

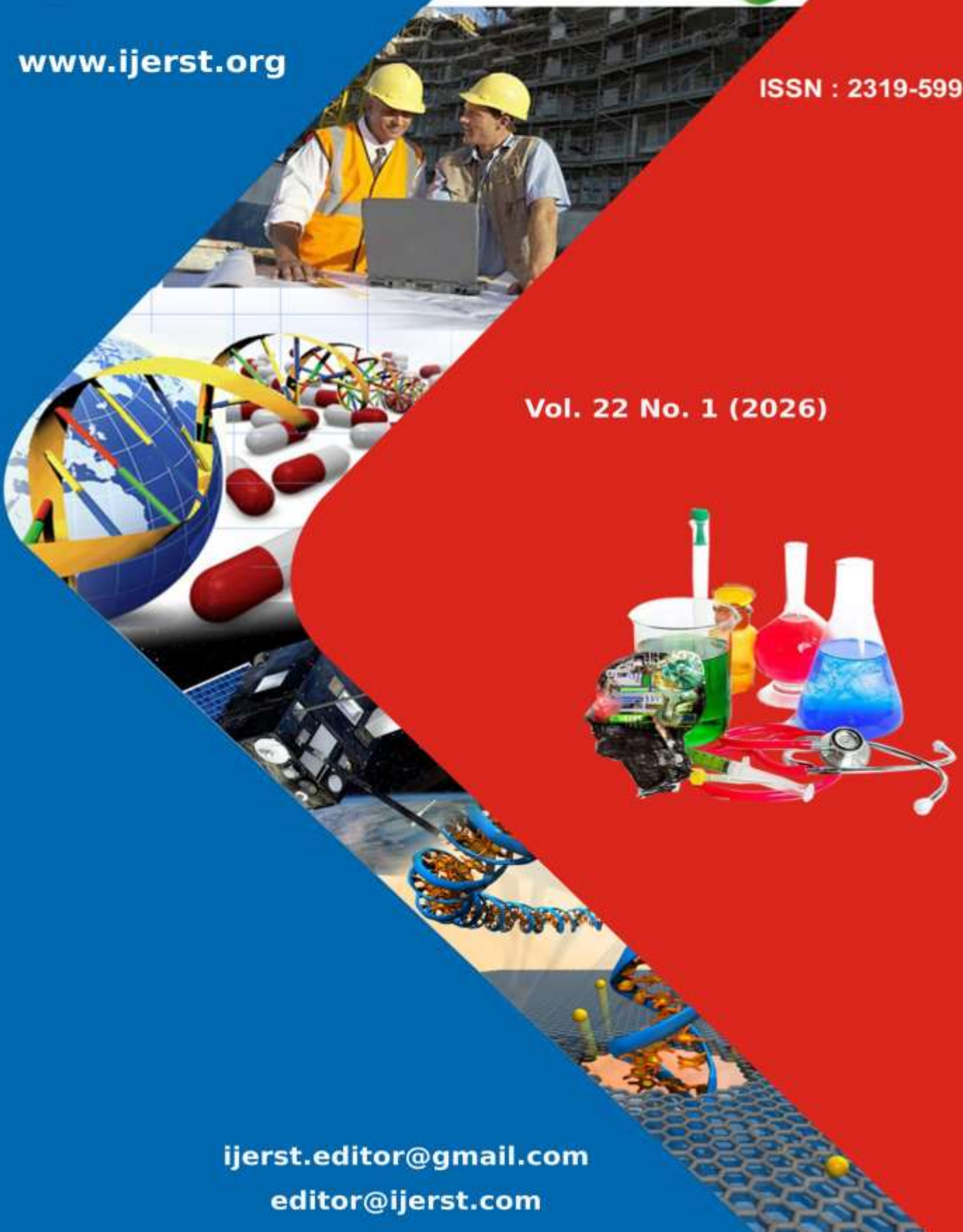


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Research Paper

AN INTELLIGENT AI-DRIVEN SURVEILLANCE FRAMEWORK FOR REAL-TIME ANOMALY DETECTION

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Abstract: The project introduces a CCTV surveillance system driven by AI that can monitor intelligently and in real time with little assistance from humans. The continual manual observation that is a major component of traditional surveillance is prone to tiredness and delayed response. A clever and proactive security solution appropriate for continuous round-the-clock monitoring is made possible by the suggested system, which combines computer vision and deep learning technologies to automatically recognize, track, and evaluate activities in video footage.

The system makes sure that people and objects are correctly detected and reliably tracked across video frames by using YOLOv8 for real-time object detection and DeepSORT for multi-object tracking. Because of this combination, the system can keep an eye on movement patterns and preserve individual identities even in environments that are busy or dynamic. CCTV footage, uploaded movies, or live streams may all be used as video input. Python and OpenCV are used for processing, and the interface is straightforward and Streamlit-based.

The project uses a rule-based anomaly detection layer built on top of detection and tracking outputs in place of a complex training-based anomaly model. Based on motion patterns and object counts, it detects suspicious circumstances such as crowd gathering, unusually rapid movement, and intrusion. Operators may quickly and easily assess events thanks to the visual cues offered by the red bounding boxes for suspicious activity and the green bounding boxes for normal activity.

Using the Brevo SMTP API, the system instantly sends out email alerts when an anomaly is found, guaranteeing prompt reporting to the relevant authorities. The framework runs on common systems without the need for specialist hardware, is entirely implemented in Python, and is portable via a virtual environment. This study shows how an intelligent, scalable, and effective surveillance solution for contemporary security applications may be produced by integrating AI, object identification, tracking, and automated warnings.

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1. INTRODUCTION

Although CCTV cameras are frequently employed for surveillance in both public and private areas, they still require constant screen monitoring by human operators. This takes a lot of time and raises the possibility of overlooking significant occasions. Advances in computer vision and artificial intelligence have made it possible for automated surveillance systems to

instantly identify suspicious activity by analyzing video feeds.

The purpose of the CCTV Anomaly Detection & Alert System is to automatically detect anomalous human activity, including running quickly or going into forbidden areas. It analyzes movements using deep learning models after processing video from webcams, uploaded files, or live broadcasts.

2. LITERATURE SURVEY

2.1 “1. You Only Look Once: Unified, Real-Time Object Detection

Authors: A. Redmon, S. Divvala, R. Girshick, and A. Farhadi

Conference: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2016

Abstract:

This paper introduces YOLO (You Only Look Once), a unified and real-time object detection system that reframes object detection as a single regression problem. Unlike traditional region-based detection methods, YOLO predicts bounding boxes and class probabilities directly from full images in one evaluation. The unified architecture enables extremely fast detection while maintaining competitive accuracy. YOLO processes images in real time and generalizes well to new domains, making it suitable for practical vision applications.

2.2 Simple Online and Realtime Tracking with a Deep Association Metric

Authors: N. Wojke, A. Bewley, and D. Paulus

Conference: 2017 IEEE International Conference on Image Processing (ICIP), 2017

Abstract:

This paper presents an enhanced version of the SORT (Simple Online and Realtime Tracking) algorithm by integrating a deep appearance descriptor for data association. The proposed method improves multi-object tracking performance by combining motion and appearance information. A deep association metric reduces identity switches and improves tracking robustness in real-time applications. The approach achieves high tracking accuracy while maintaining computational efficiency

2.3 YOLOv8 Documentation

Author/Organization: Ultralytics

Abstract:

The YOLOv8 documentation provides a comprehensive guide to the latest version of the YOLO object detection framework. It details

model architecture, training procedures, inference methods, and deployment strategies. YOLOv8 supports object detection, segmentation, classification, and tracking tasks with improved accuracy and efficiency. The documentation serves as a technical reference for developers implementing real-time computer vision systems

2.4 “Open Source Computer Vision Library (OpenCV)

Author/Organization: OpenCV

Abstract:

OpenCV is an open-source computer vision and machine learning software library designed for real-time image and video processing. It provides extensive tools for image transformation, feature detection, object detection, and video analysis. OpenCV supports multiple programming languages and platforms, making it widely used in research and industry applications. The documentation outlines implementation techniques and practical usage of vision algorithms

3. METHODOLOGY

a) Proposed Work:

The proposed system is an AI-powered CCTV Anomaly Detection System designed to automatically monitor and analyze surveillance footage in real time. It uses the YOLOv8 deep learning model to detect people accurately and employs the Deep SORT tracking algorithm to track individuals across video frames with unique IDs. The system continuously monitors suspicious activities such as entry into restricted areas and abnormal fast movements, and it sends real-time email alerts whenever such events are detected. A cooldown logic mechanism is implemented to prevent alert spamming and ensure efficient notification management. The system supports multiple input sources including webcam, uploaded video files, and live CCTV streams via RTSP/URL. It also provides live video display with bounding boxes and tracking

IDs, thereby reducing human monitoring effort and significantly improving response time.

b) System Architecture:

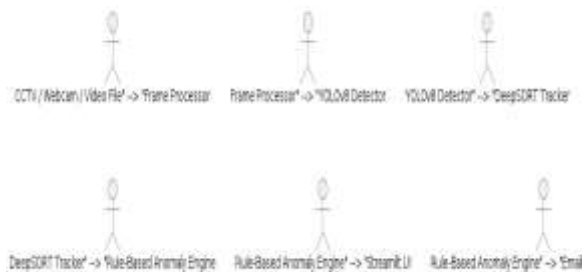


Fig 1 Proposed Architecture

The system begins by capturing video input from CCTV, webcam, or a video file, which is then passed to the Frame Processor for preprocessing. The processed frames are sent to the YOLOv8 Detector, where human detection is performed using deep learning. The detected objects are then forwarded to the Deep SORT Tracker, which assigns unique IDs and tracks individuals across frames. The tracking information is passed to the Rule-Based Anomaly Engine, where suspicious activities such as restricted area entry or abnormal fast movement are analyzed. If an anomaly is detected, the system simultaneously updates the Streamlit UI for live monitoring and triggers Email Alerts for real-time notifications. This structured pipeline ensures efficient detection, tracking, anomaly analysis, and alert generation in real time.

c) MODULES:

1. Video Input Module

- Captures video from multiple sources.
- Converts video into frames.

2. Object Detection Module

- Uses YOLOv8 deep learning model.
- Detects persons in each frame.

3. Object Tracking Module

- Uses Deep SORT.
- Assigns and tracks unique IDs for each person.

4. Restricted Area Module

- Defines polygon boundary.

- Checks whether tracked person enters the zone.

5. Speed Analysis Module

- Computes movement distance between frames.
- Detects abnormal fast motion.

6. Anomaly Detection Module

- Combines restricted area and speed conditions.
- Identifies suspicious activities.

7. Alert Module

- Sends email notifications.
- Displays on-screen alerts.
- Uses cooldown time to avoid repeated alerts.

8. User Interface Module

- Streamlit-based GUI.
- Allows source selection and monitoring control.

4. EXPERIMENTAL RESULTS

Accuracy: The capacity of a test to accurately distinguish between healthy and sick cases is a measure of its accuracy. We can determine a test's accuracy by calculating the proportion of reviewed cases with true positives and true negatives. In mathematical terms, this looks like:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$Accuracy = \frac{(TN + TP)}{T}$$

F1-Score: One way to evaluate a model's performance in machine learning is via its F1 score. It takes a model's recall and precision and mixes them. Using the whole dataset, the accuracy metric determines the frequency with which a model produced accurate predictions.

$$F1 = 2 \cdot \frac{(Recall \cdot Precision)}{(Recall + Precision)}$$

Precision: The proportion of occurrences or samples that are correctly classified out of all the ones that are classified as positive is known as precision. Consequently, the following is the formula for determining the accuracy:

$$Precision = \frac{\text{True positives}}{\text{True positives} + \text{False positives}} = \frac{TP}{(TP + FP)}$$

$$Precision = \frac{TP}{(TP + FP)}$$

Recall: The capacity of a model to detect all significant instances of a given class is measured by recall, a metric in machine learning. It sheds light on how well a model captures instances of a certain class and is calculated as the ratio of the total number of positive observations predicted to the number of actual positive observations.

$$Recall = \frac{TP}{(FN + TP)}$$

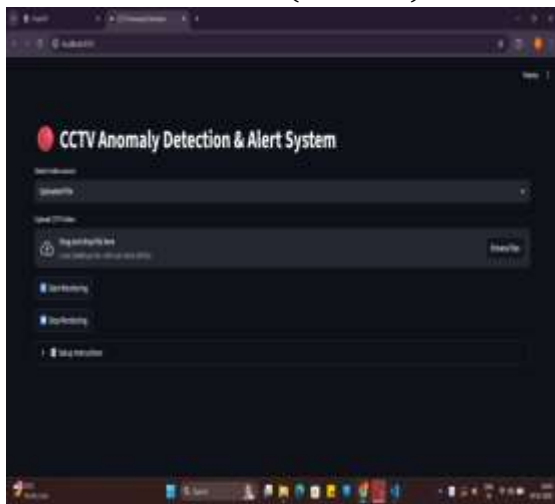


Figure 2 : Output of Proposed System(1)

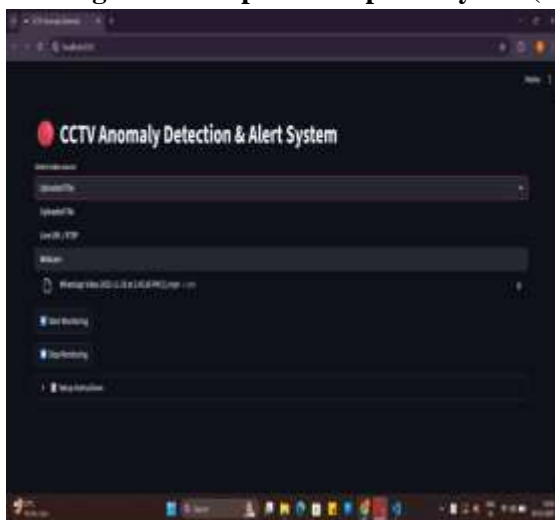


Figure 4 : Output of Proposed System(2)

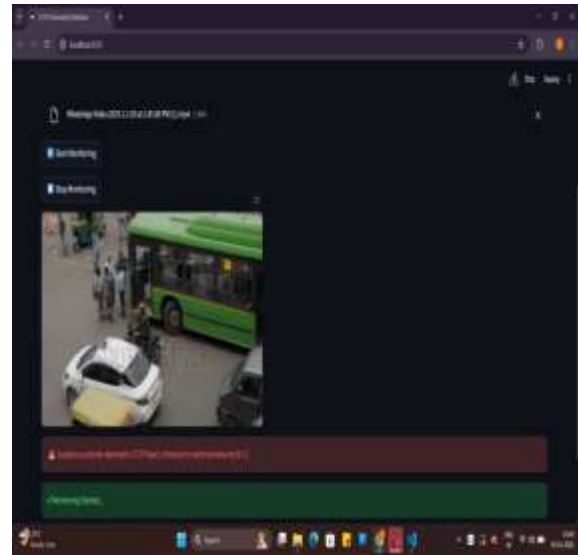


Figure 3 : Output of Proposed System(3)

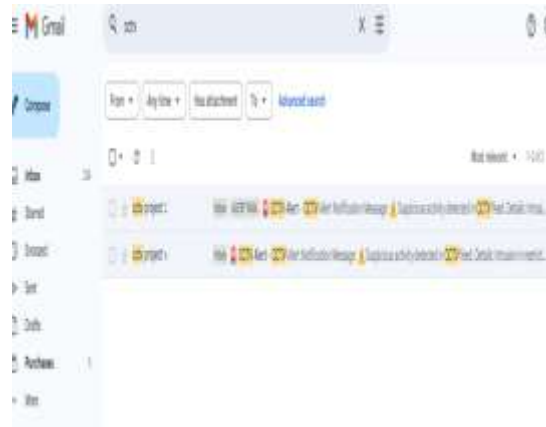


Figure 5 : Output of Proposed System(4)

5. CONCLUSION

The CCTV Anomaly Detection and Alert System was successfully designed and implemented to automate surveillance using Artificial Intelligence and Computer Vision techniques. The system effectively detects individuals using the YOLOv8 deep learning model and maintains consistent tracking IDs across frames through the Deep SORT tracking algorithm. It accurately identifies suspicious activities such as restricted area intrusions and abnormal fast movements. Upon detecting anomalies, the system sends real-time email alerts to ensure quick notification to authorities. By providing automated monitoring and live tracking, the system significantly reduces human effort and enhances security response time.

Furthermore, it operates reliably on standard hardware, demonstrating how AI can upgrade traditional CCTV systems with intelligent and efficient surveillance capabilities.

6. FUTURE SCOPE

The future enhancements of the CCTV Anomaly Detection and Alert System include integrating advanced object detection models to identify weapons such as guns and knives for improved threat detection. The system can be upgraded to trigger sound alarms along with email alerts to provide immediate on-site warnings. Additional notification methods such as SMS and mobile app alerts can be incorporated for faster communication. Anomaly detection can be further enhanced using advanced behavior analysis and AI-based pattern learning techniques to identify complex suspicious activities. Face recognition can be integrated for identity verification and access control. Cloud storage support can enable remote monitoring and secure data backup. GPU acceleration can be implemented to optimize performance for large-scale deployments. Furthermore, the system can be extended to support crowd density analysis and emergency management applications, making it more robust and scalable for smart surveillance environments.

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