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Enhanced Framework for Real-Time Vehicle Detection and Tracking

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Abstract: This study presents an original approach for real-time vehicle detection and tracking using deep learning techniques. The framework combines a high-speed object detection model with an efficient tracking algorithm to identify vehicles and maintain their identities across video frames. The system is designed to operate in dynamic traffic environments and delivers accurate and consistent results. The proposed solution is suitable for traffic monitoring, surveillance, and smart city applications.
Keywords: Real-Time Vehicle Detection, Multi-Object Tracking, Computer Vision Techniques, Deep Learning Models, Intelligent Traffic Analysis

I. INTRODUCTION

The rapid increase in the number of vehicles on roads has made traffic monitoring and management more complex and challenging. Traditional methods that rely on manual observation are often inefficient and unable to provide accurate real-time insights, especially in high-density traffic conditions. To overcome these limitations, the project titled "Enhanced Framework for Real-Time Vehicle Detection and Tracking" aims to develop an intelligent system that can automatically detect and track vehicles using video data. By applying computer vision and deep learning techniques, the system identifies different vehicles and monitors their movement continuously, enabling better analysis of traffic flow.

II. LITERATURE SURVEY

Chen,L.,&Gao,Y.(2024) The latest advancement in computer vision Vision Transformers (ViT) has been adapted in this study for vehicle detection and tracking. Unlike CNNs, Transformers use self-attention mechanisms to model global dependencies within an image, enabling better understanding of spatial relationships between vehicles. The proposed ViT-based model achieves superior accuracy under challenging conditions such as occlusions, nighttime visibility, and motion blur. **D.Shinar,E.Hauer(2024)** This editorial discusses the relationship between crash causation, preventive countermeasures, and policy implications in road safety research. It highlights the importance of translating scientific findings into practical safety interventions, such as infrastructure modifications, enforcement measures, and educational campaigns **R.Elvik (2024)** This paper critically examines the concept of causality in traffic accident research, focusing on identifying and classifying risk factors that contribute to crashes. The study presents a logical framework for linking accident occurrence to specific causes and evaluates the completeness of current explanatory models. **Zhang,Y.,&Li,W.(2023)** This paper presents an advanced framework that integrates YOLOv5 for vehicle detection with an optimized Deep SORT algorithm for tracking. YOLOv5 enhances detection accuracy through improved feature pyramids and anchor-free design, while Deep SORT ensures consistent identity tracking by leveraging appearance embeddings.

III. EXISTING SYSTEM

While CNN and RNN-based architectures have proven useful in many deep learning applications, their use in real-time, large-scale traffic prediction and vehicle-type recommendation systems introduces several limitations. Convolutional Neural Networks (CNNs), though effective for image-based tasks such as vehicle detection, often require substantial computational resources, particularly when processing high-resolution traffic footage across multiple camera feeds in real time. Traditional CNNs lack the temporal understanding needed to handle time-sequenced data, limiting their capability to model the dynamic nature of traffic flow when used alone.

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Existing System Disadvantages:

- Limited cross-modal interaction, as CNN and LSTM features are often fused only at a late stage using simple operations like concatenation or projection.
- Inability to perform fine-grained alignment between image regions and specific words or phrases in the question.

Proposed System: Complementing this, the LSTM model is employed to analyze historical traffic data including vehicle count, congestion levels, and average speed over time to forecast future traffic conditions. LSTM's ability to model long term dependencies in sequential data makes it ideal for predicting short- and long-term congestion trends. By integrating insights from both real-time detection and time series forecasting, Deep Traffic-VTS dynamically suggests the most suitable vehicle types for efficient navigation under evolving traffic conditions.

Advantages:

- Offers intelligent suggestions for which vehicle types are optimal for current and future traffic conditions.
- Enhances traffic routing, emergency response planning, and urban mobility strategies.

IV. SYSTEM ARCHITECTURE

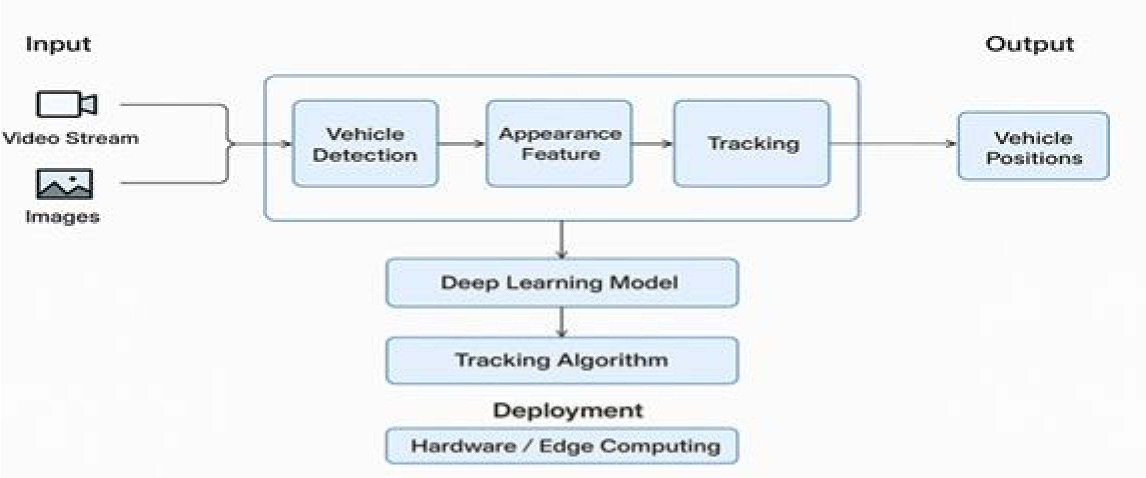

Figure 4.1 System Architecture

The Enhanced Framework for Real-Time Vehicle Detection and Tracking is designed to process continuous video streams and image inputs to accurately detect and track moving vehicles in real time. The system integrates advanced deep learning algorithms, tracking models, and edge computing deployment to achieve high performance and low latency.

V. METHODOLOGY

The system processes video input detects vehicles using a deep learning model, and tracks them using an identity-based tracking algorithm. Each vehicle is assigned a unique ID to maintain continuity across frames.

MODULES NAME:

1. Data Collection Module
2. Traffic Prediction Module (LSTM-based)
3. Vehicle Detection Module (YOLO-based)
4. Data Integration and Analysis Module
5. Adaptive Recommendation Module
6. System Evaluation Module

Modules Explanation:

1. Data Collection:

- Historical traffic data such as vehicle counts, average speed, congestion levels, and time of day is collected from sensors, traffic cameras, or government traffic databases.
- Live video feeds from urban roads are captured using CCTV cameras for real-time analysis.

2. Traffic Prediction using LSTM:

- Long Short-Term Memory (LSTM) networks are trained on historical traffic data to learn temporal patterns and trends.
- The model predicts future traffic conditions for upcoming time intervals, including potential congestion levels and traffic density.

3. Vehicle Detection using YOLO:

- YOLO (You Only Look Once) is applied to live video feeds to detect and classify vehicles in real time, such as two-wheelers, cars, buses, and emergency vehicles.
- The detection model provides information about vehicle types, count, and their location on the road network.

4. Integration and Analysis:

- Predictions from the LSTM model are combined with real-time data from YOLO to form a comprehensive view of traffic conditions.

- The system analyzes which vehicle types are suitable for specific routes and identifies congested zones requiring alternate routing.

5. Adaptive Recommendations:

- Based on integrated insights, the system suggests optimal navigation for different vehicles:
  - Two-wheelers for congested areas due to high maneuverability.
  - Larger vehicles are advised to take alternate routes or delay travel.
  - Emergency vehicles are prioritized with fastest and least congested paths.

6. System Evaluation:

- The performance of the system is evaluated based on metrics like prediction accuracy, vehicle detection accuracy, congestion reduction, travel time optimization, and response efficiency for emergency vehicles.

VI. IMPLEMENTATION

The implementation of the Enhanced Framework for Real-Time Vehicle Detection and Tracking focuses on building a modular and scalable system capable of processing video streams and detecting vehicles in real time. The system integrates deep learning-based object detection models with tracking algorithms to maintain consistent vehicle identities across frames. The implementation is divided into multiple components, including frontend, backend, database, and API layers. The detection module uses YOLO-based models for high-speed inference, while tracking is handled using DeepSORT/ByteTrack algorithms.

Algorithms Used:

Existing Algorithm

HaarCascadeClassifier:

Haar Cascade Classifier is a traditional object detection technique that relies on manually designed features and a cascade of classifiers to identify vehicles in images. It scans the image at multiple scales to detect objects, making it relatively fast for simple tasks, but it struggles to maintain accuracy in complex traffic environments with varying lighting conditions and multiple overlapping vehicles.

Proposed Algorithm

YOLO (You Only Look Once) is a deep learning-based object detection algorithm that processes the entire image in a single forward pass, enabling fast and accurate detection. In the proposed framework, an optimized lightweight version of YOLO is used to reduce computational complexity while maintaining high performance, making it suitable for real-time vehicle detection in complex traffic environments.

VII. EXPERIMENTAL RESULTS

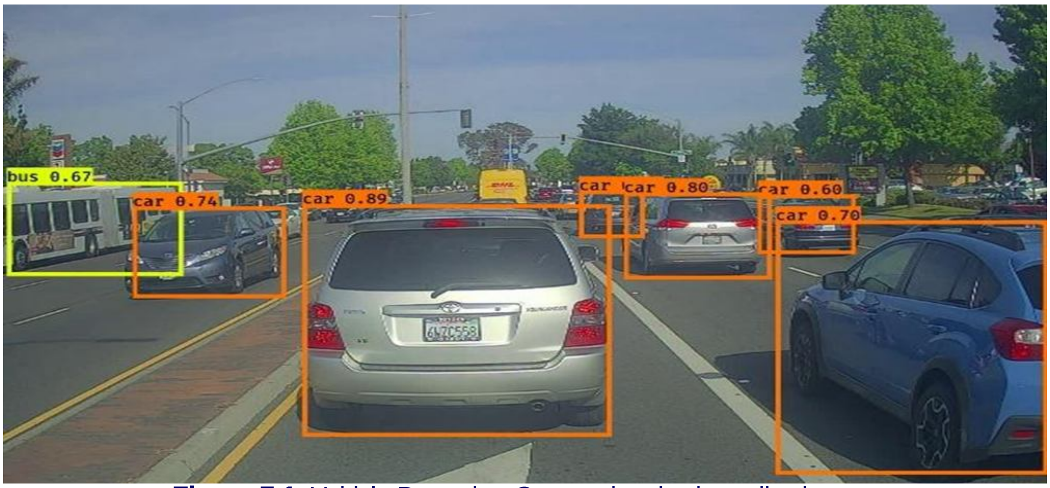

Figure 7.1: Vehicle Detection Output showing bounding boxes.

The image presents the output of a real-time vehicle detection system in which multiple vehicles on the road are recognized and highlighted using bounding boxes. Each detected object is labeled with its corresponding category, such as car or bus, along with a confidence value that indicates the model's level of certainty in its prediction. The image displays the output of a real-time vehicle detection system, where multiple vehicles on the road are automatically recognized and highlighted with bounding boxes. Each detected vehicle is labeled with its category, such as car or bus, along with a confidence value that indicates the reliability of the prediction. The image shows the output of a real-time vehicle detection and tracking system that operates using a live video stream. The system can recognize various types of vehicles, including cars, motorcycles, buses, and trucks, and displays their total count on the screen. In this case, it has identified 27 cars, 3 motorcycles, 1 bus, and no trucks. Each detected vehicle is enclosed within a bounding box and assigned a unique tracking ID, allowing the system to follow its movement across multiple frames. This demonstrates that the model performs both detection and continuous tracking effectively.

VIII.CONCLUSION

Deep Traffic-VTS presents a novel solution for managing urban traffic congestion by combining predictive analysis with real-time computer vision techniques. The system utilizes Long Short-Term Memory (LSTM) networks to forecast traffic patterns and employs YOLO (You Only Look Once) for live vehicle detection and classification.

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Figure 7.2: Vehicle Tracking Output with unique IDs.

Figure 7.3: Real-Time Traffic Monitoring visualization.

This combination enables the generation of meaningful insights that support better traffic management and informed decision-making for both commuters and authorities. By integrating these advanced methods, the system can adjust to varying traffic conditions in real time, suggest efficient routes, reduce travel delays, and contribute to lower fuel usage.

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