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Green Guard: AI Camera for Detection and Evidence Collection of Illegal Waste Dumping

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Abstract: Illegal waste dumping is a significant environmental issue affecting urban cleanliness and public health. This paper presents Green Guard, an AI-based surveillance system designed to detect illegal dumping activities and automatically collect visual evidence.

The system utilizes YOLOv8 for real-time object detection and integrates tracking and event-based validation to identify dumping behavior.

The proposed framework captures time-stamped evidence and provides a dashboard for monitoring. Experimental results demonstrate strong detection performance and reliability, making the system suitable for smart city applications.

Index Terms: Waste Detection, YOLOv8, Computer Vision, Smart Surveillance, Deep Learning.

I. INTRODUCTION

Illegal waste dumping causes severe environmental damage, including soil contamination and public health risks [6]. Traditional monitoring approaches rely on manual inspection and CCTV systems without intelligent analysis, making them inefficient and limited in scalability.

Recent advancements in computer vision and deep learning enable automated systems capable of detecting waste in real time [1]. These systems improve monitoring efficiency and reduce human intervention.

This paper proposes Green Guard, an AI-powered system that detects illegal dumping events and collects evidence automatically. Unlike existing systems, it integrates object detection, tracking, and event-based logic to improve reliability.

II. LITERATURE REVIEW

Deep learning-based approaches have shown high effectiveness in waste detection tasks. Majchrowska et al. [1] demonstrated the capability of deep neural networks in detecting waste in both natural and urban environments. Chen and Zhu [2] proposed a lightweight YOLO-based model for real-time garbage detection.

Alharbi et al. [4] introduced a system for detecting littering behavior using deep learning, while Ilyas et al. [9] focused on waste classification and detection for environmental sustainability. However, most of these systems lack integrated event-based detection and automated evidence collection.

The proposed system addresses these limitations by combining detection with behavioral analysis and structured evidence storage.

III. PROPOSED SYSTEM

A. System Overview

Green Guard is an AI-based surveillance system that detects illegal waste dumping activities and records evidence automatically. The system processes video input, detects objects, tracks individuals, and validates dumping events.

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B. System Architecture

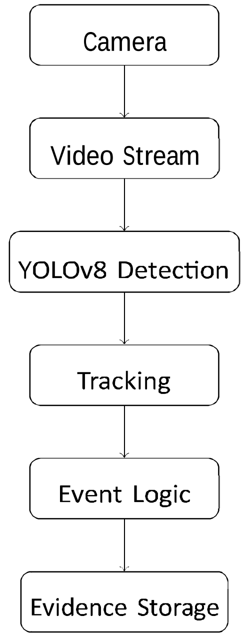

Fig. 1. System Architecture of Green Guard

As shown in Fig. 1, the system processes video input through detection, tracking, and event validation modules.

C. Key Features

The proposed Green Guard system includes the following key features:

1) Real-time Waste Detection: The system identifies waste objects instantly using the YOLOv8 deep learning model.
2) Person Tracking: Individuals are tracked across frames using unique IDs to maintain continuity.
3) Event-based Detection: Dumping events are confirmed by analyzing the interaction between person and waste over time.
4) Evidence Collection: The system captures timestamped images of both the person and the waste object.
5) Dashboard Interface: A user-friendly dashboard is provided to view and manage detected cases.
6) Scalability: The system can be deployed across multiple locations for large-scale monitoring.

IV. METHODOLOGY

A. Dataset and Preprocessing

The dataset consists of custom images and real-time video frames along with publicly available datasets [9]. Images are resized to a standard resolution suitable for YOLOv8 and annotated using bounding boxes. Data augmentation techniques such as rotation, scaling, and brightness adjustment are applied to improve generalization.

B. Detection Pipeline

The detection pipeline includes frame acquisition, preprocessing, object detection, and tracking. Each frame is processed using YOLOv8 to identify objects such as persons and waste. The detected objects are then passed to the tracking module.

C. Tracking Mechanism

The system uses a tracking algorithm to assign unique IDs to detected persons. This allows the system to track movement across frames and maintain identity consistency, enabling association between individuals and detected waste objects.

D. Distance Calculation

The Euclidean distance between a person and waste object is calculated as:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (1)$$

where (x_1, y_1) and (x_2, y_2) represent the center coordinates of the person and waste bounding boxes respectively.

E. Event Detection Logic

The system detects illegal dumping events based on temporal analysis. Initially, waste appearing near a person is identified. The system then monitors whether the person moves away while the waste remains in the scene. If these conditions are satisfied, the event is confirmed as illegal dumping.

F. Algorithm for Dump Detection

The dumping detection process follows a structured algorithm:

1) Capture video frame from input stream
2) Detect objects (person, waste) using YOLOv8
3) Track detected persons using unique IDs
4) Identify newly appeared waste objects
5) Compute distance between person and waste
6) Monitor persistence of waste over time
7) Check if person moves away or disappears
8) If conditions satisfied, confirm dumping event
9) Capture and store evidence images

G. Evidence Collection

The system captures two types of evidence: a close-up image of the person and a full-frame image of the waste. These images are stored in structured folders with timestamps for easy retrieval and analysis.

H. System Workflow

The system operates in a continuous loop where video frames are processed sequentially. Each frame undergoes object detection, followed by tracking and event validation. The workflow ensures that only valid dumping events are recorded, reducing false positives and improving system reliability.

V. IMPLEMENTATION DETAILS

The system is implemented using Python with the Ultralytics YOLOv8 framework. OpenCV is used for video processing, while Flask is used to develop the dashboard interface. The model is trained and tested on a system with GPU support for faster inference.

VI. RESULTS AND PERFORMANCE ANALYSIS

A. Evaluation Metrics

TABLE I
PERFORMANCE METRICS

Metric	Value
mAP@0.5	0.762
F1 Score	0.75
Precision	1.0
Recall	0.86

B. F1-Confidence Analysis

The F1-confidence curve indicates that the model achieves its peak performance at a confidence threshold of approximately 0.317. This represents the optimal balance between precision and recall for deployment.

C. Precision-Recall Analysis

The precision-recall curve demonstrates strong performance, particularly for waste detection. Waste objects show higher consistency in detection compared to persons, resulting in improved accuracy.

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D. Output Results

Fig. 2. Detected Person and Waste Evidence

Fig. 2 shows the captured evidence of a detected dumping event, where both the individual and the waste object are identified.

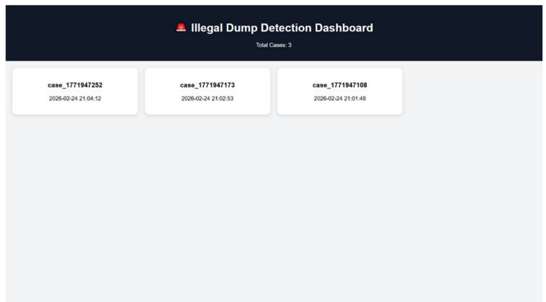

Fig. 3. Dashboard Interface

Fig. 3 illustrates the dashboard interface used to monitor and manage detected cases.

E. Observations

The model achieves high precision, indicating low false positives, while maintaining moderate recall. Waste detection is more reliable than person detection. The integration of event-based logic improves overall system accuracy.

VII. DISCUSSION

The system performs effectively in real-time scenarios and provides reliable detection results. Event-based validation significantly reduces false positives compared to frame-based detection systems. However, challenges such as low-light conditions and occlusions may affect performance.

VIII. ADVANTAGES

The proposed Green Guard system offers several advantages for real-time environmental monitoring. It enables automated detection of illegal waste dumping without requiring continuous human supervision. The integration of object detection with tracking and event-based validation improves the accuracy and reliability of the system.

The system also provides real-time evidence collection, capturing both the individual and the waste object, which can be used for enforcement and monitoring purposes. Additionally, the framework is scalable and can be deployed across multiple locations, making it suitable for smart city applications. By reducing manual inspection efforts, the system contributes to efficient waste management and improved urban cleanliness.

IX. LIMITATIONS

Despite its effectiveness, the proposed system has certain limitations. The performance of the model is sensitive to environmental conditions such as lighting and weather. In lowlight or nighttime scenarios, detection accuracy may decrease.

The system also faces challenges in crowded environments where multiple individuals are present, which may lead to incorrect association between persons and waste objects. Additionally, variations in camera angles and occlusions can affect detection performance.

Another limitation is the dependency on the quality and diversity of the training dataset. If the dataset does not cover a wide range of scenarios, the model may not generalize well to real-world conditions.

X. APPLICATIONS

The proposed Green Guard system has a wide range of applications in environmental monitoring and smart surveillance. It can be effectively deployed in smart city infrastructures to monitor public spaces and detect illegal waste dumping activities in real time. Municipal authorities can use the system to improve waste management practices and enforce regulations by collecting reliable visual evidence. The system is also applicable in industrial areas where improper disposal of waste can lead to environmental hazards. By continuously monitoring such locations, the system helps ensure compliance with environmental standards. Additionally, the solution can be used in public places such as parks, roadsides, and tourist locations to maintain cleanliness and prevent littering. Furthermore, environmental protection agencies can utilize the system for large-scale monitoring and data collection to analyze dumping patterns and take preventive measures. The integration of AI-based detection with automated evidence collection makes the system a valuable tool for sustainable urban management and environmental conservation.

XI. FUTURE SCOPE

Future work can focus on improving the robustness and scalability of the system. Enhancements such as integrating infrared or thermal cameras can improve performance in low-light conditions. The system can also be extended to support multi-class waste classification, enabling identification of different types of waste materials. Deployment on edge devices can reduce latency and enable faster real-time processing. Additionally, integrating the system with Internet of Things (IoT) infrastructure and smart city platforms can enhance monitoring capabilities. Further improvements may include incorporating advanced tracking algorithms and larger, more diverse datasets to improve detection accuracy. The integration of automated alert systems and geolocation tagging can also support efficient enforcement and decision-making.

XII. CONCLUSION

This paper presented Green Guard, an AI-powered system for detecting illegal waste dumping and collecting evidence. The integration of deep learning and event-based logic enables accurate and reliable detection. The system is scalable and suitable for real-world deployment in smart city environments.

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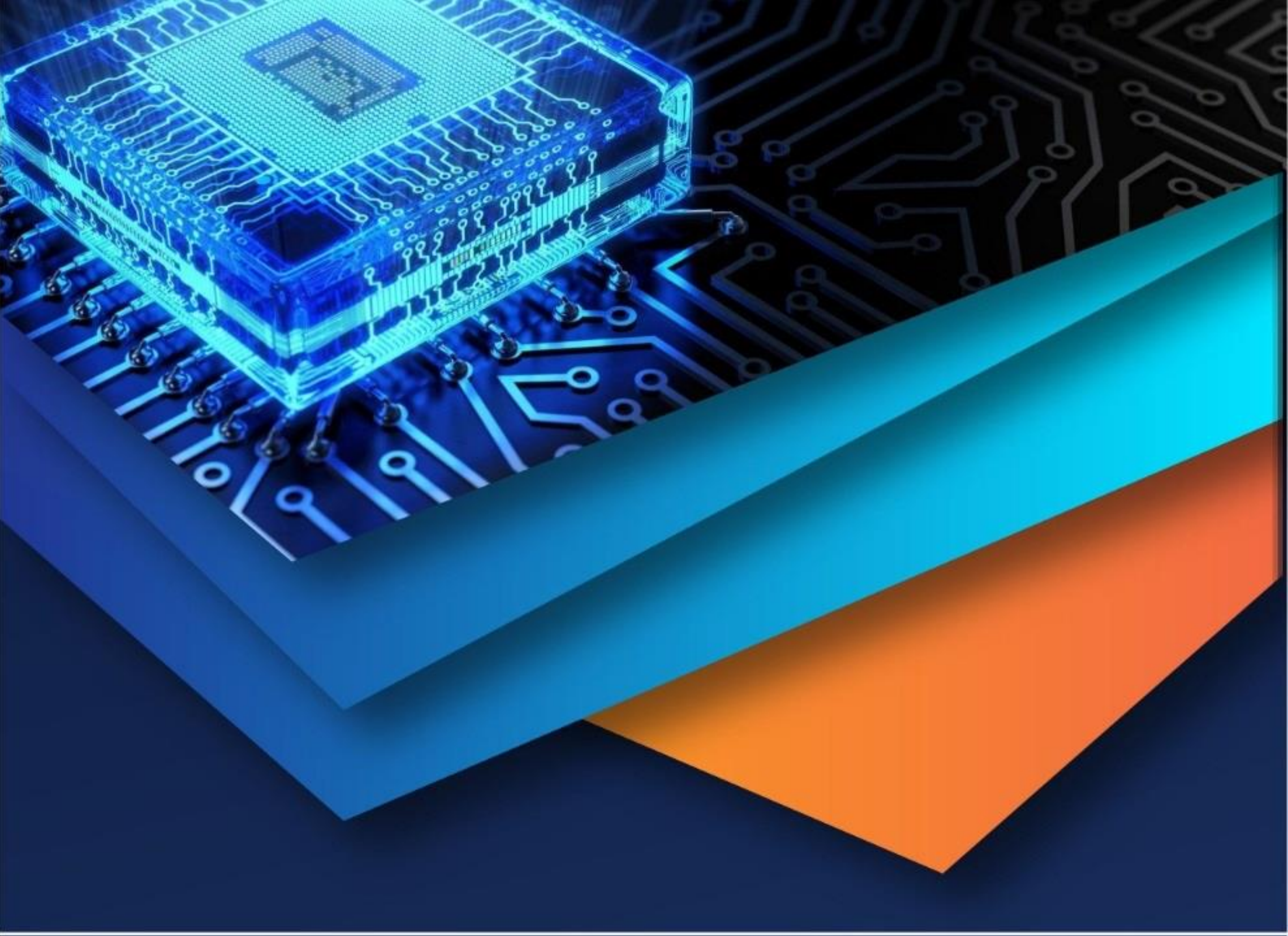

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