S	
E1	
E2	
For Office Use Only	

Masters Project Final Report

(MCS)

2019

Project Title	Notify vehicle driver about speed limits by analyzing road signs in Sri Lanka.
Student Name	A.M.B Ratnayake
Registration No. & Index No.	Registration number : 2015/MCS/062 Index No. 15440624
Supervisor's Name	Prof. N.D Kodikara

For Office Use ONLY

Notify vehicle driver about speed limits by analysing road signs in Sri Lanka.

A dissertation submitted for the Degree of Master of Computer Science

A.M.B Ratnayake
University of Colombo School of Computing
2019

Declaration

The thesis is my original work and has not been submitted previously for a degree at this or any other university/institute.

To the best of my knowledge it does not contain any material published or written by another person, except as acknowledged in the text.

Student Name: A.M.B Ratnayake

Registration Number: 2015/MCS/062

Index Number: 15440624

____

Signature: Date:2019-05-02

This is to certify that this thesis is based on the work of Mr. A.M.B Ratnayake under my supervision. The thesis has been prepared according to the format stipulated and is of acceptable standard.

Certified by:

Supervisor Name: Prof. N.D.Kodikara

____

Signature: Date:

Abstract

The number of motor traffic accidents are increasing day by day. One of the main reasons for accidents is over speeding. Over speeding also causes an uncomfortable journey and economic losses due to the traffic fines.

There are speed limit signs to assist the driver to drive safe speed in the road. But most of the drivers will not drive under speed limits due to, forgetting the speed limit, unintentionally over speeding, careless driving or unnoticing the speed limit signs. Therefore, it's better to inform driver about the speed limit as well as notify them when they are breaking the speed limit which leads to follow the speed limits in the road. Eventually passengers and driver will have a safe drive and driver will be able to avoid getting fines due to violating speed limits.

Author proposed a mobile application to assist or guide drivers about the driving speed, which helps drivers to drive under suitable speed. Thus, passengers will have a comfortable and safe journey. The proposed mobile application uses the mobile phone's camera and Global Positioning System (GPS).

The application will get a frame or image from the smart phone's camera and check that frame/image contain any circular shape objects by Circular Hougman Transformation (CHT) technique. Detected circles extracted and convert to a binary image and the Optical Character Recognition (OCR) done by using Tesseract engine, after removing the noise by using morphological operations such as Erosion and Dilation. The resultant text will use to verify whether that circular object is speed limit sign or not by checking that text contains similar text to "KMPH" text ("KMPH" is Part of a text appear in the speed limit sign).

If the system identified any speed limit sign circles that circle's center coordinates uses to extract the vehicle types board which uses to detect speed limit affecting vehicles. Extracted image converted to a binary image and uses Dilation to connect parts of a vehicle together. Then extract objects in that image after removing unwanted background. System will extract features of each object by using Histogram of Oriented Gradients (HOG) and feed into Error Correction Output Codes (ECOC) Model, which is trained using the same techniques and 219 sample speed limit sign images. Finally, if that affecting vehicle types board included the driver's vehicle type then detected speed limit value stored in the system as new speed limit.

The application use *android.location* package to detect vehicle speed. If measured speed is greater than the stored speed limit value then the system will inform that using text to speech library. Apart from that, system will announce new speed limit when the system detects a new speed limit sign which affected to the vehicle.

The application is given us hopeful accuracy as well as performance. The whole process needs around 5.23 seconds and 73.25% accuracy. Since most of the current mobile phones have multiple CPU cores, detection of speed limit sign can be done by using parallel computing. Accordingly, it could able to improve performance while not decreasing the accuracy. Users could able get better results taking few actions to get clear images such as using a clear windscreen, keeping the camera in correct angle, etc.

Acknowledgements

I would like to express my deepest appreciation to all those who provided me the possibility to complete this report.

My deepest appreciation to the project supervisor, Prof. N. D. Kodikara whose contribution in stimulating suggestions and encouragement, providing crucial information and for evaluating us.

A special gratitude for all the lecturers for providing me with the knowledge to complete this project successfully.

My deepest indebtedness to my parents who supported me in countless means over these years.

Finally, my thanks to all the colleagues and the people who supported me with their finest abilities over the duration of the project.

Table of Contents

List of Tables

List of Figures

1. Chapter 1: Introduction

Vehicle accidents or collisions increased day by day and those accidents are not only affected in economy of the country but also it affects lot of health issues and social issues. One of the main reasons for accidents is not driving vehicles in appropriate speed. Driving in an excessive speed cause accident and also lead to unnecessary problems when driver caught by the police. Driving in suitable speed is really important to avoid those improper circumstances. Therefore, this research is focusing on assisting to the driver to drive under appropriate speed by using road speed signs.

This chapter will discuss motivation, challenges in current system (manual road sign identification) and finally elaborate on the objectives of this research.

1.1 Problem

A road accident, also called a traffic collision occurs when a vehicle collides with another object such as a vehicle, pedestrian, animal, road debris or another obstacle like tree, pole or building.

Road accidents are increasing day by day. In Sri Lanka, there are 3101 deaths due to road accidents in 2017. It's increased by 98 compared to the previous year. Table 1 shows how road accidents are increased within two years [1].

Overview	2016	2017
Deaths	3003	3101
Fatal Accidents	2824	2924
Minor Accidents	13961	13592
Critical Accidents	8518	8144
Damage Only	13675	13072

Table 1:Vehicle accidents in 2016-2017

Road accidents are not only caused economic losses in a country and also major health problem in the world [2]. Low and middle-income countries like Sri Lanka is most affected by traffic accidents. Because a number of road accidents and injuries not only depend on the number of vehicles but also driver's behavior, road condition, country's level of economic and social development [3]. The poor road infrastructure, inappropriate mixing of vehicle types, inadequate traffic law enforcement and delayed implementation of road safety policies are the reasons to have increased-road accidents [3].

In most cases, excess or inappropriate speed of the vehicle affect to the number of road accidents as well as the severity of the crash injuries. Excess speed is defined as exceeding the relevant speed limit; "Inappropriate vehicle speed" refers to a vehicle move at a speed inappropriate for the road and traffic conditions [2].

Table 2:Risk factor depending on speed

Speed (km/h)	Relative Risk (Relative to a sober driver travelling at the speed limit of 60 km/h)
60	1.0
65	2.0
70	4.2
75	10.6
80	31.8

Inappropriate or excess speed cause uncomfortable journey as well as financial losses due to traffic fines. According to the statics of the traffic department of police in Sri Lanka in 2011, there are 944520 number of road rules violations and 34866 violations are speeding or excess speed limits [4]. Nearly 4% of traffic violations are the exceeding road speed limits. Therefore, encouraging drivers to drive under speed limit is very important to reduce traffic rule violations.

There are speed limits to avoid inappropriate speed on the road. Speed limit signs used to indicate speed limits in the road. Even though there are speed limits, some drivers fail to drive under those limits due to the reasons below,

- They were in a hurry.
- They generally enjoy driving fast.
- They were bored.
- They unnoticed speed limit signs.
- They forgot the speed limit.

This research is focused on avoiding missing the speed signs and forgetting speed limits. This research will find out a way to identify speed limit signs with the vehicle type and inform the user when driver break the speed limit. Therefore, this system will check the speed limit and the vehicle which is applicable.

1.2 Motivation

This research focuses on reducing a number of accidents and vehicle speed violations by warning the driver when they exceed the speed limit. On the other hand, this research will help to drivers to concentrate on road and pedestrians while the android application will assist them by recognizing the speed limit signs.

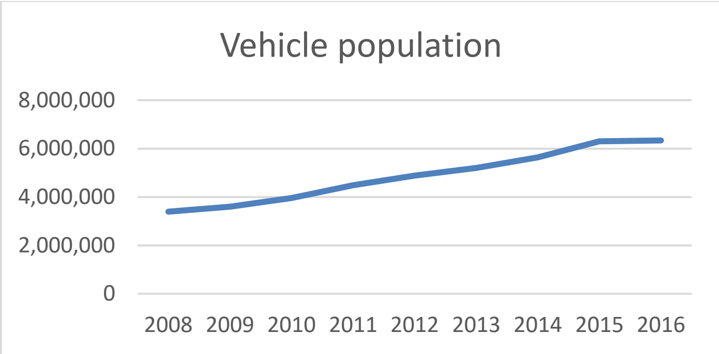


Figure 1 : Vehicle population in Sri Lanka 2008 to 2016

According to statistics of the department of motor traffics, the number of vehicles registered in Sri Lanka getting increased day by day. As a result, road traffic getting increased tremendously. Due to the heavy road traffic, drivers always will give more attention to vehicles and pedestrians. Hence, they will forget speed limits on the road or could be missing some speed limit signs. Therefore, proposed Android application able to store current speed limit and automatically warn the driver effectively by recognizing the road speed limit signs from time to time.

Finally, by using proposed Android application drivers will able to drive easily and safely without breaking speed limit unintentionally. Use of this application will help to have a comfortable journey as well.

1.3 Research Contribution

- Find out an effective way to identify speed limit signs by using smart phone camera.
- Find out an effective way to identify speed limit sign's vehicle category.
- Detecting vehicle speed and guide the driver.

1.4 Scope

This research focuses on implementing an application which helps to the driver to drive without violating speed limits. Hence driver and passengers will have a comfortable and safe journey. Therefore, this research proposes a single Android application which will detect speed limit, vehicle category mention in speed limit sign in A grade road in Sri Lanka by analyzing road sign using mobile phones camera when there is good light condition and when there are no any barriers between camera and the speed limit sign such as tree leaves, boards, posters, etc.

Assumptions and Limitations:

- This research assumes that the vehicle’s maximum speed less than 100kmph
- This research assumes that road signs are clearly visible to the driver.
- Mobile phone should have an Android operating system, camera (>=8MP), and GPS.
- This research assumes that windscreen of the vehicle is clean hence camera could take a clear image of the road sign and camera align correctly.

2. Chapter 2: Literature Review

2.1 Introduction

Road signs are providing essential information to drive vehicles safely and comfortably. Speed signs are informing the driver about the maximum speed that driver could drive. Exceeding speed limit is a violation of traffic law as well as it might lead to an accident. Therefore, this research focuses on implementing a system to notify drivers about the speed limits.

Numerous researchers carried out different types of research related to road sign detection, object detection in the digital image, circle detection, character recognition in the digital image, speed detection by using a mobile phone, etc. This research is inspired by substantive findings, recommendations and conclusions of other researches. Therefore, this chapter will explain directly and indirectly related research work and its significance, limitations, etc.

2.2 Literature review

W.K.I.L. Wanniarachchi, D.U.J. Sonnadara and M.K. Jayananda conducted a research on detection and extraction of road signs [7]. In that research they mainly focus on detection and extraction of the warning road sign. They used image processing techniques for that and they proposed an algorithm which have two basic processing (localization and extraction of the traffic signs.) This algorithm will have one input which is a road sign with background and that image should be taken approximately 10 meters from the road sign. In that research RGB image is converted to CIE XYZ color space and yellow areas can be identified. After few prepossessing, researchers proposed to use canny algorithms to detect edges. To locate the plate of road sign, that authors suggested doing dilation and flood fill to the road sign and then identify the biggest individual binding box by calculating areas of bounding boxes.

By using “Radon transformation theory”, the authors align the road sign, then binarized the plate and extracted 96x96 sized image and use this cropped image for neural network or template matching after further removing noise.

In that research paper, authors only focus on detecting and extracting the road sign and they only consider about the yellow colored road signs. On the other hand, if road sign’s color is differed due to light condition or due to distortion, the proposed system could not be able to identify. Accuracy of that algorithm is 98%.

Vincenzo Barrile, Matteo Cacciola, Giuseppe M. Meduri and Francesco C. Morabito have conducted research on road sign recognition using Hough transformation [8]. They were able to recognize road signs 97% accurately.

Tom J. Chalko find out a high accurate way to measure the speed by using Global Position System (GPS) [9]. In that research, Tom J. Chalko proposed measuring Doppler shift is the accurate way to measure speed because Doppler shift is proportional to speed.

The work of Kuei-Chung Chang and Po-Kai Liu design real-time speed limit sign recognition and over-speed warning system for mobile devices [6]. But that research wasn't identifying the vehicle categories and time duration that speed limit sign affect. Java Native Interface (JNI) native code and Region of Interest (ROI) filtering are used to improve the performance of the system. The researchers claim that they have to reach 87% of accuracy in recognition of road signs.

Automatic vertical road sign detection and recognition technique are proposed by Leonardo Brunoa, Giuseppe Parlaa and Clara Celauroa [10]. Since it has a higher rate of identification of road sign, this will be a good approach to identify road signs. This research which focuses on the detection of road signs in Italy and those road signs are different from the Sri Lankan road signs hence we need to find out the appropriate way to identify Sri Lankan road signs correctly.

RGB image is converted to HSV (color space based on the H (hue), S (saturation) and V (brightness Value) parameters) and then it has been converted to a binary image using a determined threshold value which can segment red, blue, white colors.

To detect an object in the binary image, the authors used minimum bounding box and they proposed few conditions according to optical characteristics of the image to remove unrelated objects in the image. Finally, they considered $\mathrm{R} = \mathrm{Width\ of\ object} / \mathrm{Height\ of\ object}$ to filter out road sign from the other detected objects. Those filtered objects are further classified according to their shapes and then identify the road sign.

The research focuses on detecting road signs rather analyzing those, further, that doesn't propose a way to identify speed limit for the vehicles.

Work of J.D Zhao, Z.M Bai and H.B Chen [11] has identified three preprocessing steps required. Those are image reduction by bilinear interpolation algorithm, image brightness adjustment by histogram equalization and Image filtering by the median filter.

After prepossessing colors are segmented using a new HSV color model segmentation algorithm. The image is further analyzed to extract the shape feature of the signs by calculating roundness after morphological treatment and area filtering, rectangularity and elongation. Finally feature extraction of segmented road signs are done by Histogram of Oriented Gradients (HOG). That researchers used Support Vector Machine (SVM) classifier to identify road sign.

Anu Priya George and X. Felix Joseph conducted a survey to identify efficient algorithm for object recognition [12]. In this survey researchers consider SIFT (Scale invariant feature transform), SURF (Speed up robust features) and ORB (oriented fast and rotated brief) algorithms for feature extraction. The researchers conclude that SIFT and SURF are too slow compare to the ORB algorithm and ORB algorithm more suitable for object recognition in embedded environment. According to the survey ORB overcomes the drawbacks of SIFT and SURF algorithm as well as ORB is selected as better for image rotation conditions. Hence, it's better to use ORB algorithm to identify road sign's vehicle types. Since these road signs could be rotated due to distortion or may be due to camera angle.

Mohit Bhairav Mahatme and Sonia Kuwelkar conduct a research on detecting and recognizing traffic signs based on RGB to red conversion [13]. They proposed to convert RGB image to Red by selecting pixels which are exceeding a particular threshold value. The researchers suggested median filter for preprocessing the image hence, it preserves the edges. Using another threshold value, the image is converted to binary. For image segmentation they have proposed a new technique which image will scanned in four directions and when white pixels found in all directions, they draw a box using those pixels. Similarly, the whole sign can be segmented.

Detection of road sign done by training a single layer perceptron. According to results the technique gives around 93.25% accuracy and to increase the performance of the system researchers suggest using parallel processing.

3. Chapter 3: Proposed Model

3.1 Introduction

These days the road accidents are increased due to huge number of vehicles and also mainly the reckless driving of the driver. This research motivates drivers to reduce accident risk by driving vehicle in appropriate speed.

According to findings and literature review this research propose a software tool that support below tasks

1. Detect value of speed limit road signs
2. Detect the vehicle types by using its image.
3. Measure vehicle speed by GPS signals of a smartphone.

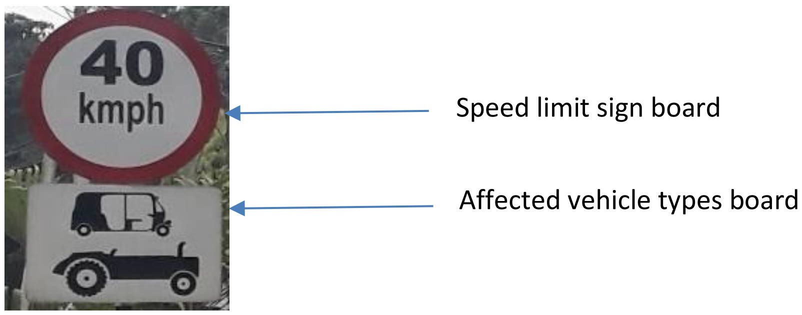


Figure 2 : Components of the speed limit sign

By analyzing a road sign similar to Figure 2 this tool will detect speed limit and vehicle types. Therefore, this software contains three modules and their functionalities are

1. Detect speed limit sign and detect speed
2. Detect affecting vehicle types
3. Measure speed

This proposed system uses smart phone's camera to take pictures of road signs and GPS signals to calculate the speed of the vehicle Figure 3 shows bird eye view of whole application. Therefore, this research proposes an Android application since there are numerous Android smart phone uses compared to other platforms such as iOS, windows, etc. (Appendix A).

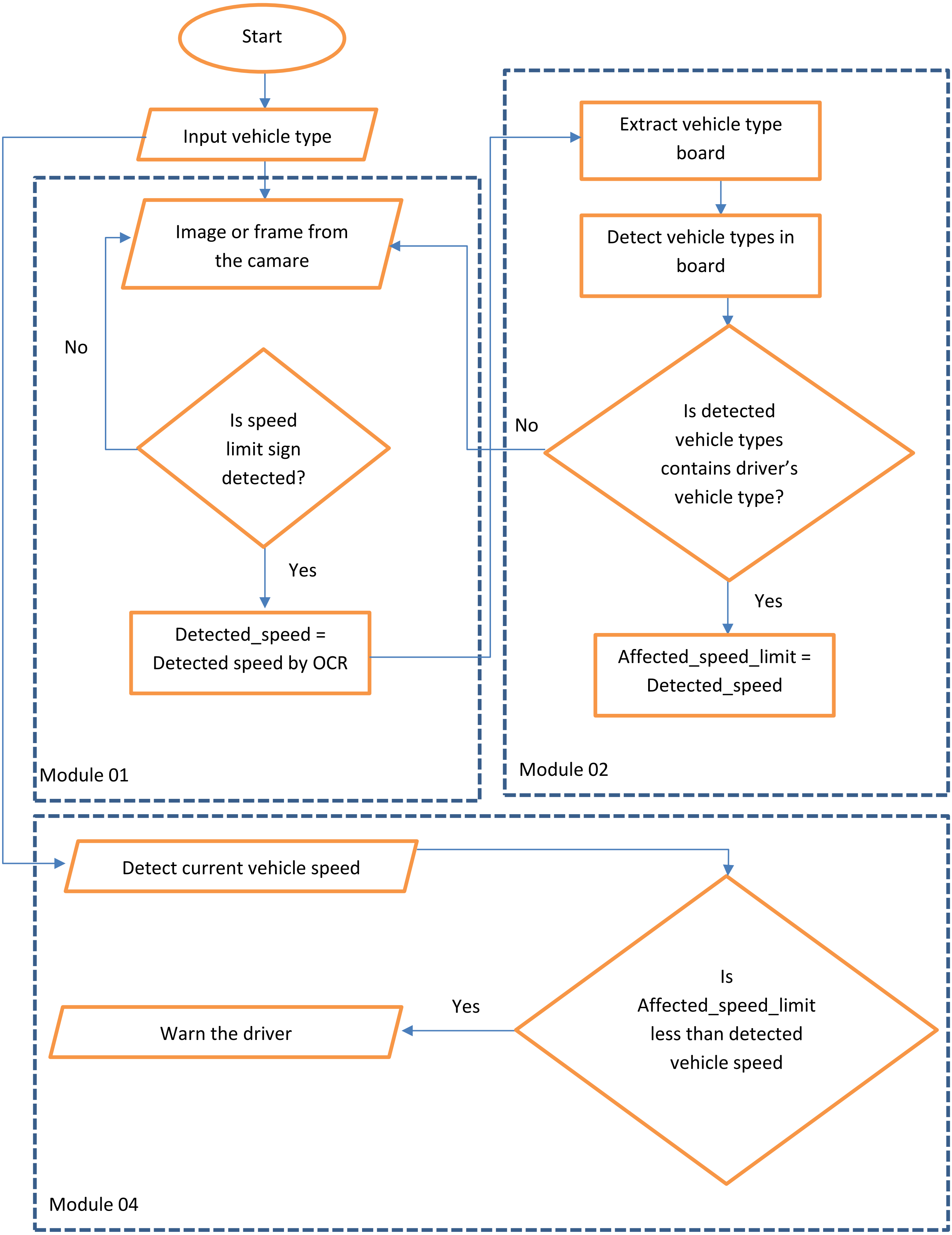


Figure 3 : Overall Picture of the application

3.2 Module 01 (Speed limit detector)

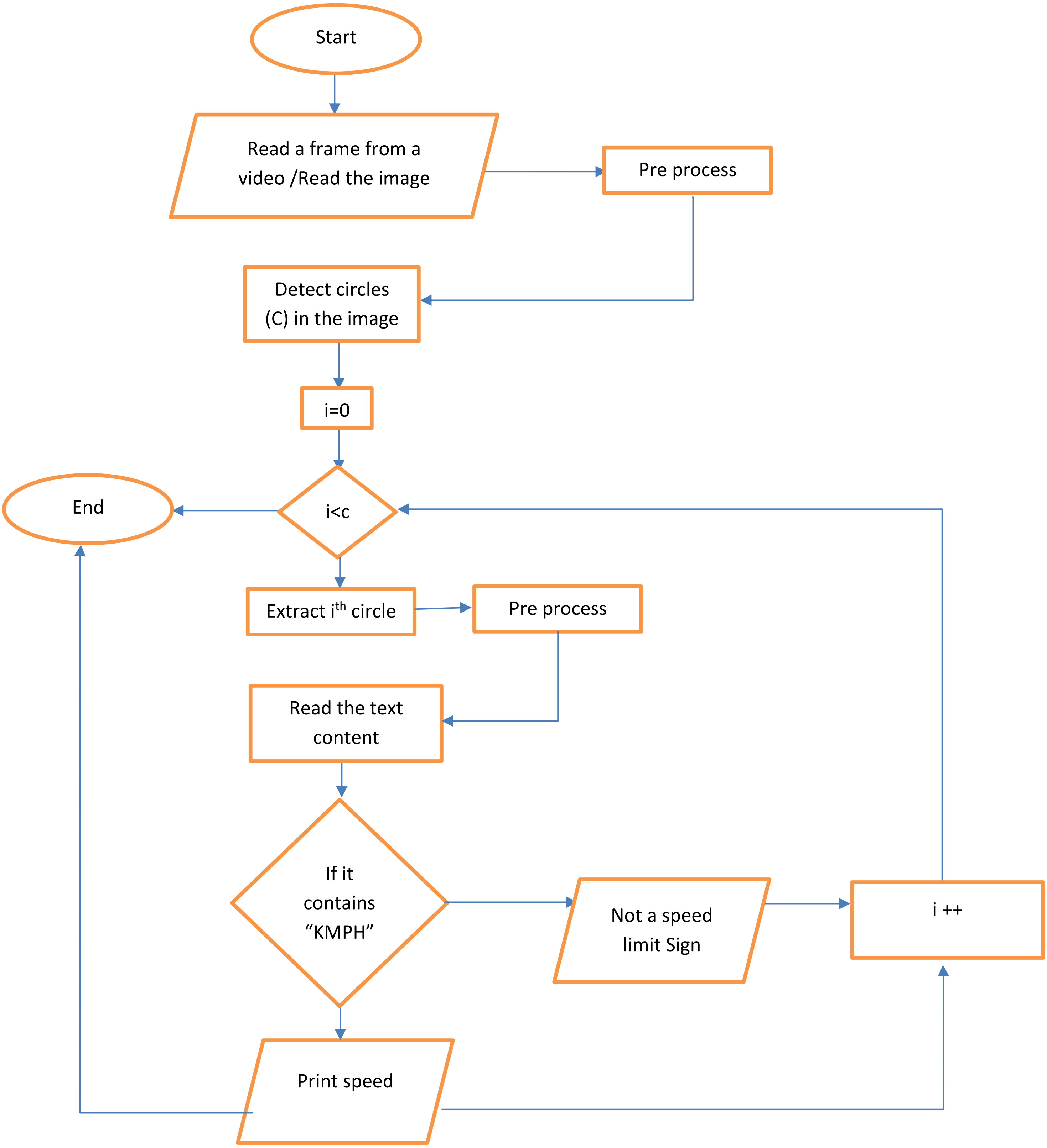


Figure 4: Flow chart of speed limit detector

Basic functionality of this Module 01 is to identify whether that image contains a speed limit sign and detect the speed mentioned in the speed limit road sign. Therefore, according to the flow chart (Figure 4) all the task has done and identified the speed limit value and the place where the speed limit is existing on the digital image. Results of this module are very critical therefore few pre-processing steps done by this module. And the result of this module passed to the Module 02 (Affected vehicle type identifier). Module 02 only execute, if Module 01 identifies a speed limit sign on that digital image.

This module is expecting a video or image input. If it's a video, then it will be extracted frame by frame and perform the detection process. The image shouldn't rotate to identify correct road sign and the speed limit, and the road sign should be clearly appeared similar to Figure 5.

Figure 5: Speed limit sign

3.3 Module 02 (Affected vehicle type identifier)

Normally there are two parts in a road sign (Figure 2). Top circular board shows the speed limit and below to that board, there is another rectangular board that shows the affecting vehicle type for that road speed limit sign. If that board is not existing, it means that speed limit is affective to all the vehicle types. In this research detecting the affective vehicles done by Module 02. The initial plan was to identify those signs using their structure, but due to noise and structure same vehicle types images were differing after extracting those.

Figure 6 : Three wheels after affecting vehicle types after extracting

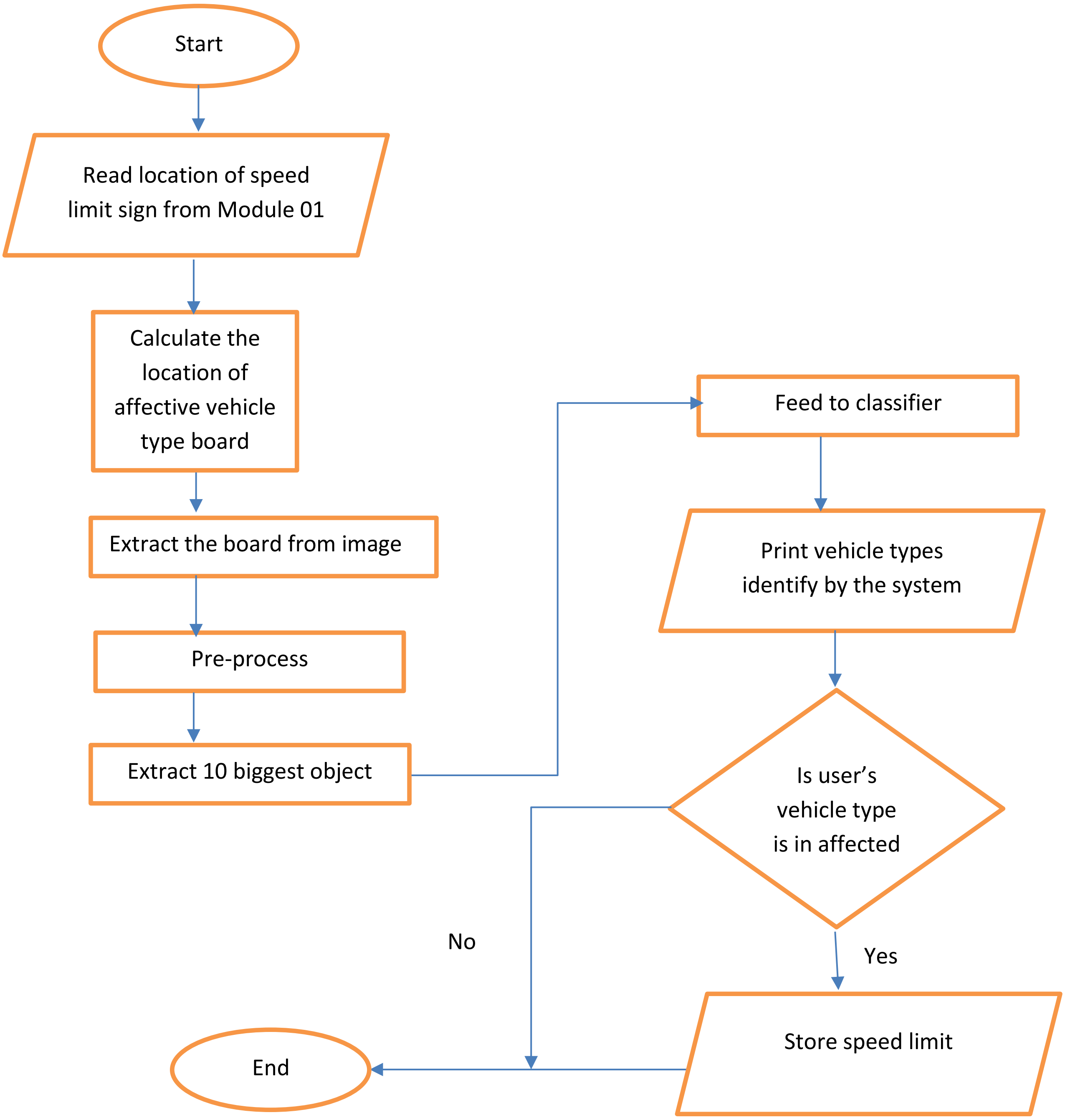


Figure 7 : Flow chart of Module 02

Figure 6 shows a few images (a,b,c) after extracting the vehicle type their shape was change bit due to lights and shadows. Therefore, this research focus on identifying those objects by using a machine learning approach.

The location of the affective vehicle type board is detected using speed limit sign's location which is the output of Module 01. The vehicle type is detected after preprocessing the second portion of the image and feed to the classier for identification. The classifier is trained with sample data collected with the previous dataset. The classifier will identify the vehicle type and if one of the vehicle type matches with the user's vehicle type, newly detected speed signs value set as the speed limit in the system. All the steps conduct according to Figure 7.

3.4 Module 03 (Vehicle Speed Detector)

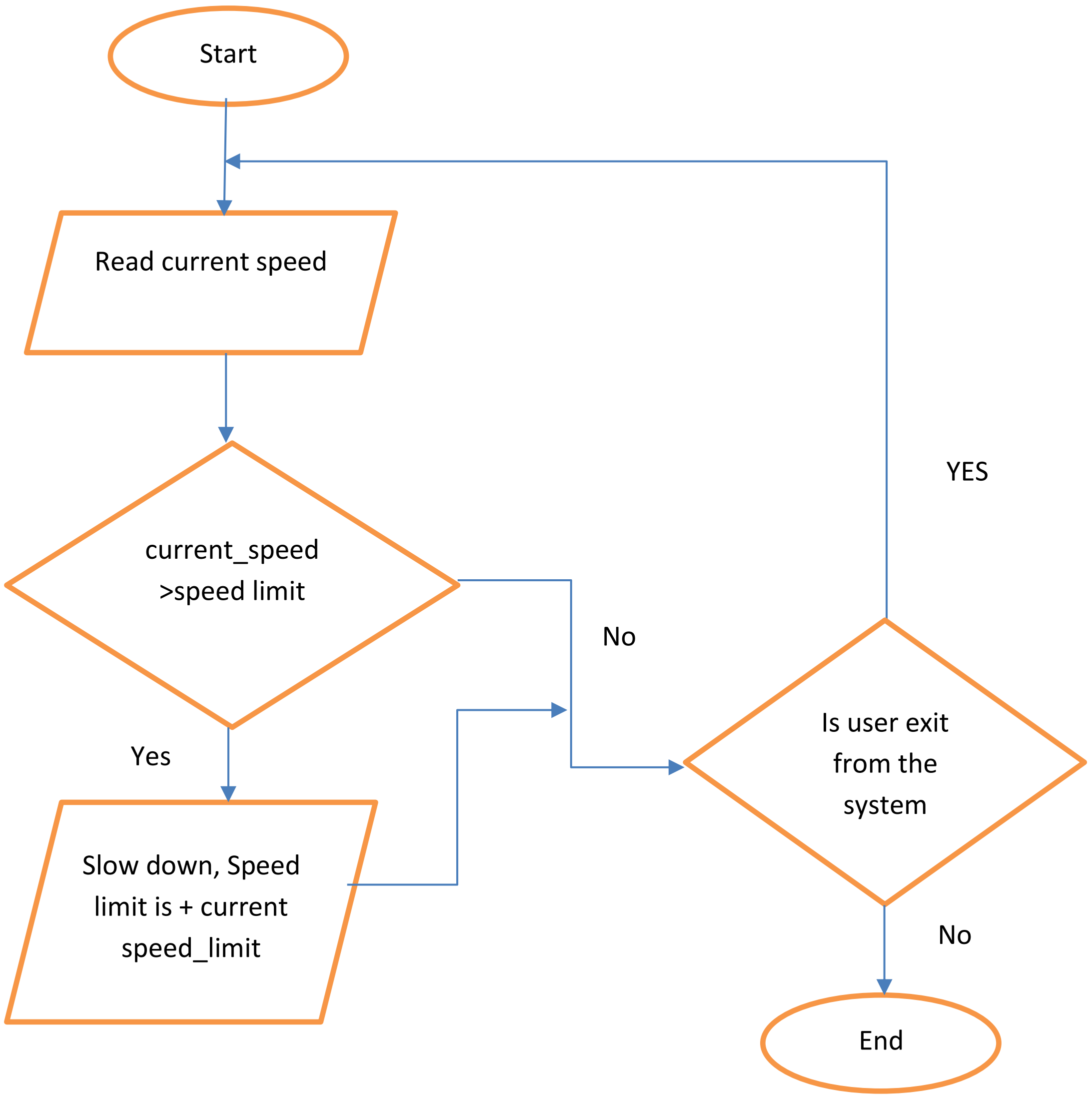


Figure 8 : Flow chart of Module 03

Calculating the current speed of the vehicle and alert user for exceeding the speed limits are done by this module. Since drivers are not able to look at the mobile phone, this system will give audio messages to the drivers without distracting them.

Finally, application will notify to user when module 3 detected a speed sign which affected to the drivers' vehicle. It'll not only shows in mobile application window it will give audio message to driver about the speed limit of the detected speed limit sign.

By using module 03 it will measure the vehicle speed and when vehicle speed is increasing the speed limit detected by the application, application screen color will change and notify the user by audio message which driver doesn't need to look at mobile phone while driving which cause to accidents. Because of every message is showing in the mobile phone screen passengers also could be aware of speed limit even though they are not familiar with road signs and they could ask driver to drive under suitable speed.

Audio messages list

When application detected a speed limit sign: "*New Speed limit is [speed limit]"*

When exceeding speed limit: "*Slow down, Current speed limit is [speed limit]"*

3.5 Android application

Android application is one of the main outcomes of this research. User needs to select vehicle category by using drop down and user needs correctly align camera by using left side camera view. Then app is ready for speed limit assistant. Application window shows camera view, selected vehicle type, lastly detected speed limit value and the current speed of the vehicle. Appendix C show screen shot of application.

4. Chapter 4: Methodology

4.1 Introduction

This research is focused to detect the speed limit, speed limit affecting vehicle types of a road sign and measure the vehicle speed to assist the driver in driving the vehicle according to the speed limits. That will help to reduce speed limit violations which cause to accidents and fines. This research uses digital image processing techniques and Machine learning to identify speed limit and vehicle type. This research uses GPS to calculate the speed of the vehicle. Therefore, this chapter explains the methodology of the research.

There are four main objectives such as detecting speed limit sign, identifying its speed, identifying speed limit affected vehicle types and measured the speed of the vehicle. Therefore, there are three modules to achieve above objectives such as,

1. Speed limit detection
2. Affected vehicle type identification
3. Vehicle Speed Detection

4.2 Module 01 (Speed limit detector)

Since all the speed limit signs are a circular shape, that property is using to identify potential places which are speed limit sign could be contain. Accordingly, first task of this module is to identify circle shapes in the image. After preprocessing the image, this research uses Circle Hough Transform based technique to detect the circles. For this research identifying circular shapes is a critical task and it should be more accurate as well as speedy because: -

1. If module detects a non-circular object as a circle, then it carries out all the processing steps and Optical Character Recognizer (OCR) function to check whether that detected shape is speed limit sign or not. Thus, it will be a waste of time, processing as well as memory.

2. If the module didn’t detect a circular object as a circle, then it might miss the speed limit sign that digital image contains.

4.2.1 Pre-processing

The image has preprocessed to speed up and improve accuracy the circle identification. Since this research uses Hough transform based algorithm to identify the circles in an image and if the radius of the circle given then it will detect the Hough transform faster. Therefore, the image has resized respect to its width to limit the number of possible radius range. After analyzing 20 images, that has speed limit sign the I identified image width 300 pixels giving promising results. Accordingly, the scaling factor (S) is calculated by the below equation. By reducing the image quality will help to reduce detection time of the circle because rang of radius needs to be considered is less.

W: actual width of image by pixels

$$S = W/300$$

After Scaling the image radius of the circle will be 7 to 50. That range was identified after analyzing 20 images. By reducing the range, it will able to improve the performance of circle detection.

4.2.2 Circle Detection

The Circular Hough Transform (CHT), used to detect circles after pre-processing. Hough Transform technique is a robust technique to detect circle even though it requires more memory and processing power[14]. The CHT is tolerant to gaps in feature boundary descriptions as well as it is relatively unaffected by image noise [15]. Therefore, this research uses Circular Hough Transform technique to detect circles in the images to identify road signs.

CHT can be used to determine the parameters such as radius and coordinates of the center of a circle in a digital image when a few points of the perimeter known. Below expression will represent a circle in if (a,b) is the coordinates of the center , R is the radius and θ is a parameter. When θ goes 0 to 360 (x,y) point trace the perimeter of the circle.

$$x=a + R\cos(\theta)$$

$$y=b+ R\sin(\theta)$$

Equation 1: Calculates x, y using angle

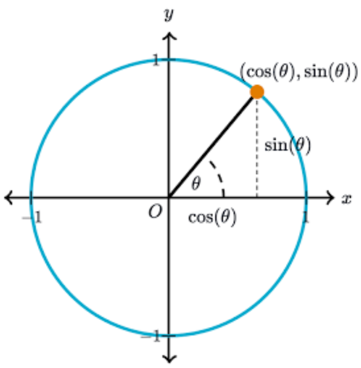


Figure 9: Circle with center is (0,0)

By identifying a, b and R,a circle can be identified. By giving a fixed value to R, that possibly makes this equation simpler, now need to determine the a and b only. For each (x,y) point in perimeter, center (a,b) will be in another circle which is radius is R.

Let's assume B, C, D, E are known points of a digital image that points are in the perimeter of the circle which radius is R and actual center is A (Figure 9). If R is known by using Hough transform, the center of the circle(A) can be detected.

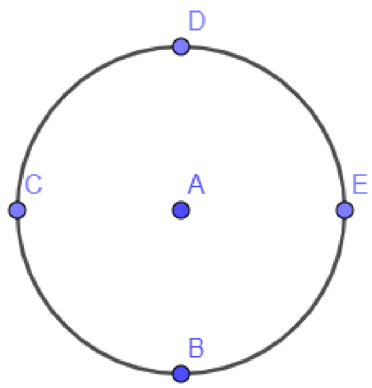


Figure 10 : Circle

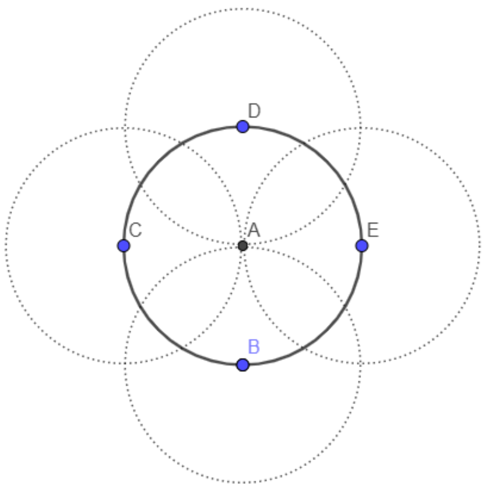


Figure 11 : Possible centers

According to the theory, the center of the circle should be in R distance from each point (B, C, D, E). By drawing circles which have their center at each point. Actual center(A) will be the point where all the circles intersect (Figure 11).

Figure 12 : Identified circle mark in blue color

After identifying circle (a,b,r), the square will be extracted from the image, which fit that circle as below figure (Figure 13). Thus, most of unwanted background removed.

Figure 13 : Extracted speed limit sign

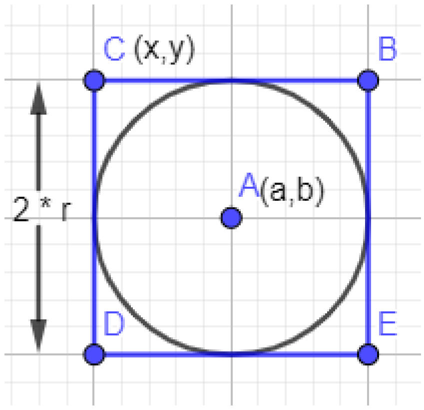


Figure 14 : Calculating the correct square to extract road speed limit circle

Coordinates of C point calculated using the following equations.

$$x = a - r$$

$$y = b - r$$

Equation 2: For extracting image

After extracting ROI, it will convert to a binary image. Since black letters in white background it can convert binary image without damaging to the letters. Now binary image contains conspicuous letters.

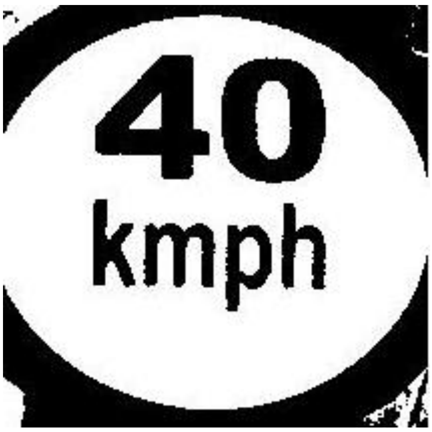


Figure 15 : After binarized ROI

Then it's required to remove noise from the image. This will reduce the recognition of unrelated characters. Therefore, identified the biggest white object in the binarized ROI and got only the black content in that ROI by using the following algorithm.

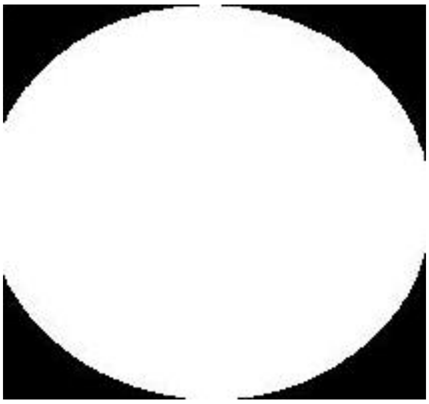


Figure 16 :After extract biggest object

```
Algorithm 1: extract content inside white background
Input: biggest white object in the image b, binarized ROI image,
       width of the image w, height of the image h
Output: binary white image which has same size as ROI newImage
   for x ← 1 to w step 1
           for y ← 1 to h step 1
                 if b[x,y] ==1
                   newImg[x,y]=croppedImg[x,y];
               end
             end
   end for
```

Figure 17 : After removing noise

By using OCR these texts will be identified. Therefore, this research uses tesseract OCR engine. It will only supposed to identify numbers, “k”,”m”,”p” and “h” only. Here researches considered both simple and capital letters. It will reduce the matching scope for the letters in one hand its improving the accuracy as well as performance.

To check whether that image contains letters related to the speed limit sign following algorithm was used.

```
Algorithm 2: Text is similar to KMPH
Input: Input String text
Output: whether text is similar to "KMPH" or Not isSimilar
   score ← 0
   if text contains "K" then
     score ← score + 1
   end
   if text contains "M" then
     score ← score + 1
   end
   if text contains "P" then
     score ← score + 1
   end
   if text contains "H" then
     score ← score + 1
   end
   if text contains "KM" then
     score ← score + 1
   end
   if text contains "MP" then
     score ← score + 1
   end
   if text contains "PH" then
     score ← score + 1
   end
   if P >= 4 then
     isSimilar = true
   else
     isSimilar = false
   end
```

In this algorithm will check whether detected characters from the tesseract engine, whether those letters at least have 3 characters according to correct order. For that, Researcher used scoring technique which will check some conditions and giving score based on that and finally by checking the score informing whether it's true or false.

4.3 Module 02 (Affected vehicle type identifier)

Researcher has identified that biggest vehicle type board's width is less than three times speed limit sign's diameter and height are less than two times speed limit diameter. Therefore, initially that area will extracted from the original image (Figure 18).

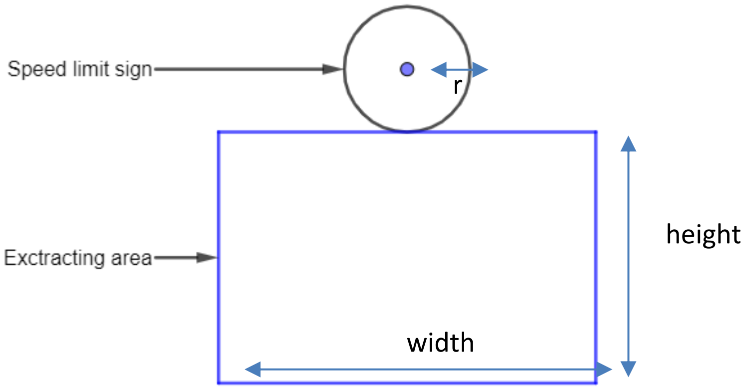


Figure 18 : Extracting area to identify affective vehicles

$$width < 6r$$

Equation 3 : Relation between radius of sign and width

$$height < 4\mathrm{r}$$

Equation 4: Relation between radius of sign and height

Thus, extracting affective vehicle board done by extracting rectangle which has width is 6r and height is 4r (r is radius of the speed sign circle). After extracting the affective vehicle board from this technique, it could be including less unwanted background similar to Figure 18.

Figure 19 : After extracting vehicle type sign

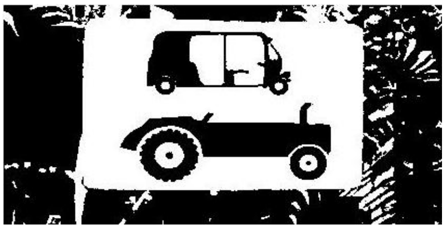


Figure 20 : After binarize ROI

Morphological operations can be used to reduce noise in the image [16]. Accordingly, extracted image convert to binarize image (Figure 20) and then conduct dilation and erosion to remove white dots and to connect vehicle parts.

Figure 21 : After morphological operations

By comparing Figure 20 and Figure 21 easily identify changes after morphological operations. Now all the part in vehicle connected to each other's and preview as a one object and some noise was removed.

Using the same algorithm mentioned in previous chapter noise will be removed. Vehicle type will only appear in the image.

Figure 22 : Biggest white object in ROI

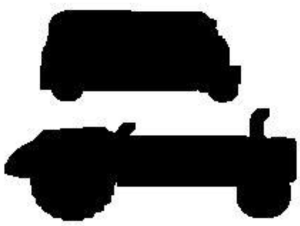


Figure 23 : After removing noise

Finally, identify the each 8-connected component in the images extracted each and extract features of each by Histogram of Oriented Gradients (HOG) image descriptor. Ultimately feed extracted features to the classifier and identify the vehicle type.

4.3.1 Feature Extraction by HOG

There are many types of research based on identifying the shape or object in a digital image. Use of Support Vector Machine (SVM) and HOG is common approach to that [16]. Two feature extraction algorithms have considered in this research such as Histogram of Oriented Gradients (HOG) and Speed up Robust features (SURF). Since the size of the vehicle object depends on the distance of camera and speed limit sign, feature extraction technique should scale invariant.

Even though SIFT descriptor detects more features points than the HOG and SURF it's slow compare to the other two as well as it finds the key points randomly [18]. Accordingly, SIFT doesn't suit for this research.

Describe object appearance and shape by the distribution of local intensity gradients or edge directions without the prior knowledge about edge location is the base of HOG [18], [19].

SURF feature extraction technique infers from the SIFT feature, most of the disadvantages in SIFT has overcome by introducing SURF [19]. SURF uses integral images and to generate key points and descriptors, it uses a technique based on multi-scale space theory.

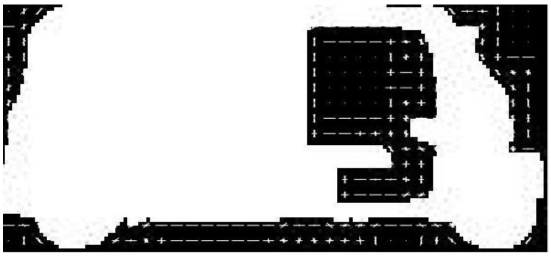


Figure 24: HOG feature points

Figure 25: SURF feature points

In this research objective of feature extraction to detect the shape of vehicle type which is binarized. Which means textural information more important than the other features. And comparing Figure 24 and Figure 25 SURF has a smaller number of the feature point, and those are not much focus on the shape of the vehicle. But HOG has identified more feature point, and most are near to the edges. Since HOG descriptor is focused more on textual information [18], to detect vehicle types in road signs HOG descriptor has been used in this research.

4.3.2 Classifier to Identify Vehicle types

When automating the speed limit sign detection mechanism, it's required to identify the affecting vehicle types stated in the speed limit sign. Hence driver could able to know whether that speed limit is affecting to the driver or not.

Therefore, it is required to identify given binary image is a bus, car, van, lorry, bike, three-wheeler, tractor or none of the above. Accordingly, all to gather there are eight classes. Therefore, this research has to use multiclass classifier. There are few techniques suit for multiclass classification problems such as decision tree, Naïve Bayes and neural network, etc. This research is proposed Error Correction Output Codes (ECOC) Model to train as the multi-class SVM to classify vehicle types. Simply when feed the HOG features of vehicle type to the model, it will predict the vehicle type.

ECOC is an ensemble method designed for multi-class classification problem. Which uses to choose one label among k labels which k is greater than two (k>2). ECOC is a method which combines many binary classifiers to solve the multi-class problem.

All to gather 219 images used to train the multi-class support vector machine. All the vehicle type shapes extracted using Module 02. Since these images are binary and each one's shape is different from one to another, this research uses convenience sample to train and test the machine. All the vehicle shapes extracted from the road sign, using the same system and save them in the hard disk. Then classify according to their shape manually and put it into different folders. Finally, multi-class SVM train class by class and final classifier save in hard disk and Table 3 shows several images used to train multi-class SVM. Here numerous None Vehicle type images were trained due to avoid categorizing noise as a vehicle type.

Class	Number of images for training
Bike	11
Bus	12
Car	15
Lorry	7
Three Wheel	8
Tractor	5
Van	11
None of the above	150

Table 3 : Images used to train.

5. Chapter 5: Testing and Evaluation

5.1 Introduction

Evaluating the outcomes of a research is very important. Since this research proposing a software to assist the driver in driving under speed limits proposed by the police and Road Development Authority (RDA), it is required to measure the accuracy as well as the performance of the application to verify whether it's working accordingly as well as whether it suits for its requirements.

Following paragraphs will explain testing and evaluation processes done to each module and results of them. All of the images taken using a smart phone's camera and most of images taken through the windscreen of the vehicle. Test is conduct manually, by feeding images to the system and categorizing those according to the results.

5.2 Module 01 (Speed limit sign detector)

The main objective of the Module 01 is to detect speed sign and identify the speed limit in the road sign. Therefore, first, it finds a circle in the image and then checks whether that circle contains at least three letters from "KMPH" text if so speed will be detected by the system.

The test mainly focused on detecting whether the system identifies the correct circle and correct speed limit value. Accuracy of this module not only affect accuracy of the whole systems, it will affect the performance of the system as well.

To evaluate the module, this research carried out a test using 150 images. Appendix B contains results of the test. In this 150 images set contains speed limit signs taken from different mobile phone cameras and from different distances from the sign. To test the system, those images feed into module 01 and check whether module 01 identifies the red circle in the speed limit sign. If that detected the image then check whether its detected the KMPH text and finally check it detect the speed limit specify in the speed limit sign. Summary of the results mention below.

Results summary

Number of images that speed sign circle detected correctly	141
Number of rotated images	12
Number of images that "KHMP" text identified correctly	108
Number of images that identified speed correctly	105

Accuracy of this module: 70 %

Calculated accuracy omitting rotated images: 76.08 %

The main reason for getting less accuracy is that test images contains 12(twelve) rotated images which are rotated more than 90 degrees. Since this research not considering the rotating the road signs and Tesseract engine doesn’t identifies rotated characters users are required to keep the camera in the correct angle. But test results show, this module can be identified in slightly rotated images.

On the other hand, this test images contains images which have a lot of noises due to dust and water drops in the windscreen, blurred images and images taken in different conditions such as night, misty and rainy (Figure 26). Images were taken in the night only uses the vehicle’s lights and mobile phone’s camera. Therefore, these results forecast the real time results.

(a) Photo taken in night

(b) Image taken when raining

Figure 26 : Images failed to detect as speed limit sign.

In figure 26, there are images which have road signs which are slightly rotated and one is bit blurred and one is taken in the night using vehicle lights but the system will able to detect those as speed limit sign and their speed limit correctly. Which is a good evidence to prove this system could be used in the real world.

(a) Photo taken in day time (b) Photo taken in night

Figure 27 : Images able to detect as speed limit and identified correct speed limit.

5.3 Module 02 (Affected vehicle type identifier)

Road speed limit sign contains speed limit as well as vehicle types which that speed limit is affected. Therefore, just identifying speed limit only will not help to the driver, because the user needs to know whether that speed sign impact on user's vehicle. Therefore, this research is considering identifying vehicle types mentioned with the speed limit road sign.

Vehicle types detection is done by using the affected vehicle type identifier. Therefore, this research use machine learning techniques to identify vehicle types. After training the multi-class SVM, the model was tested by using testing images which are extracted from actual road signs by using Module 01 and module 02. Those extracted vehicle types images save as binary images in the hard disk. Those images use to test this module. Saved images are classify by model and depending on classification confusion matrix manually. Test results are shown in Table 4 using a confusion matrix. This confusion matrix uses to calculate the accuracy of the module.

Actual \ **Predicted**	**Bike**	**Bus**	**Car**	**Lorry**	**Three wheels**	**Tractor**	**Van**	**Not a vehicle**
Bike	19	0	0	0	0	0	0	0
Bus	0	19	0	0	0	0	0	1
Car	0	0	23	0	0	0	0	2
Lorry	0	0	0	12	0	0	0	1
Three wheels	0	0	0	0	13	0	0	0
Tractor	0	0	0	0	0	10	0	0
Van	0	0	0	0	0	0	13	1
Not a vehicle	0	0	0	0	0	0	0	20

Table 5 : Confusion matrix

Accuracy of Module 02 (ECOC model): 96.27%

The final accuracy of the system (including rotated images): 67.39%

Calculated final accuracy omitting rotated images: 73.25 %

To execute module 01 and module 02, it takes 5.23 seconds averagely, which means to detect a speed limit value and to check whether that speed limit is affecting to that vehicle or not, it takes around 5.23 seconds.

5.4 Module 03 (Speed detector)

This module is for detecting the speed of the vehicle by using smart phone's sensors. Nowadays smart phones equipped with numerous sensors such as accelerometer, gyroscope, GPS, heat, etc. There are few techniques to calculate vehicle speed such as using GPS and Accelerometer. Use of GPS more accurate than the use of accelerometer [20], [21]. To reduce battery consumption smartphones will uses Wi-Fi, cell tower information to get the location. But accuracy of those techniques is less when compared to GPS and GPS will provide the smart phone moving speed as well [22]. Therefore, this research focuses on the use of GPS to detect vehicle speed. Hence this research uses *android.location* package to measure vehicle speed using an Android smart phone.

6. Chapter 6: Conclusion and Future work

This research proposed software to assist vehicle driver driving in correct speed using speed limit signs. Therefore, this software will automatically detect speed sign, its speed, its affecting vehicle types, and vehicle speed and giving notification and waring through the voice alerts.

Initially the system will detect the circles in the captured image. Therefore, Hough transform based circular detection algorithm shows promising results by identifying 92.04% circles in road signs correctly. Even though it's correctly identified the speed limit sign circle's above 90%, it has detected Non-circular shapes as circles as well. Therefore, its better preprocess more initial image due to the light condition color of the circle in road sign captured as different colors. Therefore, using a red color is not efficient to identify the road signs' circle is not efficient.

Detected circle in the images extracted and further preprocessed by using erosion and dilation to reduce noise in the image as well as increase the strength of the characters. That technique is a success in this research to remove unwanted dots from the binary image, and that is very important because if that image contains the noise then that noise might be identified as a deferent character by the OCR. Even though this is a time critical application, to avoid detecting wrong speed limit (character set from the speed limit sign). It's better to do noise remove in this stage. The technique followed the research able to extract only characters inside the speed limit sign circle.

For OCR this research uses Tesseract OCR engine it was not able to identify rotated text; therefore, system's users are required to keep their camera in correct angle. The engine does not identify especially upside-down characters. Since this system is time critical application it is not supposed correct rotations automatically because it takes more processing time.

To detect vehicle types this research uses an Error Correction Output Codes model which is a multi-class SVM. Since there are eight (8) vehicle types, it cannot use binary SVM. To train the model uses HOG features of extracted binary images of vehicle types. That module detects vehicle type with high accuracy (96.27) and within the lesser time which would be suitable for time critical application like this software.

By preprocessing it able to remove noise and unwanted backgrounds from the image, even though images have unwanted objects and noise. There were some special cases such as dust or rain drops on the windscreen, the camera wasn't focused to a road sign, due to light or mist road sign wasn't visible, and the road sign was rotated. In those cases, it unable to identify the road signs or speed limit accurately.

Finally, overall process required around 5.23 seconds, it might be changed due to image quality, number of circular objects that image contains. To use this technique in the real word it's required optimize and improve the performance. Therefore, it's better to use parallel processing to process more than one image at a time. On the other hand, after detecting the circular object in the image, parallel computing could be used to identify those are speed limit signs or not.

7. References

[1] police.lk, 'Traffic statistics, 2019. [Online]. Available: https://www.police.lk/index.php/traffic-statistics. [Accessed: 5 - Feb - 2018].

[2] Peden M, Scurfield R, Sleet D, Mohan D, Hyder AA, Jarawan E. "World report on road traffic injury prevention",2004.

[3] Samath D Dharmaratne, Achala Upendra Jayatilleke and Achini C Jayatillekec "Road traffic crashes, injury and fatality trends in Sri Lanka: 1938–2013"

[4] Traffic offences for the - Year 2011, Sri Lanka Police.

[5] traffic offences for M.T.A 148(1-14), 151(2), 162 for the year 2011, Sri Lanka Police.

[6] Kuei-Chung Chang , Po-Kai Liu "Design of real-time speed limit sign recognition and over-speed warning system on mobile device"

[7] W.K.I.L. Wanniarachchi, D.U.J. Sonnadara and M.K. Jayananda "Detection and Extraction of Road Traffic Signs",2008

[8] Vincenzo Barrile, Matteo Cacciola, Giuseppe M. Meduri and Francesco C. Morabito "AUTOMATIC RECOGNITION OF ROAD SIGNS BY HOUGH TRANSFORM"

[9] Tom J. Chalko, MSc, PhD* "High accuracy speed measurement using GPS (Global Positioning System)"

[10] Leonardo Brunoa, Giuseppe Parlaa, Clara Celauroa "Improved Traffic Signal Detection and Classification via Image Processing Algorithms"

[11] J.D Zhao, Z.M Bai and H.B Chen "Research on Road Traffic Sign Recognition Based on Video Image"

[12] Anu Priya George and X. Felix Joseph "Object Recognition Algorithms for Computer Vision System:Survay"

[13] Mohit Bhairav Mahatme and Sonia Kuwelkar "Detection and recognition of traffic signs based on RGB to red conversion"

[14] Z. Yao and W. Yi, "Curvature aided Hough transform for circle detection," Expert Syst. Appl., vol. 51, pp. 26–33, Jun. 2016.

[15] N. Cherabit, F. Zohra Chelali, and A. Djeradi, "Circular Hough Transform for Iris localization," Sci. Technol., vol. 2, no. 5, pp. 114–121, Dec. 2012.

[16] Gopal Manne and Neetesh Raghuwanshi "Vehicle Detection from Video using Morphological Operations" International Journal of Science, Engineering and Technology Research (IJSETR) Volume 6, Issue 4, April 2017, ISSN: 2278 -7798

[17] S. Sivaraman and M. M. Trivedi, "Looking at vehicles on the road: A survey of vision-based vehicle detection, tracking, and behavior analysis," IEEE Trans. Intell. Transp. Syst., 2013.

[18] Sidheswar Routray, Arun Kumar Ray and Chandrabhanu Mishra, "Analysis of Various Image Feature Extraction Methods against Noisy Image: SIFT, SURF and HOG"

[19] Shihong Yao, Tao Wang, Weiming Shen, Shaoming Pan, Yanwen Chong, and Fei Ding, "Feature Selection and Pedestrian Detection Based on Sparse Representation"

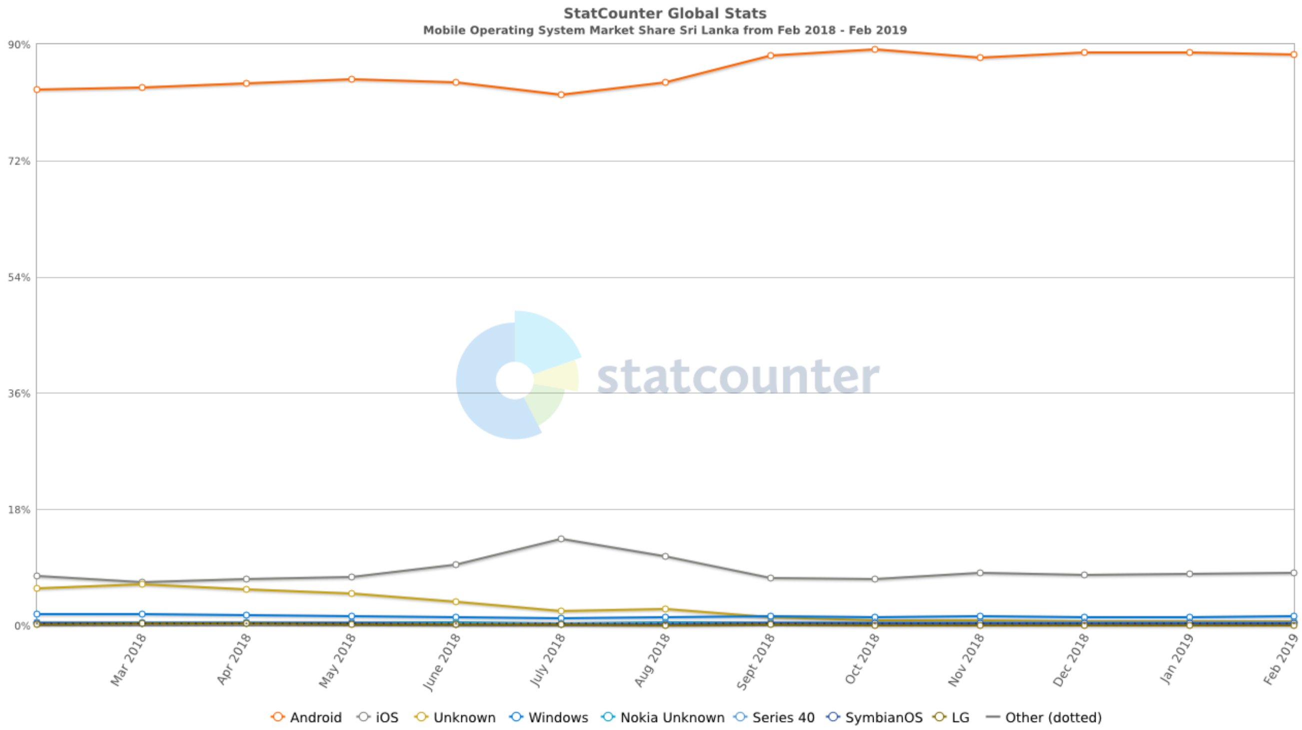
[20] G. Guido et al., "Using Smartphones as a Tool to Capture Road Traffic Attributes," Appl. Mech. Mater., 2013.

[21] H. Xia, Y. Qiao, J. Jian, and Y. Chang, "Using smart phone sensors to detect transportation modes," Sensors (Switzerland), 2014.

[22] A. Chowdhury, T. Chakravarty, and P. Balamuralidhar, "Estimating true speed of moving vehicle using smartphone-based GPS measurement," in Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics, 2014.

[23] statcounter.com, 'Social Networking Reaches Nearly One in Four Around the World', 2019. [Online]. Available: http://gs.statcounter.com/os-market-share/all/sri-lanka. [Accessed: 2-March- 2019].

Appendix A : Usage of mobile platforms (adopted from StatCounter web site [22])



Appendix B: Test result of images

Image	Speed limit sign's circle detected	Identify kmph test	Identify correct speed
1	Yes	Yes	Yes
2	Yes	No	No
3	Yes	Yes	Yes
4	Yes	No	Yes
5	Yes	Yes	Yes
6	Yes	No	No
7	Yes	No	No
8	Yes	Yes	Yes
9	Yes	Yes	Yes
10	Yes	Yes	Yes
11	Yes	Yes	Yes
12	No	No	No
13	Yes	No	No
14	Yes	No	No
15	Yes	Yes	Yes
16	No	No	No
17	Yes	Yes	Yes
18	Yes	Yes	Yes
19	Yes	Yes	Yes
20	Yes	Yes	Yes
21	Yes	Yes	Yes
22	Yes	No	No
23	Yes	Yes	Yes
24	Yes	Yes	Yes
25	Yes	Yes	No
26	Yes	Yes	Yes
27	No	No	No
28	No	No	No
29	Yes	Yes	Yes
30	Yes	Yes	Yes
31	Yes	Yes	Yes
32	Yes	Yes	Yes
33	Yes	No	No
34	Yes	Yes	Yes
35	Yes	No	No
36	Yes	Yes	Yes
37	Yes	No	No
38	Yes	No	No
39	Yes	No	No
40	No	No	No
41	Yes	Yes	Yes

42	Yes	Yes	Yes
43	Yes	No	No
44	Yes	No	No
45	Yes	No	No
46	Yes	No	No
47	Yes	No	No
48	Yes	No	No
49	Yes	No	No
50	Yes	No	No
51	Yes	Yes	Yes
52	Yes	Yes	Yes
53	Yes	Yes	Yes
54	Yes	Yes	No
55	Yes	Yes	Yes
56	Yes	No	No
57	Yes	Yes	Yes
58	Yes	No	No
59	Yes	Yes	Yes
60	Yes	Yes	Yes
61	Yes	Yes	Yes
62	No	No	No
63	Yes	Yes	Yes
64	Yes	Yes	Yes
65	Yes	Yes	Yes
66	Yes	Yes	Yes
67	Yes	Yes	Yes
68	Yes	Yes	Yes
69	Yes	Yes	Yes
70	Yes	Yes	Yes
71	Yes	No	No
72	Yes	Yes	Yes
73	Yes	Yes	Yes
74	Yes	Yes	Yes
75	Yes	Yes	Yes
76	Yes	Yes	No
77	Yes	Yes	Yes
78	Yes	Yes	Yes
79	Yes	Yes	Yes
80	Yes	No	No
81	Yes	Yes	Yes
82	Yes	No	No
83	Yes	Yes	Yes
84	Yes	Yes	Yes
85	No	No	No

86	Yes	No	No
87	Yes	No	No
88	Yes	No	No
89	Yes	Yes	Yes
90	Yes	Yes	Yes
91	Yes	Yes	Yes
92	Yes	Yes	Yes
93	Yes	Yes	Yes
94	Yes	Yes	Yes
95	Yes	Yes	Yes
96	Yes	Yes	Yes
97	Yes	Yes	Yes
98	Yes	No	No
99	Yes	Yes	Yes
100	Yes	Yes	Yes
101	Yes	Yes	Yes
102	Yes	Yes	Yes
103	Yes	Yes	Yes
104	Yes	Yes	Yes
105	Yes	Yes	Yes
106	Yes	Yes	Yes
107	Yes	No	No
108	Yes	Yes	Yes
109	Yes	Yes	Yes
110	Yes	Yes	Yes
111	Yes	Yes	Yes
112	Yes	Yes	Yes
113	Yes	Yes	Yes
114	Yes	Yes	Yes
115	Yes	Yes	Yes
116	Yes	Yes	Yes
117	Yes	Yes	Yes
118	Yes	Yes	Yes
119	No	No	No
120	Yes	Yes	Yes
121	Yes	Yes	Yes
122	Yes	Yes	Yes
123	Yes	Yes	Yes
124	Yes	No	No
125	Yes	Yes	Yes
126	Yes	Yes	Yes
127	Yes	Yes	Yes
128	Yes	Yes	Yes
129	Yes	Yes	Yes

130	No	No	No
131	Yes	Yes	Yes
132	Yes	Yes	Yes
133	Yes	Yes	No
134	Yes	Yes	Yes
135	Yes	Yes	Yes
136	Yes	Yes	Yes
137	Yes	Yes	Yes
138	Yes	No	No
139	Yes	Yes	Yes
140	Yes	Yes	Yes
141	Yes	Yes	Yes
142	Yes	No	No
143	Yes	Yes	Yes
144	Yes	Yes	Yes
145	Yes	Yes	Yes
146	Yes	Yes	Yes
147	Yes	Yes	Yes
148	Yes	Yes	Yes
149	Yes	Yes	Yes
150	Yes	Yes	Yes
Count	141	108	105

Appendix C: Screen shots of Android application

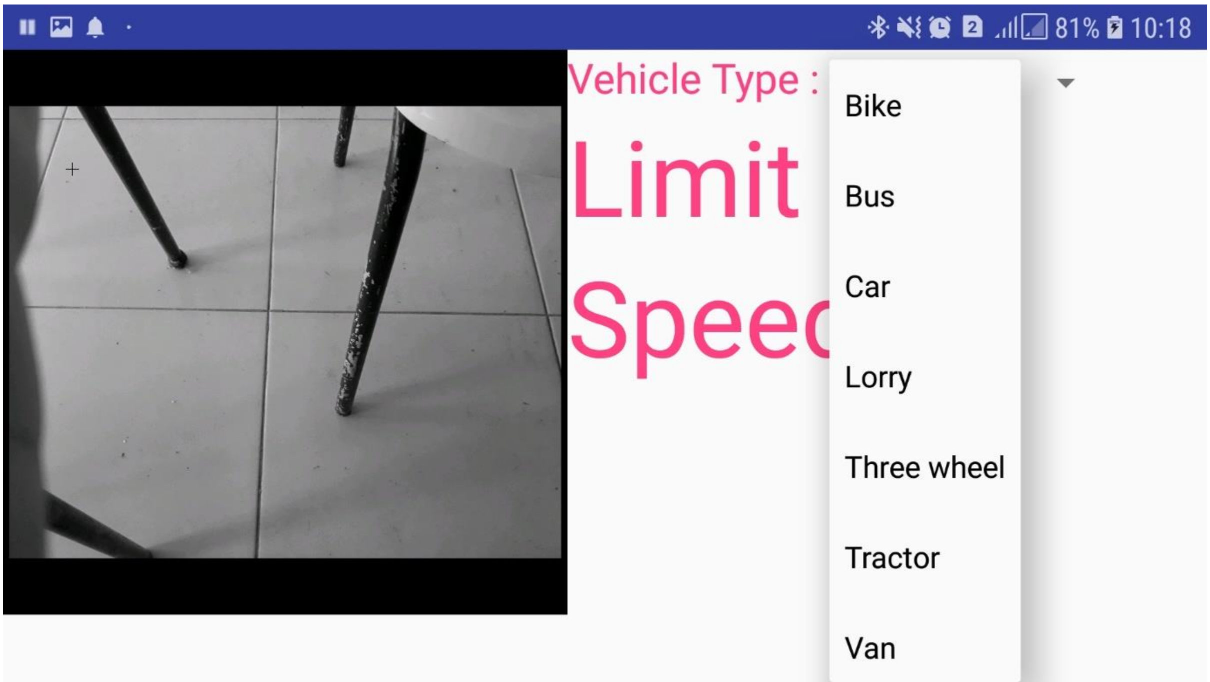


Figure 1: Vehicle type drop down

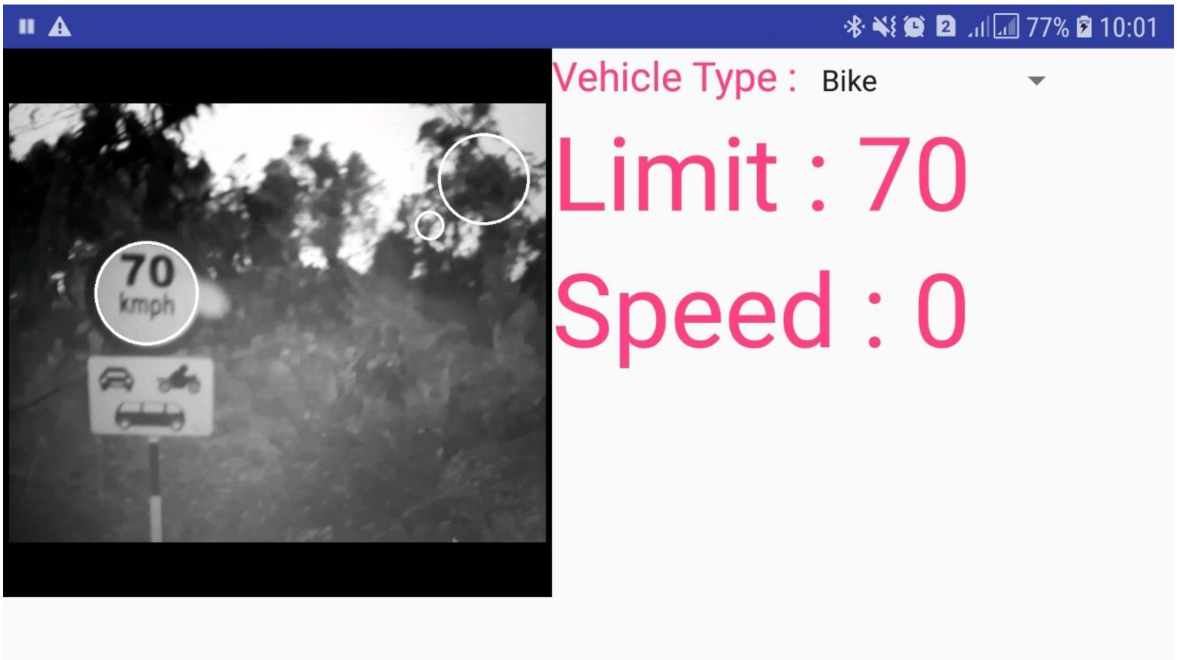


Figure 2: Android application detecting speed limit sign