Multiple Vehicle Detection and Segmentation in Malaysia Traffic Flow

Ahmad Fariz Hasan[1], Mohd Fikri Che Husin[1], Khairul Affendi Rosli[1], Mohd Norhafiz Hashim[1] and Amar Faiz Zainal Abidin[2]

[1]Department of Electronic Engineering Technology, Faculty of Engineering Technology, Universiti Malaysia Perlis, Malaysia.
[2]Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal Melaka

E-mail: farizhasan@unimap.edu.my, fikri@unimap.edu.my, khairulaffendi@unimap.edu.my, mnorhafiz@unimap.edu.my, amarfaiz@utem.edu.my

Abstract. Vision based system are widely used in the field of Intelligent Transportation System (ITS) to extract a large amount of information to analyze traffic scenes. By rapid number of vehicles on the road as well as significant increase on cameras dictated the need for traffic surveillance systems. This system can take over the burdensome task was performed by human operator in traffic monitoring centre. The main technique proposed by this paper is concentrated on developing a multiple vehicle detection and segmentation focusing on monitoring through Closed Circuit Television (CCTV) video. The system is able to automatically segment vehicle extracted from heavy traffic scene by optical flow estimation alongside with blob analysis technique in order to detect the moving vehicle. Prior to segmentation, blob analysis technique will compute the area of interest region corresponding to moving vehicle which will be used to create bounding box on that particular vehicle. Experimental validation on the proposed system was performed and the algorithm is demonstrated on various set of traffic scene.

1. Introduction
Developments of Intelligent Transportation Systems (ITS) have received a lot of attention in recent years. ITS refers to a variety of tools, such as traffic engineering concepts, software, hardware, and communications technologies, that can be applied in an integrated fashion to the transportation system to improve services in transportation systems operations, such as traffic management, commercial vehicle operations, transit management, and information to travelers [1].

Rapid development of technologies and the emergence of a new information age offer a new dimension in the operation and management of transport systems and facilities. ITS involved the application and integration of advance communication, microprocessor and information technologies into transport systems to achieve efficient utilization of infrastructure and energy resources, to improve safety and reduce the environmental impact of traffic.

One of the most significant efforts in ITS is developing visual surveillance systems that help reduce numbers of traffic incidents and traffic jams in urban and highway scenario. There are many types of devices that has been used in traffic monitoring systems such as loop detectors, sensors and cameras but vision based analysis technique has only become popular recently in transportation management due to its capability to extract rich information of road traffic compared to other sensor based systems. Normally, the detection of vehicles based on traffic surveillance in highways is performed by human operator at control centers.

Vision based system is a promising alternative since it requires no pavement adjustments and has more potential advantages such as larger detection areas, more flexibility and affordable. At the same time the system performs better and provides good quality results.

However traffic flow raises interesting but difficult problems for image processing. The various light conditions and different weather circumstance places a strong need on the robust algorithms, which require a great amount of computational power to meet the real-time operations of the traffic monitoring system [2]. This work focused on developing multiple vehicle detection and segmentation to automatically detect moving vehicle based on automated vision system. This is initial step before it can be advance to another system such as travel speed estimation, vehicle tracking and classification and so on so forth.

2. Related Works

Recently the use of image processing in Intelligent Transportation Systems (ITS) has increased with tremendous usage in traffic monitoring. This situation led to increasing growth in research and development in this field. Most of the research and development are strongly motivated by significant increase in the number of vehicles, change in population density and as well as urbanization.

Common techniques used for vehicle detections and segmentation can be summarized as follows: Background subtraction and Frame differencing. A. Elgammal et al. [3] introduces background subtraction where technique involves is subtracting the observed image from the estimated image and threshold the result to generate the detect vehicles. This technique can be used to detect and segment both static and moving vehicles but it depends on the background modeling technique. If the background is updated periodically then only vehicle in motion can be detected because static vehicle will become part of the background. Shuguang Zhao et al. [4] introduce frame differencing method which is almost similar to background subtraction technique. The only different in this technique is, it does not use specific background frame (without vehicles) for subtraction. This technique is robust to environmental change, but unable to detect stationary vehicles.

Several studies exist in the literature on automatic video analysis for vehicle detection and segmentation. Techniques explained earlier alone are insufficient to extract traffic flow measurements, thus, most of the work incorporates additional algorithms such as tracking, occlusion removal and etc which are essential for extracting traffic flow parameters. Goo Jun et al. [5] presented a method where the occlude vehicles were divided into many small patches and group the patches according to the clusters of motion vector found by tracking features point. Their proposed system is constructed in several steps which are: background subtraction, occlusion detection, motion analysis and vehicle segmentation.

In [6] vehicle counting method based on blob analysis and feature based tracking is presented. The proposed algorithm is composed of three steps, moving object segmentation (background subtraction), blob analysis, and tracking. A vehicle is modeled as a rectangular patch and classified via blob analysis. Through blob analysis feature such as texture, color and shape are extracted. Those features used to discriminate different objects at the same frame and to recognize the same object at different time which is important for counting. Tracking moving targets is achieved by comparing the extracted features and measuring the minimal distance between two temporal images.

3. Research Methodologies

The basic idea of the vehicle segmentation and tracking was to use three major techniques which are optical flow, morphology and Blob Analysis.

3.1 Grayscale

Processing a color image is three times slower as it has to be performed on three different layers. Besides that, a color image also requires three times the memory space compared to a gray level image. These drawbacks are definitely undesirable for real-time application especially when the color information in not required. For an input video, the first step is to generate its gray scale value from the video itself. Since some cameras capture color images, this process is significant because it removes 24-bit color value and converts them into 8-bit gray level image. This is necessary since gray scale contains the value of each pixel in a single sample which means it carries only intensity information and makes it easier for further analysis.

3.2 Optical Flow Estimation

In this paper, optical flow is used to estimate the velocities of vehicle prior for segmentation. There are two methods widely used to compute optical flow estimation which are Lucas Kanade method and Horn Schunck method. For this work, Lucas Kanade method has been choosen. Optical flow is a pattern of apparent motion of object in a visual scene caused by the relative motion between an observer and the scene. The sequences ordered of image allow the estimation of motion image velocities. The optical flow methods try to calculate the motion between two image frames which are taken at time 't' and 't+1' at every pixel position].

A common starting point, for optical flow estimation is to assume that pixel intensities are translated from one frame to the next,

$$I\left(\vec{x},t\right)=I\left(\vec{x}+\vec{u},t+1\right) \tag{1}$$

Where $I\left(\vec{x},t\right)$ is image intensities in the function of space $\vec{x}=(x,y)^{\mathrm{T}}$ and time t, and $\vec{u}=(u_1,u_2)^{\mathrm{T}}$ is the image velocities. Given a pixel P, all the pixels in the neighbourhood of P have the same velocity as P. Consider a $m\times m$ window $m>1$, centred at pixel P, the following equation can be formulated as,

$$I_{x1}V_x+I_{y1}V_y=-I_{t1} \tag{2}$$
$$I_{x2}V_x+I_{y2}V_y=-I_{t2} \tag{3}$$
$$I_{xn}V_x+I_{yn}V_y=-I_{tn} \tag{4}$$

Where Vx and Vy are the components of the velocity of optical flow associated with the considered voxel, respectively laying on the X axis and on the Y axis. From the equation above, there are more than two equations; therefore it can be represented in matrix form. Hence,

$$\begin{bmatrix}I_{x1} & I_{y1}\\ I_{x2} & I_{y2}\\ \vdots & \vdots\\ I_{xn} & I_{yn}\end{bmatrix}\begin{bmatrix}V_x\\ V_y\end{bmatrix}=\begin{bmatrix}-I_{t1}\\ -I_{t2}\\ \vdots\\ -I_{tn}\end{bmatrix} \tag{5}$$

Or equivalently it can be written as;

$$A\vec{v}=-b \tag{6}$$

Using least square method;

$$A^T A \vec{x} = A^T(-b) \text{ or } \vec{v} = \left(A^T A\right)^{-1} A^T (-b) \tag{7}$$

Or equivalently it can be written as;

$$\begin{bmatrix} V_x \\ V_y \end{bmatrix} = \begin{bmatrix} \Sigma I_{xi}^2 & \Sigma I_{xi} I_{yi} \\ \Sigma I_{xi} I_{yi} & \Sigma I_{yi}^2 \end{bmatrix}^{-1} \begin{bmatrix} -\Sigma I_{xi} I_{ti} \\ -\Sigma I_{yi} I_{ti} \end{bmatrix} \tag{8}$$

With the summation running from 1 to n. Therefore the value of velocity between frame to frame can be computed here.

In another word, equation 1 can be writen as follows;

$$f(u, v) = \iint \left(I_x u + I_y v + I_t\right)^2 dxdy) \tag{9}$$

Equation 7 is integrated with respect to the dimension of W. Assuming the velocity is the same all over W, that is u and v do not depend upon dx nor dy, therefore it can be writen as the following system,

$$u \iint I_x^2 dxdy + v \iint I_x I_y dxdy + \iint I_x I_t dxdy = 0 \tag{10}$$

$$u \iint I_x I_y dxdy + v \iint I_y^2 dxdy + \iint I_y I_t dxdy = 0 \tag{11}$$

This technique will estimate the motion of vehicles velocities based on image sequences. The motion of vehicles in a visual scene is caused by the relative motion between an observer and the scene.

3.3 Threshold

Thresholding is required to perform segmentation on the basis of the different intensities or colors in the foreground and background regions of an image. Thresholding is a pixel point operation that performs a comparison on each pixel value to determine if the intensity value is above or below an input threshold variable Tval. The goal of thresholding is to partition an image into regions that separates objects from the background. In this project, global thresholding will be used. Global thresholding uses a fixed threshold for all pixels in the image and therefore works well only if the gray-level distribution histogram contains distinctively separated peaks corresponding to the objects and background. It will creates a binary image from optical flow estimation by turning all pixels below a certain threshold value to 0 and value above threshold to 1 whereby 0 will represent black image while 1 will refer to white image.

Morphological dilation and erosion are performed to obtain a clear and filled region upon the obtained result from threshold technique. Square structuring element is used for one time. Median filter was been used in filtering process in order to remove some of the unwanted noise from threshold result.

Once the threshold is cleared and the region is filled from morphological process, blob analysis is used to compute statistic for connected regions in a binary image. In this work, blob analysis technique has been set to calculate the area of connected region. It will scan through the entire pixel to determine the connected region based on threshold in order to determine whether the interested value is belong to moving vehicle or not. As the result from the blob analysis is figure out, the segmentation process will take place to detect the vehicle.

3.4 Segmentation

Segmentation process is the last part of the algorithm which is to distinguish the objects of interest from the background and unwanted objects. This part of processing is responsible to identify the moving vehicle from the static objects or the background. Segmentation is preferred based on optical flow estimation as discussed earlier. It involves, partitioning an image into groups of pixels which are homogeneous with respect to some criterion. Different groups must not intersect each other and adjacent groups must be heterogeneous. The bounding boxes were determined based on the ratio of interested region when performing blob analysis.

4. Experiments and Results

The video is captured using a camera video with a resolution 384×288 pixel from a fixed distance. The distance between camera and the target object is an important factor as the ratio of object size in pixels over the real size varies. The algorithm was tested on two different video sequences. Table 1 shows video specification on different frame.

Table 1. Video specification of test samples

Video	Length	Size	Frame Number	No. of Vehicle
1	29 sec	384 x 288	166	17
			212	15
			221	14
2	16 sec	384 x 288	48	26
			77	28
			141	24

4.1 Analysis from video 1

Figure 1 shows the result obtained for video 1. It can be summarized in Table 2. Some of the vehicles are not detected and segmented due to occlusion. This is due to the fact that the vehicles are moving together. This is one of the problems using optical flow that need further research in the future.

Table 2. Comparison for analysis 1

Frame Number	Manual Inspection	Proposed Algorithm	Correctness (%)
166	17	6	35.0
212	15	7	46.6
221	14	7	50.0

4.2 Analysis from video 2

Figure 2 shows the results obtained for video 2. It can be summarized in Table 3. Some of the vehicles are not detected and segmented due to some of the vehicles are far at the back, and are just about to start moving. The optical flow technique is only able to segregate out the moving vehicles only. This technique is not robust when applied on stationary vehicles.

Table 3. Comparison for analysis 2

Frame Number	Manual Inspection	Proposed Algorithm	Correctness (%)
48	26	9	36.6
77	28	14	50.0
141	24	14	58.3

4.3 Comparison between Proposed Algorithm and other technique when tested with different resolution.

As can be seen, the proposed technique show the promising result compare to other technique where in this work, other technique developed is used foreground detection technique [8]. Table 4 and 5 shows the evaluation on the different technique while running on the different video resolution. Furthermore, while running on high resolution video, the result is much better because the video resolution is much more clearer compare to the one that has been compressed but the trade of is, it required huge computation time in order to complete for 1 video since it consist up to millions of pixel in one frame. For video number one, it requires 15 minutes while for video two is up to 10 minutes to complete the task. Figure 3 and Figure 4 shows the result obtained for video 1 and video 2 respectively.

Table 4. Comparison using different technique on different resolution video for video 1

| Case Study	Evaluation of vehicle detection			
	Proposed Algorithm (Optical Flow Technique)		Other Algorithm (Foreground Subtraction Technique)	
Manual Inspection	CCTV	HD	CCTV	HD
28	15	22	8	6
Frame Number	257	257	257	257
Percentage of Inspection (%)	53.57	78.57	28.57	21.43

Table 5. Comparison using different technique on different resolution video for video 2

| Case Study	Evaluation of vehicle detection			
	Proposed Algorithm (Optical Flow Technique)		Other Algorithm (Foreground Subtraction Technique)	
Manual Inspection	CCTV	HD	CCTV	HD
28	15	22	8	6
Frame Number	316	316	316	316
Percentage of Inspection (%)	53.57	78.57	28.57	21.43

(a)

(b)

(c)
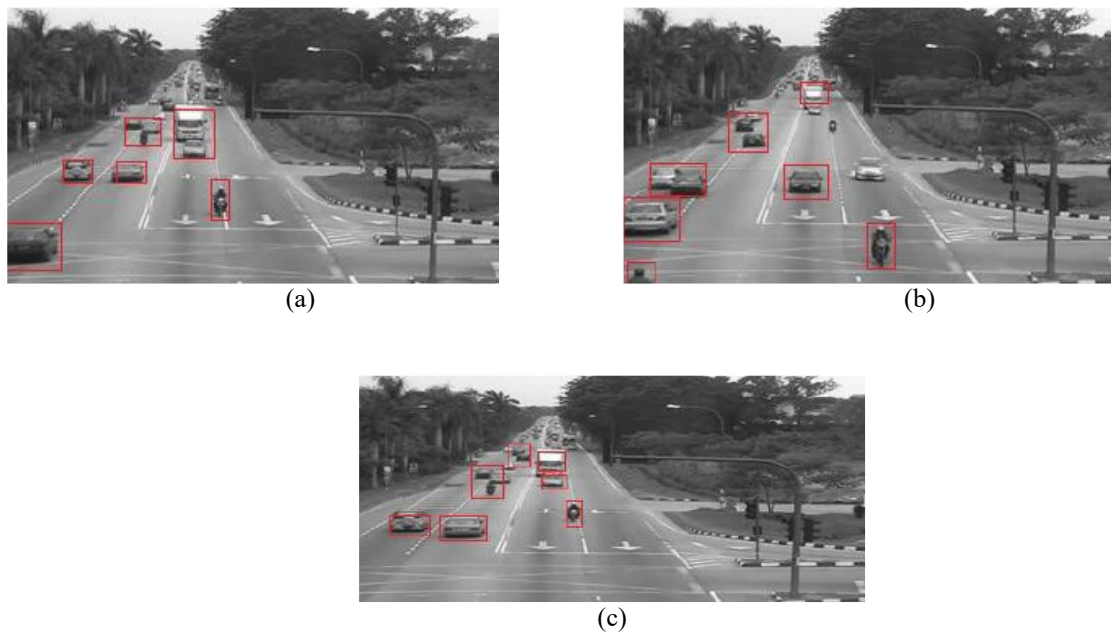
Figure 1: Result from video 1 (a) Frame 166 (b) Frame 212 (c) Frame 221

(a)

(b)

(c)
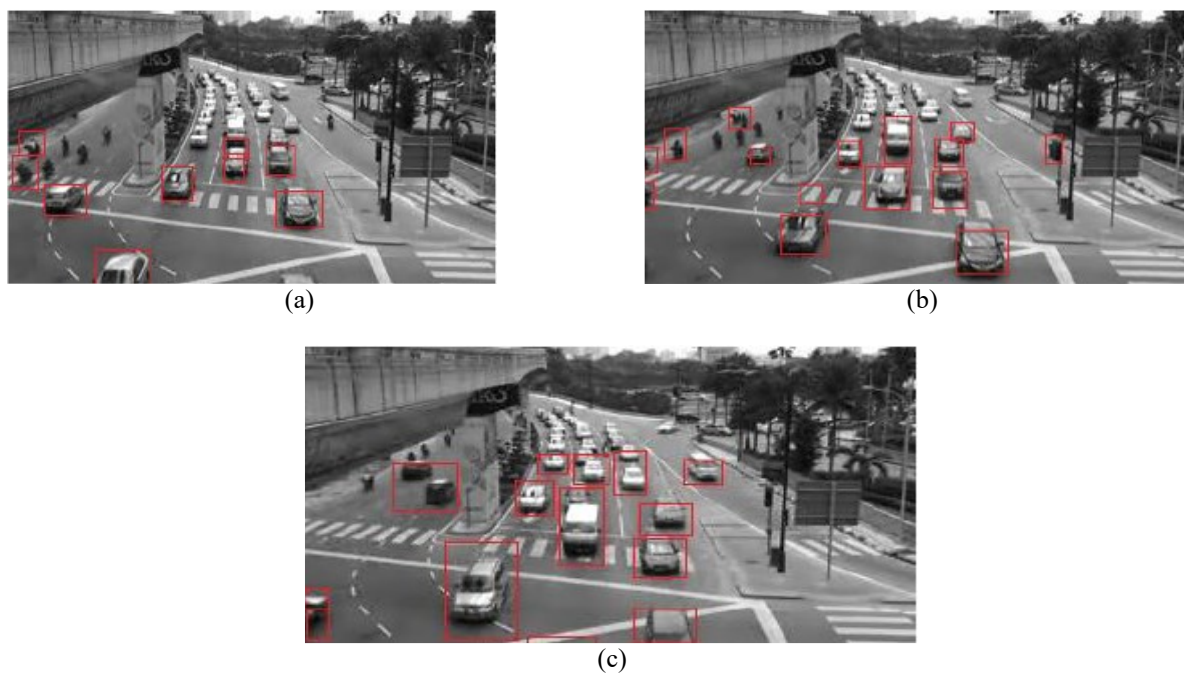
Figure 2: Result from video 2 (a) At frame 48 (b) At frame 77 (c) At frame 141
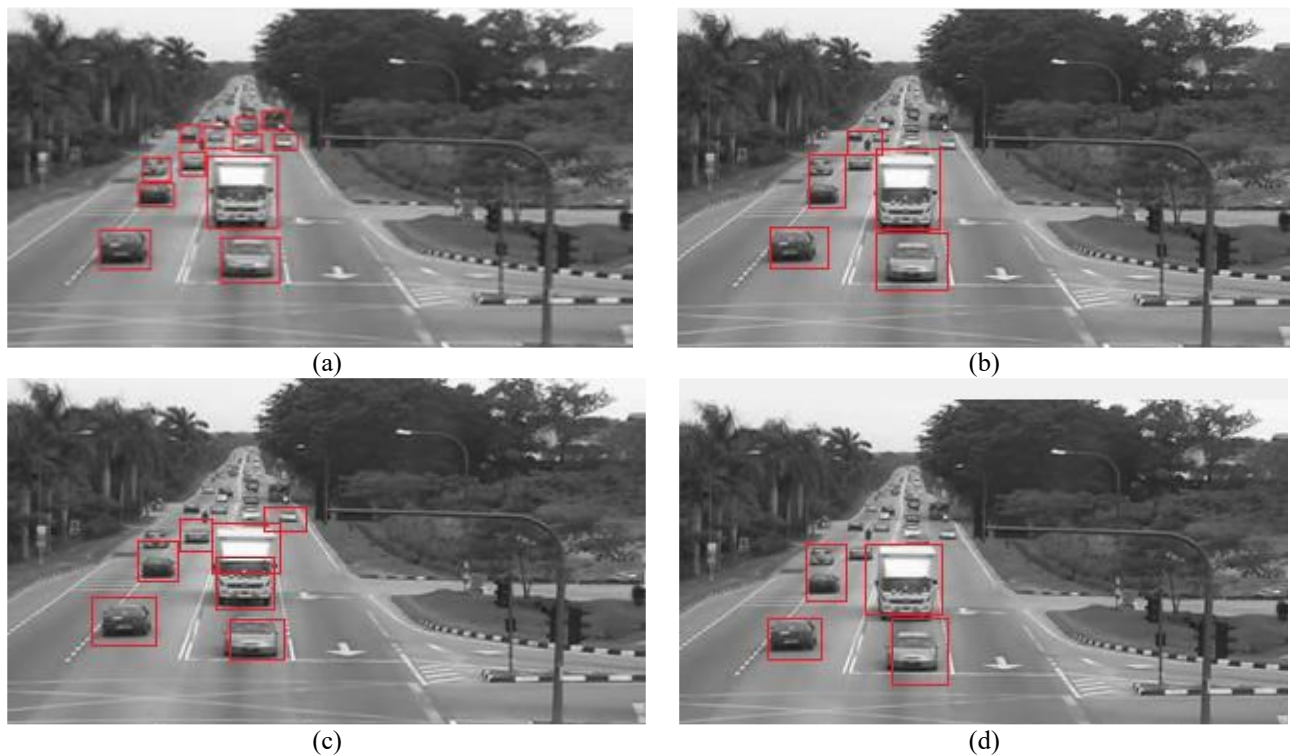
Figure 3: Result for video 1, (a) using optical flow on HD resolution, (b) using optical flow on CCTV video, (c) using foreground detection on HD resolution, (d) using foreground detection on CCTV video

Figure 4. Result for video 2, (a) using optical flow on HD resolution, (b) using optical flow on CCTV video, (c) using foreground detection on HD resolution, (d) using foreground detection on CCTV video.

5. Conclusion

In this study, the algorithm has been has successfully implemented using MATLAB 2010. As a result, the algorithm is able to detect and segmented moving vehicles, as long as the targeted objects appear fully within the camera view range. Although the algorithm has a reasonable success rate, the algorithm has various limitations and does not perform well on stationary vehicles and occlusion. Thus the performance can be improved and the present algorithm can be further developed for better reliability and effectiveness. Even the HD resolution gives better result but in order to achieve real-time performance, the algorithm was tested on CCTV video which greatly reduces processing time.

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