AUTOMATED VEHICLE COUNTING AND CLASSIFICATION SYSTEM FOR TRAFFIC CENSUS

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
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(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Department of Electrical & Electronic Engineering
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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Nazif Hawari Mohmood Nor

ABSTRACT

Traffic census is important for the purpose of upgrading and widening the road. The information gained from the traffic census can be used in the budget planning for road maintenance. Traffic census can be done automatically or by counting and classifying the vehicles manually using human labor. Most of the automatic traffic census system used nowadays focus on counting the vehicles by using devices called magnetic loop detector. This device is costly and once installed, it cannot be removed. To overcome this problem, an automated traffic census system based on image processing is introduced which can be used to count and to classify the classes of the vehicle. Computer vision technology is used to achieve this objective. For the vehicle detection, background subtraction and approximate median algorithm are used. The system uses the length of the vehicle for the purpose of classification. The chosen algorithm for vehicle detection is called approximate median as it is more accurate compared to background subtraction method. On the other hand, although the results gained by using approximate median method is more accurate than a simple background subtraction method, it has its drawback too which is more complex calculation hence taking more time to execute the algorithm. Some optimizations have been done on the approximate median algorithm and the result is very promising as it has shortened the execution time while the accuracy of the detection remains the same. In conclusion, this project is a success since it can count and classify the vehicles, but further works need to be done to achieve better accuracy.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

BLOB	binary large object
UTP	Universiti Teknologi PETRONAS

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Traffic census also known as traffic survey is conducted to determine the number, movements and classification of roadway vehicle at given location. There are many ways to do traffic census either by manual counting or automatic counting. The objective of this project is to develop a system that is able to count and classify the types of vehicles automatically. The system will be designed using MATLAB with a few goals, which are to determine the number of vehicles on the road and classify the vehicles either light or heavy vehicle. Classification of heavy vehicles is important for the purposes of transportation planning and traffic operations. Traffic census is important for the sake of future road development in term of upgrading the road, widening the existing road and infrastructure development. The proposed automated vehicle counting will be introduced by using image processing that will identify the moving object on the video or on the camera and classify the object. The accuracy of the results will be determined by counting the vehicles manually and compare the results produce by the system.

1.2 Problem Statement

1.2.1 *Problem Identification*

Automatic traffic counting exist nowadays mostly focuses on to determine the number of vehicle that use the road not the class of vehicle. This project aims to count and classify each type of vehicle and classify it automatically without the need of human to classify it, like manual counting method.

1.2.2 *Significance of Project*

Traffic census is important for the sake of future road development in term of upgrading the road, widening the existing road and for infrastructure development. The data collected are useful to identify point of congestion on various roads and will help the developer to upgrade the existed road in term of the number of vehicle use the road. Vehicle classification is important to compute the percentages of vehicle classes that use state-aid streets and highway.

1.3 **Objective and Scope of the project**

1.3.1 *Main Objective*

To develop traffic census system based on image processing that can count vehicle and classify the class of vehicle accordingly.

To provide another alternative for traffic census that is non-intrusive compared to magnetic loop detector, the widely use device for traffic census that need to be planted on the road.

1.3.2 *Scope of Project*

This project will start by doing some literature review on motion detection based on image processing and methodology of image processing using MATLAB tools. Further testing and improvement will be carried out to gain the desired accuracy of result.

1.4 **Relevancy of Project**

Since the existing devices for counting vehicles are mostly based on loops detectors, which are costly and unreliable, this project will become appreciable. The cost of installing the equipment that is camera, to be used with the project is cheaper compared to the cost of installing magnetic loops detector. Furthermore, this project is able to classify the type of vehicle that uses the road, which is not available for loops detector.

1.5 **Feasibility of Project**

The project will be done in two semesters that includes three area of study which are research, development of application and also beta-testing and improvement of the full prototype. The project will use MATLAB as a tool to apply image processing algorithm for detecting, counting and classifying the vehicle.

CHAPTER 2
LITERATURE REVIEW

2.1 Importance of Traffic Census

Manual counts are used to determine the vehicle classification, turning movements, directions of travel, pedestrian movements or vehicle occupancy. Automatic counts are used to determine vehicle hourly patterns, daily or seasonal variations and growth trends, or annual traffic estimates [10].

The objective of traffic census is to determine the number of vehicle that uses the roadway. The data gain from the survey will be used for traffic monitoring, management and planning traffic infrastructure.

2.2 Vehicle Counting Overview

There is a lot of traffic counting method available and it is important to differentiate between intrusive and non-intrusive method [8]. The major intrusive methods are bending plate, pneumatic road tube, piezo-electric sensor, and inductive loop detector. Manual observation, passive and active infra-red, passive magnetic, and radar are example of major non-intrusive method. Inductive loops detectors are one of the most popular intrusive methods used to count vehicles.

However, there are disadvantages of using loops detector which are costs and reliability [6]. Loops detector has high cost and safety risk associated with their installation and maintenance [6]. These sensors are required to be drill on the road and once it is installed, they cannot be relocated [7]. Another disadvantage of using loop detectors is the equipment can only be used for real time [4]. The user cannot simply put other kind of input such as video file to the equipment to count the number of vehicle [4]. A vision based traffic counting has several advantages compared to conventional traffic counting using magnetic loops detector. Traffic counting based on image processing can give spatial information about a scene and can be recorded easily for further analysis [2]. The devices also can be easily installed, maintained and minimize the safety risk to the user compared to the installation and maintenance of magnetic loops detectors [2].

2.3 Lane Masking

As explained in [2], this technique is used to separate parts of the image that will be used in the computation. Parts of the image needed are multiplied by 1 and a part of the image that is not needed is multiplied by 0. The result is the images that only contain the parts needed for computation. This technique can reduce the computation time and reduce the noise generated by the background.

An example of lane masking technique is shown in the figures below. Notice that a part of the image that is not needed in the computation is eliminated by applying the technique.

Figure 1: Before masking

Figure 2: After masking

2.4 **Moving Object Detection**

In detecting moving object, there are some algorithms available that vary based on its complexity and quality presented. Among them are background subtraction and approximate median method. Additional technique such as neighboring, thickening and pixel bridging are necessary in getting a smoother result.

2.4.1 ***Background Subtraction***

Background subtraction is a method where each video frame is compared against reference frame or background image. Moving objects are detected when pixels in current frame is deviate significantly with the reference frame [10]. There are a lot of challenges in developing a good background subtraction algorithm. First of all, it must be robust against changes in illumination such as gradual and sudden changes; for example cloud. Second, the algorithm must avoid detecting non-stationary background objects such as moving leaves, weather change, and shadow cast by moving objects. This is where the lane masking technique is useful, by eliminating that part in the image; the chance for the algorithm to detect such noise is minimalized. Lastly, the internal background model should react quickly to changes in background, such as starting and stopping vehicle [9].

The most basic method for background subtraction is as shown below:

$$|frame_i - frame_{i-1}| > Th$$

Where

i = current frame, Th = value of threshold

In this method, the background image is just the previous frame. After the subtraction, if the value left are bigger than threshold values, then a foreground image are detected. Figure below shows an example of applying background subtraction to the consecutive frame.

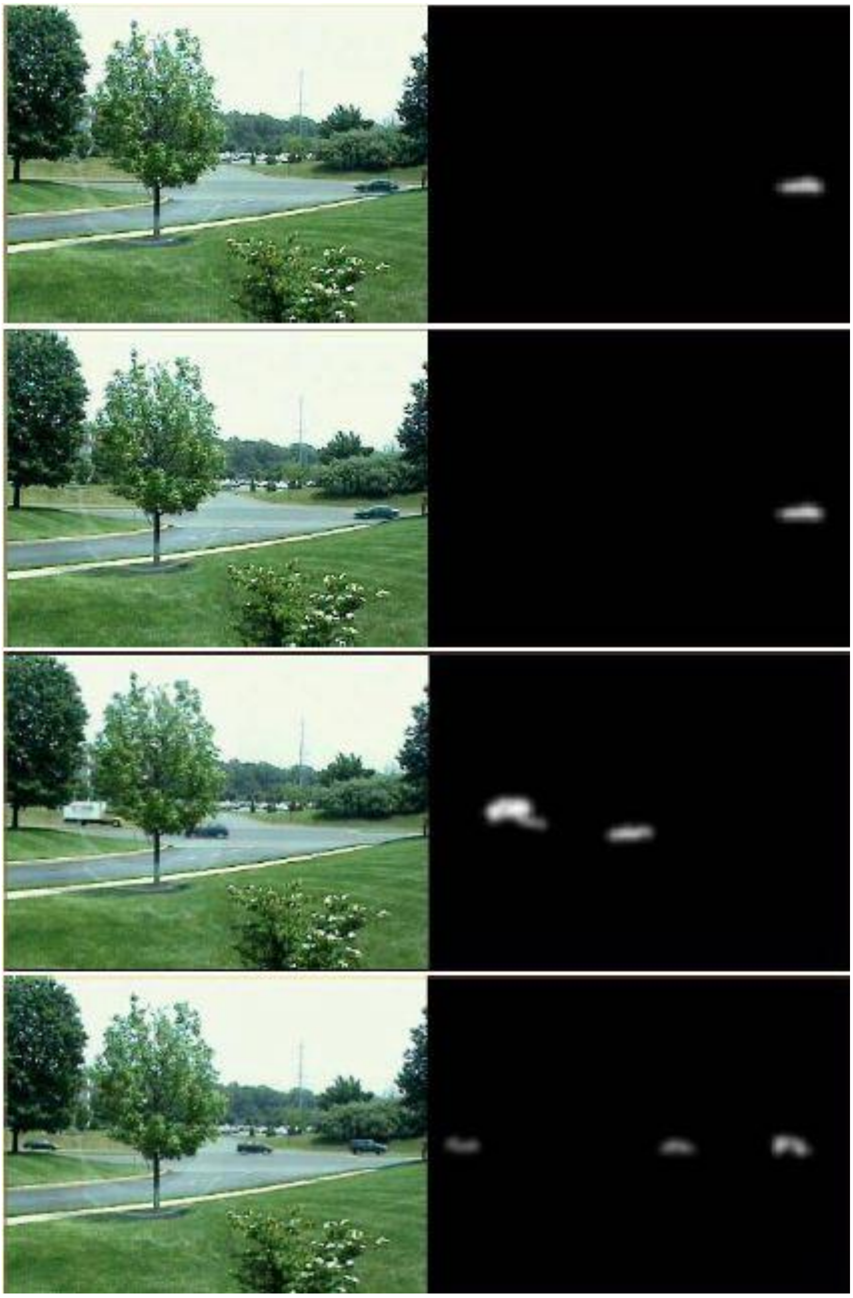


Figure 3: Background subtraction

The white colors that appear on the right side of the picture indicate foreground image had been detected. This means there are existences of moving object within the image. After the subtraction, the resulting image must undergo some other process to gain a better output which is median filtering and hole elimination.

2.4.2 *Approximate Median*

As explained in [10], approximate median works by comparing the pixel value in the current frame to the corresponding background pixel. If the pixel value in the current frame has a bigger value compared to the corresponding pixel in the background pixel, that background pixel are then incremented by 1. Otherwise, if the pixel value in the current frame is smaller than the corresponding pixel in the background image, that background pixel are then decremented by 1. The new updated background images are then will be used in the background subtraction for the next frame.

To detect the object movements, frame differencing method are used which is the same method as explained in the background subtraction section. The only difference is that the images for background frame are taken from the updated background frame during the approximate median process.

The formula for approximate median method is shown as below:

$$frameBG(k,j)_i = \begin{cases} frameBG(k,j)_i + 1, & frame(k,j)_i > frameBG(k,j)_{i-1} \\ frameBG(k,j)_i - 1, & frame(k,j)_i < frameBG(k,j)_{i-1} \end{cases}$$

To detect the object movement, the formula shown as below is used:

$$|frame(k,j)_i - frameBG(k,j)_{i-1}| > Th$$

Where,

$i \geq 2$ $\qquad$ $k \geq 1$ (Height of the image)

$frameBG_1 = frame_i$ $\qquad$ $j \geq 1$ (Width of the image)

2.5 Vehicle Counting

To count the vehicle, the most important information need to be gathered from the BLOBs is the centroid. By finding the centroid, the locations of the BLOB in the image are figured and can be used by virtual detector to count the vehicle.

2.5.1 *Draw Bounding Box*

Bounding box are drawn around each detected moving object to identify whether each BLOB produce are connected to each other. Each separated BLOB can be seen clearly after the box is drawn around each one of them. This is useful in determining the resulting BLOB that should be connected or separated. Suppose that there are two moving objects in the picture that are not connected, but after the detection process, the BLOB produces are connected to each other. By drawing a bounding box around each BLOB detected, the two main BLOBs that are connected can be seen clearly and there are faulty happen during moving object detection process.

2.5.2 *Plotting the Centroid*

By finding the centroid of each BLOB detected, the location of the moving object in the image can be identified. The centroids of the object are important in vehicle counting process.

2.5.3 *Virtual Detector*

Virtual detector works just like the magnetic loop detector as proposed in [3]. Each BLOB that passes through the rectangle region called virtual detector on every lane is count as one vehicle. The centroid of each BLOB is very useful in detecting the vehicle that passes through the virtual detector.

When the centroid of the vehicle are in the range of the virtual detector, the detector will register that a hit. When the centroid of the vehicle is outside the range of virtual detector, the detector will register as a miss. Two consecutive hit and miss registered accordingly by the detector will count as one vehicle. The same rule applies on each detector in every lane.

2.6 **Vehicle Classification**

To classify the class of the vehicle, the length of the vehicle detected is measured as explain in [3]. Certain length is decided to classify the vehicles according to its class. The length of the heavy vehicle; truck, bus and lorry is decided based on the average length of the heavy vehicle sees by the computer. If the detected vehicles are in the range of light vehicle, then the vehicle is classified as light vehicle. The same rules apply for the heavy vehicle and motorcycle.

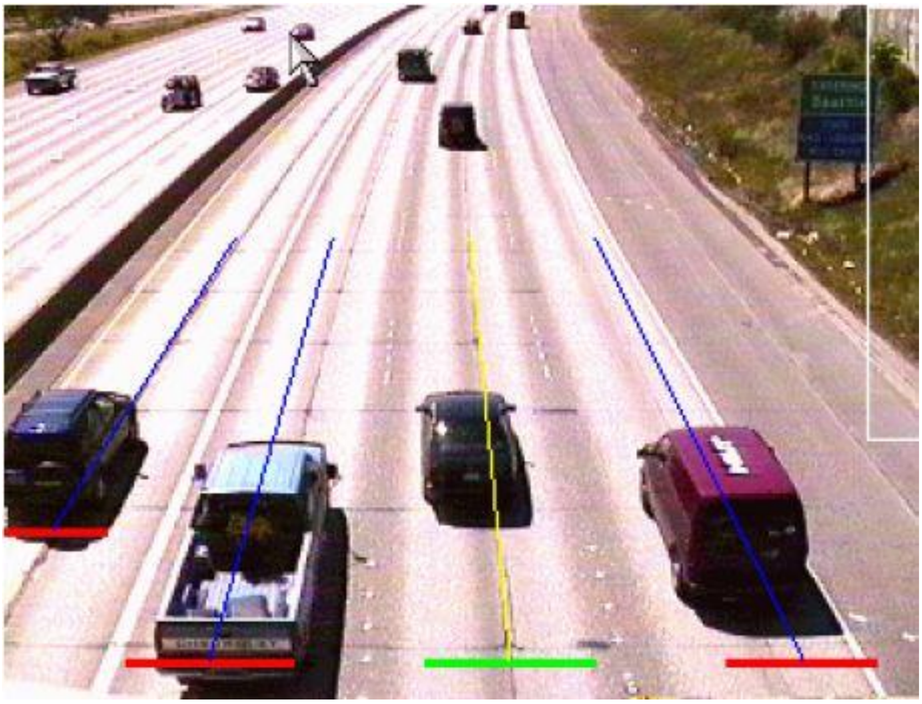


Figure 4: Vehicle classification based on length

CHAPTER 3
METHODOLOGY

3.1 Research Methodology

In order to achieve the main objectives of this project, the goals for the two sub objectives highlighted earlier must be accomplished. In outlining the importance of traffic census, detail review as well as brief research about the topic is focused on the selected papers which concentrate on the application of image processing to detect moving object, in this case the vehicle.

For the second sub objective which is to utilize the availability of image processing technology to ease up human works, literature reviews as well as well as brief research about the topic are carried out on several resources such as books, journals, and internet.

The result gain from the system is then compared with the manual counting to determine the accuracy of the result. Further improvement will be done to gain the desired results.

3.2 Flow Chart

The following flow chart explains the methodology in executing the project:

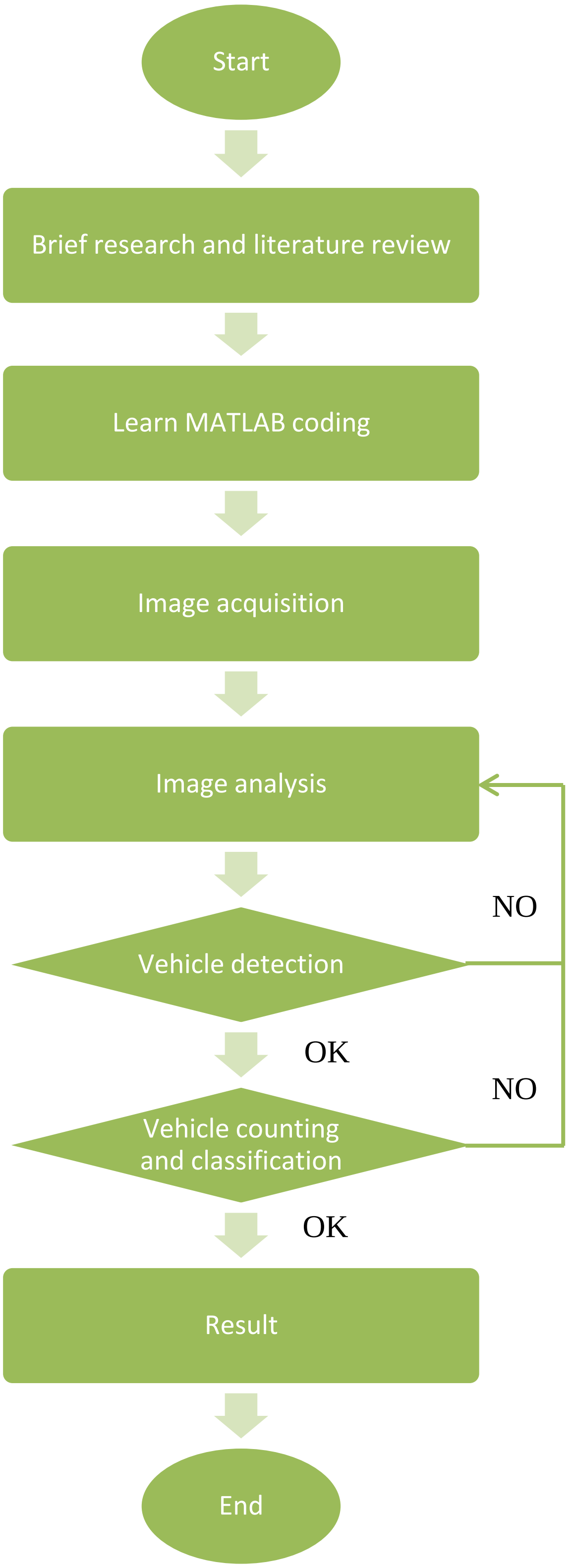


Figure 5: Methodology

3.3 **Gantt Chart**

In order to effectively monitor the progress of this project, a Gantt chart consists of 2 semester duration has been constructed.

Table 1: Gantt Chart FYP I

ACTIVITIES	**FINAL YEAR PROJECT I**													
	WEEK NO.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Choose topic														
Brief research and literature review														
Learn MATLAB coding														
Image acquisition														
Image analysis														
Collecting data														

Table 2: Milestones FYP I

Completion of topic selection	Week 1
Completion of brief research and literature review	Week 5
Completion of image acquisition	Week 6
Completion of image analysis	Week 12
Completion of applying image processing algorithm using MATLAB coding	Week 14
Completion of collecting data	Week 14

Table 3: Gantt Chart FYP II

ACTIVITIES	FINAL YEAR PROJECT II													
	WEEK NO.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Improve accuracy of result														
Beta testing														

Table 4: Milestones FYP II

Completion of improving the accuracy of result	Week 8
Completion of beta-testing	Week 14

3.4 **Tool Required**

The MATLAB R2011b software is used as the main tool for detecting the vehicle using image processing technology. MATLAB is an ideal tool for working with image processing since it is highly efficient in performing matrix calculations. Image Processing Toolbox which is included with the MATLAB software will provide useful tool for working with image processing.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 **Results**

The results for every method that is highlighted in the literature review section are shown below. The last part of this section shown the results gain from an accuracy test done on the algorithm to evaluate its functionality in real situation.

4.1.1 ***Lane Masking Results***

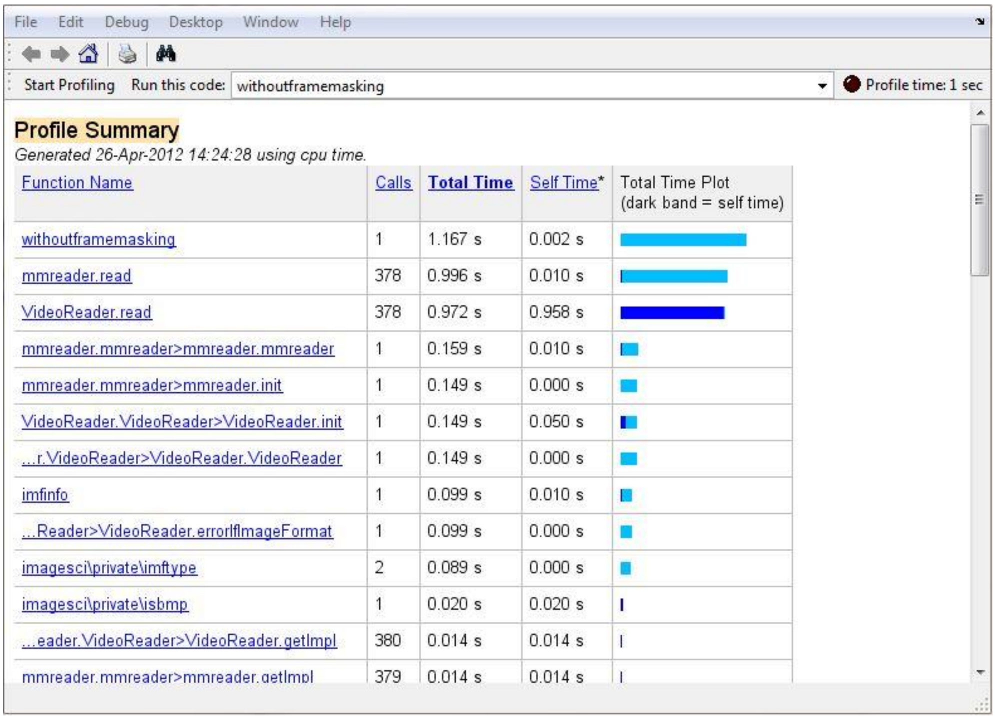
In lane masking technique, parts of the image that is not needed in the calculation is removed. The project had passed this phase without any problem. The results of this method are shown below.

Figure 6: Original image before masking

Figure 7: Frame masking result

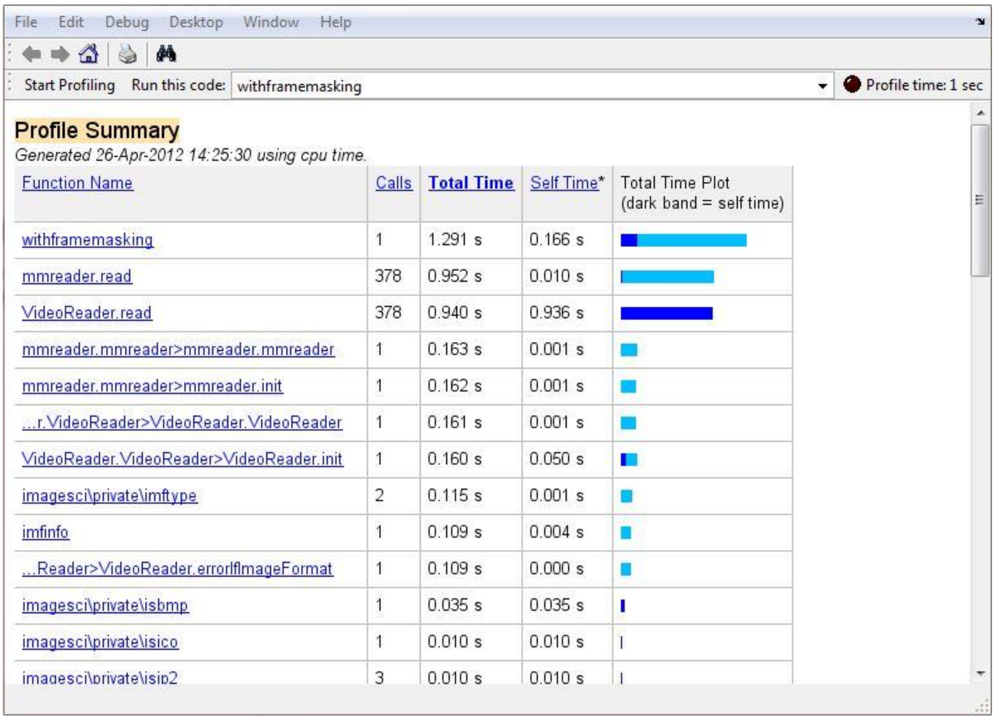
Figure 6 shows the original image without frame masking. After the masking process, the output is shown in Figure 7. In Figure 7, parts of the image that has been eliminated are in black colour, and parts of the image that is useful for the project are stay in the original value. This process reduce the noise generate from the area of the image that is not needed, hence improve the overall result of the process.

By adding lane masking instruction in the process, there is not much difference in time taken for MATLAB to run the script, with the masking or without the masking. The results for the execution time are shown in the figures below.



Function Name	Calls	Total Time	Self Time*	Total Time Plot (dark band = self time)
withoutframemasking	1	1.167 s	0.002 s	
mmreader.read	378	0.996 s	0.010 s	
VideoReader.read	378	0.972 s	0.958 s	
mmreader.mmreader>mmreader.mmreader	1	0.159 s	0.010 s	
mmreader.mmreader>mmreader.init	1	0.149 s	0.000 s	
VideoReader.VideoReader>VideoReader.init	1	0.149 s	0.050 s	
...r.VideoReader>VideoReader.VideoReader	1	0.149 s	0.000 s	
imfinfo	1	0.099 s	0.010 s	
...Reader>VideoReader.errorIfImageFormat	1	0.099 s	0.000 s	
imagesci\private\imftype	2	0.089 s	0.000 s	
imagesci\private\isbmp	1	0.020 s	0.020 s	
...eader.VideoReader>VideoReader.getImpl	380	0.014 s	0.014 s	
mmreader.mmreader>mmreader.getImpl	379	0.014 s	0.014 s	

Figure 8: Execution time without frame masking



File Edit Debug Desktop Window Help

Start Profiling Run this code: withframemasking Profile time: 1 sec

Profile Summary

Generated 26-Apr-2012 14:25:30 using cpu time.

Function Name	Calls	Total Time	Self Time*	Total Time Plot (dark band = self time)
withframemasking	1	1.291 s	0.166 s	
mmreader.read	378	0.952 s	0.010 s	
VideoReader.read	378	0.940 s	0.936 s	
mmreader.mmreader>mmreader.mmreader	1	0.163 s	0.001 s	
mmreader.mmreader>mmreader.init	1	0.162 s	0.001 s	
...r.VideoReader>VideoReader.VideoReader	1	0.161 s	0.001 s	
VideoReader.VideoReader>VideoReader.init	1	0.160 s	0.050 s	
imagesci\private\imftype	2	0.115 s	0.001 s	
imfinfo	1	0.109 s	0.004 s	
...Reader>VideoReader.errorIfImageFormat	1	0.109 s	0.000 s	
imagesci\private\isbmp	1	0.035 s	0.035 s	
imagesci\private\isico	1	0.010 s	0.010 s	
imagesci\private\isjp2	3	0.010 s	0.010 s	

Figure 9: Execution time with frame masking

The result is gain from running a 12 seconds video, without running the video after execution. The result shown is only the time taken for MATLAB to execute each instruction. Notice that the difference in total execution time shown in Figure 8 (with frame masking) compared to Figure 9 (without frame masking) is 0.124 seconds. The difference can be neglected as it is quite small and will not make the performance of the whole algorithm much slower. Plus, by applying masking on each frame, the noise generated from the moving background object such as trees can be neglected, thus improving the performance of the system in term of detecting moving objects.

4.1.2 *Background Subtraction Results*

Figures below showed the output of background subtraction or frame differencing. Figure 10 shown the original image before subtraction and Figure 11 shown the output image right after subtraction, without converting it to grayscale or black and white image.

Figure 10: Original frame

Figure 11: Output image after subtraction (RGB)

4.1.3 *Pixel neighbouring, bridging and thickening*

To get a better output, the output image after subtraction process are converted to grayscale image and then median filtering are applied to reduce the noise generated. The results are shown in Figure 12. The images are then converted in black and white image for the purpose of further process. The threshold value for black and white conversion are set to be 20, which means the pixel value of grayscale image are converted if only the value is more than 20. The resulting images are shown in figures below.

Figure 12: Output image in grayscale

Figure 13: Output image in black and white

Figure 14: Output image in black and white after image filtering

Figure 13 shows the original black and white image of the output. Notice that there is some part of the vehicle that is not connected after the conversion. To connect all those separate part that belongs to the same vehicle, the image must undergo some other process which is bridging, thickening and neighbouring. The results of these alterations are shown in Figure 14. This process is needed because the BLOBs that represent one vehicle must be connected altogether to avoid the confusion for the next process.

4.1.4 *Approximate Median*

Approximate median is just another method used to detect the BLOB of moving vehicle. By using this method, the output gained are much more better compared to frame differencing method as the moving BLOB are not much separated from each other after the process. The downside of this method is that the times taken to execute the same video are much longer compared to frame differencing method.

Frame differencing method only took 27 seconds to execute a 32 seconds video file while approximate median method took 127 seconds to execute the same video file.

The output image of implementing approximate median method is shown in Figure 15.

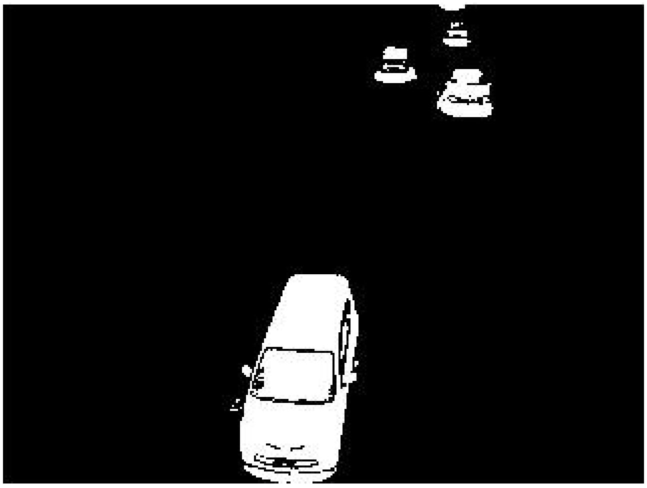


Figure 15: Output image of approximate median method

4.1.5 *Draw Bounding Box*

Bounding box is drawn around each BLOB for the purpose of tracking the BLOB. Once the box are drawn, it is easier for the user to determine whether the BLOB shown are represents for one vehicle or two or more vehicles that are connected to each other due to the close distance between them.

The results for the implementation are shown in Figure 16. The bounding box is drawn around each BLOB, thus separating it from each other. The user can now define whether those separated BLOBs are should be separated or connected, hence the correction on the configuration of the algorithm can be made to obtain the best results.

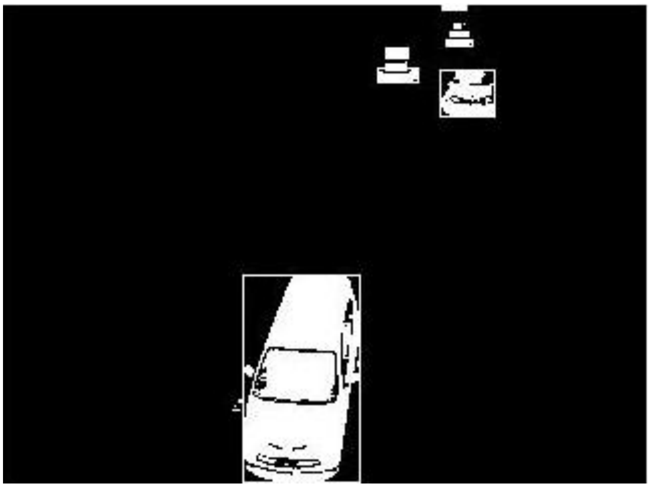


Figure 16: Draw bounding box around each BLOB

4.1.6 *Plotting the Centroid*

Apart from drawing the bounding box around each BLOB to separate them from each other, the centroid on each BLOB are determine to define the exact location of each BLOB. Each separated BLOB now will have a centroid that shows its location.

To avoid plotting the centroid on a small BLOB, the selected BLOB that has an area of bigger than 1000 pixel square will only have the centroid plotted on it. Assuming that the small BLOB which is less than 1000 pixel square is not a vehicle, this will improve the results of counting the vehicle.

The results of plotting the centroid on the image of Figure 15 are shown in Figure 16. The plotted centroid on the BLOB indicates that the areas of the BLOB are bigger than 1000 pixel square, thus represents a vehicle. Figure 17 shows the plotted centroid on the original image.

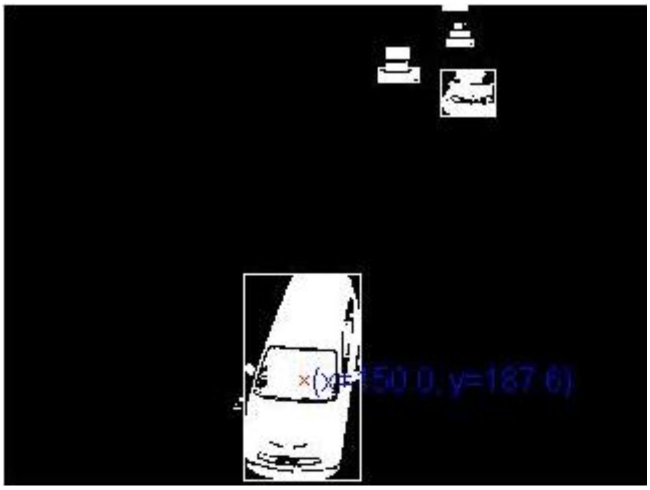


Figure 17: Plotting the centroid on the BLOB

Figure 18: Plotting the centroid on the original image

4.1.7 *Counting the Vehicles*

The centroids obtained in the previous process are now used in counting the vehicle. To count the vehicle, red boxes, representing the detector are defined on the image. The detector works when the centroids are inside the red box, the detector will detect as hit. Once the centroid leave the box, the detector will detect as miss. When the detector detect two consecutive frames as hit and miss accordingly, the detector will define that as a vehicle and the vehicle counter will count up. The methods for counting the vehicles are shown in the Figure 19 and 20.

Figure 19: Detector detect as a hit

Figure 20: Detector detect as a miss

4.1.8 *Classifying the vehicle*

To classify the class of vehicle, the system use the length of the vehicle detected. The moment the vehicle passed through the virtual detector, the system will analyze the length of the vehicle and classify it according to its class. As for now, the system can classify motorcycles, cars, and heavy vehicle; lorry and bus.

The accuracy test was done based on 20 minutes video taken in front of UTP's flyover from 4:50 pm to 5:10 pm on a sunny day. The video are reliable for testing purpose because of the traffic congestion and the type of vehicle that use the road at the time; bus, lorry, car and motorcycle. The accuracy test for counting and classification of the vehicle are shown in the table below.

Table 5: Counting and classification results

	Actual	System	Error	Accuracy
Heavy vehicle (lorry, bus)	37	16	21	43.24 %
Light vehicle (car, van)	389	416	27	93.06 %
Motorcycle	73	77	4	94.52 %

4.2 **Discussion**

Based on the results of detecting the BLOB of moving object, it is clearly shown that by using approximate median method, the resulting output are much more accurate compared to frame differencing method. Although the time taken for the approximate median method are much longer compared to the frame differencing method, the quality of the results are much more important compared to the speed of the execution. More research will be done to reduce the execution time taken for the approximate median method.

After doing some optimization on the codes for approximate median method, the time taken to execute the codes has been lower into half. The results are shown in the table below

Table 6: Codes optimization

	(a)Video length	(b)Execution time	(c) Optimization $\frac{(b)_{original} - (b)_{optimize}}{(b)_{original}} \times 100\%$	Ratio (a)/(b)
Original code	32 seconds	127 seconds	0 %	3.9688
Optimize code	32 seconds	62 seconds	51.1811 %	1.9375

Since the bounding box can be drawn around the BLOB, the length of the box can be used in classifying the vehicle. For example if the length of a light vehicle, which is vehicle in the range of 100 to 150 pixels, then the vehicle will be classified as light vehicle. If the length of the vehicle is more than 150 pixels, the vehicle will be classified as heavy vehicle. Examples of heavy vehicle are lorry and bus.

The accuracy of classification for heavy vehicle is quite low (43.24%) because the system misclassifies the lorry that is in the same length as car as a light vehicle. Another problem that causes the misclassification is because the BLOB generated from the system for the heavy vehicle is separated although it belongs to the same vehicle. For example, the BLOB for a lorry are divided into two or more parts, this problem can be seen clearly as there are more than one bounding box that are belongs to the same vehicle. Figures below shown the problem arise for this particular matter.

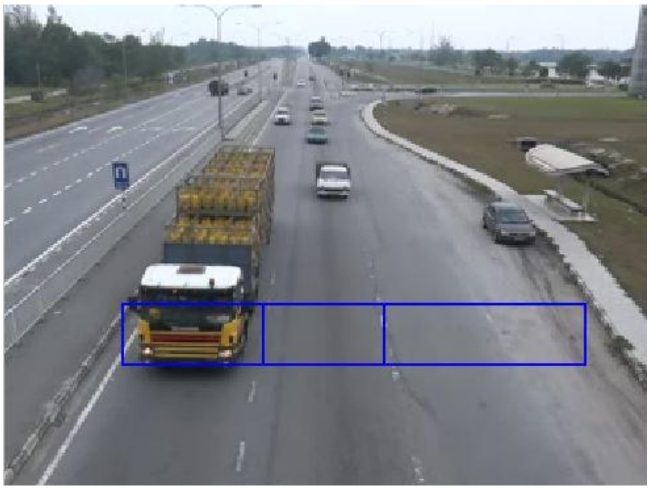


Figure 21: Original frame

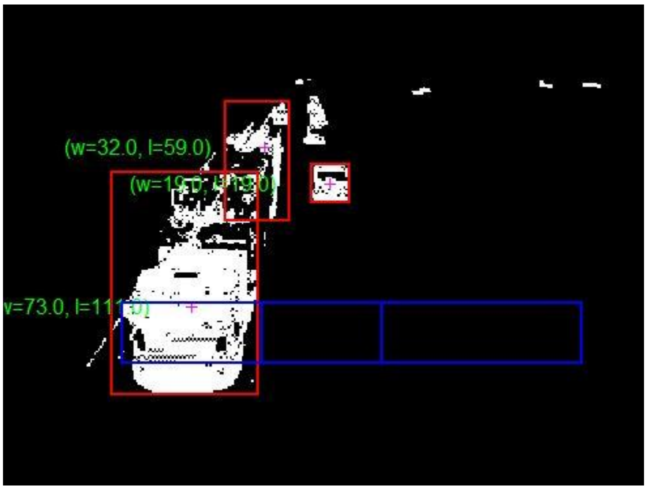


Figure 22: BLOBs produce based on Figure 21

CHAPTER 5
CONCLUSION AND RECOMMMENDATION

5.1 **Conclusion**

The lane masking technique is important process in reducing the noise generated from the background. Background subtraction process is the key feature of this project. A successful background subtraction can lead to a better detection result. Additional method such as bridging, neighbouring and thickening the pixel are complimentary in making sure the system producing a better result.

In conclusion, it can be said that this project is able to be completed with the given time line to achieve the required objectives.

5.2 **Recommendation**

A variety of technique has been implemented on this project such as masking, frame differencing and approximate median. This work can be expanded to investigate which technique that will give a better image analysis. Furthermore, there some other techniques that can produce a better output result but involving in more complex algorithm in detecting moving object which are Mixture of Gaussian, optical flow, and edge extraction. This technique can be implemented for the sake of future development of the project.

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