A Project report on

Integrated Traffic Monitoring System using YOLO for Speed Estimation and Vehicle Counting

A Dissertation submitted to JNTU Hyderabad in partial fulfillment of the academic requirements for the award of the degree.

Bachelor of Technology

in

Computer Science and Engineering

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CERTIFICATE

This is to certify that the Major Project Phase I report entitled **"Integrated Traffic Monitoring System using YOLO for Speed Estimation and Vehicle Counting"** being submitted by A.Nithin Kumar Reddy(20H51A0504), Balaji Bhandare(20H51A0531), Gangula Sindhu(20H51A0592) in partial fulfillment for the award of **Bachelor of Technology in** **Computer Science and Engineering** is a record of bonafide work carried out his/her under my guidance and supervision.

The results embodies in this project report have not been submitted to any other University or Institute for the award of any Degree.

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ABSTRACT

Modern urban environments face complex challenges in traffic management and safety. The primary aim of this project is 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.

Our system aggregates data from diverse sources, including cameras and other relevant data streams. This integration enables a comprehensive view of traffic conditions, allowing for better-informed decision-making by traffic management authorities. Real-time Processing: Operating in real-time, our system provides immediate information, enabling rapid responses to traffic incidents, accidents, or congestion. Beyond monitoring, our system also assists in enforcing traffic regulations by identifying and documenting violations. This capability contributes to improved road safety by discouraging risky behavior. The potential benefits of our project are numerous, including reduced accidents, improved traffic flow, reduced congestion, and better-informed traffic authorities. By optimizing traffic management and safety, our system contributes to a higher quality of urban life.

CHAPTER 1
INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

In contemporary urban environments, the management of traffic and ensuring road safety has evolved 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 project's 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. The project aims to develop a system that enhances road safety, reduces congestion, minimizes accidents, and empowers traffic management authorities with the tools they need to make informed decisions. By addressing this problem, the project strives to create urban environments where transportation is not only safer and more efficient but also contributes to an improved quality of life for residents and commuters alike.

1.2 Research Objective

The research objectives of the project are:

- **Development of an Intelligent Traffic Monitoring System**: The main research objective is to design, develop, and implement an intelligent traffic monitoring system that integrates YOLO object detection for real-time traffic management and safety enhancement.
- **Real-time Speed Estimation**: Develop algorithms and techniques to accurately estimate the speed of vehicles in real-time as they traverse monitored areas, with a focus on identifying and addressing speed violations.
- **Real-time Vehicle Counting**: Create a system capable of real-time vehicle counting using YOLO, counting both incoming and outgoing vehicles, to provide essential data for traffic flow management and congestion reduction.
- **Seamless Data Integration**: Develop mechanisms for the seamless integration of data from various sources, such as cameras and other data streams, to provide a unified and comprehensive view of traffic conditions.
- **Traffic Regulation Enforcement**: Implement features and algorithms to identify and document traffic violations, contributing to the enforcement of traffic regulations and overall road safety.
- **Visualization and Reporting**: Create user-friendly graphical interfaces and reporting tools to effectively communicate data and insights to traffic authorities and stakeholders, facilitating data-driven decision-making.

1.3 Project Scope and Limitations

The scope of project is

- **Real-time Speed Estimation**: The project aims to develop algorithms and techniques for real-time speed estimation, emphasizing accuracy and reliability in identifying and addressing speed violations.
- **Real-time Vehicle Counting**: The system will be designed to perform real-time vehicle counting using YOLO, counting both incoming and outgoing vehicles, providing valuable data for traffic flow management and congestion reduction.
- **Scalability and Adaptability**: The system will be designed to be scalable and adaptable for deployment in diverse urban environments, accommodating different road types and traffic conditions.
- **Real-time Processing:** The project will develop the system to operate in real-time, providing immediate responses to traffic incidents, accidents, and congestion, enhancing traffic management and safety.

Limitations

- **Privacy Concerns**: The project must address potential privacy concerns related to data collection and surveillance, ensuring compliance with privacy regulations and ethical considerations.
- **Hardware Limitations:** The effectiveness of the system may be limited by the quality and capabilities of the hardware components, such as cameras and sensors, used for data collection.
- **Resource Constraints**: The project's scope may be limited by budget, time, and resource constraints, which could affect the depth and complexity of system development.
- **Regulatory and Legal Considerations**: The project should consider legal and regulatory factors related to traffic monitoring and data collection, ensuring compliance with relevant laws.

CHAPTER 2
BACKGROUND WORK

CHAPTER 2

BACKGROUND WORK

2.1 Intelligent Traffic System Using Machine Learning Techniques

2.1.1 Introduction

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.

2.1.2 Merits, Demerits and Challenges

Merits

- Real-time detection: YOLO can detect objects, including vehicles, in real-time, making it suitable for applications that require fast processing.
- Single-stage detection: YOLO performs object detection in a single pass, which simplifies the detection process and reduces computational complexity.
- Good performance on small objects: YOLO has shown good performance in detecting small objects, which can be beneficial for detecting vehicles in challenging scenarios.

Demerits

- Accuracy trade-off: While YOLO is known for its speed, it may sacrifice some accuracy compared to slower but more complex detection algorithms.
- Limited generalization: YOLO may struggle with detecting vehicles in challenging conditions such as extreme lighting or occlusions.

Challenges

- Accuracy and Precision: YOLO may not always achieve high accuracy and precision in vehicle counting, especially in challenging conditions such as low light, bad weather, or complex traffic scenarios. Overcoming these challenges to maintain accurate counts is a significant concern.
- Vehicle Occlusion: When vehicles overlap or partially obstruct each other, it can be challenging for YOLO to accurately detect and count them. Accurately handling occlusion scenarios is a common challenge.
- Size and Scale Variation: Vehicles come in various sizes, from motorcycles to trucks, and this size variation can pose challenges for object detection algorithms like YOLO. Ensuring that the system can accurately detect and count vehicles of different sizes is essential.

2.1.3 Implementation of Intelligent Traffic System Using Machine Learning Techniques

- 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.

2.2 Vehicle Counting and Traffic Congestion Detection Using Yolov3

2.2.1 Introduction

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.

2.2.2 Merits, Demerits and Challenges

Merits

- Accurate Vehicle Counting: YOLOv3 provides accurate and efficient vehicle counting, helping traffic management authorities gather reliable data for congestion analysis and road management.
- Real-Time Processing: YOLOv3 is optimized for real-time object detection, making it suitable for live traffic monitoring and congestion detection.
- High-Speed Inference: The model's architecture allows for high-speed inference, enabling it to process video streams from traffic cameras with minimal delay.
- Versatility: YOLOv3 can detect various types of vehicles, including cars, trucks, motorcycles, and buses, making it suitable for diverse traffic scenarios.
- Object Localization: It not only counts vehicles but also localizes their positions, which can be valuable for tracking and analyzing traffic flow.

Demerits

- Resource-Intensive: YOLOv3 is computationally intensive, requiring powerful hardware for real-time processing, which may not be feasible for all deployment scenarios.
- Complex Implementation: Setting up and configuring YOLOv3 for vehicle counting and congestion detection can be complex and may require expertise in deep learning.
- Data Annotation: Annotating large datasets for YOLOv3 training can be time-consuming and may require significant manual effort.
- Accuracy in Challenging Conditions: The model's accuracy can decrease in challenging conditions, such as heavy rain, low light, or extreme weather, which can affect congestion detection.
- Model Maintenance: Continuous model maintenance and retraining may be necessary to adapt to changing traffic patterns and ensure accuracy.

Challenges

- Data Collection: Collecting and annotating diverse traffic datasets to train the YOLOv3 model is labor-intensive and requires a significant amount of data.
- Privacy Concerns: The use of traffic cameras raises privacy concerns, and ensuring compliance with privacy regulations is essential.
- Scalability: Scaling the system for use with multiple cameras and across a large urban area can be challenging, requiring additional infrastructure and optimization.
- Environmental Factors: Handling variations in environmental conditions, such as glare, shadows, and reflections, is crucial for reliable congestion detection.
- Ethical Considerations: Ethical concerns about surveillance, data collection, and data usage should be addressed throughout the project to ensure responsible implementation.

2.2.3 Implementation of Vehicle Counting and Traffic Congestion Detection Using Yolov3

- 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)

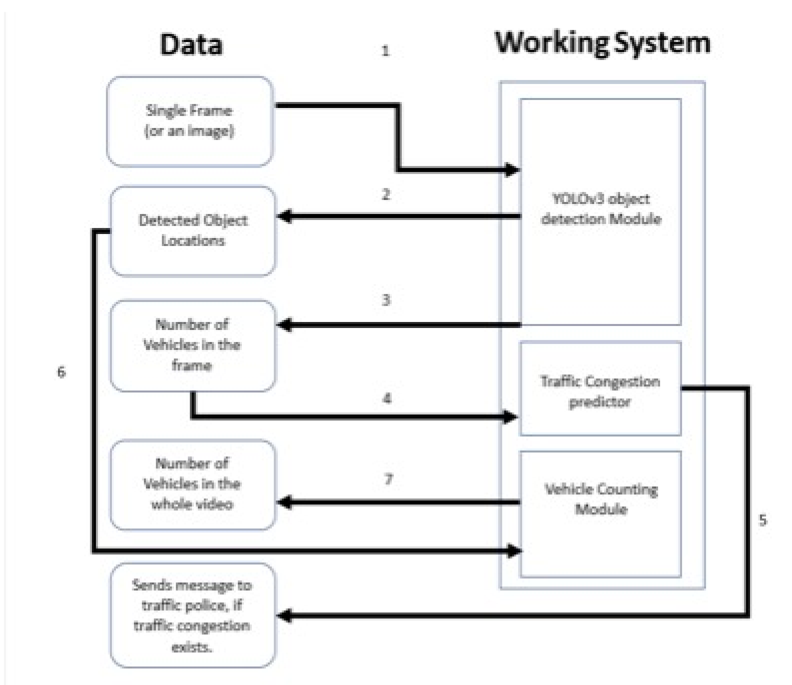

Fig 1.1 Architecture of vehicle counting system

2.3 Vehicle speed detection using image processing

2.3.1 Introduction

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.

2.3.2 Merits, Demerits and Challenges

Merits

- Non-intrusive: Image processing-based speed detection is non-intrusive and does not require physical devices on the road, reducing disruption to traffic flow.
- Cost-Efficient: It can be a cost-effective solution compared to physical sensors, making it suitable for various road types and locations.
- Versatility: Image processing can be applied to various camera types, including CCTV cameras, making it adaptable to existing infrastructure.
- High Accuracy: When properly calibrated and configured, image processing can provide accurate vehicle speed measurements, contributing to road safety.
- Real-time Monitoring: It allows for real-time speed monitoring, enabling rapid response to speed violations and traffic incidents.

Demerits

- Environmental Conditions: Adverse weather conditions, low light, and image obstructions (e.g., fog or rain) can impact the accuracy of speed detection.
- Calibration and Maintenance: Regular calibration and maintenance of cameras are essential for accurate speed measurement, which can be resource-intensive.
- Privacy Concerns: Vehicle speed detection using cameras raises privacy concerns, and appropriate safeguards are needed to protect individuals' privacy.
- Data Storage and Processing: Processing a continuous stream of images from multiple cameras requires significant storage and computational resources.
- Accuracy Variation: The accuracy of image processing can vary based on camera placement, image quality, and the size of vehicles, which may affect results.

Challenges

- Image Quality: Ensuring consistent image quality in varying weather conditions and lighting is challenging, as poor-quality images can impact accuracy.
- Data Annotation: Annotating data for model training and validation can be labor-intensive, involving manual labeling of vehicle positions and speeds.
- Model Training: Training models for speed detection requires extensive datasets and can be computationally intensive, posing challenges for resource-constrained environments.
- Real-Time Processing: Processing images in real time can be resource-demanding, and delays in processing can affect the system's responsiveness to speed violations.
- Legal Compliance: Complying with legal and regulatory requirements for speed enforcement is essential, and legal challenges may arise from inaccuracies.

2.3.3 Implementation of Vehicle speed detection using image processing

- 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

1. Video image processing: Block extraction and subtraction technique is applied into region of interest instead the complete video sequence or images.
2. 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.
3. 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.
4. 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.

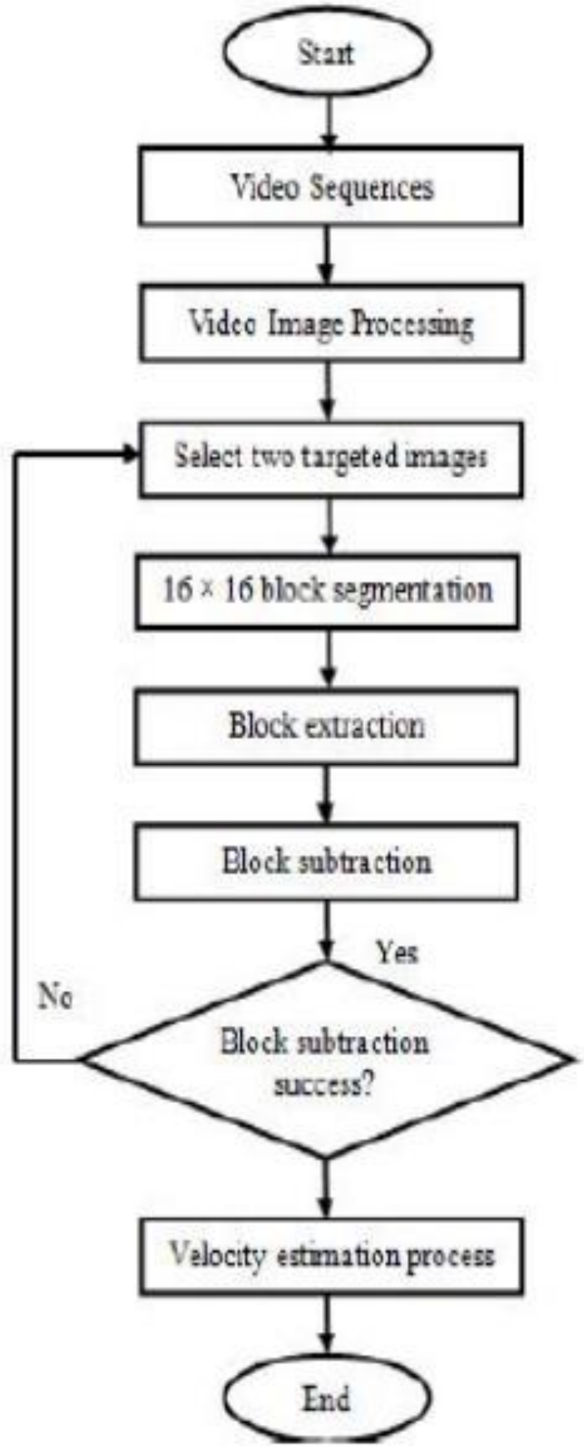

Fig 1.2 Vehicle speed detection algorithm

CHAPTER 3
RESULTS AND DISCUSSION

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Performance metrics

Aspect	**YOLO**	**YOLO v3**
Speed	Real-time processing	Near real-time
Simplicity	Simple architecture	Complex architecture
Resource Efficiency	Low resource usage	Moderate resource usage
Accuracy	Moderate accuracy	Improved accuracy
Multiple scales	Not explicitly designed for multiple scales	Operates at multiple detection scales, better at handling varied vehicle sizes.
Network architecture	Simpler architecture	More complex architecture
Scalability	Suitable for real-time applications	Better scalability for diverse traffic scenarios.
Complexity	Easier to configure	May require more extensive training and fine-tuning

Table 3.1 Performance metrics

CHAPTER 4

CONCLUSION

CHAPTER 4

CONCLUSION

In comparing YOLO (You Only Look Once) and YOLOv3 for vehicle detection and counting, it's evident that both models offer distinct advantages and considerations. YOLO, known for its real-time processing and resource efficiency, is a suitable choice for applications where speed and simplicity are paramount. However, it may exhibit moderate accuracy in more complex traffic scenarios. In contrast, YOLOv3 brings improved accuracy to the table, particularly in challenging situations with varying vehicle sizes. With its ability to operate at multiple detection scales and better scalability, YOLOv3 offers an advantage in scenarios with diverse traffic conditions. Nevertheless, it comes with a slightly reduced real-time processing speed due to its more complex architecture and may require additional computational resources. The selection between YOLO and YOLOv3 for vehicle detection and counting should be made based on the specific demands of the application, striking a balance between speed, accuracy, and available resources.

Image processing techniques implemented as a MATLAB algorithm for vehicle speed detection offer a robust and versatile solution for traffic management and road safety. This approach involves capturing video data from strategically placed cameras, performing preprocessing tasks like resizing and enhancing image quality, and using image processing methods for vehicle detection and tracking. By analyzing the positions of vehicles over time, the algorithm calculates their speeds accurately. With the ability to adapt to various camera setups and road conditions, this method proves its versatility. However, it is essential to address challenges related to environmental factors, camera calibration, and data privacy, while also continuously fine-tuning the system for optimal accuracy.

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GitHub Link

1. https://github.com/Nithin1572/MajorProject