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Original Research Paper

AI-Based Real-Time Waste Sorting System for Recycling Plants Using YOLO and Deep Learning Models

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ABSTRACT

Modern recycling facilities must have effective waste segregation because of the growing amount of mixed garbage and the ineffectiveness of manual sorting techniques. Manual segregation is time-consuming, labor-intensive, and puts workers' health at risk. This research describes an AI-based real-time waste sorting system that uses deep learning and YOLO approaches to overcome these issues. The YOLO model concurrently detects and classifies various trash objects in the proposed system, which uses a camera to record live video streams of rubbish on a conveyor belt. The waste that was found is divided into five categories: glass, metal, organic, plastic and e-waste. By preventing duplicate detections, object tracking guarantees precise counting. While Flask offers a web-based interface for real-time viewing of detection and counting results, OpenCV is used for image processing.

KEY WORDS:* *Waste Segregation, YOLO, Deep Learning, Computer Vision, Recycling, Object Detection.

INTRODUCTION

Solid waste creation has dramatically expanded due to rapid urbanization and industrial growth, posing serious problems for waste management systems. Recycling facilities frequently receive mixed garbage, which makes manual segregation challenging and ineffective. The heavy reliance on human labor in traditional sorting techniques results in high operating costs, slower processing speeds, and more worker exposure to dangerous contaminants.Automated waste sorting systems with real-time performance are now possible because to recent developments in computer vision and artificial intelligence. Industrial applications can benefit from object detection models like YOLO (You Only Look Once), which provide high accuracy and quick inference. This study suggests an AI-based real-time garbage sorting system that uses YOLO to automatically identify, categorize, and count waste items, increasing recycling plants' accuracy, efficiency, and safety.

LITERATURE REVIEW

Redmon et al. introduced the YOLO (You Only Look Once) framework for real-time object detection, which enabled fast and accurate detection of multiple objects in a single frame. Their work demonstrated that YOLO is well suited for time-critical applications such as automated waste sorting, where speed and accuracy are essential. However, early versions of YOLO faced challenges in detecting small or overlapping objects.

Yang et al. proposed a deep learning–based waste classification system using convolutional neural networks (CNNs) to identify different waste materials. While the model achieved good classification accuracy, it was limited to image-level prediction and did not support real-time multi-object detection, restricting its use in conveyor-based recycling plants.

Mittal et al. developed a vision-based garbage classification system aimed at improving recycling efficiency using deep learning. Although effective in controlled environments, the system lacked object tracking mechanisms, leading to repeated counting of the same waste items. Recent studies have addressed this limitation by integrating YOLO with OpenCV and object tracking algorithms, improving real-time detection, classification, and counting accuracy. Despite these advancements, issues such as object occlusion and scalability in industrial environments remain open challenges.

EXISTING METHOD

The majority of the waste segregation technologies used in recycling facilities today rely on mechanical separation and hand sorting. Because hazardous waste materials are involved, manual sorting is labor-intensive, time-consuming, and puts workers' health and safety at risk. Although mechanical methods like air classifiers and magnetic separators are used to separate particular waste kinds, their ability to handle mixed and visually identical garbage is restricted, and they frequently have expensive installation and maintenance costs.

Existing vision-based approaches used machine learning and conventional image processing to try to automate waste sorting. These systems were extremely sensitive to changes in illumination, background clutter, and object overlap since they depended on manually created attributes like color, form, and texture.

PROPOSED METHOD:

The proposed method introduces an AI-based real-time waste segregation system using YOLO and deep learning techniques to automate sorting in recycling plants. A camera continuously captures live video of waste items moving on a conveyor belt. Each video frame is processed using OpenCV and passed to a trained YOLO model, which detects and classifies multiple waste objects simultaneously into categories such as plastic, organic, metal, glass, paper, and e-waste. To ensure accurate counting, object tracking is implemented so that the same waste item is not counted repeatedly across consecutive frames. The detection results, including object labels and category-wise counts, are displayed in real time through a Flask-based web interface. This approach improves sorting accuracy, reduces manual effort, and enhances operational safety and efficiency.

SYSTEM ARCHITECTURE

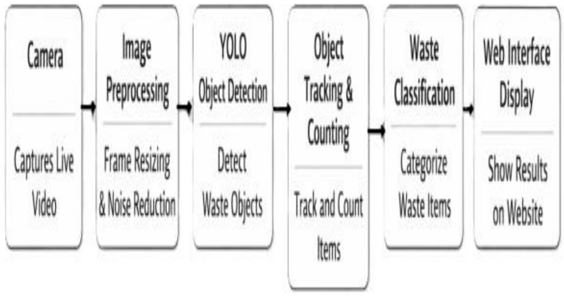

Fig 2: Block Diagram

METHODOLOGY DESCRIPTION

The proposed system follows a structured pipeline for real-time waste detection and classification. Initially, a camera captures live video input from the environment. The captured frames undergo image preprocessing, which includes resizing and noise reduction to enhance image quality and ensure consistency for further processing.

Next, the preprocessed images are passed to the YOLO-based object detection model, which identifies and localizes waste objects in real time. Once detected, an object tracking and counting module monitors the movement of these items across frames, ensuring accurate tracking and maintaining a count of waste objects. After tracking, the system performs waste classification, where detected items are categorized into different types (such as recyclable or non-recyclable). Finally, the processed results, including detected objects and their categories, are displayed through a web interface, enabling users to monitor outputs in real time.

RESULTS AND DISCUSSION

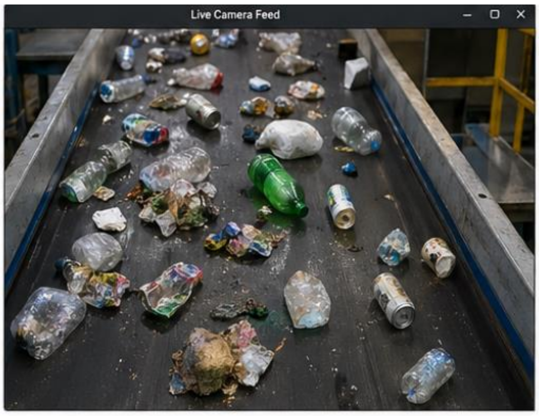

Fig 2: Input video capture

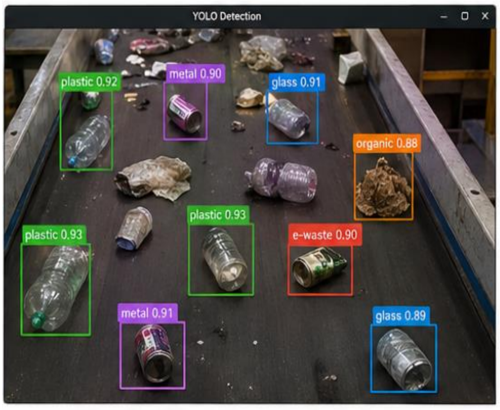

Fig 3: YOLO based waste sorting

CONCLUSION AND FUTURE ENHANCEMENT

CONCLUSION

The proposed AI-based waste sorting system successfully automates the detection, classification, and counting of waste items in real time using YOLO and deep learning techniques. By integrating object detection, tracking, and a web-based interface, the system reduces manual effort, improves sorting accuracy, and enhances operational safety in recycling plants.

FUTURE ENHANCEMENTS

Future work can focus on expanding the range of waste categories, improving performance under heavy object overlap, and integrating robotic actuators for automatic physical sorting. Deployment on edge devices and large-scale industrial environments can further enhance system efficiency an scalability.

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