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Research Paper

Vehicle Speed Estimation Using OpenCV Framework

Yenuganti Siva Lakshmi[1], Prathigudupu Navya Sri[2*], Siddi Mounika[3], Tata Usha Sri[4], Yallamati Suresh[5]

[1,2,3,4,5]Dept. of Information Technology, Vasireddy Venkatadri Institute of Technology, Andhra Pradesh, India

**Corresponding Author: navyasriprathigudupu@gmail.com*

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Abstract: This article tracks and monitors vehicle speeds by utilizing computer vision techniques and libraries such as OpenCV and dlib. Using video inputs, it effectively recognizes vehicles, records their motions, and determines their speeds by calculating the time interval between frames and the distances they travel. In a CSV file, the gathered speed data is methodically documented and contains relevant details including timestamps, vehicle identities, and observed speeds in kilometers per hour. Another important element of the system is that it enforces a predetermined speed limit and sends out alarm messages to vehicles that go over it. This allows for real-time visual notifications that show the speed value and timestamp. Such a versatile system offers vital support in traffic management, traffic data analysis, and road safety enforcement, among its many possible use cases.

Keywords: OpenCV, Dlib, Data logging, Object detection, Vehicle speed monitoring, Vehicle Speed Estimation.

1. Introduction

The rapid growth in vehicular traffic on our roadways has underscored the need for effective traffic monitoring and speed enforcement systems to ensure road safety and efficient traffic management. One innovative approach to address this challenge is the utilization of computer vision techniques in tandem with libraries like OpenCV and dlib. These technologies have enabled the development of a vehicle speed monitoring and tracking system that can capture, identify, and track vehicles in real time.

1.1 Real-Time Speed Estimation and Data Logging: One remarkable feature of this system is its ability to generate precise speed data in real time. The collected data is systematically organized and recorded in a CSV file. This dataset includes critical information such as unique vehicle identifiers, timestamps, and the corresponding speeds, measured in kilometers per hour. The system not only captures speed information but also ensures that it is meticulously documented, making it a valuable resource for further analysis.

1.2 Utilizing Computer Vision for Vehicle Speed Monitoring: At the core of this system lies the profound utility of computer vision. It empowers the system to analyze video input and proficiently identify vehicles in real time. This initial step sets the stage for comprehensive monitoring as it enables the tracking of vehicles' movements. The integration of computer vision techniques allows the system to estimate the speeds of these vehicles by calculating the distance they travel between each pair of consecutive frames and the associated time elapsed.

2. Literature Survey

Research begins with a crucial literature review, in this section, it outlines initial studies conducted by various researchers relevant to this subject. We will review key articles and expand upon their findings in our subsequent work.

Enhancing Road Safety with Automated Speed Monitoring - M. Gonzalez (2021): This study focuses on enhancing road safety through the implementation of automated speed monitoring systems. The problem addressed is the need for accurate speed estimation and real-time alerting when speed limits are exceeded.

A Comprehensive Survey of Vehicle Speed Monitoring Systems -A. Patel(2020): This survey paper provides an overview of various vehicle speed monitoring systems, highlighting their strengths and limitations. It identifies the need for advanced systems that combine computer vision and machine learning to enhance speed monitoring accuracy.

Real-time Estimating Vehicle Speed with Visual Analysis - Smith.J (2019): This paper explores the development of a real-time system for estimating vehicle speed using computer vision techniques. The primary challenge addressed is the accurate and efficient calculation of vehicle speeds using image processing and tracking methods.

3. Existing System

Real-time vehicle speed estimation is accomplished through video input, with speed data displayed atop detected vehicles. The focus is solely on speed monitoring and straightforward data visualization, streamlining traffic analysis and management. The following features of existing system includes:

Video-Based Vehicle Speed Estimation: This system analyzes video input to estimate the speed of vehicles. It employs computer vision techniques to calculate and display vehicle speeds.

Real-Time Speed Display: The system provides real-time speed information directly on the video frame. Speed values are presented at the top of each detected vehicle as they move through the video.

Non-Alert Speed Monitoring: Unlike alert-based systems, this solution focuses on monitoring and reporting vehicle speeds without issuing alerts for speed limit violations.

Streamlined Data Visualization: It simplifies data presentation by directly overlaying vehicle speeds on the video frame. This approach offers a clear and visual means of speed information.

Practical Traffic Analysis: The system enhances traffic analysis by providing a visual representation of vehicle speeds. This data can be valuable for various purposes, including traffic management and research.

4. Proposed System

The proposed system utilizes advanced technology to monitor and log vehicle speeds in real-time. It employs vehicle detection, dynamic tracking, and real-time speed display. Estimated speeds are overlaid on the video, and data is logged in a CSV file. The system provides a clear visual representation of speed information, and it's non-intrusive, leaving speed enforcement to external processes. It's a valuable tool for traffic analysis and management. The key characteristics of proposed work could involve:

Real-time Speed Estimation: This system is designed for real-time vehicle speed estimation using video input. It employs computer vision techniques and object tracking to continuously monitor and estimate the speed of vehicles in a video stream. The calculated speeds are directly displayed on the video frame.

Dynamic Object Tracking: The system utilizes object tracking to assign unique identifiers to detected vehicles, allowing for accurate speed calculations. It tracks vehicles as they move through video frames, maintaining a comprehensive record of their positions and velocities.

Speed Limit Monitoring: The system includes the ability to set a predefined speed limit, and it visually indicates when a vehicle exceeds this limit. This feature enhances traffic monitoring and safety enforcement, making it a valuable tool for traffic management.

Data Logging and Visualization: The system logs speed data, including vehicle identifiers, timestamps, and speed measurements, into a CSV file. Simultaneously, it visually displays the estimated speeds on the video frame, providing valuable insights for traffic analysis and management.

Practical Traffic Analysis: With a focus on real-time speed estimation and data visualization, this system simplifies the process of assessing vehicle speeds. It serves as a practical tool for traffic analysis, offering a clear and non-intrusive means of monitoring vehicle speeds in various traffic scenarios.

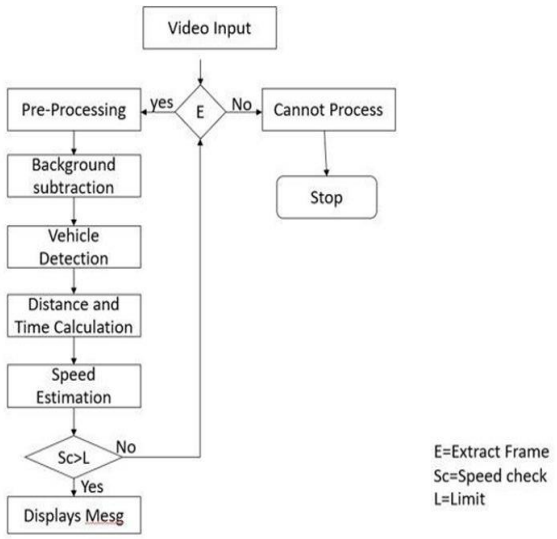

Figure- 1. Proposed system with Vehicle Speed Estimation.

5. Implementation

The implementation of vehicle speed estimation follow these steps:

Import Libraries: The necessary Python libraries and modules are imported. cv2 from OpenCV is used for image and video processing, dlib for object tracking, math for mathematical calculations, and datetime for working with timestamps.csv is imported for writing data to a CSV file.

Load Classifier and Video File: In this it loads a pre-trained vehicle classifier using the car Cascade variable, which is crucial for detecting vehicles in the video. The cv2.VideoCapture function is used to open a video file named "vehicle1.mp4" for processing.

Constants and CSV Initialization: The important constants such as the video dimensions (WIDTH and HEIGHT) and the speed limit (SPEED_LIMIT) are defined. These values are used throughout the code for video processing and speed calculation. Additionally, a CSV file (speed_log.csv) is initialized for data logging.

CSV File Handling: The code handles the CSV file by first ensuring it's empty (if it already exists) and then opening it in append mode. The CSV header, including "Vehicle ID," "Timestamp," and "Speed (km/h)," is written to the file to describe the data format.

Speed Estimation and Tracking Functions: Two essential are defined. The 'estimate Speed' function calculates the speed of a vehicle based on its position in successive video frames. The 'trackMultipleObjects' function is responsible for tracking multiple vehicles, performing object tracking, and estimating their speeds.

Object Tracking Loop: Inside the 'trackMultipleObjects' function, a loop processes each frame of the video. It manages object tracking using dlib's tracker, detects vehicles in the video frames, and calculates their speeds. Speed violations are checked against the speed limit.

Display and Save Results: The presentation of the video with annotated information, such as vehicle speed and timestamp. It also saves the processed video to an output file, "outTraffic.avi." The program allows for user interaction through the 'cv2.waitKey' function, which waits for a user to press the 'ESC' key to exit the program.

6. Results and Discussion

Implementing proposed system provides clear representation of vehicle speed information and it uses computer vision to monitor and log vehicle speeds. The following distinct outputs are shown below:

Vehicle Detection: In the video frames, vehicles are being successfully detected using the pre-trained classifier. The detection process involves identifying the presence of vehicles within the frames, and the results are used for further analysis and tracking.

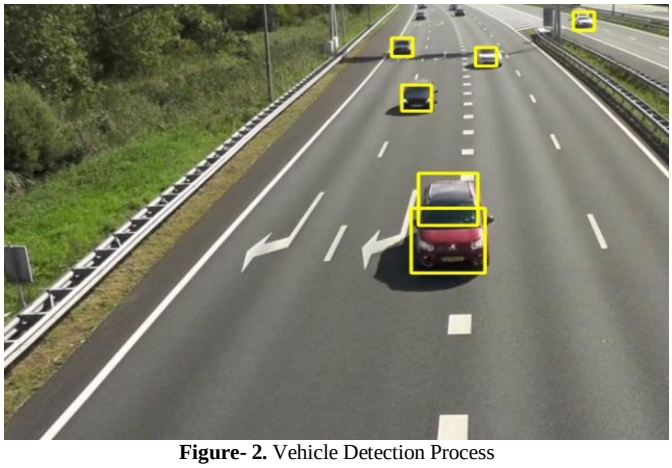

Figure- 2. Vehicle Detection Process

Speed Estimation for Detected Vehicles: The video frames are used to estimate the speed of each detected vehicle. This speed estimation process calculates vehicle speeds based on their positions in consecutive frames, providing real-time speed analysis.

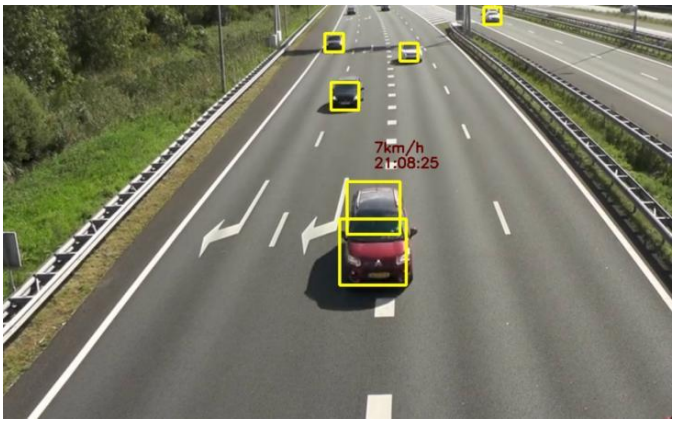

Figure- 3. Vehicle Detection With Speed

Speed Monitoring and Alerts: Within the system, the speed of each vehicle is estimated, and an alert message is displayed when a vehicle exceeds the defined speed limit. This figure illustrates the speed monitoring and alert mechanism in place for effective traffic management.

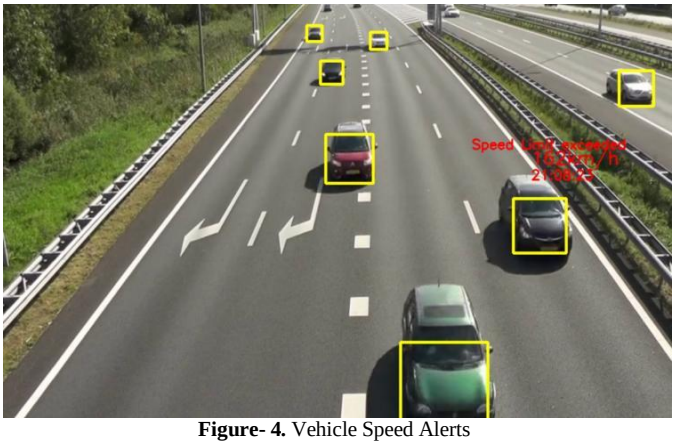

Figure- 4. Vehicle Speed Alerts

CSV Output: In this system, crucial data including vehicle IDs, timestamps, and recorded speed measurements are meticulously logged into a CSV file. This information serves as a valuable resource for traffic analysis and management, enabling authorities to monitor vehicle behaviours, identify speed violations, and make informed decisions to enhance road safety and traffic efficiency.

Vehicle ID	Timestam	Speed (km/h)
6	14:10:56	14
6	14:10:56	14
6	14:10:56	14
6	14:10:56	14
6	14:10:57	14
6	14:10:57	14
6	14:10:57	14
6	14:10:57	14
6	14:10:57	14
6	14:10:57	14
6	14:10:57	14
6	14:10:57	14
6	14:10:57	14
6	14:10:58	14
6	14:10:58	14
6	14:10:58	14
6	14:10:58	14
6	14:10:58	14
6	14:10:59	14
10	14:11:01	7
6	14:11:01	14
10	14:11:01	7
6	14:11:02	14
10	14:11:02	7
10	14:11:02	7
10	14:11:02	7
10	14:11:02	7
10	14:11:02	7
12	14:11:02	0
10	14:11:02	7
10	14:11:03	7
12	14:11:03	14
10	14:11:03	7
12	14:11:03	14
10	14:11:03	7
12	14:11:03	14
10	14:11:03	7
12	14:11:03	14
10	14:11:03	7
12	14:11:03	14
11	14:11:04	7
12	14:11:04	14
5	14:11:04	58
10	14:11:04	7
11	14:11:04	7
12	14:11:04	14
5	14:11:04	58
10	14:11:04	7
11	14:11:04	7
12	14:11:04	14
5	14:11:04	58
10	14:11:04	7
11	14:11:04	7
12	14:11:04	14
5	14:11:04	58
10	14:11:04	7
11	14:11:04	7

Figure- 5. CSV Data logging.

7. Conclusion and Future Scope

The video-based vehicle speed estimation system offers an efficient and non-intrusive solution for real-time speed monitoring. By analyzing video footage, the system estimates the speeds of vehicles with precision, eliminating the need for physical sensors on the road. It can simultaneously track multiple vehicles, making it adaptable to diverse traffic scenarios. The recorded data, including vehicle IDs, timestamps, and speed measurements, provides valuable insights for traffic analysis and management. Traffic engineers can utilize this information to understand traffic patterns, identify congestion hotspots, and ensure compliance with speed limits.

Future enhancements could take this system to the next level. Advanced analytics, such as traffic density analysis, can help in optimizing traffic management and road planning by providing a deeper understanding of traffic flow throughout the day. Integrating machine learning models for vehicle detection and tracking can improve speed estimations, especially in varying road and weather conditions. This system's potential extension into smart traffic management systems, complete with automated reporting, has the potential to revolutionize traffic control. It can enable more comprehensive and effective measures for safer and more efficient roadways, with the ability to adapt to real-time traffic dynamics and enhance the overall quality of urban mobility

Conflict of interest

There are no conflicts of interest, according to the authors. None of the writers have any personal or financial relationships to groups or companies that might be interpreted as having influence over the study. There are no conflicting interests to disclose, and the research is self-funded.

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Author's Contribution

The success of the Vehicle Speed Estimation using OpenCV Framework was achieved through the combined efforts of multiple authors, each of whom made unique and valuable contributions.

Author 1:

- Developed the core algorithm for real-time vehicle speed estimation using computer vision techniques.
- Implemented vehicle tracking and estimation of speed by calculating distances between vehicle positions in consecutive frames.
- Utilized OpenCV's car detection classifier and Dlib's correlation tracker for efficient vehicle tracking.

Author 2:

- Designed and implemented a data logging system to record crucial information, including vehicle IDs, timestamps, and speed measurements.
- Ensured the data was organized and stored in a CSV file, making it suitable for subsequent traffic analysis.
- Contributed to the analysis of recorded data, providing valuable insights into traffic patterns, congestion areas, and speed limit violations.

Author 3:

- Integrated the various system components, including vehicle tracking, speed estimation, and data logging, into a cohesive and user-friendly solution.
- Designed and implemented a user interface for visualizing real-time speed information and alert messages on the video frames.
- Collaborated with other authors to ensure the seamless operation of the system and a smooth user experience**.**

Author 4:

- Took responsibility for documenting the system's code and functionality, making it comprehensible and maintainable for future users and developers.
- Participated in the optimization of the system's performance, ensuring that it can handle real-time traffic scenarios efficiently.
- Played a key role in fine-tuning the system's responsiveness to changing traffic conditions, contributing to its overall effectiveness.

Author 5:

- The research benefitted significantly from the guidance and expertise provided by mentors. The collaborative work of all authors was essential in bringing this project to fruition. Our multidisciplinary approach enriched the data examination and elevated the research's overall quality.

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