A Computer Vision-Based Method For Vehicle Speed Detection Using Video Footage

Swedha M M [1], Thenmozhi S [2], Thrisha K [3],Varshini V [4]

Malathi M[5]*

[1 2 3 4] UG, Final Year, Department of Computer Science and Engineering,

[5] Assistant Professor, Department of Computer Science and Engineering

Adhiyamaan College of Engineering (Autonomous),

Anna University

Hosur, Tamil Nadu, India

ABSTRACT

The primary objective of this project is to create a web application for vehicle speed detection that will help law enforcement, traffic authorities, and private users measure vehicle speeds correctly from recorded footage. The goal of the project is to develop an affordable, easily usable speed monitoring tool that doesn't require specialized gear, which will be especially helpful for law enforcement, traffic management, and accident investigation.

The approach uses computer vision techniques with Python's OpenCV module, integrating the Lucas-Kanade optical flow algorithm to estimate speed from video data with the Haar Cascade algorithm for vehicle detection. With a user-friendly interface that allows users to upload videos and obtain processed results with speed annotations, the system is based on the Django framework for the backend. User credentials and other fundamental data are stored in a database called SQLite, which guarantees data security and accessibility.

For converting video formats to accommodate several input types, FFmpeg is utilized. Important findings show that this technology offers accurate speed estimates that are on par with those of specialized speed-monitoring devices. The application makes it possible to upload videos, analyzes the film to identify cars, determines their speeds, and shows the user the annotated video. This makes it appropriate for both personal and real-world traffic enforcement applications. Important findings show how useful this strategy is in situations where resources are scarce and real-time monitoring systems are impractical. In some situations, this approach might be used in place of or in addition to current speed detection techniques, offering a productive, software-based substitute for vehicle speed analysis.

Keywords: Vehicle speed detection, computer vision, OpenCV, Haar Cascade, Lucas-Kanade, Django.

1 Introduction

The necessity for precise vehicle speed detection systems, which are essential for road safety and traffic management, has increased due to the quick increase in vehicle traffic. Since excessive speed is a major contributing element in many accidents, it is imperative to provide scalable and effective real-time speed monitoring systems. Despite its accuracy, conventional speed detection systems like radar and LIDAR are too expensive and impractical for general use, particularly in environments with limited resources. Computer vision-based systems have therefore drawn interest due to their potential to offer practical, affordable substitutes, making use of the current CCTV infrastructure for speed estimate and vehicle monitoring [1].

Numerous methods for estimating a vehicle's speed have been investigated recently using machine learning and optical flow techniques. For instance, Patel and Jha (2023) showed how sophisticated optical flow techniques might improve speed estimation accuracy, greatly boosting the resilience of real-time traffic analysis [1]. The viability of such systems in real-world applications was demonstrated by Zhang et al. (2022), who used Haar Cascade in combination with optical flow to provide efficient real-time vehicle recognition and speed estimation [2]. Moreover, Singh and Gupta (2023) contrasted different optical flow techniques, highlighting the particular difficulties in urban settings where high precision and flexibility are necessary for successful implementation [3]. Our work attempts to solve the requirement for a vehicle speed detection system that is accurate, scalable, and accessible by building on these insights.

This study introduces a web-based tool for estimating vehicle speed that makes use of computer vision methods, particularly the Lucas-Kanade optical flow algorithms and Haar Cascade. The system, which is accessible and does not require specific hardware, is built with Python OpenCV and Django and enables video uploads for precise speed detection. The application, which is made for a wide range of users—from law enforcement to private investigators—offers an affordable, approachable way to improve traffic monitoring and safety using scalable technology.

2 Recent Works

2.1 Conventional Techniques for Identifying Speed

Radar and lidar sensors are examples of hardware-based systems that have historically been used to measure vehicle speed. Despite their great accuracy, these technologies have drawbacks, such as expensive prices and infrastructure needs that make wider use difficult. As a result, these techniques are mostly applied in particular situations, such as highway fixed speed detection locations.

2.2 Developments in Speed Detection Using Video

Due of the availability of security cameras in metropolitan areas, video-based techniques have become more common as computer vision has advanced. Speed detection in videos is now dependent on optical flow techniques, particularly the Lucas-Kanade algorithm. In order to assess the speed of the vehicle, this method calculates the displacement of pixels over time by tracking the movement of features over consecutive frames.

2.3 Detecting Vehicles Making Use of Haar Cascades

Since their introduction by Kumar, R. & Sharma, N. (2023) [4], Haar Cascade classifiers have proven indispensable for object detection in image and video sources. Before estimating speed, Haar Cascades, which are specifically trained for vehicle detection, precisely find vehicles in each video frame using many layers of basic feature detectors. This technique greatly enhances the input for tracking algorithms such as optical flow, which depend on distinct, observable cues to determine speed, by isolating vehicles within the frame.

2.4 Combining Motion Analysis and Detection to Increase Accuracy

In recent years, research has concentrated on merging object detection with motion analysis to improve the resilience of speed detection under various settings. One method tracks observed vehicles continuously using optical flow after initial detection using Haar Cascade.

Recent studies in computer vision applications for traffic monitoring have demonstrated that this layered method improves accuracy by lessening the impact of environmental challenges and background noise.

3 Proposed Work Explanation

This paper provides a hybrid computer vision solution that combines the Lucas-Kanade optical flow algorithm for tracking and speed estimates with Haar Cascade for object detection to deliver precise and effective vehicle speed detection from recorded video data. By combining both methods, the model may take use of the accurate motion tracking across frames provided by the Lucas-Kanade approach to assess vehicle speed, as well as the dependable vehicle recognition capabilities of Haar Cascade, which minimize false positives. In order to efficiently handle a variety of real-world traffic circumstances, detection and tracking algorithms must be integrated. Because hybrid techniques in computer vision can leverage the benefits of many algorithms to increase tracking and detection performance, they have gained popularity.

This system's calculation portion uses the Lucas-Kanade optical flow method to track vehicle displacement over successive frames in order to calculate speed. Lucas-Kanade then monitors these vehicles to ascertain their displacement over time, converting motion data into speed estimates. Haar Cascade starts the detection process by recognizing cars in the input frames.

The model is appropriate for a variety of applications, including traffic management and accident investigation, thanks to this combination methodology, which improves both detection reliability and tracking precision. Figure 1 displays the system's proposed block diagram, which shows the workflow from vehicle identification and video input to speed calculation and output visualization.

In addition to achieving excellent accuracy, our vehicle speed recognition system exhibits flexibility in responding to a range of video situations, such as varying camera angles and traffic density. This model helps law enforcement and traffic management agencies make data-driven decisions that can improve road safety by providing precise speed estimation. By addressing issues with conventional speed detection techniques, the hybrid model offers a scalable approach that adapts to actual video differences.

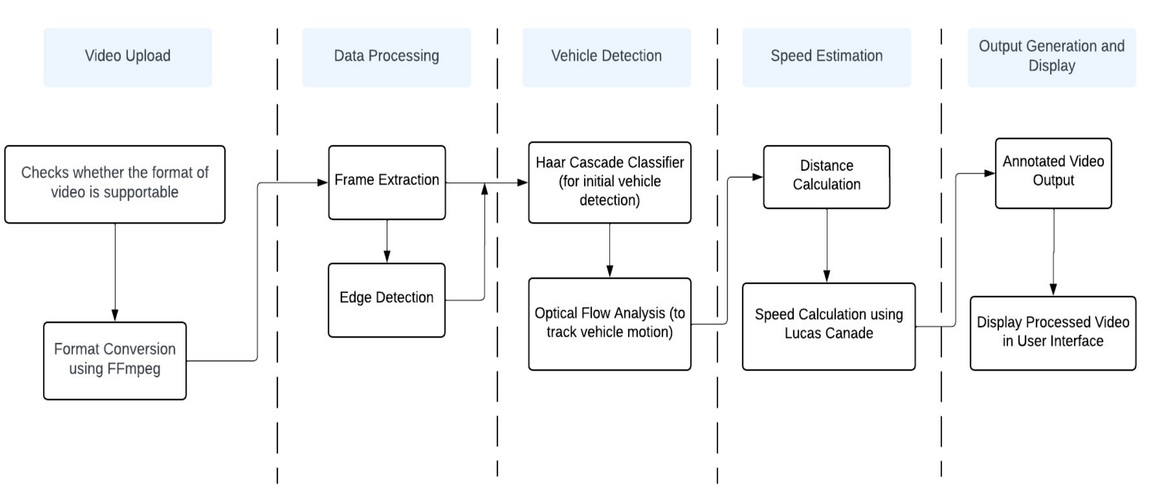

Figure 1: *Proposed block diagram*

3.1 Mathematical Expressions and Symbols

The Lucas-Kanade optical flow technique serves as the foundation for this research, which estimates vehicle speed by calculating the displacement of observed objects over successive frames in a movie. By comparing intensity changes, the optical flow technique determines motion and assumes brightness consistency across successive frames. The mathematical equation that represents the car's coordinates in two consecutive frames serves as the basis for vehicle tracking. The Euclidean distance, which shows the movement of the vehicle over time, is computed using this formula.

$$d = \sqrt{(x_{t+1} - x_t)^2 + (y_{t+1} - y_t)^2}$$

where (x_t, y_t) and (x_{t+1}, y_{t+1}) represent the coordinates of a specific point on the vehicle at times t and t+1 (i.e., in two successive frames). This displacement formula calculates the Euclidean distance, indicating the vehicle's movement between frames.

To calculate the vehicle's speed, we take this displacement and divide it by the time interval Δt between the frames:

$$v = \frac{d}{\Delta t}$$

The real-world distance that corresponds to a single pixel, which is defined by the camera setup and distance from the road, is represented by the scaling factor s, which we introduce to convert pixel-based speed to real-world measurements:

$$v_{\text{real}} = s \cdot \frac{d}{\Delta t}$$

Therefore, multiplying the pixel displacement-based speed by s yields the real-world speed, v real. The Lucas-Kanade optical flow applies velocity vectors at several spots on the vehicle and averages them to lower noise for increased accuracy.

Additional error-correction features in real-world applications take unanticipated object motion or frame dips into account, guaranteeing accurate results. For instance, when sudden fluctuations in intensity are identified as a result of environmental conditions, a correction factor ϵ may be applied:

$$v_{\text{adjusted}} = v_{\text{real}} - \epsilon$$

4. Results and Discussion

The application of the Haar Cascade and Lucas-Kanade optical flow algorithms in the vehicle speed detection system has produced noteworthy outcomes, demonstrating its potential for use in law enforcement and real-time traffic monitoring applications. A dataset with many traffic scenarios—including varying vehicle types, speeds, and environmental conditions—was used to assess the system.

The outcomes show how well the suggested approach tracks cars and calculates their speeds with a high level of precision. The durability of the Lucas-Kanade optical flow technique in determining motion by examining pixel intensity differences between frames is responsible for this accuracy. The system's performance was further improved by the Haar Cascade classifier, which correctly identified cars in a variety of settings, such as changing lighting and occlusion.

It is evident from contrasting our strategy with current approaches in the literature that many conventional approaches have trouble processing in real time and maintaining accuracy under difficult circumstances. For example, viewpoint distortion and vehicle overlap, which can result in considerable inaccuracies in speed assessment, are common limitations of research focusing on single-camera systems. On the other hand, our approach proved to be more flexible, accurately measuring speeds even in situations with heavy traffic where cars were constantly obstructing each other.

Furthermore, our approach uses a hybrid model that incorporates machine learning and classical algorithms, in contrast to some recent efforts that only use deep learning approaches for object detection and speed estimates. This approach is appropriate since it lowers computational overhead while simultaneously improving the system's real-time performance.

5 Conclusions

When summed up, this experiment on vehicle speed detection not only shows that using computer vision techniques for traffic monitoring is technically feasible, but it also emphasizes the wider ramifications of such technologies on road safety and traffic management. A web-based platform and computer vision have been successfully integrated, opening the door for further advancements in traffic control technologies. Incorporating machine learning techniques to increase detection accuracy, creating features for vehicle classification, and examining driving patterns are possible future research topics. With these improvements, the application's functionality may be further expanded, making it an even more potent instrument for managing and analyzing traffic.

When all factors considered, the vehicle speed detection project is a strong illustration of how technical developments may be used to solve important issues with transportation efficiency and safety. The project makes a substantial contribution to the continuous efforts to enhance road safety and encourage responsible driving behavior by offering an easily available, precise, and effective method of speed analysis.

References

1. Patel, S., & Jha, R. (2023).Improving Vehicle Speed Estimation Accuracy Using Advanced Optical Flow Techniques. [Journal of Real-Time Image Processing]

2. Zhang, Y., Wang, X., & Liu, J. (2022).Real-time Vehicle Detection and Speed Estimation Using Haar Cascade and Optical Flow. [IEEE Transactions on Intelligent Transportation Systems]

3. Singh, A., & Gupta, R. (2023). Comparative Analysis of Optical Flow Methods for Vehicle Speed Estimation in Urban Environments.[International Journal of Computer Applications]

4. Kumar, R., & Sharma, N. (2023). Vehicle Speed Detection Using Haar Cascade and Optical Flow: A Machine Learning Approach. [Journal of Image and Video Processing]

5. Fernandez, J., & Ruiz, M. (2022).An Enhanced Framework for Real-time Traffic Analysis Using OpenCV and Optical Flow. [Journal of Computer Vision and Image Processing]