# EXPRESSWAY VEHICLE TRACKING SYSTEM IMAGE PROCESSING

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Project Final Report

B.Sc. (Hons) Degree in Information Technology

Department of Information Technology

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## Declaration

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## ABSTRACT

Currently in Sri Lanka there are three major expressways functioning. Most of the people in Sri Lanka are using these expressways for their travelling purposes. There are accidents occurring in these expressways because of the violation of rules that are established within the highway. Over speed driving, illegally parking, Road lane violation and travelling in reverse direction are some of the rules violations identified in this research. There is no proper way to identify these rules violations currently in Sri Lanka expressways. However, identifying the vehicles that are violating these rules is needed to reduce the amount of accidents and increase the safety of people. Therefore, the main aim of this research is to develop a system that can identify above mentioned rules violations effectively. The automatic identification of vehicles in surveillance camera videos has been an important research area these days. In this research, the system is developed using image and video processing techniques combining with the machine learning and deep learning algorithms to detect above mentioned rules violations. Inputs to the system are obtained through the CCTV cameras on expressways and by processing the information obtained from those cameras the output is obtained. The developed system can detect vehicle type, vehicle number plate, detect speed rule violating vehicles, detect illegally parking vehicles, detect road lane violating vehicles and detect vehicles that are travelling in reverse direction on the road. The developed system has an accuracy that can be satisfied with and the system is very easy to use.

***Keywords: detect vehicle type, detect vehicle number plate, detect speed rule violating vehicles, detect illegally parking vehicles, detect road lane violating vehicles, detect travelling in reverse vehicles, machine learning, deep learning, image and video processing, CCTV cameras.***

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# Introduction

## 1. Background

### 1.1 Overview

This chapter acts as the preface to the thesis document of “EXPRESSWAY VEHICLE TRACKING SYSTEM IMAGE PROCESSING”. The researcher discusses the problems background of the research project and giving an IT based solution by using latest technologies. The researcher establishes the problem statement, and following to that, proposes the research solution for the problem statement and illustrates rich picture diagrams of the solution. Research aims and objectives are later stated in this chapter.

## 2. Literature survey

#### 2.1.1 Vehicle Type and Number Plate Detection

With the development of computer vision, machine learning methods, camera hardware, and image processing, concerns about automated video surveillance systems have become more pressing. Manual monitoring has become laborious and time-consuming. As a result, real-time video monitoring for motor vehicle regulation violations has become a hot topic. In a data-driven world, video feeds from CCTV cameras are just as essential as data produced by social media, sensors, and medical systems. Expressway facilities should have the most modern and comprehensive security and monitoring systems available. In Sri Lanka, the surveillance systems for traffic rule breaches are non-autonomous CCTV systems that need constant monitoring by humans. This solution will include an automated intelligent surveillance system that will identify traffic rule breaches and will have the option of automatically generating a bill with penalty costs at the departure point.

Vehicle detection is critical since it serves as the first stage in real-time surveillance systems for motor vehicle offences. Vehicle detection accuracy influences all subsequent stages in the process. Numerous methods have been discovered, along with their associated benefits and drawbacks. Although many studies and initiatives have been performed in this field of intelligent transportation, relatively few studies have been conducted in the Sri Lankan context regarding the intelligent transportation and surveillance sectors.

### 1.1.1 Image processing

Picture processing is a technique that is extensively used to identify any kind of item or pattern, as well as to conduct operations on the recorded image and recover useful information. Digital image processing is classified into four categories: image enhancement, picture restoration, image analysis, as well as image compression. A high-resolution camera is the primary component utilized in image processing. In addition, an image processing unit or computer having on-board image processing algorithms. A gigabyte of storage to hold the pixels of the pictures while they are being processed.

- **Image enhancement -** A modified picture (ex: median filtering, linear contrast modification) may assist a human viewer in extracting important and usable information from it.
- **Image restoration -** A method of restoring a picture from a degraded form that is often blurry or noisy. A picture may be deteriorated for a variety of causes, such as blur caused by camera shaking. Image noise is often produced by environmental factors like rain, snow, and even thermal signals.
- **Image analysis -** Images with relevant information would be used to outline and characterize things. Picture analysis techniques include edge extraction, image segmentation, texture analysis, and motion analysis.
- **Image compression -** Compressing a picture reduces the number of bytes while maintaining the image's quality. Compression has the benefit of allowing for the storage of more pictures per unit of disk or memory.

## 1.2 Object detection

An image or video may be searched for specific items using the computer vision method known as object detection. In comparison to pictures, the segmented box may assist a person or driver quickly recognize and find things. Object detection's purpose is to transfer this knowledge to a machine.

Object detection may be accomplished using a variety of methods. The popular deep learning methods based on CNNs, like YOLO and SSD, use counterrevolutionary neural networks to learn to identify objects automatically within frames. More information on machine learning is provided below to help explain object detection in more detail.

## 1.3 Machine Learning

Decision-making and prediction are the emphasis of machine learning, a subfield of Artificial Intelligence (AI). Primarily, the goal is to enable the computer to continue developing on its own, without the need for any human input. There are two types of machine learning algorithms: supervised and unsupervised. Supervised algorithms use labeled examples to apply what they've learned in the past to fresh data.

## 1.4 Supervised learning

When using supervised learning, some data is labeled before being fed into the algorithm, which uses the input to categorize the label based on what it has learned. To approximate a mapping function, supervised learning attempts to take fresh input datasets and anticipate the correct output. Until it meets an acceptable standard of performance, the algorithm learning process continues repeatedly until it is complete. Classification and regression issues are subsets of the overall issue.

- **Regression -** an illustration of this issue is the inability to accurately anticipate a continuous amount output.
- **Classification -** is an example of a prediction issue for a discrete class label output.

## 1.5 Unsupervised learning

Data is not labeled to categorize or predict in unsupervised learning, which is a machine learning method. Instead, the algorithm looks for patterns in the processed data that aren't immediately apparent, or it gets insight into the data itself. As a result, unsupervised learning may be very helpful when working with large amounts of data, but it is less precise and reliable than supervised learning. Clustering and association issues are subcategories of the problem that arises.

### 1.6 Machine learning evaluation

Machine learning algorithms may be improved by evaluating several elements of the method, such as its speed, accuracy, and precision. mAP, or Mean Average Precision, is used to measure how well an object identification model performs when trained on a given set of input data. It is necessary to utilize Intersection of Union (IoU) to evaluate if a predicted bounds is true positive, false positive, or false negative while doing AP calculations in object detection Some concepts like accuracy and recall need to be defined to provide a more thorough explanation of these measures. Precision evaluates the accuracy of the predictions made ahead of time, whereas recall reflects how well discover all the positives once that start looking for them.

$$Precision = \frac{TP}{TP + FN} \tag{1}$$

$$Recall = \frac{TP}{TP + FP} \tag{2}$$

*Figure 1 Equation 1 Precision and recall*

True Positive (TP) - The prediction was correct, and the actual result is positive.
False Positive (FP) - The prediction which was made is incorrect, as well as the actual result positive.
False Negatives (FN) - The prediction was incorrect, and the real result is negative.

### 1.7 Deep learning

Deep learning is a machine learning method that relies on learning a suitable feature representation from the input data on its own, rather than having to be explicitly programmed. Deep learning designs include deep belief networks

(DBNs), stacking auto encoders, and convolution neural networks (CNNs), which are the most successful picture categorization techniques. As a subset of AI Technology, machine Learning refers to methods that allow a machine to behave like a person. It is inspired by the human brain and develops the pattern by imitating the human brain's own layout, which is composed of neurons.

### 1.8 Machine Learning process

When it comes to artificial intelligence, it's critical to choose the right machine learning algorithm for the job at hand. However, when utilizing machine learning to address issues, there are many additional factors to consider. The answer is based on the already collected and labeled data. When a class is overrepresented, a model may have trouble identifying data instances. Especially when specific items are often mistaken, negative data should be provided. Inconsistencies and outliers should be extracted from the data by trimming it. As a result of this, the algorithm may overfit its test data, resulting in subpar results on real-world data. As a result, instead of learning to generalize, it has just remembered the information. Increasing the amount of data available helps in the resolution of this issue.

#### 1. Convolutional Neural Network (CNN)

Classification, picture identification, segmentation, and object detection have all been made easier using Convolutional Neural Networks, a kind of Neural Network. Many convolutional as well as subsampling layers make up a CNN. Each layer in the CNN's design includes input and output ports. There are many convolutional layers that have been convolved with a multiplication in the secret layers.

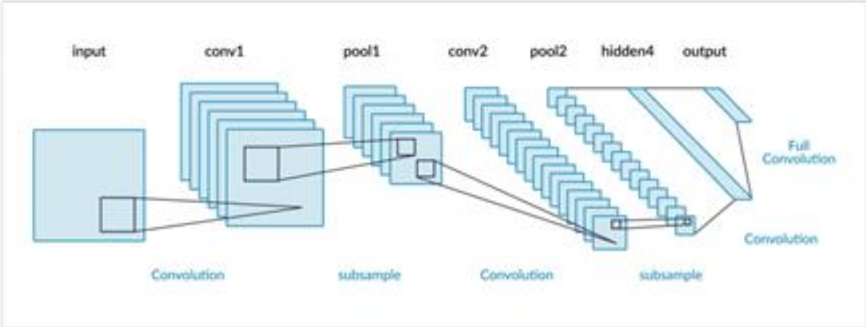



*Figure 2 CNN Architecture*

In computer vision applications such as image classifications well as detection, CNNs have been used to generate reliable results [5]. CNNs are a type of deep, feed-forward artificial neural networks. Traditional neural networks are like CNNs, however CNNs have more layers. It uses a nonlinear activation to assign weights, biases, and outputs. Neurons in the CNN are organized in a three-dimensional (3D) volumetric) manner. [9]

Neural networks have become a significant area in computer vision-related tasks. Through neural networks, spatial hierarchies of features can be learned automatically and adaptively using backpropagation (building blocks, pooling layers, convolution layers). Also, Neural networks have been identified to be a dominant framework for background subtraction in a video.

## 1.9 Regions with Convolutional Neural Network Features

The use of region-based convolution neural networks (R-CNNs) in object identification is a pioneering technique. The following are two fundamental ideas that have been identified:

1. R-CNN combined with the CNN method.
2. Regional proposals

In the region proposal concept, it is made to locate objects which are dismember using and approach called the bottom to top approach. When the training data is inadequate, supervise trainings will be used for a field of specific fine-tuning process.

## 1.10 Faster Regions with Convolutional Neural Network Features

The deep convolutional neural network is a popular approach. Layers of convolution filter can learn the hierarchical presentation of that input data of images. Low level convolutional layers can learn to capture simple features like textures and lines.

## 1.11 YOLOv3

Real-time object identification algorithm YOLOv3 detects items in video streams, live feeds, or pictures. [6] [7] YOLO detects objects by using deep convolutional neural network characteristics acquired over time. Joseph Redmon and Ali Farhadi are credited with creating YOLO versions 1-3. Hence the authors decided to use the YOLOv3 as most appropriate technology to detect the vehicles.

Version 1 of YOLO was released in 2016; version 3 of YOLO, the one under discussion here, was released in 2018. In comparison to YOLO and YOLOv2, YOLOv3 is an enhanced version. To put YOLO into action, deep learning libraries Keras and OpenCV are used. Artificial Intelligence (AI) algorithms utilize object categorization methods to identify items within a class as interesting. [8] In pictures, the systems group related things together, but others are ignored until specifically instructed to do so.

YOLO is a real-time object detection Convolutional Neural Network (CNN). Using classifiers, CNNs analyze pictures as structured data arrays and look for patterns in the data. When compared to other networks, YOLO is lightning-fast while yet maintaining precision. When the model is tested, it has access to the whole picture and may use that information to make predictions about what will happen next in the image. [9] Convolutional neural network algorithms such as YOLO and others provide a "score" to areas depending on how closely they resemble preset categories.

A high score indicates a positive detection of whichever class it most closely resembles high-scoring areas. According on the areas of the video that score well against preset classes of cars, YOLO may be utilized, for example, in a live traffic stream to identify various types of automobiles.

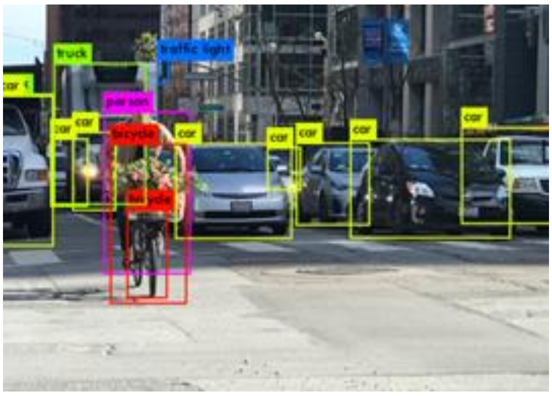



*Figure 3 YOLOv3 computer vision example*

## 1.12 Speed / Accuracy trade offs

It's difficult to keep them both at a high level, which complicates their relationship even more. These systems are the focus in real-time environments, decisions must be made quickly, which necessitates quick detection of pedestrians and vehicles. It may choose between making choices quickly and thus having a greater mistake rate or making decisions slowly and therefore having a better accuracy.

The trade-off between detection speed and detection accuracy must be balanced; otherwise, detection speed will be high while detection accuracy will be low. Speed and precision must be matched to avoid sacrificing one for the other.

## 1.13 Transfer learning

Transfer learning, a machine learning technique, is a way for transferring knowledge across domains. Humans' natural ability to transfer information is the inspiration for transfer learning, which utilizes knowledge from such a source domain (a related domain) to enhance learning outcomes. Even with sophisticated computer hardware, training a model from scratch takes time when using transfer learning from those other existing models. Transfer learning makes it possible for the user to make use of previously learned information.

## 1.14 Vehicle type detection

In the areas of highway management, intelligent vehicle identification and has become more essential. However, vehicle detection remains a problem owing to varying vehicle sizes, which has a direct impact on the accuracy of vehicle counts. [1]

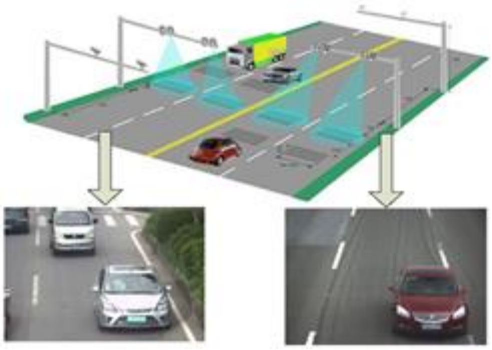


Figure 4 Vehicle type detection rich picture

Mainly, two basic approaches can be identified as in-vehicle detection such as Motivation based approach and appearances-based approach

- <u>Motion-based approach features</u>

An image's static background will be clearly distinguished from its moving foreground subjects. The pixel difference between two successive frames will be computed using this method. [2] [3]

- <u>Appearance Based approach features</u>

This method considers an object's colour, shape, texture, and size. Appearance-based methods are capable of identifying and distinguishing fixed items. This kind of approach often makes use of previous data for modelling. The appearance-based feature approach may be used to discuss models such as the part-based model and the feature-based technique.

## 1.15 Classification of vehicles

The Vehicle Classification's goal is to divide recognized vehicles into subclasses like vans, bicycles, and cars. When it comes to categorizing cars, there are many methods to choose from.

- **<u>Geometry-Based Approaches</u>**

Vehicle detection and classification are performed on highway pictures using fixed cameras. In terms of size, vehicle blobs are employed. Vehicles may be divided into two groups depending on their height and length: buses and non-busses. The Region of Interest characteristics make it difficult to classify cars precisely.

- **<u>Appearance-Based Approaches</u>**

The appearance-based methodology makes use of characteristics that are dependent on gradient corners and edges. [4] Appearance-based characteristics may be used to identify car models that are based on three-dimensional models, and classification can be accomplished utilizing models.

- **<u>Approaches Based on Texture</u>**

The texture is another basic parameter that can be used for the classifications. Multi-Block Local Binary Patterns can be used to classify vehicles under this approach. In Local Binary Patterns, it creates a binary string for each pixel.

## 1.16 License plate detection

Each vehicle has a unique identification number that may be used to differentiate it from other cars. It is essential for traffic management and law enforcement to properly recognize the license plate. The same number that appears on the license plate that may be used to get further information about the vehicle's owner.[9]

However, owing to the speed of a moving vehicle, it is impossible to recognize the license plate only by human observation. Identifying a license plate number from an input picture taken from CCTV video is one of the primary goals of this suggested research project. Numerous methods and algorithms for number plate identification and recognition have been discovered, each with its own set of benefits and drawbacks.

Since 2000, Sri Lanka's license plate character format has been standardized, consisting of two English letters followed by four numbers separated by a dash on a white or yellow background, with an imprinted government logo. Additionally, two tiny English letters were added to the license plate to indicate the issuing province, such as SP. (Example: southern province) To get a better perspective, all photos of cars were taken about 3-5 meters distant from the back of the vehicle. Following that, yellow areas were extracted to manage the RGB color space. The authors noted that the RGB color space changes according to ambient illumination conditions and inclement weather. Thus, recorded pictures have been transformed to binary images, with yellow images receiving a value of 1 and other images receiving a value of 0.

Following that, an edge detection method was used to identify discontinuities in intensity data with the assistance of a dexterous edge spotting operator. Following that, the gradient is computed using the Gaussian filter's derivative. Utilizing to determine the edges of recorded images. To reduce noise, pictures having a certain standard deviation are processed using a Gaussian filter. Following that, each point's edge detection and local gradient are calculated. The edge point is described as a spot having a localized high strength. Rise to ridges is indicated by the magnitude image's edge points.

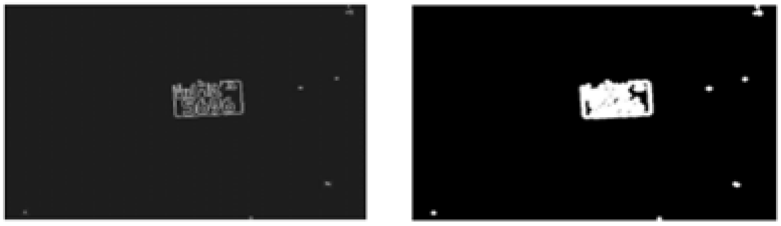


*Figure 4 Binarized extracted yellow regions of the image after processing through the edge detection operator.*

After the edges have been successfully extracted, a morphological process dilates the image to indicate where the plate is located. To dilate the binary picture, a diamond-shaped structural feature was used. And used a flood-filling algorithm to dilate the photos. It was critical to keep in mind that precise bounding boxes used together with the given regions while creating the model. As a result, bounding boxes were generated for each area. Selecting the highest regions most impacted by bounding boxes resulted in the effective extraction of license plate positions.

## 1.17 Vehicle speed rule violation detection

- Vehicle speed detection

The study [13] has used the live video stream from the surveillance cameras for speed detection and this is developed using MATLAB software and core2duo processor with 2Ghz. In this case, the system design and implementation is carried out in three phases, viz. vehicle detection, vehicle tracking, speed calculation. Because of the less complexity and reliability, this study has used a method called adaptive background subtraction to detect the vehicle. In this method, in any case of change, the background image keeps updating itself. The next phase which is vehicle tracking phase is separated into two sub parts namely object segmentation and object labeling, bounding box and center extraction. The first sub part which is object labeling, is done to eliminate shadows to evade false detections. Then some morphological operations like convex hull, dilation, erosion, opening, closing and hole filling are used to obtain the images with vehicles that as proper blobs. And these images are obtained without the noise. In the second sub part which is object labeling, bounding box and center extraction, a unique label is given to the detected vehicle and this label was kept until the vehicle leaves the seen. Then a bounding box is drawn, and the center of the bounding box is calculated and saved as centroid in an array. In the third phase or the final phase, which is detecting the speeds of vehicles, a calibration factor is used to calculate the speed. This factor is obtained by dividing the actual length of the object by length of the same object in the image. And then speed is calculated in km/h. Here the speed is updated at every 0.5second.

According to [14], this study developed the speed detection system in six phases. The system inputs are obtained through an uncalibrated camera. And then the frames are extracted out of those input videos and those obtained frames are preprocessed using an OpenCV library. Then as the next phase, Vehicle detection is done. For this process a classifier is used. This classifier is known as the Haar Classifier. The result of this classifier are the coordinates of the rectangle that surround the detected vehicle. And for tracking the detected vehicle from frame to frame this study has used a library called dlib. And from those above phases the position of the vehicle is obtained. Then for the speed calculation distance is obtained using the change in pixels. Then that obtained distance is converted to meters using ppm (pixel per meter value). Then using the camera's frame rate the time spent to travel the distance is obtained. Finally, the speed is calculated.

According to the [15], the authors have done research to propose a new algorithm based on the detection of moving targets in a surveillance video to estimate the speed of vehicles. The input video image size is 640 x 480 and the frames per second is 18. The approach taken here is divided into four sub phases namely, background model establishment and update, detection of moving vehicle, localization of vehicle centroid and vehicle speed calculation. In the first phase which is background model establishment and update, a median method in RGB space is used in rebuilding of background. In the second phase which is detection of a moving vehicle, a combination of background difference method and three frame difference method is used. Then for the third phase which is localization of vehicle centroid, the centroid is calculated using an equation. In the final phase, which is vehicle speed calculation, camera calibration is used connect the pixel distance and actual distance which needs to find the actual speed of the vehicle.

According to the [16], this study is conducted using video records as the inputs. Authors have used Samsung iPOLiSSNP – 5200H camera that have 1280 x 1024 image size and 10fps to capture the input videos. The process is divided into three sections namely object detection, object tracking and speed detection. For the first phase this study has used Gaussian Mixture

Model which is an adaptive background subtraction method. And then DBSCAN clustering method is adopted to generate clusters that defines the segments of foreground points. After using bounding boxes these segments are marked. For the second part which is to track the vehicle, Kalman filter and Optical flow methods are used. The Kalman filter method is applied to evade the complications that are associated with temporary occlusions and Optical flow is applied to get an accurate speed delivery. By combining these two methods the movements of pixels per second is detected. For the third phase which is speed detection, pixel weight is needed to know. And for this speed detection process they have computed a factor by dividing the width of double lane road by its pixel presentation. Then for estimating the speed of the target, the average speed of all the points in that target is calculated. After by multiplying those two factors speed of the vehicle is computed.

- Vehicle color detection

The study [17] is proposed an algorithm which is deep learning based to do the vehicle color recognition. In this study, as the feature extractor they have used Convolutional Neural Network (CNN). In this research, for each image a feature vector is calculated. Then for the classifier the Support Vector Machine (SVM) is used. This SVM is responsible for detecting the color of the vehicle. And then for the training process they have used images that are resized to a fixed size. Next in the training, by using the backpropagation, the parameters of the network are repetitively updated. Training images and their labels are used to accomplish this task. After the training parameters are saved, the CNN architecture creates feature maps in every layer by using the images as inputs. In this study as for the feature to conduct the color recognition, the output from the last three layers is used as the output from first three layers is not much suitable. Thereafter, each obtained image is separated into two level grid and the features of all subregions and image are integrated which is like SP strategy to integrate spatial information. This study incorporates deep learning and SP to achieve high performance in vehicle color recognition. Authors are saying that this study is the first study to incorporate deep learning and SP.

According [18], the study has used Convolutional Neural Network (CNN) to achieve the color recognition of vehicles. In here, CNN network has 2 main networks and 8 layers. The first two layers of CNN architecture perform the convolutional process based on the normalization and pooling. These two layers are considered as convolutional layer. The study has used ReLU (Rectified Linear Unit) as for the activation function of this layer. The normalization part is done using an equation. By doing this normalization the accuracy of CNN is increased. Pooling is the last procedure in the first two layers. From the two types of pooling, this study has used the 3x3 sized max pooling with stride 2. Then third, fourth and fifth layers are forming into two groups. The third and the fourth layers are considered as convolutional layers. But they don't based on normalization and pooling mechanisms. The output of these layers is same as inputs. The fifth layer is only based on pooling mechanism. Before reaching fully connected networks, the fifth layer is chained and compressed into one vector. The sixth and seventh layers are fully connected. To reduce overfitting this, fully connected layer consists with a method called dropout regularization. Softmax regression layer is the last layer, and it is explained in an equation that authors have developed. In this study the model is trained by stochastic gradient. They have used batches with 115 examples in each and with a momentum of 0.9 and with a weight decay of 0.0005.

### 3. Vehicle reverse violation detection

The function of the traffic rules violation system is becoming increasingly important as the fourth industrial revolution progresses, guaranteeing the safety and efficiency of drivers. The goal of this system is to collect relevant and precise traffic data while maximizing the usage of surveillance technology. According to the National Information, Sri Lanka has more than two thousand closed-circuit television (CCTV) cameras installed by the year 2018 in expressways. There is no way that CCTV footage can be a perfect answer for all traffic offenses. However, combined with facts, witnesses, and records, it is routinely and increasingly utilized by government authorities to detect significant breaches. Driving the wrong way along a road occurs for a variety of causes, including driver distraction or confusion, failure to see pavement markings or traffic signs, willful violation of the laws, and so on. Even while new pavement markings and signage are creative, they may not be adequate to warn vehicles of wrong-way travels, resulting in vehicle accidents. Despite the fact that it is nearly impossible to govern human driving behavior, it is critical to identify and analyze irregular activity in everyday traffic settings in order to avoid catastrophic vehicle accidents. Until now, the duty of identification has been handled by persons who work for monitoring firms. Nonetheless, as the number of camera devices grows, so does the requirement for intelligent software that is automated. Intelligent software that is automated is in high demand. Sensor-based detection, radar-based detection, and video imaging-based detection are the three primary kinds of wrong-direction detection methods. The goal of this study is to automate the detection of moving infractions so that less human contact is required, as well as to identify them (using a single video camera)

While our suggested system is based on video imaging-based detection, it also takes into account three major computer vision difficulties, including vehicle localization, tracking, and direction determination. Vision-based learning is one of the most cost-effective techniques since it saves people's time while also reducing expenses by employing fewer equipment and eliminating defective goods.

## 4 Parking Violation detection and Lane violation Detection

The ever-increasing number of violations of traffic rules has become a critical challenge in Sri Lanka. The solution is to install violation detection systems on the expressway. It is an essential part of road security and safety. There is a huge increase with the use of vehicles on the expressway. Consequently, there is an increase in violations of traffic rules. Such violations lead to more road accidents.

A real problem related to traffic jams and highway accidents. This may occur due to limited allocation of the traffic police to the expressway. The system acts as an individual system without any assistance from other external systems, such as the sensors. The system can detect violations of vehicle parking and drive in the wrong lane. The system automatically detects traffic rules violated vehicles by methods of video processing techniques [1].

The aim of this research work is to build up an automated system that could not only locate, but also automatically recognize vehicle license plates. Previous vehicle tracking systems implemented in a few developed urban areas also include the use of sensors and electronic devices to turn on cameras throughout red light and computer vision or sensors to detect red lights.

This interdependence video processing technique makes the whole thing more complex. Thus, in order to eliminate this issue, the traffic rules violated the vehicle tracking system are studied on the basis of video processing techniques. The system that sets out the list of all vehicles that violate the rules.

In this specific situation, the research community has received considerable attention in the past ten years to the automated detection of violations of vehicle traffic rules [2]. Video sensors also provide reliable, effective and scalable approach to various traffic applications with low deployment and maintenance costs, as well as a huge coverage area, such as traffic surveillance and monitoring applications [3], additional support for video processing-based traffic flow monitoring with the support of unmanned aerial vehicles [4],[5].

Every other video camera-based violation monitoring system that can operate automated incident detection usually includes multi-stage processing of video sequences from CCTV cameras from expressways. The effective detection of illegal parking has attracted research attention from various domains. Researchers are working to develop new algorithms aimed at improving detection accuracy [6]. Most of these efforts have used videos taken from fixed cameras [7]. To overcome this problem of the coverage of fixed cameras, recent studies have used alternate solution data sources, including certain biking trajectories, to detect illegal parking [6]. Our work improves on these previous studies by using CCTV cameras that can be implemented on object detection.

Video surveillance involves technology to automate the process of understanding video patterns to detect and monitor spatial or temporal events within a given instance. With the increased deployment of camera monitoring systems globally in expressways, video feeds from thousands of cameras can now be evaluated more effectively. These videos could also be used more smartly in areas such as crime, violence, or the prevention of accidents.

Many illegal parking identification research has camera setups that consists of the following: one fixed camera, multiple fixed cameras, one – anti camera, and without being cameras [5]. In many articles, illegally parked vehicles are one of the causes of road traffic accidents. If a vehicle is parked illegally on a busy highway, other vehicles may hit another vehicle and potentially cause accidents. This event could give rise to a public health and safety problem [1]. The traffic tracking system should be able to avoid this sort of incident by detecting any prospective illegally parked vehicle in the detection range, triggering an alert and notifying the highway officer on duty of this information [2].

Due to its applicability to numerous practical situations, the problem of tracking vehicles in different scenarios has been widely studied. One major application is the concern of detecting vehicles that have been illegally parked in various locations. A device capable of accurately detecting this type in real-time would help to simplify and significantly improve video surveillance and would be of great benefit to the expressway tracking system.

Our research has implemented an algorithm for the automatic identification in real time of illegally parked vehicles and road lane violations. Our algorithm's simplicity and efficacy make our method try out different in a higher embedded actual world. In addition, in the update step, we construct the entire real-time system and analyze its efficiency with other along another.

There has already been a significant amount of research relevant to special traffic surveillance tasks. Vehicle detection systems using fixed cameras [1] seem to be the most typical, and our system collapses within this category. Vehicle detection systems to moving cameras [6] use a variety of methods, such as image classification, time differentiation, and specific pattern finding instead of using a background model. Extra related documents have been thoroughly reviewed in [7]. So, several researchers have tried to deal with vehicle object recognition by classifying occluded blobs. So many researchers are involved in the detection of events using machine vision monitoring techniques [8].

As for all the above evaluations, it was perfectly clear that the idea of traffic rules violation detection would have several advantages and that many problems would be addressed and that an effective solution would be presented. Even though there is research on the topic of violation detection concept, there is no common research in the area of lane driving detection.

## 2. Research Gap

### 2.3. Vehicle Type and Number Plate Detection

Studies on new trends in intelligent transportation have been conducted, and observations and interviews have been conducted on Sri Lanka's current method of graphic rule violation detection and expressway operations to determine where the study needs to be conducted next. Due to the increased difficulty in monitoring fraudulent traffic, it was decided to create a new department called the traffic police. Now every police station has an enforcement section to deal with issues like speeding and other infractions of traffic rules. Even in Sri Lanka's expressway system, authorities utilized the same method and traffic police personnel from the closest branch to watch for traffic rule breaches. According to the current method, police officers are trained and placed in various locations where they observe rule violations and issue penalty papers when they find them. However, this is an ineffective process since human observation is prone to mistake. it is more difficult to get a ticket on the expressway and only when police see a violation will a penalty sheet with the charge and vehicle identification number be issued to each exit point.

To top it all off, drivers who want to pay for their tolls on the Expressway may obtain a ticket at the entrance point to do so.

Agents will examine the receipt to determine the particulars, and then manually display the bill in accordance with the receipt information they find. The total cost is calculated based on the distance traveled and the kind of vehicle used. Despite this, each departure point from the incident area must be notified of Chargers-related traffic rule violations. The fee must be manually tacked on by agents at the point of departure.

Even though the Expressway's CCTV cameras are on duty 24 hours a day, seven days a week, human operators are on duty to monitor them as necessary. Because of the existing method' inefficiency and complexity, the authors chose to build a machine learning and image processing-based intelligent automated surveillance system.

Real-time CCTV video of the highway would be used for all detection in the planned system. Detection of the vehicle object and license plate at the entry is possible with the new planned traffic infraction surveillance system. Aside from that, it categorizes the car item to calculate the service fee When a car breaks one of the expressway's regulations, the proposed system would automatically identify it and issue a citation.

Table 1 Existing systems vs developed systems

| Existing Systems | Developed System |
| --- | --- |
| The Expressway, monitoring is done by human operators when there is an inquiry. | Via an input image taken from CCTV images, recognize a license plate. |

| | |
|---|---|
| Vehicle detection and classification via video sequences. | Vehicle detection and classification via image processing. |
| Allows to identify with a specific vehicle property. | Detect new vehicle types automatically via front view of the vehicle. |
| Detection existing vehicle types. | Detection **new** vehicle types. |
| Identify the traffic patterns via deep learning concepts. | Detect new vehicle types vi deep learning concepts. |

### 1.3. Vehicle speed rule violation detection

Though the most research areas cover the speed detection using image and video processing with a considerable accuracy in speed estimation, but there is no way to identify both speed and color of those vehicles that are exceeding the maximum speed limit which is 100km/h. But the system which is developed in this research mainly has both above mentioned two features along with another set of features. This system can detect the vehicles that are violating the speed rule that was established within the highway and recognize the colors of those vehicles and show those speeds and colors as the details to the user of the system. Following table 1.1 gives a comparison of features between the systems proposed by past studies and the system proposed in this research.

| Features | Research [13] | Research [14] | Research [15] | Research [16] | New product |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Good accuracy in speed calculation | Yes | Yes | Yes | Yes | Yes |
| Recognizing the colors of vehicles | No | No | No | No | Yes |
| Detecting speed limit exceeding vehicles in video in red | No | No | No | No | Yes |
| Display vehicle speeds and colors in the video on UI | No | No | No | No | Yes |
| Show speed violating vehicles to officer with colors and speeds | No | No | No | No | Yes |

*Table 1.1: Comparison of past research with new system*

According to above comparison, the newly developed system has new features than the other systems and this system can estimate the speeds of moving vehicles with a good accuracy and the system clearly identifies the vehicles which are exceeding the maximum permitted speed limit of the expressway and able to show those details to the officer of law with the colors and speeds of those vehicles.

### 1.4. Vehicle reverse violation detection

When we contemplate Sri Lanka's expressway. There are certain traffic laws to obey when driving on the expressway, such as maintaining a safe distance from the vehicle in front, the outer lane is for driving, while the inner lane is only for overtaking, not attempting to reverse a car, or turning back and driving in the opposite direction, and so on. However, all of these violation notifications have been viewed as the exception rather than the rule so far, with no one taking action. There isn't a more intelligent solution for that.

Here, we mainly focus on some specific type of violations. The first is finding a signal violation as a car approaches an overtake (change outer lane to inner lane). When entering through the wrong ramp and passing the toll gate or missing the exit ramp, the second violation is a reverse violation or a turn back. So, in order to detect those violations, we proposed a smarter solution i.e., without the help of human beings, and informed the monitoring center through a CCTV caption by using image processing techniques. So, they can take necessary actions at the exit ramp. This will reduce the risk of accidents as I have already mentioned.

| Research | Wrong way drive violation detection | Proposed methodology with greater accuracy |
|---|---|---|
| [22] | ✓ | ✗ |
| [25] | ✓ | ✓ |

| | | |
|---|---|---|
| [27] | ✓ | ✗ |
| [28] | ✓ | ✗ |
| Proposed system | ✓ | ✓ |

- **Does not have an accurate complete solution for a parking & lane violated vehicle detection system.**

Most of the previous research is focused only on vehicle detection. It means they were focused only to get good accuracy for identifying vehicles. This research based on traffic rules violated vehicle detection for expressway management domain. So, in this domain users don't have the technology of an automated system of violation detection. They refused all solutions due to it's not understandable for non-technical persons and carrying on their own manual testing process. So, in deep research, the author identified that expressway management domain users don't know about AI in the real-time scenario, they don't know the procedure to produce the results. That's why still, those approaches are therefore not successful in the automated perspective. The author focused on this primary gap to resolve this issue, focus on the use of explicable AI techniques and create complete solutions to get understandable. For understandable purposes, the author implemented explainable deep learning techniques for visualization.

| Features | Research [1] | Research [2] | Research [3] | Research [4] | Proposed System |
|---|---|---|---|---|---|
| Parking Violation Detection | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | True | True | False | True | True |
| Fast Moving vehicle detection | False | True | True | False | True |
| Lane violation Detection | False | False | False | False | True |
| Better Accuracy existing system | True | True | False | False | True |
| Display Violated vehicle | False | False | False | True | True |
| Violated Vehicle Counting & Display | False | False | False | False | True |

## 2. Research Problem

Currently there are three major expressways functioning in Sri Lanka. The number of vehicles continuously increases day by day in the expressway because of many reasons such as convenience to travel without facing the traffic, time saving etc. However, due to this increasement of vehicle population on the expressways, the accidents that occur on expressways are also increasing. The Major cause for these accidents are expressway rules violation by vehicles. This study has identified major rules violations in expressways such as speed rule violation where the vehicles exceed the maximum permitted speed limit of the expressway which is 100km/h, illegally parking where the vehicles park on the expressway without permission, road lane violation where a vehicle drives on the wrong lane continuously and reverse violation where a vehicle driving in the reverse direction. Because of these mentioned violations severe damages had occurred to the properties as well as the lives of the people.

Therefore, detecting these rules violations has become a major concern for the police department. Current process that is used to detect the vehicle's speeds in Sri Lanka is LiDAR guns. This technology detects the speeds of a vehicle with good accuracy. However this method has several drawbacks like it can not detect speeds of several vehicles at a time, must be handheld operated, very costly etc. Therefore it is better to have a cost effective method which can detect the multiple vehicle speeds at a time and it should be able to operate easily. And when talking about other rules violations there is no proper way to monitor those violations as well.

## 1.5 Research objectives

### 2.3. Main objectives

#### 2.3.1. Vehicle speed rule violation detection

This system used image and video processing techniques. The videos obtained from surveillance cameras located in the expressway were used as the inputs to the system. By processing those videos, the system recognizes the vehicles that are exceeding the maximum permitted speed limit which is 100kmph. And the system detects the color of those vehicles and shows those details to the officer of law. The system calculates the speeds of vehicles with a satisfactory accuracy.

#### 2.3.2. Vehicle reverse violation detection

The primary goal of putting this system in place is to decrease the number of incidents by adding a monitoring mechanism to identify breaches on expressways. Vehicles are, without a doubt, necessary to satisfy our daily needs. However, as previously stated, traffic violations are causing an increasing number of accidents every day. As a result, the primary goal is to protect people from such mishaps.

**Sub objectives**

### 2.4. Vehicle Type and Number Plate Detection

**Table 2 Specific objectives**

| ID | Specific Objectives |
|---|---|
| **OB 1** | **Critically study the current practices and issues in vehicle detection, new vehicle types of detection and number plate detection.** |
| **OB 2** | **Design and develop the functionality of vehicle detection and classification.** |
| **OB3** | **Design and develop the functionality of number plate detection.** |
| **OB4** | **Tests and evaluate the system and compare the functionality against the software requirement specification** |

**Vehicle speed rule violation detection**

1. Detecting the vehicles in the input video frame.

   In here the vehicles that need to detect the speed is detected from the background seen for carrying out the speed and color detection.

2. Calculating the speed of vehicles in the video with a good accuracy and displaying the speed.

Finding the speeds of every vehicle in the video by processing the videos taken from CCTV cameras as the input. Calculating the speed with a good accuracy. And displaying the calculated speeds of the relevant vehicles.

3. Recognize the vehicles that are over speed driving.

   From the vehicles in the video the system finds the vehicles that are exceeding the maximum permitted speed limit.

4. Recognize the color of the vehicles.

   Identifying the colors of the vehicles in the input CCTV videos. And display those identified colors of the relevant vehicles.

5. Show the details of over speed driving vehicles to the officer in charge.

   Vehicles that are exceeding the maximum speed limit will be shown in red color and their colors and speeds are shown to the officer.

**Vehicle reverse violation detection**

The special goals that must be met in order to achieve the primary objectives are as follows:

1. Detects the vehicles captured from the CCTV and divided into single frames.
2. Track the vehicles by drawing a trajectory point on vehicles' way and verify the vehicle position.
3. Predict the vehicle current position and the previous position according to the detection threshold, duration, direction, and standard deviation given by the system.
4. Check if vehicles' have reached the previous position that will be violated as a reverse violation.
5. Check the accuracy measures of the generated results.
6. The detected violations are passed through the CCTV to the monitoring center with specific information of violated vehicles.

**Parking Violation detection and Lane violation Detection**

The solution system has a method for tracking traffic rules that have accused of violating vehicles, furthermore the activities will be monitored by the device that will be viewed using the software application, which enables the traffic police to improve the detection of vehicle behavior patterns, such as the detection of parking violations and lane violations.

1. Detecting and counting vehicle given in CCTV video
2. Detecting vehicle movement

   If vehicle not movement detect especially the vehicle and 30s not movement system show that vehicle illegally parked vehicle

3. Detecting 1st lane and 2nd lane then if a vehicle is driving on the second lane, no vehicles detect on 1st lane system identify that vehicle lane violated vehicle and show red color box.
4. Final output saves the video given output directory.

## 6. Methodology

### Vehicle Type and Number Plate Detection

**Hypothesis**

If a proper application format minimizes problems in the business process, it should be easier for them to carry out their work. This is because there are problems with using most of the existing systems. Therefore, a well-analyzed system has been introduced so that all the tasks can be done effectively and efficiently with maximum benefits

The developed traffic rule violation surveillance system has the capability to facilitate for following functionalities.

- Detect the vehicle object.
- Detect the number plate when a vehicle violates a traffic rule. / Detect new vehicle types.

## 7. Gathering of Requirements

The software requirements refer to the intended software application's capabilities and characteristics. Requirements Describe the software product's users' expectations. From the user's perspective, the specified needs may be known or unknown, obvious, or hidden, anticipated or unexpected.

## 8. Requirement Engineering

Requirement engineering is the method of assembling, analyzing, and documenting software requirements from the client. There are four steps in requirement engineering such as, feasibility study, requirement gathering, software requirement specification and software requirement validation. Requirement engineering is an important part of the project development phase as "Expressway vehicle tracking system image processing system" is a real project scenario.

## 9. Feasibility Study

When the customer comes to develop the desired product, it gives an overview of all the functions that need to be performed and all the features that are expected from any of software. Referring to this information, analysts conduct a detailed study of the expected system and whether it is viable to develop its functionality. The researcher therefore conducted a discussion with the southern expressway officers and conducted a high-feasibility study to identify all the requirements.

## 10. Requirement gathering

If the feasibility study is positive for accepting the project, the next stage begins with collecting requirements from the system users. So, the researcher communicated systems users to be and some of people who use the Southern expressway as always to find out what the software must provide and what features that software should be included.
Several methods were used to elicit the needs to determine the precise requirements, define the scope, and get acquainted with the current process. The techniques utilized to elicit the requirements were as follows:

- Observation
- Interview
- Literature review

**Observation** - Researchers observed and documented the present process that takes place on the highway regarding the system, as well as the gaps and remedies that were discovered.

**Interview** - Interviews with responsible agents at the expressway entrance as well as police officers assigned to the motor traffic unit, who provide important service, were conducted to get a comprehensive knowledge of the existing procedure and its challenges.

**Literature Review** - To obtain a good understanding and collect needs, authors did a domain and existing work literature study.

### 2.5. Software Requirement specification

Software Requirement Specification defines how software interacts with hardware, external interfaces, system response time, maintenance capability, security, quality, limitations, and more. In southern express way they primarily demand a user-friendly interface because they are not highly technological people. Maintenance capability, quality, limitations, and much more were considered by the researcher.

### 2.6. Software requirement validation

After developing the requirements specifications, the requirements set out in this document are valid.

### 2.7. Functional Requirements

The functional requirements describe the service that the program should deliver. They provide information on the software system or its components. A function is just the inputs, behavior, and outputs of a software system. It may be a computational, user interaction, data manipulation, business process, or any other function that specifies what a system can do.

The following are the main functional requirements identified by the researcher about the system.

1. Vehicle type detection
2. License plate detection

Those are major roles of the developed system is to identify and classify the vehicle type. It was the key requirements of the research project and the researchers recognized many of its benefits.

### 2.8. Nonfunctional requirements

- User friendly
- Easy to access
- Efficient
- Serviceability
- Reliability

### 2.9. Data Analysis

Data analysis is the process of collecting, translating, refining, and modelling data with the aim of finding the information that authors need.


Figure 6 Data analysis process chart

### Method

The functional tree diagram is designed to show all the functions required to meet the thesis's objectives.

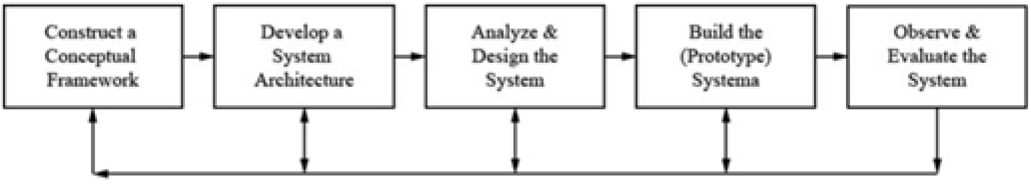



*Figure 5 System development research process*

## 3. Construct a conceptual framework

Establishing the issue domain and research questions is an essential first step. It will turn up relevant material that will be beneficial to this project. It's also a fantastic chance to learn more about machine learning as well as object recognition, which can subsequently be used to the system's development.

### 3.3. Develop a system architecture

Laptops are used to analyze and identify threats. Real-time video will be captured by the Axis camera mounted on the vehicle's dashboard as it travels along the road. The YOLOv3 algorithm detects objects and divides them into segments using a segmentation technique called bounding boxes that was created. Depending on whatever section when looking at, there are either vehicles or people on the road ahead. The algorithm and identified items may also be monitored by the driver or person utilizing the system and its performance. General Data Protection Regulation requires that no data be kept on the laptop. This should be noted. In addition, the essential stages in the machine learning training process have been discovered

### 3.4. Data collection

A sufficient data set which includes the video frames captured by CCTV cameras located in the southern expressway will be acquired from the Expressway Operation Maintenance & Management Division. Next, the data were divided into two sections in 70% and 30% ratio respectively for the training and testing purpose.
The data was gathered and determined the model's accuracy depending on quantity and quality. The initial step was to search for annotated datasets for items, such as automobiles, in object identification algorithms. The data were analyzed to understand if there were any red flags, such as missing or incorrectly labeled pictures.

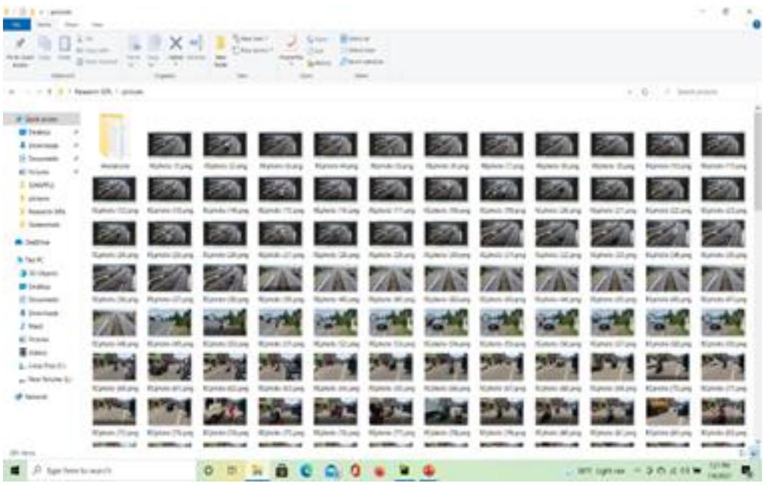


*Figure 6 Dataset*

*Figure 7 Sample labeling*

## 4. Data preparation

Data preparation will follow once training data has been collected, including putting it into the proper place and getting it ready for machine learning training. Because the sequence of the data should have no effect on what the model learns, the data will be assembled first and then the order will be randomized. The dataset will be deleted if it contains negative data since it has the potential to degrade performance. To better identify objects, the pictures will be re-labeled with new labels based on the new bounding boxes. Most of the dataset will be used to train the model, with the remainder being used to assess the model's performance.

*Figure 8 Train the model*

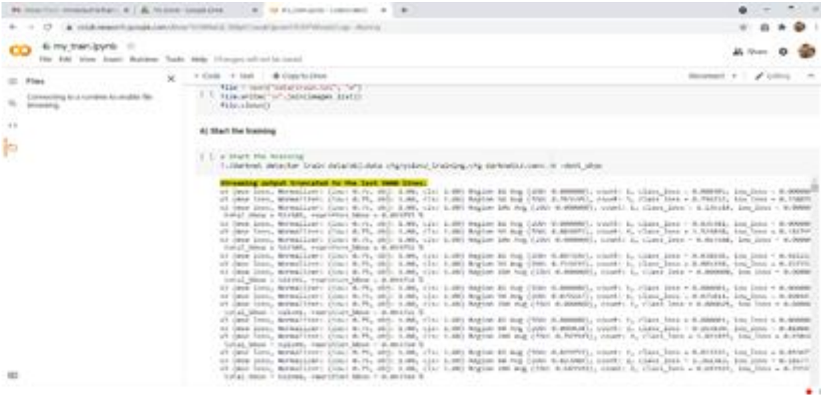


*Figure 9 Train the model*

### 5. Choosing a model

An appropriate algorithm will be selected after examining relevant literature.

### 6. Training

Before beginning a machine learning process, familiarize yourself with the preceding stages. A good place to start is by identifying a problem and then developing an algorithm to address it. Data used to train the model must be labeled properly, since objects are often misidentified throughout the training process. Using a model which trains the training data too well may result in overfitting. This may have detrimental effects on the model's performance over time. Adding additional data may help counteract over fitting. For example, if a model is trained to identify trucks, it might be helpful in training another model to detect automobiles. When training a model using fresh data, the goal of training is to improve performance. While working on this project, we enhanced the dataset by include pictures taken from various angles as well as bounding boxes that failed to capture the item.

### 7. Evaluation

To see whether the model is accurate enough, it is put through its paces and assessed.

### 8. Parameter tuning

The model's input layer was changed. This is the number of steps required to process the whole dataset depending on the batch size. For better accuracy and quicker training, this model is tuned.

### 9. Predictions

In this phase, the model will be put to the test in a real-world setting where factors like light as well as weather are unpredictable, in order to see whether it is accurate in its detection and if it has improved over time.

### 10. Initialize the package/library

It was chosen to utilize OpenCV-Python since it is a library of Python bindings intended to address computer vision issues because the goal is to identify objects in real-time.

### 11. Initialize the parameters

Due to its simpler network and faster detection performance, the YOLOv3 was selected for this application. Because the system must execute object detection in a second or milliseconds, the model's performance must be quick to keep up.

### 12. Confidence score

According to the confidence score, it may trigger a response with a value as low as 0. If the matching score falls short of the cut-off point, the system will advise the user to try again later or to try a different query. If the item's confidence score is lower than the threshold, our system will not detect it. The cut-off threshold in our system is configured to activate detection per object.

### 2.1.2 Speed rule violation detection

The captured input videos are sent to the computer and then the system detects the speeds of vehicles and recognizes the colors of the vehicles in the video. And then the system will detect the vehicles that are exceeding the maximum speed limit of the expressway and give colors of those vehicles as a detail to the officer in charge.

This methodology part is also divided into five subunits as given below.

i. System inputs
ii. vehicle detection
iii. Obtaining the vehicle position

iv. vehicle speed detection

v. vehicle color detection

In the System inputs subunit, the discussion was focused on the input data for the system and how such input data is initially processed. In the vehicle detection phase, attention was paid to identify the vehicle, of which the speed to be calculated, from the background scene. In obtaining the location of the vehicle is discussing how the vehicle location is obtained between two frames. The vehicle speed detection part discusses how to detect and calculate the speeds of the vehicles in the video and in the last part, which is vehicle color detection part, the discussion has been focused on the approach that has been taken to achieve the task.

Figure 2.1 depicted below illustrates the whole process of the component diagrammatically. Figure 2.2 illustrates the sequence diagram which shows the flow of the process in the system. Table 2.1 illustrates the use case scenario for the system.

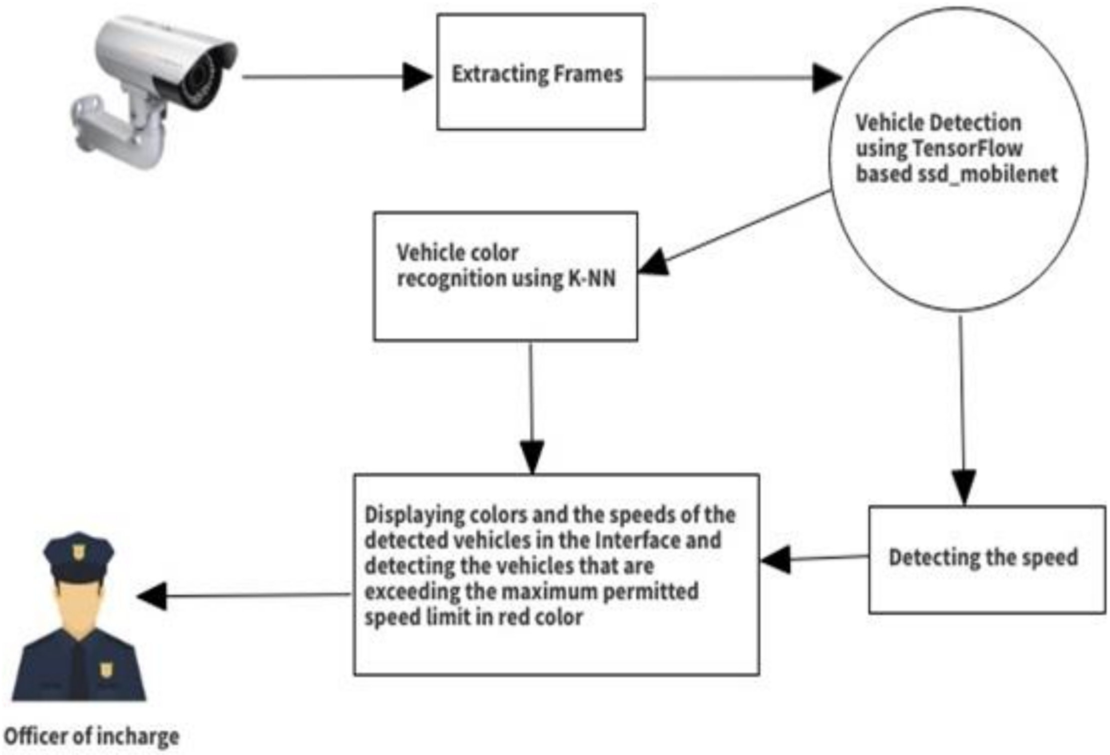



Figure 2.1: Component overview diagram

| | | |
|---|---|---|
| Use case name | Vehicle speed violation detection | |
| Description | Detecting the vehicles that are exceeding maximum speed limit and giving the colors and speeds of those vehicles as details. | |
| Pre-condition | Run the system | |
| Post condition | Take necessary actions against the speed violation vehicles. | |
| Primary actor | Officer in charge | |
| Main flow | Step | Action |
| | 1 | Insert CCTV video |
| | 2 | Extracting frames from the video |
| | 3 | Vehicle detection |
| | 4 | Obtaining locations |
| | 5 | Speed calculation |

| | | |
|---|---|---|
| | 6 | Color detection |
| | 7 | Detecting vehicles that are exceeding the 100km/h in red color. |
| | 8 | Displaying the colors and speeds of the detected vehicles |
| Extension | Step | Action |
| | 1a | If not insert the input video, an error message is displayed. |

Table 2.1: Use case scenario

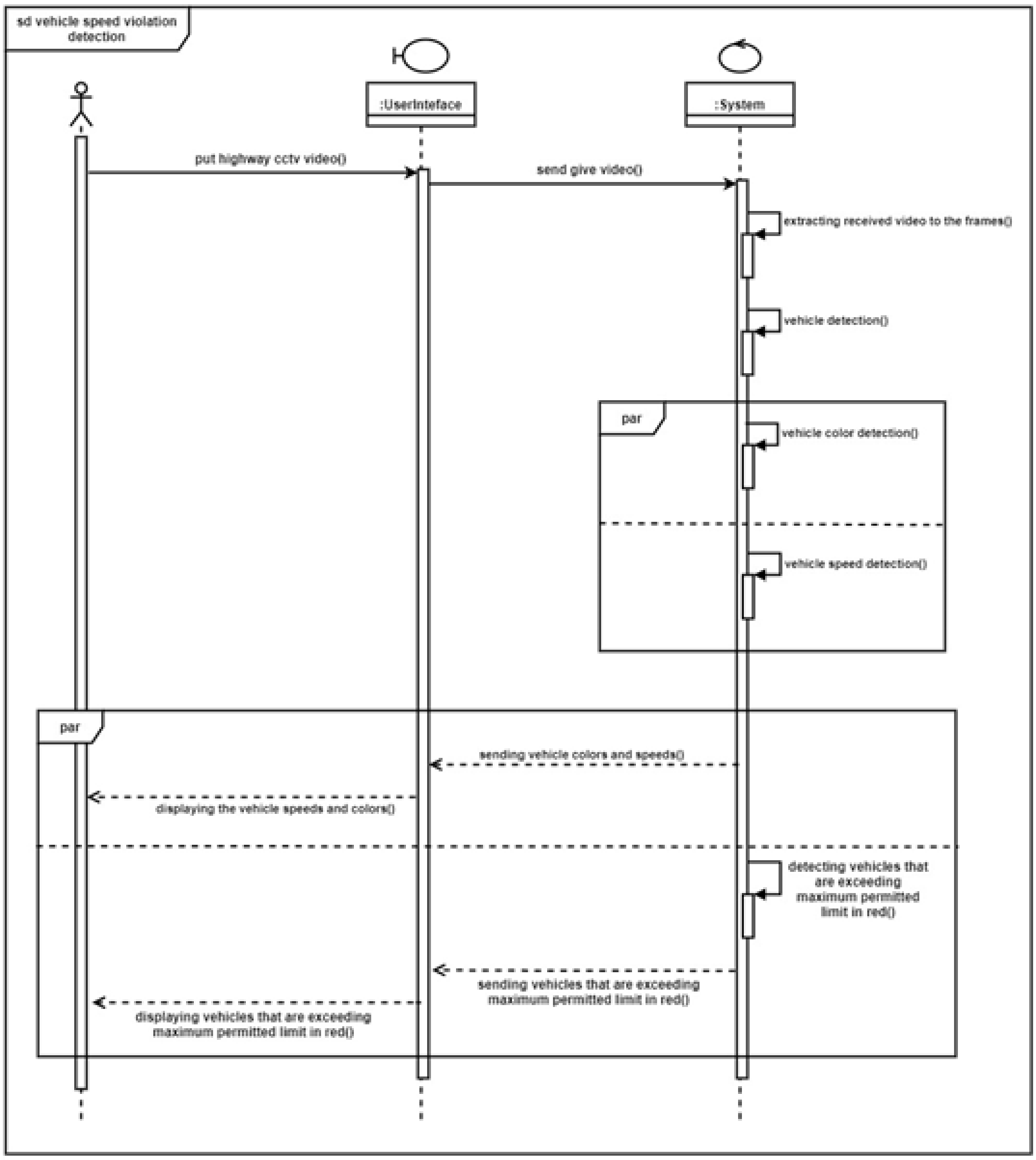


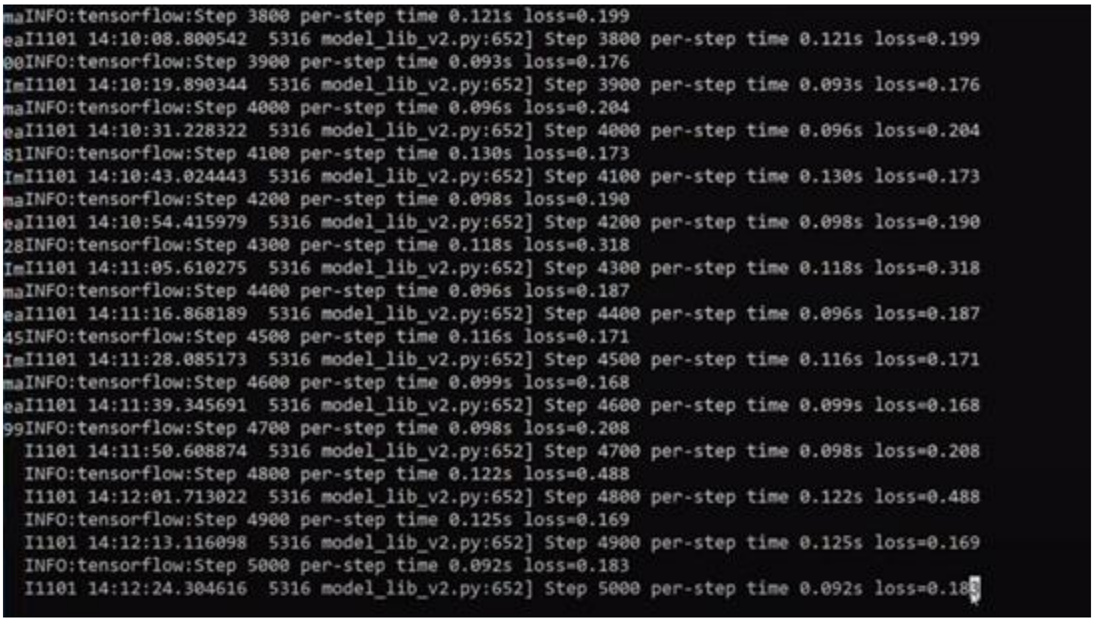

Figure 2.2: Sequence diagram.

#### 2.1.2.1 System inputs

Inputs videos to the system are obtained from the surveillance cameras located in the expressways. Thereafter, those input videos are sent to the system. Then the system extracts the frames from the video. In here, using OpenCV (Open-Source Computer Vision Library) which is an open-source machine learning and computer vision library is used to extract the frames out of the video. And these each obtained video frames are processed using an SSD (Single Shot Multibox Detector) model which is developed on TensorFlow to detect the vehicles.

### 2.1.2.2 Vehicle detection

In vehicle detection phase, the video frame is taken as the input and the output will be the bounding box surrounded those detected vehicles. In here, ssd_mobilenet model which is built on top of the TensorFlow was trained using labeled data as shown in Figure 2.3 below. In here size of dataset which used for training the model is 500. And for labeling process this study has used labelImg software. Figure 2.4 below represents the labeling process. From this model the output is the coordinates of the bounding boxes surrounded each detected vehicle. The coordinates of the top left corner of bounding box are x_min and y_min. The coordinates of the bottom right corner of bounding box are x_max and y_max.



```
maINFO:tensorflow:Step 3800 per-step time 0.121s loss=0.199
eaI1101 14:10:08.800542  5316 model_lib_v2.py:652] Step 3800 per-step time 0.121s loss=0.199
00INFO:tensorflow:Step 3900 per-step time 0.093s loss=0.176
ImI1101 14:10:19.890344  5316 model_lib_v2.py:652] Step 3900 per-step time 0.093s loss=0.176
maINFO:tensorflow:Step 4000 per-step time 0.096s loss=0.204
eaI1101 14:10:31.228322  5316 model_lib_v2.py:652] Step 4000 per-step time 0.096s loss=0.204
81INFO:tensorflow:Step 4100 per-step time 0.130s loss=0.173
ImI1101 14:10:43.024443  5316 model_lib_v2.py:652] Step 4100 per-step time 0.130s loss=0.173
maINFO:tensorflow:Step 4200 per-step time 0.098s loss=0.190
eaI1101 14:10:54.415979  5316 model_lib_v2.py:652] Step 4200 per-step time 0.098s loss=0.190
28INFO:tensorflow:Step 4300 per-step time 0.118s loss=0.318
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maINFO:tensorflow:Step 4400 per-step time 0.096s loss=0.187
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maINFO:tensorflow:Step 4600 per-step time 0.099s loss=0.168
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99INFO:tensorflow:Step 4700 per-step time 0.098s loss=0.208
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  INFO:tensorflow:Step 4900 per-step time 0.125s loss=0.169
  I1101 14:12:13.116098  5316 model_lib_v2.py:652] Step 4900 per-step time 0.125s loss=0.169
  INFO:tensorflow:Step 5000 per-step time 0.092s loss=0.183
  I1101 14:12:24.304616  5316 model_lib_v2.py:652] Step 5000 per-step time 0.092s loss=0.18
```

Figure 2.3: Training process of the ssd_mobilenet

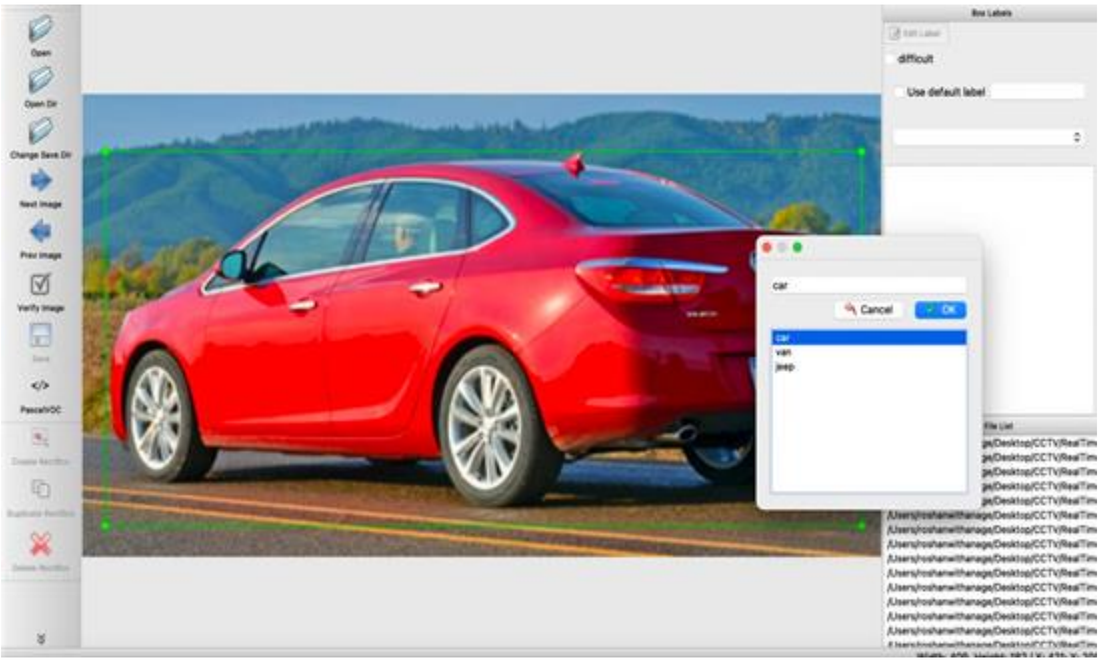



Figure 2.4: Labeling the data

#### 2.1.2.3 Obtaining the location of vehicle

After a vehicle comes to a particular range in the video, the coordinates of the bounding box x_min, y_min, x_max and y_max are obtained. When the vehicle moves to next frame, in there also the coordinates of the bounding box as mentioned earlier are obtained. Then by calculating the pixel difference between those obtained coordinates, the vehicle displacement is obtained.

#### 2.1.2.4 Vehicle speed detection

The vehicle speed detection is done using the OpenCV based on pixel manipulation and calculation. From the above phases the position of the vehicle is obtained in term of pixel units. Two factors that are needed for speed calculation are distance and the time spent to cover that distance. In here, first using the coordinates obtained the distance is calculated in pixels. Thereafter, the obtained distance is converted to SI units of the distance. Then the time spent is obtained by the frame rate. Finally, the speed of the vehicle is calculated.

In addition to the detection of the speeds of vehicles, it is necessary to detect the vehicles which are exceeding the maximum permitted speed limit. From above mentioned procedure, the speeds of every vehicle in the video are detected. And using above detected speeds, it is possible to detect the vehicles that are exceeding the maximum permitted speed limit very conveniently.

### 2.1.2.5 Vehicle color detection

Color recognition of the vehicles is done using the K-Nearest Neighbor (K-NN) Classifier. In this approach, image R, G, B color histogram values are used to train the classifier. Here the main objective is to develop a model that can recognize the colors such as Black, White, Blue, Red, Green, Orange, etc., and identifying the vehicle color using this model. There are three main steps that need to be done to develop the color recognition of vehicles. Those steps are feature extraction, K-NN classifier training and classification done by the trained classifier. The flow of this process is shown in Figure 2.8.


Figure 2.8: Flow of main steps of color recognition process

- **Feature Extraction**

This is the first phase of the color recognition process. This step is done to get the R, G, B histogram values of the images that are being trained. A color histogram is used to visually represent the distribution of distinct colors in an image. This histogram indicated the number of pixels in an image which have colors in a defined list of color categories that span the image color space to acquire the attainable colors. In here, the image's RGB color histogram can be obtained. As the parameters for RGB, the bin number of the histogram is applied with the highest value of pixel count. This process allows us to obtain dominant RGB values for creating feature vectors for training process.

- · **K-NN Classifier training**

In the classifier training K-NN classifier is trained by using RGB histogram values. K-NN algorithm is a simple and easy to use algorithm that can be used to address the different patterns in classification and regression problems. This algorithm is unsupervised. K-NN algorithm works by from all the available test observations in the training data set, computing the distance of one test observation. And next determine the 'K' nearest neighbor of that test observation. This procedure is repeated for each test observation to discover the commonalities present in the data. Selection of optimum distance measure is necessary to make the algorithm perform optimally on the data set. For calculating distance, Euclidean distance was chosen here.

- · **Classification using trained K-NN**

The classifier is the algorithm that used to perform the classification. This is used to arrange the given data to group. In this approach, first the detected vehicle image is cropped and get an image piece from the center of the cropped image. Then that obtained piece of image is sent to the trained K-NN classifier to find the suitable color for the image. Then finally, the recognized color is returned.

From the above phases the colors of the vehicles in the video are obtained. These vehicle colors and speeds are calculated when the vehicle comes to a particular region of the video. Thereafter, both obtained speeds and colors are displayed in the user interface. Finally, the vehicles that are detected as those which are exceeding maximum permitted speed limit which is 100km/h are shown to the officer in charge with the speeds and colors of those vehicles as the details.

### 2.1.2 Vehicle reverse violation detection

This section explains the methods and procedures we intend to use to build our system. Violations are detected using Faster R-CNN Deep Learning methods by collecting video footage from CCTV cameras. R-CNN and Fast R-CNN use an area proposal algorithm as a pre-processing step before running the CNN. The suggested algorithms are standard methods that are not reliant on CNN, such as Edge Boxes [5] or Selective Search [6]. In Fast R-CNN, the use of these tools becomes the processing bottleneck when compared to running the CNN.

By incorporating the region proposal mechanism into the CNN training and prediction steps, faster R-CNN solves this problem.

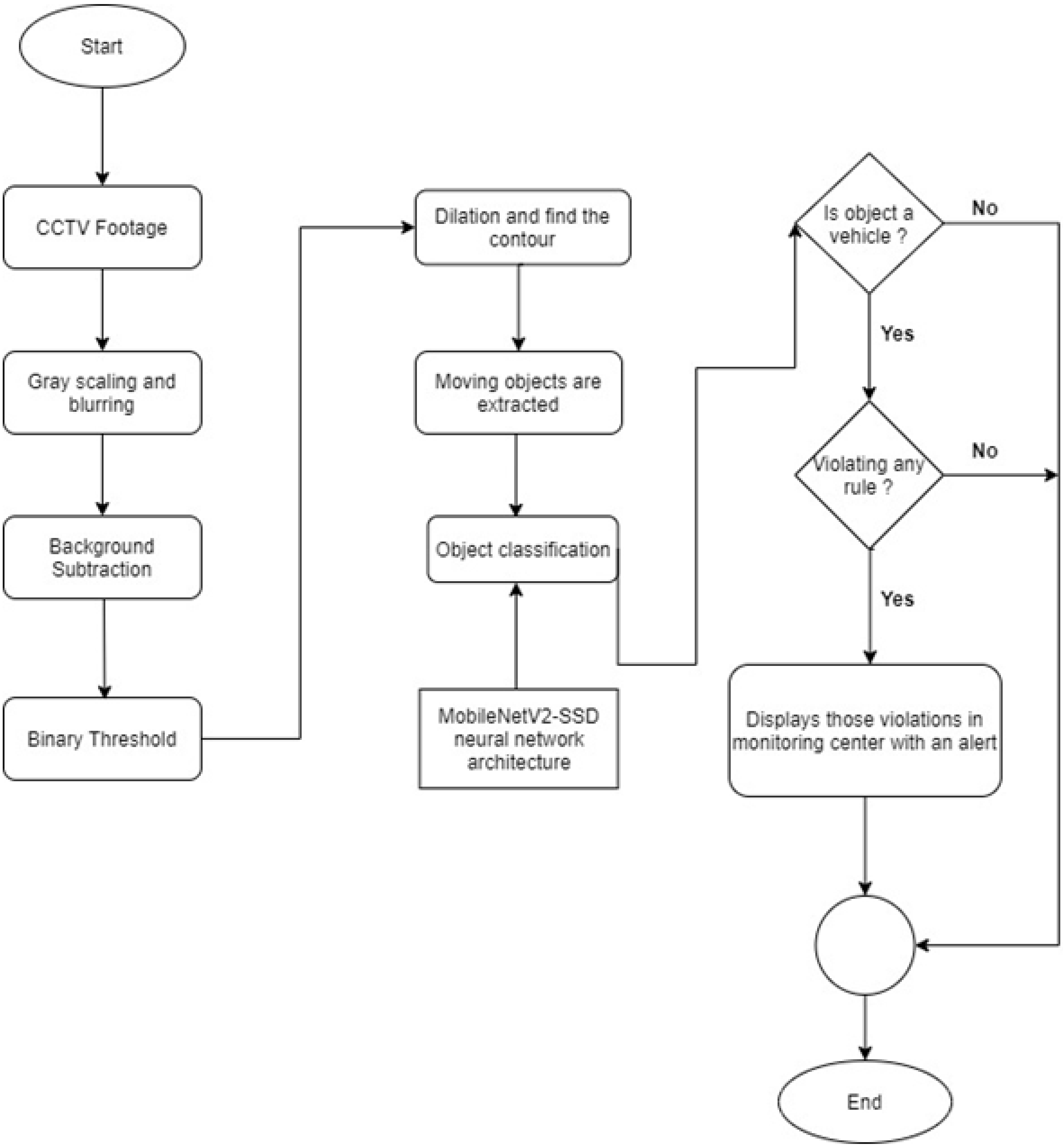



*Figure 2.1.1: Flowchart of violation detection of vehicles*

## 2.2 Image and Video Processing

- **Gray scaling and blurring:** As the part of preprocessing the input frame got from the CCTV footage, the image is gray scaled and blurred with Gaussian Blur method.

- **Background subtraction:** Background subtraction method is used to subtract the current frame from the reference frame to get the desired object's area.

- **Binary threshold:** Binarization method is used to remove all the holes and noises from the frame and get the desired object area accurately.

- **Dilation and find the contour:** After getting the thresholded image, it is dilated to fill the holes and the contour is found from the image. Drawing points over the contours desired moving objects are taken.

- **Reverse violation detection:** When a vehicle comes from a wrong direction (reverse way), it is detected by tracking the vehicle. The direction of the vehicle is determined using its current position and previous few positions.

## 2.3 The input of the prediction module

This system consists of two main components-:

- Vehicle violation detection model
- A Graphical User Interface (GUI)

First video footage that is captured from CCTV is sent to the system. Vehicles are detected from the footage. Tracking the activity of vehicles, systems determine if there is any violation or not.

The Graphical User Interface (GUI) makes the system interactive for the user to use. can monitor the traffic footage and get the alert of violation with the detected license plate of a vehicle. Authority can take further action using the GUI.

- **Reverse violation detection**

Same as when we consider the reverse violation in an expressway, you should not attempt to reverse your vehicle or turn back and drive against the traffic direction when you entered through a wrong ramp and had passed the toll gate or if you missed the exit ramp. In those situations, CCTV detects those violating vehicles as well as detects a license plate and that will display the GUI. Then appropriate actions will be done by the authority. Those monitored video sequences are separated into frames.

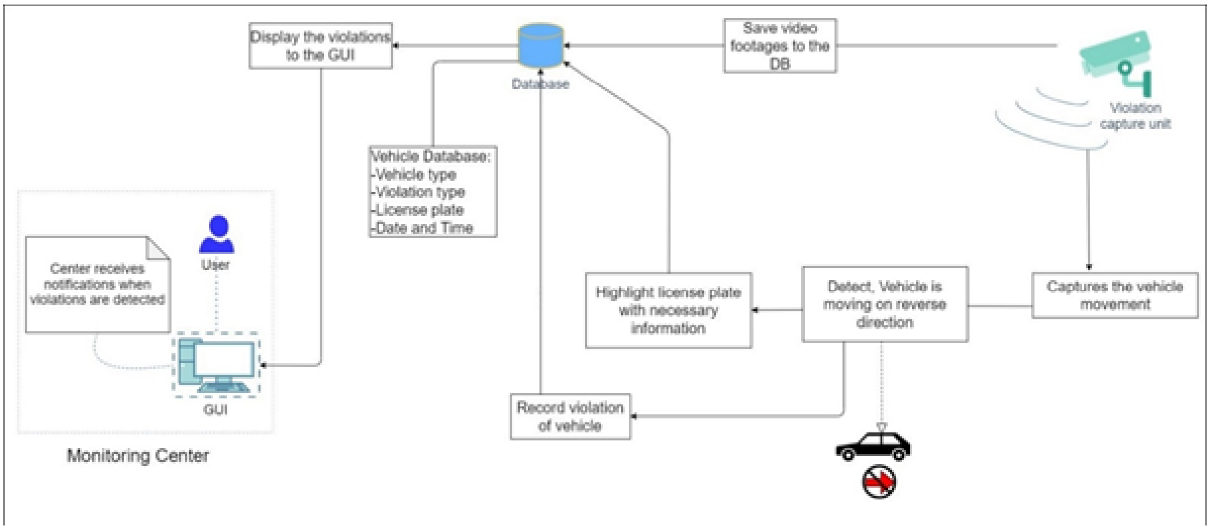



*Figure 2.1.2: Wrong-way detection module high-level overview*

**MobileNetv2-SSD model**

MobileNetV2 is a convolutional neural network architecture that seeks to perform well on mobile devices as well as GUI-based applications. It is based on an inverted residual structure where the residual connections are between the bottleneck layers. The intermediate expansion layer uses lightweight depthwise convolutions to filter features as a source of non-linearity. As a whole, the architecture of MobileNetV2 contains the initial fully convolution layer with 32 filters, followed by 19 residual bottleneck layers**.**

In MobileNetV2, there are two types of blocks. One is the residual block with a stride of 1. Another one is blocked with the stride of 2 for downsizing. There are 3 layers for both types of blocks. This time, the first layer is 1×1 convolution with ReLU6. The second layer is the depth-wise convolution. The third layer is another 1×1 convolution but without any non-linearity. It is claimed that if ReLU is used again, the deep networks only have the power of a linear classifier on the non-zero volume part of the output domain.

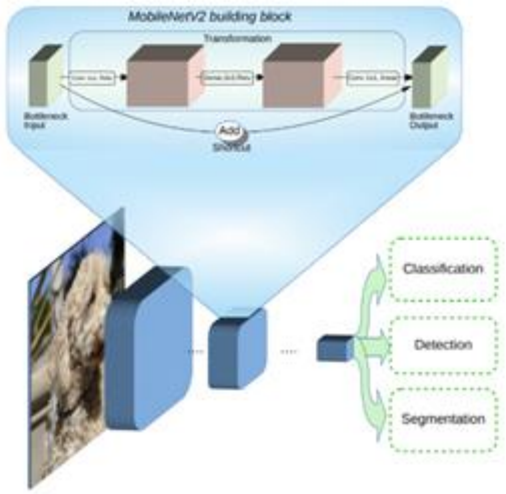



*Figure 2.1.3: Detection hierarchy of MobileNetV2 SSD model*

**Kalman filter**

Kalman filtering is an algorithm that provides estimates of some unknown variables given the measurements observed over time. Kalman filters have been demonstrating its usefulness in various applications. Kalman filters have relatively simple forms and require small computational power. However, it is still not easy for people who are not familiar with estimation theory to understand and implement the Kalman filters. Whereas there exist some excellent kinds of literature such as [1] addressing derivation and theory behind the Kalman filter, this chapter focuses on a more practical perspective.

**Process of Prediction**

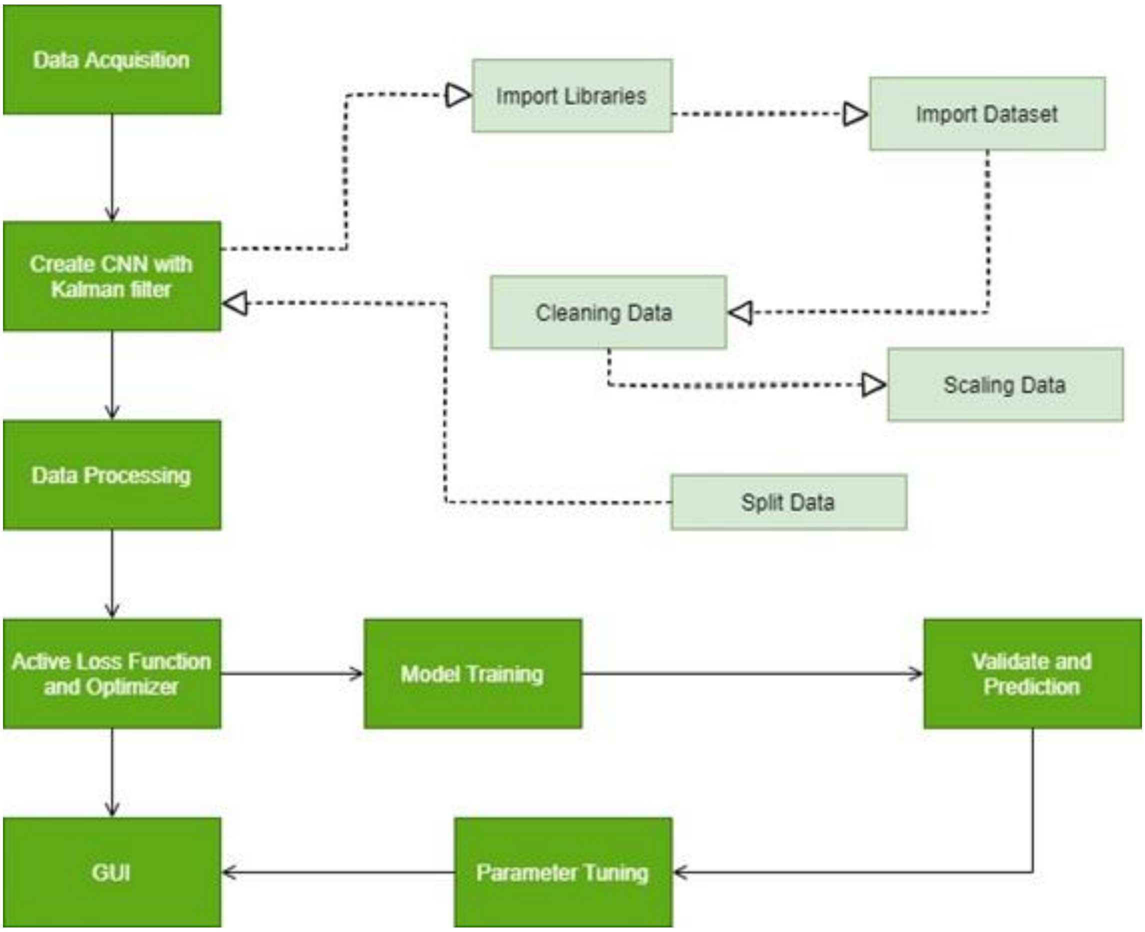



*Figure 2.1.11: Process of the prediction module*

Step 1.0: Data Acquisition

All the necessary data have been collected from the expressway in several locations. Those datasets can be accessed in both jpeg image format and the mp4 video format.

Step 2.0: Data Processing

All collected data are analyzed using various data analysis techniques such as prescriptive analysis, descriptive analysis methods used in qualitative data analysis.

Step 2.1: Import Libraries

All the necessary Python libraries are imported during this step. Pandas, Numpy, Seaborn, Keras, Tensorflow libraries are imported for data analysis, visualization, and CNN model building processes.

Step 2.2: Import Dataset

The collected video-based dataset is imported at this stage.

Step 2.3: Data Preprocessing

In this step imported video datasets are preprocessed to understand the true positive and false positive of available data. We put on video sequences and expect our machine learning and deep learning model to get trained.

Step 3.0: Create the CNN with Kalman filter

The CNN is created on top of a specific library. The main components of tracking are defined as follows.

- Number of inputs of each detection
- Number of time steps of each detection
- Number of divided frames
- Number of layers
- Number of outputs
- Learning rates
- Batch size
- Number of epochs

Once all these parameters are defined, the layers of the Kalman Filter are created.

Step 4.0: Training the model

In this step, the model is trained batch-wise, up to the number of epochs defined earlier. For each and every iteration, a loss is generated and it is gradually decreased.

Step 5.0: Validate the model and Prediction

The test data are passed to the trained model and the necessary plots are taken and a comparison is done between the test observations vs. predicted output.

Step 6.0: Parameter tuning

At this stage, several parameters are changed by considering the outputs and the quality metric values obtained. Therefore, the model is retrained and reevaluated until it produces the most accurate result. Finally, the model is saved in .xml format.

Step 7.0: Creating a User Experienced GUI

As the final step, Front-end was created using python, TKinter, and WxPython frameworks which used kivy as the open-source python library.

**Used Tools and Technologies**

This process mainly used python as the programming language and specific python libraries which are mainly used for prediction such as certifi, cycler, filterpy, Keras, Numpy, scipy, and Pandas.
Also, TensorFlow and Kalman filters are used to run the Keras library which is used for the MobileNetv2-SSD model. All the testing is done using Jupyter notebook in Anaconda Navigator with Windows platform. Also, the OpenVINO toolkit provided by Intel to facilitate faster inference of deep learning models is used to create cost-effective and robust computer vision applications, it supports a large number of deep learning models out of the box.

## 2.2 Implementation and Testing

- ### 2.2.1 Vehicle Type and Number Plate Detection

  This chapter contain the details about the testing and the implementation process of the research. The researcher clearly discusses about planes used to conduct the testing process and the results. In the implementation, the researcher discusses about the implementation process of the solution including the purpose, system overview, main steps of implementing the solution with technical requirements, and the changeovers.

After the development of the model, the next stage is the testing phase. This stage helps to identify the various problems that are found after development. This allows you to get the right output without any problems. When the test phase is complete, it is a sign that the user can get a proper output from the developed model.

#### 2.2.1.1 Testing

This is defined for testing completed software. During the life cycle of software development, it is important to test the system before activating it. Therefore, it helps to identify problems properly and take solutions as the next step. The main purpose of the test is to identify deficiencies in the developed system. Even if a system is fully developed, it may still have various problems. They must be clear and resolved before they can be implemented. Considering the research project, two main modules are integrated into one system such as license plates detection and vehicle type recognition. When all two modules were combined, the researcher examined the entire system and it appeared that there were no major problems.


Figure 19 Main dashboard

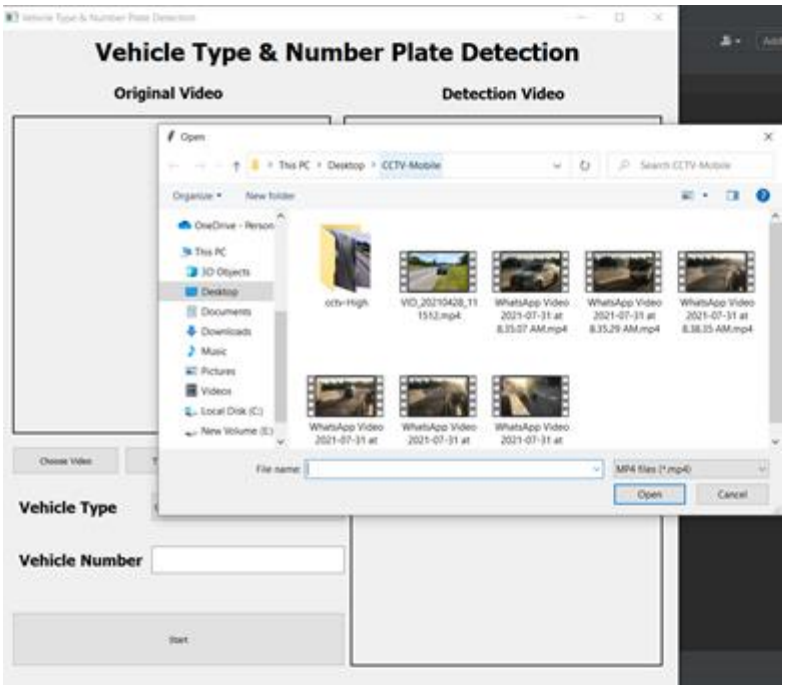



Figure 20 Video Uploading - I

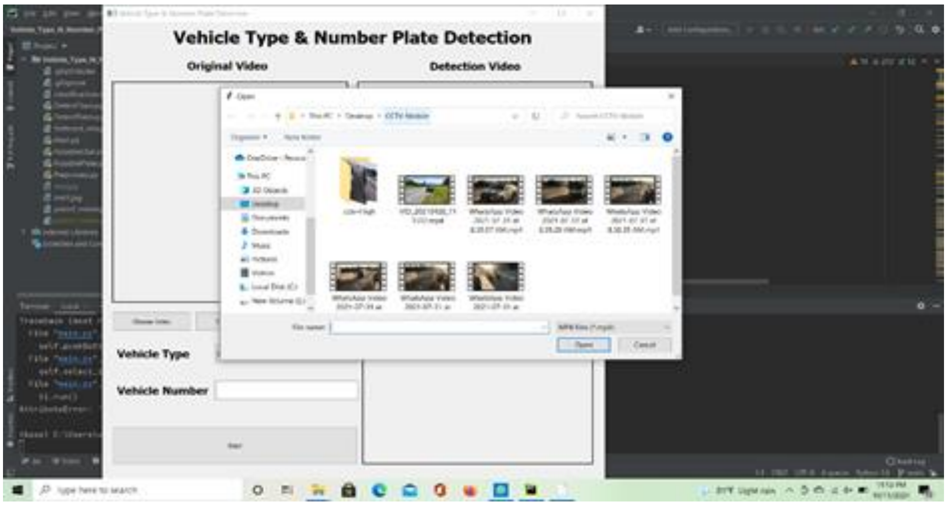



Figure 21 Video uploading II


Figure 22 Vehicle type detection


Figure 23 Number plate detection

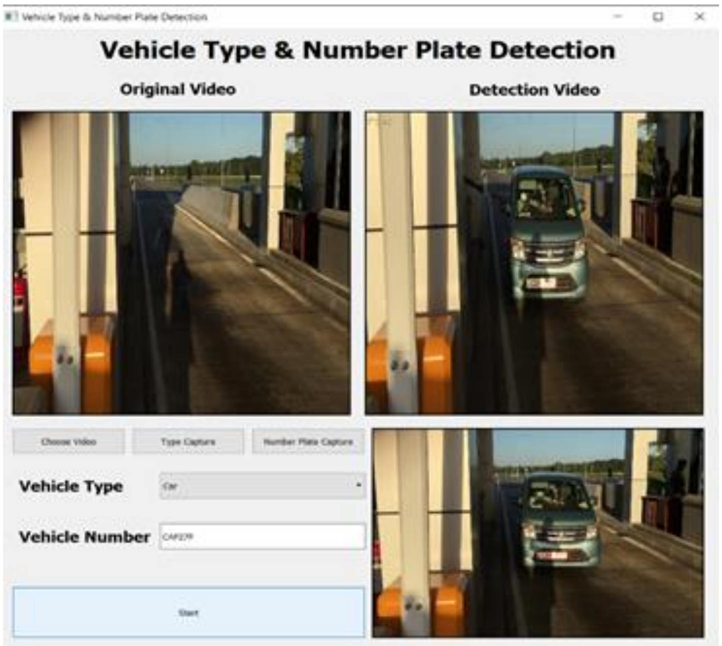



Figure 24 Original video vs detected video

### 2.2.2 Implementation

Implementation is the most critical stage of a project's life cycle since it is where the created model interacts with the actual world. This occurs after the development testing phase. This level is primarily on quality and performance.

During the installation process, many difficulties may emerge, such as troubleshooting, infrastructure concerns, and so on. As a result, the activation step should be carried out with careful attention for the user environment.

### 2.2.3 Tasks of the system implementation

There are several key points that need high attention in the implementation process. They are listed as follows,

- Overall activation should be well planned.
- Provide training sessions for users and give them an overall idea of the flow.
- Each process and how it works
- Identify the assets required for implementation.
- Ensure system security.

### 2.2.4 System changeover

This involves how the system changes from the current model to the newly developed model. There are various modes of operation, such as activation, parallel execution, phase activation, etc. The proper procedure must be followed. Different activation methods will have different effects on how the system works. Direct implementation means that the developed method works directly with the current system, but it is somewhat risky. Parallel implementation is the implementation of the newly developed system in parallel with the old system. Phase implementation is the step-by-step implementation of the developed model into the real environment. Before choosing the implementation method to follow, it is important to identify the nature of the existing models. Otherwise, it will adversely affect the whole process. This is not a big deal if the developed model is a new concept, as users will not be confused by switching system usage to each other. After considering all these factors, the researcher suggests installing the new model without completely replacing their existing manual system.

### 2.2.5 User training

It is very important to consider this part, because even if the system is running successfully, if the user does not understand how it works, it will be a big failure. Therefore, the expressway officers should be given a user manual or proper training on how to use it. Available activities. Although the model works perfectly and effectively, it is useless if users do not have a proper idea of how to use it. Therefore, relevant training should be provided to avoid problems that may arise when using the system.

### 2.2.2 Speed rule violation detection

#### 2.2.2.1 Building the hypothesis

Existing mechanism that is used in Sri Lanka to detect the vehicle speeds on expressway and detect the vehicles that are exceeding the permitted maximum speed limit which is 100km/h is quite inconvenient. Therefore, it is better to have more convenient way to do the above mechanism. It is identified that image and video processing techniques can be used to develop a system that can detect the vehicle speeds and identify the speed rule violating vehicles in the expressway. This is a good alternative method that can use to replace current mechanism.

There are some past researches that have done in this sector but there are several problems in those approaches. Therefore, a system that can function effectively and efficiently and give better results to the user has to be developed.

This developed product can mainly perform the following functionalities very efficiently.

- Can detect the speeds and the colors of the vehicles in the surveillance camera videos that are located in the expressway.
- Can detect the vehicles that are exceeding the maximum permitted speed limit of the expressway which is 100km/h.
- Can give the speed and color of the vehicle as details of the vehicles that are detected for exceeding maximum permitted speed limit.

#### 2.2.2.2 Feasibility study

It is needed to do a feasibility study to check whether the functionalities that needed by the user of the system can be viable to develop. Therefore, the expressway police officers were consulted to gather the requirements and conduct a feasibility study to check those stated requirements are viable to develop.

#### 2.2.2.3 Requirement gathering and analysis

According to the finding of the feasibility study, it has been decided to proceed with the project. Therefore, as for the next stage the requirements of the system have been gathered. For this purpose, the officers of the southern expressway have been contacted.

After gathering the requirements, a requirement analysis has been carried out to identify the most significant requirements of the project. For this purpose, it is thoroughly observed the current method that is used to detect the vehicle speed of the highway and identified some gaps associated in that method. And then the officers in charge of the southern highway were interviewed to get sufficient knowledge about those existing systems and to know about the challenges they are facing while adopting these methods. Thereafter, past researches have been studied to get a better understanding about the scope and to analyze the collected requirements to identify the most precise requirements for the system.

After the requirement analysis, it was possible to identify the functional requirements, non-functional requirements, system requirements and personnel requirements of the system. Functional requirements describe what the system must do. The main functional requirements that have been identified are as follows.

- Detect the speeds of the vehicles
- Detect the colors of the vehicles
- Detect the vehicles that are exceeding the maximum permitted speed limit of the expressway which is 100km/h and give colors and speeds of those vehicles as the details.

Nonfunctional requirements are the quality attributes of the system. They describe some constrains that need to strengthen the system functionality. The nonfunctional requirements that have been identified include.

- Accuracy in detecting the speeds and colors of the vehicles
- User friendliness
- Performance

As for the system requirements of the system following requirements has been identified.

- OS can be windows, macOSX, Unix
- CPU can be intel or AMD processor with 64-bit support
- GPU can be Nvidia GeForce MX150 or higher than that
- Minimum disk storage is 5GB

When using the system, the user must have following requirements.

- Must have some knowledge in using software applications.

#### 2.2.2.4 Designing the system

In this phase the system is designed to detect the speeds of the vehicles in the expressway and to identify the vehicles that are exceeding the maximum speed limit which is 100km/h. This phase is very important because in this phase it should be precisely decided how the system should be developed to achieve the functional and nonfunctional requirements that were identified in previous phases.

To get a better understanding about the design approaches, past researches that have suggested similar systems to detect the speeds of the vehicles were reviewed. Those past systems have implemented using image and video processing techniques to detect the speeds of the vehicles. They have used various technologies combined with image processing and video processing techniques to develop those systems. These previously conducted researches were very helpful to get a clear understanding about the suitable approaches and technologies that can be used to develop this system to provide a better output.

However, it has been identified that there is an issue between accuracy and the performance in this approach. Accuracy and Performance non-functional requirements are negatively impact each other. Therefore, in this phase some trade-off has to be done to resolve this issue.

#### 2.2.2.5 Implementation

The language that has been used to implement the system is the python language and PyCharm was used as for the ide. All the requirements that have been identified are implemented in this stage. Following Figure 2.5 showing user interface of the system before user selecting the input video.


Figure 2.5: User Interface of the system before the video was selected

Figure 2.6 shows the user interface with input video with the results.

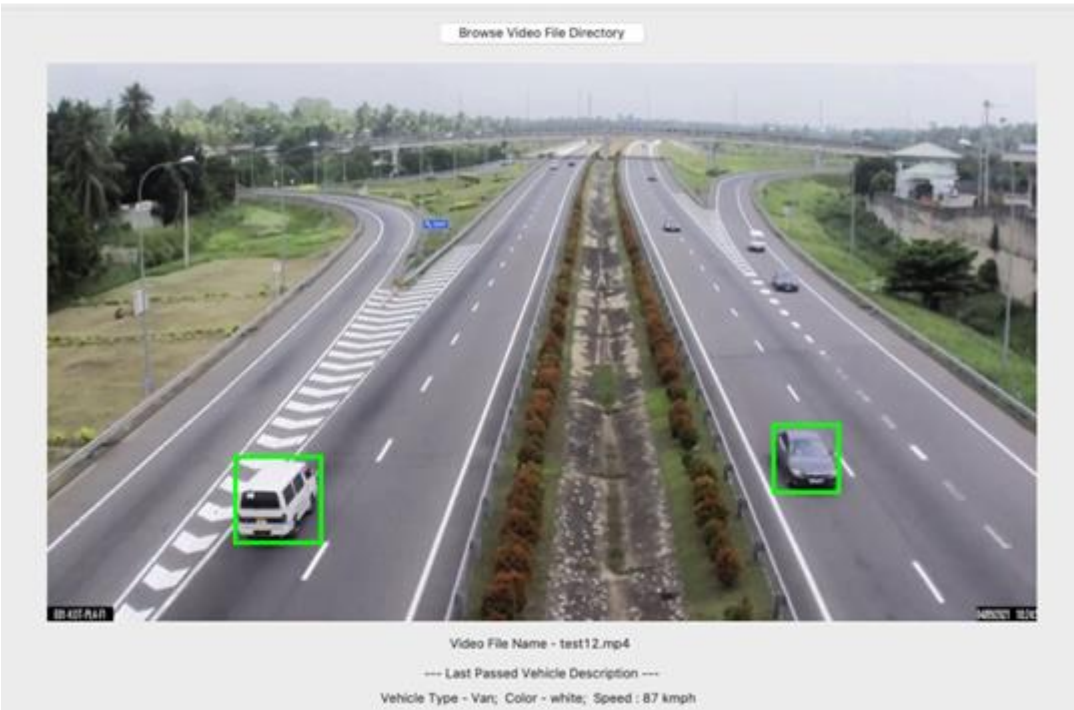



Figure 2.6: shows the user interface with results

**2.2.2.6 Testing**

This part is separated into two namely, testing and maintenance. The testing part describes how the developed system features were tested and maintenance part describes about the system maintenance.

- **Testing**

Testing the system is an essential phase. The system must be tested to find whether it is calculating the speeds of the vehicles in the video with a good accuracy, whether the system is detecting the vehicles that are overspeed driving and whether the system is detecting the colors of the vehicles that are overspeed driving.

In the testing process, estimated outputs from the system must be compared with actual data. Under the prevailing circumstances in the country, it was not possible to obtain actual speeds of vehicles that are passing the locations from where the input videos has been obtained. Therefore, some videos of vehicles with known speeds were recorded in Northern expressway near Kurunegala as an alternative solution. Four videos have been obtained at known speeds of 70 to 90 km/h. Testing of the model has been carried out using these videos. Following Table 2.1 contains the videos with relative speeds.

| Video number | Speed of the vehicle |
|---|---|
| 1 | 70km/h |
| 2 | 80km/h |
| 3 | 85km/h |
| 4 | 90km/h |

Table 2.2: Known speeds of testing videos.

By using above videos, testing the accuracy of speed calculation of the system have been carried out. And for testing the accuracy of the color detection also carried out. The speed and the color of the vehicle is detected in a particular region.

Figure 2.7 showing the estimated speed and the color given by the system for the input video with speed 70km/h. As for the result obtained speed of the vehicle is 63km/h and obtained color of the vehicle is white. In this case system produces results with an accuracy of 90%.


Figure 2.7: Testing using video 1

Figure 2.8 showing the estimated speed and the color given by the system for the input video with speed 80km/h. As for the result obtained speed of the vehicle is 92km/h and obtained color of the vehicle is white. In this case system has achieved 85% accuracy.


Figure 2.8: Testing using video 2

Figure 2.9 showing the estimated speed and the color given by the system for the input video with speed 85km/h. As for the result obtained speed of the vehicle is 87km/h and obtained color of the vehicle is white. In this case system has achieved 97% accuracy.


Figure 2.9: Testing using video 3

Figure 2.10 showing the estimated speed and the color given by the system for the input video with speed 90km/h. As for the result obtained speed of the vehicle is 98 km/h and obtained color of the vehicle is white. In this case system has achieved 91% accuracy.


Figure 2.10: Testing using video 4

### 2.2.3 Reverse way violation detection

#### 2.2.3.1 Requirement Gathering and analysis

At the beginning of the research project, data gathering was a challenging task with the technology of the country in order to obtain real-time video-based data of the expressway.

First, a study has been done in order to get a clear understanding of the existing systems. There are many traffic rule violation applications developed in other countries. Therefore, those applications helped to gain a clear idea for this module and they helped to identify the improvements and the requirements needed for the project.

In the meantime, reviewing previously done researches also helped to identify the suitable approaches, machine learning algorithms that can be used, and methodologies that need to be followed in order to make this module a success.

#### 2.2.3.2 Design

In this phase of development, the design of the violation detection system was prepared. The system design assisted to build an overall architectural design using the system requirements. This stage is very important for a strong foundation of the system since it is the medium where the proposed features and functionalities are introduced for the users. According to the reverse violation prediction module, real-time violation detection updates and the predicted reverse violations are identified as the main features and functionalities of the application. Using the high-level architecture of the module, the feasibility of transforming the requirements for proper methods was considered. Data sources, storage platforms, and visualization methods are concerned well in this process.

#### 2.3.2.3 Implementation

All the specifications related to reverse violation prediction were implemented at this stage. After completion of the prediction model development, real-time object detection with rules violations connected the CCTV database in order to output prediction results from the trained model. The generated results were passed using a MobileNetv2-SSD model to the GUI.

**<u>GUI of the proposed desktop application</u>**

- **Trajectory point view for reverse violation detection**


*Figure 2.2.1.1: Interface- Trajectory point view for reverse violation detection*

- **Vehicle reverse violation detection**


***Figure 2.2.1.2: Interface- Vehicle reverse violation detection***

### 2.3.2.4 Testing

Since, this module has been a prediction model, done with the use of a machine learning algorithm, black-box testing was performed. Therefore, out of black-box testing techniques to machine learning models, model performance testing was done. Following are the most significant test cases out of several test cases performed.

**Test Case 01:**

Here, the batch size and the number of epochs were taken as 40.

*Table 2.2.2.1: TEST CASE 01 PARAMETER VALUES*

| Parameter | Keyword used | Value |
|---|---|---|
| No of inputs | n_input | 1 |
| No of outputs | n_output | 1 |
| No of time steps | n_timesteps | 12 |
| No of iterations | epochs | 40 |
| Learning Rate | lr | 0.01 |
| Batch size | batch_size | 40 |

- Accuracy gained by the model: 96.34 %
- Overall CNNs value: 0.1492

**Test Case 02:**

Here, the batch size and the number of epochs were taken as 200.

*Table 2.2.2.1: TEST CASE 02 PARAMETER VALUES*

| Parameter | Keyword used | Value |
|---|---|---|
| No of inputs | n_input | 1 |

| | | |
|---|---|---|
| No of outputs | n_output | 1 |
| No of time steps | n_timesteps | 12 |
| No of iterations | epochs | 200 |
| Learning Rate | lr | 0.01 |
| Batch size | batch_size | 40 |

- Accuracy gained by the model: 91.52 %
- Overall CNNs value: 0.1659

**<u>Test Case 03:</u>**

Since, the results of the above test cases were not able to provide a satisfactory accuracy, in this test case number of epochs and the batch size were changed as 100 and 30 respectively, keeping other parameter values constant.

*Table 2.2.2.1: TEST CASE 03 PARAMETER VALUES*

| Parameter | Keyword used | Value |
|---|---|---|
| No of inputs | n_input | 1 |
| No of outputs | n_output | 1 |
| No of time steps | n_timesteps | 12 |
| No of iterations | epochs | 100 |
| Learning Rate | lr | 0.01 |
| Batch size | batch_size | 30 |

- Accuracy gained by the model: 92.24 %
- Overall CNNs value: 0.1622

**<u>Test Case 04:</u>**

The number of epochs was changed to 100 and other values remained constant.

*Table 2.2.2.1: TEST CASE 04 PARAMETER VALUES*

| Parameter | Keyword used | Value |
|---|---|---|
| No of inputs | n_input | 1 |
| No of outputs | n_output | 1 |
| No of time steps | n_timesteps | 12 |
| No of iterations | epochs | 100 |
| Learning Rate | lr | 0.01 |
| Batch size | batch_size | 30 |

- Accuracy gained by the model: 96.34 %
- Overall CNNs value: 0.0053

**<u>Test Case 05:</u>**

Since the results provided by Test Case 05 were at a satisfied level, a slight change was made to the number of epochs changing it from 100 to 500.

*Table 2.2.2.1: TEST CASE 04 PARAMETER VALUES*

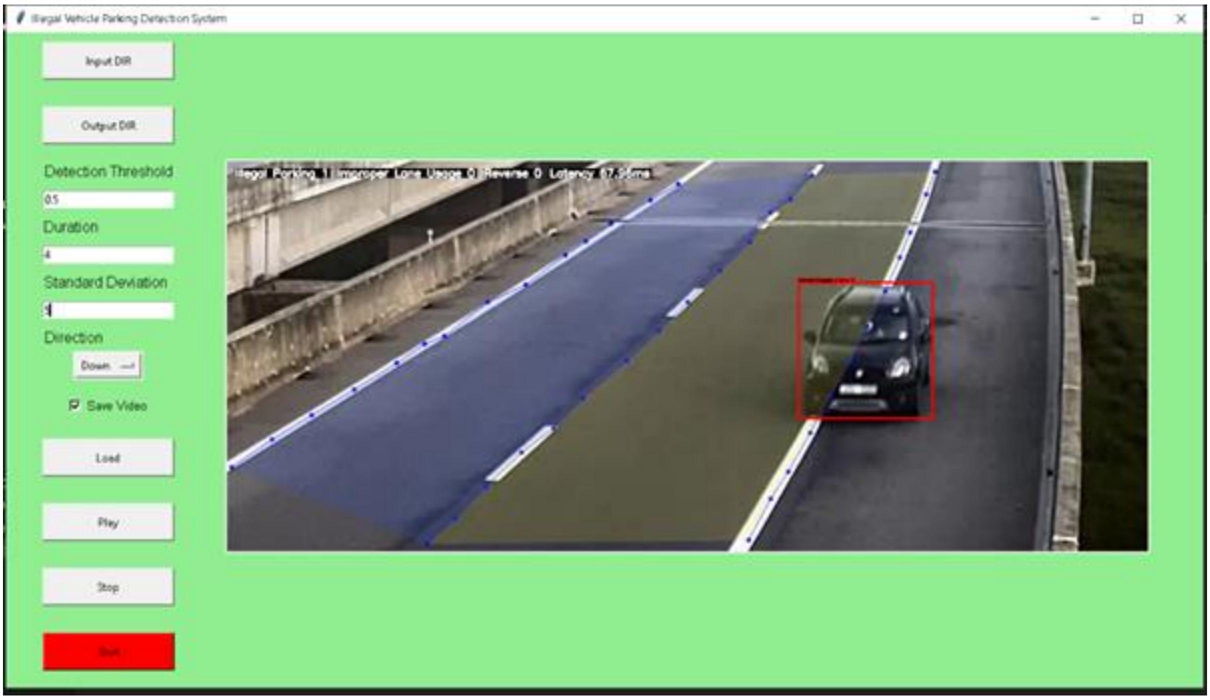
| Parameter | Keyword used | Value |
|---|---|---|
| No of inputs | n_input | 1 |
| No of outputs | n_output | 1 |
| No of time steps | n_timesteps | 12 |
| No of iterations | epochs | 500 |
| Learning Rate | lr | 0.01 |
| Batch size | batch_size | 10 |

- Accuracy gained by the model: 88.4 %
- Overall CNNs value: 0.045

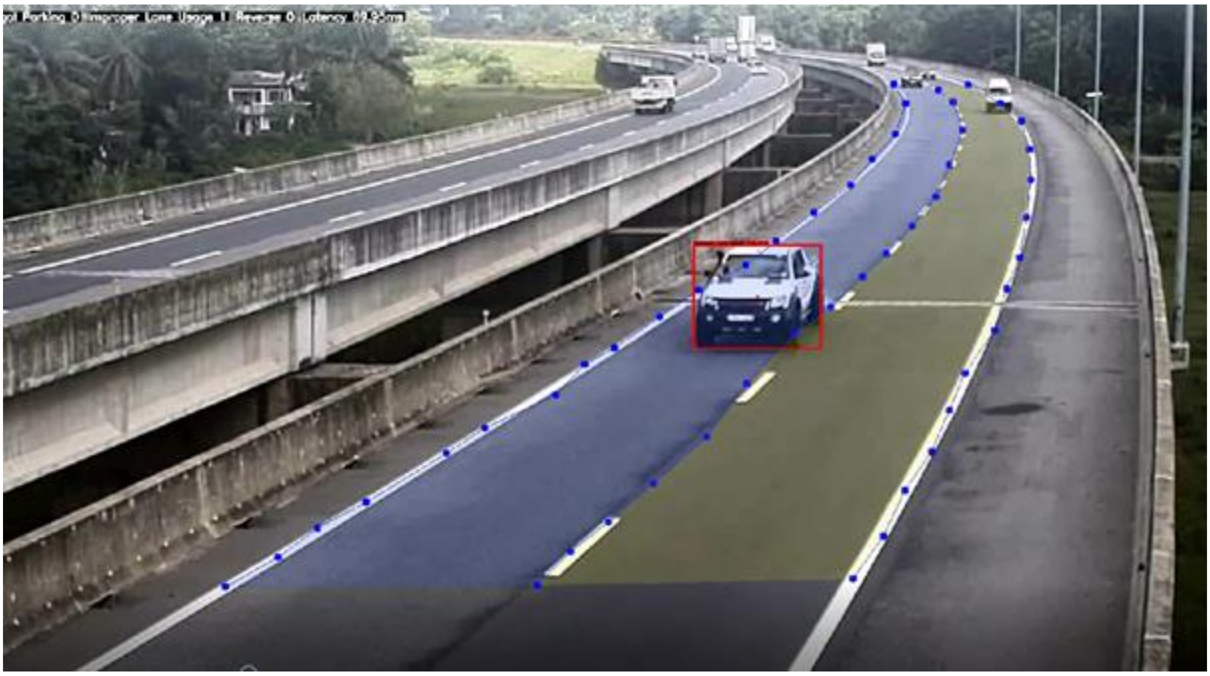
### 3. Parking Violation Detection Testing and Lane Violation Detection Testing

The solution system has a method for tracking traffic rules that have accused of violating vehicles, furthermore the activities will be monitored by the device that will be viewed using the software application, which enables the traffic police to improve the detection of vehicle behavior patterns, such as the detection of parking violations and road lane violations.

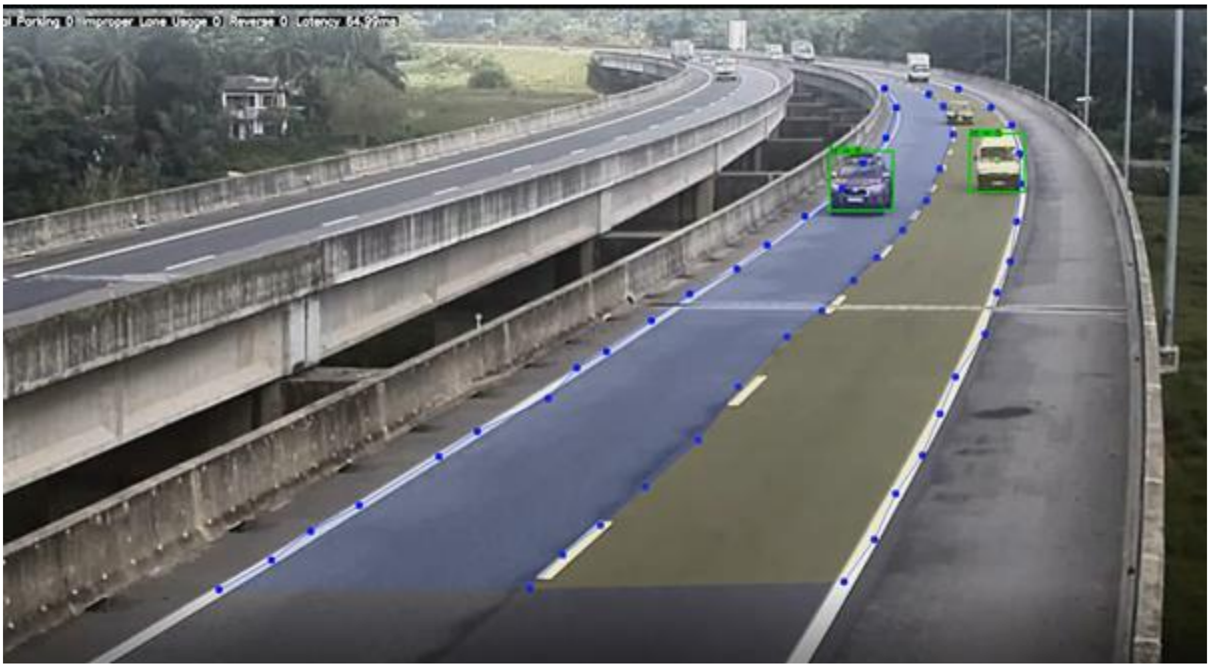
Parking violation test




Lane violation detection test




Vehicle overtaking detection and check system output - system not detected overtaking vehicle shows lane violation category




- **Maintenance**

To keep the developed system always available for the users and to make the system free from errors and breakdowns, in this phase the system is properly maintained.

### 2.3 Commercialization

1. Our system can be used in expressways.
2. First give a trial version of the software to the user.
3. If the user agrees to use the software after using the trial version, then user can purchase the software.
4. If there are any additional customizations required, then user must pay for those customizations.

## 3.0 Results and Discussion

### 3.1 Vehicle Type and Number Plate Detection

#### 3.1.1 Results

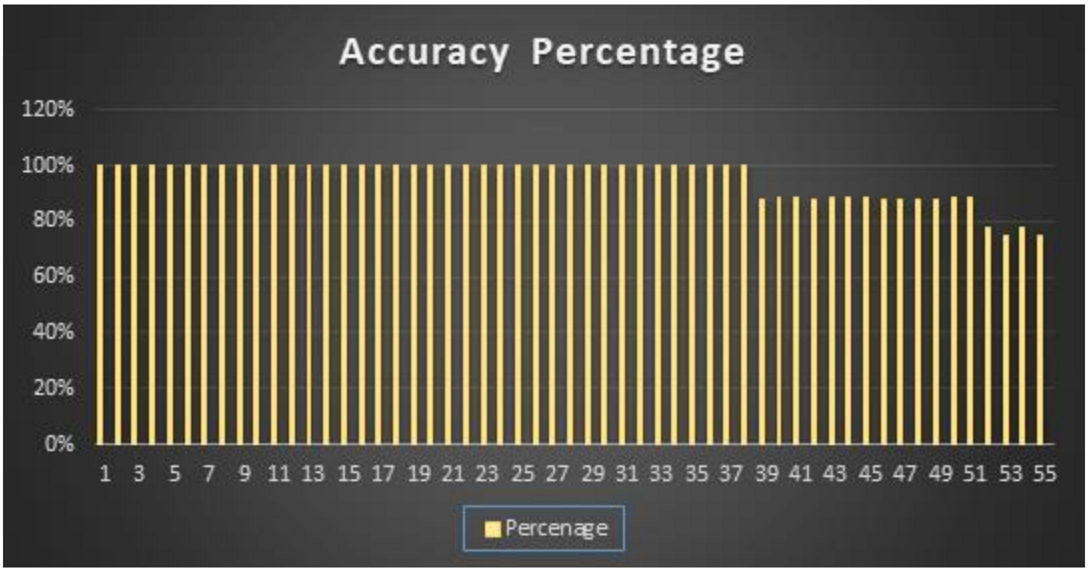
**This method cannot be compared to other techniques since there is no single set of rules or unified datasets on that tests can be performed. The images on that the tests were performed are listed in the table below.**

| Input Number | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | No of correct | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WP CAQ 7180 | W | P | C | A | Q | 7 | 1 | 8 | 0 | 9 | 100 % |
| WP CAK 7299 | W | P | C | A | K | 7 | 2 | 9 | 9 | 9 | 100 % |
| 18-9685 | 1 | 8 | - | 9 | 6 | 8 | 5 | | | 7 | 100 % |
| WP GS4060 | W | P | G | S | 4 | 0 | 6 | 0 | | 8 | 100 % |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WP PM0 967 | W | P | P | M | 0 | 9 | 6 | 7 | | 8 | 100 % |
| WP PH74 23 | W | P | P | H | 7 | 4 | 2 | 3 | | 8 | 100 % |
| WP CAX 6686 | W | P | C | A | X | 6 | 6 | 8 | 6 | 9 | 100 % |
| WP KM0 456 | W | P | K | M | 0 | 4 | 5 | 6 | | 8 | 100 % |
| WP KS61 46 | W | P | K | S | 6 | 1 | 4 | 6 | | 8 | 100 % |
| WP CAR 5462 | W | P | C | A | R | 5 | 4 | 6 | 2 | 9 | 100 % |
| WP PB98 30 | W | P | P | B | 9 | 8 | 3 | 0 | | 8 | 100 % |
| WP ND3 791 | W | P | N | D | 3 | 7 | 9 | 1 | | 8 | 100 % |
| WP KX5 340 | W | P | K | X | 5 | 3 | 4 | 0 | | 8 | 100 % |
| WPC AP57 36 | W | P | C | A | 5 | 7 | 3 | 6 | | 8 | 100 % |
| SP GR9 898 | S | P | G | R | 9 | 8 | 9 | 8 | | 8 | 100 % |
| UP CBB 3204 | U | P | C | B | B | 3 | 2 | 0 | 4 | 9 | 100 % |
| WP KI 0659 | W | P | K | I | 0 | 6 | 5 | 9 | | 8 | 100 % |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UP LL59 96 | U | P | L | L | 5 | 9 | 9 | 6 | | 8 | 100 % |

**Accuracy percentage of the images**




The following data is derived from the testing:

1. The tests are carried out on 55 different pictures.
2. 7 Images have only 1 out of 9 character wrong.
3. 6 Images have only 1 out of 8 character wrong.
4. 2 Images have only 2 out of 9 character wrong.
5. 2 Images have only 2 out of 8 character wrong.

**Total 55 images were used in experiments:**

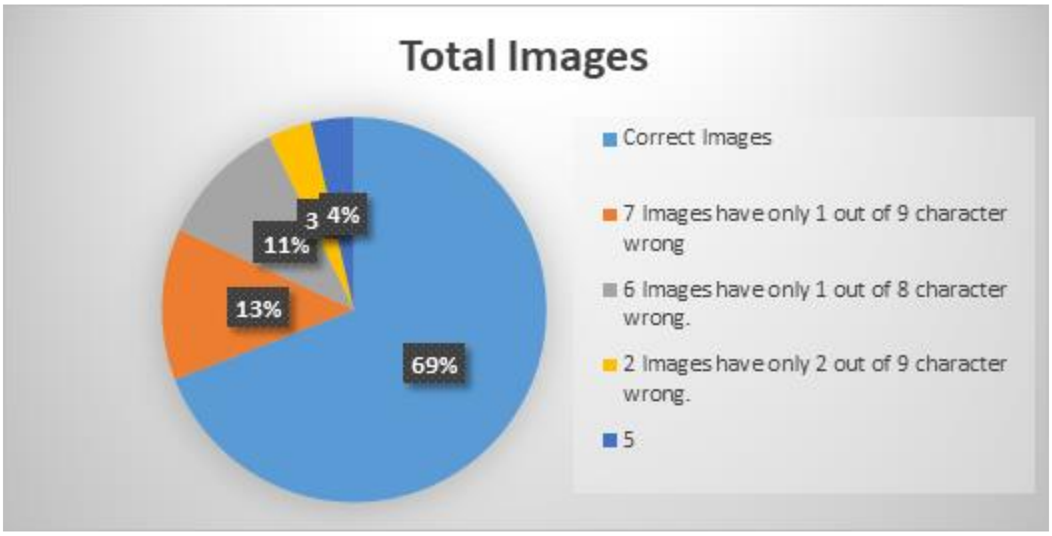



Figure 26 Total Images

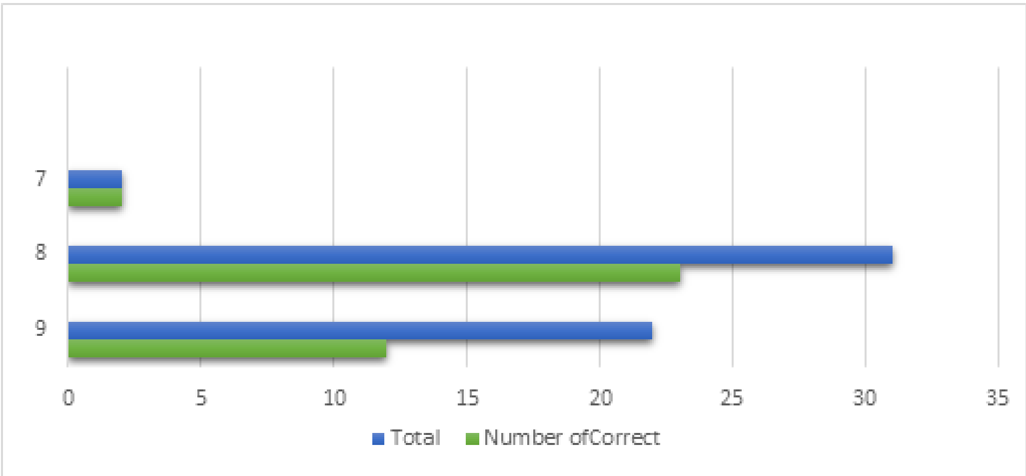



Figure 27 Number of correct images recognized

### 3.1.2 Evaluaztion

#### 3.1.2.1 What was evaluated?

- Accuracy of the detection of the vehicles in the video.
- Recognizing the license plate numbers of vehicles.

#### 3.1.2.2 Purpose of the evaluation

To check the accuracy of detect of the vehicles. And to check whether the system is correctly detecting the vehicles that are new model of the express way and to check whether the system is correctly identifying the license plate numbers of those vehicles.

#### 3.1.2.3 How did the evaluation did?

The authors compared the estimated outputs with the actual data. Therefore, researchers got the actual vehicle model and license plate data with the help of the Police Department. And these actual data were collected near the locations of the surveillance cameras which researchers were obtaining data from.

By using above collected actual data, researchers compared the system outputs with the actual new model of the vehicles. And compared the recognized license plate numbers of vehicles with the actual license plate numbers of those vehicles.

#### 3.1.2.4 Discussion

In Sri Lanka, the characteristics of the License Plates are strictly maintained. Included in this list are factors such as license plate size and color, as well as the number of characters on the plate and their sizes, colors, and fonts used on each one. While in Sri Lanka, a standard procedure for the License plate is still not used, making the process of localization and identification of the License plate very difficult and time consuming. Other than that, the scripts utilized to write the License plate are not all the same throughout the country.

The various difficulties faced by the system

1. Poor Images: One reason for this is that the Licence plate would be too far away while taking the picture; this results in poor image quality. Another explanation is that the camera used to capture the pictures was of poor quality.
2. Blurred Images: The pictures get smeared as though they were captured in slow motion. A motion blurred picture is one in which the movement of the objects in an immobile image or in a series of images, such as a movie, may be seen as streaking. During the covering or recording of an image, this problem is mainly caused by fast movement, which disturbs the picture.
3. Poor lightning and law contrast images: Overexposure in the surroundings, reflections from different things in the area, or shadows projected onto the license plate are the most common causes of this problem.
4. Object Obscure: Objects or substances that adhere to the plate or a portion of the plate, such as dirt or tow bar wire, make it difficult to take a good picture of the Licence Plate.
5. Problems of having different license plates: Many provinces have distinct readings for the license plates on the front and rear. Some simply ask for the installation of back plates, leaving the owner free to customize the front with their own characters. License plates for the same vehicle will now have unique designs because of this.
6. Trouble caused on account of different fonts used: The Licence Plate has a different font style, which exacerbates the issue.

Some of these flaws can be fixed using software, while the other ones must be addressed using the system's hardware components. Objects covering the License Plate may cause difficulties, which can be avoided by raising the surveillance camera's height. However, it introduces other challenges, such as correcting the License Plate's amplified and expanded skew. The License Plates' faults are due to a variety of small-scale processes. There is a chance that a single character will be incorrect when certain vehicles are allowed entry into prohibited regions. This is since an unauthorized car with a comparable License Plate is not seen as anything special and is seen as quite straightforward. However, this level of error and opacity would be considered unacceptable in a wide range of new System applications. The author suggests the following improvements to the research provided in this thesis to make it even better.

The emphasis of our future research will be night monitoring and the improvement of previously published algorithms. All our proposed system's other parts need to be improved, with a particular emphasis on occlusion management, vehicle matching, and increasing character recognition accuracy by utilizing neural networks and back propagation algorithms. The initial step in this process is to train the network, and to do so, input and goal must be provided. The segmented character on the license plate may now input the neural network to simulate after the network had been trained and effectively used in the real world. In an ideal world, input characters would be compared to neural network training data and the ASCII code for the matching input character would be produced.

## 3.2 Speed rule violation detection

### 3.2.1 Results

When comparing the actual speeds with estimated speeds given by the system according to the above test results, the developed system has a satisfactory accuracy varying from 85% to 97% in calculating speeds. And the vehicles in the input videos are correctly identified from the background. The system identifies and displays the vehicles which are exceeding the 100km/h speed limit with a red rectangle enclosing it. System identifies the colors of the vehicles in the video accurately. And the system displays the colors and speeds of the vehicles. And the system gives the colors and speeds of overspeed driving vehicles as the details. Figure 3.1 illustrates the detecting the speeds and colors of the vehicle. This color and speed detection will take place when the vehicle comes to a particular region. Figure 3.2 illustrates the detecting the vehicles that are driving beyond the maximum permitted speed limit in red color.

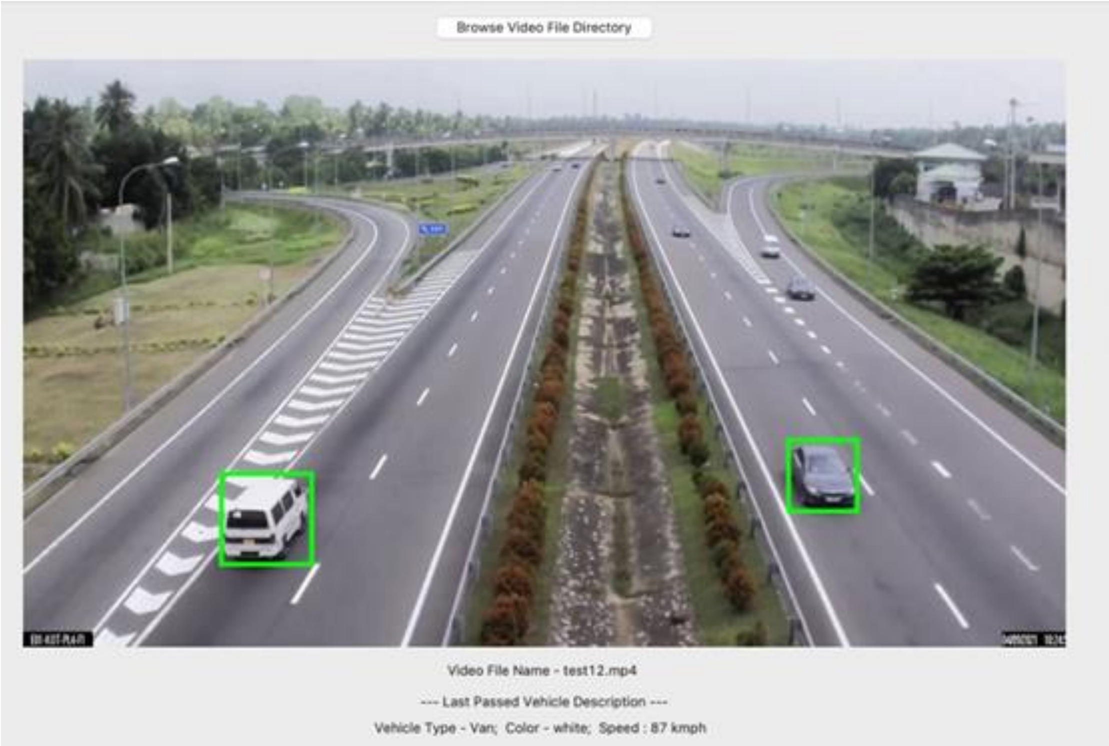



Figure 3.1: Detecting vehicle speeds and colors

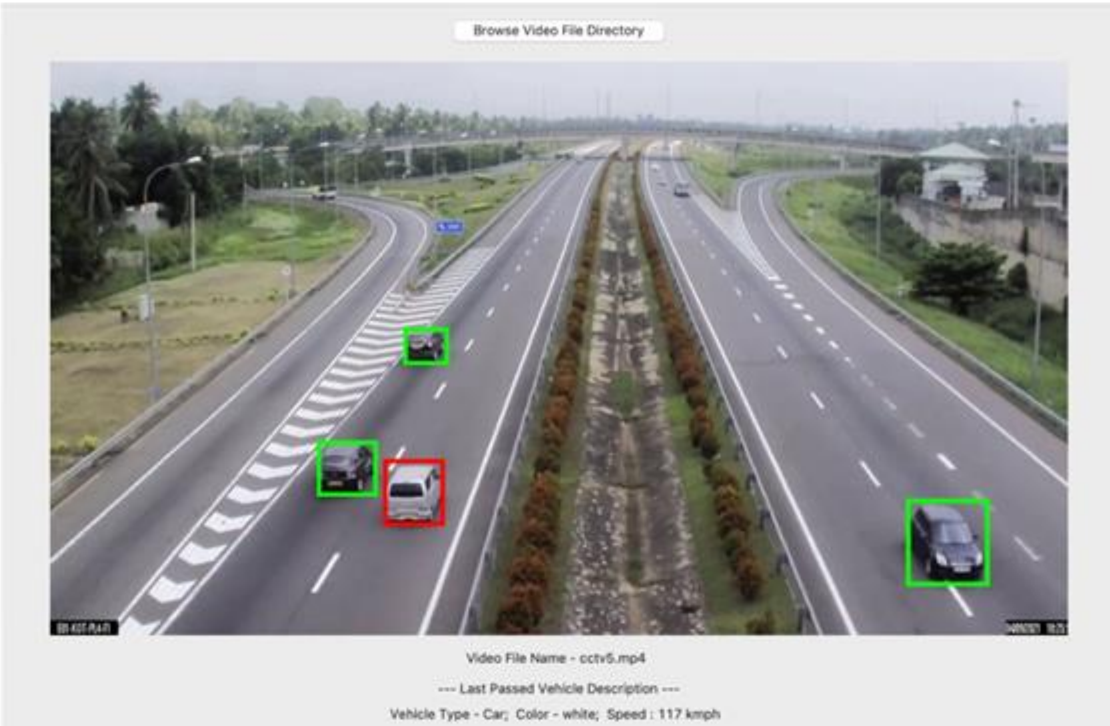



Figure 3.2: Detecting the vehicles that are overspeed driving in red color

### 3.2.2 Discussion

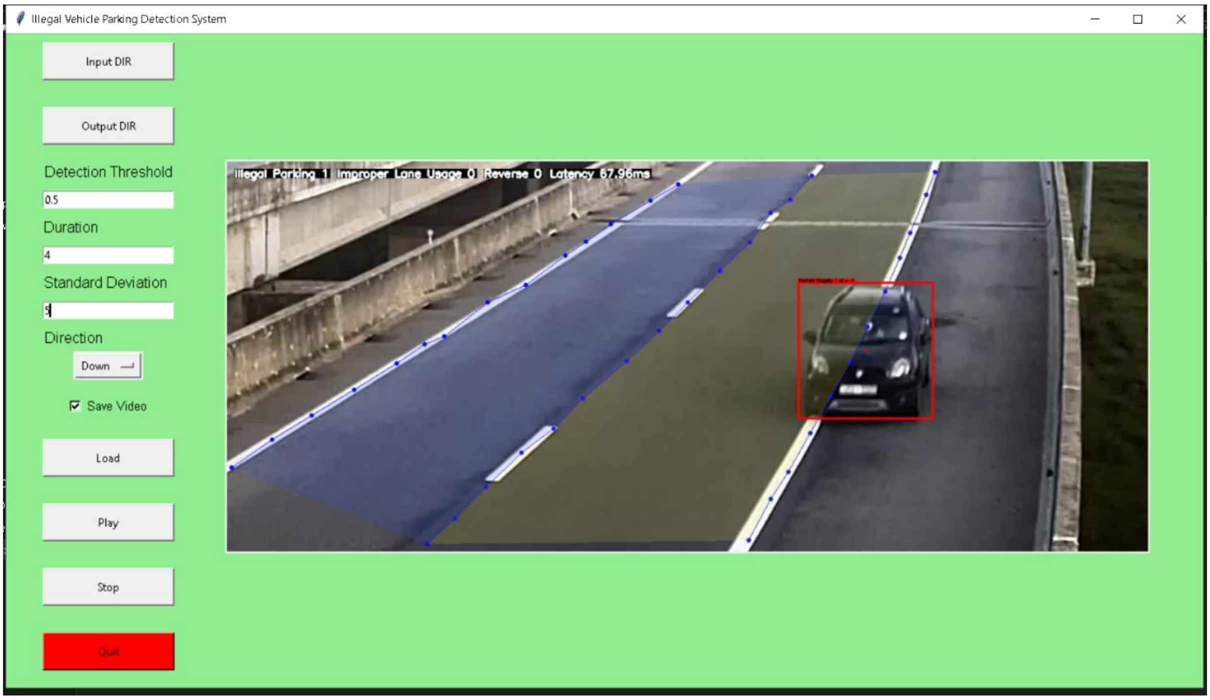
In Sri Lanka expressways, the maximum permitted speed limit which is a vehicle can travel is 100km/h. The main reason for the establishment of this rule is for the safety of people who are using the highway for travelling purposes. However, there are vehicles that go beyond this speed limit. This rule violation can result for many accidents causing sever damages for both properties and passengers. Therefore, identification of vehicle speeds is very important.

Currently, LiDAR systems that are being used in Sri Lanka have several drawbacks as clearly mentioned in the research problem. Therefore, it is better to have an alternative method to replace the current system. As being identified, usage of image and video processing techniques has become more popular, cost effective and considered as a fine approach in this area. In this research for developing the vehicle color and speed detection model, ssd_mobilenet model which is built on top of the TensorFlow has been used for the vehicle detection. Thereafter, pixel manipulation and calculation were done to obtain the speeds of vehicles and K-NN classifier has been used for the color recognition of vehicles.

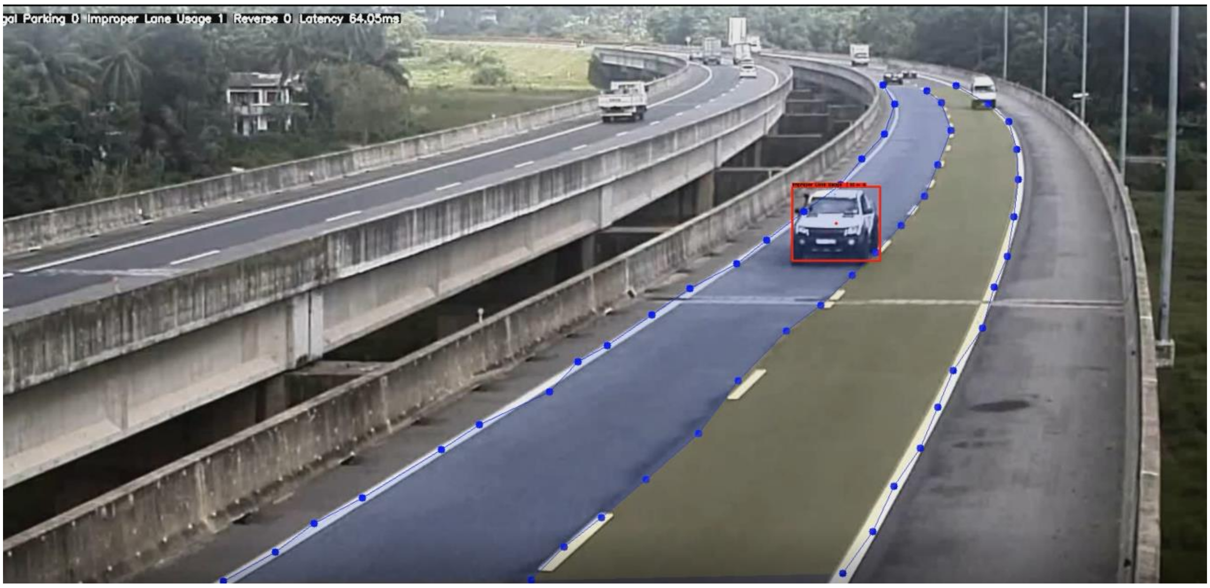
In this research, first, attention was paid to the YOLO for developing the speed detection model. However, the factors like angle of the camera and height of the camera above the ground are found to be affected negatively to the accuracy of the detected speed. Input videos are obtained from the Kaduwela, Kahathuduwa and Kottawa stations and the heights of the CCTV camaras fixed at these locations have different values. The camera angle of one station is different from that of the other. Under these circumstances, the results produced by the model were far below the expected accuracy. As such, the YOLO approach for developing the model in detecting the vehicles' speeds had to be given up and ssd_mobilenet model was chosen.

This system produces accurate results when the resolution of input videos is set to 640 x 360. Therefore, videos with resolutions higher than the 640 x 360 should be reduced to this desired resolution before inputting to the system to get more accurate results. Moreover, the accuracy of the speed detection is significantly depending on the position and the angle of the camera.

Parking Violation detection




Lane violation detection




## 3.3 Reverse way violation detection

### 3.3.1 Results

- **Prediction Module**

This section mainly focuses on the experiments conducted in order to find the best parameters of the designed model. Some of the experiments discussed in this document are done using the data in the "Kaduwela" expressway, ideally which predicts the reverse violation of daytime. The data used for the experiments are based on daytime between the intervals of (8.00 am) to (4.00 pm). The following setup is used to run the experiment related to the reverse violation prediction module.

```
# Convolutional network building
network = input_data(shape=[None, 32, 32, 3],
                     data_preprocessing=img_prep,
                     data_augmentation=img_aug)
network = conv_2d(network, 32, 3, activation='relu')
network = max_pool_2d(network, 2)
network = conv_2d(network, 64, 3, activation='relu')
network = conv_2d(network, 64, 3, activation='relu')
network = max_pool_2d(network, 2)
network = fully_connected(network, 512, activation='relu')
network = dropout(network, 0.5)
network = fully_connected(network, 10, activation='softmax')
network = regression(network, optimizer='adam',
                     loss='categorical_crossentropy',
                     learning_rate=0.001)
```

*Figure 3.1.1: Code relevant to the CNN model building*

*Table 3.1.1: VALUES USED FOR THE PARAMETERS IN THE NETWORK*

| Parameter | Keyword used | Value |
|---|---|---|
| No of inputs | n_input | 1 |
| No of outputs | n_output | 1 |
| No of time steps | n_timesteps | 12 |
| No of iterations | epochs | 100 |
| Batch size | batch_size | 30 |

### 3.3.2 Experimental Setup

The performed experiments are done using a Lenovo ideapad (2018) with processor power 2.2 GHz, Intel Core i3, Memory 8GB, Intel(R) HD Graphics 5500, and the operating system used is Windows 10 Home. The model is trained using the CPU of the above-mentioned machine.

**Experiment 1:** This experiment was done in order to find the model accuracy by changing the number of epochs.

*Table 3.2.1: MODEL PERFORMANCE WITH TRAINING EPOCHS COUNT*

| Training Epochs | 100 | 400 |
|---|---|---|
| Best Fit % | 86.7 | 84.8 |

The graphs shown below are the graphical output of the predicted results over actual data.

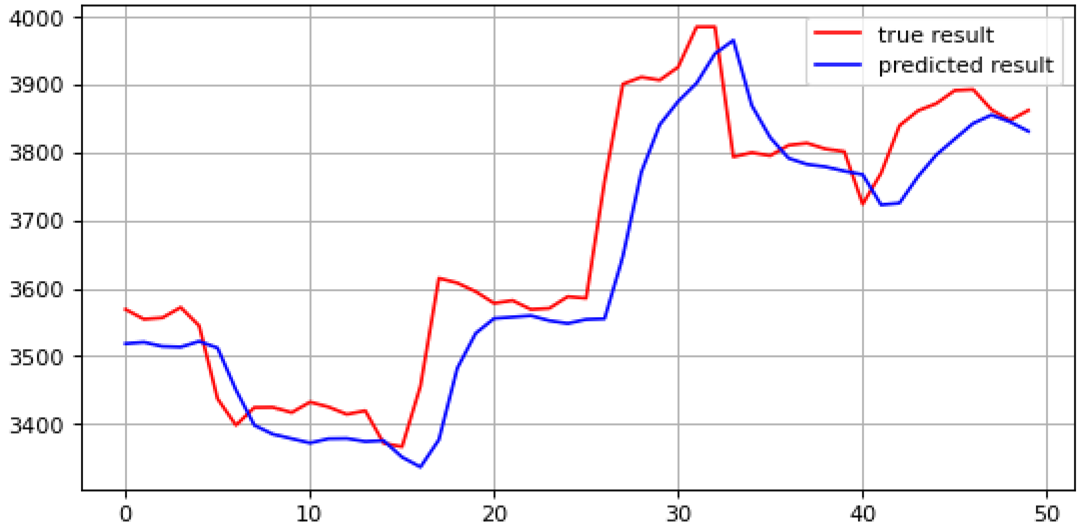



*Figure 3.2.1: Predicted results over actual data with 100 training epochs*

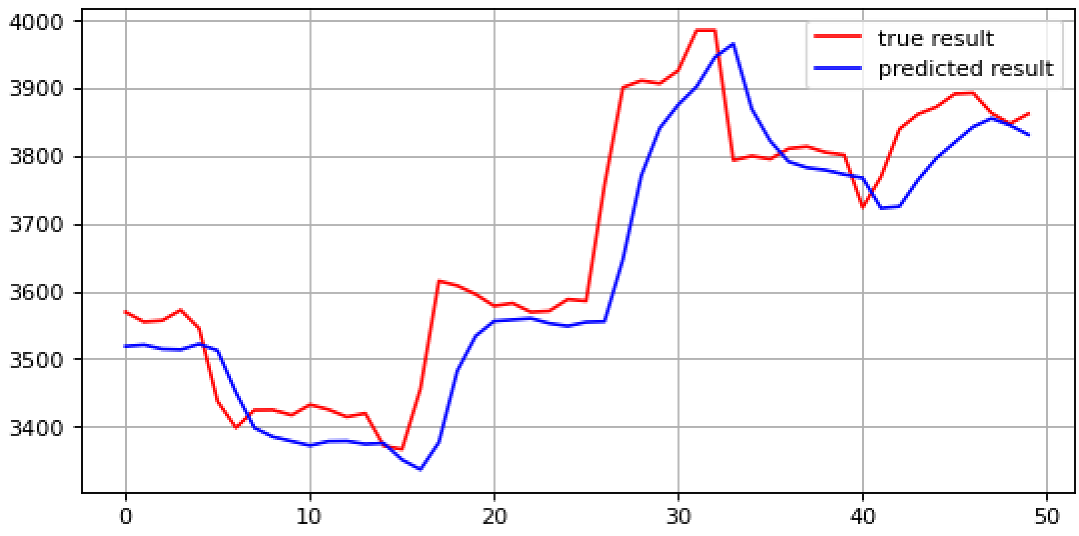



*Figure 3.2.2: Predicted results over test data with 400 training epochs*

Therefore, it is clear that increasing the number of training epochs increased the model accuracy. By changing the number of epochs, it takes more time to train the model.

## CHAPTER 4: Conclusion

Currently, vehicle rules violation in expressways are major concern to police department as those violations occur sever damages to the properties and people lives. Therefore, in this study our aim is to build an automated expressway rules violation detection system with a good accuracy. This system is very cost effective and produces good results. This system can be developed to work on weather changes and to work in nighttime.

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