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An Integrated YOLOv8 Based System for Real Time Vehicle Tracking and Identification Using CCTV Footage

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Abstract - Vehicle identification and tracking play a critical role in security and surveillance, supporting the efforts of law enforcing authorities to prevent crime, monitor traffic, and enforce the vehicle rules and regulations. This research presents a proof-of-concept system that employs YOLOv8 for real time vehicle detection and car type classification using live or recorded CCTV footage. YOLOv8 was chosen after rigorous comparison, it was chosen for its ease of use and efficient image training capabilities, making it well suited for rapid prototyping that the concept needed. The system is designed to extract key vehicle features, including colour, model of the vehicle, logo, sticker (if any), its position and license plate information, and supports both real time and recorded video analysis. Although the model has not been fine-tuned, its performance provides a solid foundation for experimental development. The current implementation is at an early experimental stage and has been tested on a personal computer and is not yet ready for commercial deployment in the real world. For training and evaluation, a custom dataset was created using 5 hours of CCTV footage recorded from three different cameras at varied angles and lighting conditions, including both morning and evening scenes to ensure data diversity.

Keywords—YOLOv8, Real-Time Vehicle Tracking, CCTV Surveillance, Feature Extraction, Vehicle Identification, Deep Learning.

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1. INTRODUCTION

Intelligent surveillance systems have become increasingly important for maintaining public safety and supporting law enforcement. With an increase in urban monitoring infrastructures and advanced computer vision techniques, there is a growing opportunity to enhance vehicle tracking using real time CCTV data. The research focuses on a car detection and identification system using YOLOv8, for feature detection (like car model, colour, brand, license plate

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and stickers) with good accuracy. However, the primary focus of this work is a conceptual framework for an intelligent vehicle tracking system aimed at supporting real-world investigation scenarios, with object recognition treated as an assumed capability rather than the core contribution. We also developed a Graphical User Interface (GUI) to enable description-based vehicle tracking within the proposed system. This dual approach of real time vehicle detection combined with description-based tracking has significant applications in enhancing security, surveillance, and post incident analysis, making it an important asset in modern law enforcement workflows.

For this application we created a deep learning model. Deep learning is a revolutionizing technique that has enabled systems to automatically learn complex patterns from vast data, leading to superior accuracy and efficiency. In vehicle detection, our indigenously developed lightweight deep learning model excels at identifying and classifying vehicles in diverse and challenging environments, even under occlusion or low-resolution conditions. This capability is extremely crucial for intelligent transportation systems, traffic monitoring, and autonomous vehicles, where rapid and reliable detection directly impacts safety and operational effectiveness. The adaptability and speed of deep learning make it indispensable for modern real time solutions.

2. RELATED WORK

Recent advances in deep learning have significantly enhanced vehicle detection, classification, and tracking, providing robust solutions for intelligent transportation systems. The most recent contributions, particularly from 2020 to 2025, have pushed this field forward, addressing challenges in Automatic Number Plate Recognition (ANPR), vehicle type classification, and real-time tracking. This section reviews these advancements, integrating foundational and contemporary studies to contextualize our proposed multistage detection and tracking system.

Early work by Bailmare [1] laid the groundwork for ANPR by improving character segmentation to enhance recognition accuracy. While effective for well-captured plates, such segmentation-based methods are sensitive to image noise and illumination changes, making them less robust for CCTV feeds; our detection-first, OCR-later approach mitigates this. Puranik et al. [2] developed an OCR-based number plate recognition system aimed at practical deployment, but it relied on conventional preprocessing and lacked integration with multi-attribute vehicle analysis, a gap addressed in our multi-stage framework.

Memon et al. [3] proposed a video-based vehicle detection, counting, and classification system with real-time capabilities. However, its focus was on traffic flow analytics rather than detailed per-vehicle feature logging, which our system achieves by extracting type, colour, orientation, and brand information. Yang [4] introduced self-adaptive background modelling for vehicle detection—effective for static scenes, but less adaptable to moving cameras or occlusion, limitations our YOLOv8-based approach overcomes.

Huang et al. [5] improved YOLOv3-tiny for vehicle detection in natural scenes, achieving high accuracy under challenging conditions, but without extending the pipeline to other attributes or tracking. Surveys by Rangana et al. [6] and Lubna et al. [7] summarized deep learning ANPR advancements but did not address integration with GUI-based investigative tools. Bralić and Musić [8] built a real-time deep learning traffic surveillance system for detection and classification, but their work did not incorporate spatial feature localization, such as our sticker grid.

Prajapati et al. [9] combined YOLOv7 with PaddleOCR for accurate number plate recognition, showing the value of hybrid models; however, they limited analysis to plates, whereas our system performs multi-attribute extraction. Shelke et al. [10] reviewed number plate identification and wrong-way detection methods, focusing on safety monitoring but without multi-feature forensic search. Shrivastava et al. [11] used CNNs for number plate recognition, and Rahman et al. [12] implemented YOLO with centroid tracking for wrong-way detection—both strong in their domains but single-task in scope, unlike our unified pipeline.

Yousaf et al. [13] applied patch-based CNNs for logo and brand recognition, improving classification, but without coupling this with number plate text or spatial sticker localization. Puranic et al. [14] used template matching for plate recognition, and Asif [15] used OCR-based approaches—both of which are sensitive to plate variations that our YOLOv8 detection stage can handle before OCR. Emambocus et al. [16] surveyed neural network optimization via swarm intelligence, valuable for performance gains but not applied to integrated vehicle investigation systems.

Dalvi et al. [17] developed a comprehensive ANPR system, but their focus remained on plate detection and text extraction, without additional attributes or centralized logging. Mir et al. [18] reviewed ANPR for real-time applications but did not cover multi-feature integration. Gautam et al. [19] combined corner-point detection and OCR, enhancing plate localization, yet their scope was still plate-only. Feng and Yue [20] designed deep learning models for detecting car window openings, targeting niche vehicle monitoring cases without broader forensic use. Kumar et al. [21] incorporated vehicle detection into assistive robotics for the visually impaired, showing safety applications but not multi-feature vehicle tracking.

Deorukhakar et al. [22] combined deep learning with real-time processing for robust urban ANPR yet omitted multi-attribute logging and searchability. Liu and Shen [23] improved YOLOv8 for vehicle detection and tracking in dynamic scenarios, and Shao et al. [24] refined YOLOv8 for remote sensing images; both advanced detection accuracy but lacked integration with GUI-based investigative systems. Sreedhar et al. [25] proposed Autotrack, an edge-based query-driven tracking framework, and Narayan et al. [26] used graph-based vehicle tracking for scalability; neither incorporated descriptive feature extraction. Mohammad et al. [27] enhanced segmentation-based number plate recognition for challenging conditions but remained plate-centric. Sabry and Emad [28] used vehicle detection for traffic accident estimation, a safety application outside the scope of multi-attribute tracking.

Despite these advancements, several areas remain underexplored, such as vehicle type classification (e.g., SUVs, sedans, hatchbacks), user-added car stickers or markings, and integration into centralized tracking databases for law enforcement. Our proposed system distinguishes itself by addressing all the gaps in the research along with incorporating a GUI that enables reverse visual searches of vehicle data. In addition to detecting car features, it includes a tracking system that logs these features and links them with CCTV footage for seamless vehicle tracking. Our framework provides a scalable and practical solution for real-time monitoring and forensic applications, combining a searchable vehicle log, application-specific feature detection, car classification, and an intuitive GUI.

3. RESEARCH METHODOLOGY

3.1 Multistage Vehicle Detection and Feature Extraction

Our vehicle identification and tracking system is built around a simple and intuitive pipeline that breaks the process down into manageable steps, keeping the whole model flexible, accurate, easy to follow and easy to use.

a) Frame Acquisition: The detection starts with the system picking up frames directly from regular CCTV footage. The footage can be real time or recorded.

b) Vehicle Type Detection: Once a frame is captured, it is run through the first stage that is a YOLOv8 model that classifies car types like SUVs, sedans, and hatchbacks. After detecting a vehicle with either of these types, the system crops it out of the scene so it can focus just on the car and leaving the background and other meagre details behind.

c) Colour Detection: Next, the cropped vehicle image goes through a colour detection step which forms the second stage as feature extraction. Using a simple histogram analysis, the system figures out the car's most dominant colour like black, white, or red.

d) Orientation Detection: To understand how the car is positioned in the frame, the image is sent through another YOLOv8 model which is the third stage that checks which sides of the vehicle are visible whether it's the front, back, left, right, or a combination of them.

e) Feature Detection: A fourth stage YOLOv8 model is used to detect specific vehicle features such as the logo, number plate, window, and stickers. Each detected feature is cropped for further focused analysis.

f) Logo Classification: In the fifth stage, cropped image of the car's logo is processed by a YOLOv8 model, which is specifically trained to identify and classify the vehicle's brand from a set of nine predefined car companies.

g) Sticker Localization with Spatial Grid: The sixth stage determines the sticker position on the window, a 3×3 spatial grid is overlaid, dividing the window into the following regions. The system tracks the sticker's position within these zones to improve spatial accuracy and tracking
   - Top row: Top left, Top centre, Top right.
   - Middle row: Mid left, Mid centre, Mid right.

- Bottom row: Bottom left, Bottom centre, Bottom right.

h) Number Plate Recognition: In the seventh stage the cropped number plate is processed using Easy OCR to extract textual data (license number).

This system offers a dependable and scalable solution for tracking vehicles from start to finish, seamlessly identifying their colour, orientation, features, and location of the features all from raw CCTV footage. Figure 1 shows the adopted methodology for extraction of features. Figure 2 is a snapshot of the models working. Table 1 shows the final dataset used for this purpose.

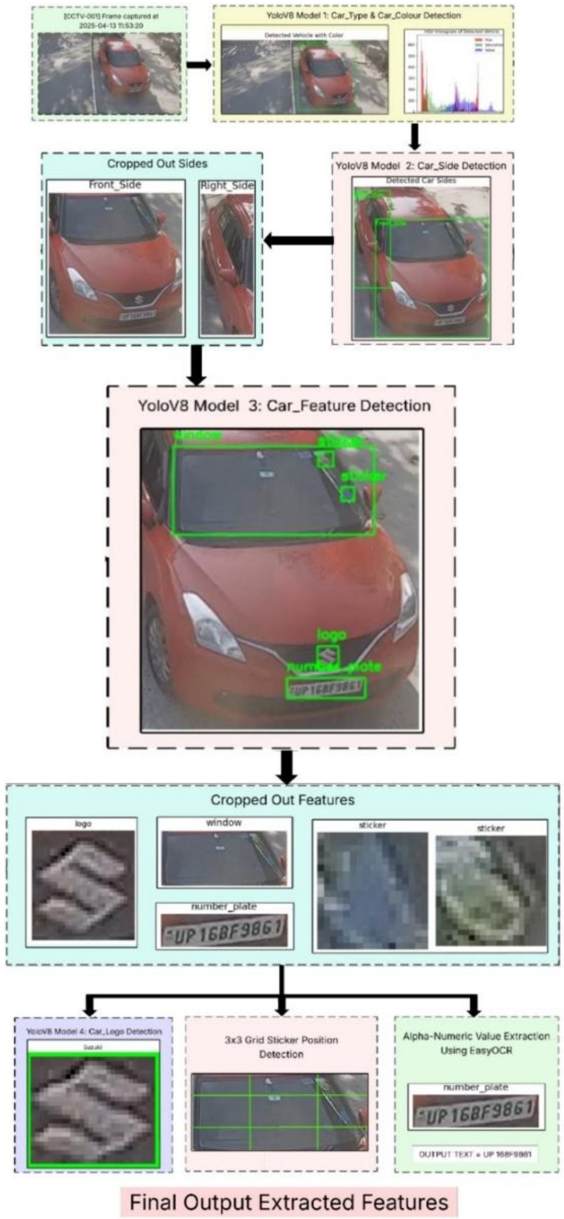

Figure 1. System Architecture for Car Feature Extraction and Identification

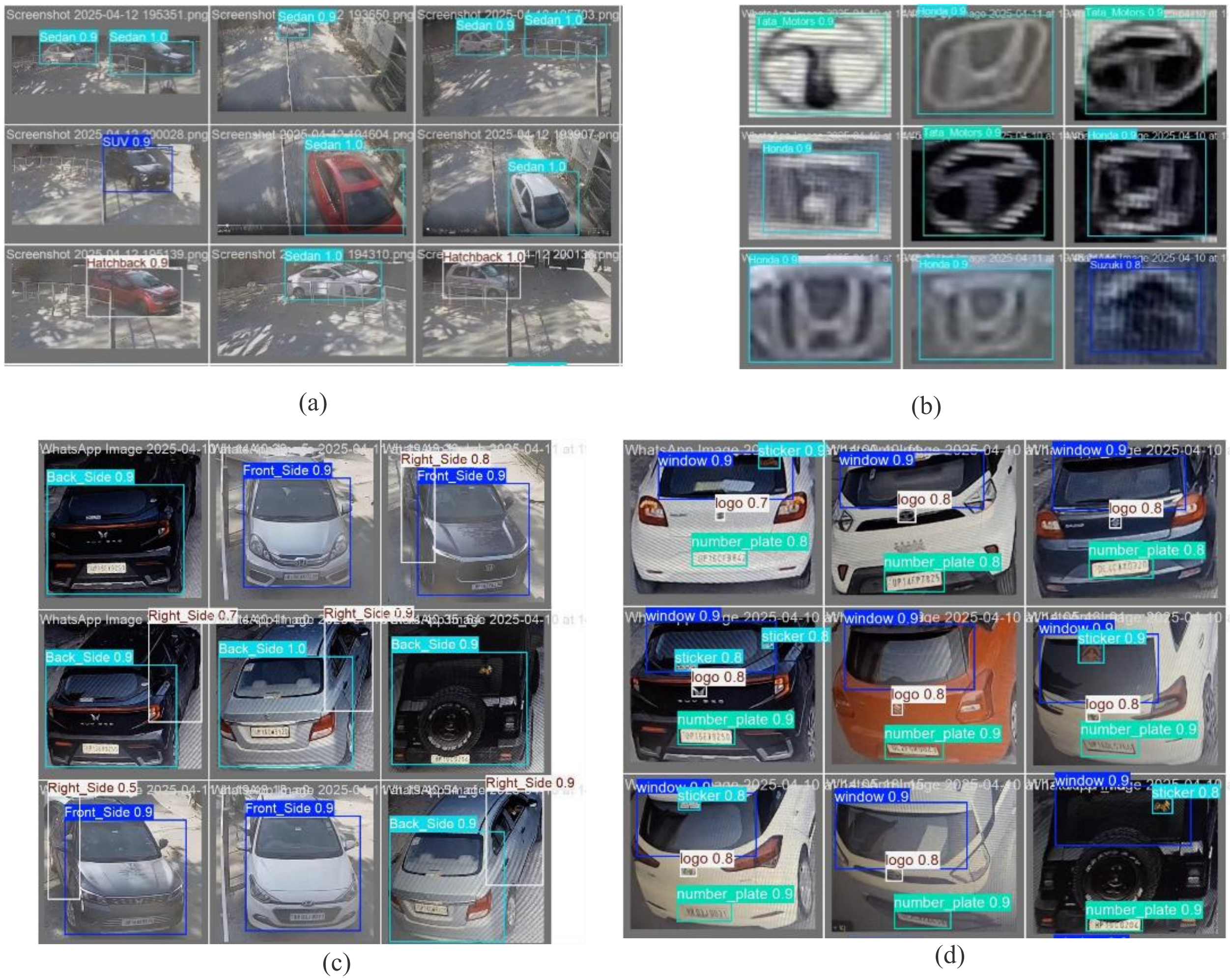

Figure 2. (a) YoloV8 Model 1 Vehicle Type Detection, (b) YoloV8 Model 3 Logo Detection, (c) YoloV8 Model 2 Orientation Detection, (d) YoloV8 Model 4 Feature Detection

Table 1. Data Collection for Each Class

Model	Classes	Images per class
Car Type	Sedan, SUV, Hatchback	285, 280, 275
Car View	Front, Back, Right Side, Left Side	150, 130, 125, 120
Car Features	Window, Sticker, Logo, Number plate	200, 210, 180, 190
Logo brand ID	Toyota, Honda, Hyundai, Tata, Mahindra, Ford, Volkswagen	60, 85, 80, 75, 70, 65, 60

For this research, we developed and employed a bespoke dataset that was specifically designed to support the purposes of car colour, brand/model, and license plate identification. The dataset contains a combination of video frames extracted from CCTV recordings and manually gathered vehicle images. The CCTV footage provides active real-world interactions among vehicles over varied environments, while the images of manually selected and annotated samples are present to ensure we have a balanced, representative set of information gathered over different areas, times of day, weather conditions, and road conditions. This diversity in dataset is important because it simulates the broad diversity of conditions our system will see when operating in the real world. Further, images in the dataset that were annotated were labelled with correct information like car brand, model, colour, and readable license plates. By collecting this dataset specifically for the challenges, we are trying to solve, we were able to develop a customized resource that directly addresses the requirements of our vehicle tracking system. This bespoke solution has been a great assist in targeting the unique needs of car identification, and it also helped ensure that the dataset is universal enough to include many environmental conditions and anomalies like partial occlusions of vehicles and its details, changing lighting conditions, and diverse camera angles. Such a diversified dataset is important for conditioning the system to face real-world diversity and enhancing the accuracy and resilience of our system in identifying vehicles under adverse and non-ideal conditions.

3.2 Conceptualization of the Database Tracking System

The second phase of the proposed system involves compiling all the extracted attributes such as car type, car colour, logo, sticker position, license plate, and side view information, into a structured database such as an Excel or a SQL file. These are time stamped entries, with location tag for each CCTV camera. The processed data collected at each CCTV node is sent to a centralized data centre, where logs from multiple CCTV camera sources are combined and aggregated into one single unified data table format. Each car entry is appended with metadata like CCTV ID, time of appearance, date and location of the camera.

A GUI makes it simple for authorized users in this case law enforcing officials, to enter descriptive details such as "*a black SUV with a sticker on the top left of the front windshield*" of the car in question and find potential matches from the central database in record time. The model uses threshold matching algorithm to rank and display the most relevant results as per each query. By linking sightings of the same vehicle across multiple CCTV cameras, it creates a chronological log for the car movement across various CCTV nodes. The model is extremely robust and can handle incomplete or vague information from eyewitnesses, due to extensive feature extraction. Even if some details are missing, the model still manages to provide reliable and robust results. Figure 3 shows the schematic of the proposed structure for tracking cars. Figure 4 is a snapshot of the database representation cataloguing all the detected attributes of the car. Figure 5 shows the GUI for the proposed methodology.

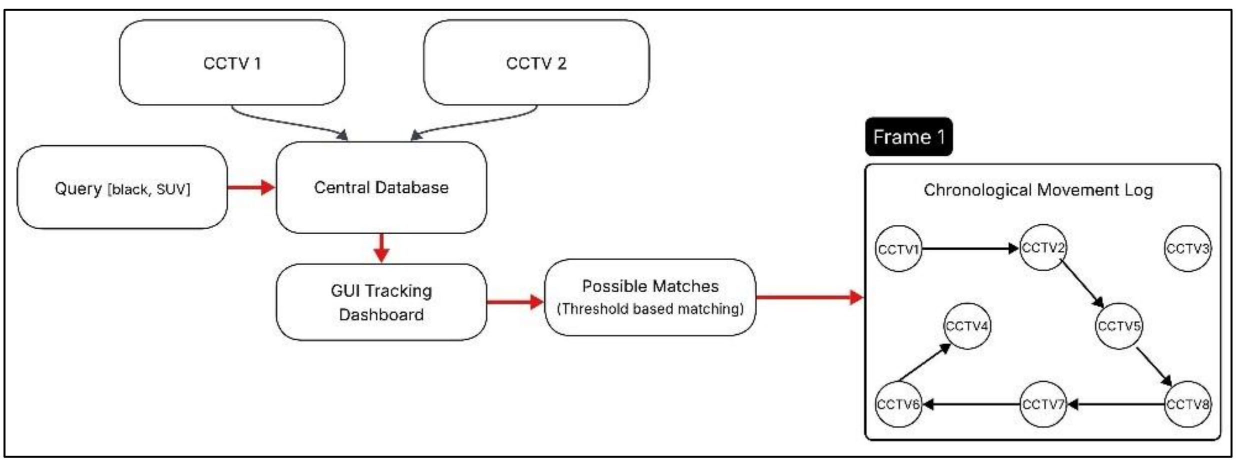

Figure 3. Proposed System for Car Tracking from Database

	A	B	C	D	E	F	G
1	CCTV ID	Timestamp	Car Type	Color	Sticker Position	Logo	Number Plate
2	CCTV-001	2025-04-13 11:53:20	Hatchback	red	Front_side[Top-right, Mid-right]	Suzuki	UP 168F9861
3	CCTV-002	2025-04-13 11:55:29	Sedan	white	Front_side[None]	Hyundai	UP 14DR7090
4	CCTV-003	2025-04-13 11:55:58	Hatchback	black	Back_side[Top-right,Top-center]	Honda	UP 16DZ6530
5	CCTV-002	2025-04-13 12:08:52	SUV	white	Front_side[Top-right]	Hyundai	UP 16DW9120

Figure 4. Structured Tabular Representation of Vehicle Attribute Database

Figure 5 is an annotated version of the prototype screenshot, it illustrates the graphical user interface of the system, and the ability to retrieve relevant results even in the absence of few data attributes in this case the missing attributes are sticker position and license plate. In this instance, the query was executed using the limited data available with the user that is car logo, car type, date, and time, still the system successfully returned matching entries. The map displayed on the right side of Figure 5 is a simulated version designed to visualize the final car tracking interface in a map like format. It does not reflect real time data, as the system is currently experimental, and has been run on specifically curated dataset. Upon deployment, the GUI will display the actual route taken by the vehicle over the real city map, enabling accurate location-based tracking.

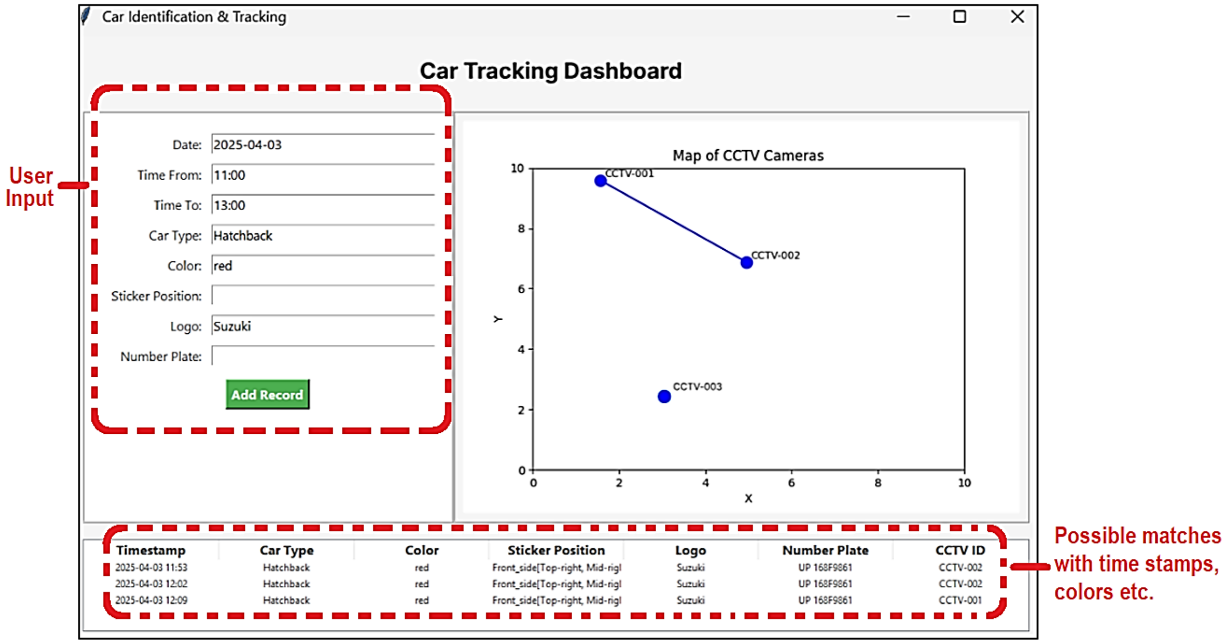

Figure 5. Graphical User Interface for Attribute Based Vehicle Search and Tracking

4. RESULT AND DISCUSSIONS

The car detection and tracking system proposed in this research demonstrated results in extracting crucial features such as car type, car colour, visible stickers, logos, and license plates from recorded CCTV footage. YOLOv8 provided accuracy of 90.7% for Model 1 (car type detection), 94.1% for Model 2 (orientation detection), 90.0% for Model 4 (feature detections), 93.8% for Model 3 (logo detection) even in low resolution and varied lighting. Our custom data set consists of real-world CCTV footage from 3 CCTV cameras capturing different angles of cars allowed the model to adapt to practical conditions. Furthermore, the approach for a structured compilation of extracted visible features into a searchable format significantly enhanced post detection utility of the model and the whole concept. This lays the foundation for long-term vehicle tracking while enabling real-time identification and surveillance.

The concept of the proposed vehicle tracking system, which uses descriptive inputs of visual features to retrieve path history of car and tracking the movement via different CCTV nodes from stored data, presents a very novel approach to aiding vehicle related investigations. This feature would prove to be especially beneficial in cases with unclear license plates, but certain visual identifiers remain memorable to witnesses. While real time tracking was not fully implemented, the system performance in detection and data structuring shows the feasibility of the complete pipeline. The development of a GUI for querying and visualizing vehicle logs further supports its practical usability. The current results validate the core capabilities of the system and highlight its potential in law enforcement, surveillance, and urban traffic monitoring.

5. LIMITATION AND FUTURE SCOPE

The proposed system is certainly capable of a lot when it comes to detection, identification, and finding or tracking vehicles, however there is still room for improvement on some aspects of the model. Perhaps one of the more difficult issues we faced was with detecting plates, particularly when traffic is concentrated. Where cars are close to each other and the number plate is completely or partially blocked, as in case of a traffic jam or slow-moving traffic, it becomes hard for the system to clearly capture the license plates of the vehicles. This makes it impossible to get clear information when the vehicle is blocked at the back. Also, the system is not yet capable of compensating for physical aspects of the vehicles such as dents, scratches, or other damages to cars, which might be noticeable to human eye however are hard to capture on camera or on CCTV. These might be vital in identification in some cases, so being able to detect those types of visual identifiers would make the system even more trustworthy. On a larger scale, although the system is efficient in managing and storing car data, we have yet to completely deploy the tracking mechanism that would enable users to search and track car movements in real-time. The user interface and search-based tracking system are still under development. The current study serves as proof of concept, with the emphasis placed on demonstrating the system's feasibility rather than optimizing or benchmarking detection accuracy.

Our plans for future work include the following.

- Enhance number plate recognition in crowded scenes through the integration of tracking-based improvements and temporal analysis between frames.
- Incorporating a vast dataset for even better accuracy, currently we had aimed to provide a proof of concept, and the agenda was easily achieved by 2640 images in total.
- Include damage detection on vehicles.
- Completely implement and optimize the GUI in support of real time search, filtering, and visual tracking of vehicles between CCTV nodes.
- Generalize the above proposed concept to cover dashboard car cameras data.

With the above in consideration, the system can have its potential further developed into an intelligent, whole coverage surveillance system that could be used across public safety infrastructure and traffic monitoring systems.

6. CONCLUSION

In the research, conceptual architecture, for car identification and tracking using CCTV footage, utilizing the YOLOv8 model for detecting car features, was proposed. The model was further fine-tuned to work with university surveillance data, and it demonstrated promising results in car detection and feature extraction. The approach discussed above is a scalable and practical framework for future intelligent surveillance and tracking systems. However, certain limitations, such as poor performance under low light conditions and occasional OCR inaccuracies, are areas for improvement. Future work may include integrating night vision enhancements, or working in minimum light conditions, improving OCR reliability, and extending the system to identify other vehicle types (trucks, bikes, jeeps, scooters etc.).

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AUTHOR CONTRIBUTIONS

Riya Jain: Conceptualization, Methodology, Software, Data Curation, Validation, Writing – Original Draft Preparation;
Piyush Kumar: Conceptualization, Methodology, Software, Data Curation, Validation, Writing – Original Draft Preparation;
Ashwani Kumar Dubey: Conceptualization, Methodology, Supervision, Writing – Review & Editing;
Angela Amphawan: Conceptualization, Methodology, Supervision, Writing – Review & Editing;
Neo Tse Kian: Methodology, Writing – Review & Editing.

CONFLICT OF INTERESTS

No conflict of interest was disclosed.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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