

AERIAL IMAGE OF MONITORING USM CAMPUS SURROUNDING AREA FOR TRAFFIC CONGESTION PROBLEM

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ABSTRAK

Teknik pemrosesan imej merupakan alat yang sangat dipercayai penggunaannya bagi proses mengenalpasti dan menjejaki objek terutama sekali di dalam pengawasan trafik. Terdapat pelbagai kaedah yang boleh digunakan bagi melakukan pemrosesan imej bergantung kepada tujuannya yang tertentu. Teknik yang dilaksanakan bagi projek ini adalah dengan menggunakan model campuran Gaussian sebagai segmentasi latar belakang dan bagi memperoleh latar depan yang mempunyai elemen yang dinamik. Elemen latar belakang gambar terdiri daripada pixel yang statik dimana ia akan disingkirkan melalui pemerhatian dan ramalan perubahan. Model campuran Gaussian merupakan teknik yang sangat kukuh bagi menjejaki kenderaan dan berguna untuk pengawasan keadaan trafik di jalan raya. Pengimejan udara digunakan bagi projek ini bagi menyingkirkan pertindihan maklumat yang diperolehi daripada pengesanan darat. Pandangan melalui udara bagi pemantauan trafik jugak lebih meyakinkan kerana ia membantu bagi menyingkirkan kekurangan yang dihadapi bagi pemantauan dari pandangan melalui darat. Pandangan pemantauan juga lebih luas dan jelas kerana ia mengatasi masalah pertindihan kenderaan bagi proses pengesanan dan penjejakan kenderaan.

ABSTRACT

Image processing technique is a very powerful tool to be used in object detection and tracking especially in traffic monitoring. There are plenty of ways to perform image processing technique depends on its specific focus of interest. The one that have been implemented in this project utilise Gaussian mixture model as the background segmentation and subtraction to obtain the foreground image that contains dynamic elements. The background elements contains static pixel which will be eliminated to observe the changes and predict its update. Gaussian mixture model is very robust for vehicle tracking and useful to observe the traffic condition on the road. Aerial imaging for foreground visual have been implemented to eliminate the overlapped information obtain by the ground detection. Foreground view for traffic monitoring also very convenient as it helps to eliminate the flaws that might been encounter for the ground view. The monitoring view is wider and much clearer as it overcome the vehicle overlapping problem for vehicles detection and tracking.

CHAPTER ONE: INTRODUCTION

Roadway networks cover large area and commonly problematic when it comes to monitoring process. As the population increases in urban area, traffic road are much more congested and the capacity of the road infrastructure need to be assessed to coop with the high demand from the road user. Number of accidents occurs also need to be considered in order to provide the user with secure and efficient transportation system. Aerial imaging provide depth to traffic monitoring as it cover bigger area to be analysed beside providing better visual aid for data collection. Ground-based monitoring system contains few drawbacks as it only cover small and stationary view sight.

For instance, Versavel (1999) have used multiple cameras to study the incident detection, traffic monitoring and incident clearing [1]; Koutsia *et al.*, (2008) also used multiple cameras in order to perform the foreground object detection within its region of interest and filed of view, traffic monitoring and also surveillance system [2]. There are limitations to the ground surveillance system and to overcome the problem, new exploration has been done to provide improvement in traffic monitoring field.

Airborne traffic surveillance system (ATSS) have been used since 1990s to bring the traffic monitoring system to a whole new level as it uses unmanned aerial vehicle (UAV) to fly at certain altitude to collect the data from high resolution aerial image [3, 4]. UAV movements are not restricted and very flexible in terms of coverage area. It can fly above the road and maneuver freely with the controller and live view display. The MQ-9 Reaper [5] , one of the drones used by United State of America's homeland security able to recognize an object with the size of a milk carton from 60,000 feet altitude.



Figure 1.1: Image of MQ-9 Reaper used by Homeland Security

Real time visual tracking system may seem efficient as the monitoring can be done directly from the real time display. This system required high setup to build the signal tower and the range for the signal it can transmit the traffic data might be limited because it is depending on the radius of the signal. However, a research also have been done to develop a cost effective, and intelligent real time traffic monitoring system using wireless smart sensor networks [6].

Digital image processing also proven very useful in experiment and industrial by providing massive advantages in simulating and analysing for solution purpose. The algorithm and program of digital image processing with MATLAB provide depth to the analysis as it is a high-performance language that helps to integrate the visual, programming and computation in a user-friendly environment. With the growth metropolitan area, aerial imaging for data collection might turn to be a proficient method. The unmanned aerial vehicle (UAV) exhibits number of advantages when used for data acquisition process in traffic monitoring and foreground detection. In this research, digital image processing by using MATLAB software is used to classify, count, and filter the number of cars in a few region of interest to monitor the traffic condition from offline video taken by the drone.

In this advance days where more powerful ATSS have been developed, offline method might be considered primitive because its inability to achieve the real time visualisation system. Even if it was true, it is still widely used to analyse the behaviour of the traffic. The video will be recorded by the UAV during its flight session on surveyed area and will be studied on the ground station when it land.

Vehicle counting will be done on the ground station where the algorithm will be developed in order to recognize the type of vehicle. Digital image processing has been used frequently to track and observe moving object based on video recorded [7]. For this research, only the number of cars will be counted and studied along the road for the purpose of traffic monitoring.

1.2 Problem statement

Traffic Monitoring System (TMS) using ground detection have been implemented and used to study the pattern of traffic behaviour. However, the ground detection contains flaws than tend to compromises the data collected. Overlapped image might cause the detection become harder inaccurate data. Static traffic monitoring system uses nowadays also seem to have problems due to limited vision of vehicles in the region of interest when collecting the data. One of the methods to overcome this problem is by implementing aerial surveillance to collect the data. Quadrotor will be used to obtain the foreground visual information and for surveillance purpose.

Video taken need to be stable enough with clear visual thus making the flight stability routine is very vital. A lot of variables need to be counted and improvised so that the data collected does not show false positive result. Besides, the study of traffic behaviour also needs to be done to ensure the pattern can be made for further studies.

1.3 Objective

- i. To construct the algorithm for vehicle detection using MATLAB software to analyse the congestion problem and traffic monitoring.
- ii. To record and capture the aerial view of traffic for foreground vehicle detection and to analyse the traffic behaviour.
- iii. To validate the developed algorithm by simulating the aerial images and verify its accuracy in producing the correct number of vehicles detected.

1.4 Scope of Research

In order to implement the vehicle detection from foreground view, a drone is used as the medium to capture the images. The aerial view is vital as it is the focus for the vehicle detection for this project. The research also focuses on the vehicle detection for traffic monitoring and congestion problem. Image processing is used for detection instead of signal detection to provide the figurative example and explanation for the traffic behaviour. The aerial view is utilised for this research instead of ground view to overcome the overlapping problem that usually occur for ground detection.

CAPTER TWO: LITERATURE REVIEW

2.1. Reliable Tracking of Moving Object in Traffic Video.

Video processing, intelligent monitoring and target recognition is the essential variables that needed to compose a reliable moving object tracking process. MATLAB will provide a platform to operate this process. The early stages required neat series of preparation like frame separation, thresholding, segmentation and also edge detection of traffic video. Each one of the processes is essential as it will help to control all the variables that might exist in conducting the project.

MATLAB coding is vital in achieving the process by comparing the reference frame with every new frame in the video. By using the edge detection mechanism and object recognition phase, the recognition process can be performed in much more efficient way as it helps to provide the visual aid to the researcher. The percentage of accuracy in object detection displays great impact on the tracking and recognition process when the steps are fully developed for future use [11]. This case has been found from a research done by Varun Kumar M from VIT University. He investigated on tracking and recognition of moving object in traffic video. On his project, the optical stream strategy is utilised.

He included edge identification technique and utilized the picture division technique as part of article location. This project could provide massive advantages to our research.

2.2. Detecting and Tracking Vehicles in Traffic by Unmanned Aerial Vehicle (UAV).

The precision of the detection is vital as the false positive result (known when considering non-vehicle as vehicle) will directly cause failure in the next step for vehicle tracking (because vehicle tracking is relatively correspondent to the vehicle detecting result). When the vehicle detected have different shape compared to typical vehicle shape, false negative failure will occur. This phenomenon is likely known as ghost vehicle that frequently generated unpredictable errors which make the detection process become much more difficult. It disrupts the data collection process and will cause mountain of problems as the project is conducted in further stage.

The limitations for each vehicle detected also need to be considered. For instance, at 120m altitude, the width limitation for vehicle recognition is 30 to 45 pixels. With UAV flying at relevant altitude range, the vehicle detection could provide acceptable accuracy. Thus, maintaining the optimum and reliable height is essential. The resolution of the camera also plays a big role when it comes to gaining better accuracy. Low resolution camera will required more process of image processing needs to be done to correct it. However, even with the aid of the processes, the tracking process also will be harder and not guarantee to be successful as the actual shape of the vehicle can't be detected precisely [9]. Liang Wang, Fangliang Chen and Huiming Yin did similar experiment in tracking vehicle using UAV. The workflow chart of the system is consisted of four major modules; image registration, image feature extraction, vehicle shape detection and vehicle tracking. Each module represents the power of combination between the application of computer vision and transportation.

All of the module sued in their experiment should work together as a unit to produce accuracy in vehicle tracking and vehicle recognition.

2.3. Region of Interest (ROI) in Traffic Images

To improve the data collection process, specific region of study can be used to reduce the variables existed. The introduction of region of interest might help to simplify the image analysing process. By using this technique, data collection area will be narrowed down instead of analysing the vast area with unknown and uncontrollable variables. The main idea is to analyse an image with multiple uncertainty from the traffic video by stacking the spatial information. It is very important for the subsequence image segmentation and object detection thus.

The moving vehicle can be detected whenever it enters the ROI with the exact time and location directly registered while vehicle is moving in the ROI. This process is repeated in every subsequence frame until the vehicle is not in ROI. This creates a very general platform to reduce the variation and variables in vast region of experiment [8]. The research on this topic has been done by Zhenyu An, Zhenwei Shi, and Changshui Zhang. Even though the experiment is done on different topic, it uses the same technique that can be utilised for the project. The core idea is to simulate an image with multiple bands from the given traffic image by stacking the spatial information.

2.4. Vehicle Detect Method Based on Gaussian Mixture Model

A Gaussian Mixture Model (GMM) is a parametric probability density function represented as a weighted sum of Gaussian component densities. GMMs are commonly used as parametric model of the probability distribution of continuous measurements or features in a biometric system, such as vocal-tract related spectral features in a speaker recognition system.

GMM parameters are estimated from training data using the iterative Expectation Maximization (EM) algorithm or Maximum A Posteriori (MAP) estimation from a well-trained prior model.

Gaussian mixture model can be implemented to every each frame to achieve result with precise background. It extract the vehicle by subtracting the background of the video taken. The geometrical shape of the road needs to be considered during making the model. However, this technique only have been applied on ground traffic monitoring and never been used on aerial imaging.

Thus, it might produce new challenge and different aspects of variable need to be considered. This technique has been used by Mohammad Ali Alavianmehr, Ali Zahmatkesh and Amir Sodagaran, in their research on A New Vehicle Detect Method Based on Gaussian Mixture Model along with Estimate Moment Velocity Using Optical Flow. The utilised this model in conducting real time traffic monitoring from video surveillance application. The results shows from their research prove that this is one of the robust, adaptive and accurate techniques to be used in their research for detecting moving vehicle [13].

2.5. Detecting Moving Objects, Ghosts, and Shadows in Video Streams

Background subtraction technique is one of the infamous methods to perform object detection. In this paper, it focuses on the vehicle detection including the shadow detection to eliminate the ghost effect for the next subsequence frame. The shadow detection is done based on its appearance in respect to the background frame .Median function is used to compute the statistical background model instead of the Gaussian is due to its computational cost effectiveness.

Selectivity is done not by reasoning on single moving object points, but on detected and recognizes the moving object [15]. This is much more reliable and produce less sensitive to noise compared to the point-based selectivity. The foreground detected from the background subtraction is merged into the labelled blobs according to the connectivity. The chromaticity also is taken into the computation for background subtraction to improve the detection.

CHAPTER THREE: METHODOLOGY

3.1 Pre Processing

For the early stage of this project, series of processes have been outlined and need to be performed before going to next stage. The pre process stage is done on the static image at first. The process layout can be referred to the work flowchart of the image processing on Figure 3.1. All these processes are done by using Image Processing Toolbox in MATLAB software. Mock images have been used to prepare the algorithm and control the variables presence in the image. Note that the pre-processing stage is done so that the preparation for the data collection can be done and to determine the variables that need to be considered when conducting the experiment. These processes is needed in order to perform the simulation

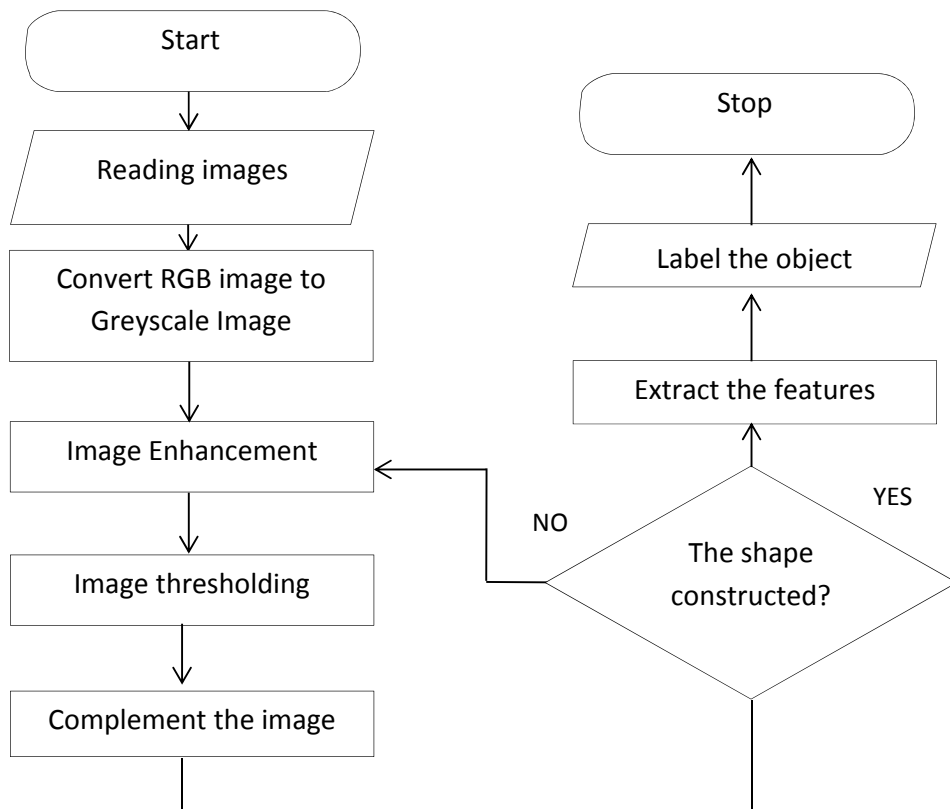


Figure 3.1: Work flowchart for pre-processing stage

3.1.1 Reading the image

The process began with reading the images into the MATLAB Image Processing Toolbox by using 'imread' command. Almost all formats for images can be read by MATLAB and from the workspace windows also u can see the pixel size of the images. Here, filename is a string containing the complete name of the image file.

```
f=imread('A1.jpg');
```

```
imshow(f);
```



Figure 3.2: Example of image read by the software.

Note that the format of the image also needs to be specified in the program so that it can read the correct image. The image can be resized to increase the size or to reduce is so that proper image can be analysed. The image also can be directly called from another folder or directory by including the full or relative path to that directory in filenames.

3.1.2 Convert RGB image to Greyscale

Typical image read by MATLAB usually come with RGB colour unless the original image is already in greyscale colour mode. The main reason to convert the image into black and white is to remove the colour variables that might exist when we about to do the segmentation process later. There are various functions to manipulate the image and for this process the function that used is 'rgb2gray'. The syntax is:

$$g = \text{rgb2gray}(f)$$

The input RGB image can be in of class uint8, uint16 or double; the output image is the same class as the input.

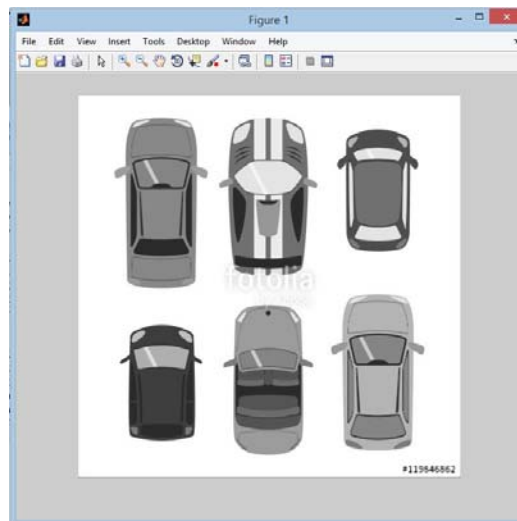


Figure 3.3: Greyscale image of the original image after converting it.

3.1.3 Image enhancement

When dealing colour images, the term intensity plays a big part in denoting the colour images component in certain colour spaces. The intensity transformation function is suitable function to use to improve the image colour intensity.

The function `imadjust` is the basic IPT tool for intensity transformation of greyscale image. It uses the syntax:

```
h=imadjust(g);
```

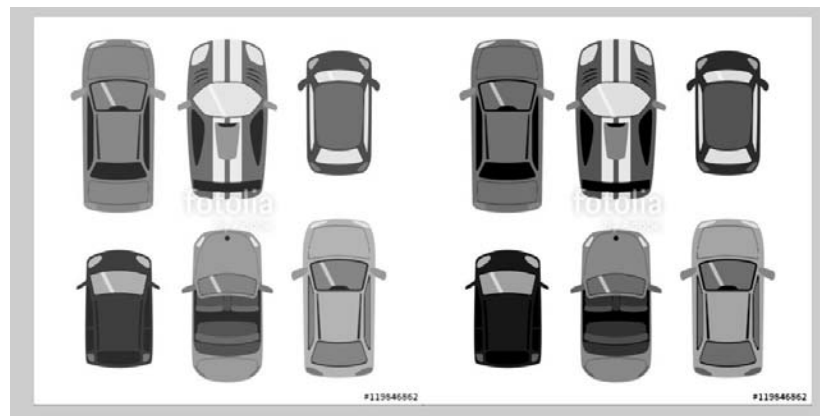


Figure 3.4: Left: Image before the adjustment process; Right: Image after adjustment.

This function maps the intensity values in grayscale image 'g' to new values in 'h' such that 1% of data is saturated at low and high intensities of 'g'. This increases the contrast of the output image 'h'

3.1.4 Image thresholding

Image thresholding is a simple, yet powerful, way of partitioning an image into a foreground and background. Image thresholding is most effective in images with high levels of contrast. Thresholding function converts the grayscale image to a binary image. The output image BW replaces all pixels in the input image with luminance greater than level with the value 1 (white) and replaces all other pixels with the value 0 (black). Specify level in the range [0,1]. This range is relative to the signal levels possible for the image's class. Therefore, a level value of 0.5 is midway between black and white, regardless of class. If level is not specified, `im2bw` will use the value 0.5.

It has syntax:

```
i1=im2bw(image,level);
```

However, for this project, thresholding is done to each colour plane, which is red, green and blue plane. First, the level for each plane needs to be specified before the thresholding process. When the thresholding for each plane is complete, it will be sum up together to reduce the noise. The syntax is:

```
levelr=0.82;  
levelg=0.825;  
levelb=0.9;
```

```
i1=im2bw(rmat,levelr);  
i2=im2bw(gmat,levelg);  
i3=im2bw(bmat,levelb);  
fsum = (i1&i2&i3);
```

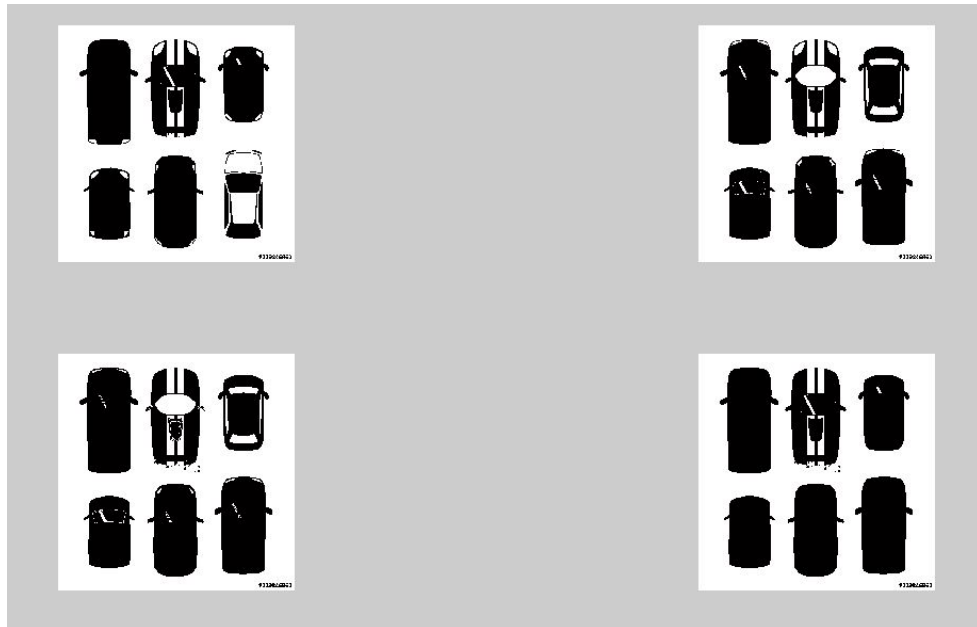


Figure 3.5: The subplot images of the threshold results.

3.1.5 Complementing the image

Complementing the image is important because usually to recognize an object, it is easier to have darker background than lighter background. 'imcomplement' function computes the complement of the image 'fsum'. The image to be complemented can be a binary, grayscale, or RGB image. But beforehand the image has been converted into binary image. In complement of a binary image, zeros become ones and ones become zeros; black and white are reversed. In the complement of an intensity or RGB image, each pixel value is subtracted from the maximum pixel value supported by the class (or 1.0 for double-precision images) and the difference is used as the pixel value in the output image. In the output image, dark areas become lighter and light areas become darker. It has the syntax:

```
fcomp=imcomplement(fsum);
```

Figure 3.6 shows the result of complemented image.

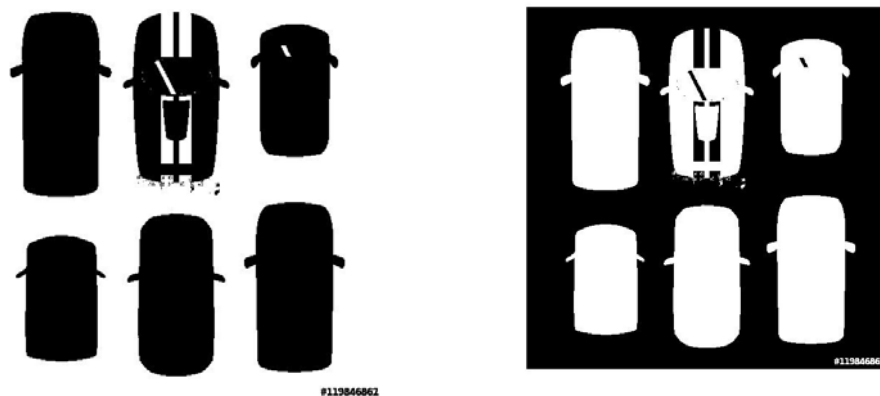


Figure 3.6: left image: Before complement; Right image: After complement

3.1.6 Construct the shape

In constructing the morphological shape for the image, strel function is introduced. Strel construct structuring elements with variety of shapes and sizes. Its basic syntax is:

```
fse=strel('disk',5);
```

For this example, the disk shape is the shape desired where it create a flat disk shaped structuring element with radius of 5 pixels.

After the shape of the object has been achieved, the image segmentation is proceeding with filling the holes existed in the image by using 'imfill' function.. Its basic syntax is:

```
ffill=imfill(fcomp,'holes');
```

This function is utilised to fill the holes in the binary image BW. A hole is a set of background pixels that cannot be reached by filling in the background from the edge of the image. The result is such in Figure2.7.

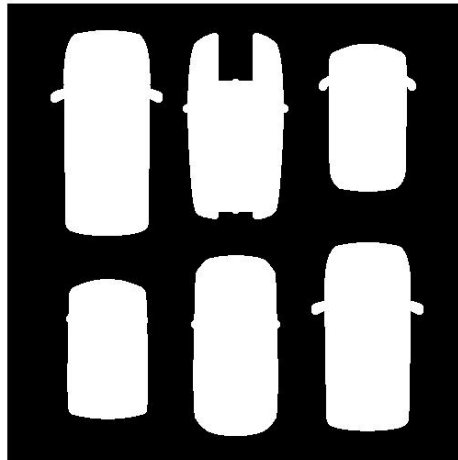


Figure 3.7: Results after structural element and filling the holes.

3.2 Experimental Setup

The experiment is set up by using a Phantom 3 Standard drone to record the aerial view and capture the image for vehicle detection and counting. The drone is controlled manually from the ground station with the real time display. The real time display control is vital for this experiment to get the clear and unobstructed aerial view for the image and the video in order to process the data for congestion analysis.



Figure 3.8: DJI phantom3 standard drone used to capture the aerial imaging.

The area of study for the congestion problem is focused on the main entrance for Engineering Campus, Universiti Sains Malaysia as shown in Figure 3.9. This is because it is the main road used by most of staff and the student. The experiment is done during the peak hour where it is the normal period for the staffs and the students to use the road and the specification of the flight can be referred to Table 3.1.

The drone used also has built in GPS system in order for it to maintain the static coordinate during its flight. This is very important for the experiment as the video recorded need to be in static motion in order to maintain the flight height and area of study for the experiment.

Table 3.1: The specification and parameters set for the drone to fly and record the aerial view.

| No | Parameters | Capabilities value |
|----|----------------------|--------------------|
| 1 | Flight time (minute) | 30 |
| 2 | Video Resolution | 1920×1080 |
| 3 | Altitude(meter) | 82 |
| 4 | Weather Condition | Sunny day |
| 5 | Wind Speed(mph) | <20 |
| 6 | Camera Angle | 90° to the ground |



Figure 3.9: Area of study for the congestion problem at the main entrance.

3.3 Background Subtraction

For foreground segmentation and background subtraction, Gaussian Mixture Model has been used in this project. This is because of its robustness for the filtering the background and foreground images and also towards the dynamic changes in series of images. The method has been used vastly in object detection as it segment the background and the foreground images while updating the specific changes depends on the rule of the system. Gaussian mixture models made probabilistic assumption on the collected set of data and the result tabulated based on the distribution parameter.

For this project, the implementation of the mix models is done by classifying the background correspond to the static elements such as the building and road and as for the foreground pixels, it will correspond to the dynamic elements such as vehicle that moving and keep changing. When the video is processed, the average for series of initial frame without vehicle in it will be used as the background images as it is in the stationary behaviour.

After analysing the initial frame, the new changes in pixels in new frames will be observed and compared to the past observation on the initial frame. This method is based on the model shown in the following equation.

$$\{X_1, \dots, X_t\} = \{I(x_0, y_0, i): 1 \leq i \leq t\} \quad (1)$$

The main purpose of the implementation of the Gaussian mixture model is to analyse the incoming pixels observation that related to the mixture models and furthermore identify them as the foreground or background. For the static elements of the video, the pixels process will be constant and has low variance and as for the dynamic elements within the frames, there will be poor match and high variance due to its lack of prior evidence.

3.4 Traffic Monitoring

The traffic condition for the congestion will be observed based on the number of cars detected on the main gate. The area within the vehicles will be counted is approximately 50m from the gate entrance as shown in Figure 3.10. There are cases that are used to observe the traffic condition and it is tabulated on the Table 3.2. These cases are selected based on the approximation of maximum number of cars that stopped and have been detected on the study area. By following the condition for each case, the analysis can be done on the occurrence frequency and the pattern can be observed.



Figure 3.10: The area of study for vehicle counting for traffic condition.

Table 3.2: 3 cases include in consideration for traffic condition.

| Type of case | Parameters | Condition |
|--------------|--------------------------------|-----------|
| Case 1 | Number of cars detected < 5 | Smooth |
| Case 2 | $5 \leq$ Number of cars < 10 | Dense |
| Case 3 | Number of cars ≥ 10 | Congested |

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Simulation

The simulation verification is done by running the prepared algorithm for vehicle detection and analysing the result. The process flow for the simulation operation can be referred to the Figure 4.1.

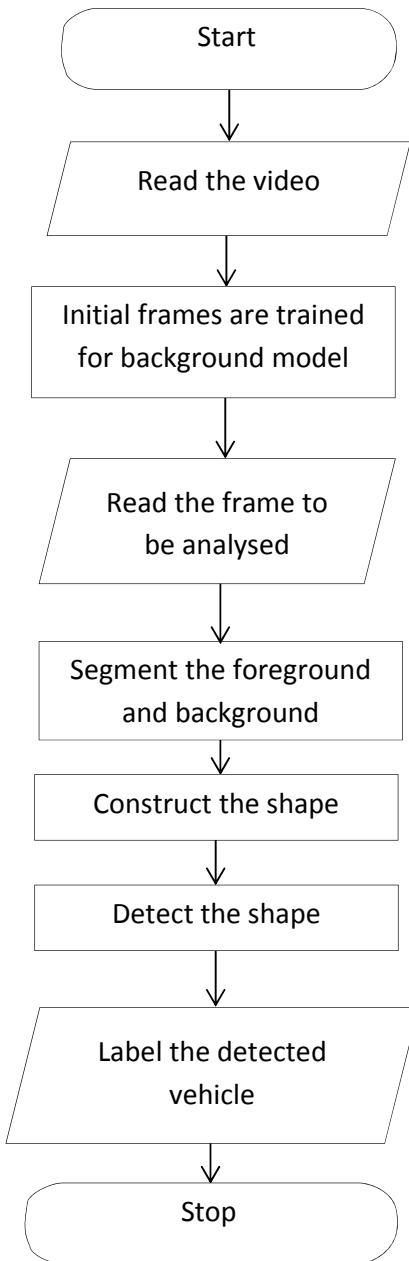


Figure 4.1: The process flow chart for simulation for vehicle detection

4.1.1 Training Frames

After the video has been obtained, the simulation began at first with the reading of the video input onto the simulation algorithm. The program ran through the series of 50 initial frames from the video to train the frames and identify it as the background element. This is because instead of processing the whole video at once, it is much simpler to start with the initial frames and later the moving objects are segmented from the background element. This is to ensure that the program could detect the object with minimal error.

Furthermore, the foreground detector needs to analyse certain number of video frames at the beginning to perform the Gaussian mixture model. With the 50 frames selected to be sampled, it is initialized with two Gaussian modes in the mixture model. The background image is the constructed after the model is done and all the elements from these cumulative frames are then subtracted by the next selected frame to obtain the foreground image. Figure 4.2 shows the example of the video frame that been selected to run the simulation.



Figure 4.2: Example of video frame selected for image processing

4.1.2 Foreground Detection

When a frame is selected to be analysed, all the elements from the background image are subtracted to produce the foreground image as in Figure 4.3. This is because when there are changes occur on the following frames, it will create an anomaly as the element inside the selected image is changing. For this case, the moving vehicle detected from the image will produce significant changes between the background image and the selected image.

As the segmentation of background and foreground element occurred, the only conspicuous element that is left to be observed is the vehicle. Note that the segmentation process occurred in binary medium as the image gone through the thresholding which in this case appeared to be white and black. The hue and saturation of the RGB colour is eliminated but its luminance is conserve.

The foreground element that is detected is in white colour and the background image that is subtracted is in black colour. The purpose of making the image to appear in black and white is because to simplify the analysing process of the image without involving too many factors that needs to be considered such as the car's colour and the lighting effect.

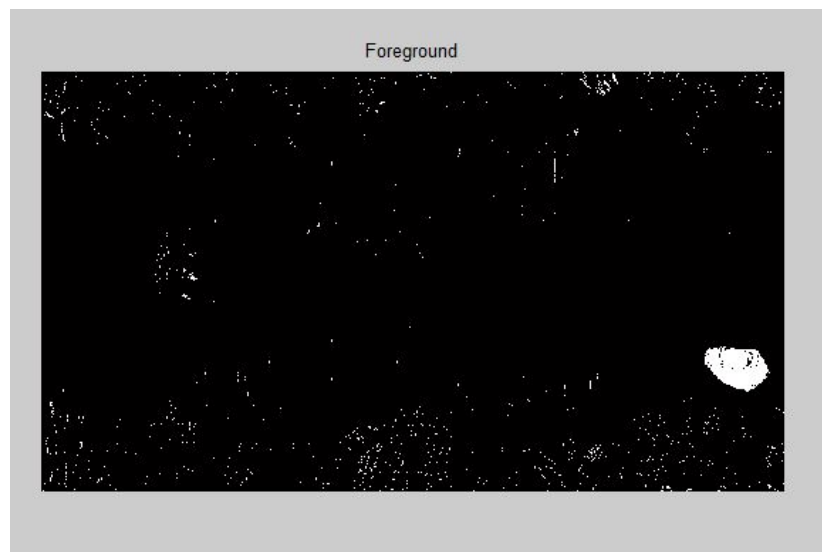


Figure 4.3: Foreground image of the frame after the background have been subtracted.

4.1.3 Constructing the Shape

When foreground image is opened with the morphological opening is performed, it is opened with the structural element applied to it. The opening process is done by applying erosion and then followed by the dilation to the image using the similar structural element for both operations.

Structural element is then used on the foreground image to get the shape or the structure of the object and also the clean foreground image without any other noise that disturbing the system. The structural element used for this simulation is the rectangle shape as it is the closest shape that is similar to the car detected from the foreground view. The shape that is acquired after implementing the structural element is constructed on the image can be seen in Figure 4.4.

The parameter used for the structural element is $MN = [12 \ 8]$. M element is representing the number of row covered in the structural element neighbourhood, while the N is representing the number of column.

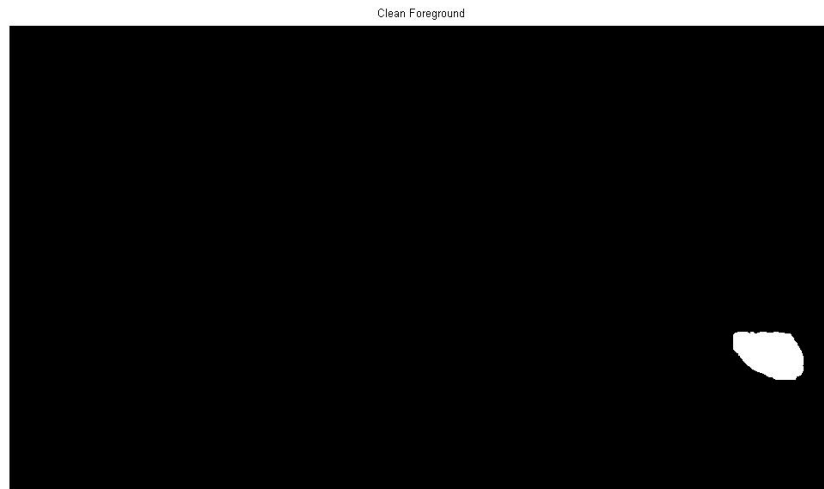


Figure 4.4: Clean foreground image after the structural element being applied.

4.1.4 Detecting the Object

Next, the bounding box of each connected component corresponding to a detected object is located by using `vision.BlobAnalysis` syntax. Blob analysis compute and return the statistic of the binary image concerning the properties set.

For this case the properties that are chosen to construct the bounding box of the detected car is `BoundingBoxOutputPort` and `MinimumBlobArea`. `BoundingBoxOutput` is used to give the output of the coordinate of the bounding box constructed around the detected car. It means that every constructed object during the structural element phase will produce it individual bounding box around them.

The `MinimumBlobArea` meanwhile specified the minimum blob area in the pixels that is allowed. 200 is the minimum blob area used for this project in order to filter the unnecessary disturbance that exists in the foreground image. The example can be seen in Figure 4.5, where there are noises that appeared on the foreground image even after the background element has being subtracted and segmented. The detection for bounding box created is done by selecting the allowing blob area and rejecting the blobs that have less than 200 pixels.

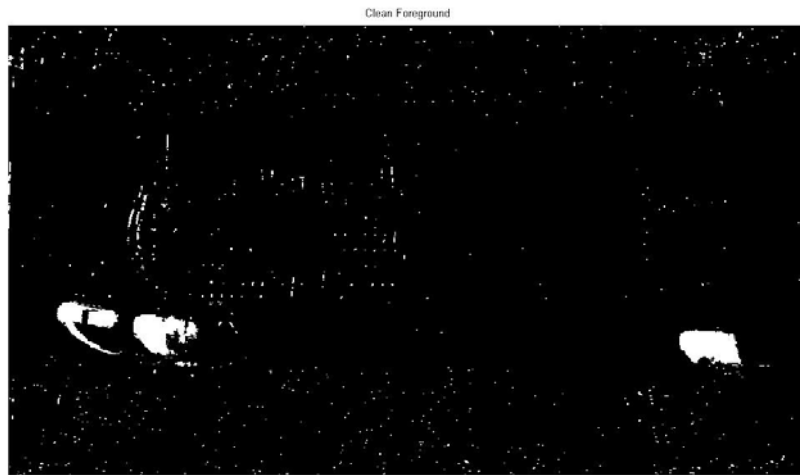


Figure 4.5: The noise existed in the clean foreground image after segmentation.