# Customized Deep Learning Technique for Vehicle Detection Along with Speed Estimation

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**Abstract**

The method proposed over here in this paper is a vehicle speed estimation technique on moving vehicle under the cctv camera surveillance. For real-time vehicle detection, the YOLO (You Only Look Once) technique is employed, and the centroid approach is used to estimate vehicle speed. The video frame is converted to grayscale so that it may be processed by the computer as 0 and 1. The brightness of the scale is represented by each number. Then, by looking at these statistics, we train the YOLO Convolutional Neural Network to learn to identify the final detection. YOLO reframes object recognition as a single regression issue by taking the entire image and going directly from image pixels to bounding box coordinates and class probabilities. The next step is to compute bounding boxes (boxes that encompass the objects) using IoU (Intersect over Union) and NMS (non-maximum suppression). The IoU indicates how closely the machine's predicted bounding box fits the bounding box of the real item. However, because of the process, a problem of over-identification with a specific object arises. NMS ensures that the best cell is found among all these bounding boxes. Rather than concluding that a single car in the image has numerous causes, NMS chooses the boxes with the highest likelihood of determining the same vehicle. The vehicle centroid values are calculated after the cars have been detected. The distance traveled by vehicle is calculated using the centroid value. The speed of the vehicle is calculated after sorting out the distance that has been covered by the vehicle.

YOLO is an effective and efficient strategy that epitomizes the spirit of machine learning in the suggested methodology for our vehicle recognition and speed estimation system. YOLO initially trains with 416*416 photographs, then retrains for 30 epochs at a 10-3 learning rate using 416*416 images. After training, the classifier has a top-one accuracy of 99.4% and a top-five accuracy of 99.3%.

**Keywords:** Vehicle detection, Speed estimation, YOLO, CNN, IoU, NMS, Regression, Bounding box, Grayscale, Centroid

## 1. Introduction

### 1.1. Motivation

Vehicles have become an integral part of human society. The transcendence of vehicles from a mere symbol of status to the fundamental need for day-to-day life has been phenomenal. With the insurgence of population, capital, and sophistication in technology, vehicles have become more personal, cost-efficient, and accessible. When the population was sparse, human labor and control were enough to regulate the overall traffic system of the nations which continues to date. But with the rising volume of number of vehicles of all kinds and the increase in density exerting pressure on existing resources, it has become rather impossible for traditional techniques to monitor vehicles.

## 1.2. Problem Statement

This has given rise to various undesirable repercussions with overspeeding being one of the most common criminal acts. Consequently, scores of people lose their life due to vehicle-related accidents directly/indirectly caused by overspeeding each year. [6,7] Hence the need for a smart system to detect the vehicles and monitor their speed. Some facts are:

- It is estimated that more than 1.31 million people die each year due to vehicle crashes and traffic-related accidents which for most of the time are related to overspeeding.
- The United Nations General Assembly has set an ambitious target of reducing the global number of speed-related traffic crashes by 2030 by almost half.
- Road traffic vehicle crashes are a financial burden to a lot of countries.
- Vulnerable road users like pedestrians and traffic personnel are direct victims of these unfortunate accidents.
- The most affected people are from developing and underdeveloped countries.
- Infants, children, and adults who are pillars of a country's fortune are major victims of these crashes.

*Source: WHO (World Health Organization)*

## 1.3. Scope

Because of its non-intrusiveness and ability to collect comprehensive vehicle behavior data, video-based vehicle detection technology is an important aspect of the Intelligent Transportation System (ITS). Based on the YOLO v5 object detection technique and centroid tracker technique, this research provides an efficient video-based vehicle detection system. The method was used to create a stand-alone object recognition and tracking system that identifies vehicles and other objects and centroid tracker estimates speeds on arterial and freeway highways. The suggested video-based vehicle recognition system was created to minimize the need for complicated calibration, to be more robust to contrast fluctuations, and to perform better with low-resolution videos. The algorithm's performance in terms of vehicle detection accuracy and speed was assessed. When compared to a commercial vehicle detection system, the proposed system performs similarly or better since a lot of developers and researchers are engaging more on this technique.

## 1.4. Aim

This research aims to train a YOLO-based system to detect vehicles and estimate the speed of tracked vehicles using a centroid tracker to achieve high accuracy. [1,2,3,4,6,7] YOLO is an algorithm that uses neural networks to provide real-time object detection for effective speed estimation. The centroid tracker then tracks the centroid of detected objects i.e., vehicles. A lot has been done for the sophistication of this technology ever since the rush of machine learning for building intelligent systems, but faster and faster, accurate, and highly effective algorithms have been developed over this period. This research paper aims to contribute to this ever-growing field to offer a different paradigm to the already existing vast academia. The combination of [8,9,11] YOLOv5 and centroid tracker for vehicle detection, tracking, and speed estimation has been rarely used and this research paper offers a unique angle on this subject.

## 1. Literature review / survey

The following table shows the works that have been done over the years in topic or the similar works to the topic.

| YEAR | AUTHOR | TITLE & ARCHITECTURE | DOMAIN & PROBLEM STATEMENT | CONCLUSION & STATEMENT |
|---|---|---|---|---|
| 2016 | [1] Joseph Redmon, Santosh Divvala et | You Only Look Once: Unified, Real-Time Object Detection | You Only Look Once, a quick and simple approach for identifying real-time photographs, was introduced in this study. The model was developed to detect images correctly and rapidly, as well as to discriminate between art and actual photographs. | In contrast to object recognition algorithms like as RCNN, YOLO has created a single integrated architecture for dividing the visual image into bounding boxes and calculating the class probabilities for each frame. This allowed YOLO to complete the task much faster and more accurately. It may also be capable of forecasting artwork with accuracy. |
| 2018 | [2] Chengji Liu et | Object Detection Based on YOLO Network | To construct a general object identification network, Images were degraded using advanced techniques such as noise, blurring, rotating, and cropping. Degraded training sets were used to train the model, | When applied to damaged images, the model trained with standard sets demonstrated poor generalization ability and robustness, according to the experiment. After |

| | | | | |
|---|---|---|---|---|
| | | | which resulted in increased generalization and durability. | that, the model was trained on degraded images, which improved average accuracy. The wide degenerative model's average accuracy for degraded images was shown to be greater than the standard models. |
| 2018 | [3] Wenbo Lan et | Pedestrian Detection Based on YOLO Network Model | The network structure of the YOLO algorithm has been improved and a new network structure has been constructed. YOLOR needs to improve the ability of the network to extract information from the characteristics of pedestrians on the ground by adding a transit layer to the original YOLO network. | The YOLO v2 and YOLO-R network models were assessed using the INRIA data collection's test set. According to the findings, the YOLO-R network model outperforms the YOLO v2 network model. The number of frames detected per second reached 25 frames per second, which met the real time performance requirements. |
| 2018 | [4] Rumin Zhang, Yifeng et | An Algorithm for Obstacle Detection based on YOLO and Light Filed Camera | In the indoor context, an obstacle detection approach is proposed that categorizes and names components in a picture by combining the YOLO object detection technology with a light field camera. | Images of typical obstacles are categorized and used to teach YOLO how to avoid them. Obstacles that you are not interested in are removed by the object filter. The effectiveness of this obstacle detection |

| | | | | |
|---|---|---|---|---|
| | | | | approach is demonstrated using a variety of scenarios, including pedestrians, chairs, books, and more. |
| 2019 | [5] Zhimin Mo1 et | Identification and Detection of Automotive Door Panel Solder Joints based on YOLO | The YOLO algorithm is a real-time method for detecting solder joints in automobile door panels. Provides the type and location of solder joints. This task uses YOLO techniques to better identify small solder joints using multi-level predictions, predictions on feature maps of various sizes, and YOLO techniques that combine prediction results to obtain results. | The proposed YOLO technology accurately determines the position of solder joints in real time. This increases the productivity of the production line and is especially important for the flexibility of car door panels and real-time welding. result |
| 2021 | [26] Zheng Ge, Songtao Liu, Feng | YOLOX: Exceeding YOLO series in 2021 | The YOLOX detector is a new high-performance detector based on the YOLO family of detectors. | The suggested YOLO method is an upgraded and lightweight version transcending the archaic YOLO series in 2021. |

### 2.1. Background

YOLO is an abbreviation for [1] You Only Look Once. When estimating vehicle speed, it is essential to first detect the object, locate the object, and find out where the object is in the image. YOLO (You Only Look Once) first worked in 2015. This was a [1] new approach to reformulate object recognition as a regression problem and run it on a single neural network. This has explosively expanded the field of object detection and achieved far better results than it was ten years ago. The YOLO algorithm first splits all specified input images (take a video example) into an S * S grid system. Each cut in the frame is responsible for detecting real-time objects. Next, the number of bounding boxes is predicted by (x, y, w, h, confidence value). x and y are the coordinates, w and h are the width and height, and the confidence value is the probability that the box will contain an object and the precision of the bounding box. So far, YOLO has been updated to 5 versions and is rated as one of the best object detection algorithms. The 5th generation includes YOLO v1 to YOLO v5. However, the performance of YOLOv5 [5] is higher than the other versions in terms of both accuracy and speed. This paper discusses the history of the YOLO algorithms used so far, as well as their results and limitations. The first version of YOLO, YOLO v1, was released in 2015 by Joseph Redmon et al. It has been released. Prior to the invention of YOLO, CNNs like RCNN used the Region Proposal Network for real-time object detection, which was difficult to optimize and slowed down. Since then, only the inventor of YOLO has been motivated to continuously train and create a one-level CNN that can be effectively applied in real time. This version of YOLO uses the Darknet framework trained on the ImageNet 1000 dataset. The limitations of YOLOv1 include the difficulty of finding small objects that appear in the group and the occurrence of more localization errors than the fast RCNN. After discovering so many limitations in YOLOv1, Joseph Redmon and Ali Farhadi released the second version of YOLO (YOLO9000) in 2016. [2] YOLOv2 uses the Region Proposal Network to identify objects using the Frames input and the Single Shot Multibox Detector. The most important change in YOLOv2 was batch normalization. This reduces the shift of unit values in the hidden layer and improves the stability of the neural network. High resolution classifier: This has increased the input size from 224 * 224 to 448 * 448. Darknet 19: YOLO v2 uses the Darknet 19 architecture with 19 layers of convolution, 5 layers of maxpooling, and a SoftMax layer for classification objects. Darknet is a neural network framework written in C and CUDA. Fast object detection, which is very important for real-time prediction. Speaking of which, the limitations found in YOLO v2 weren't in previous versions. With so many object detection algorithms today, the conflict is how accurately and quickly the object is detected. The author called [3,4,5] YOLO v3 a gradual improvement because it is faster and more accurate than the other two previous versions of YOLO. The main improvement made in YOLOv3 is the prediction of the bounding box. YOLOv3 provides a score for each bounding box object. It also uses logistic regression to predict objectivity scores. Darknet53: YOLO v2 used Darknet 19 as a feature extractor, while YOLO v3 uses the Darknet 53 network as a feature extractor for the 53-convolution layer. YOLOv3 is much deeper than YOLOv2 and has shortcuts. Darknet53 uses shortcut connections to configure 3x3 and 1x1 main filters. YOLOv3 Limitations: Average accuracy for medium and large objects should be improvised. The Darknet53 implementation is written in C and needs to be changed to Python to improve performance and accurate results. [4] YOLOv4 is a real-time object detection model published by Alexey Bochoknovskiy, ChienYao Wang and HongYuan Mark Liao in April 2020, delivering cutting-edge performance in Coco datasets. In YOLOv4, CSPDarknet53 is selected as the backbone added by the SPP block. Import and validate BagofFreebies and BagofSpecials object detection methods. It is also a more efficient and powerful object detection model. This allows anyone to train ultra-fast and accurate object detectors using 1080Ti or 2080Ti GPUs. Compared to YOLOv3, AP and FPS increased by 10% and 12%, respectively. YOLOv4 Limitations: Exact models are slow, fast models are not. Most modern neural networks are neither real-time capable nor suitable for traditional GPUs. Due to some limitations or shortcomings in YOLOv4, Glenn Jocher used the PyTorch framework to release YOLOv5 on May 18, 2020. [5] YOLO v5 is the latest version of YOLO with improved mosaic data expansion and automatic learning of bounding box anchors. YOLOv5 is almost 90% smaller than YOLOv4 but has proven to be much faster than YOLOv4.

### 2.2. Methods/ methodologies

1990 saw the development of a technique /algorithm that was based on centroid tracking in real time for the purpose which was later integrated in python OpenCV for detecting speed we are going to use in the project for vehicle speed estimation by integrating with YOLO v5. Because it relies on the Euclidean distance between current object centroids and new object centroids between contemporaneous frames/images in a movie, it's dubbed the centroid tracking algorithm. Also, [10] the Python package OpenCV for computer vision employs the centroid tracking method to monitor objects or vehicles and estimate their speed. In the realm of computer vision, it is one of the most often used approaches. It is adaptable and dynamic due to its connection with the Python package. The table below compares the several versions of YOLO.

| | **Number of n layers** | **FLOPS** | **FPS** | **Map value** | **Used set of data** |
|---|---|---|---|---|---|
| YOLO V1 | 26 | Not-given | 45 | 63.50 | VOC-data |
| YOLO V1-Tiny | 9 | Not-given | 155 | 52.80 | VOC-data |
| YOLO V2 | 32 | 62.95 | 40 | 48.20 | COCO-data |
| YOLO V2-Tiny | 16 | 05.42 | 244 | 23.60 | COCO-data |
| YOLO V3 | 106 | 140.70 | 20 | 57.80 | COCO-data |
| YOLO V3-Tiny | 24 | 05.57 | 220 | 33.20 | COCO-data |
| YOLO v4 | 53 | NA | 65 | 88.93 | COCO-data |
| YOLO v5 | 224.00 (depends) | 51.30 (depends) | 140 | 50.7 | COCO-data |

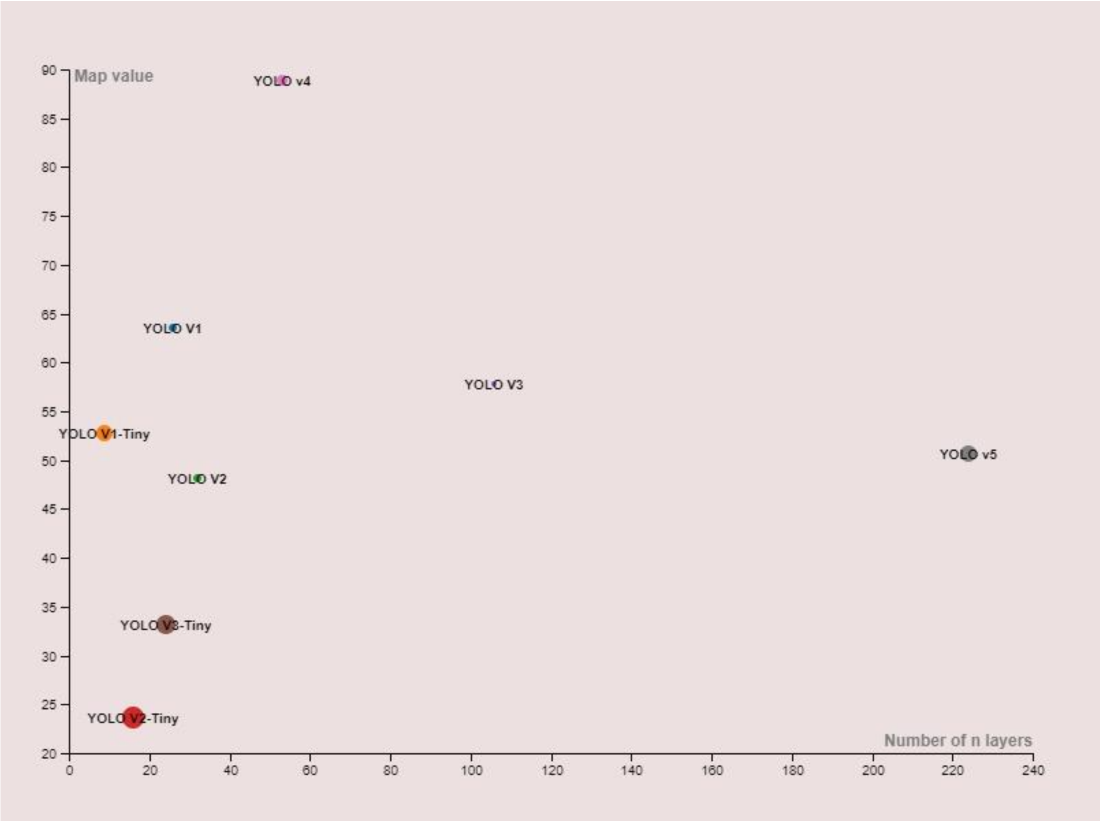


*Figure 1: Bubble chart for performance of different yolo models.*

The proposed centroid tracker algorithm for vehicle tracking and speed estimation works based on following images. Following image is the summary of the working of the algorithm. The bounding boxes are located on different locations of a same vehicle which have their own centroid value. Hence, using Euclidean distance formula distance is calculated between the two centroid points. The speed is then calculated using the formula s = d/t, where, s is the speed, d is the distance and t is the time.

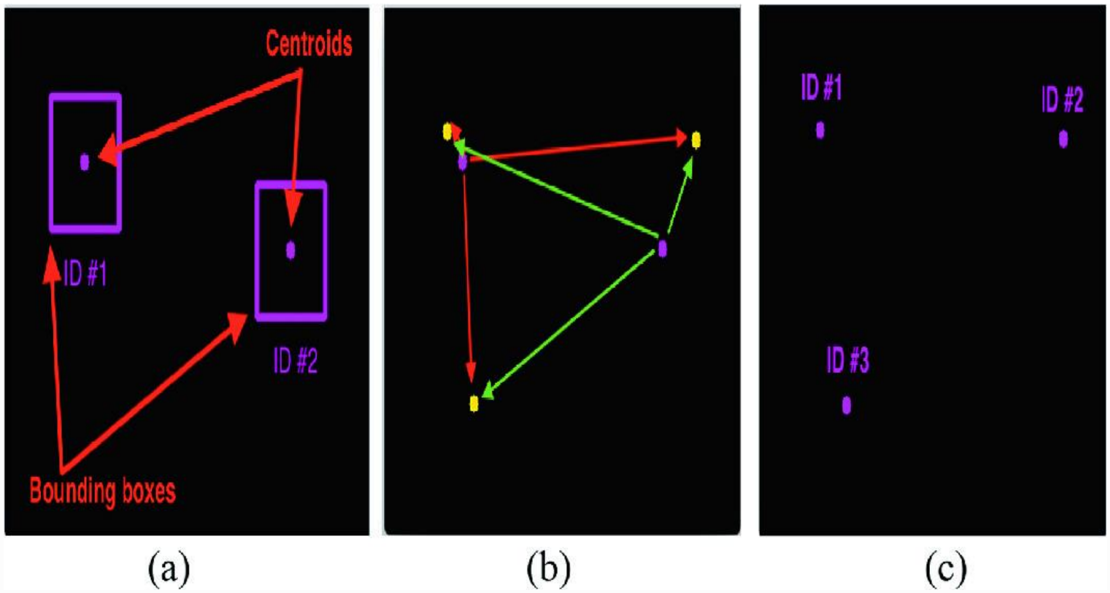


*Figure 2: O.Sweth;s image (Counting and Tracking of Vehicles and Pedestrians in Real Time Using You Only Look Once V3)*

### 2.3. Recent Advances

There has been a lot of activity recently in the field of YOLO, which we use to identify and detect automobiles. In the tech industry, controversy and increased interest in the issue have made news, as have new releases. The new YOLOV5 P5 and P6 nano models, which reduce the model size and inference speed footprint of earlier models, are featured in the YOLOv5-v6. 0 release, which includes 465 PRs from 73 contributors. The new micro variants are small enough to run on both mobile and desktop computers. As a result, a lot of work is being done in this area. The project has a large developer community in the field of centroid tracker (OpenCV). Developers are sophisticating it all the time.

### 2.3.Summary/ research gap

Thus, over the long period of time, researchers, inventors, and institutions alike have come together to work and solve on an issue. We believe this research on custom training deep learning models with YOLO v5 and centroid tracker will further move this noble cause. However, there are gaps and challenges ahead. Due to the following five challenges, object detection is traditionally regarded to be much more difficult than image classification: dual priority, speed, diverse scales, limited data, and class imbalance. There is controversy in the development of YOLO and YOLO v5 Is not developed or released by the original authors of the research due to various reasons. The centroid tracker has also issue with accuracy and precision and gives us the way to further develop this technology.

## 3. Proposed Work

### 3.1. Available Dataset

Working surveillance cameras in highways have been widely installed in roads widely but traffic images are very rarely released public due to copyright, privacy, and many

other security problems. From the image that are collected, we can categorize the image datasets in three types: images taken by camera of the vehicle, images taken by the CCTV camera, and images taken by cameras that does not monitor.
The dataset that has been preferred to be used in this study is “Stanford car dataset”. The dataset consists of exactly 196 classes of different cars modified to single class called “Vehicle” and the total number of images is 16146 images of different cars taken from the rear. To sum up the characteristic of data is:

Total number of pictures in the set: 16,146
Total number of classes: 196
Train/test split: almost 50%
Train: 11k
Validation: 3.2k
Test: 1.6k
Image resolution: 360*240

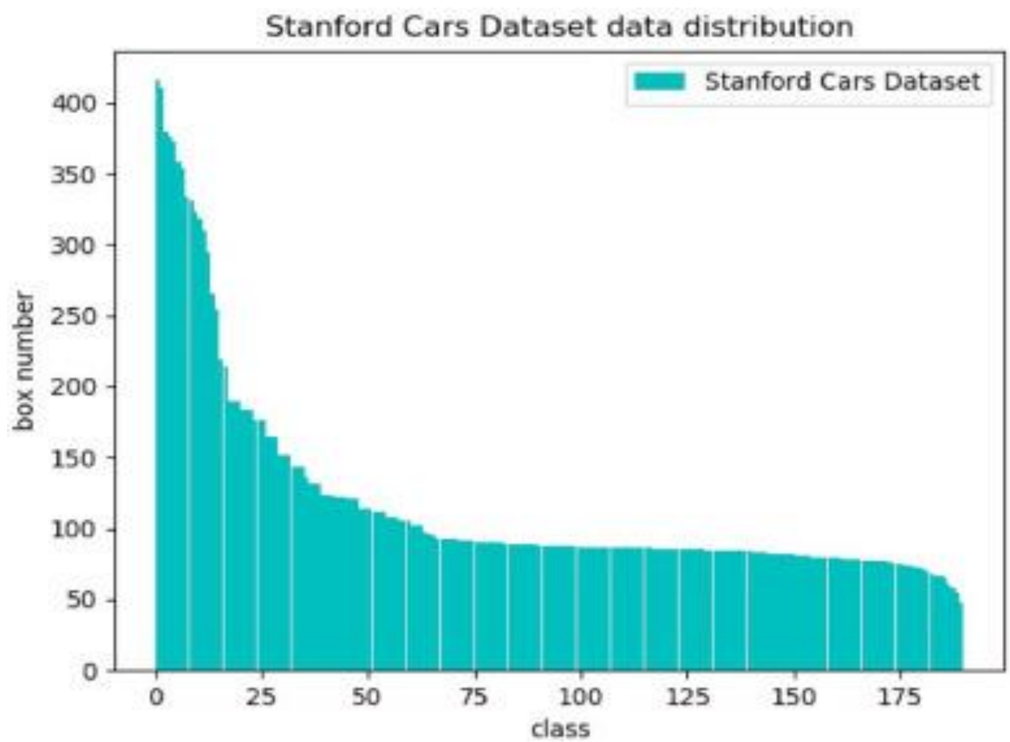


*Fig 3: Xiao Ke’s image [25] (Fine-grained vehicle type detection and recognition based on dense attention network)*

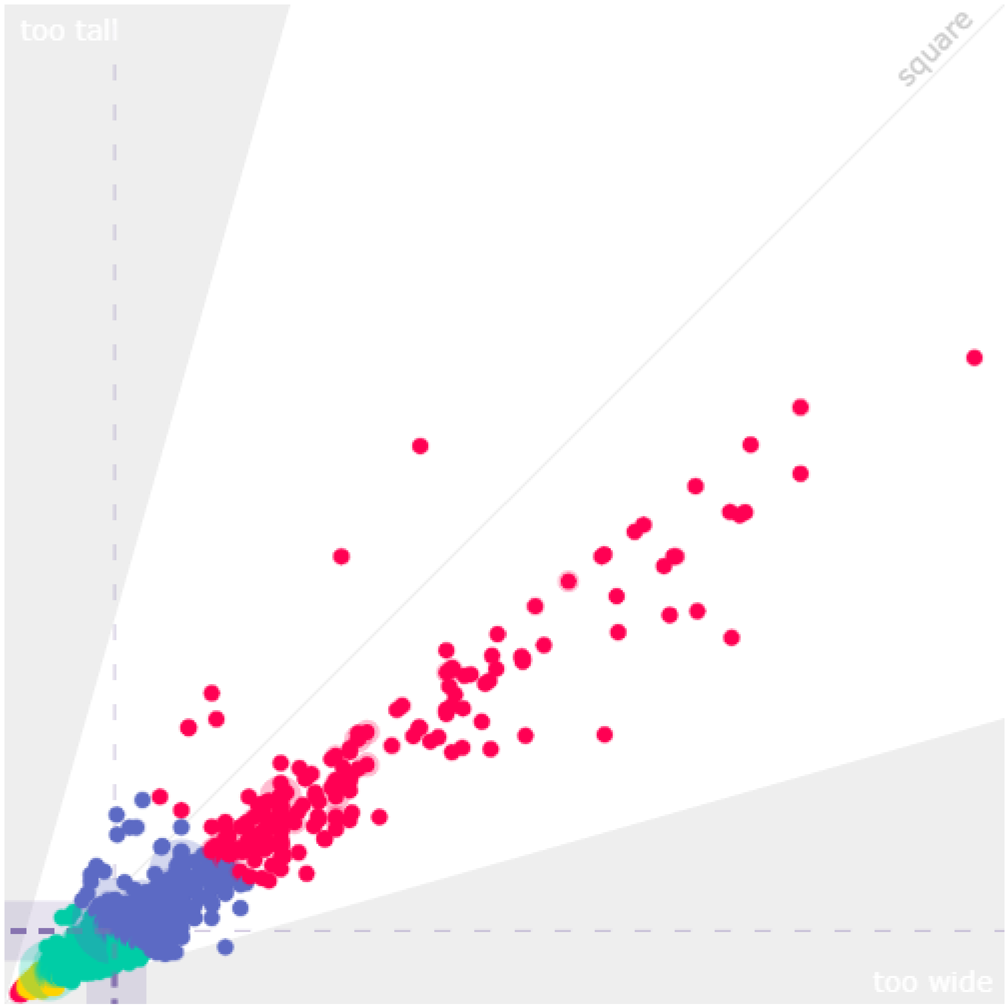

*Fig 4: Spread of the Stanford car dataset.*

### 3.2.Proposed Objectives

To build an effective vehicle detecting, tracking and speed estimation system, this paper proposes a brand-new technique of integrating YOLOv5 algorithm with centroid tracker. This paper proposes to combine the YOLO v5 algorithm with Python's OpenCV library centroid tracker based on two conditions, i.e., between the virtual detection zone and virtual detection of vehicles on the road. The below flow-chart shows the working methodology of the system this paper proposes. A lot of training data from various vehicle surveillance cameras are collected which are located on parking lots, highways etc. The video dataset is annotated for image data which is used as training dataset for our model. The first part of this model is to use YOLO v5 (You Only Look Once) for vehicle identification. We feed the model with the training dataset so that the model can identify the vehicles from other objects distinctively. The second part is to use centroid tracker to track the identified vehicles by assigning them with centroid coordinates. This centroid is then used to estimate the speed/velocity of the vehicles. The testing dataset can be any traffic footage with the moving vehicles in which vehicles can be tracked and the speed can be estimated based on centroid tracking algorithm. This proposed technology can then be implemented to solve various traffic management issues and can be a benchmark in the field. It can further enhance the development of similar systems in the academia.

### 3.3. Proposed Methodology

The paper suggests this methodology as a new methodology which aligns with sophistication in the academia.

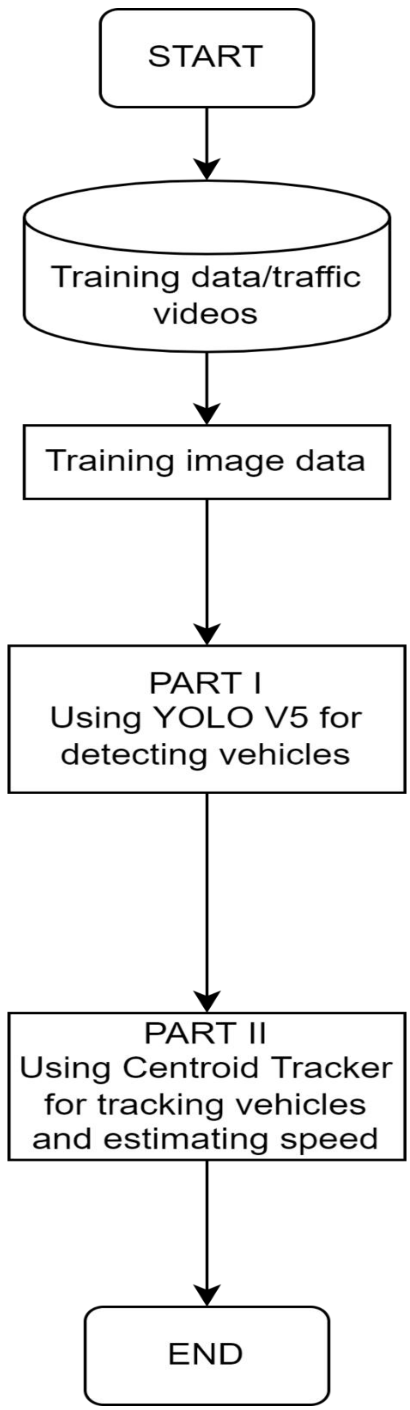

*Figure 4: proposed methodology*

## 4. Hardware and Software requirements

**Processor**

- 8th Gen Intel® Core™ i7-8750HQ Quad Core Processor

**Operating Systems**

- Windows 10

**Video Card**

- NVIDIA® GeForce® GTX 1050, 4 GB GDDR5 video memory

**Display**

- FHD (1920 x 1080) IPS Anti-Glare LED-Backlit Display

**Memory**[1]

- 4-16 GB, DDR4, 2666 MHz; up to 32 GB **Hard Drive**
- Dual drive configuration with 256GB SSD + 1TB 5400 RPM Hard Drive
  256 GB SSD

## 5. Implication

This study presents a thorough examination of the vision-based vehicle speed estimation problem. In the most essential application domains, traffic monitoring and control (traffic cameras) and speed limit enforcement, we review the literature (speed cameras). A new taxonomy based on the major components of a vision-based speed detection system is proposed, including vehicle recognition, and tracking algorithms like YOLOv5 and Centroid Tracker, distance and speed estimation, application domains, and ground truth production. We present a comprehensive overview of the most recent research on vehicle speed estimation using computer vision and a complex technique. Finally, we discuss the current state of the art's limits and propose the most critical and necessary future steps for the research community.

## 6. Research Plan

A lot has been done in the field of object detection and speed estimation. Ever since the introduction of YOLO in 2016, researchers on various echelon of the academia have invested resources and time on this algorithm. The centroid tracker algorithm has been one of the most used algorithms in tracking and estimating and counting objects.

The research plan of this paper is to integrate the version 5 of YOLO with the centroid tracker and estimate the speed of the vehicles effectively. With the ample of datasets on hand and a lot of research materials for reference, we are using knowledge garnered over the course of many years by researchers to propose a solution for existing vehicle speed detection dilemma in our modern world. Various online repositories of data have been used to train and test the model/system in this research project.

## 7. Result of the study

A robust and real-time system that detects the vehicles and estimates their speed which relays information to the respective concerned body for traffic control and systematic functioning of the intelligent transportation system.

The performance of the model can be analyzed from following test scores:

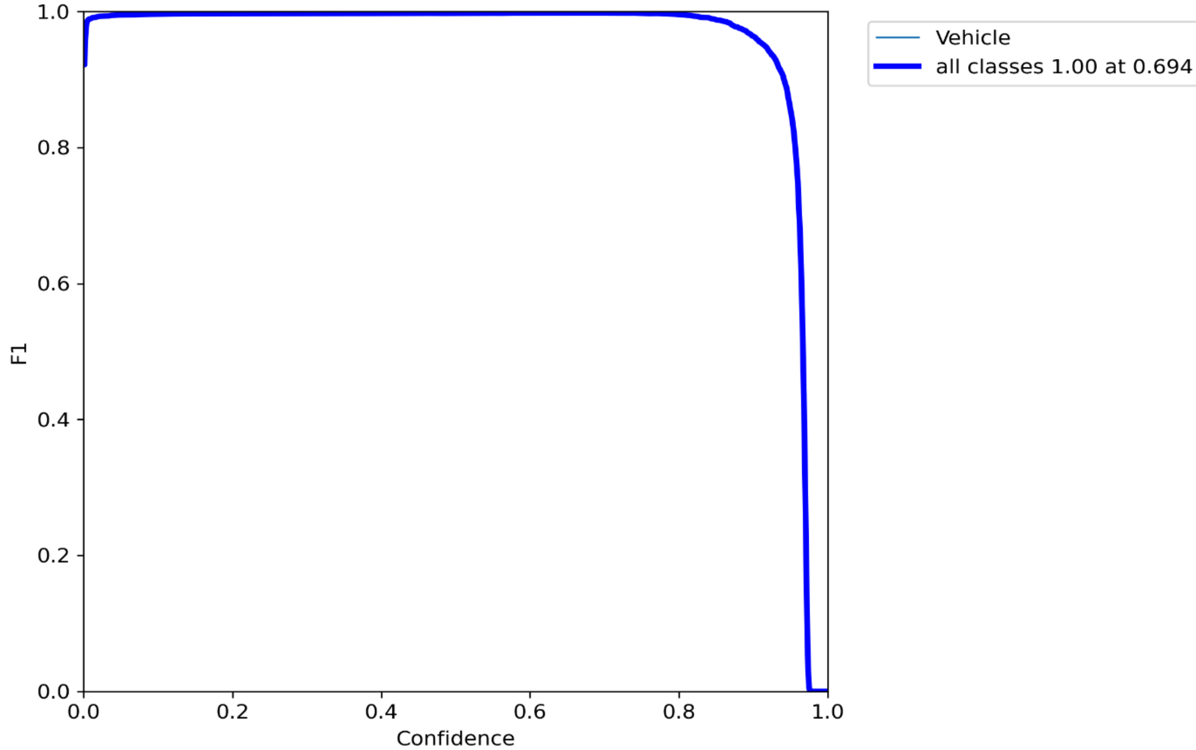


*Fig 5: F1 curve of the performance of the trained model*

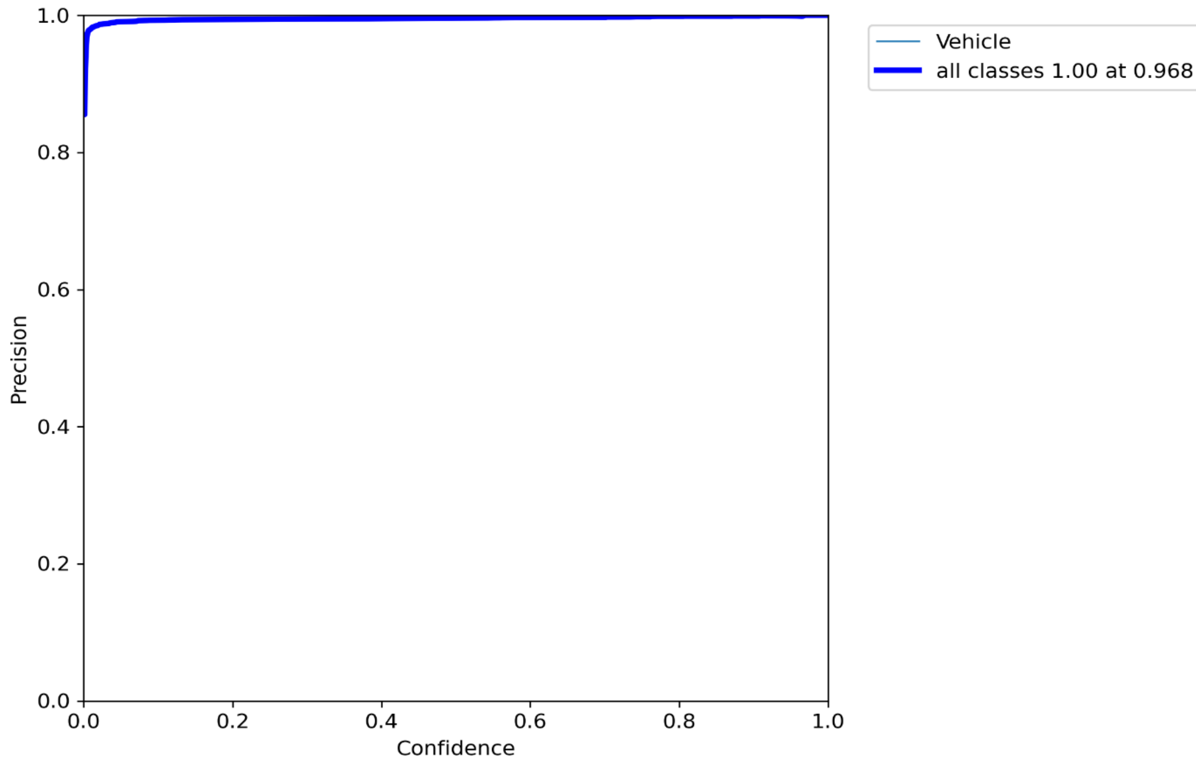


*Fig 6: Precision curve of the trained model*

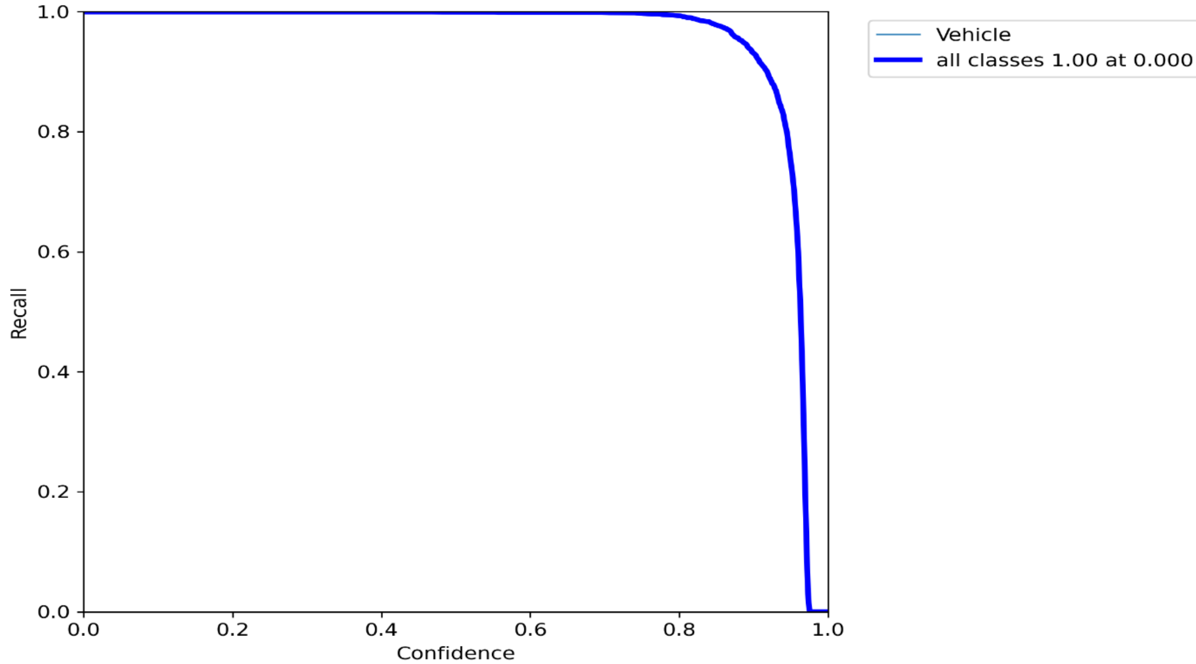


*Fig 7: Recall curve of the trained model*

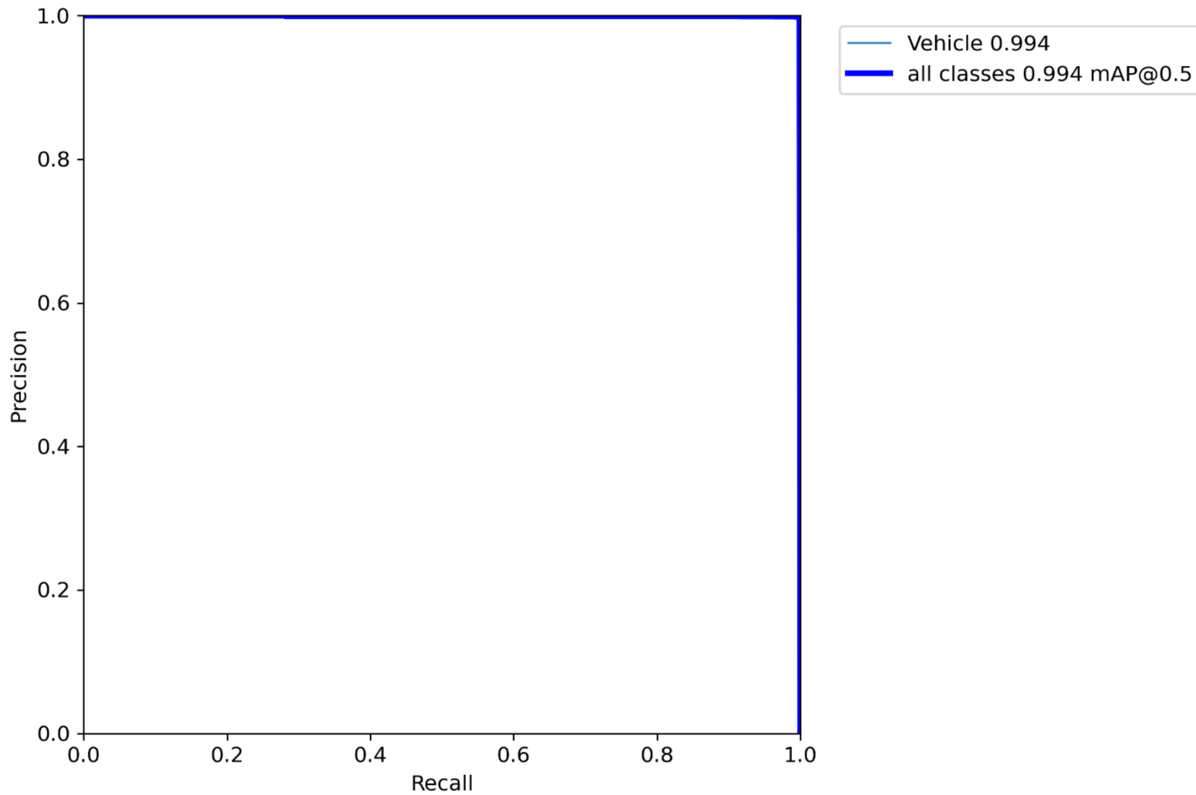


*Fig 8: Precision Recall graph of the trained model*

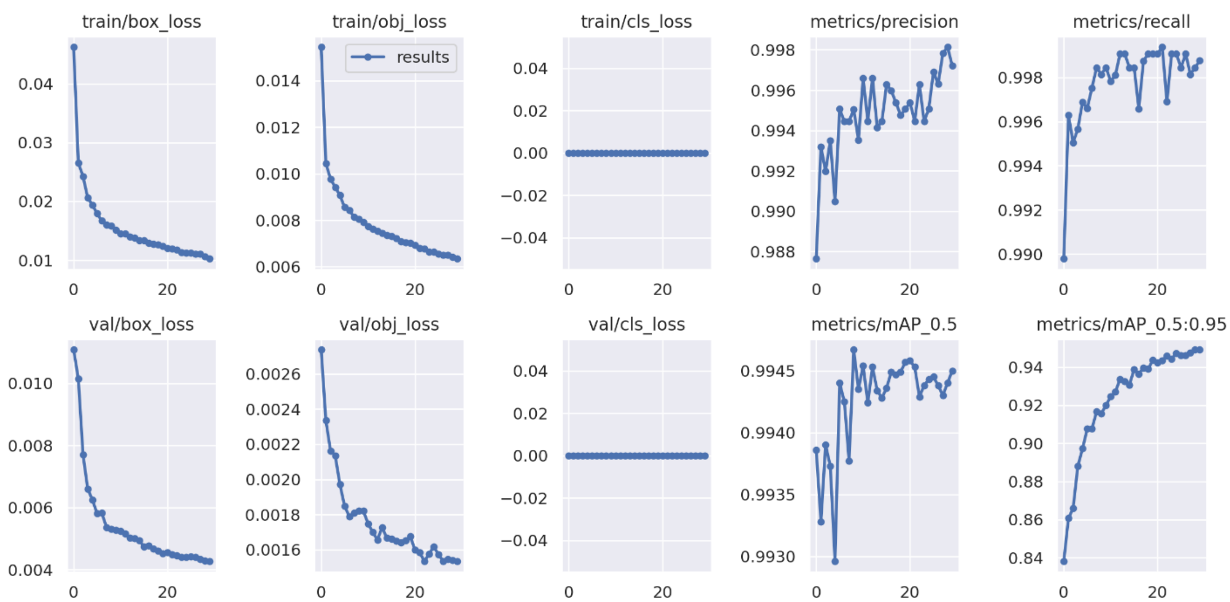


*Fig 8: Results of the trained model.*

The test samples of the trained YOLOV5 model are as follows:


*Fig 9: test sample 1 with precision of 0.97 almost 1*


*Fig 10: Test sample 2 with precision 0.*


*Fig 11: Test sample 3 with precision 0.97*


*Figure 12: Test sample 4 with precision 0.95*

The above figures are the model performance results. The figures [5], [6], [7], [8], [9], [10], [11] and [12] give us the view of the performance of the model. The model has performed impeccably and is ready for detecting vehicles in real world scenario integrated with a speed estimation algorithm. Almost all the scores approach to 1. The model was trained on 270 layers and gflops and is targeted for 30 fps systems. The glimpse of final result is:

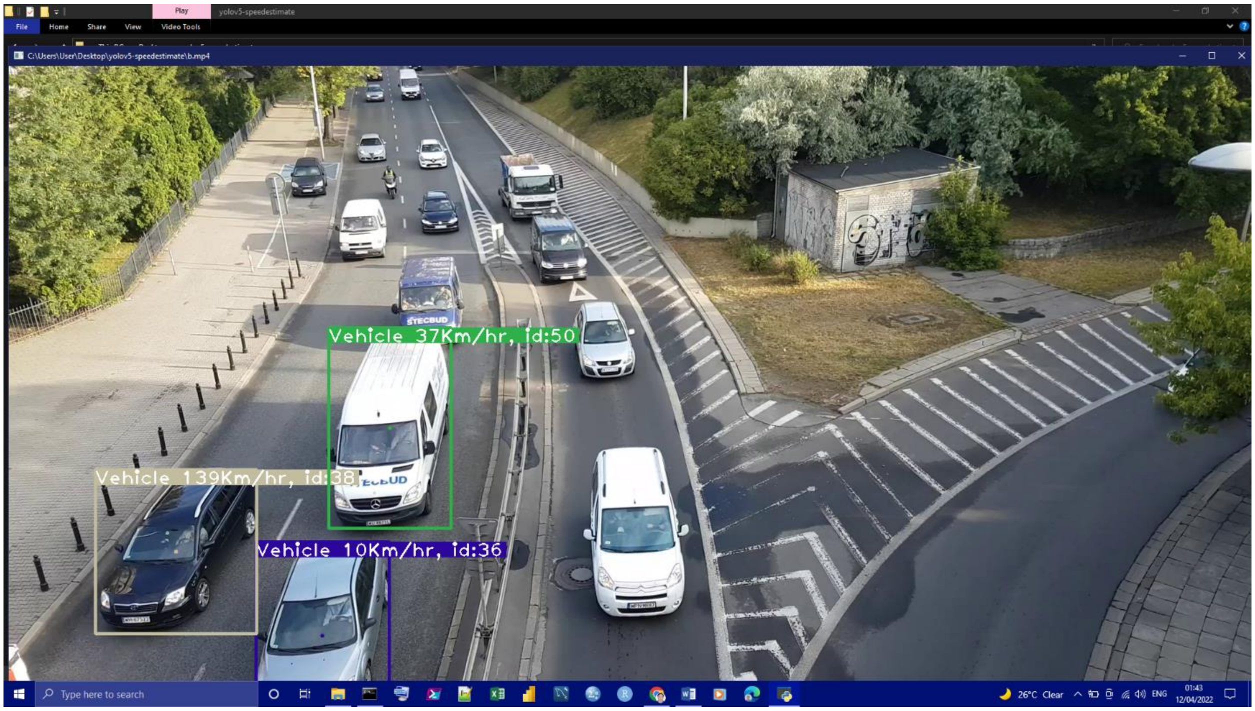


*Fig13: Actual final product of the model estimating speed on a free road.*

Thus, we can get this result from the overall completion of the result. The entire project is coded with python programming language with the use of YOLOv5 from ultralytics. At optimal conditions, YOLOv5 gives us the performance of GFLOPS of 17.0, params of 7.3M, speed of 2.2ms which is great. The size of the neural network at the optimal condition can be up to 640.

## 8. The conclusion

Thus, vehicle tracking and ultimately estimating speed is just a single applicability of YOLOv5 and its extended family of awesome models. The applicability of it is diverse and dynamic. The model itself is quite dynamic and robust and its adaptability is top notch. When used properly in an intelligent traffic system, the application can lead to greater things and can be achieved as some of the most important cornerstones of scientific community. In our little experiment, we found impeccable performance results of the YOLOv5 model integrated with the speed estimation algorithm to give a result of a dynamic system. In the real world, with further extensive training and research, the model can do wonders in various field.

**Credit Author Statement:**

**Benjamin Tamang**: Conceptualization, Methodology, Data Exploration and preparation, Investigation, Formulating prototype, Prototype building, training

**Sanskar Poudel**: Data extraction, Research planning, Software Management

**Bipin Damase**: Implication, Research Plan

**Sagar Bhandari**: Literature Survey, Research Plan Formulation, Hardware system

**Dr. Sagar Dhanraj Pande:** Supervision and monitoring

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