ENHANCED TRAFFIC SURVEILLANCE SYSTEM: A YOLO BASED SPEED ESTIMATION AND VEHICLE ENUMERATION.

#1 B. Balaji, #2 G. Sindhu, #3 A. Nithin Kumar Reddy, #4 Ms. A. Mounika Rajeswari

[1,2,3] UG Student, Department of CSE, CMR College of Engineering & Technology, Hyderabad, Telangana, India

[4] Assistant Professor, Department of CSE, CMR College of Engineering & Technology, Hyderabad, Telangana, India

Corresponding Author: A. Nithin Kumar Reddy, nithinreddy1572@gmail.com

***Abstract*— Modern urban environments face complex challenges in traffic management and safety. This project aims to develop an intelligent and efficient traffic monitoring system capable of enhancing road safety, enforcing traffic regulations, and providing valuable insights for traffic management authorities. This project introduces a comprehensive traffic monitoring and management system that leverages the YOLO (You Only Look Once) object detection algorithm. The system addresses critical aspects of traffic control including speed estimation and vehicle counting within a single integrated pipeline. Speed estimation refers to the process of calculating the velocity of vehicles in real-time as they traverse a monitored area. Speed estimation, a cornerstone of traffic monitoring, is executed using advanced optical flow and tracking techniques empowered by YOLO. The system calculates vehicle speeds in real time, aiding in the identification of speed violations and the optimization of traffic flow. Real-time vehicle counting using YOLO is seamlessly integrated into the pipeline. The vehicle counts include incoming and outgoing provide valuable insights for traffic authorities, aiding in informed decisions about road capacity and congestion management.**

Keywords — Integration, Traffic monitoring, YOLO applications, Speed estimation, Vehicle counting, Pipe lines, Speed estimation.

I. INTRODUCTION

In contemporary urban environments, the management of traffic and ensuring into a multifaceted challenge. The exponential growth in the number of vehicles on the road, coupled with the dynamic nature of urban traffic, has given rise to a range of interconnected issues. These include a high frequency of traffic accidents, widespread speed violations, recurring congestion, and a pressing need for data-driven insights in traffic management. The fundamental problem at the heart of this project lies in the limitations of existing traffic monitoring and management systems. These systems typically lack the sophistication and comprehensiveness required to address the intricate web of issues that modern urban traffic presents.

The projects primary challenge is to overcome the limitations of existing traffic monitoring and management systems. The need for a novel solution that combines real-time speed estimation, vehicle counting, traffic regulation enforcement, seamless data integration, scalability, and adaptability is imperative. This challenge calls for innovative technological interventions to create a system capable of transcending the constraints of traditional traffic management, offering a comprehensive approach that proactively addresses the multifaceted issues of modern urban traffic. This project aims to develop a system that enhances road safety, reduce congestion, minimizes accidents, and empowers traffic management authorities with the tools they need to make informed decisions.

II. RELATED WORK

In the quest for innovation and efficiency, modern projects frequently rely on existing solutions as fundamental building blocks for development. This approach not only recognizes the expertise and advancements of those who came before us but also nurtures a collaborative ecosystem where ideas can evolve and confront new challenges. In our project, we wholeheartedly embrace this ethos, conscientiously integrating elements from existing solutions to enrich our endeavor. These existing solutions serve as guiding lights, offering insights and frameworks that shape the direction of our project.

A. Vehicle speed detection using image processing.

Image processing has been widely applied to traffic analysis for a variety of purposes. As traffic research field is very wide and it has many goals that include detection of queue, detection of incident, classification of vehicles, and counting vehicles. One of the most important of these purposes is to estimate the speed of a vehicle, a vehicle. Traffic congestion poses lot of problems for people. Because of this, many accidents occur. To reduce this problem, new approach has been developed for estimating the speed of vehicle. A radar technology was used to determine the speed on highways. But it has a disadvantage of high cost. Then a lidar detector was designed to detect the infrared emissions of law enforcement agencies lidar speed detection devices and warn motorists that their speed is being measured. Its disadvantage is it has to be held or placed at a static point. These drawbacks of speed detection techniques motivated to develop new technique for that purpose.

B. Implementation of vehicle counting and traffic congestion detection using YoloV3.

Intelligent vehicle detection, classification, and counting are becoming increasingly important in the field of highway management. This work is carried out to detect and classify the vehicles using the OpenCV module from Python which performs image processing and the pre-trained yolov3 algorithm which performs the detection and classification of vehicles on the images and videos. And later based upon the number of vehicles detected we predict the traffic congestion. This project has dual functionality which includes the prediction of traffic congestion mentioned above and also includes tracking of the vehicles, i.e. giving unique IDs to individual vehicles and counting those individual vehicles.

C. **Intelligent traffic system using machine learning techniques.**

Urban planning plays a crucial role in ensuring effective traffic management, as traffic-related issues like congestion, accidents, and delays can have significant negative impacts on the economy, society, and environment. However, with the rapidly growing global population, managing traffic is becoming increasingly difficult. To address the problem of traffic management, the authors of a recent study proposed the use of machine learning (ML) technology to automate traffic management and aid ambulances in navigating through heavy traffic. ML involves developing algorithms that can learn from data and improve over time. The authors used a variety of algorithms, databases, and mathematical computations to create traffic management systems that can handle high levels of traffic. They also implemented object detection techniques and processed photos and videos using Python, a popular programming language.

III. METHODS AND DISCUSSIONS

A. ***High-level methodology***

The project's methodology unfolds with meticulous attention to detail across several critical stages. Firstly, in Data Acquisition and Preprocessing, the video is processed for noise. This involves not only ensuring the video clarity but also adjusting its parameters for optimal clarity.

Through this setup, individual frames are extracted from the continuous video stream, meticulously ensuring a suitable frame rate to capture the dynamics of traffic effectively. To prepare this data for analysis, various preprocessing techniques are employed, such as resizing and normalization. These steps are crucial to standardize the data and make it compatible with subsequent stages of the process.

Moving on to Vehicle Detection, the focus shifts to leveraging cutting-edge machine learning models, specifically pre-trained variant YOLOv8 which excel in detecting and localizing vehicles within images. These models are meticulously optimized for vehicle detection, ensuring high accuracy and efficiency.

Each frame from the video stream is fed into these models, which then output bounding boxes and class labels corresponding to the identified vehicles. To refine these detections and eliminate redundancy, sophisticated algorithms like non-maximum suppression are applied, ensuring that only the most pertinent vehicle detections are retained.

The subsequent stage, Vehicle Tracking, introduces the utilization of advanced computer vision techniques, particularly the optical flow algorithm. This algorithm facilitates the robust tracking of distinctive features within the detected bounding boxes across consecutive frames of the video stream. By leveraging motion vectors derived from optical flow analysis, the trajectories of vehicles are estimated, providing crucial insights into their movement patterns and behaviors within the traffic scene.

As the project progresses, attention turns to Vehicle Counting, where the primary objective is to accurately quantify the flow of vehicles through the monitored area. This is achieved by strategically defining virtual counting lines across the traffic lanes and implementing algorithms to track the crossing of these lines by vehicle trajectories. Through meticulous analysis, separate counters can be established for each direction of traffic, ensuring comprehensive monitoring and analysis capabilities.

Speed Estimation emerges as another pivotal aspect of the project, requiring the integration of geometric and temporal analysis techniques. By leveraging the known parameters of the bounding box coordinates of vehicles across frames, the distance traveled by each vehicle is calculated with precision. Coupled with the determined time intervals between frames, derived from the video frame rate, the speed of vehicles is estimated using fundamental kinematic principles, forming the basis for insightful analysis of traffic dynamics.

Ultimately, the culmination of these intricate processes is manifested in the Output and Visualization stage, where the project's findings are presented in an intuitive and comprehensible manner. Real-time updates on vehicle counts and estimated speeds are displayed prominently, providing immediate insights into the traffic conditions.

Moreover, to facilitate deeper understanding and validation of the results, visual overlays such as bounding boxes, trajectories, and speed information are superimposed onto the video stream. This not only enhances the interpretability of the data but also offers a tangible means of verifying the accuracy of the analysis, thus ensuring the robustness and reliability of the project's outcomes.

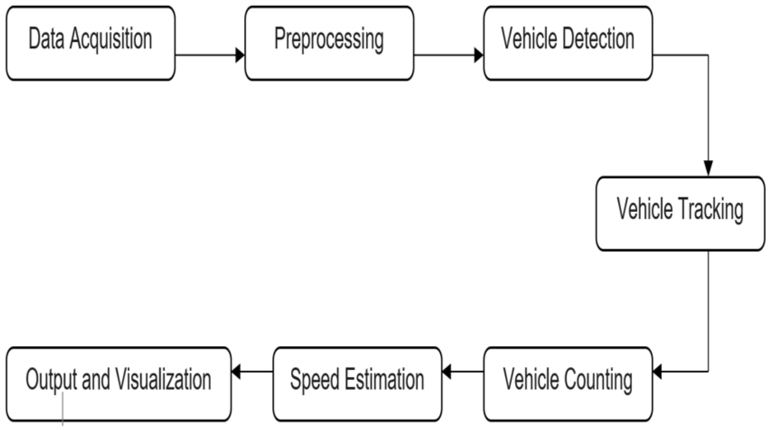

Fig. Architecture of the Model

B. *YOLO*

YOLO, or "You Only Look Once", is a game-changer in object detection. This powerful algorithm in computer vision excels at finding and classifying objects in images and videos in real-time. Unlike older methods that require multiple steps, YOLO performs both tasks simultaneously, making it incredibly fast. This speed, coupled with high accuracy, makes it perfect for real-world applications like self-driving cars and video surveillance.

Despite its speed, YOLO isn't perfect. It can struggle with small objects, overlapping objects, and certain challenging scenarios. Additionally, while accurate, it may not be as precise as other algorithms that prioritize precision over speed. However, its strengths outweigh its limitations, making it a valuable tool for object detection across diverse fields. From autonomous vehicles and robotics to medical imaging and security, YOLO continues to evolve and push the boundaries of computer vision.

IV. RESULTS AND DISCUSSIONS

The exploration of existing solutions sheds light on the diverse approaches and methodologies available to enhance the capabilities of integration of multiple models.

A. **Vehicle speed detection using image processing.**

Approach:

In this approach 2 extracted images are selected to apply the motion estimation process in the developed MATLAB algorithm. Standalone images is segmented into 16×16 small blocks using the division technique. Then the blocks are extracted from video coding to be compared with its respective image in current image and the previous image. The blocks are compared to detect the changes in pixels which is used to estimate the velocity of the respective moving vehicle. The successive steps are :

Video image processing: Block extraction and subtraction technique is applied into region of interest instead the complete video sequence or images.

Vehicle velocity estimation: Once the image is extracted and segmented into blocks, the motion vector technique is applied to calculate the pixels changes among the two blocks to measure the speed of the moving vehicle. The motion vector is applied with the vector valued function to demonstrate the vehicle speed detection algorithm for the video from surveillance cameras.

Vector-valued function for vehicle motion velocity: This is to verify the respective number of changes in blocks within two consecutive images. The input of a vector valued function may be a scalar or a vector where as the output is a vector. When vector valued function is applied, the vehicle speed can be determined.

Digital Video Recorder (DVR) card setting estimation: If we want to associate the sequence images with vector valued function algorithms, a digital video recorder (DVR) card is required. It is installed to capture the video from the camera and save into a particular folder in the hard drive.

Benefits:

Non-Intrusive, Cost efficient, versatility, High Accuracy, Real time monitoring.

B. **Implementation of vehicle counting and traffic congestion detection using YoloV3:**

Approach:

Takes a frame from the whole video as input. It is passed through the first convolutional layer with arbitrary padding and filter size(kernel). The size of the image might get shrunk based on the padding value and filter used. When using the pre-trained YOLOv3 model, the weights and biases of different layers are already set to detect the desired vehicles in the given frame. As the image passes through the YOLOv3 model, the activations are generated after each layer based on the pixel intensities of the frame and the neural network's weights and biases. These activations are sent as input to the next layer and the next layer in the next step and so on. Finally, in the last layer, the activations in terms of probabilities are evaluated based on all those previous different types of layers (convolutional, pooling, fully connected).

Benefits:

Accurate vehicle counting, Real time processing, High speed interference, versatility, Object localization.

C. **Intelligent traffic system using machine learning techniques:**

Approach:

Collect and annotate a diverse traffic dataset with bounding boxes. Choose between YOLO for vehicle counting. Preprocess data to suit the chosen model's input format. Train the selected model on annotated data. Validate and test model performance on new data. Implement post-processing (e.g., NMS) for accurate counting (YOLO). Deploy the model for real-time inference. Monitor accuracy and retrain as needed. Address privacy and ethical concerns. Scale the system for multiple cameras. Plan for regular system maintenance and monitoring.

Benefits: Real time detection, Single stage detection, God performance on small objects.

Comparison:

Accurate Vehicle counting: The integration of yolo for detection and optical flow for tracking could lead to highly accurate counts, minimizing error rates compared to traditional methods.

Reliable speed estimation: Speed estimations derived from distance and time calculations combined with robust tracking should offer reliable values, valuable for traffic analysis and potential enforcement applications.

Real time data acquisition: The system's ability to process the video streams in real time provides timely insights into traffic patterns and enables immediate responsiveness to changing conditions.

Visualized Insights: Overlaying tracking information and speed measurements on the video stream offers valuable visual feedback for operators and researchers to observe traffic flow dynamics and individual vehicle behavior.

Data-driven Analysis: Collected data can be further analyzed to identify peak traffic times, understand individual vehicle behavior, and inform traffic flow optimization strategies.

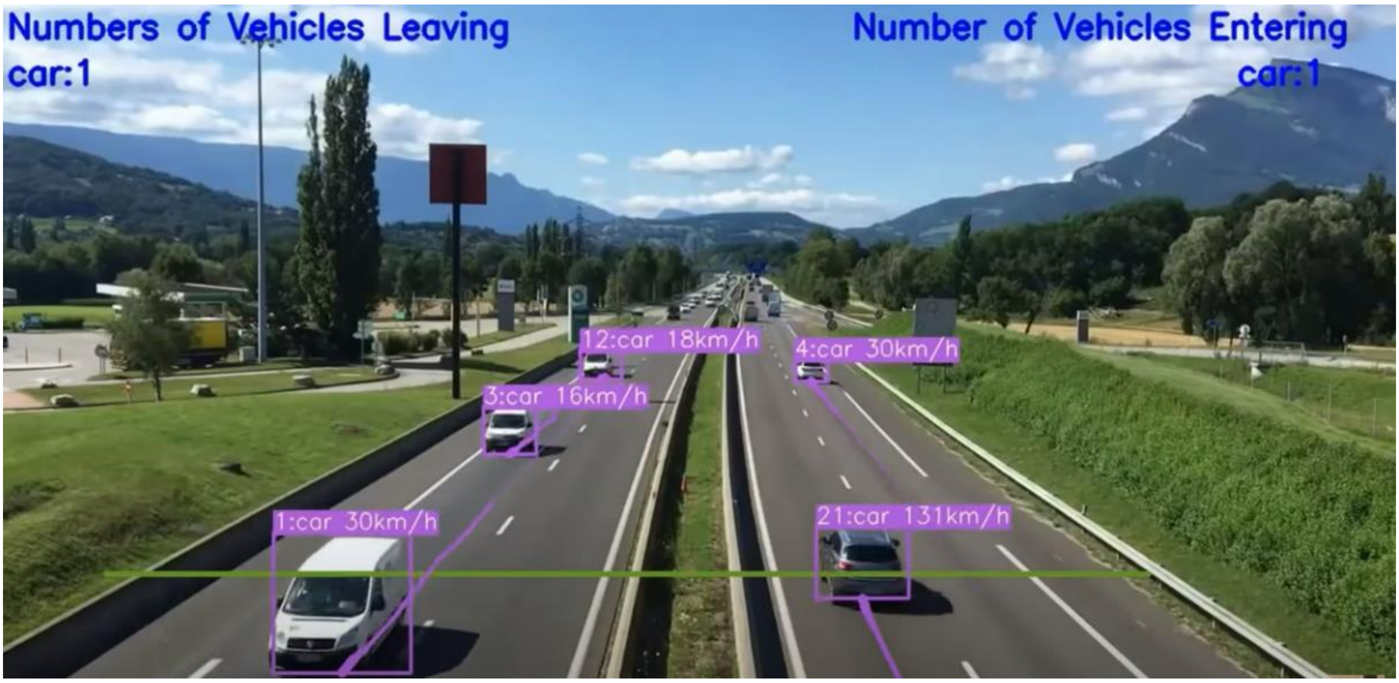

Fig. Detection image 1

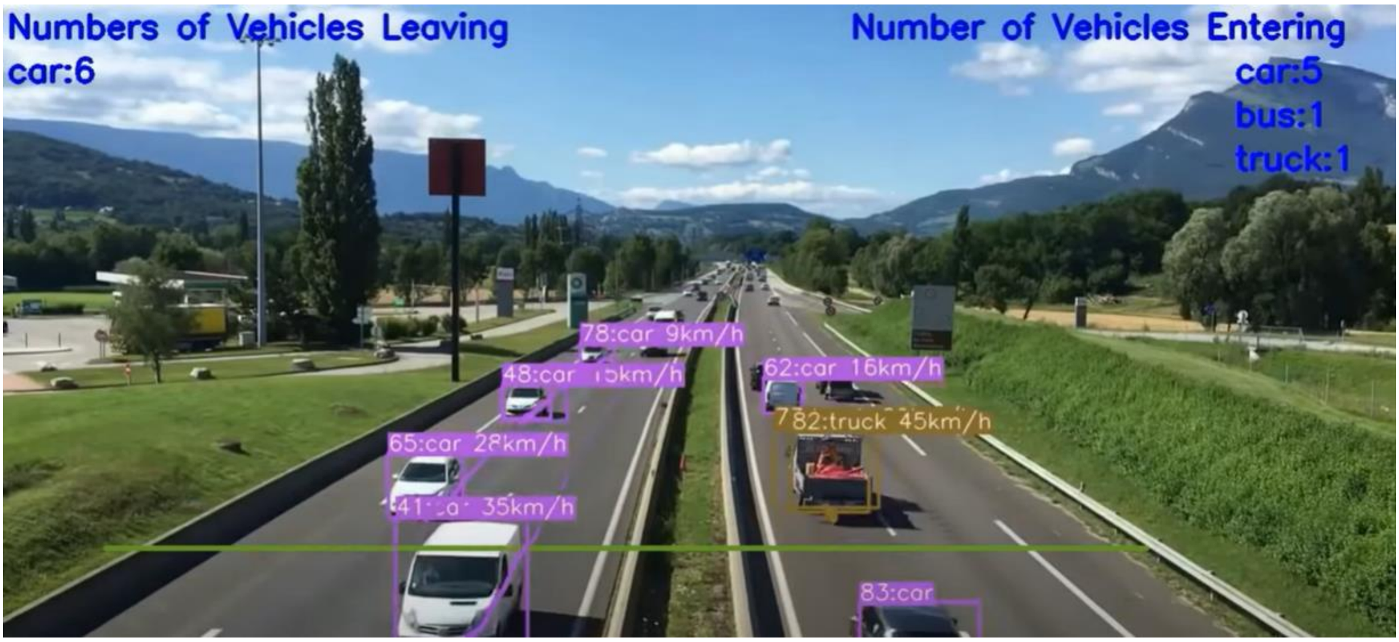

Fig 2: Detection image 2

V. CONCLUSION

This project represents a comprehensive exploration into the synergy between YOLO object detection and optical flow algorithms, with the primary aim of facilitating vehicle counting and speed estimation in traffic scenarios. By combining these advanced technologies, the project endeavors to achieve a multifaceted approach to traffic analysis, encompassing both quantitative metrics and qualitative visual insights.

The integration of YOLO object detection enables precise identification and localization of vehicles within the traffic scene. Leveraging state-of-the-art deep learning techniques, YOLO facilitates the accurate detection of vehicles of various shapes, sizes, and orientations. This capability forms the cornerstone of the project's ability to generate highly accurate vehicle count data, providing stakeholders with a reliable foundation for traffic analysis and management.

Moreover, the incorporation of optical flow algorithms enhances the project's analytical capabilities by enabling robust feature tracking and motion estimation. By tracking key points within the detected vehicle bounding boxes across consecutive frames, the project can discern the trajectories of individual vehicles with high fidelity. This not only contributes to the accuracy of vehicle counting but also enables the estimation of vehicle speeds based on their motion patterns over time.

The potential benefits of this integrated approach are manifold. Firstly, the project promises to deliver highly accurate vehicle count data, which is essential for traffic management, urban planning, and infrastructure development. By providing stakeholders with precise insights into traffic volume and flow patterns, the project empowers decision-makers to implement targeted interventions to alleviate congestion and enhance safety on roadways.

Furthermore, the reliable speed estimation capabilities afforded by the project offer valuable insights into traffic dynamics and behavior. By quantifying the speed of individual vehicles, as well as aggregating speed data across the traffic network, stakeholders can identify potential bottlenecks, assess the impact of interventions, and optimize traffic flow for efficiency and safety.

Beyond its immediate applications, the project holds promise for integration with existing traffic management systems and further data analysis efforts. By seamlessly integrating with established infrastructure and workflows, the project can extend its utility and impact within real-world traffic environments. Additionally, ongoing data analysis and refinement of algorithms offer exciting possibilities for advancing the state-of-the-art in traffic monitoring and research.

In conclusion, this project represents a significant step forward in the quest for smarter and safer transportation systems. By harnessing the power of AI-powered solutions, such as YOLO object detection and optical flow algorithms, the project lays the groundwork for a powerful tool in traffic monitoring and analysis. With its potential to deliver accurate vehicle count data, reliable speed estimation, and valuable visual insights, the project stands poised to make a meaningful contribution to the enhancement of urban mobility and road safety.

VI. REFERENCES

[1] Ammar Awni Abbass University of Baghdad "Estimating vehicle speed using image processing", AL-Mansour Journal / No.14/ Special Issue (Part Two) 2010.

[2] Osman Ibrahim, Hazem ElGendy, and Ahmed M. ElShafee, Member, IEEE " Speed Detection Camera System using Image Processing Techniques on Video Streams ", International Journal of Computer and Electrical Engineering, Vol. 3, No. 6, December 2011.

[3] S. S. S. Ranjit, S. A. Anas, S. K. Subramaniam, K. C. Lim, A. F. I. Fayeez, A. R. Amirah," Real-Time Vehicle Speed Detection Algorithm using Motion Vector Technique ", Proc. of Int. Conf. on Advances in Electrical & Electronics 2012.

[4] Siddharth Jhumat," Vehicle Speed Estimation in Accident Prone Areas using Image Processing ", International Journal of Advanced Research in Computer and Communication Engineering Vol. 3, Issue 5, May 2014.

[5]https://www.researchgate.net/publication/327337312_A_Review_on_Vehicle_Speed_Detection_using_Image_Processing.