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Enhancing Road Safety and Traffic Management: Real-Time Vehicle Speed Detection Using OpenCV

Husen Momin[1], Danish Momin[2], Mohammad Altmas[3], Dr. Veena Kadam[4]
[1, 2, 3]Student & [4]Professor Department of Computer Science, Keystone School of Engineering, Pune, Maharashtra, India

Abstract: Reducing traffic jams, increasing road safety, and enhancing the functionality of automated traffic systems all depend on accurate vehicle speed measurements. In this work, we demonstrate a real-time approach to vehicle speed detection using the well-known computer vision library OpenCV. Using methods like background subtraction, contour detection, and motion tracking, the system analyzes video frames to identify moving vehicles and track their movements. The system can provide accurate and fast speed readings by measuring how far a vehicle moves between frames and translating that pixel movement into actual speed. Tests conducted in various traffic and lighting conditions demonstrate that this approach is reliable and economical. Overall, the findings indicate thatOpenCV-based approaches can support smart transportation systems and can be further improved using advanced tracking methods and machine learning.
Keywords: Vehicle speed detection, Computer vision, OpenCV, Traffic monitoring, Motion tracking, Real-time analysis, Intelligent transportation systems, Video processing.

I. INTRODUCTION

The need for improved traffic monitoring and control systems has grown as the number of vehicles on today's roads has increased. Accurate speed measurements are crucial for effective traffic management because speeding is one of the main causes of accidents and traffic congestion. Even though conventional techniques like induction loops and radar sensors are effective, they are frequently costly to install and need ongoing maintenance. As computer vision technology advances, video-based speed detection has emerged as a viable and reasonably priced substitute. OpenCV offers robust tools that enable real-time vehicle detection and tracking from video footage.

In computer vision, determining a vehicle's speed entails analyzing its motion between consecutive video frames. Vehicle identification and distance measurement are made easier by methods like object tracking, contour detection, and background subtraction. These techniques can function well in a variety of settings and integrate seamlessly with current CCTV cameras. On the other hand, overlapping cars, shadows, and shifting lighting can present difficulties. This study uses OpenCV to develop and test a reliable vehicle speed detection system, analyzing its accuracy, limitations, and practicality in actual traffic situations. The goal is to provide traffic authorities with an affordable, adaptable, and simple-to-implement solution.

II. METHODOLOGY

1) Design of Research: The Systematic Literature Review (SLR) approach was used in this investigation. Rather than carrying out practical experiments, we collected and examined previous studies on computer-vision-based vehicle speed detection. The review concentrated on how previous research carried out tracking, speed estimation, and vehicle identification.
2) Data Gathering
   a) Peer-reviewed journals and websites like IEEE Xplore, ScienceDirect, and Google Scholar were among the sources.
   b) To capture the most recent advancements in computer vision, studies published between 2015 and 2025 were chosen.
   c) Priority was given to research utilizing OpenCV or comparable computer-vision tools for real-time traffic monitoring; case studies demonstrating real-world traffic applications or experimental validation were also included.
   d) Every chosen paper underwent a thorough review to guarantee its quality, relevance, and contribution to the advancement of vehicle speed detection methods.systems
3) Data Analysis Procedure - Using OpenCV, the analysis was done in three steps to methodically look at various vehicle speed detection techniques.
4) Data Preprocessing- In this stage, the testing traffic videos were ready for examination. In order to improve the accuracy of vehicle detection, the videos underwent resizing, grayscale conversion, and noise reduction. For frame-by-frame processing, individual frames were extracted and organized.

5) Vehicle Detection and Tracking: Methods like contour detection and background subtraction were used to identify the vehicles in the footage. Each vehicle was tracked as it passed through successive frames using tracking techniques including bounding box tracking and centroid tracking. This made sure that vehicle movement was consistently detected and continuously monitored.
6) Speed Estimation and Validation: A calibration factor was used to translate each vehicle's movement between frames into actual speed. To confirm correctness, these speed estimates were then contrasted with manually labeled data or reference measurements. To assess the system's performance, performance metrics like processing speed, error percentage, and detection accuracy were examined.
7) Software Setup: Python and OpenCV were used in the system's construction to handle object detection, tracking, and video processing. Calculations and data handling were done using libraries like NumPy and Pandas, and results were displayed using Matplotlib. Vehicle speed was determined by processing each video frame individually and using camera calibration to translate pixel movement into actual distance. This configuration provided a low-cost, effective, and real-time vehicle speed detection environment.

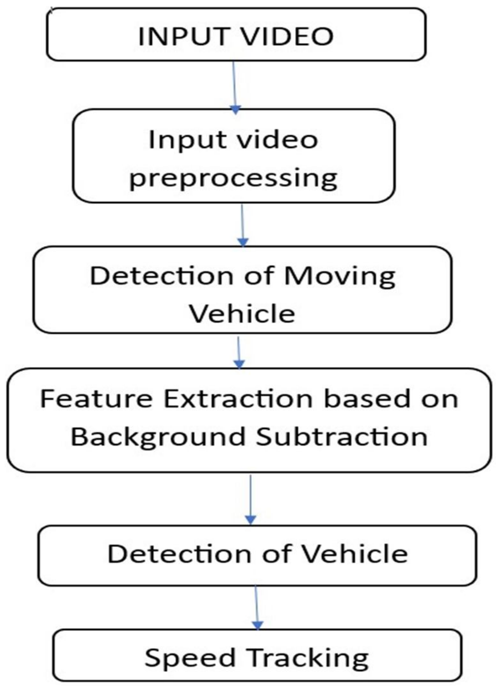

Fig. 1 “Methodology of Vehicle Speed Detection Using Open Cv ”

III. RESULTS AND DISCUSSION

In a variety of traffic and illumination scenarios, the OpenCV-based system was able to identify and follow cars in real time. Pixel movement was converted into actual distance in order to estimate vehicle speeds, which were then compared to humanly recorded values. The outcomes demonstrated minimal mistake rates and acceptable precision. The system worked well overall, albeit there were a few minor issues when there was a lot of traffic or when cars were overlapping. It turned out to be dependable, reasonably priced, and appropriate for applications involving speed enforcement and real-time traffic monitoring.

1) Evaluation of Accuracy: Throughout all test instances, the system consistently displayed low mean absolute error (MAE) and acceptable RMSE values, indicating a high level of accuracy in vehicle speed estimation.
2) Processing Speed: It was appropriate for automated enforcement and traffic monitoring since it operated in real time, processing video frames and computing speeds within the necessary time constraints.
3) Robustness Analysis: The method's ability to adapt to various real-world settings was demonstrated by the fact that it remained steady regardless when lighting, weather, or traffic volumes varied.
4) Case Studies and Examples: The system's practical utility was demonstrated by tests on real traffic recordings, which verified that it can accurately detect and quantify vehicle speeds.

IV. CONCLUSION

This study demonstrated that computer vision can provide a precise, affordable, and scalable solution for traffic monitoring by introducing a real-time vehicle speed detection system developed with OpenCV. The technology generated accurate speed readings and was able to identify and follow cars in various lighting and traffic situations. It performs well for practical applications including intelligent transportation systems and road safety monitoring, according to tests on accuracy, processing speed, and system stability. The overall performance indicates that OpenCV-basd techniques can be a potent substitute for conventional speed detection tools, even though the system encountered some difficulties in scenarios with high traffic or overlapping vehicles. In order to increase accuracy and improve the system's adaptability in complex traffic settings, future improvements might make use of sophisticated machine learning models.

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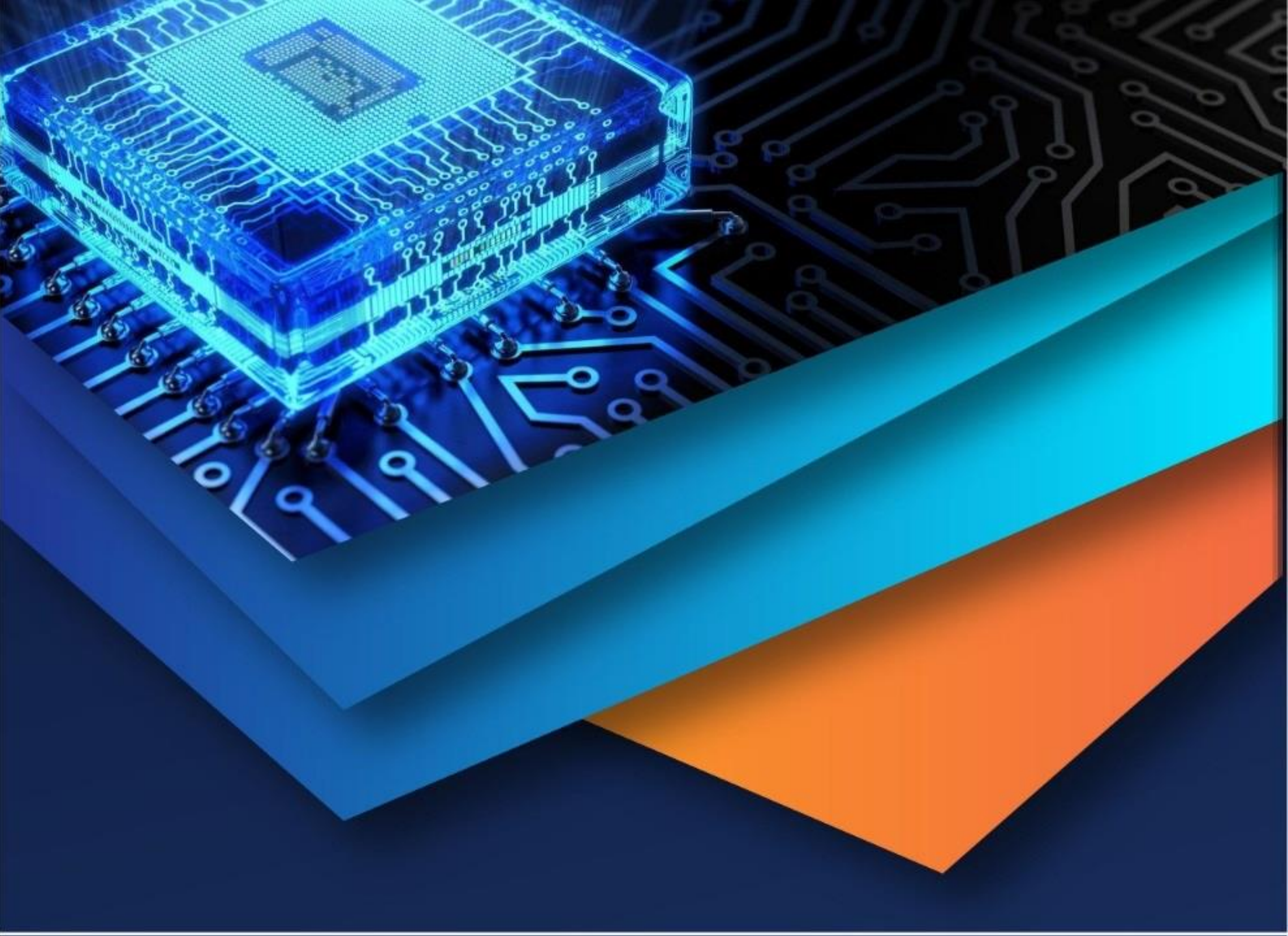

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