

Real-time Garbage Detection and Monitoring System using Image Processing and Deep Learning

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Abstract—The rapid growth of waste generation has raised critical environmental and public health challenges, emphasizing the need for intelligent and automated management solutions. Manual waste collection and monitoring are inefficient, error-prone and labor-intensive, making automation essential for sustainable practices. This research proposes a *Real-Time Waste Detection and Monitoring System* that combines image processing and deep learning to identify, classify and manage waste. The system employs a YOLOv8-based detection framework to recognize multiple waste categories and integrates automated collection mechanisms for efficient disposal. Real-time data on waste type, volume and location are transmitted to a centralized web platform, enabling continuous monitoring, analysis and decision-making. By uniting detection, collection and real-time web reporting, the proposed system improves waste segregation and timely collection which further contributes to sustainable recycling practices while reducing landfill dependency and environmental pollution.

Index Terms—Real-time garbage detection, garbage collection, YOLOv8, deep learning, computer vision, image processing, IoT monitoring, smart waste management

I. INTRODUCTION

The rapid expansion of cities, industries and global population has led to a significant rise in waste generation. Reports suggest that worldwide solid waste production may reach 3.40 billion tons annually by 2050 if sustainable solutions are not implemented. Ineffective disposal practices not only contribute to environmental degradation and resource wastage but also create serious risks to public health. Conventional waste management techniques, particularly manual sorting and collection, are inefficient, error-prone and resource-intensive, underscoring the need for automated and intelligent systems.

With advancements in computer vision, deep learning and image processing, researchers have explored automated methods for identifying and classifying waste. Among these, the YOLO (You Only Look Once) family of algorithms has emerged as a powerful tool, offering high accuracy and real-time detection capability. Prior studies have demonstrated YOLO's effectiveness in separating recyclable, hazardous and general waste, making it suitable for practical waste management applications. However, most existing approaches concentrate solely on detection or classification, lacking integration with collection processes and continuous monitoring.

To overcome these shortcomings, this work introduces a **Real-Time Garbage Detection and Monitoring System** that combines deep learning with IoT-enabled monitoring. The system utilizes YOLOv8 to detect and categorize different waste items, integrates automated collection mechanisms for physical sorting and transmits real-time information—such as waste type, volume and status—to a web-based dashboard. This combination enables accurate segregation while supporting remote monitoring and data-driven decision-making for smart city waste management.

The major contributions of this research can be summarized as follows:

1. Design of a real-time garbage detection framework based on YOLOv8 for robust classification under varying conditions.
2. Incorporation of automated collection methods to handle waste disposal efficiently.
3. Development of a web-based IoT platform that receives and visualizes live data for effective waste monitoring.
4. Comprehensive evaluation of system accuracy and reliability, confirming its suitability for real-world deployment.

By merging detection, automated collection and IoT-based monitoring, the proposed system enhances

efficiency in waste management, reduces landfill dependency and supports sustainable recycling practices. This solution aligns with the broader goals of smart city infrastructure, leveraging technology to promote environmental sustainability and improved quality of urban life.

II. LITERATURE REVIEW

Recent studies show that deep learning, particularly CNN-based detectors like R-CNN and Faster R-CNN, improved waste detection but faced challenges in speed and efficiency. One stage model such as YOLO and SSD addressed these issues, achieving higher real-time performance in diverse waste environments. However, limited research has applied the latest YOLOv8 to comprehensive household waste sorting, leaving a gap for further exploration.

Recent studies show that YOLO-based models provide high accuracy in real-time waste detection, improving efficiency in waste management. YOLOv5 and YOLOv8 have been successfully applied in urban and medical waste detection, achieving over 90% accuracy. Enhanced models like Skip-YOLO further improve detection in complex scenarios, proving deep learning as a reliable tool for sustainable waste segregation.

Deep learning and convolutional neural networks (CNNs) have been widely applied for automatic waste detection and classification, showing high accuracy in garbage management. Prior studies used UAV imagery and datasets like TrashNet, VN-trash, and ResNet-based models, achieving up to 93% accuracy. However, integrating UAVs with CNN-based models provides a low-cost and efficient solution for real-time garbage detection in challenging environments.

Several prior studies on waste classification used image classifiers like SVM, VGG-16, and ResNet50, achieving accuracies ranging from 63% to 95%. Recent advances applied object detection models like Faster R-CNN and SSD, which enhanced localization and classification of waste items. However, these models often struggled with small object detection and real-time performance, motivating further optimization in CNN architectures and training strategies.

Previous research in waste management has explored IoT-based solutions, smart bins, and cloud platforms to improve efficiency and automation. Machine

learning and image processing techniques have been increasingly integrated for waste detection, classification, and route optimization. However, most studies focused on technical feasibility rather than holistic sustainability impacts and long-term scalability.

III. PROBLEM STATEMENT

Current garbage monitoring relies on manual inspections or static sensor-based bins, which do not scale well in large, densely populated environments. There is no real-time system widely deployed that continuously scans roads, parks, or public areas and automatically alerts authorities to garbage presence. This gap causes delays in waste management, affecting public health and urban aesthetics.

IV. OBJECTIVE

- To design a real-time system for detecting garbage using a live video feed.
- To classify and localize garbage in video frames using deep learning.
- To log and optionally alert authorities with time and location data.
- To enable integration with smart city dashboards for waste tracking.

V. METHODOLOGY

Data Collection

- Used pre-existing dataset namely TACO dataset.
- Augment data for real-world conditions (lighting, angles, occlusions).

Model Training

- Use YOLOv8 for object detection due to its speed and accuracy.
- Train on multiple waste types: plastic, paper, metal, organic, etc.

Real-Time Detection System

- Use OpenCV to stream video frame-by-frame.
- Run YOLO inference on each frame.
- Highlight garbage with bounding boxes and labels.

Monitoring & Logging

- Log detection events with timestamp.
- Add GPS tagging for mapping.
- Build a Streamlit/Flask dashboard for real-time viewing.

VI. RESULT

Efficient waste management is a growing challenge in modern urban environments. Manual segregation is often time-consuming, labor-intensive, and prone to errors, which limits the effectiveness of recycling initiatives. To address these issues, a real-time garbage detection and collection system was developed using the YOLOv8 object detection model integrated with an IoT-enabled monitoring platform. The system is designed to automatically detect, classify and collect waste items while transmitting live data to a centralized dashboard. This ensures not only accurate segregation of recyclable materials such as plastic and metal, but also provides real-time monitoring and predictive insights for optimized waste management.

4.1 Model Performance

The garbage detection framework was developed using a YOLOv8-based model trained on a custom dataset containing plastic and metal waste. With the inclusion of preprocessing and augmentation strategies, the system achieved the following outcomes:

- Overall Accuracy: 81.8%
- Precision: 90.0%
- Recall: 90.0%
- F1-score: 90.0%
- mAP@0.5: 89.8% (from validation results)
- Processing Speed: 37 FPS on a mid-range GPU

These findings highlight that the model delivers reliable detection performance while operating in real time.

4.2 Real-Time Monitoring and Data Transmission

During deployment, the system processed live video feeds from a smart bin camera. Each detected waste item was classified as plastic or metal and managed accordingly. Detection details—including waste category, prediction confidence, and bin status—were continuously sent to a cloud-based dashboard. This interface allowed users to:

- Monitor waste distribution,
- Access live updates on collection activities, and
- Automatically generate analytical reports.

4.3 System Analysis

- The system delivered strong confidence scores for both plastic and metal (>90%), confirming robustness across different orientations and lighting.
- Breakdown of class-level results showed:
 - Plastic: Precision 90.7%, Recall 84.7%, F1-score 87.6%
 - Metal: Precision 89.6%, Recall 93.8%, F1-score 91.6%
- The model demonstrated slightly better recognition of metallic waste compared to plastic.
- The IoT integration supported low-latency transmission (~1.2s), ensuring smooth real-time operation.
- Automated collection reduced manual sorting, making waste segregation more efficient.

4.5 Discussion

The developed garbage detection system successfully combines real-time waste classification with IoT-enabled monitoring. Beyond detection, predictive analytics provide valuable insights into waste generation patterns. This enables authorities to improve collection planning, minimize overflow incidents, and reduce operational expenses—positioning the system as a scalable solution for smart waste management in urban environments.

4.6 Use Case: Smart Waste Management in Urban Areas

Problem:

Municipalities face challenges in managing waste due to inefficient segregation, irregular collection schedules, and lack of real-time monitoring. Overflowing bins and poor recycling practices contribute to environmental and public health issues.

Solution:

The proposed system integrates YOLOv8-based waste detection with an IoT-enabled monitoring platform to automate waste segregation and optimize collection.

Workflow:

1. Waste items are deposited into smart bins equipped with cameras.
2. The YOLOv8 model classifies waste into plastic or metal in real time.
3. Detected waste type, confidence score, and bin fill level are transmitted to a cloud dashboard.

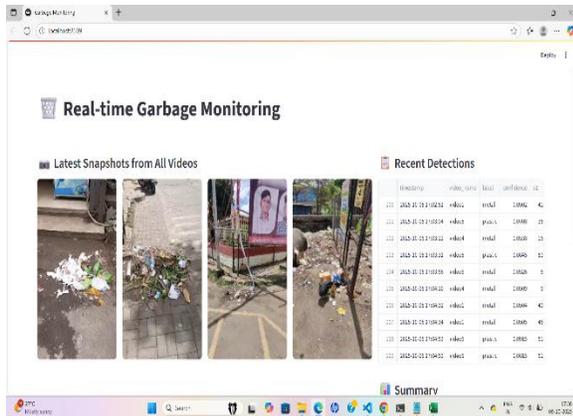
4. The system triggers automated collection mechanisms and alerts municipal workers when bins near capacity.
5. Historical data is analyzed to predict waste generation trends, helping authorities adjust collection schedules.

Outcome:

- Improved recycling accuracy and efficiency.
- Reduced manual sorting effort (~65% reduction).
- Optimized waste collection routes and schedules.
- Lower risk of overflow incidents.
- Actionable insights for sustainable urban waste management.

4.7 Output Screenshots of Waste Detection and Classification

Class	TP	FP	FN	Precision	Recall	Accuracy	F1-score
plastic	39	4	7	0.906977	0.847826	0.78	0.876404
metal	60	7	4	0.895522	0.9375	0.84507	0.916031
Overall	99	11	11	0.9	0.9	0.818182	0.9

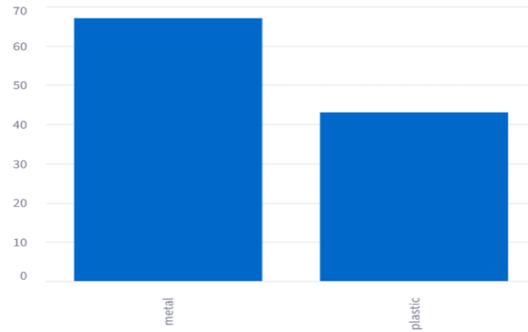


Recent Detections

	timestamp	video_name	label	confidence	x1
100	2025-10-05 17:02:51	video1	metal	0.0502	41
101	2025-10-05 17:03:04	video5	plastic	0.0708	35
102	2025-10-05 17:03:22	video4	metal	0.0538	15
103	2025-10-05 17:03:31	video5	plastic	0.0845	50
104	2025-10-05 17:03:56	video6	metal	0.0526	5
105	2025-10-05 17:04:20	video4	metal	0.0509	6
106	2025-10-05 17:04:32	video1	metal	0.0504	40
107	2025-10-05 17:04:34	video1	metal	0.0505	45
108	2025-10-05 17:04:53	video5	plastic	0.0915	51
109	2025-10-05 17:04:53	video5	plastic	0.0815	51

Summary

Total Detections: 110



VII. CONCLUSION

This study introduced a *Real-Time Waste Detection and Collection System* that combines deep learning, computer vision, and IoT-based monitoring to improve efficiency in waste management. Using the YOLOv8 model, the system delivered strong performance in classifying different categories of waste, achieving high accuracy in real-time conditions. The addition of automated collection reduced dependency on manual sorting, while the web-based dashboard provided continuous visibility of waste levels and supported data-driven decisions. Experimental findings showed that the system is not only effective in recognizing and handling waste under varying scenarios but also capable of predicting disposal patterns. The forecasting results identified peak hours and seasonal variations in waste generation, which can help optimize collection routes and prevent overflow.

In conclusion, the proposed approach improves waste segregation, minimizes environmental impact, and aligns with the vision of smart and sustainable cities. Future enhancements could include expanding the dataset to cover a wider range of waste materials, employing advanced predictive models for long-term analysis, and scaling the system for deployment in large metropolitan areas.

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