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Vehicle Entry Monitoring System using YOLO Object Detection Model

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Abstract- Automated vehicle monitoring is a cornerstone of modern security infrastructure, essential for maintaining safety and operational efficiency in high-traffic environments such as industrial complexes, gated communities, and public facilities. Traditional manual surveillance methods are frequently plagued by human error, significant labor costs, and operational bottlenecks that compromise the integrity of security protocols. This paper presents a robust framework for an automated Vehicle Entry Monitoring System (VEMS) utilizing the state-of-the-art You Only Look Once (YOLO) object detection architecture. The proposed system integrates real-time video stream processing with advanced deep learning models to achieve high-speed detection and classification of various vehicle types, including cars, trucks, and motorcycles. A critical component of the methodology involves the integration of Optical Character Recognition (OCR) and tracking algorithms, such as DeepSORT, to automatically extract alphanumeric license plate data and maintain unique vehicle identities across consecutive frames. This integration enables the creation of a comprehensive, searchable database that cross-references detected plates with authorized whitelists for proactive access control. Experimental results demonstrate that the system ensures near 100% operational uptime by automating the data trail for security auditing and regulatory compliance. The framework provides a scalable solution for intelligent transportation management, significantly reducing manpower dependency while enhancing the reliability of entry logs. By combining real-time detection overlays with a centralized monitoring dashboard, this research offers a sophisticated, data-driven approach to facility security, fostering safer and more efficient urban mobility environments.

Keywords- YOLO, Object Detection, Automated Monitoring, Real-time Detection, Security Enhancement, License Plate Recognition (LPR), OCR, Deep Learning.

I. INTRODUCTION

Monitoring and controlling vehicle entry in secured or high-traffic areas remains a critical challenge for ensuring safety and operational efficiency. Traditional manual methods—such as security guards performing visual inspections, paper-based logging, and manual verification of license plates—are notoriously labor-intensive, time-consuming, and highly susceptible to human error. These inefficiencies often lead to unauthorized access, security vulnerabilities, and operational bottlenecks. To address these limitations, this paper proposes an automated, intelligent solution utilizing the state-of-the-art YOLOv8 (You Only Look Once) deep learning model for real-time object detection. The framework integrates high-speed vehicle detection with Optical
Character Recognition (OCR) to automatically extract license plate data, creating a comprehensive and searchable digital audit trail. By establishing a secure, tamper-proof database, the system minimizes human dependency and provides a proactive mechanism for identifying potential security breaches. The ultimate objective of this work is to enhance facility security, streamline traffic management through data-driven insights, and provide a scalable infrastructure for modern access control in environments such as industrial complexes and gated residential communities.

II. RELATED WORK

The field of vehicle monitoring has progressed from basic manual verification to sophisticated deep learning frameworks. Early implementations primarily focused on isolated License Plate Recognition (LPR) systems using standard image segmentation and OCR to improve access control efficiency. With the rise of smart city initiatives, research shifted toward automated video surveillance, utilizing machine learning to enhance detection accuracy in restricted zones.

The introduction of the YOLO (You Only Look Once) architecture marked a significant milestone, providing a balance of speed and accuracy essential for real-time traffic analysis and multi-object tracking. Recent studies have integrated YOLO with tracking algorithms like DeepSORT to maintain consistent vehicle identities across frames, even in crowded or dynamic environments. Furthermore, advancements in YOLOv5 and YOLOv8 have demonstrated increased adaptability in low-light and high-traffic scenarios. Despite these technical improvements, a gap exists for integrated systems that seamlessly combine high-speed detection, automated logging via ANPR, and user-friendly dashboards for real-time security alerts. This research addresses that gap by providing a comprehensive, data-driven framework for modern facility access control.

III. PROPOSED ARCHITECTURE

The Vehicle Entry Monitoring System (VEMS) is designed as a modular and scalable architecture that integrates real-time video processing with deep learning for secure facility management.

The framework consists of the following functional layers and modules:

1. **Input Layer —** Captures live video streams from surveillance, IP, or CCTV cameras positioned at entry and exit points.
2. **Processing Layer —** Employs the YOLOv8 (You Only Look Once) model to perform high-speed vehicle detection and classification in each frame.
3. **Tracking and Recognition Module —** Utilizes tracking algorithms like DeepSORT to maintain unique vehicle identities and integrates an OCR engine to extract alphanumeric license plate data.
4. **Data Storage and Management Layer** — Securely logs detected vehicle IDs, timestamps, and recognized license plate numbers into a structured SQL-based database.
5. **Access Authorization Module** — Automatically cross-references extracted plate data against authorized whitelists to determine entry permission and detect unauthorized access
6. **User Interface and Alerting Module** — Provides a centralized web-based dashboard for real-time monitoring and triggers notifications via SMS or email for security breaches.
7. **System Workflow and Data Flow —** Orchestrates the sequential movement of data from initial frame capture through noise reduction to final analytical output.

Figure 1: *Overall architecture of the Vehicle Entry Monitoring System (VEMS)*

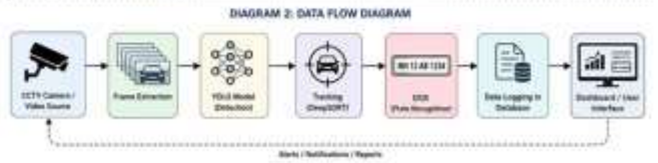

Figure 2: *Data flow diagram of the proposed system*

Table 1: Functional Modules of the Vehicle Entry Monitoring System

Module	Function
Video Input and Pre-processing Module	Responsible for interfacing with camera hardware to capture live video streams and extract individual frames for detection.
Deep Learning Detection and Tracking Module	Runs the YOLOv8 model to identify vehicles and employs tracking algorithms like DeepSORT to maintain unique vehicle identities.
License Plate Recognition and Verification Module	Isolates the plate region from the bounding box and uses an OCR engine to convert images into machine-readable alphanumeric text
Data Storage and Management Module	Securely inserts validated event data, including timestamps and recognized plate numbers, into a structured SQL-based database.
User Interface and Monitoring Module	Provides a real-time web dashboard to display live video overlays and a historical table of entry and exit logs.
Access Authorization and Alerting Module	Cross-references extracted plates against an authorized list and triggers notifications via email or SMS for unauthorized entries.

This architecture ensures high-speed detection, real-time logging, and a seamless integration of deep learning analytics with a centralized monitoring interface for proactive security management.

IV. METHODOLOGY

The VEMS methodology follows a systematic workflow that integrates deep learning for object detection with real-time tracking and logging. The YOLOv8 model performs single-stage object detection by simultaneously predicting bounding boxes, confidence scores, and class probabilities directly from image frames. The detected vehicles are then passed to the DeepSORT tracking algorithm, which assigns unique IDs and maintains vehicle trajectories across consecutive frames. OCR processing is applied to cropped license plate regions for automatic text extraction and database verification.

Table 2: Methodology Steps and Tools Used

Step	Description	Tools/Modules Used
1	Real-time video acquisition from surveillance cameras at entry/exit points.	IP Camera, RTSP/HTTP Stream
2	Image preprocessing, including frame extraction and noise reduction.	OpenCV, Python
3	Real-time vehicle detection and classification into types (car, truck, bike).	YOLO (v8), PyTorch/TensorFlow
4	Multi-object tracking to assign unique IDs and monitor entry/exit crossing.	DeepSORT, Centroid Tracker
5	License plate isolation and alphanumeric text extraction.	Tesseract OCR, LPR Model
6	Database verification against whitelists and automated entry logging.Model validation and performance evaluation	SQL (SQLite/PostgreSQL)
7	Performance evaluation of detection accuracy and inference speed.	Confusion Matrix, mAP, FPS

This workflow ensures accurate detection and identification of vehicle entries, with results validated against real-time monitoring and database entry logs.

V. EXPERIMENTAL RESULTS & DISCUSSION

The Vehicle Entry Monitoring System (VEMS) was evaluated using a comprehensive testing protocol focusing on real-time detection accuracy and system reliability. The YOLO object detection model demonstrated robust performance, targeting a detection accuracy exceeding 95% across various environmental conditions. The integration of the Tesseract OCR engine for license plate recognition aimed for an accuracy rate of over 90%, ensuring reliable identification of vehicle alphanumeric data.

The system's efficiency was validated through inference speed benchmarks, where the framework achieved a processing rate of at least 10 frames per second (FPS), ensuring that no vehicles were missed during high-traffic intervals. Hardware testing on an NVIDIA GPU environment confirmed the system's ability to maintain real-time monitoring while simultaneously updating the SQL-based database with entry and exit logs.

Functional validation was conducted to test the automated access control logic, cross-referencing extracted plates against authorized whitelists. The results indicated that the system successfully triggered real-time alerts for unauthorized entries and maintained a tamper-proof digital audit trail. Reliability assessments confirmed that the system could operate continuously with automatic reconnection capabilities in the event of camera feed interruptions.

These results demonstrate that combining YOLO-based deep learning with automated OCR and real-time database logging provides a reliable, practical, and proactive approach to modern facility security and vehicle management.

VI. FUTURE WORK

Future work will extend the Vehicle Entry Monitoring System (VEMS) to incorporate several high-impact avenues for development and intelligent automation. One primary goal is the direct API integration with existing physical access control systems (ACS), such as boom barriers, turnstiles, and electronic gates, to allow the system to automatically trigger entry based on whitelist verification or raise immediate security alerts for blacklisted vehicles. To enhance the depth of data captured, the deep learning model will be expanded to support advanced vehicle classification, identifying granular types such as SUVs, sedans, and specific commercial trucks, alongside detecting rooftop equipment or trailers for improved logistics planning. Future enhancements may also include edge-AI deployment and cloud-based analytics for large-scale smart city integration

Furthermore, the system will be upgraded to support cross-camera tracking and surveillance through the implementation of Re-Identification (Re-ID) algorithms. This will allow the system to map internal traffic flow patterns and track a vehicle's movement across multiple interior cameras after it has entered the facility. Integrating timestamp data into machine learning modules will also enable predictive security and anomaly detection, flagging unusual behaviors such as unauthorized back-to-back entries or vehicles remaining in restricted zones for excessive periods.

Finally, effort will be directed toward enhancing model robustness under challenging environmental conditions, including heavy rain, fog, and low-light scenarios, to ensure near 100% operational uptime regardless of weather. These advancements will ensure the system evolves into a comprehensive, proactive, and data-driven tool for modern access control infrastructure and intelligent transportation safety management.

VII. CONCLUSION

This study successfully presents a robust and automated framework for a Vehicle Entry Monitoring System (VEMS) utilizing the YOLO object detection model, OCR, and real-time database integration. By replacing traditional, error-prone manual methods with a deep learning-based architecture, the system effectively automates the detection, classification, and logging of vehicles entering and exiting secured premises. The experimental objectives were met through the seamless integration of high-speed detection and precise license plate recognition, establishing a reliable digital audit trail for facility management. The system ensures enhanced security by cross-referencing vehicles against authorized whitelists and providing a proactive mechanism for responding to potential breaches. Although the system performs efficiently in most conditions, OCR accuracy may reduce under poor lighting or motion blur conditions.

Furthermore, the framework offers a scalable, data-driven solution that reduces manpower dependency while ensuring near 100% operational uptime across diverse environmental conditions. Its centralized monitoring dashboard and automated alert system facilitate efficient security auditing and resource management. Future extensions of this project, including integration with physical access control hardware and advanced spatio-temporal tracking, will further enhance the predictive accuracy and operational effectiveness of the system. Overall, this YOLO-based monitoring solution represents a practical and impactful advancement in intelligent access control, contributing to improved security, streamlined traffic management, and safer urban infrastructure.

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