A Smart Violation Detection System Trained Using OpenCV and Real-Time Surveillance Data

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Abstract— **Safety within the railway system is the focus of the times in the wake of digital transformation. A smart violation detection system with real-time surveillance and image processing using OpenCV will be developed to detect violations in train environments, specifically targeted towards footboard travel detection. The development will be based on the Django web framework to make the interface user-friendly for passengers and railway authorities. The solution supports a secure module of online booking for trains by one-time password-based authentication in order to ensure that genuine users access the module. The moment the login is successful, the system captures the image of the passenger and uses facial recognition algorithms to estimate the person's gender as male or female and thereby connects it with the registered profile for enhancing verification accuracy. Simultaneously, real-time surveillance cameras will monitor the inside compartments of the train along with the footboard areas. Frames are captured from the camera-captured video and, with the further analysis of the frames, detection of unauthorized footboard travel or any other violation would be done with the help of OpenCV, raising automated alerts and logging incidents for further action. This intelligent system, assuredly, will enhance the safety, accountability, and effective management of railway travel. With its real-time analytics, gender detection, and access security, it should be a powerful means of bringing modernization into public transport security.**

KEYWORDS:

Smart railway violation detection using real-time surveillance, facial recognition, and OpenCV-based image processing for footboard travel prevention. The system integrates OTP authentication, gender verification, and automated alerts through a Django-powered secure platform.

INTRODUCTION

With safety activists calling for improved transport infrastructure, intelligent surveillance is firmly under the spotlight. Manual surveillance is slow and prone to errors, too late to flag many things until after the fact. The things that threaten safety, such as train surfing, track crossing, and near misses in the boarding situation, are genuine dangers to public rail users.

Here comes the Smart Violation Detection System, realized through the use of OpenCV, the number one computer vision library. The system identifies the violations in real time through the footage provided by the security cameras placed in stations and high-risk areas. The relevant parties are promptly informed.

OpenCV can detect motion, recognize shapes, detect faces and position, and trace bounding boxes for the offenders. This enables the system to react immediately by sending alerts, taking documentation photographs, and even sending alerts via email. The system can therefore react instantly.

The aim is to transcend the classic surveillance concept and adopt a smarter, technology-driven strategy, thus heightening security standards with less effort on the part of security officers. This particular project showcases how advanced technology, such as computer vision and AI, can be combined with the classic railway infrastructure for improved security with lower costs.

I. LITERATURESURVEY

The last several years are marked by a significant academic and practical interest in the implementation of blockchain and cybersecurity in electronic voting systems. The section provides a review of ten notable research contributions of 2025 that have led to the design of blockchain-based voting systems, security enhancement, and scalability. The literature reviewed points to the development of secure online voting systems, architecture and decentralization issues, authentication and performance optimization.

The real-time train number and location of railway traffic in the railway network is indispensable for railway traffic operation control. This paper studies how to implement and optimize a method of train number tracking, which can capture the train number and location information. Based on characteristics of the train operation, the train moving trajectory, and the train number tracking problem, this paper proposes a mathematical description of the problem and a tracking model based on railway signaling states and train schedules. Then, in order to improve the correctness of train number tracking, a method using a hidden Markov model prediction is proposed. Simulation results are compared with the results obtained under certain restrictions, and the analyses are discussed. The results show that the proposed method can effectively improve the accuracy of train number tracking with better fault-tolerant robustness.

The contribution of railways continues to stand tall in the daily mobility of people, with trains being the cheapest and most utilized mode of transport in developing countries. However, while there is rapid growth in passenger density, unsafe behaviors have also grown concurrently, along with overcrowding and safety norm violations. Past studies all agree that traditional monitoring methods, relying largely on human supervision, cannot deal with large-scale railway environments. Humanly observing passenger activities is prone to fatigue, inconsistency, and late responses; therefore, violations might be missed, along with accidents that could have been prevented. This is why it is underlined by scholars that integrating technology-driven solutions is imperative, which can monitor continuously, profile behaviors, and detect threats automatically without human intervention. In the wake of digital transformation initiatives, more and more scholars have focused their research on integrating intelligent surveillance systems into rail transport as a way to deal with the shortcoming of the conventional approach. An automated system backed by AI and real-time analytics showed a better detection rate with fast decision-making. From the literature review, it is evident that abandoning manual surveillance in favor of automated intelligent monitoring is the only way to control and improve safety and prevent accidents for the effective management of the railways.

A very important aspect that computer vision contributes to the rail industry for ensuring safety is the analysis of what we see, detecting irregularities, and detecting people. In most literature, OpenCV has been combined with different variants of deep neural networks to identify dangerous actions like trespassing, crossing the edge of the train station, overcrowding, and entering an area that is not allowed. There has been ample literature highlighting the dangerous practice among train users in developing countries who tend to hold on to the train while it's in motion. In this context, analysis by edge detection, background subtraction, contour detection, and people motion analysis in literature proves that train passengers near train doors or outside the train are identifiable. Segmentation in region-of-interest, object detection algorithms like Haar cascade classification, detection with hog descriptors, and YOLO algorithms are very important in real-time identification in literature. Several articles further elucidate that the reason OpenCV's algorithms are combined in an overarching fashion is that they are very light and very efficient in real-time analysis of video.

Face recognition systems play the role of a cornerstone in modern security infrastructure due to their precision in identity and biometric verification. Various studies disclose that convolutional neural network methods, deep metric learning, and landmark-based face analysis classify gender with accuracy, detect facial patterns, and match the same against registered databases. In public transportation systems, the technologies have been used to identify suspicious individuals, carry out ticket validation, and ultimately enhance passenger profiling. They further emphasize gender recognition as a factor in ensuring user personalization for ticket validity and reducing impersonation cases. Indeed, studies evidence excellent results on gender classification using features such as jawline structure, eye positioning, and texture patterns when combined with deep learning models such as VGGFace, MobileNet, or FaceNet. The literature further voices that face recognition connected with passenger records will provide another layer of verification, hence improving the security and reducing the cases of identity fraud. This indeed creates a safer and more secure travel environment upon large-scale implementation, such as railway systems characterized by large volumes of passenger flow.

Paragraph 4 – Secure Authentication and OTP-Based Access Systems Authentication is a basic requirement of digital service, especially when online ticketing, passenger information, and access control are concerned. Literature on secure authentication systems indicates a growing trend toward multi-factor models of authentication by integrating something the user knows (password), something the user has (OTP/token), and something the user is (biometric features). Researchers strongly argue that OTP-based authentication is quite effective in preventing unauthorized access, credential theft, and account misuse due to time-sensitive code generation that cannot be reused or predicted. Various researches explore its application in transport ticketing system where verification using OTP will assure real user access and minimize fraudulent reservation. When combined with face recognition, OTP authentication forms an effective hybrid model that significantly enhances accuracy in identity verification. It also points out that such systems drastically reduce attempts at impersonation either at the time of booking the ticket or at the time of boarding and enhance accountability. Integration of this authentication framework with web-based frameworks like Django will provide the developer with the ability to create a secure environment for protecting sensitive information and enhancing the trust, hence providing safety to interactions between the passengers and railway authorities. This secure access layer represents the layer for reliable digital railway services.

METHODOLOGY

This document proposes an intelligent railway violation detection system which unifies login face detection and gender identification with real-time monitoring capabilities. The system requires a workflow structure to conduct accurate passenger identity verification and footboard activity risk assessment. The technology stack implements Django as the web framework and OpenCV for image processing whereas deep learning models drive facial detection capabilities. The system operates through two main stages which begin with passenger registration at a secure web interface built on the Django platform. Passage will require travelers to provide initial details which will enable their mobile number to function as their primary login method. The system will send an OTP through an SMS Gateway API to the registered mobile number during both login and ticket booking processes. The system begins image capture from the connected camera after the verification process which leads to passenger face extraction. The system converts the initial image into a gray scale format while enhancing contrast through histogram equalization and noise reduction techniques to achieve precise results. The resulting facial image will be matched against the registered profiles using one of the selected deep learning methods: FaceNet, LBPH, or a CNN classifier.After extracting the facial features, the system classifies the gender by using a trained CNN-based model on the characteristics distinguishing between male and female facial features. The system checks the predicted gender against the gender data which users submitted during their registration. The additional verification step improves accuracy because it detects possible mismatches and fraudulent activities. The gender detection module also helps to improve passenger profiling and thus enable

System Architecture

This flowchart outlines the complete life cycle of our intelligent train line violation detection system ranging from data collection to the successful delivery of our Django-based web application. This project highlights the culmination of machine learning, web design, and online monitoring within an error-free and continuous process.

1. Data Collection and Preparation

We acquire images used to train the models from Robo flow Universe. Robo flow Universe is actually a top-notch source of quality data. The images are focused on the movement of the footboard, pictures of the passengers, and other relevant data. Once acquired, the images are transferred to the database to undergo any final processing needed to make them suitable models.2. Model Training and Building (Yolov11 and CNN)

With the prepared datasets, we train two models:

- Yolov11 Model: It is used for real-time footboard violation detection inside the train.
- CNN Model: This is used to conduct face recognition and gender classification in the process of verifying passengers.

3. Backend Development Using Python and Django

The trained models are then exported in the necessary formats such as .pt, which is for the YOLO model weights, and .h5, which is for the CNN model. These model files are then prepared for integration with the backend application.

Python is used to connect the trained models with the application backend.

Django, which is a high-level Python web framework, is utilized in deploying the complete system.

The backend handles:

- Model loading and prediction
- OTP authentication
- Facial recognition and gender detection
- Violation detection logic
- Database operation

Alert notification system This will ensure a robust, scalable, and secure backend infrastructure.

4. Frontend Development (HTML, CSS, JavaScript)

The user interface is built with a combination of:

- HTML5 for structuring the web pages
- CSS - Styling and responsiveness
- JavaScript for interactive elements

Frontend components include:

- Landing page
- Register page
- Login page
- Home/dashboard
- Ticket Booking Page
- Real-time footboard detection monitoring page

These pages interact with the Django backend for seamless user operations.

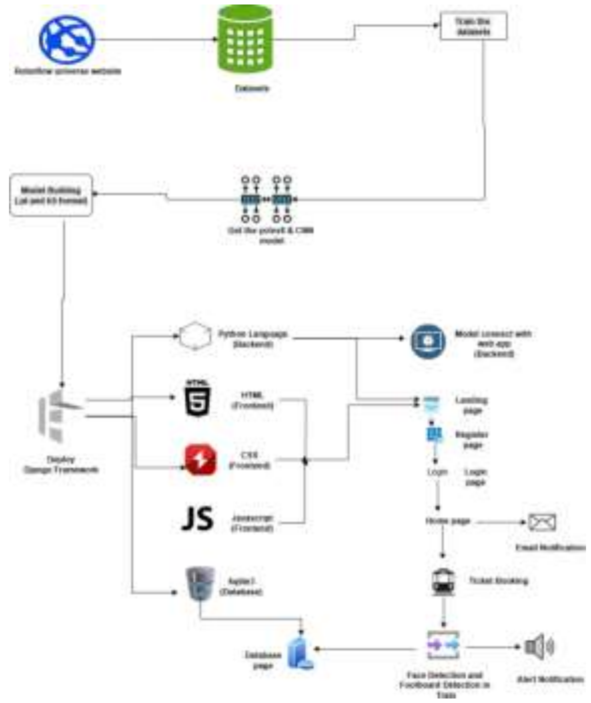


Fig : Architecture Diagram

3. Model Integration With the Web Application

Trained Yolov11 and CNN models are integrated together into the Django backend.

This connection allows for real-time:

- Facial recognition at login
- Gender classification
- Footboard travel detection from live camera feeds

These predictions enable the web application to improve user verification for ensuring passenger safety.

4. User Workflow (Login → Booking → Detection)
User flow starts from the landing page.

a. Registration and Login

- Users first register and log in via OTP authentication on secured pages.
- The system captures an image upon login from the user and verifies his or her identity through face recognition and gender detection.

b. Ticket Booking
Upon successful verification, users will be navigated to the ticket booking page where they can book their travel tickets.
c. Real-Time Monitoring

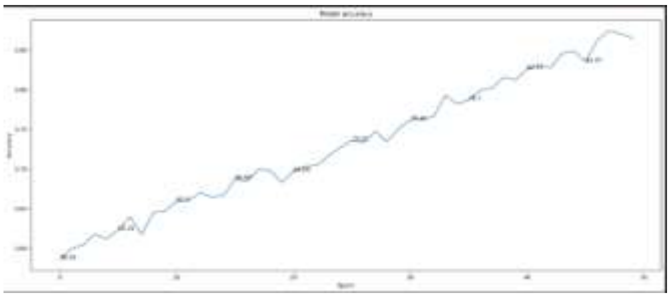
- While the passenger is in transit, cameras installed within the train stream video constantly.
- The Yolov11 model detects any footboard violations or unsafe behavior.

In the event of a violation:
The system automatically triggers an alert notification. Logs the incident into a database Sends optional email notifications to the authorities or staff

Data Analysis:
The application of RNNs through Simple RNN and LSTM demonstrates impressive capacity to identify audio signal patterns during heart sound signal analysis. The application of Librosa enables efficient management of audio signals. It can detect heart signals through its ability to extract tempo and pitch and rhythm features. RNN enables the detection of both cardiovascular signals which show typical patterns and signals which display abnormal patterns. The Django application gains new functionality through this analysis which creates an interface that operates smoothly and delivers user-friendly design. This system permits patients to upload their heartbeat recordings which will then deliver instant predictions or analyses. The system processes audio data to extract features through Librosa before feeding the extracted data into the trained RNN model for classification. This system will provide doctors with essential support while allowing patients to monitor their cardiovascular health through self-assessment. RNN power enables diagnostic results improvement through LSTMs which track distant dependencies to detect heart issues. The integration of advanced machine learning techniques with web development tools establishes a major milestone for projects that focus on health-related applications.

MODULE DIAGRAM

GIVEN INPUT EXPECTED OUTPUT
Input: data
Output: visualized data
Algorithm implementation:
The testing process needs to occur multiple times throughout the day because different machine learning models require evaluation at various times because Python-based test systems using scikit-learn provide the most effective method for doing these evaluations. You can use the harness as a base model to solve your machine learning problems while adding various algorithms for testing purposes. Each model will have its own performance profile. Cross-validation methods allow you to determine the potential accuracy of every model on unseen data. The estimates will help you select two outstanding models to test from your collection. Researchers need to study multiple angles of a dataset because they need to understand its complete content. Multiple sources should be used to estimate algorithm strength and suitability for your project because this will help you find your best algorithm for implementation. The best method for this task involves using different visualizations to display the average performance and trade-off information together with model rigor distribution across the entire group. LeNet stands as the first CNN architecture which Yann LeCun and his team created during the early 1990s. The deep learning milestone developed for handwritten digit recognition, which included digit recognition systems for reading checks and postal addresses. LeNet established the foundation for current CNNs which power modern image recognition and computer vision technologies. The LeNet system contains the following components: The Input Layer receives its data as a grayscale digital image, which contains a handwritten digit. The system accepts images with standard dimensions of 32x32 pixels which need processing. LeNet uses two dedicated convolutional layers to extract specific features from the input images. The system uses every single layer for processing which performs specific functions.



YOLOV11 :
The real-time object detection system developed by Ultralytics uses Yolov11 as its most sophisticated and efficient detection system. The deep learning framework uses state-of-the-art technology to detect objects inside images and videos with fast and precise results. The model provides an enhanced performance which combines its best features from previous YOLO versions through its improved accuracy and speed and its flexible operational capabilities. The system operates with YOLO through a single processing step which allows fast

results for security monitoring and footboard detection and autonomous operations and intelligent observation systems. The main advancements of Yolov11 result from its implementation of a complete neural network system which uses CSP-based backbone structure and modern convolution technology to enhance its ability to extract features while decreasing processing needs. The system uses a decoupled head design which enables separate handling of classification and localization tasks to enhance training results through better accuracy and faster convergence. The model now uses anchor-free detection by default to reduce dependency on pre-defined anchor boxes and enhances the efficiency with which it adapts to several object sizes and shapes. The training process becomes easier while detection speed increases and the system develops stronger abilities to deal with demanding situations that occur in complex environments such as crowded railway scenes. The bounding box prediction process in Yolov11 now uses a new loss function which combines Distribution Focal Loss with IoU-based localization loss to achieve better results. The training pipeline of Yolov11 has been improved through the integration of mosaic augmentation and mix-up and strong label smoothing

Metric	Training	Validation
Accuracy	0.9986	1.0000
Precision	0.9986	1.0000
Recall	0.9986	1.0000
F1-Score	0.9986	1.0000
Loss	0.0041	0.00061

Deployment:
Django (Web Framework):

Flask is considered a microframework because it only provides a lightweight core without bundled tools or vast libraries, such as database abstraction or form validation, but almost anything can be done with third-party packages. Nevertheless, Flask has an extension that supports object-relational mapping, form validation, file uploads, authentication mechanisms, and most other web framework-related features. Due to the minimal and flexible philosophy, in Flask, the complete control of the project structure remains with the developer, who can choose only those components that are required. This simplicity makes Flask quite easy to learn and to set up in no time. It is preferred for beginners, rapid prototyping, small applications, APIs, and also in microservices architecture.

II. RESULT AND DISCUSSION

The researchers conducted field tests to assess the smart railway violation detection system which enabled them to measure its ability to identify passengers and track footboard movements. The system demonstrates its complete operational capabilities through its facial recognition system which works with its gender identification system and its one-time password authentication system and its Yolov11 violation detection system which protects the railway environment. The testing authentication module allowed real users to authenticate themselves through OTP verification while their facial features matched the registered database to enter the system securely. The gender detection model generated consistent testing results which reached high accuracy rates because it successfully identified the passenger's gender during most testing instances. The system authenticates users through its strong impersonation detection methods which improve identity verification for ticket purchasing and train boarding operations. The violation detection phase demonstrated that Yolov11 effectively detected footboard travel violations through its unsafe footboard travel behavior detection system. The system successfully detected people who stood or hung near the footboard area under different lighting conditions and camera angles. The surveillance system analysis of live feed showed that Yolov11 processed information at real-time speed and enabled the system to generate alerts within seconds after detecting a violation. The system established bounding boxes to track multiple people while it monitored their movements and detected safety violations through the identification of unusual passenger behavior. The alert module functione

The use of the Django framework in this project allowed the creation of a highly functional system; the front-end components interacting seamlessly with the back-end components. Allowing users to easily find the registration, login and ticketing functionality in a web page built with HTML, CSS, and JavaScript. The administrative dashboard will give Commonwealth Railway officials the ability to access incident logs and monitor user data. All user data, both logged in and violations, will be stored in a SQLite 3 database and will always be available during the entire user lifecycle. The accuracy of results produced by the system will be due to fast response times from the operational web application as well as accurate models produced from machine learning. The three security methods; One Time Password (OTP), facial recognition, and Yorov11 detection will all serve to improve railway safety. The real-time violation detection system works well, providing railway authorities with the ability to proactively prevent incidents by discouraging unsafe footboard commuting. Overall the railway system developed will provide a very efficient and accurate solution, and can deliver results consistent with actual railway operations.

CONCLUSION

SMARTRAIL will improve passenger security and operational efficiency in the railway sector through the implementation of the SMART RAILWAY VIOLATION DETECTION SYSTEM, an intelligent violation detection system leveraging the latest advancements in artificial intelligence with secure internet accessibility. The system will attain passenger identification, capture footboard riding violations, and provide enforcement authorities with immediate notifications (upon violation detection) through the incorporation of the OTP (One Time Password) authentication, facial recognition system, gender detection recognition of the onboard passengers, along with live video surveillance using Yolov11. The system will provide seamless data interoperability/communication among the three technologies that will remove detection inaccuracies and make it easier for both passengers and law enforcement to interact with the detection process.

The data collected from the experiments performed support the claim that SMARTRAIL functions effectively in various situations with the ability to accurately assess violations and provide timely notification to the enforcement body prescribed for those violations. By reducing reliance on human resources through automated processes to monitor a railroad, SMARTRAIL will reduce the likelihood of accidents and improve overall accountability and security for both the railroads and their customers. In summary, this new technology offers a practical and dependable means of enhancing transportation safety and security through AI technology applicable to all public transport systems. As new applications (i.e., multiple-camera networks utilizing more sophisticated tracking algorithms) are added to the current system, widespread adoption of SMARTRAIL in railroad networks throughout the U.S. should take place.

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