposure to waste causes respiratory infections, skin diseases, and other health issues.

Segregating waste at its source can significantly reduce health risks and improve recycling efficiency. Waste is generally classified into wet, dry, and metallic categories, each having high reuse potential. Although industrial waste sorting systems exist, domestic-level automated segregation remains limited. Therefore, this project aims to design a compact, low-cost, and user-friendly smart waste segregation system suitable for urban environments.

AI-powered automated segregation systems help eliminate human dependency and increase accuracy. Convolutional Neural Networks (CNNs) have shown exceptional performance in image classification tasks. This work utilizes a ResNet-18 based deep learning model to classify waste and integrates it with an IoT-based hardware setup for real-time sorting.

II. LITERATURE REVIEW

The increasing concern for efficient waste management has motivated several researchers to explore intelligent and automated methods for waste monitoring, segregation, and recycling. In recent years, deep learning and IoT-based solutions have received significant attention due to their accuracy, adaptability, and potential to automate conventional manual processes.

Deep learning models have shown remarkable capability in waste classification tasks. Nakib et al. [3] demonstrated how machine learning can effectively automate real-time environmental resource management systems, highlighting the capability of AI to operate in dynamic and real-world environments. Similarly, Rahman et al. [5] proposed an intelligent waste management framework integrating deep learning with IoT devices. Their system successfully classified different waste categories using CNN architectures and transmitted the results through IoT modules for real-time monitoring, proving the feasibility of AI-driven smart waste infrastructures.

Zhang et al. [6] presented an efficient deep learning-based recyclable waste recognition system capable of identifying plastic, paper, glass, and other recyclable materials. Their study emphasized improving classification accuracy using optimized CNN models; however, the work did not integrate automated disposal or bin-level implementation. Ahmed et al. [7] further extended this line of research by developing a sustainable waste sorting model that achieved high accuracy in classifying recyclable materials. Their study focused on improving environmental sustainability but lacked real-time smart bin integration.

IoT-assisted smart garbage monitoring systems have also been explored in multiple research works. Haribabu et al. [2] implemented a smart waste collection model using Arduino, ultrasonic sensors, and GSM modules to monitor bin levels and alert authorities when bins reached their threshold capacity. Similarly, Shujatullah Khan et al. [8] proposed an autonomous garbage monitoring architecture using IR sensors, Wi-Fi, GSM, and Zigbee communication, enabling

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

automatic notification and improved garbage collection logistics.

Several works have also emphasized enhancing efficiency in municipal waste collection systems. Ankitha S. et al. [9] proposed a smart city initiative integrating IoT-enabled dustbins assigned with unique IDs that communicate with a central monitoring system when full, ensuring optimized waste collection routes and reducing unnecessary fuel consumption.

In addition to municipal waste, researchers have also focused on specialized waste streams. Zhou et al. [8] developed a deep learning-based medical waste classification model to improve handling of hazardous biomedical materials, demonstrating the versatility of deep learning in handling different waste domains. Abdu and Noor [9] conducted an extensive survey of AI-based waste detection research and concluded that while classification accuracy has significantly improved, real-time deployment and hardware integration remain major challenges.

From the above studies, it is evident that although existing works have successfully implemented CNN-based classification and IoT-assisted waste monitoring systems, very few solutions integrate both approaches into a complete smart bin ecosystem with automated physical segregation. Most research focuses either on software-based classification accuracy or IoT-based monitoring, creating a gap for systems that can classify, segregate, monitor, and report waste autonomously.

III. GAPS IDENTIFIED IN THE EXISTING WORKS

Although several studies have explored deep learning and IoT-based approaches for waste detection, monitoring, and classification, a number of research gaps still remain unaddressed. Most existing deep learning–based waste management systems primarily emphasize improving classification accuracy using CNN architectures. Works such as those by Zhang et al. [6], Rahman et al. [5], and Ahmed et al. [7] successfully demonstrate efficient recognition of recyclable and non-recyclable materials. However, these systems largely operate in simulation or dataset-based environments and rarely progress towards complete real-time deployment with integrated hardware-based segregation. Thus, there is a lack of systems that bridge the gap between software classification and physical waste segregation mechanisms.

Similarly, IoT-based smart garbage monitoring solutions presented by Haribabu et al. [2] and Shujatullah Khan et al. [8] mainly focus on bin-level monitoring, alert notification, and indication of garbage accumulation levels. While these systems help authorities monitor waste collection more efficiently, they do not incorporate automatic identification and sorting of waste types. Their architecture is restricted to sensing bin levels and sending alerts through GSM, Wi-Fi, or Zigbee networks, leaving the segregation process still dependent on human intervention.

Another considerable gap identified is the limited integration of AI-driven classification with centralized municipal management systems. Although some systems transmit data to servers or mobile applications, they seldom utilize intelligent decision-making for route optimization, prioritization of waste collection zones, or predictive analytics. As a result, garbage collection continues to follow periodic or manual scheduling rather than dynamic, data-driven planning, which leads to overflowing bins, delayed response times, and unhygienic environments.

Additionally, many studies do not address the health and safety concerns of manual waste handlers. Despite proving technological feasibility, few systems explicitly aim to reduce direct human exposure to hazardous or contaminated materials. There is also minimal focus on cost-effectiveness, compact design, and ease of implementation, which are essential for large-scale deployment in urban and semi-urban environments.

A further gap exists in addressing real-time odor and gas detection, bin-level hygiene assessment, and continuous environmental monitoring. While some works measure waste levels, only a limited number attempt to incorporate odor sensing, toxic gas detection, or real-time environmental hazard alerts, which are crucial for maintaining public health standards.

Finally, the literature lacks systems that provide a complete end-to-end intelligent waste management solution integrating the following components simultaneously:

- AI-based waste classification
- Physical segregation into multiple categories
- IoT-based monitoring and live status updates
- Real-time municipal integration
- Low-cost and scalable hardware implementation

Therefore, there is a clear research need for a compact, automated, AI-supported, and IoT-enabled smart waste segregation system capable of reducing manual involvement, enhancing segregation accuracy, improving environmental hygiene, and supporting smart city infrastructure.

IV. METHODOLOGY

The sub-bins for the different types of waste are made into two separate layers. The sub-bins are removable for cleaning purposes. The design uses a dual motor and tray mechanism. The waste is disposed of into a common waste tray, the only part visible to the user. It is detected by the IR sensor. This activates the moisture sensor which is fitted on the tray. There is a pre-set threshold value for classification as dry & wet waste. If the moisture sensor reading is above that value, it is classified as wet waste else it is classified as dry waste. The pre-set value may be suitably chosen to provide accurate segregation. The three bins for wet waste , plastic waste and metal waste are fixed in position below, on the left and right sides of the tray. The Ultrasonic sensor senses the levels of the garbage in the bin. And the sensed data is sent through the Microcontroller. The Atmel Microcontroller is programmed

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

in Embedded C . Thus obtained status will be notified in the BLYNK, It is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network.

Objectives :

- Monitor the level of trash
- Segregate dry, wet or metal waste and detect the gas generated from the waste
- Alert the municipal authority of the status of the waste to take action.

V. PROPOSED SYSTEM

Most of the times, the garbage bins are overflowing with excess waste and are scattered out in the street. These scattered wastes get either decayed or burnt in that place or overflows all over which leads to serious health issues to humans. The wastes which are dumped are segregated by Humans which leads to health problems to them. To overcome this problem a well organised waste segregation and monitoring system has been designed. It is an IoT based Waste Segregation and Monitoring system which is an innovative way to keep the cities clean and healthy. Since the population of our world is increasing rapidly, the environment should be clean and hygienic in order to lead a better life. This is a model for Waste Segregation for Smart cities.

Figure 1: Three bins that collects dry, wet and metal wastes

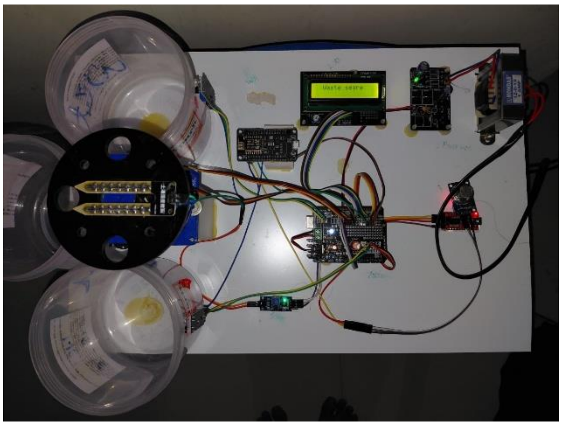

Figure 2 : Prototype of an automated smart waste segregation system showing the microcontroller unit, sensing modules, LCD display, servo motor mechanism, and separate collection bins for classification of waste into different categories.

Figure 3 : LCD display of the smart waste segregation system indicating the status message during the operation of the waste sorting process.

The foremost goal of this project is to automatically segregate the wastes and to perceive the level of the dustbins which is delivered through wireless mesh network. With such information, litter bin providers and cleaning contractors are able to make better decision for the efficient disposal . IR sensor identifies the objects, Moisture and metal sensors detects the wet and metal waste. Ultrasonic sensor observes the levels of bin. The waste is dropped inside the bin where the sensor identifies the type of the waste. The Bin consists of three partitions inside were each bin collects each waste respectively. The motor then rotates and respective partitions gets opened and respective wastes are collected. The status of the bin is displayed in BLYNK server.

VI. ARCHITECTURE DIAGRAM

The sub-bins for the different types of waste are made into two separate layers. The sub-bins are removable for cleaning purposes. The design uses a dual motor and tray mechanism. The waste is disposed of into a common waste tray, the only part visible to the user. It is detected by the IR sensor. This activates the moisture sensor which is fitted on the tray. There is a pre-set threshold value for classification as dry or wet waste. If the moisture sensor reading is above that value, it is classified as wet waste else it is classified as dry waste. The pre-set value may be suitably chosen to provide accurate segregation. The three bins for dry waste , wet waste and metal waste are fixed in position below, on the left and right sides of the tray. The IR sensor senses the levels of the garbage in the bin. And the sensed data is sent through the ATmega328P Microcontroller. The Microcontroller is programmed in Embedded C . Thus obtained status will be notified in the BLYNK, It is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network.

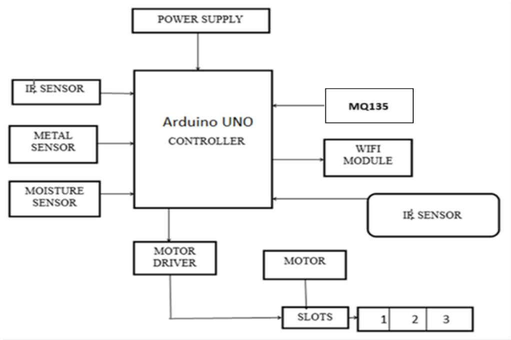

Figure 4 : Block Diagram of the proposed system

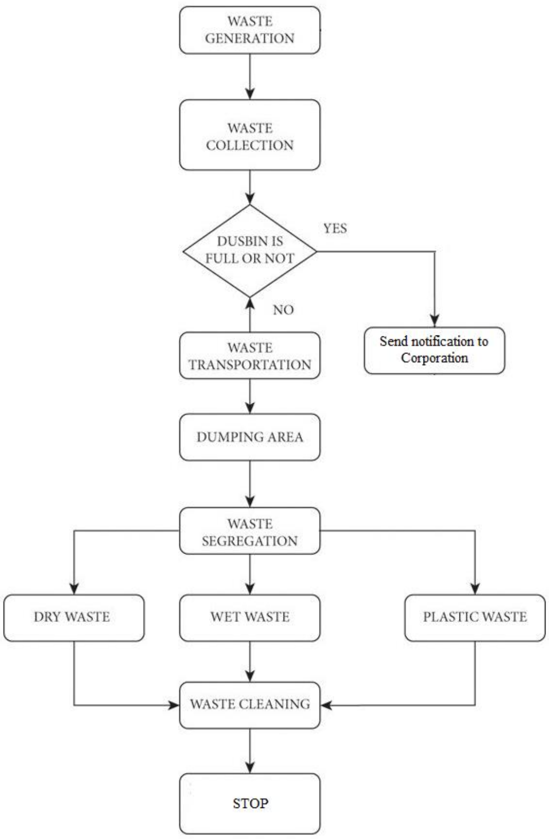

Figure 5 : Flowchart of the system

VII. CONCLUSION

This paper enhances the cleanliness of the smart cities by the practical application of "Automatic waste management and segregation system using IOT". With urbanization and increasing population, disposal of waste is a major concern. This proposed system is an effective waste segregation system that has no human intervention or interference to separate dry and wet waste. It provides timely collection and disposal. The proposed system can be deployed on a domestic scale in a household or a large scale in public places.

The proposed Smart Bin is an efficient waste segregation system that requires no human intervention to separate dry and wet waste and paves the path for timely collection and disposal. The proposed system can be deployed a domestic scale in households or on a large scale in public places. The proposed AI-based Waste Sorting System using Transfer Learning in PyTorch successfully demonstrates how deep learning models can be leveraged to automate the waste classification process and support sustainable waste management practices. The experimental results validate the model's high accuracy (~94.75%), with robust performance across multiple waste categories (organic, recyclable, hazardous, and other).

The integration of the trained model with a Raspberry Pi-controlled hardware prototype highlights the system's real-world applicability, where waste items can be detected, classified, and physically sorted into separate bins using servo motors. The system operates efficiently with low inference time on GPUs and demonstrates promising results even on embedded devices.

REFERENCES

[1] Sustainable Waste Management Using Deep Learning and Smart Bins"
[2] Haribabu P, Kassa SR, Nagaraju J, Karthik R, Shirisha N, Anila M, "Implementation of a smart waste management system using IoT" in International Conference on Intelligent Sustainable System (ICISS) (pp. 1155-1156), IEEE.
[3] Nakib, A. M., Luo, Y., Emon, J. H., & Chowdhury, S. (2024). Machine learning-based water requirement forecast and automated water distribution control system. Computer Science & IT Research Journal, 5(6), 1453-1468.
[4] Nakib, A. M., & Barua, B. AQUA FLOW MASTER: INTELLIGENT LIQUID FLOW CONTROL AND MONITORING SYSTEM.
[5] Rahman, M. W., Islam, R., Hasan, A., Bithi, N. I., Hasan, M. M., & Rahman, M. M. (2022). Intelligent waste management system using deep learning with IoT. Journal of King Saud University-Computer and Information Sciences, 34(5), 2072-2087.
[6] Zhang, Q., Zhang, X., Mu, X., Wang, Z., Tian, R., Wang, X., & Liu, X. (2021). Recyclable waste image recognition based on deep learning. Resources, Conservation and Recycling, 171, 105636..
[7] Ahmed, M. I. B., Alotaibi, R. B., Al-Qahtani, R. A., Al-Qahtani, R. S., Al-Hetela, S. S., Al-Matar, K. A., ... & Krishnasamy, G. (2023). Deep learning approach to recyclable products classification: Towards sustainable waste management. Sustainability, 15(14), 11138.
[8] Zhou, H., Yu, X., Alhaskawi, A., Dong, Y., Wang, Z., Jin, Q., ... & Lu, H. (2022). A deep learning approach for medical waste classification. Scientific reports, 12(1), 2159.
[9] Abdu, H., & Noor, M. H. M. (2022). A survey on waste detection and classification using deep learning. IEEE Access, 10, 128151-128165.