EXPRESSWAY SPEED RULE VIOLATION DETECTION SYSTEM USING IMAGE AND VIDEO PROCESSING

Project Id: 2021-238

Final Project Thesis

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Specializing in Software Engineering

Department of Information Technology

Sri Lanka Institute of Information Technology
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DECLARATION

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IT18148732	Tennakoon T.M.P.J.A.	

The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

…………………………………. …………………………..

Signature of the supervisor Date

(Ms. Chamari Silva)

…………………………………. …………………………..

Signature of the co-supervisor Date

(Ms. Geethanjali Wimalaratne)

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My last tribute, but not the least, is to my dearest parents who were always behind me and extended their fullest corporation in many ways to make this research successful.

Abstract

Currently, due to the increase of vehicle usage and other reasons, people tend use expressways for travelling purposes. However, massive number of accidents are occurring in Sri Lankan expressways because of the violations of rules established within the expressways. These accidents occur causing sever damages to the properties and even causing the death of people. Over speed driving or driving beyond the maximum speed limit, which is 100kmh in express ways, is a major cause for these accidents. Therefore, speed detection has become an important part in Sri Lankan expressways. Current technology, that is used in detecting the speed of the vehicles in Sri Lanka, is LiDAR (Light Detection and Ranging) technology. But this technology contains several drawbacks. Therefore, this research has given a good alternative which uses the image and video processing techniques to overcome those shortcomings. For this research, a system was developed using video stream from the surveillance cameras that are in expressways as the inputs. System can automatically estimate the speeds and colors of the vehicles in the video and automatically detect the over speed driving vehicles and show it to the officer in charge. This system is very cost effective because currently using LiDAR systems are very expensive to retail and their maintenance cost is also very high. And these LiDAR systems are somewhat difficult to use when there is a need to detect the speeds of several vehicles at the same time. But this system is convenient to use because this can detect speeds and colors of several vehicles simultaneously and provides accurate results as well.

Keywords – Over speed driving, LiDAR technology, speed detection, Image and Video processing

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1. INTRODUCTION

Speed management of motor vehicles pays an important role in reducing accidents on the roads. Sri Lanka police, as the sole authority responsible for traffic management in the country, uses vehicle speed detectors with LiDAR technology to capture overspeed vehicles as a part of controlling the vehicle speeds to reduce the road accidents. Due to inheritance drawbacks in these devices, this research is focused to develop low cost and efficient automated system that uses image and video processing techniques for detecting the speeds and colors of the vehicles violating speed rules in expressways of the country.

This report discussed the approach taken to develop the above-mentioned automated system. The document contains four main parts (1) Introduction, (2) Methodology, (3) Results and Discussion, (4) Conclusion. And the Introduction part is divided into 5 sub parts (1.1) Background, (1.2) Literature survey, (1.3) Research Gap, (1.4) Research Problem and (1.5) Research Objectives.

1.1 Background

Express way system of Sri Lanka is launched to the society in 2011 [1] and currently three major express ways namely Colombo-Katunayake, Southern and Outer circular road are in operation. In addition to that, three more expressways viz. Central Expressway, Northern Expressway and Ruwanpura Expressway, have been designed and one is under construction. A part of Central Expressway will be available for public uses within next couple of months.

Many people tend to use express ways because of numerous reasons such as the time saving, traffic, convenient to drive etc.; This leads to increase the number of vehicles in express ways of Sri Lanka [1]. According to the police reports of express way main traffic police branch, the number of accidents in express ways is increasing drastically in recent years [1]. The increasing number of vehicles on expressways naturally increase the rate of accidents meeting on roads. In general, the vehicle speeds on expressways are much higher than that on normal roads and consequently the accidents on expressways are much sever than that on normal roads. The Sri Lankan Police, as the mere organization, which is responsible in managing this situation, must take significant measures to mitigate possible accidents on expressways.

With respect to the three major express ways currently being operated in Sri Lanka, overall, 3724 accidents [1] were reported between 2011 and 2018 [1] including death of 40 people because of fatal accidents [1]. According to data, number of accidents are increased over last years. Figure 1.1 illustrates an accident that happened in the expressway.

Figure 1.1: Vehicles crashing on Expressway

A major cause of the express way accidents is speed driving [2] where drivers are exceeding the maximum permitted speed limit of the express ways. Therefore, it is a prime requirement to capture and penalize the drivers who violate speed limits prescribed for expressways, thereby, to reduce the number of over speeding vehicles which are vulnerable in making accidents. As such, the law enforcing officers need efficient and effective facility to detect the speed of vehicles and to ascertain whether the vehicles are exceeding the permissible speed limit before enforcing the law on the drivers violating speed limits.

A current technology that is used to detect the speed of a vehicle is Radar/LiDAR technology. Radar guns run on the Doppler shift phenomenon [2][3] which means radio waves are fallen on the vehicle of which speed should be determined and the reflected radio waves frequency varies depending on the vehicle moving rate [2]. This change of reflected waves can use to calculate the speed of the vehicle [2]. The only difference in LiDAR technology that it uses Infra-Red or a Lasar wave to calculate the speed of the vehicle.

Radar technology is giving good results but there are several drawbacks in this technology [2] as speed of the only one vehicle can be found at a time, results may be affected by the other radio waves generated by the devices which are operated nearby, and radar must be accurately pointed on the vehicle. Radar/LiDAR systems are very expensive [2] because their purchasing and maintenance costs are considerably high. Apart from that, these devices must be operated manually by an operators and hence the efficiency is rather low.

Considering the above drawbacks associated with the current technology and the high-level development gained in the image processing technology, this approach provides an alternative method which is cost effective and produces promising results. Therefore, image and video processing technology has been used to detect the speed of the vehicle together with its color and to capture the vehicles that are exceeding the maximum permitted speed limit of the express ways.

1.2 Literature Survey

This section describes the past studies carried out to detect the speeds and colors of the vehicles. Most of the literature reveal that image and video processing can be used to estimate the speeds of vehicles with a significant level of accuracy.

The study [2] has used the live video stream from the CCTV cameras for speed detection and this is developed using MATLAB software. In this case, the system design and implementation is carried out in three phases, viz. detection the vehicle, tracking the vehicle, calculation of the speed. Because of 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 is being updated continously. 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 after speed is calculated in km/h. In here the speed is updated at every 0.5second.

According to [3], this study is 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 processed using an OpenCV library. Then as the next phase, detection the vehicle is done. For this process a classifier is used. This classifier is known as has Haar Classifier. The result of this classifier are the coordinates of the rectangle that surround the detected vehicle. And for the tracking the detected vehicle from frame to frame this study has used a library called dlib. And from those above phases the location of the vehicle is obtained. Then for the speed calculation distance is obtained using the change in pixels. The obtained distance is converted to meters using ppm (pixel per meter value). Then using the frame of camera the time spent to travel the distance is obtained. Finally, the speed is calculated.

According to the [4], the authors have done research to propose a new algorithm based on the detection of moving target 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 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 [5], 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 two 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.

Currently, vehicle number plate detection has become a main research area. This can be used to identify the vehicles that are over speed driving. But for detecting number plates of fast-moving vehicles with reliable accuracy cannot be achieved easily because of some problems like containing noise, blur videos and crashed videos. Therefore, color recognition of vehicles can act as an alternative for this issue.

The study [6] proposed an algorithm which is deep learning based to do color recognition of the vehicle. In this study, as the feature extractor they have used Convolutional Neural Network (CNN). A feature vector is calculated for each image in this research. 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 constant size. Next during the training, by using the backpropagation, the network parameters 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 has been separated into a grid of with two levels 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 [7], 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.

According to above mentioned past researches, the speed estimation using image and video processing gives significant results and as there is lesser number of hardware involve in these methods it is very cost effective. There are some studies that propose to recognize the colors. But there is hardly any research conducted to detect both colors and speeds of the moving vehicles simultaneously and to detect the vehicles that are exceeding the maximum speed limit of the expressways. Therefore, this model has been developed to identify the vehicles that exceed the maximum permitted speed limit, which is 100kmph, and to recognize the colors of those vehicles as a detail.

1.3 Research Gap

Currently, most using technologies to detect the speeds of the vehicles are radar and LiDAR systems. They give promising results to the users. However, those technologies consist of several drawbacks which makes those radar and LiDAR systems are inconvenient and inefficient to use. Therefore, detecting vehicle speed using image and video processing techniques has become popular currently.

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. Table 1.1 gives a comparison of features between the systems proposed by past studies and the system proposed in this research.

Features	Research [2]	Research [3]	Research [4]	Research [5]	New product
Good accuracy in speed calculation	✓	✓	✓	✓	✓
Recognizing the colors of vehicles	X	X	X	X	✓
Detecting speed limit exceeding vehicles in video in red	X	X	X	X	✓
Display vehicle speeds and colors in the video on UI	X	X	X	X	✓
Show speed violating vehicles to officer with colors and speeds	X	X	X	X	✓

Table 1.1: Comparison of past researches 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.

According to the above-mentioned details, this system gives more promising results to the user and very efficient to use. Therefore, this system would be more popular than the systems that are proposed by past studies.

1.4 Research Problem

Currently, there are three major expressways functioning in Sri Lanka. In addition to that, three more expressways are designed and one more expressway is under construction. Most of the people in the country are tend use these expressways because of numerous reasons such as to save their time, less traffic and convenient to drive without tiredness, etc. Because of those reasons, number of vehicles in the expressways are daily increasing.

Increasing the number of vehicles in the expressways naturally leading to increasing the number of accidents in the expressways. When considering the police reports from the main traffic police branch, the number of accidents occurring in expressways in Sri Lanka are drastically increased in recent years [1]. In considering the three major expressways, overall, 3724 accidents occurred between year 2011 and 2018 were reported [1]. Because of sever accidents, death of 40 people [1] were reported. A major reason for these accidents is driving beyond maximum speed limit of the expressway which is 100km/h. Therefore, it is a major concern to detect the vehicles that are exceeding the maximum speed limit which helps the police to take necessary actions against them.

Currently, in Sri Lankan expressways the technology that use to detect the speeds of the vehicles is LiDAR technology. This method gives promising results to the user. However, there are several drawbacks in this LiDAR technology. A major drawback in this technology is, it is very expensive to retail and maintain. According to the information from the police department, the cost of a speed detector is approximately one million. Because of this high cost of a speed detector there are only few speed detectors are being operated in the expressways. And there are some other drawbacks associated with these speed detectors. They are, speed detectors can only detect the speed of one vehicle at time, must be handheld operated and require periodical maintenance. Sri Lanka is a still developing country. Therefore, it is better if it is possible to use an alternative method which is not expensive as the currently using speed detectors to detect the speeds of the vehicles and identify the over speed driving vehicles. The Figure 1.2 illustrates the speed detection of vehicles using handheld LiDAR guns.

Figure 1.2: Detecting the speeds of vehicles using LiDAR guns

Because of above reasons this research suggested an alternative method which uses image and video processing techniques to detect the speeds. This system can detect the speeds of multiple vehicles at the same time and identify the vehicles that exceeding the maximum speed limit of the expressways and recognize the colors of those vehicles as a detail.

1.5 Objectives

1.5.1 Main Objectives

Since currently using speed detectors in Sri Lanka expressways is very expensive and consists of several other drawbacks. Therefore, the system that has been developed here can replace the traditional expensive hardware system with a cost-effective software system. By using this system, cost for the LiDAR systems can be saved and can detect the speeds of many vehicles with a good accuracy at a time.

This system uses 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 detects the speeds of all vehicles and 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 significant accuracy.

1.5.2 Specific Objectives

1. Detecting the vehicles in the input video.

   In here, the vehicles of which the speed are to be detected should be distinctly identified 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 with 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.

2 METHODOLOGY

This section contains the approach that has been taken to build the system. It includes the mechanisms and techniques that have been adopted to build the system to detects the speeds of vehicles and speed limit violating vehicles. Description of the inputs, processes and outputs of the system have been discussed here.

This methodology section is mainly divided into three parts namely, 2.1 Methodology, 2.2 Implementation and testing and 2.3 Commercialization aspects of the product. In the Methodology section, it is discussed the approach that has been taken to develop the system.

Implementation and Testing is discussing how the hypothesis was built, how the feasibility study was done, how the requirement gathering, and analysis was done, how the design of the system was done, how the implementation of the system was done with user interfaces of the system, how the developed system was tested and how the system is maintaining.

And the next section contains the commercialization aspects of the product including purchasing possibilities for the users.

2.1 Methodology

As the first step of the project, it was necessary to verify the possibility of obtaining required videos from the CCTV camaras fixed in the expressways to use as input data to the system. The police officers carrying out duties in expressways and stationed at Galanigama interchanged of the Southern expressway were contacted. The videos from CCTV camaras fixed at Kahathuduwa, Kaduwela and Kottawa interchanges could be obtained from the Officer In-charge of the Galanigama expressway police station.

The captured videos are input to the computer and the system then detects the speeds of vehicles and identify 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 displacement
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.

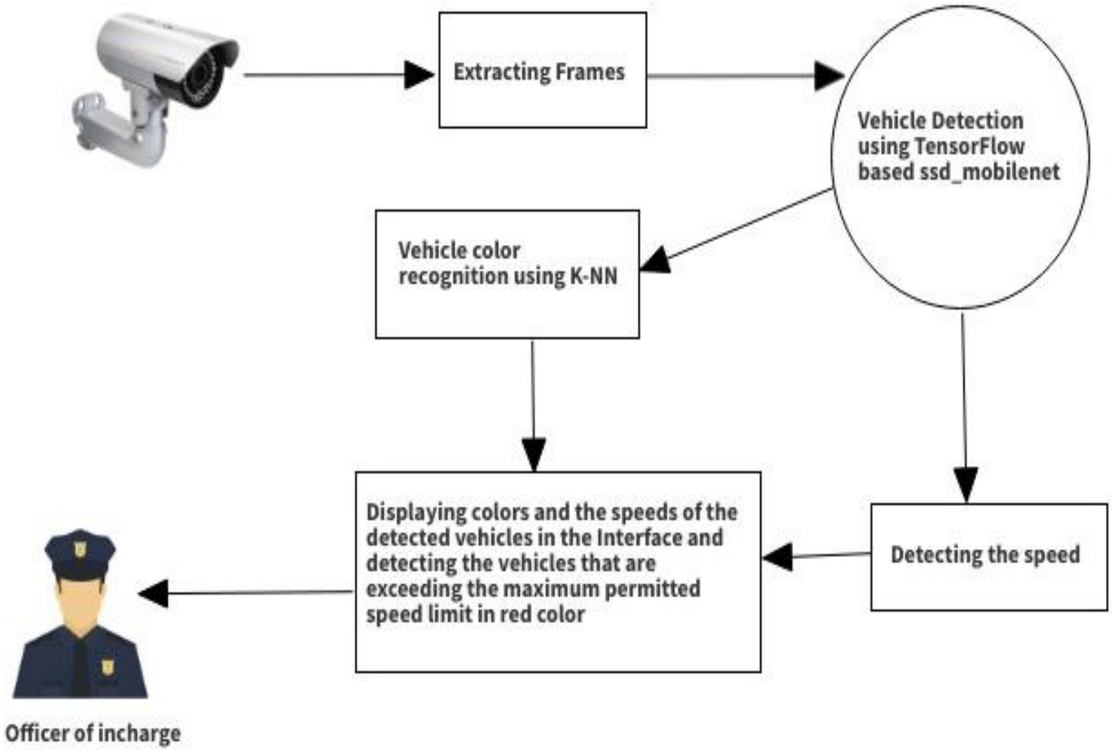

Figure 2.1: Component overview diagram

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

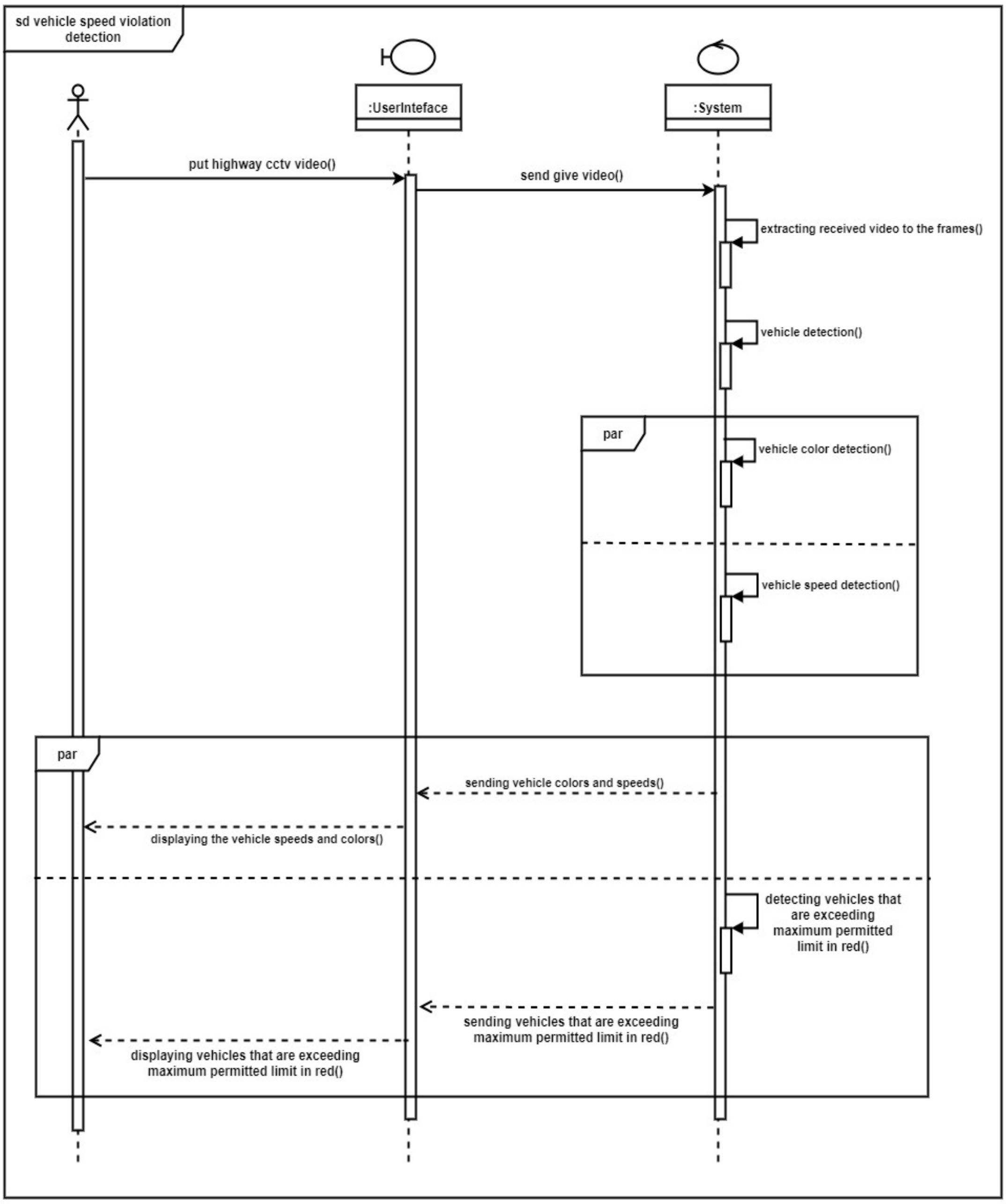

Figure 2.2: Sequence diagram.

2.1.1 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.

- **TensorFlow**

Since the TensorFlow is used in research methodology, it is better to get some knowledge about the TensorFlow. Google brain team has developed this open-source library TensorFlow to use in numerical computations and machine learning. This TensorFlow eases the processes like acquiring data, training models, giving predictions, and processing future results [8].

TensorFlow has a combination of algorithms and models in deep learning and machine learning. The Python language has been used for developing front-end API in building the applications. And these built applications can execute in improved C++ [8]. TensorFlow allows to make graphs that describes dataflows. There graphs are a kind of formations that explaining how these data flows through the series of processing nodes. These graphs are consisted of nodes and edges that connecting these nodes. In these graphs mathematical operation is represented by a node and multidimensional data array, or a tensor is represented by an edge [8].

TensorFlow makes all this available to the programmer using python language. Python language is easy to use, it provides helpful ways for specifying how good abstractions might be linked together. TensorFlow applications are simply python applications. However, python does not execute the actual math operations. The transformation libraries made accessible by TensorFlow are developed in improved C++ codes. Python provides the communication among the components and offers a good programming abstraction in connecting them.

TensorFlow applications may be launched on almost any suitable target, which can be a local workstation, a cloud cluster, android and iOS devices, CPU or GPU. If the Google Cloud is utilized, TensorFlow may be enhanced by running it on Google's TensorFlow Processing Unit (TPU) hardware [8]. Models generated in TensorFlow, can be installed on many devices and used for providing predictions.

Abstraction is the most important feature TensorFlow gives for the machine learning development. Instead of getting work on the minutiae of implementing algorithms or finding out how to connect the one function output another function input, the developer was allowed to concentrate on the general logic of the application. TensorFlow can handles the subtleties in the background. And TensorFlow provides extra benefits to the developers that need to debug and get insights into TensorFlow applications. Instead of creating the whole graph as a single object and evaluating it all at once, the eager execution mode allows you to evaluate and change each graph action independently and straightforwardly. Through an interactive, web-based dashboard, the TensorFlow visualization package allows to analyze and characterize the behavior of graphs.

- **Single Shot Multibox Detector**

To have a better understanding of SSD it is needed to get an understanding about the terms of this design. There are three terms which are, Single Shot, Multibox and Detector [9]. The term single shot refers to the object localization and classification being completed in a single forward pass of the network [9]. The term Multibox is used to describe the bounding box in regression method. The term Detector is used to describe a sort of object detector that also classified the items it detected.

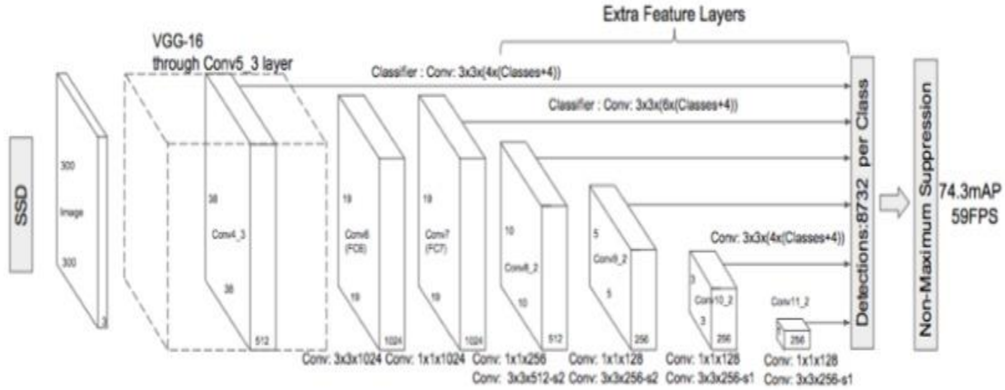

Figure 2.3: Single Shot Multibox Detector Architecture [9]

As seen in the Figure 2.3 above, the SSD is based on the famous VGG-16 architecture but does not have completely linked layers. This architecture was selected as the basic network as of its exceptional performance of its picture classification. Rather than the conventional VGG with completely linked layers a collection of auxiliary convolutional layers from con6 onwards have been inserted, allowing for extraction of the features at different scales and progressively decreasing the size of the input to each consecutive layer. The Figure 2.4 illustrates the VGG Architecture.

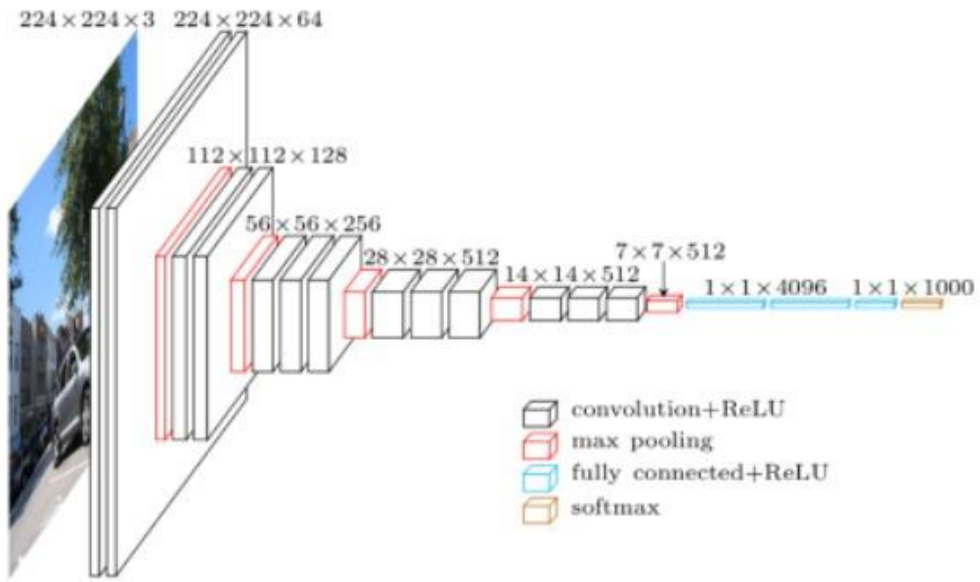

Figure 2.4: VGG Architecture [9]

SSD bounding box regression methodology is based on Multibox, which is an approach for quickly generating class-agnostic bounding box coordinate suggestions [9]. An initiation type convolutional network is employed in the process performed on Multibox. The 1x1 convolutions shown in Figure 2.5 aid in dimensionality reduction since the number of dimensions decreases [9] (although width and height stay constant).

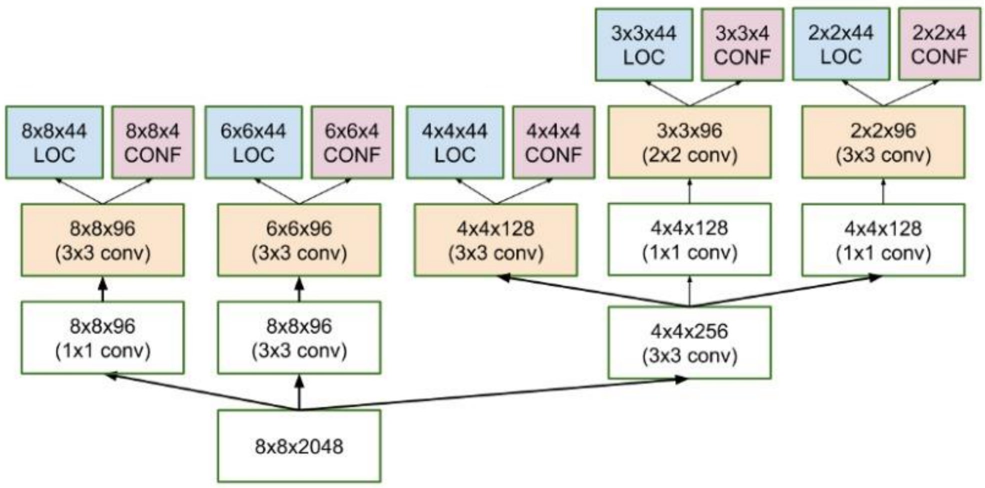

Figure 2.5: Multiscale convolutional prediction of multibox's location and confidences [9]

The loss function in Multibox also integrated two key components. They are confidence loss and location loss.

- Confidence (CONF) loss – this metric indicates the network's assurance in the objectivity of the calculated bounding box. This loss is calculated using categorical cross-entropy [9].
- Location (LOC) loss – This metric evaluates how much the network's estimated bounding boxes differ from the training set's ground truth bounding boxes. L2-Norm is utilized in this case [9].

2.1.2 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 2.6 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 2.7 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 the bounding box are x_min and y_min. The coordinates of the bottom right corner of the bounding box are x_max and y_max.

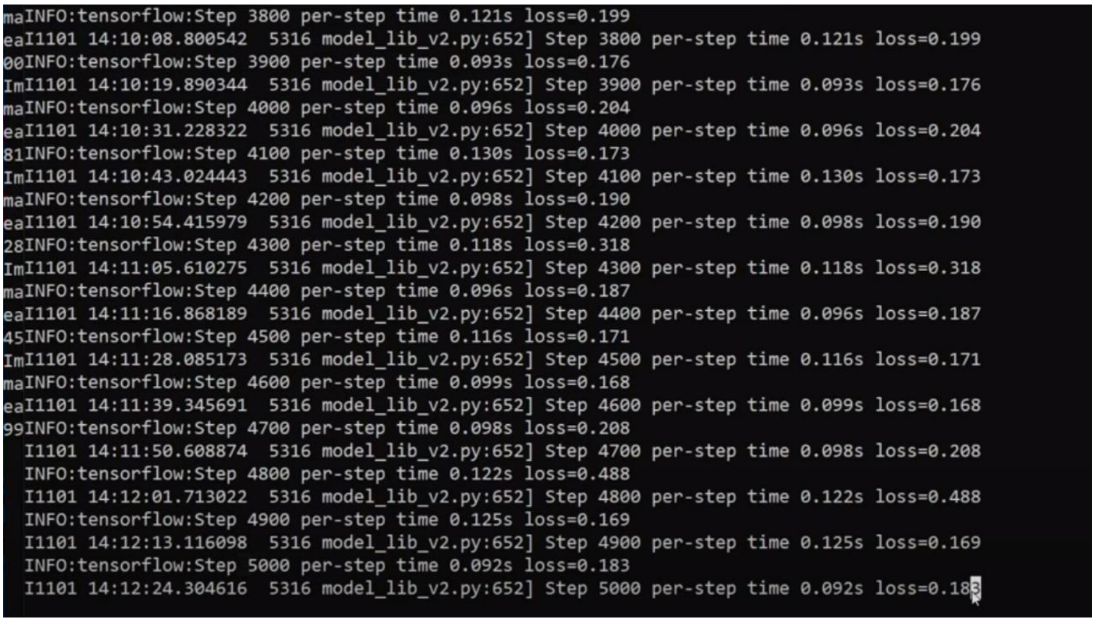

Figure 2.6: Training process of the ssd_mobilenet

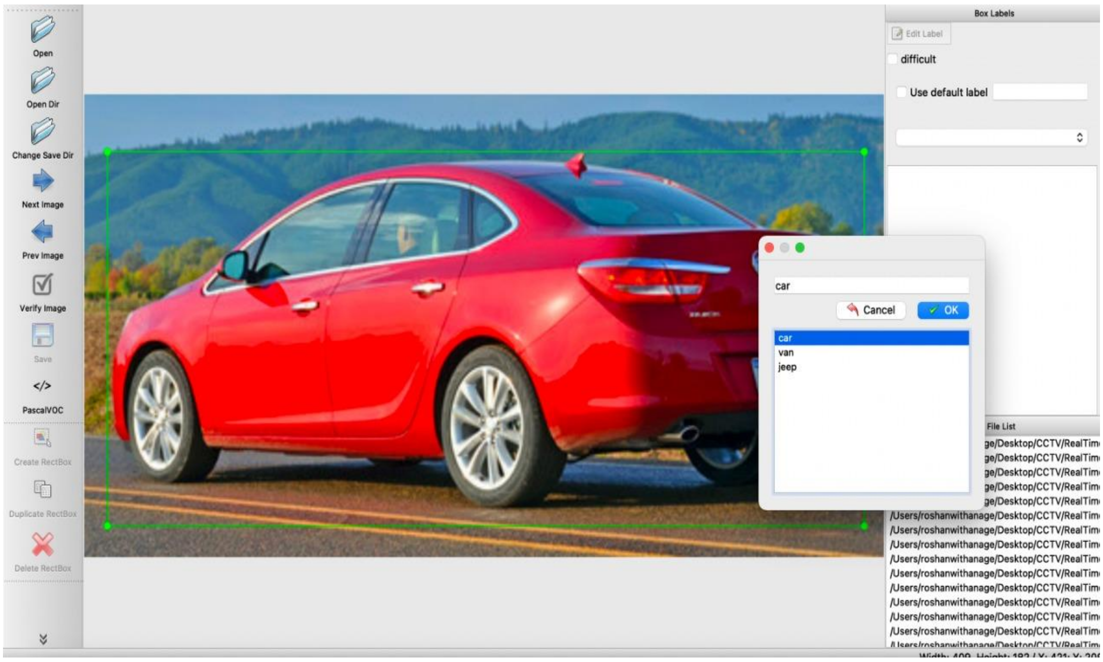

Figure 2.7: Labeling the data

2.1.3 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.

2.1.4 Vehicle speed detection

Detection of the vehicle speed is done using OpenCV based on pixel manipulation and calculation. From the above phases the vehicle's position is obtained in term of pixel units. The distance and the time spent to cover that distance are required to calculate the speed of the vehicle. 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, using the above data, the vehicle speed can be computed.

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.

2.1.5 Vehicle color detection

Color recognition of the vehicles is done by 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. Example for RGB color histogram for red color images is shown in Figure 2.9. 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.

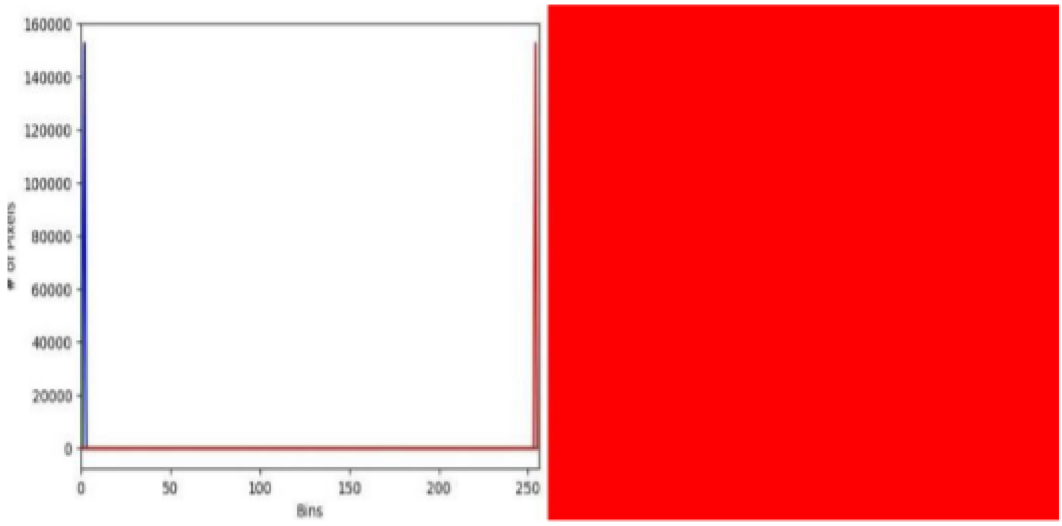

Figure 2.9: Example of RGB color histogram for red images [10]

- **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.

2.2 Implementation and Testing

2.2.1 Implementation

This section is divided into five parts namely, Building the hypothesis, Feasibility study, requirement gathering and analysis, system designing and implementation. In the hypothesis the research problem has been identified and discuss about the expected results. In feasibility study, whether the system is viable to develop should be checked. In requirement gathering and analysis discussion is focused on how the functional, nonfunctional, system and personnel requirements of the system are gathered and how an analysis is carried to identify the most precise requirements for the system. In the design phase, approaches that can be adopted to develop the system according to the functional and nonfunctional requirements have been identified. Finally discuss the technologies that have been used to develop the system and its user interfaces.

- **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.

- **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.

- **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.

- **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.

- **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 2.10 showing user interface of the system before user selecting the input video.

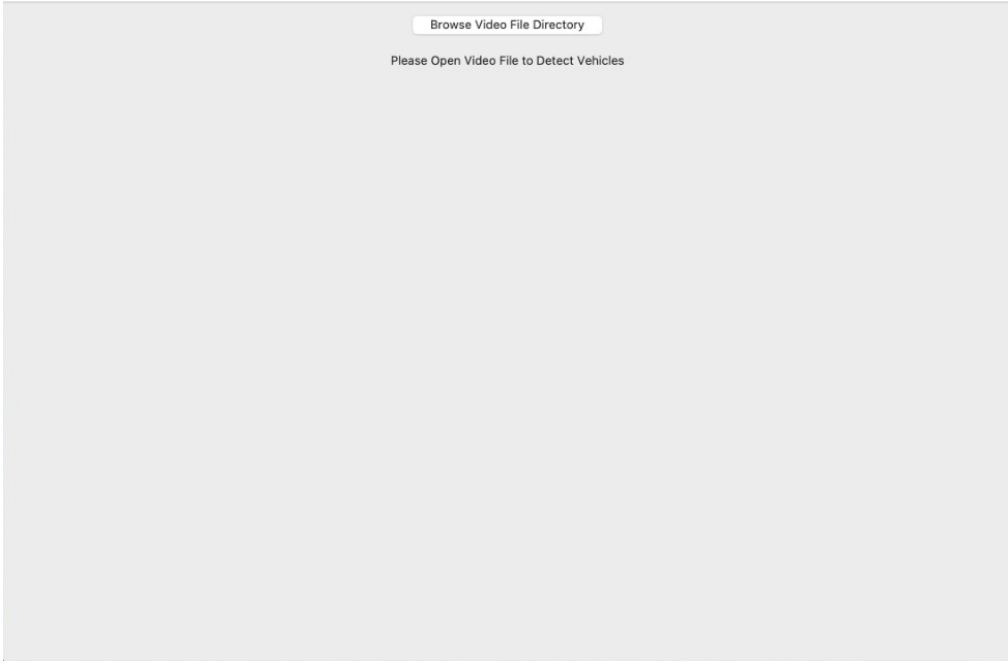

Figure 2.10: User Interface of the system before the video was selected

Figure 2.11 illustrates the browsing for the input video.

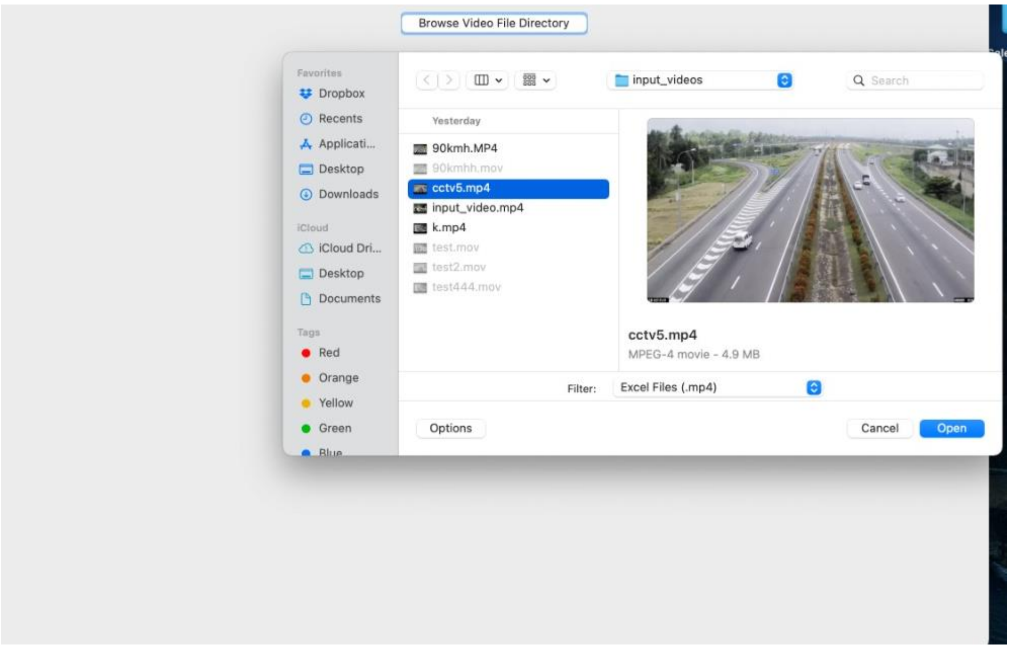

Figure 2.11: Browsing for the input video

Figure 2.12 shows the user interface with input video with the results.

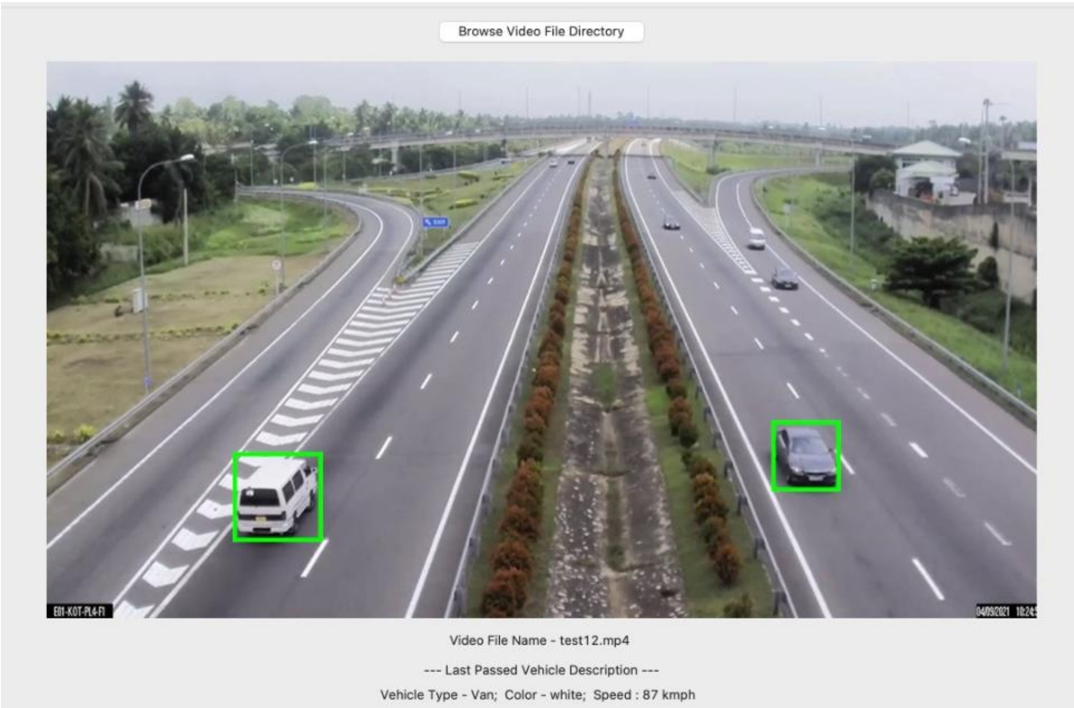

Figure 2.12: The user interface with results

2.2.2 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 2.13 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 2.13: Testing using video 1

Figure 2.14 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 2.14: Testing using video 2

Figure 2.15 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.

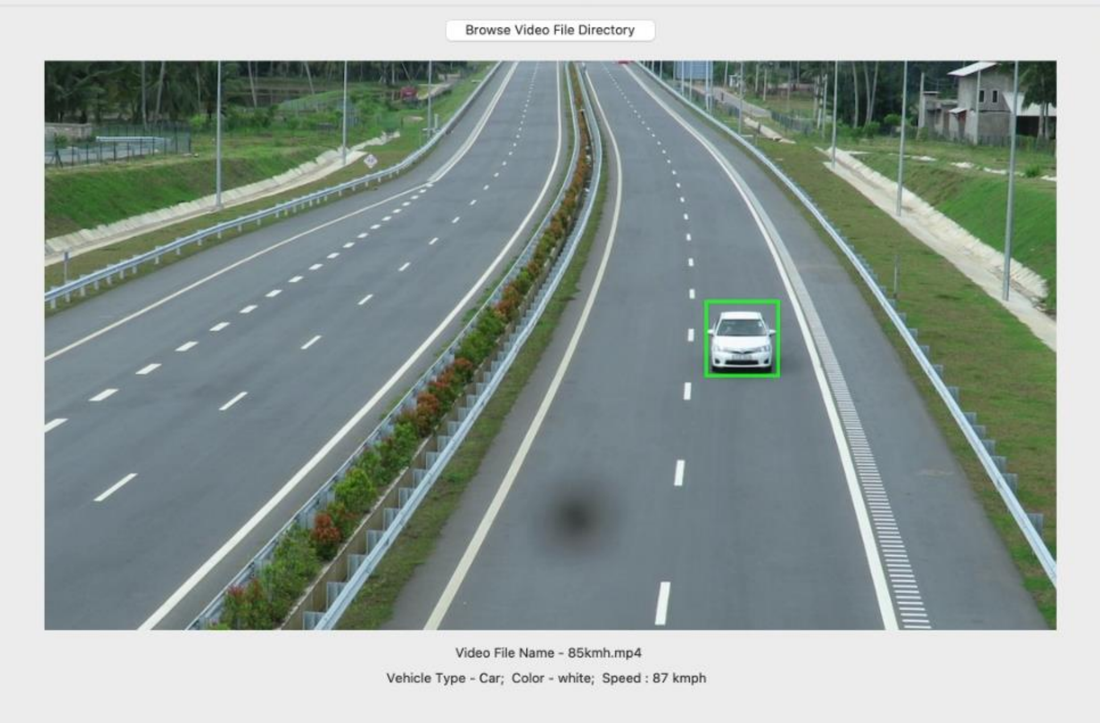

Figure 2.15: Testing using video 3

Figure 2.16 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 2.16: Testing using video 4

- **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 maintaining.

2.3 Commercialization aspects of the product

This system is developed to be used in expressways. First, a trial version of this software will be given to the users to check the software is working according to their requirements. If the user agrees to use the software after using the trial version, then user can purchase the software. If there are any additional customizations required after the purchase, then user must pay for those customizations.

3 RESULTS AND DISCUSSION

3.1 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 encloses 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.

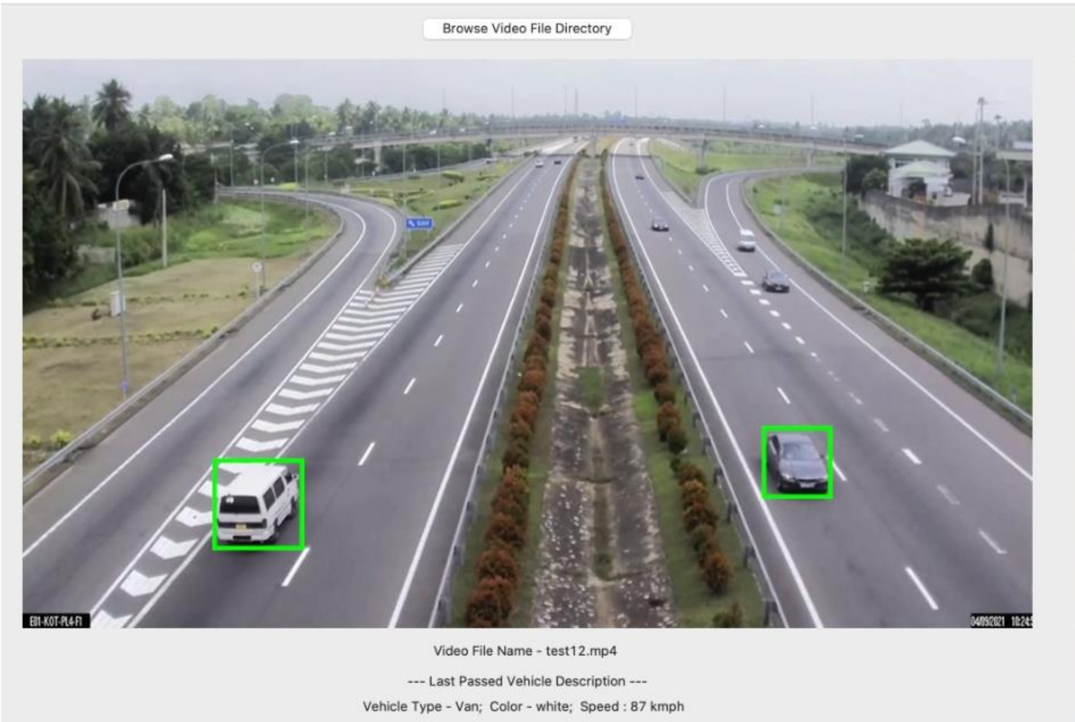

Figure 3.1: Detecting vehicle speeds and colors

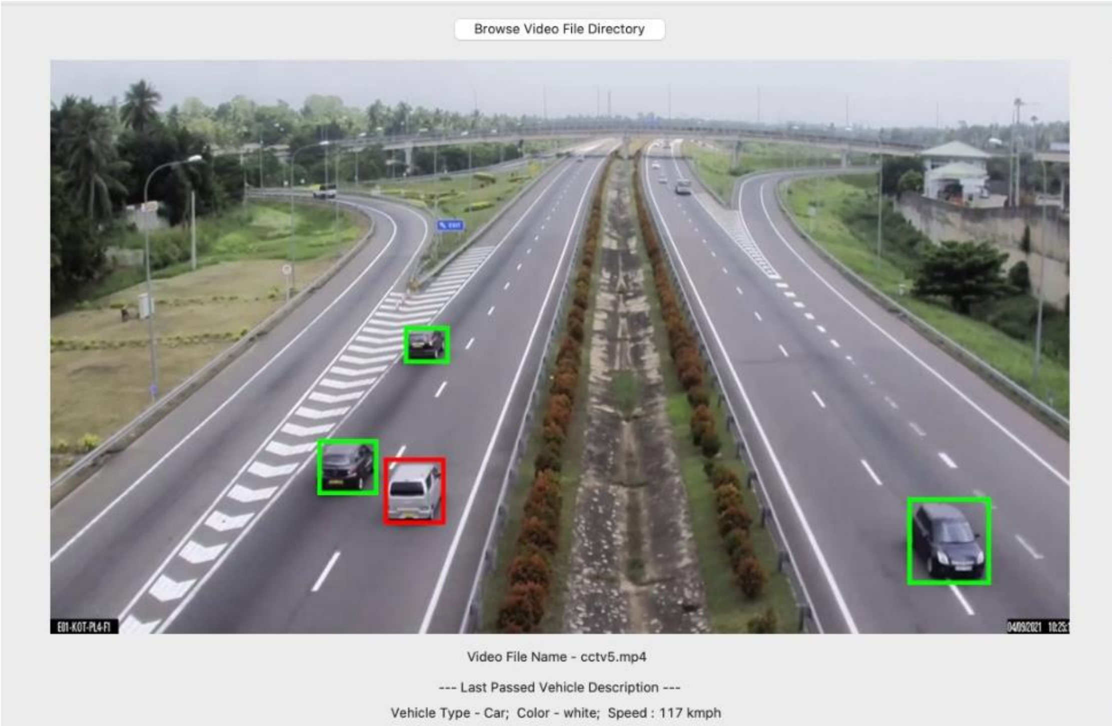

Figure 3.2: Detecting the vehicles that are overspeed driving in red color

3.2 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.

4 CONCLUSION

Accidents in Sri Lankan expressways are increasing drastically day by day. The main course for these accidents has been identified as the over speed driving. Damage due to the accidents on the expressways are sever than the accidents on normal roads because of the high speed of the vehicles. It is necessary to identify over speeding vehicles to take necessary measure to reduce over speeding vehicles and thereby to reduce the number of accidents occur on expressways.

The current method adapted in Sri Lanka is LiDAR guns are accurate but very costly. As such, the number of LiDAR guns that are being used in expressways are not sufficient to control the situation.

As a result, system which is developed during this research with using the image and video processing techniques is a good alternative to replace those traditional LiDAR guns because of its cost effectiveness and advantage of identifying speeds of several vehicles simultaneously. However, camera position and its angle directly affecting the final accuracy of calculated speed of the vehicle. Therefore, it is necessary to be cautious regarding the position and angles of surveillance camera when using this system.

When developing this kind of a system it is necessary to consider the accuracy as well as the performance. In this system ssd_mobilenet is more suitable in vehicle detection rather than using YOLO because of it produces accurate results rapidly. And for the color recognition K-NN classifier is more appropriate than other approaches as it provides fast and accurate results.

Input videos to the system should have the constant resolution of 640 x 360 to get more accurate results. Since the system expects low resolution videos as the inputs, inexpensive CCTV cameras with desired resolution can be used on the expressways. And this system can be run on a computer with medium processing power and memory. Therefore, when comparing with the LiDAR guns this approach is more cost effective.

Finally, when comparing to the current technology the accuracy in speed detection is not as good as LiDAR guns. However, this approach has sufficient accuracy in speed detection and color recognition of vehicles. Considering the reasons mentioned above, the system developed using image and video processing technology can be concluded as an efficient and effective solution to overcome the drawbacks of the prevailing technology.

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Plagiarism Report

Final Report

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