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FINAL YEAR PROJECT 2

(FULL REPORT)

REAL TIME VIDEO TRAFFIC LIGHT DETECTION AND INTERPRETATION USING IMAGE PROCESSING METHOD

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"I hereby declared that I have read though this report entitle "Real Time Video Traffic Light Detection and Interpretation Using Image Processing Method" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronic Engineering"

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REAL TIME VIDEO TRAFFIC LIGHT DETECTION AND INTERPRETATION USING IMAGE PROCESSING METHOD

NUR AMALYNA BINTI RAMLAN

A report submitted in partial fulfilment of the requirements for the Degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

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I hereby declared that this report entitle "Real Time Video Traffic Light Detection and Interpretation Using Image Processing Method" is the result of my own work except as cited in the references. This report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……………………………………

Name : Nur Amalyna binti Ramlan

Date : ……………………………………

To my beloved mother and father

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ABSTRACT

The purpose of this project is meant to develop a real-time traffic light recognition using image processing algorithm. Invariant in factor lightning and weather condition that lead to misinterpret the colour of traffic light is one of the factor of accident at traffic light conjunction besides the behaviour of the driver itself. The process to identify the colour and shape of traffic light are Image Acquisition, Pre-Processing, Detection, Feature Extraction and Interpretation. Simple thresholding method that act as colour segmentation provides a better division of the traffic light colours. Circle Hough Transform and HSV colour features based on the traffic light aspect are used to decide whether the spots on the frames are likely to be traffic lights' colour and shape. The detection of traffic light is obtained after identifying the feature that need to be extracted at the end of the result and by comparing the pixel value in recognition process. The research has been improved by focussing on detection and interpretation of traffic light based on real time video rather than image sample as the input by processing all frames contained in the video.

ABSTRAK

Tujuan projek ini adalah untuk menghasilkan pengiktirafan lampu isyarat dalam masa nyata menggunakan algoritma pemprosesan imej. Kepelbagaian dalam faktor pemcahayaan dan keadaan cuaca yang membawa kepada kesalahan dalam mentafsir warna lampu isyarat adalah salah satu faktor kemalangan selain daripada tingkah laku pemandu itu sendiri. Proses untuk mengenal pasti warna dan bentuk lampu isyarat adalah melalui proses Perolehan Imej, Pemprosesan pra, Pengesanan, Pengekstrakan dan Tafsiran Ciri. Kaedah thresholding yang ringkas bertindak sebagai segmentasi warna untuk membezakan warna setiap lampu isyarat dengan lebih baik. Circle Hough Transform (CHT) dan ciri-ciri warna HSV berdasarkan aspek lampu isyarat digunakan untuk menentukan sama ada bintik di bingkai mungkin berwarna dan mempunyai bentuk yang sama seperti lampu isyarat. Pengesanan lampu isyarat akan diperolehi selepas mengenal pasti ciri yang perlu diekstrak pada akhir proses pengekstrakan. Penyelidikan ini telah dipertingkatkan dengan menumpukan pada pengesanan dan penafsiran lampu isyarat berdasarkan video yang dirakam ketika masa nyata berbanding sampel imej sebagai input.

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CHAPTER 1

INTRODUCTION

This chapter will represent the background and motivation to the study, the statement of the problem, general and specific objective and the scope of the study.

1.1 Introduction

Traffic light was designed normally at the busiest street and highway intersection to achieve a purpose of facilitating the safe movement of cars and avoiding car collisions. Notwithstanding, The Federal Highway Administrations guarantees that around 45% of auto accidents occur at a street crossing point and the reason is normally identified with running a stop sign [1].

A pressing need for the introduction of advanced technology and equipment to prevent increasing number of accident must be done. The world are approaching a point where car can drive themselves better than humans. This lead to the creation of autonomous car which has been rolled out earlier by Tesla, Mercedes and Google. The detection of traffic light colour is the focal point in autonomous car [2]. This type of detection system is more reliable and faster which will be a great solution of producing zero accidents as it will control the car automatically and efficiently to obey the traffic light sign. Apart of protecting drivers from death and injury, it also eliminates property damage, reduces traffic problems and could bring down car insurance rates. [3]

1.2 Motivation

The detection of traffic lights has a critical place everywhere throughout the world. When looking at the reasons of expanding car accidents, it appears that a large portion of them are caused by human mistake. [4] Violating a red traffic light is one of the factor of serious road car accident in Malaysia. Detection of traffic lights may ensure securing the human life. Some of these reasons of violating the traffic light are because of driver negligence, driver disregard and lack of traffic lights at some point. Autonomous vehicles have been produced on account of new technology to reduce the accident caused by traffic lights. [5] Real time traffic light recognition using image processing method technique will help to detect the variant colour of traffic light. The system in these vehicles can automatically detect traffic lights and this system can alert the driver.

Over the past few decades, lots of attempts have been made to autonomous vehicles. High demand in autonomous vehicle also lead to the research about this project. Moreover, real time video traffic light detection system is still under research in Malaysia which is one of the purpose to make a deeper research about this project. Nowadays, driving on highway with autonomous vehicles has turned out to be increasingly dependable, while fully autonomous driving in real urban environment is still an extreme and challenging task .Robust detection and recognition of traffic lights is fundamental for autonomous vehicle to take appropriate actions on intersection in urban environment. However robust detection of traffic lights is not easy to be carried, for there would be a horrendous chaos of objects in an image in which colours are similar to the one of the traffic lights, and the shape of traffic light is so simple that it's hard to extract sufficient features [6]. The worse situation may be met that the traffic lights have a variety of types, of which, some are horizontal arrangements while some are verticals, and also, some are composed of only circles while some include arrows.

1.3 Problem Statement

There are many strict rules and penalties made by the government, most of drivers still do not adhere to the rules and disregard their own safety. They purposely break and ignoring the traffic light sign especially when the colour turns into red. There are three types of traffic light's colour that is green, yellow and red which has their own function. Most of the driver especially senior citizens always missed the traffic light sign [7]. As a precaution, they need to be alerted earlier at a certain distance which will prevent an emergency brake and car collisions. Other than that, people with colour vision deficiency need a technology which able to interpret the colour of traffic light sign for them while driving. They did not get any chance to take their driving license because of their disability especially to detect the colour of the traffic light and cars' brake lamp. Invariant in factor lightning and weather condition which may lead to misinterpret the colour of traffic light is also one of the main factor of car accident in Malaysia.

1.4 Objective

The fundamental target of this examination is to build up a proficient traffic light recognition framework. The objective of this project is as follows:

- To develop a real-time traffic light recognition using image processing algorithm.
- To extract identified and related features from video to do classification process
- To improve the accuracy of the classification process.

1.5 Scope Of Research

The study of this research is focussing on the detection of three different traffic light colour based on real time video. The real time video is recognized during day time with a good illumination only. The type of traffic light for testing is circle shape only which means that arrow and human walking traffic light are not considered in this research. There are only traffic lights in the area of Ayer Keroh and Durian Tunggal that being covered in this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and Basic Principle

Image Processing is a method to improve raw images earned from cameras or sensors placed on transportation and satellites or pictures taken for various applications. Image processing includes something that related to image representation, compression method and various complex operation, which can be executed on the image data. Image enhancement operations like sharpening, blurring, brightening and edge enhancement is under the group of image processing. The input is an image from cameras or videos while an image with a set of characteristics will be the output. An image will be used in this technique is in two-dimensional signal and standard signal-processing method will be implemented to it. Image processing frequently corresponding to digital image processing.

2.1.1 Image Acquisition:

Image acquisition or can be called as digital imaging is the formation of photographic images. The term is often assumed to imply or include the processing, compression, storage, printing, and display of such images. Image is basically in the form of two-dimensional function f(x, y) on the plane that can be seen in the Figure 2.1 below. The intensity or grey level of the image can be determined by the amplitude of image at any point. These x and y values will be converted to a fixed discrete values to produce a digital image. The input image is taken from stare data base and drive data base. Analog image must be converted to digital image so that digital computer can process the image [8]. Each digital image comprise of a fixed elements and each fixed element represent a pixel.

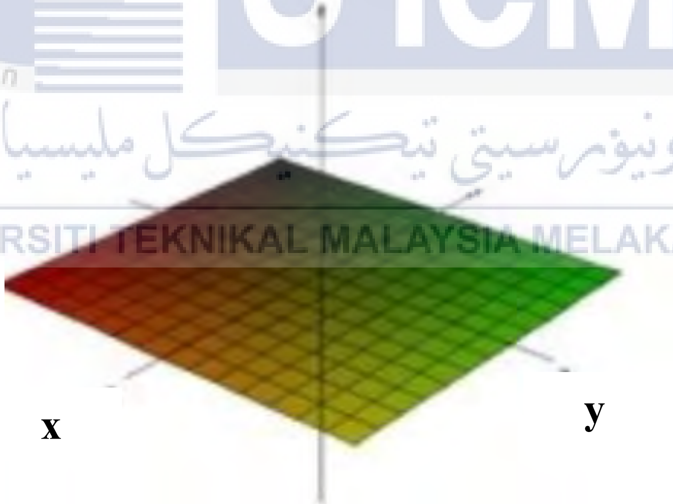


Figure 2.1: Two-dimensional (2D) function f(x, y)

2.1.2 Type of Colour Based-Technique

2.1.2.1 RGB Colour Space Technique

Humans perceive colour through wavelength-sensitive sensory cells called cones. There are three unique assortments of cones, each has an alternate affectability to electromagnetic radiation (light) of various wavelength. One cone is basically delicate to green light, one to red light, and one to blue light. By emitting a confined combination of these three hues (red, green and blue), and thus stimulate the three sorts of cones freely, any detectable colour can be generated. This cause colour images that contain the amount of Red (R), Green (G) and Blue (B) often to be stored as three separate image matrices in RGB format. The significant purpose for the RGB colour model is for the detecting, portrayal and show of image in electronic system, for example, TVs, PCs, colour and most video camera. However it has likewise been utilized as a part of traditional photograph.

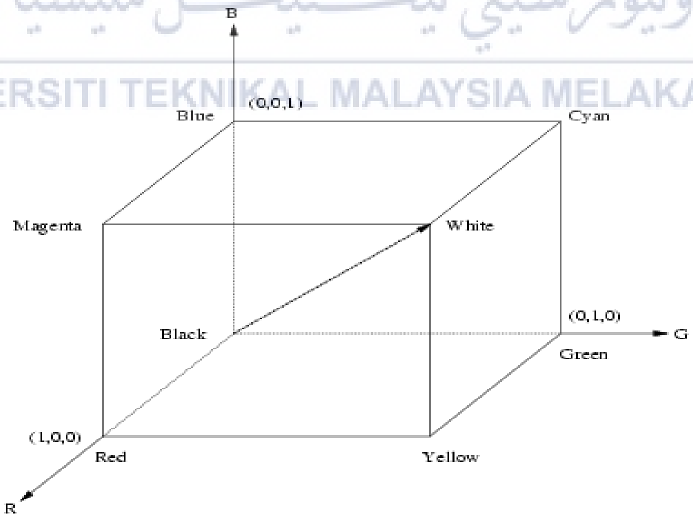


Figure 2.2: The geometry of the RGB shading model for determining hues utilizing a Cartesian facilitate framework

The three additive primary colours, red, green, and blue is a starting to come out the name of the model. From the RGB display, an image comprises of three image planes as shown in Figure 2. 2, one in each of the primary hues: red, green and blue. A specific colour is determined by indicating the amount of each of the primary segments present [9].

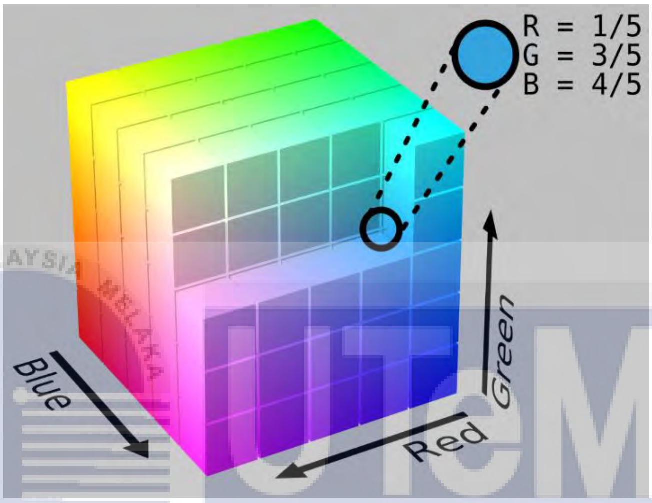


Figure 2.3: The RGB colour cube

The RGB colour model is a colour addition. Broad array of colours is reproduced by mixing together the red, green and blue light in various ways. The colours present in the light is added to produce new colours, and it is suitable for the blending of coloured light. As referring to the Figure 2.3 above, it demonstrates the additive mixing of red, green and blue primaries. Three secondary colours yellow (red + green), cyan (blue + green) and magenta (red + blue), and white ((red + green + blue) are formed from the mixing of all those of colours.

2.1.2.2 HSV Colour Space Technique

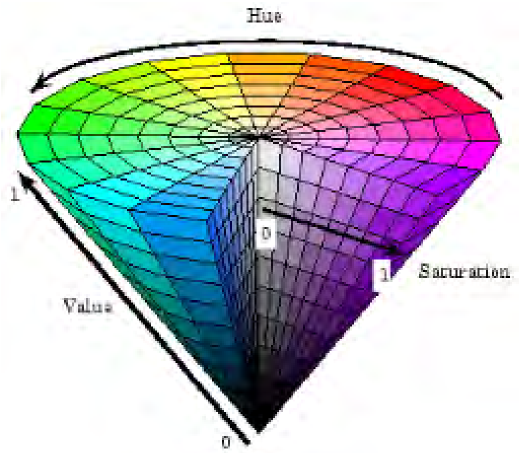


Figure 2.4: Cone of HSV colour space

HSV terms is indicating to three values that is Hue, Saturation and Value/Brightness. Its colour model for HSB and HSV is the same. This colour space characterize about colours in terms of *Hue* which is the actual colour, *Saturation* indicates the amount of grey r while *Brightness* refers to the quantity of white or black that is being mixed in the colour [9]. A cone or cylinder illustrate the HSV colour wheel. The depth explanations of the HSV is explained at bullet list shown below while referring to the Figure 2.4:

- Hue is expressed as a number that rotate counter clockwise at angle from 0 to 360 degrees. It will show the certain value of hue such as the hue of red that starts at 0, yellow at 60, green at 120, and blue at 240. If the hue value is 0 or 255, the colour will be black and white which will not be affected by saturation and brightness.
- Saturation is the amount of grey from zero percent to 100 percent in the colour. The value will increase as the colour move away from the axis to the lateral surface from 0 (0 %) to 255 (100 %). The colour will change from colourfulness to fully saturate as the value raised.
- Value define about the brightness or concentration of the white colour. It works in conjunction with saturation. The value is in between 0 (0%) and 255 (100%).

At the vertex of the cone represent the black colour and as the height move upwards to the base, the value will increase to produce lighter colour.

The first step HSV colour is by selecting one of the available hues. After that, shade and brightness value will be adjusted. It is proven that this kind of colour space can present colour that similar to the way of how human identify colour which is the drawback of RGB colour space.

HSV isolated luma (image intensity) from chroma (colour information). This colour space is frequently used in doing histogram equalization that need only the intensity of component rather than colour component alone. The factor of regularly using of HSV colour space in many application is simply due to the wide available of code for converting between RGB and HSV besides is easily implemented. The formula to find HSV value from RGB value [9] is as follows:

To find the *Hue* Value:

$$H = \begin{cases} \dfrac{60\,(G - B)}{S}, & if\ V = R \\ 180 + \dfrac{60 - (B - R)}{S}, & if\ V = G \\ 240 + \dfrac{60\,(R - G)}{S}, & if\ V = B \end{cases} \tag{2.1}$$

To find the *Saturation* value:

$$S = \frac{255\,(V - \min(R, G, B))}{V} \tag{2.2}$$

To find the *Brightness* value:

$$V = \max(R, G, B) \tag{2.3}$$

a

2.1.3 Image Enhancement

Image enhancement is the process of modifying digital images so that the results are more appropriate for display or further analysis. Key characteristics is easier to be identified when noise has been eliminated.

2.1.3.1 Morphological Operation

Morphological image processing is a set of non-linear process related to the shape or analysis of features in an image. Morphological operations really suited to the processing of binary images because it depends on the respective ordering of pixel values rather than their numerical values. Greyscale images also should applied this morphological operations because their light transmission functions are unidentified.

Dilation and erosion are fundamental of morphological processing operations. The interaction of a set called a structuring element with a set of pixels of interest in the image will produce both dilation and erosion process. The structuring element has both a shape and an origin.

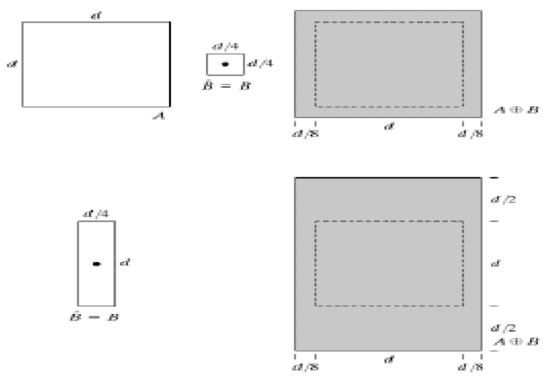


Figure 2.6: Dilation process

Dilation is any pixel in the output image touched by the in the structuring element [11] as shown in the Figure 2.6 above set to ON when any point of the structuring element touches a ON pixel in the original image. This tends to close up holes in an image by expanding the ON regions. It also makes objects larger. The value of the output pixel is the *maximum* value of all the pixels in the input pixel's neighbourhood. In a binary image, if any of the pixels is set to the value1, the output pixel is set to 1.

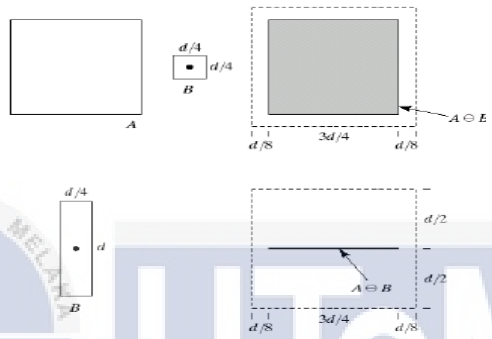


Figure 2.7: Erosion Process

Erosion is any pixel in the output image touched by the in the structuring element is set as shown in the Figure 2.7 above to ON when every point of the structuring element touches a ON pixel in the original image [11]. This tends to makes objects smaller by removing pixels. The value of the output pixel is the *minimum* value of all the pixels in the input pixel's neighbourhood. In a binary image, if any of the pixels is set to 0, the output pixel is set to 0.

The Figure 2.8 below shows the example of eliminating spot noise process from images using erosion and dilation process.

(a) **(b** **(c)**

Figure 2.8: Eliminating spot noise from images. (a) Original image, (b) eroded, image and, (c) dilated image.

2.1.3.2 Circle Hough Transform

Circle Hough Transform (CHT) is used to detect circular shape of traffic light in a digital image and it is carried out after Edge Detection In this method, the curves of a given shape can be set apart [12].

There are two stages in this method which are fixing radius. This can discover optimal centre of circles in a two dimensional, 2D parameter space. Besides, optimal radius in one dimensional, 1D parameter space need to be found in the second stage. The parameter space would be three dimensional, (a, b, r). The parameter space would be decreased to 2D. The centre point of the original circle related to the intersection point of all circles as shown in Figure 2.9 in the parameter space and the intersection point can be located by using accumulator matrix. The voting number of points increased by one the circle passing through it. The centre of the circle can be determined by having the local maxima point of position (a, b) in the parameter space. Figure 2.9 below shows the intersection of circle to find the centre of the circle.

Figure 2.9: Intersection of circle

The equation of the circle [13] is:

$$r^2 = (x - a)^2 + (y - b)^2 \; (3) \qquad (2.4)$$

Here a and b represent the coordinates for the centre, and r is the radius of the circle.

The parametric equation of this circle [11] is:

$$x = a + r * cos(\theta) \qquad (2.5)$$

$$y = b + r * sin(\theta) \qquad (2.6)$$

$$a = x - Rcos(\theta) \qquad (2.7)$$

$$b = y - Rsin(\theta) \qquad (2.8)$$

2.1.4 Image Matching:

Recognition methods that refer to the matching correspond to each class by a prototype pattern vector. There will be a reference image which will be compared pixel by pixel to the real time image project for decision making. Memory will store the real image in matric form in conjunction with real time image that is converted in the desired matric. As a result, images will be matched if it has same pixel values and this method is called pixel matching. In addition, a counter is used to calculate number of any mismatch in pixel value. Percentage of matching is expressed as [14]:

$$\%\text{match} = \frac{\text{No of pixels matched successfully}}{\text{Total no of pixels}} \quad (2.9)$$

2.1.4.1 HOG Features

HOG referring to Histograms of Oriented Gradients. It is in the group of "feature descriptor" type to make the classification process to be easier. The purpose of feature descriptor is to recognise the object. Although the object is viewed under different conditions and illumination, the object can be generalized when the probability of feature detected is nearly the same with feature descriptor. These descriptors is essential for describing local object appearance and structure within an image by the allocation of intensity gradient. Image is divided into cells which is the small connected regions. A histogram of gradient directions or edge orientations will be assembled by the cell that contain pixels within the cell. The descriptor symbolize the combination of these histograms. The Figure 2.10 below shows demonstration of the histogram of gradients in each cell

Figure 2.10: A demonstration of the histogram of gradients in each cell

This method can maintain invariance of geometric and photometric transformations that are only happen when region of spatial is large. This method is very famous for pedestrian recognition and has been discovered by [14] body movement can be neglected and just focusing on the main feature of object to be detected only by having the properties of coarse spatial sampling, fine orientation sampling, and strong local photometric. Some of the gradient magnitude information is retained and the location of the edges is only recorded to cell resolution. The detail of the image can be enhanced by using a pyramid for detection which will adjust the object size.

2.2 Review of Previous Related Work

There are several method approached from previous researchers have been applied in achieving the real time video for traffic light detection and interpretation system. The review of previous related work will only compare the pre-processing and recognition stage which is one of the significant method in image processing.

2.2.1 Pre-Processing Stage

In the pre-processing stage, image data is improved to stifles undesirable distortions or enhances the essential feature of image for further processing. Most of the researchers used colour space conversion in this process [15] colour space conversion, binarization and morphology features filtering methods in this stage. However, there are some improvement in their second journal [16] where they use image segmentation, morphology process and threshold segmentation in YCbCr colour space. The detection of real time traffic light in their latest journal are more accurate and efficient than previous journal as YCbCr can reduce computational time used by algorithm. The disadvantage of binarization process that has been used is that the details can be exchanged like end to bifurcation and backwards. Additionally some little subtle elements in edges can vanish.

The researcher [19] only use colour density identification (CD) as its pre-processing stage. RGB image is received as the input for the framework and produces the traffic light state (red, yellow, green or no Signal) of the scene. The algorithm has three stages: clustering, filtering, and state identification. Density is routinely utilized for process control, estimation of negative and positive film, and plotting a characteristic curve. Notwithstanding, the times of utilizing density are numbered. This colour density method produce a drawback by not taking into account a number of aspects related to the way humans see colour. So, the possibility of inaccuracy in detecting the traffic colour will be higher especially when the traffic light is either bright or dim.

Besides, the researchers [22 ,23] used the conversion of RGB colour space to HSV colour space for their project in this pre-processing stage. It is because of the advantage of HSV colour itself where it can maintain colour consistency in different illumination.

2.2.2 Feature Extraction Stage

The researchers [15, 16] use the same method for both of their journal in feature extraction stage which are Gabor wavelet transform and 2D independent component analysis (2DICA). Gabor wavelets are used here to detect edges, corners and blobs. However, the Gabor wavelet transform have some disadvantages where for fine analysis, it turns out to be computationally intensive. The discrete wavelet change is less effective and natural. It take some energy to invest in wavelets as a preparation to pick the best possible ones for a particular reason, and to implement it accurately. So it will reduce the accuracy during extraction traffic light feature. The researchers [18] use three methods in this stage to detect the traffic light which are image down-sampling, circular regions detection and modified Hough Transform. This method will be applied in this research in feature extraction stage due to not affected by any noise in this method besides neglecting any obstruction in the image gaps between the edges. This method also scale-invariance, local contrast normalization, coarse spatial binning and weighted gradient orientations

2.2.3 Recognition Stage

The purpose of recognition is identifying and detecting certain object in digital image or video that contain feature that has been extracted. Once again, there is the same method to be applied [15, 16] for both of their journal. The method for recognition that have been used is K-nearest neighbours' algorithm and the rate of recognition exceeds 91%. From this algorithm, a prediction from the local neighbourhood will be obtained. The feature of traffic light which is the shape and colour will be memorized by the K and if there is similar to the one that is being classified, it will be retrieved. The similarity of traffic light will be compared by distance function. However, it produce some drawback where it is computationally expensive to find the k nearest neighbours when the dataset is very large. The model also cannot be interpreted. Basically, the performance depends totally on the number of dimensions of image and this will produce an inconsistent performance in detecting the traffic light colour. The method that has been used in recognition stage by the previous researchers [23] is classifying the pixels value contained in the traffic light's colour and matching the pixel value with the image input. This method is just focussing on the pixel value of the colour only. There is no need to recognise the bounding box and arrow shape of traffic light since the objective is just primarily detecting circle traffic light's colour. This is the main factor for the unused of the complicated method which purposing to detect the edges and memorising the shape of the traffic light. This kind of project does not need to be trained by image processing's tools.

2.3 Summary of the Review

Table 2.1: Journal Comparison

No	Article title	Method	Result/Conclusion
1.	Real-time Recognition System of Traffic Light in Urban Environment **[15]**	**Pre-Processing:** • Colour space conversion • Binarization • Morphology features filtering methods **Recognition:** • K-nearest neighbours algorithm	• Robustness to noise • Rate of recognition exceeds 91%.
2.	Real-time Arrow Traffic Light Recognition System for Intelligent Vehicle **[16]**	**Pre-processing:** • Image segmentation • morphology processing, • Threshold segmentation in YCbCr colour space **Recognition:** • K-nearest neighbours algorithm	• Robustness to noise • Recognition rate of proposed method exceeds 91%,
3.	Robust real-time traffic light detection and distance estimation using a single camera **[17]**	**Pre-Processing:** • Colour based segmentation based on Fuzzy Logic Clustering **Recognition:** • Bayesian filters	• 99.4% of accuracy

No	Author/Title	Method	Results/Discussion
4	Real-Time Traffic L ight Detection on Resource-Limited Mobile Platform **[18]**	**Pre-processing:** • Image down-sampling **Recognition**: • strong classifier is made from multiple weak features	• Detection rate has achieved above 70%
5	Traffic light detection and recognition for autonomous vehicles **[19]**	**Pre-processing:** • (RGB) color space is converted to hue-saturation-value (HSV) **Recognition**: • HOG descriptor. • Hierarchical SVM classifier	• Performs well in the daytime but not as well at night • Can detect both circular traffic lights and those with arrows, only the classical suspended, vertical traffic lights were detected
6	Real-time traffic light detection using colour density **[20]**	**Pre-processing:** • Using colour density identification (CD) • RGB image as an input	• 95% accuracy on highways • 85% accuracy in urban areas • Able to run in real-time with 60FPS

No	Author/Title	Method	Results/Discussion
7	An efficient vision-based traffic light detection and state recognition for autonomous vehicles **[21]**	**Pre-processing :** • HSV based color segmentation • Stable Extremal Region (MSER) **Recognition:** • Convolutional neural network (CNN) • Histogram of Oriented Gradients (HOG) features • Support Vector Machine (SVM)	• Detection rate has achieved above 70%
8	A vision based traffic light detection and recognition approach for intelligent vehicles **[22]**	**Pre-processing:** • RGB image is converted into HSV format **Recognition:** • SVM (Support Vector Machines)	• Performs well in the daytime but not as well at night • Can detect both circular traffic lights and those with arrows, only the classical suspended, vertical traffic lights were detected
9	Increasing accuracy of traffic light colour detection and recognition using machine learning **[23]**	**Pre-processing:** • HSV colour representation **Recognition** • Apply learning algorithm • Classify area of pixels contains traffic light colour • Pixel matching	• Detection performance over the one based on value-range colour segmentation technique.

CHAPTER 3

METHODOLOGY

3.1 Principles of Methods or Techniques Used

In this chapter, the process flow of this project will be discussed in achieving the objective that have been stated in Chapter 1. The main process of traffic light colour identification includes five main stages that is Image Acquisition, Pre-processing, Detection, Feature Extraction and Recognition as shown in the Figure 3.1 below

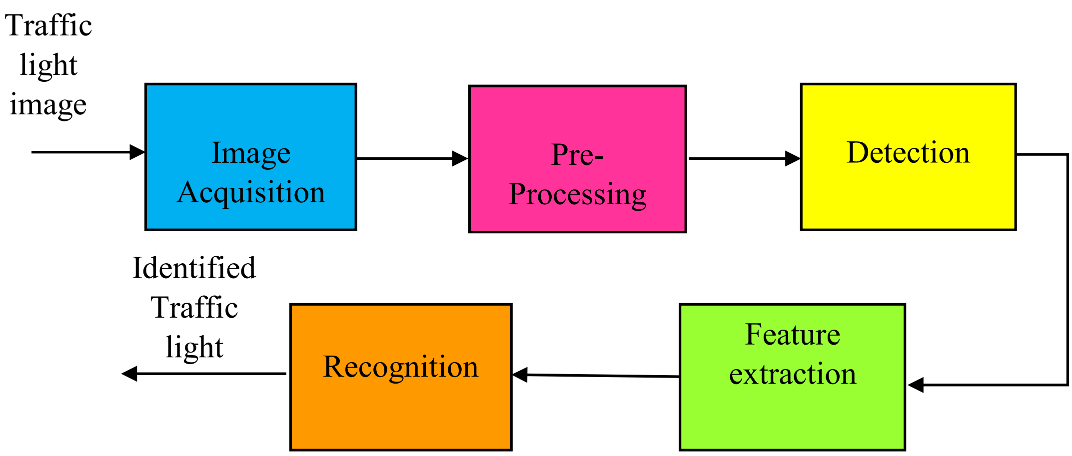


Figure 3.1: Block Diagram of main process of traffic light colour identification

3.1.1 Traffic Light

Traffic light is signalling device to make sure the flow of traffic is controlled smoothly. There are three state of traffic lights that are red, yellow and green. The standard structure of traffic light's bounding box is having red light above the green, with yellow in between. Some of the traffic signal is mounted horizontally or sideways.

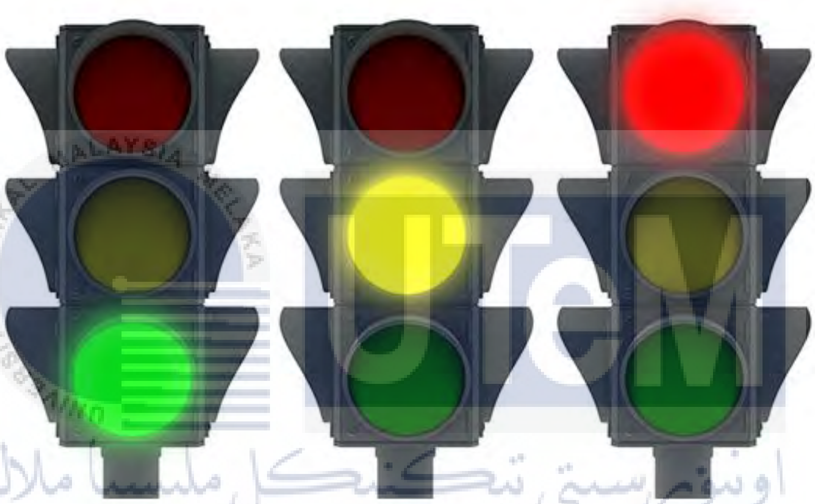


Figure 3.2: The state of traffic light

As shown in Figure 3.2 above**,** all the drivers need to be alerted with the flashing colour of green, amber and red of traffic light. In this research, the detection must be on the flashing traffic light colour rather than other dim colour. So it is significant to determine the pixel intensity of each traffic colour correctly as to differentiate between bright or dim colour of the traffic light. In this project, the flashing or bright colour of traffic is not determined by the brightness, but it is totally depended by the amount of intensity of the colour [22]. Intensity refers to the measure of light or the numerical estimation of a pixel while brightness relies upon visual perception when comparing with a reference. .

The next section will be discussing on how to process, extract and recognise the image of traffic light in order to detect the flashing traffic light colour accurately.

3.2 Discussion on Selected Technique and Approach Used

3.2.1 Image Acquisition

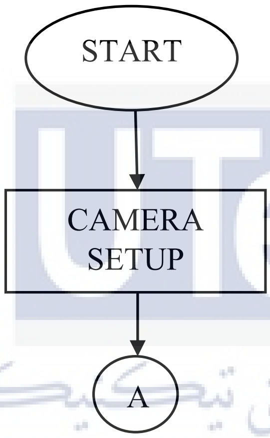


Figure 3.3: Flow chart of Image Acquisition Stage

Process flow of Image Acquisition stage is stated in Figure 3.3 above. A stationary camera was used to face straight ahead and is mounted to rear view mirror. At this point, the camera will have wider field of detection and can detect the colour of the traffic light earlier at certain fixed distance without any disturbance. The camera was connected via USB cable to a laptop that contain SSD as hard drives to avoid corruption during recording the video due to vibration occurred while driving. The type of camera that is used is c310 Logitech HD Webcam. Its resolution and frame rate were 640x480 at 5 FPS and 15 FPS respectively. The exposure time of the camera is managed carefully. Exposure is showing quantity of light that reaching the photographic film and it is determined by shutter speed and lens aperture. For example, far away or dark lamps dark images can be detected from bright images produced by the process of aperture while dark image produced will allow to detect close or very bright lamps. In this case, the gain and shutter speeds for the camera were fixed to avoid saturation of the traffic lights. This is because of the detection of algorithm just depended primarily on colour especially when there is no structure was visible during night. During night, the exposure is set to bulb mode. The aperture is opened up more while the amount of ISO is set to be the lowest. The design of the camera setup will be as shown in Figure 3.4 below:

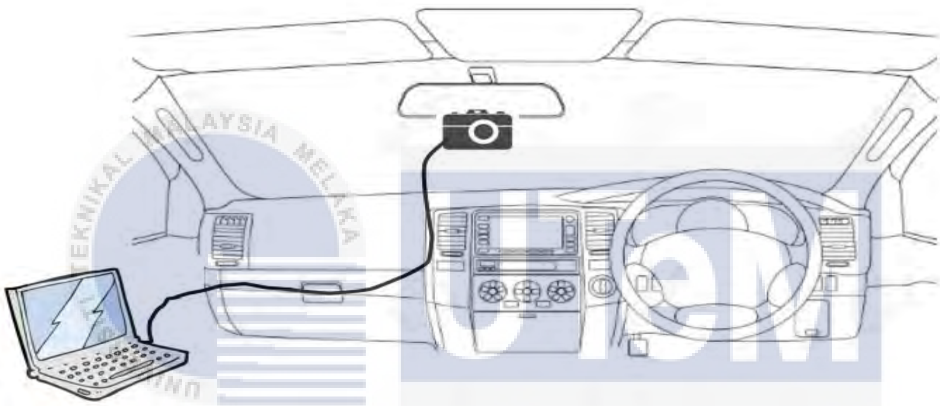
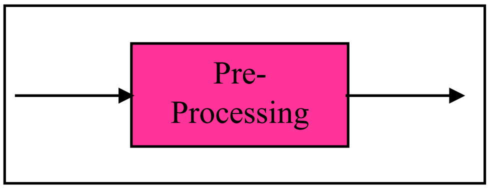


Figure 3.4: The camera setup from car interior

3.2.2 Pre-Processing



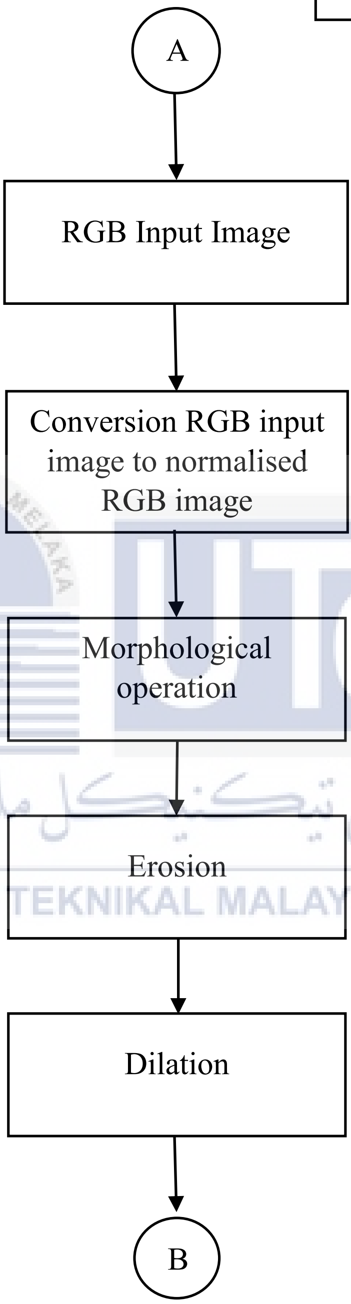


Figure 3.5: Flow chart of Pre-Processing Stage

3.2.2.1 RGB input image

All process flow of Pre-Processing stage is stated in Figure 3.5 above. Colour sensitive is the most significant feature of traffic lights. In that case, the presence of certain factor like weather or time may varying different lightning conditions of the colours of traffic lights. This will make it to be difficult to be processed. Three RGB data (R; G; B) from raw images were used. RGB samples were selected from a constant atmospheric conditions that is sunny day (early mornings and early evening) during the day time with a good illumination only. The RGB value of the traffic light specified colour is determined. The value of all the colours based on RGB colours is as follows:

- GREEN : (0 , 255 , 0)
- AMBER : (255, 255 , 0)
- RED : (255, 0 , 0)

However, RGB colour space is sensitive to the light intensity. So in order to uniform the drift in colours, the colour space should be converted. RGB normalisation process is then used because RGB normalized colour space is quite invariant to lighting change and object geometry, being robust to lighting conditions. It support more distinguishable colours for traffic light lamps.

3.2.2.2 RGB Normalisation

RGB Normalisation is a caution filtering for an image. It will blur the image and bright certain important parts only. When normalizing the RGB values of an image, each pixel's value in an image is divided by the sum of the pixel's value over all channels.

To perform a RGB normalization the individual colour channels are summed and each channel is divided by the sum. The equation [23] is as follows:

$$f(x, y) = (\mathrm{R}, \mathrm{G}, \mathrm{B}) \tag{3.1}$$

$$S = R + G + B \tag{3.2}$$

$$R = \frac{R}{S} \times 255 \tag{3.3}$$

$$G = \frac{G}{S} \times 255 \tag{3.4}$$

$$B = \frac{B}{S} \times 255 \tag{3.5}$$

$$if\ S = 0\,,\ then\ R = G = B \tag{3.6}$$

Where;

- S = total
- R, G, B = pixel values
- 255 = scaling factor

3.2.2.3 Colour segmentation

One of the important step in this system is colour segmentation which act to discriminate colour states among traffic light. It streamlines the vision problem by assuming that objects are hued distinctively, and that gross shading contrasts that matter. As a result, image can be processed very rapidly after getting rid the information about colour and brightness variations that provides many valuable cues about the shapes and textures of 3D surfaces from the image.

In this research, simplest colour segmentation method used is called the thresholding method. This method is based on a clip-level (or a threshold value) to turn a gray-scale image into a binary image. The specific threshold value will be determined to detect the three different possible colour of traffic light. Saturation spots, relating to lenses centre or false alarms in building, trees and sunshine will be the main challenges in this colour segmentation process. Each sample image taken has its own different type and amount of pixels.

3.2.2.4 Filtering

Morphological operations referring to[15, 16] was performed based on an erosion and a dilation to act on the red, amber and green traffic light images will be composed in this stage and then filtering rules will take after the process. It is carried out to get rid little conceivable elements in the background by removing some pixel that is not important in erosion process. Dilation process will add some pixels to the pixels left in the image after going through the erosion process. This process will re-establish the original size of the blobs and make them more compact. The equations for dilation and erosion [24] process are as follows:

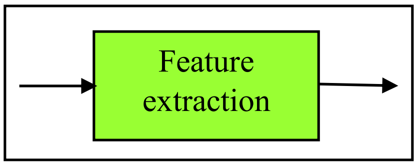
Dilation:

$$A \oplus B = \{ z \in E | (B^8)z \cap A \neq \emptyset \} \tag{3.7}$$

Erosion:

$$A \oplus B = \{ z \in E | Bz \subseteq A \} \tag{3.8}$$

3.2.3 Feature Extraction



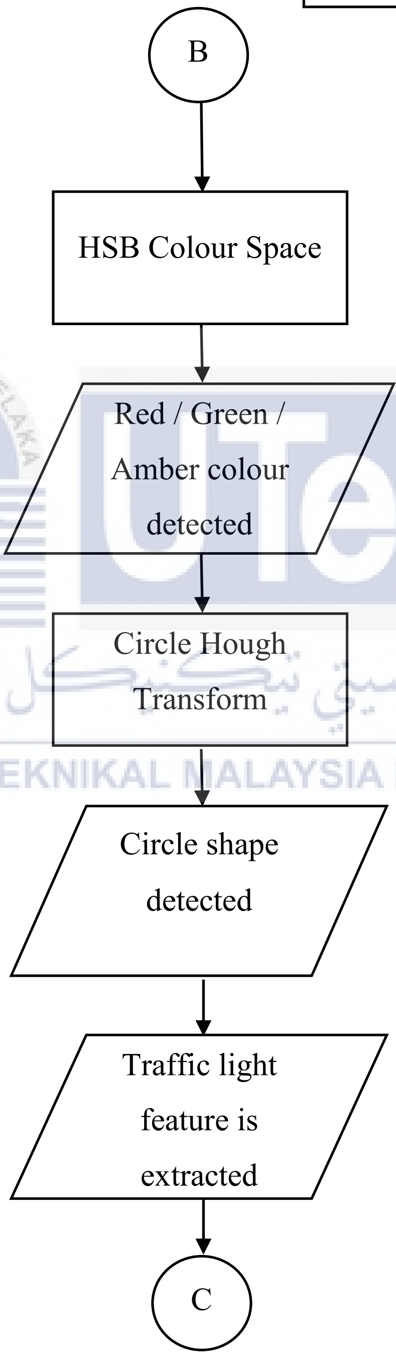


Figure 3.6: Flow chart of Feature Extraction Stage

Feature extraction is a process of deriving new features from the original features in order to reduce the cost of feature measurement, increase classifier efficiency, and allow higher classification accuracy. Process flow of Feature Extraction stage is stated in Figure 3.6.

3.2.3.1 HSV Colour Space

The main feature extraction in this project is mainly about colour. A dominant colour of traffic light from an image produced from the real time video need to be extracted for processing. All pixels in an image are different. In this research, HSV colour – *hue, saturation, value* is used in feature extraction stage and its value can be determined from a represented cone. The pixels are grouped by calculating distances between the colours. There are three colours of traffic light that need to be extracted which are red, amber and green. The pixel intensity for the specific colour of traffic light is determined. The basic value of all the colours based on HSV colours is as follows:

- GREEN : (120° , 100% , 100%)
- AMBER: (60° , 100%, 100%)
- RED: (0° , 100%, 100%)

For this kind of application, only dominant hue for all those colours are extracted and that hue contain average brightness and saturation, rather than for the entire image. This process will determine the accurate colour of traffic light and prevent detecting the false positive colours like street light lamps and car brake's lamps. Feature extraction will determine and tell whether the detected colour is either red, amber or green of traffic light. The formula to find the HSV colours is as equation 2.1, 2.2 and 2.3 in Chapter 2.

3.2.3.2 Circle Hough Transform (CHT)

This method is used to detect circular shape of traffic light in a digital image. The equations 2.4 in Chapter 2 for circles is the main key in this process. Three parameters from the equation which are the triplets of (x, y, r) need to be determined that are highly possibly to be the circles of traffic light in the image sample. So, every point in the (x, y) space will be corresponding to a circle in the (a, b) space due to the rearrangement of the equations 2.7 and 2.8.

A complete circle of radius, r is created when the θ change from 0 to 360 degrees. The radius of circles shape of traffic light colour is fixed. All the above equations will be applied to the loaded image in MATLAB software. Edges will be detected and producing a binary image. Circle is produced in the (a, b) space from every of edge of the pixel. After that, cast will 'vote' those point of circle in the (a, b) space in the accumulator cells and the cells with greater number of votes will concluded as the centre of circle as shown in Figure 3.7. The determined centre coordinate will make it easier to clarify the pixel value of the traffic light's colour. The pixel value of each colour of traffic light is depended primarily on the coordinate of the centre. The pixel value is being compared by several radius of traffic light's circle shape. The value for maximum, intermediate and minimum radius are being recorded and observed. Figure 3.8 shows the flow chart in Circle Hough Transform process. The RGB value of the result is as shown in Chapter 4.

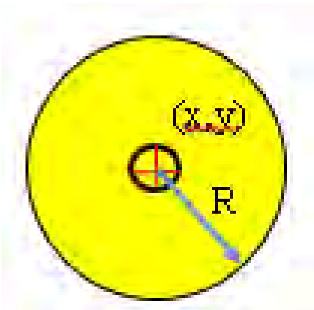


Figure 3.7: Circle of traffic light

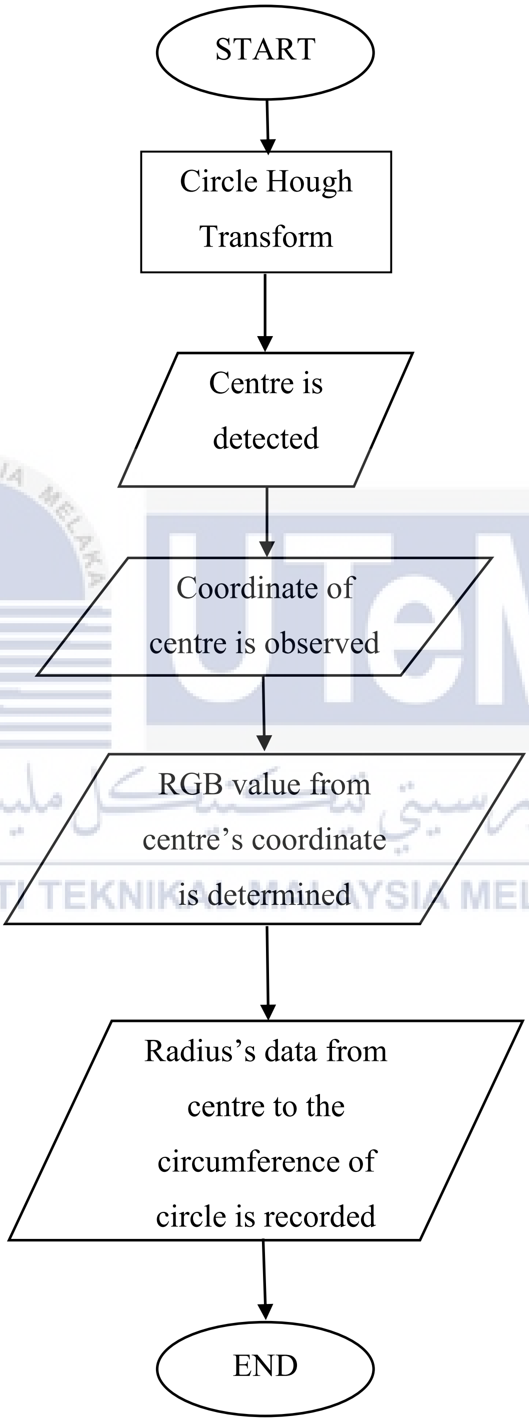
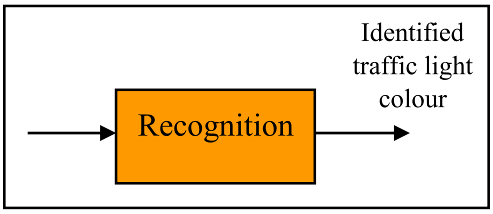


Figure 3.8: Flow chart of Circle Hough Transform Process

3.2.4 Recognition



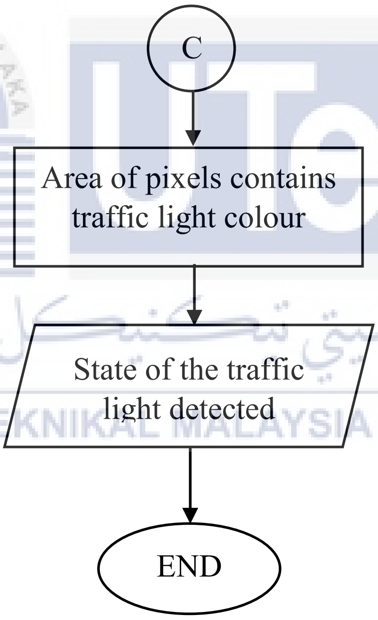


Figure 3.9: Flow chart of Recognition Process

Process flow of Recognition stage is stated in Figure 3.9 Image recognition is the process of identifying and detecting an object or a feature in a digital image or video. The process that has been used is image matching. Area of pixels that contained in the traffic light's blob is determined. There will be a reference image which will be compared pixel by pixel to the real time image project for decision making. As a result, images will be matched if it has same pixel values and this method is called pixel matching. All the region that contain almost the same amount of pixel value and circle shape will later represent the entire traffic light which accomplish the recognition of traffic light colour and its circle shape. The calculation in finding percentage of pixel matching is being measured based on the equation 2.9 in Chapter 2.

3.3 Video processing

A video taken consist a lot of frames to be processed. All the frames need to go through all the main processes of traffic light's colour identification stated in Figure 3.1. All this frames are being processed by looping the coding in the MATLAB software for the image input and produce it in terms of video as the result.

CHAPTER 4

RESULT

4.1 Result and Discussion

4.1.1 Traffic Light Colour Detection from an Image

4.1.1.1 Green Colour Detection of Traffic Light

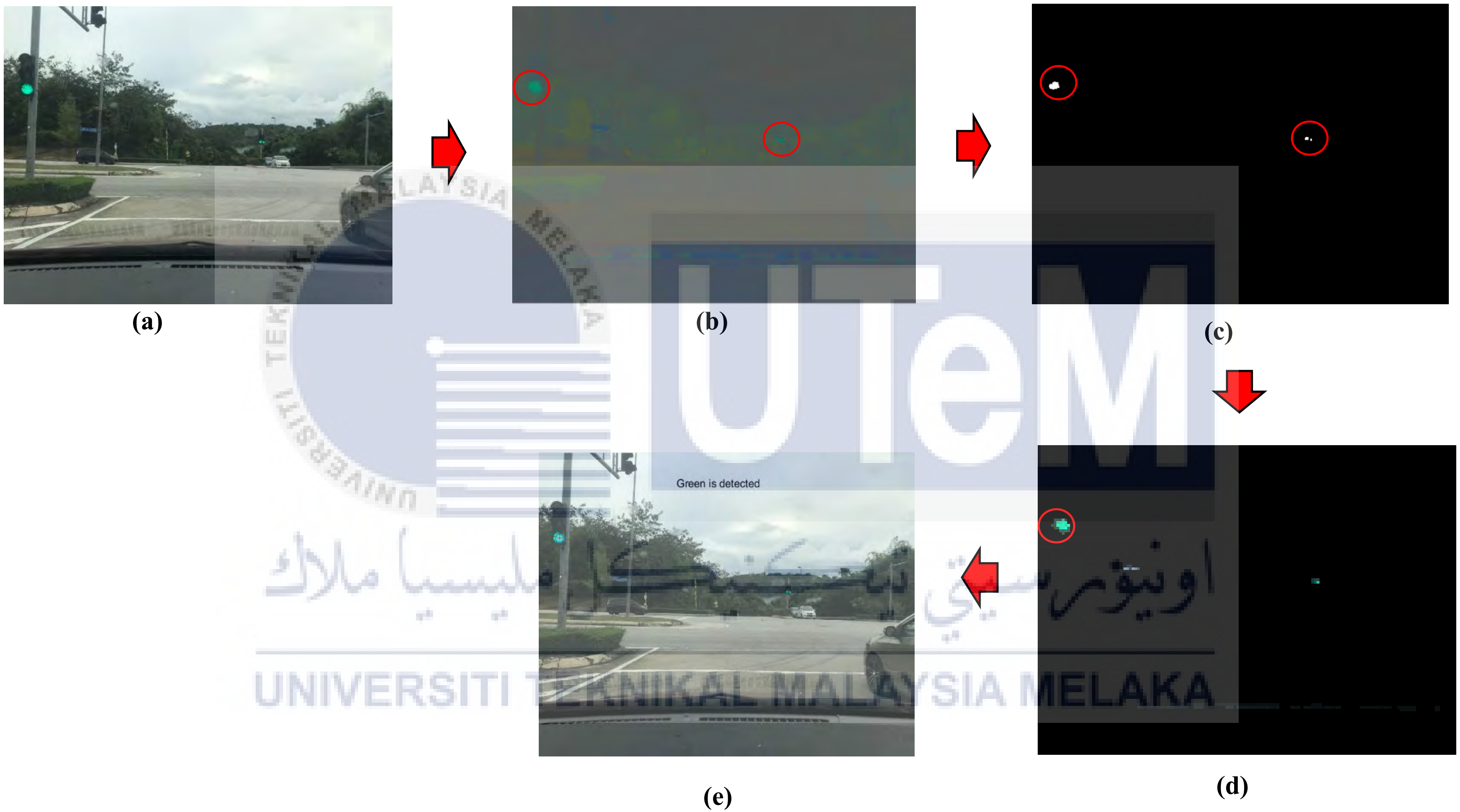


Figure 4.1: Sequence of Detection Process Green Colour of Traffic Light

4.1.1.2 Red Colour Detection of Traffic Light

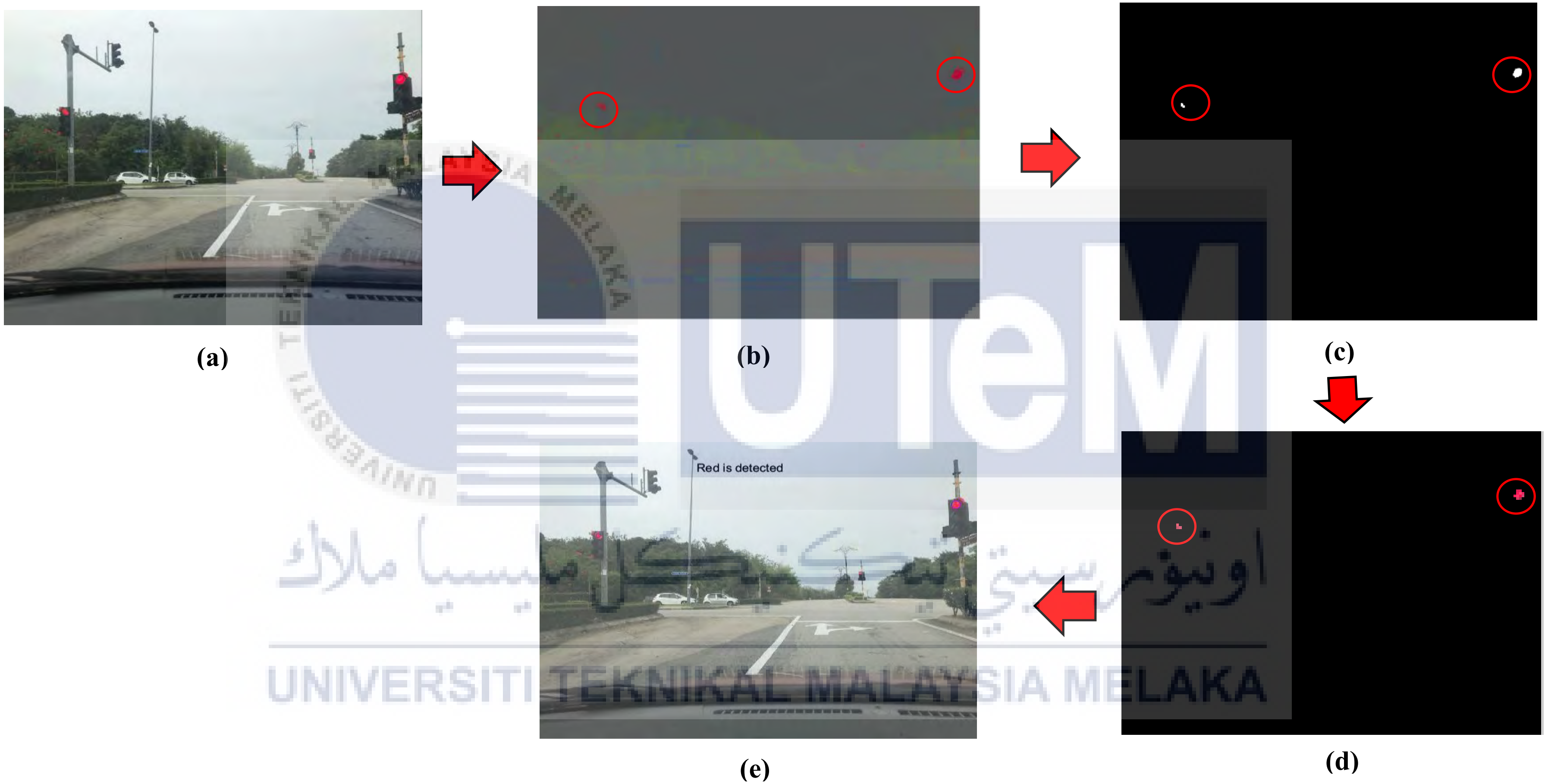


Figure 4.2: Sequence of Detection Process Red Colour of Traffic Light

4.1.1.3 Yellow Colour Detection of Traffic Light

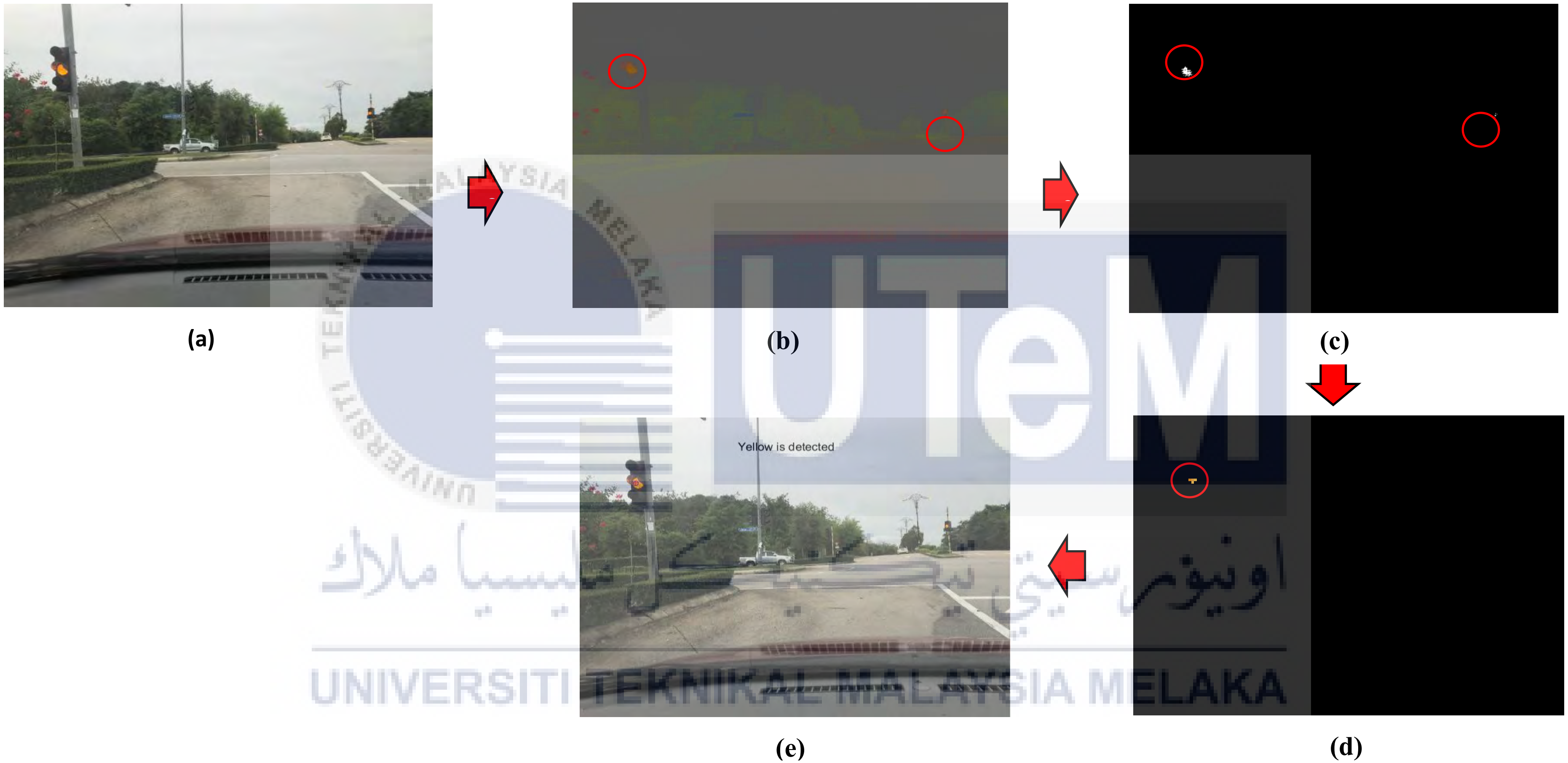


Figure 4.3: Sequence of Detection Process Yellow Colour of Traffic Light

From Figure 4.1 and 4.2, both the green and red traffic light is detected using the same process mentioned from the previous chapter. Figure 4.1 (b), 4.2(b) and 4.3 (b) shows the result obtained after going through RGB normalisation process. This process is done to remove the change in illumination of the original image in Figure 4.1 (a) and Figure 4.2 (a). This process will reduce the effects of light, removes highlighted regions and shadows which make that object easier to be detected. Applying a normalized RGB colour threshold removes most of the elements in the scene that are not possible candidates for being a traffic light. After that, the normalised image will be processed by erosion and dilation method in Figure 4.1 (c), 4.2(c) and 4.3 (c) This process will remove noise at the image background to increase accuracy for classification process. Three new filtered images were created relating to the three traffic light colours. After that, the image will be extracted to find the feature of traffic light which is colour and circle detection. The colour feature will be extracted using HSV method as shown in Figure 4.1 (d), 4.2 (d) and 4.3(d) to classify accurately whether the detected colour is green, yellow or red based on its pixel value. The possibility for false positive colours like street light lamps and car brake's lamps to be occurred can be reduced in this process. Besides, the circle shape of traffic light is detected in Figure 4.1 (e), 4.2 (e) and 4.3(e) and the centre of the circle is identified. Those process in (d) and (e) will help in recognising that those feature that being extracted is traffic light colour and shape. Pixel matching process will clarify whether green, yellow and red traffic light's colour is detected in the real time video.

4.1.2 Percentage Accuracy in Traffic Light Detection:

The accuracy of each colour of traffic light is determined by examining the total number of frame of video that has been processed. The traffic light's colour is detected in each frame which will produce false positive and false negative as the result. The false negative is the incorrectly detected of traffic light colour which may occur due to some factors. The percentage of accuracy in detecting the colour of traffic light through video is shown in equation below:

$$Percentage\ of\ accuracy = 1 - classifation\ error \quad (4.1)$$

$$Classification\ error, E = \frac{f}{n} \times 100\% \quad (4.2)$$

Where;

f = number of incorrectly classified samples (false positive + false negative)

n = number of samples

4.1.2.1Accuracy of green traffic light

Table 4.1: The accuracy of green traffic light

Name of video	No of frames	True positive	False positive	Accuracy
Video 1	252	207	45	82.1%
Video 2	264	225	39	85.2%
Video 3	208	148	28	84.0%
				Average: 83.8%

4.1.2.2 Accuracy of Yellow traffic light

Table 4.2: The accuracy of yellow traffic light

Name of video	No of frames	True positive	False positive	Accuracy
Video 1	174	137	37	78.7%
Video 2	105	74	31	70.4%
Video 3	149	116	28	77.8%
				Average: 75.6%

4.1.2.3 Accuracy of Red traffic light

Table 4.3: The accuracy of red traffic light

Name of video	No of frames	True positive	False positive	Accuracy
Video 1	293	196	97	66.89%
Video 2	198	145	53	73.23%
Video 3	237	167	70	70.46%
				Average: 70.19%

Figure 4.4 shows that the detection on real time video of green traffic light detection and interpretation using image processing method has achieved the highest accuracy to be compared to the other red and yellow traffic light's colour. There are just a little amount of false negative produced by this type of colour. The detection on green traffic light can be made effectively at a far distance compared to the other colours. Although this type of colour is easier from the others to be interpreted, this colour still produce an amount of false positive. One of the main factor that caused the

false positive is the illumination and light intensity during recording the traffic light. The cloudy and foggy day will reduce the accuracy in detection. Besides, the video recorded by the camera mount in the car will be influenced when the camera facing a higher light intensity at the background of traffic light while detecting its colour. The flashing colour of the traffic light will become too saturated and turn dimmer which affecting their actual RGB value. The saturation of traffic light need to be avoided because it is some sort of distortion which may interfere the measurement of bright regions of scene because every recorded image is limited to some maximum value. This type of factor is also the main cause for the other two colours.

In a meanwhile, the detection of red traffic light has achieved a very low percentage in term of accuracy. The large amount of false positive is due to several factors. The long distance of red traffic light from the camera will produce an orangey colour which will be misinterpreted by the system to recognise the colour to be a yellow traffic light. Other than that, the presence of the other car's circle brake lamps may affect the detection too.

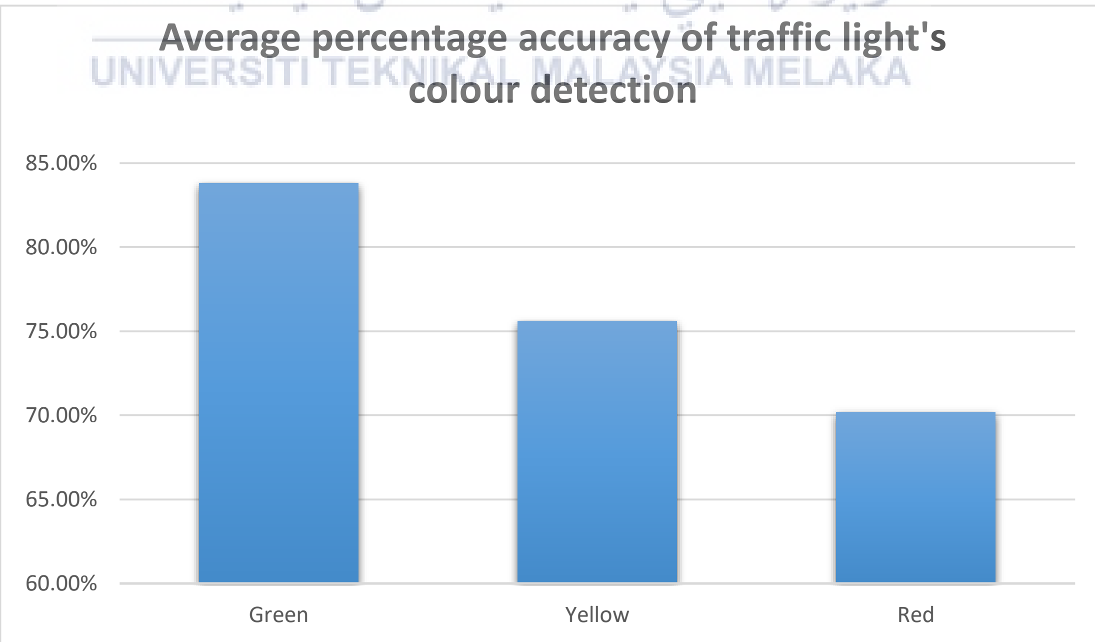


Figure 4.1: Average percentage accuracy of traffic light's color detection

4.1.3 RGB Values

Tables on Appendix B show the RGB value list data of 11 samples of frame for the three type of traffic light's colour. The RGB value of each colour is determined by examining the centre of detected region of traffic light as shown in Figure 4.5 and 4.6.

Figure 4.5: Circle's centre is detected

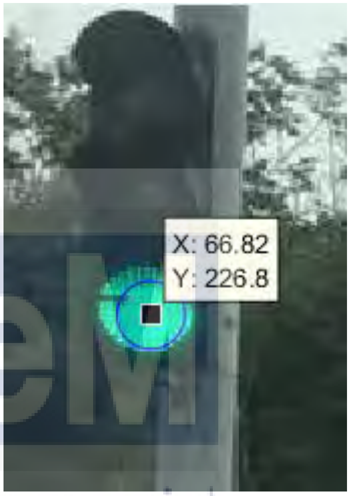


Figure 4.6: Coordinate for circle's centre is determined

The exact RGB value for green traffic light is observed to be totally different from the basic value colour of RGB for green where the green traffic light's colour consist of (0, 255, and 255) instead of (0, 255, and 0). However, the RGB value contained in red and yellow traffic light's colour are almost equal to the basic colour of RGB value that are (0, 255,255) and (255, 0, 0). The values can be observed through the graphs obtained in Figure 4.7, 4.8 and 4.9.

4.1.3.1 Radius versus RGB value

Figure below shows the comparison between the radius and the RGB values for each type of traffic light's colour. The radius parameter's value produced from the circle shape of traffic light detected has proven to be a major factor that affecting the RGB value for the traffic light's colour. The radius value of circle shape of traffic light will be larger once the distance of the detected traffic light from the camera mount in the car is short. The short distance will produce the exact RGB value of the traffic light's colour.

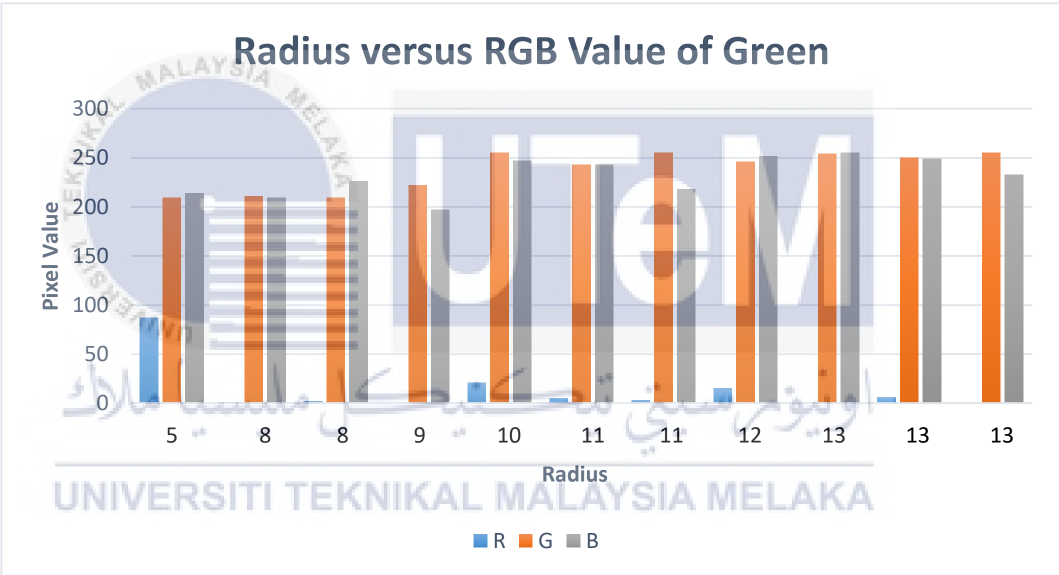


Figure 4.7: Graph comparison between radius and Pixel Value of Green

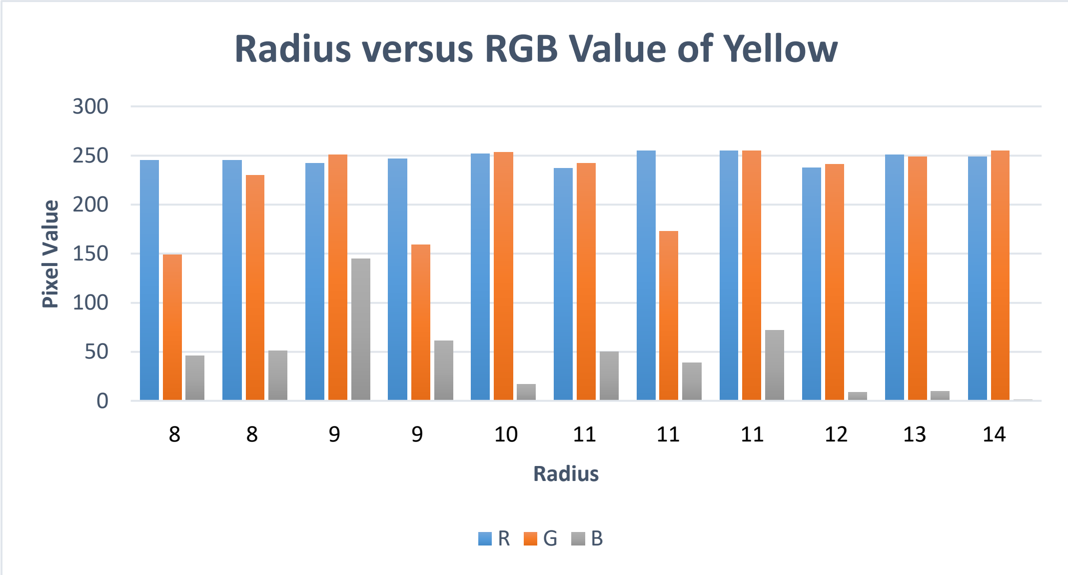


Figure 4.8: Graph comparison between radius and Pixel Value of Yellow

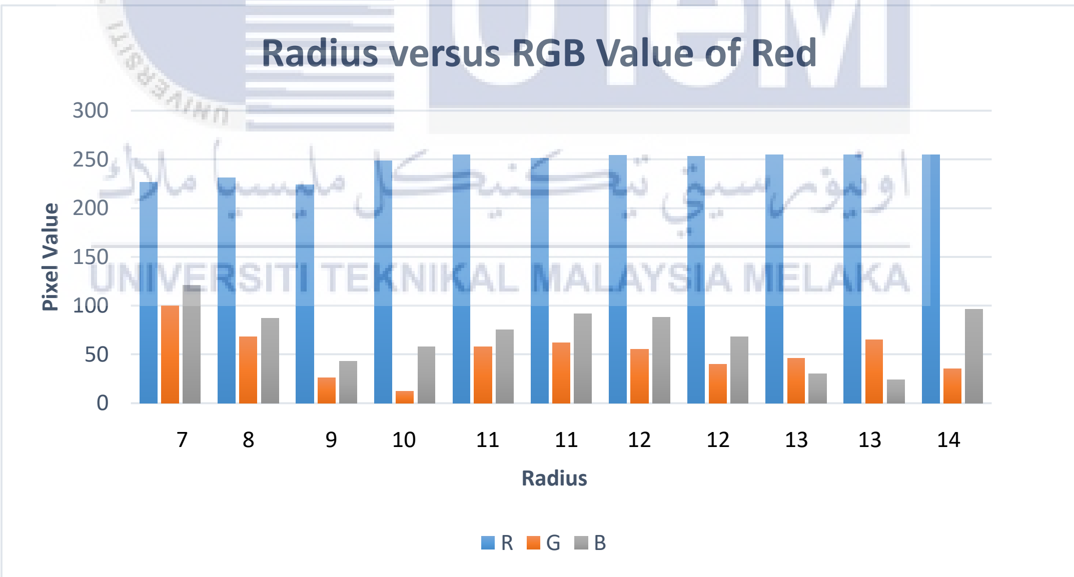


Figure 4.9: Graph comparison between radius and Pixel Value of Red

4.1.4 Comparison of traffic light's colour detection between daytime and night time

Based on table above, RGB value of the traffic light's colour during night is observed to be totally different from the day time and opposing the fact of RGB value of real colour of the traffic light. This happened due to the camera used is not achieving the advance technology to detect the real pixel value of the colour. The value of RGB observed for all the three types of colours are (255, 255, 255) which representing a white colour. It is the main factor for the unsuccessful of detecting the colour during the night time. Figure below shows the image of traffic light colour taken during the night time.

Figure 4.10: Green traffic light during night time

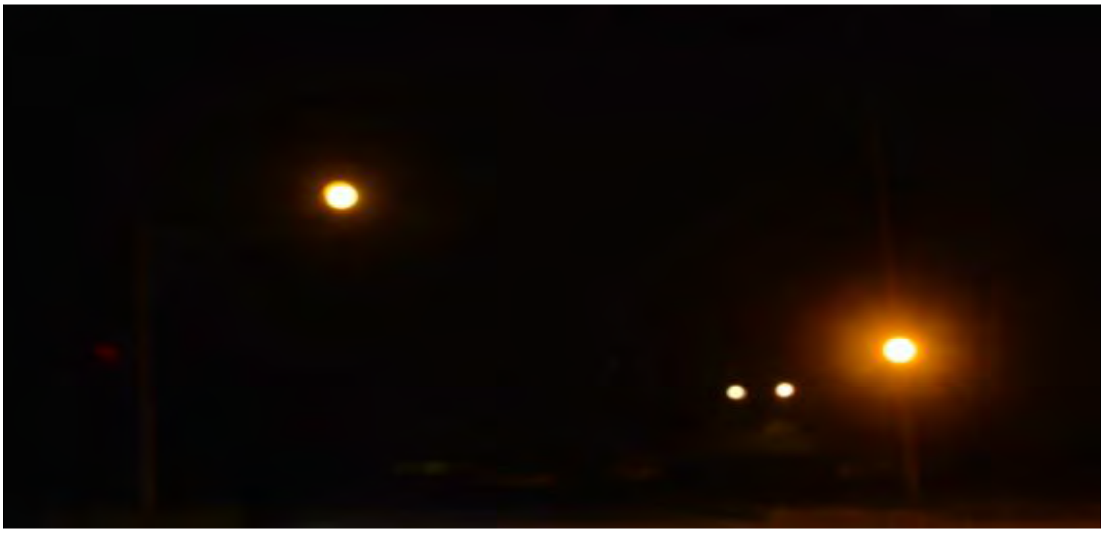


Figure 4.11: Yellow traffic light during night time

Figure 4.12: Red traffic light during night time

CHAPTER 5

CONCLUSION

5.1 Conclusion

In this thesis, an image processing method has been proposed for real time traffic lights interpretation and recognition. The objective is nearly achieved where identified and related features from image to do classification process has been extracted. The method is potentially adaptable to different body forms and colours for the whole world traffic lights. There a lot of methods need to be taken through five stage in detecting traffic light which are colour segmentation method, morphological operations, shape and colour extraction besides image matching as traffic light recognition. In previous PSM 1, the image acquisition only use 2D image as the input while video is used as an input in this PSM 2. The accuracy of the image also is improved by filtering the noise produced by the image and determining the false positive in each frame of video recorded.

5.2 Future Work

As recommendation, this project will be continued to be implemented in future work with higher accuracy and less producing false positive. The use of colour space technique which is the conversion of RGB to HSV method can be improved by using the other methods that is more efficient such as fuzzy logic clustering and YCbCr colour space. This kind of method can reduce the effect of illumination towards RGB value for traffic light's colour. In urban area, traffic lights are preferred to be designed with arrow shape instead of circle shape and this detection on the variety of shape can be implemented too in future.

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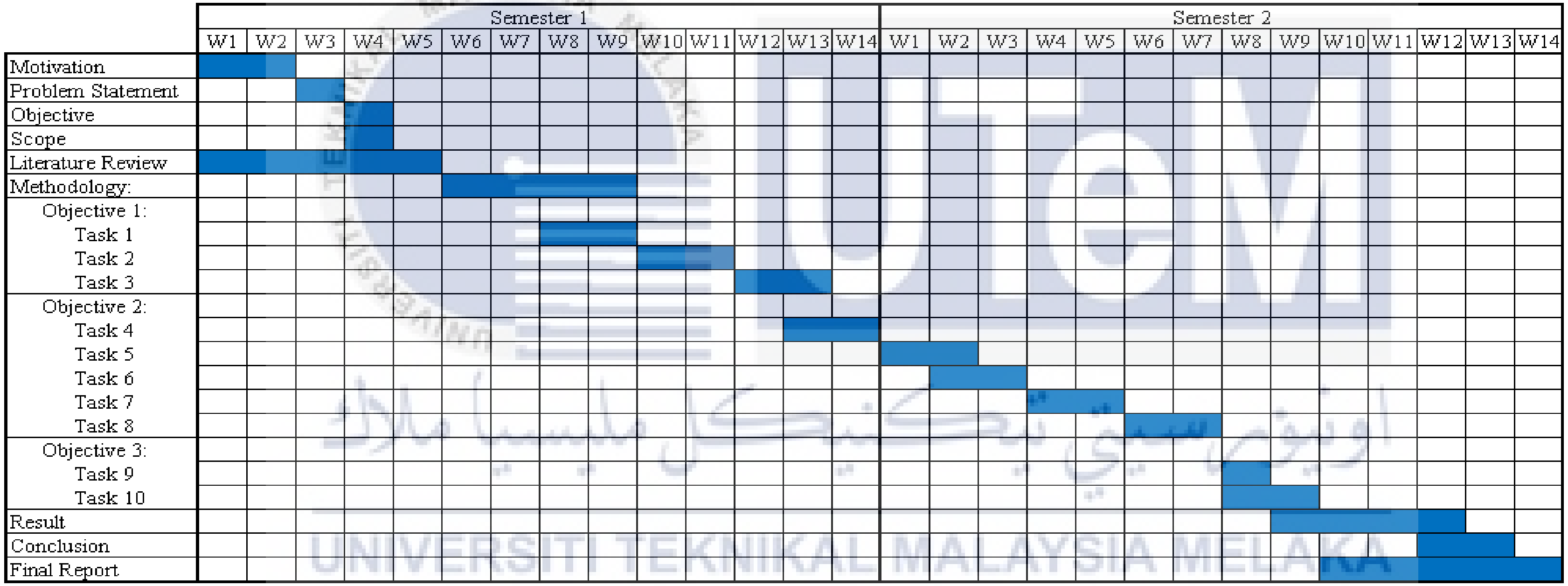
APPENDIX A

Table A: Gantt chart of study



Task No.	Task Name
1	Analysis of method
2	Image sample collected
3	Calculation based on method
4	Coding and simulation of detection process
5	Real time video system setup
6	Analysis of improved method
7	Calculation based on improved method
8	Coding and simulation of recognition process
9	Construct and design project hardware
10	Hardware implementation

APPENDIX B

Table B1: List data for RGB Value of Green

Green					
Radius	Centre		Pixel Value		
	x	y	R	G	B
13	66.8234	226.8267	0	254	255
12	2.14E+03	1.83E+03	15	246	252
5	1.77E+03	1.65E+03	87	209	214
11	829.3529	1.59E+03	5	243	243
8	1.45E+03	1.71E+03	1	211	209
10	2.10E+03	1.28E+03	21	255	247
11	1.79E+03	1.47E+03	3	255	218
13	1.69E+03	1.15E+03	6	250	249
8	1.63E+03	1.80E+03	2	209	226
9	1.76E+03	1936.056	0	222	197
13	1797.407	1899.18	0	255	233

Table B2: List data for RGB Value of Yellow

Yellow					
Radius			Pixel Value		
	x	y	R	G	B
13	1.75E+03	1.63E+03	251	249	10
11	2.14E+03	1.49E+03	237	242	50
8	1.91E+03	1.97E+03	245	149	46
11	1.04E+03	2.01E+03	255	173	39
9	1.75E+03	2.11E+03	247	159	61
14	2.35E+03	2.02E+03	249	255	1
12	2.37E+03	2.01E+03	238	241	9
10	1.70E+03	2.06E+03	252	253	17
8	2.33E+03	2.12E+03	245	230	51
11	394	2473	255	255	72
9	2842	1833	242	251	145

Table B3: List data for RGB Value of Red

Red					
Radius	Centre		Pixel Value		
	x	y	R	G	B
8	144.4299	178.9738	231	68	87
12	162	264	254	55	88
11	1.23+03	221.4622	251	62	92
14	2.37E+03	1.90E+03	255	35	96
13	148.7	241.6	255	46	30
13	2.55E+02	6.50E+01	255	65	24
7	1.02E+03	1.80E+02	227	100	121
12	1.78E+03	3.39E+02	253	40	68
10	1.16E+03	5.34E+02	249	12	58
9	97	331	224	26	43
11	1431	256	255	58	75

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