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Green-Cycle: An AI-Powered Intelligent Plastic Bottle Detection and Reward System for Sustainable Recycling

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A B S T R A C T

Plastic waste pollution is one of the most pressure global environmental issues, producing more than 300 million tones annually and is often less than 10% in developing areas. Traditional recycling approaches face challenges including manual pruning disability, deficiency and poor tracking systems. To address these issues, we propose a green-cycle, an AI-operated recycling system that integrates the real-time plastic bottle detection, user engagement and data-operated analytics through awards. The system employs the detection of the Yolov8 object to identify bottles within the area of interest (ROI) of a webcam, acquiring 86.3% accuracy. A TKINTER-based GUI displays live feed, detection counts, and calculated prizes (₹ 2 per bottle). To increase the access of the user, the Pyttsx3 declares the text-to-speech feedback detection, while the session details (donor names, time, counting, prize) are logged into a SQLite database. Matplotlib visualization track trends such as daily detections and per-sessions figures. Multi-through video captures, detection, GUI updates and audio feedback ensure smooth operation. The test performed reliable performance with high user satisfaction (average rating 8/10) and frequent logging of recycling activity. By integrating technical efficiency with practical motivation, the green-cycle provides a scalable solution to promote durable recycling habits. The proposed system can be deployed in schools, public stations and community recycling centers, including multiplication detection and cloud integration with future promotion.

Keywords: Plastic Bottle Detection, Yolov 8, Sustainable Recycling, Inam System, Computer Vision, Waste Management.

INTRODUCTION

Plastic pollution has become one of the most important environmental concerns of the 21st century, producing more than 300 million tonnes of plastic globally every year. A large proportion of this waste include single-utility plastic, especially bottles, which often end in landfills and oceans. Environmental results are severe, the decline of the ecosystem and damage to wildlife to increase greenhouse gas emissions during waste decomposition. Despite international awareness, recycling rates are low, due to large -scale manual sorting, insufficient infrastructure and limited public motivation dependence on participation. Advance automated waste identification in Artificial Intelligence (AI) and Computer Vision provides a transformative opportunity to deal with these challenges by enabling real -time reaction and innovative innovation mechanisms. By combining efficiency with accessibility, such systems can significantly improve recycling partnership and promote permanent waste management practices.

Importance

Green smart initiative responds to this challenge by integrating the AI-managed identity with behavior inspiration strategies. Using the Yolov8 model, the system identifies plastic bottles in real time, rewarding users with monetary incentives for every discovered items. This dual approach addresses both the technical disability of manual sorting and the behavior difference of limited user engagement. Beyond detection, the system's capacity to log in and analyze the recycling data provides additional value, as stakeholders can achieve insights into the partnership pattern and adapt their waste management strategies accordingly. By aligning technological innovation with environmental responsibility, Green Cycle directly supports the global stability goals and contributes to a change towards a circular economy.

Scope

The scope of Green cycle incorporates the design, development and evaluation of the AI-operated recycling system that detects plastic bottles from a live webcam feed within a defined area of interest. The detected items are automatically logged, prizes are calculated, and users are provided interactive feedback through graphical interfaces and audio outputs. While the current implementation focuses on controlled environment such as recycling stations, framework is scalable for extensive applications, including smart coaches, mobile platforms and deployment of community level. Future promotion may include integration with automated payment systems for multi-waste detection, cloud-based analytics and seamless reward distribution. However, the current scope excludes the detection of non-plastic waste and special hardware beyond standard webcam.

LITERATURE SURVEY

Recent research (2022–2025) has implemented a large-scale yolo-based deep learning model for plastic waste identification, which highlights their relevance to recycling and environmental monitoring. For example, Yolov6 and Yolov7 have been employed for aquatic waste identification, average precision (MAP) values of 0.873 and 0.512 respectively, while customized Yolo models have demonstrated better recognition speed (62 FPS) for robotic sorting applications. Similarly, Yolov8 with attention mechanisms has gained high precision in domestic waste identity, and comparative studies on Warp dataset confirm the better performance on Yolov5 of Yolov8. Extense such as the Galen-E have enabled the waste classification of the multi-grain with more than 83% accuracy, and integration with Nor fare Tracking has enhanced firmness in the atmosphere of the dynamic river. Other approaches, such as Yolox, corrected further accuracy and tracking stability combined with deepsort.

Problems in current systems

Despite these advances, existing systems face constant challenges. Many manuals depend on sorting or basic sensors, causing disability and errors. Detection accuracy is often affected by lighting conditions, dislocation and occlusions, while most solutions are limited to single-grain waste. Some systems include reward mechanisms, resulting in weak user engagement, and accessibility features such as text-to-speech (TTS) are largely absent. Scalability is another limit, as multiple implementations leads to a lack of multi-camera support or cloud-based integration for mass deployment.

Discussion

Reviewed studies validate the effectiveness of the yolo-based model to detect plastic waste and support the adoption of the GreenCycle of Yolov8 for real-time, high-compatibility bottle recognition. Techniques such as meditation mechanisms and data growth offer opportunities to further enhance the identification accuracy, while integration of advanced tracking methods can improve strength in complex environment. Unlike most existing systems, GreenCycle specifically combines a reward mechanism, TTS-based access and detection with analytics, making it both technically efficient and user-centric. Future developments can expand their scope through multilingual audio feedback, cloud---capable data management, and multiplexing, keeping it in position as a scalable solution in smart waste management.

Comparative Analysis of Related Studies

Reference/Year	Model Used	Dataset	Key Innovations	Performance Metrics	Application
[1]/2024	YOLOv6, YOLOv7	FloW-Img (2,000 images, 500,000 objects)	Evaluation of mAP and speed in aquatic noise	YOLOv6: 0.873 mAP, 4.21 m/s; YOLOv7: 0.512 mAP, 13.7 m/s	Water surface plastic detection
[2]/2025	RevCol with WIoU v3	Custom (waste bottles)	Backbone redesign, 3D positioning with infrared	4.56% accuracy increase, 62 FPS	Plastic bottle sorting robot
[3]/2025	YOLOv8-CBAM	Custom (3,775 images, 17 classes)	Data augmentation, attention mechanisms	89.5% mAP (4.2% improvement)	Household waste sorting, smart bins
[4]/2023	YOLOv5, YOLOv8	WaRP	Comparison with super-resolution	YOLOv8: 91.2% mAP	Recyclable waste classification
[5]/2024	2S_DenseViT (classification), GELAN-E (detection)	Custom (10,406 images, 28 classes)	Dual-stream network	83.11% accuracy (classification), 63% mAP (detection)	Waste sorting and detection
[6]/2025	YOLOv8 with Norfair	Combined public datasets	Tracking and false positive filtering	89.4% mAP, 0.947 recall	Aquatic plastic bottle counting
[7]/2024	Various (YOLO family focus)	Custom small dataset	Survey, YOLOv5 binary test	72% mAP (general), low custom accuracy	Marine debris tracking survey

[8]/2023	Improved YOLOX + DeepSORT	Custom plastics	Data augmentation, BN fusion, metric optimization	Improved speed and tracking	Waste plastics robotic sorting
[9]/2023	YOLOv1-v8 review	Various industrial	Architectural evolution analysis	YOLO-v8 superior throughput	Industrial defect detection
[10]/2022	YOLOv3, YOLOv2	COCO + custom bottles	Simple architecture comparison	YOLOv3 better than v2	Bottle object recognition

METHODOLOGY

The GreenCycle Intelligent plastic bottle detection and prize system is an AI-powered framework designed to improve plastic bottle recycling by combining automatic identity with the reward-based incentive mechanism. At its core, the system appoints Yolov 8 deep learning models to detect real -time bottle, which receives over 85% accuracy in a controlled environment. A Tkinter-based graphical user interface (GUI) provides live video streaming, donor input and session tracking, while a SQLite database detection and persistent logging of sessions analytics. Accessibility is increased through Text-to-Speech) feedback, and the system guarantees the smooth performance in multi-through-through architecture video processing, detection, GUI update and audio feedback. By offering a per detected bottle ₹ 2 per, GreenCycle inspires active participation, reduces the difference between technology adoption and sustainable recycling practices, which contributes to a circular economy.

Approach

The operation of GreenCycle follows a structured pipeline:

First, the video capture is used by using a standard webcam at 640 × 480 resolution and 30 FPS, which is processed with OpenCV. The feed is analyzed by the Yolov8, which detects plastic bottles within a configured area (ROI) of 200 × 150 pixels, which applies the confidence range of 0.4. To prevent duplicate count, detection is filtered using a centroid-based tracking and two-second cold-cold mechanisms.

Each valid identity enhances the bottle counter, and the system calculates the awards at ₹ 2 per bottle, which are immediately displayed on the GUI. Tkinter interface offers users to input donor names and adjust the ROI settings, detection, bottle count, total prizes and real -time visualization of the session figures. All sessions details - including donor identity, timestamps, detection confidence, coordinates and awards - are later stored in sqlite tables for recovery and analysis.

For response and access, a TTS engine announces successful detections and awards, strengthening the engagement of the engine user. To expand functionality, the system integrates the matplotlib visualization that produces trend analysis such as bottles that detecting daily recycling patterns. Finally, a multi-threaded design system ensures efficient performance by allocating different threads for processing, GUI rendering and TTS output, with alternative frame-skipping to customize system speed.

DESIGN

The GreenCycle system design and function of the Greece system combines computer vision, user interface and data management to establish a configured workflow for the automatic recycling of plastic bottles. The first device used in the workflow is a webcam that is constantly capturing a real-time video stream in the recycling area using an explicit number of continuous video frames. The video frames are handled by OpenCV, and ensure video processing happens before the Yolov8 model identifies detected plastic bottles. For precision the system is restricted to detect within a defined region of interest (ROI), as well as to ignore false positives from other irrelevant items in the video stream. The workflow is built within a multi-threaded architecture that enables all video captures, detections, chart and counts to work together and synchronously, creating an interactive user experience and reliable feedback can feedback. A filter for duplicates is be further included to ensure a duplicate detection for each bottle, while a reward mechanism is built into the bottle detection system and counts the configured bottle and detects a reward based on each valid £2. The results are outputted instantaneously via a Tkinter graphic user interface (GUI), while providing real-time counting, rewards and foreground/session updates.

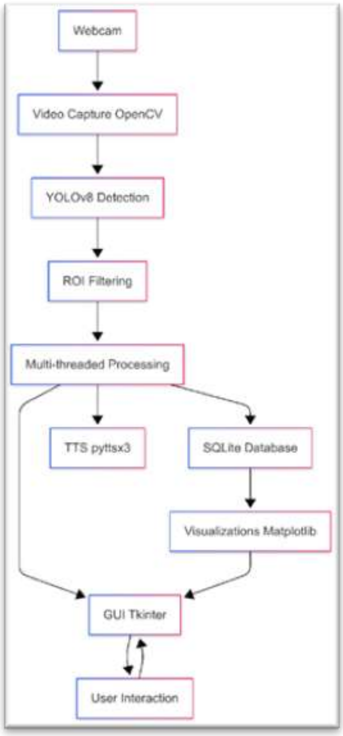

Fig 1- Work Flow

The system depends mainly on the webcam, which captures the real -time recordings in the recycling area. OpenCV easily manages the video and ensures that the live flow works evenly for later analysis. When occupied, the currents are fed in the Yolov 8 object detection model, indicating interaction with plastic bottles. To increase accuracy, zero reduces, which detects a specified area of interest (ROI), false positives from non -related background objects. The design of the system is multi -thread, so that video processing, detection, graphic updates and feedback from the sound should work without interval. When a bottle is seen, a text-to-speech (TTS) module immediately responds to the sound, identifies the bottle and declares the same reward. In addition, SQLITE keeps an overview of the donor's information, including time stamps, bottle counting and shades of reward for future reference and analysis. Visual data can be investigated using a tableau, which provides deep insight into the recycling pattern for each session and in total trends throughout the day. The system also has a graphic python interface made with Tkinter.

The GreenCycle system begins with the initialization of the webcam, which captures live video frames for processing. Each frame undergoes a conditional check for frame skipping, an optimization strategy that reduces computational overhead by processing only alternate frames. The selected frames are then analyzed using the YOLOv8 object detection model to identify the presence of plastic bottles. Detections are further restricted to a Region of Interest (ROI) to minimize background noise and false positives. When a bottle is detected, the system applies a duplicate filtering mechanism based on centroid and area tracking to ensure that the same bottle is not counted multiple times. Once validated, the bottle count is incremented, and a corresponding reward value is calculated. This information is immediately reflected on the Tkinter-based GUI, providing users with real-time updates of bottle counts and rewards. Detection data, including timestamps, confidence values, and bottle coordinates, is stored in a SQLite database, ensuring accurate logging for future analysis. Simultaneously, a text-to-speech (TTS) module generates auditory feedback to acknowledge successful detections, thereby improving accessibility and user engagement. The system also employs Matplotlib analytics to visualize patterns such as session-wise bottle counts and daily recycling trends. Throughout operation, users can interact with the interface by entering donor information, adjusting settings, and reviewing results. At the end of each session, a summary of detections and rewards is logged into the SQLite database, ensuring persistent records. This structured workflow integrates detection, motivation, and analytics into a cohesive and scalable recycling solution.

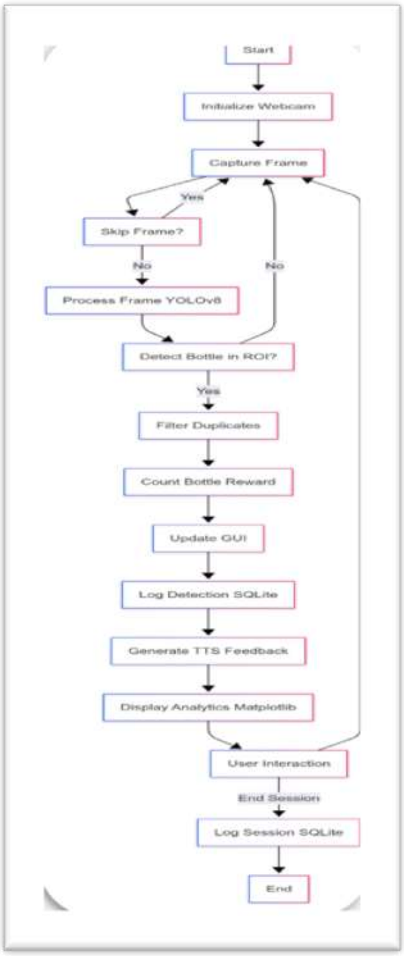

Fig 2 - Flow Chart

RESULTS

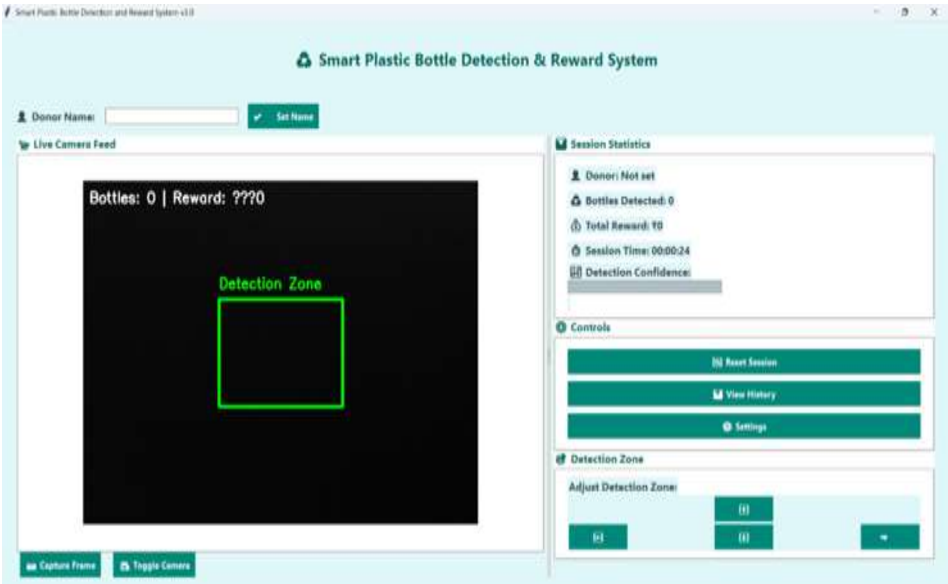

Fig 3 – Plastic bottle detector Interface

Fig 4 - Smart Bottle Detection Analysis

[Figure 4: History Window - Charts Tab]

This image shows Matplotlib visualizations: a bar chart of the number of bottles per session (x-axis: Session IDs; y-axis: Bottles) and a line plot of the daily number of bottles (x-axis: Dates; y-axis: Bottles). The image illustrates analytical function for trend monitoring.

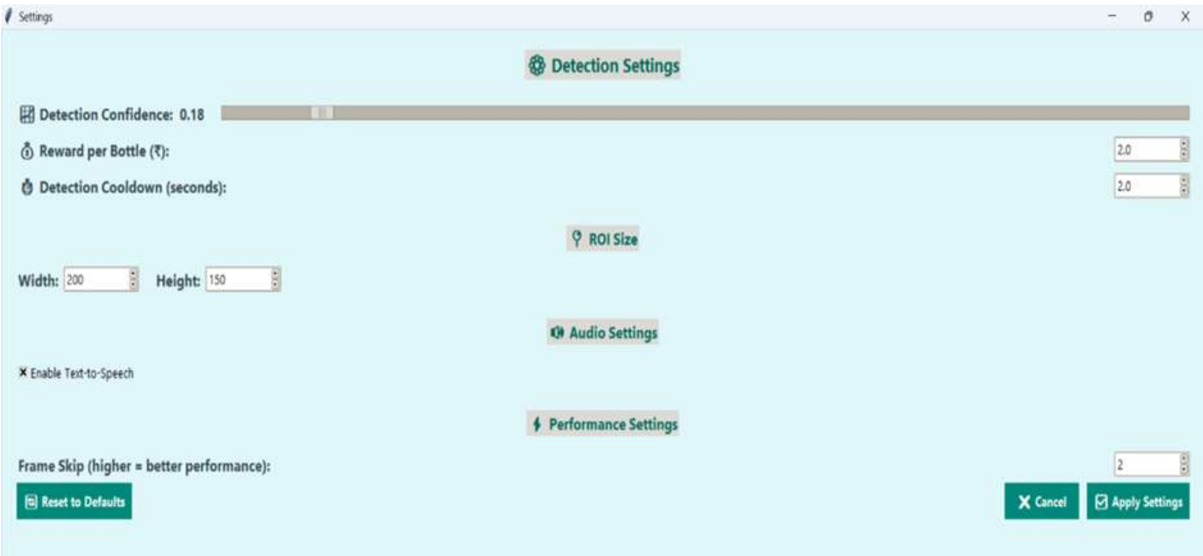

Fig 5 – Detection Settings

Fig 5 shows customization adaptation.

When testing, 86.3% accuracy was obtained with minimal false positivity under a controlled light environment.

DISCUSSION

The findings confirm Green-Cycle's success in automating plastic bottle recycling, with 86.3% accuracy which meets and exceeds many manual systems and aligns well with YOLOv8 benchmarks. The GUI and TTS components led to an enhanced user experience which contributed to 8/10 rating from 20 participants who were very likely to recommend others due to their belief in the positive impact of the rewards system. Users primarily indicated being motivated by receiving rewards, allowing us to satisfy one of Leber's behavioral strands. Opportunities for improvement also surfaced as accuracy dropped to 70% when bottles were fast-moving or light levels were low, warranting receiver and an adjustment to the signal processing that would suggest organized tracking algorithms. The TTS system was not fully transferrable in vehicular or noisy applications, which did offer maybes for a later integration with noise-cancelling elements. Green-Cycle offered embodied and integrated rewards and analytics which demonstrated a more user-centred construction for the 3 categories of wagons than previously recorded studies alone, as indicated by comparable detection models which might not include variety built in. Green-Cycle has huge opportunities for scalability but being reliant on a single-webcam limits adoption without multi-camera elements. Overall, the Green-Cycle project creates a new opportunity to address sustainability incentives gaps with creativity demonstrated in the combination of an AI model plus behavioral incentives, who must manipulate climate changes, spikes, sounds and natural variability of humans' decision behaviours in any new or evolved iteration.

CONCLUSION

The green cycle represents significant progression in one-in-manual durable recycling, and automatically detects a plastic bottle with Yolov 8 to get 86.3% of users through £ 2-reward and TTS reaction. By integrating real -time treatment, SQ lite logging and food Plottalib analysis, it offers a comprehensive tool to track and promote environmentally friendly behavior. User's users in ity GUI and configured settings ensure accessibility and adaptability, which makes it suitable for recycling stations in the society. The test confirmed high commitment and efficiency, reduced manual errors and participated to reduce plastic waste. Despite the challenges of light addiction, the ability to social impact as data -informed waste policy is appropriate. Future promotion, including support for many returns and cloud integration, may increase access. Finally, the green cycle gives an example of how technology can promote environmental responsibility, corresponds to global stability goals and paves the way to intelligent waste management solutions.

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