Vehicle Detection and Tracking using Gaussian Mixture Model and Kalman Filter

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***Abstract*—Intelligent Transport System (ITS) is a method used in traffic arrangements to make efficient road transport system. One of the ITS application is the detection and tracking of vehicle objects. In this research, Gaussian Mixture Model (GMM) method was applied for vehicle detection and Kalman Filter method was applied for object tracking. The data used are vehicles video under two different conditions. First condition is *light traffic* and second condition is *heavy traffic.* Validation of detection system is conducted using Receiver Operating Characteristic (ROC) analysis. The result of this research shows that the light traffic condition gets 100% for the precision value, 94.44% for sensitivity, 100% for specificity, and 97.22% for accuracy. While the heavy traffic condition gets 75.79% for the precision value, 88.89% for sensitivity, 70.37% for specificity, and 79.63% for accuracy. With avarage consistency of Kalman Filter for object tracking is 100%.**

Keywords— Intelligent Transport System, Gaussian Mixture Model, Kalman Filter, Video

I. INTRODUCTION

Recently, the technological advance in various fields is growing rapidly, particularly in the field of transport, namely Intelligent Transport System (ITS). ITS is a method used traffic arrangements to make efficient road-based transport system and it has been applied in the developed countries. Example of ITS application is the use of CCTV cameras for surveillance. The transportation authority and decision-makers can easily obtain data to be used in traffic engineering, such as data on the number of vehicles and vehicle speed.

To obtain data on the number of vehicles and vehicle speed through CCTV, the first thing to be done is to detect vehicle object. There are several methods that can be used for vehicles detection such as Histogram of Oriented Gradient (HOG), Viola Jones and GMM [1] - [3]. Object detection through CCTV is done by distinguishing between object to be detected with other objects. HOG and Viola Jones are detection methods that relying on existed database in detection process. This database consists of two forms of data i.e. positive and negative database. Positive database is collection of data that contain the object to be detected, while the negative database is collection of data that does not contain the object to be detected. This scenario of data distinction is usually applied to detect objects from image. GMM method is detection method that compares between foreground object (moving object) and background object (stationary object). This approach is usually applied for detecting object within a video. The second thing besides vehicle detecting is tracking the object in traffic surveillance using CCTV. One of the methods that can be used in object tracking is Kalman Filter method [4]-[6].

In this research, vehicle detection is conducted using GMM method combined with object tracking with Kalman Filter. Combining those techniques are expected to achieve higher accuracy in system detection. The rest consecutive subsection in this paper are as follows: Methodology, Discussion and Conclusion.

II. METHODOLOGY

This research used (**.mov**) format video as input with frame rate of 25 fps and resolution of 640 x 480. Data was taken from top of a pedestrian bridge with static camera position. The steps of the research were described in the following block diagram.

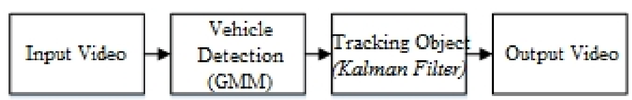

FIGURE 1. SYSTEM BLOCK DIAGRAM

Based on the figure 1, first step is video preparation as input for the system. Next step is Vehicle detection using GMM method. In this step, foreground objects and background objects were separated. The object detected as vehicle was marked with bounding box. The last step was tracking the detected object in each frame using Kalman Filter.

Figure 2 shows the whole flowchart of vehicle detection system. The steps of vehicle detection system shows in the flowchart are discussed as follows.

A. Extract Frame

The first step was to process vehicle video. Video is a collection of several frames. The longer the duration of a video, the bigger number of frames it contained. Video then

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extracted to become several frames and processed one by one until last frame in the video. As shown in Figure 2, each frame was processed sequentially until last frame in the video.

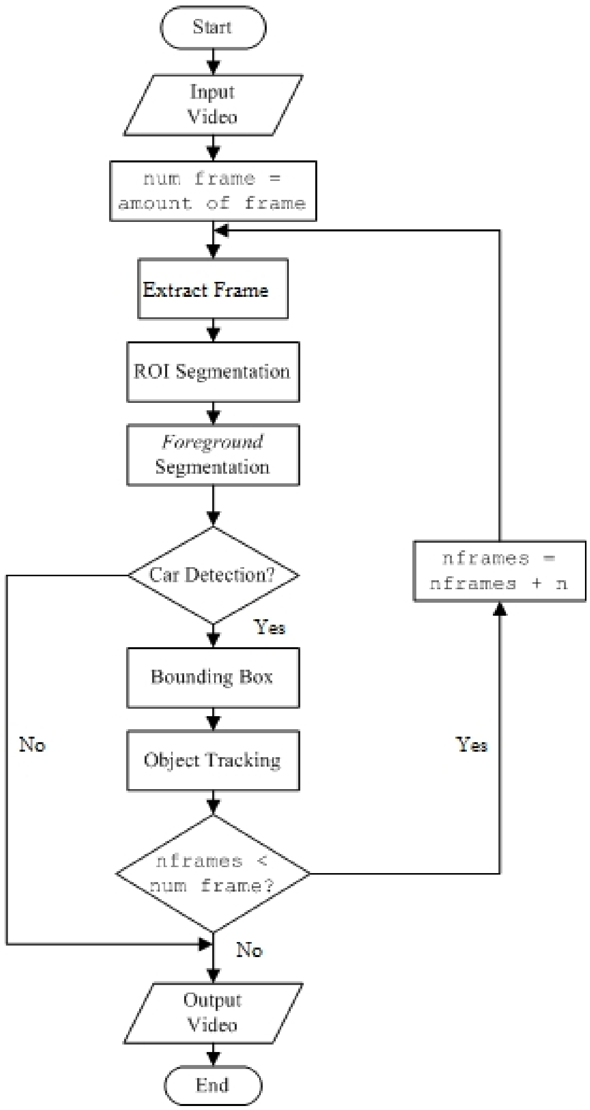

FIGURE 2. FLOWCHART OF CAR DETECTION SYSTEM

B. ROI Segmentation

Region of Interests (ROI) is area that contains the object to be detected [6]. ROI segmentation is needed to limit the area to be processed. The first step in ROI segmentation is determining the positions of polygon pixel that will be used to cover an area that is not an observation point of detection. The second step is closing the *Non-Region of Interest* area with polygon made previously. *Non – Region of Interest* area will be considered as background, so the object that passing through this area will be ignored. Figure 3 shows the ROI segmentation on the frame of input video. Figure 3(a) is original image before given the limited of area. Figure 3(b) shows the limit of ROI and Non-ROI areas.

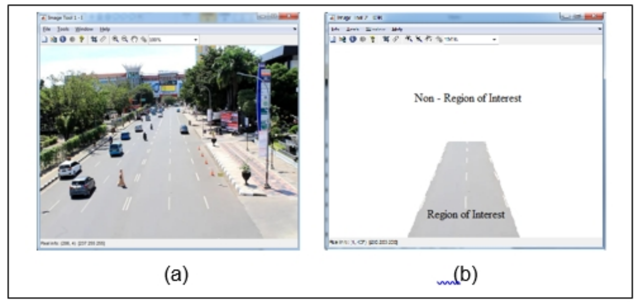

FIGURE 3. ROI SEGMENTATION. (A) ORIGINAL IMAGE, (B) REGION OF INTEREST AREA

C. Gaussian Mixture Model (GMM)

GMM is a density model that consists of several Gaussian component functions. This method can perform well when used for extraction process of background because its reliability against the changes in light and condition during repeated object detection [3]. Pixel in the video scene is modeled in Gaussian distribution. Each pixel in the frame was compared with model formed from GMM. Pixels with similarity values under the standard deviation and highest weight factor were considered as background, while pixels with higher standard deviation and lower weight factor considered as foreground [7].

Pixel then categorized into one of GMM candidate model. If the color of pixel is categorized as a background model then the pixel will be given zero (0) or black color. While the pixel is uncategorized in background model then it will be considered as foreground and given one (1) or white color. Then, the resulting binary image will be processed further. Foreground is a moving object and changing position in every frame of video (dynamic), while background is an object with the position unchanged in every video frames (static) [3].

After foreground object detected, the filter process is done to fill the hole on the foreground object. This research uses morphology process to filter the noise and fill the hole on the detected object.

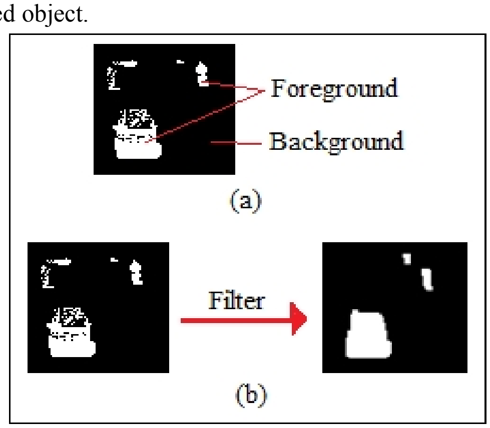

FIGURE 4. MORPHOLOGY PROCESS FOR FOREGROUND DETECTION. (A) FOREGROUND AND BACKGROUND, (B) FILTER.

Figure 4(a) shows the foreground object and detected background. At the point (a) shows that there are holes on the foreground object. In order to clarify the foreground object was detected then the morphology process was performed. Morphology operation is a filter that combines between erosion and dilation process in binary or grayscale image. Filtering on the morphology process is showed in figure 4(b).

D. Car Detection

The detected foreground object is adapted with blob area. The object corresponding with blob area is detected as the vehicle object and marked by a bounding box. While the object detected as foreground but not corresponding with blob area will be ignored and is not marked by a bounding box. Figure 5 shows that the vehicle object is detected and marked by a bounding box.

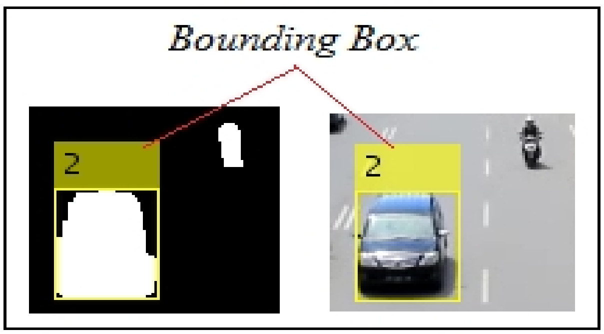

FIGURE 5. BOUNDING BOX

E. Kalman Filter

After the vehicle object was detected, the system then proceeds with object tracking. Object tracking is a method in vision computer to find the location of detected object [8]. In this research, Kalman Filter method was used for object tracking. Kalman filter is a well-performed recursive method used to track the object in video frame [4],[9]. Kalman filter uses information of detected object on the previous frame and provides the new position estimation of the object.

Kalman filter consists of two steps namely prediction and correction [6], [9]. The prediction step is responsible for projecting the future condition and the current object position. While correction step provides reciprocity, namely combines the actual measurement with the prior estimation for getting improved posterior estimation [6].

III. RESULT

This research uses video data with .mov format and a resolution of 640 x 480 pixels. Data retrieval was done on the roadway in urban area with observing two conditions, i.e. light traffic and heavy traffic.

The used method is Gaussian Mixture Model (GMM) for detection object and kalman filter for tracking objects. Object detection in the video is determined based on the foreground size. Causes of error detection on GMM methods include shadow vehicle is detected as an object and two adjacent vehicles are considered as a single object [10]. Under these conditions, data collection was done during the day with a consideration of light.

Determining ROI boundary performed before object detection, called segmentation ROI, to filter unneeded object area. In this study, the area outside the boundaries of the ROI is called Non-ROI area. Moving object in the area of Non-ROI will be ignored and considered as a background. Segmentation ROI will determine boundary pixel positions of the non-ROI area.

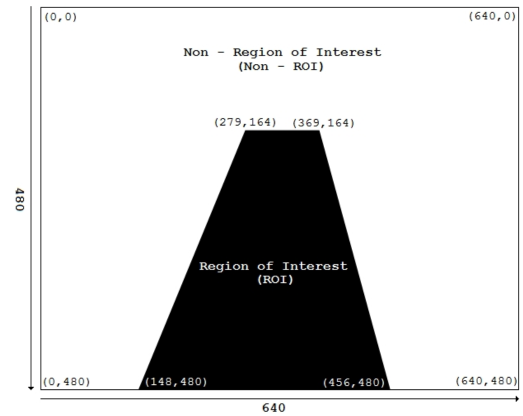

FIGURE 6. PIXELS POSITION OF NON – ROI AREA BOUNDARY

Figure 6 shows the pixels position of Non – ROI area. After determining the pixels position of Non – ROI area boundary, then the next is created the polygon for covering the area. The next step detects object using GMM.

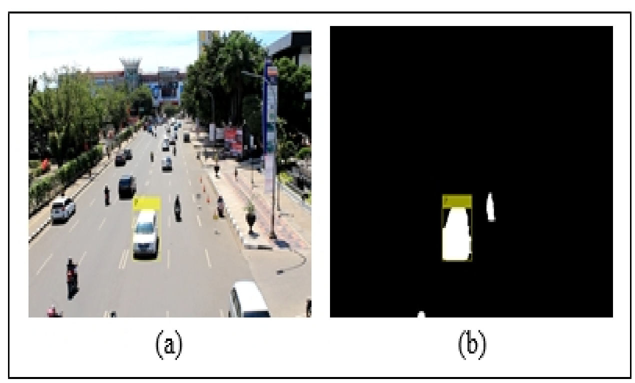

FIGURE 7. OBJECT DETECTION IN THE LIGHT TRAFFIC CONDITION.
(A) ORIGINAL IMAGE, (B) BINARY IMAGE

Figure 7 shows the detection of vehicle object using GMM for light traffic condition. GMM method detects the moving object based on the blob size of foreground that has been detected. When foreground fulfill the size of the blob, it will be treated as an object and a given bounding box. Otherwise, the object will be ignored as shown in Figure 7 (b). In light traffic condition, vehicles were seen clearly separated so that no error detection.

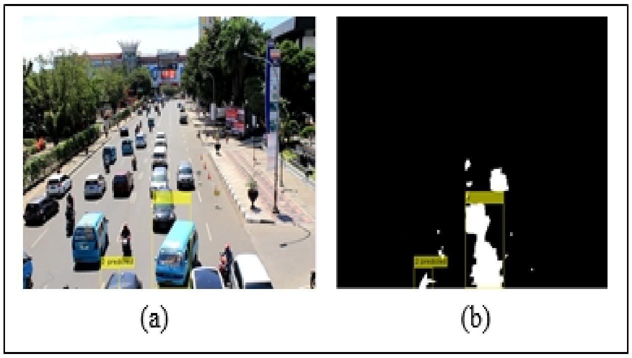

FIGURE 8. OBJECT DETECTION IN THE HEAVY TRAFFIC CONDITION
(A) ORIGINAL IMAGE, (B) BINARY IMAGE

Figure 8 shows vehicle detection in the heavy traffic condition. Figure 8(a) indicates that the vehicle is overlap with another vehicle, so that two adjacent vehicles are detected as single object, such as showed on figure 8(b).

Performance of detection system is measured by *Receiver Operating Characteristic* (ROC) analysis. The parameters in the ROC analysis are TP (*True Positif),* FN (*False Negative*), FP (*False Positive*) and TN (*True Negative*). The system performance is determined by equation below.

Precision / Positive Predictive Value (PPV):

$$Precision(PPV) = \frac{TP}{TP + FP} \quad \ldots\ldots\ldots\ldots (1)$$

Specificity / True Negative Rate (TNR):

$$Specificity(TNR) = \frac{TN}{N} = \frac{TN}{FP + TN} \quad \ldots\ldots\ldots\ldots (2)$$

Sensitivity / Recall / True Positive Rate (TPR):

$$Recall(TPR) = \frac{TP}{P} = \frac{TP}{TP + FN} \quad \ldots\ldots\ldots\ldots (3)$$

Accuracy:

$$Accuracy = \frac{TP + TN}{TP + FN + FP + TN} \quad \ldots\ldots\ldots\ldots (4)$$

TABLE I. THE RESULT OF DETECTION SYSTEM

No	Video Name	Traffic Condition	Real Object	Object Detection				PPV %	TPR %	TNR %	ACC %
				TP	FP	FN	TN				
1	Cyber_1.mov	Light Traffic	4	4	0	0	4	100,00	100,00	100,00	100,00
2	Cyber_2.mov	Light Traffic	6	5	0	1	6	100,00	83,33	100,00	91,67
3	Cyber_3.mov	Light Traffic	4	4	0	0	4	100,00	100,00	100,00	100,00
Average								100,00	94,44	100,00	97,22
4	Cyber_4.mov	Heavy Traffic	6	6	1	0	5	85,71	100,00	83,33	91,67
5	Cyber_5.mov	Heavy Traffic	9	6	2	3	7	75,00	66,67	77,78	72,22
6	Cyber_6.mov	Heavy Traffic	8	8	4	0	4	66,67	100,00	50,00	75,00
Average								**75,79**	**88,89**	**70,37**	**79,63**

Table I shows that precision value for light traffic is 100% while for heavy traffic is 75.79%. Sensitivity value for light traffic is 94.44% while for heavy traffic is 88.89%. Specificity value for light traffic is 100% while for heavy traffic is 70.37%. System accuracy for light traffic is 97.22% while for the heavy traffic is 79.63%. This proves that GMM method is better for the light traffic condition.

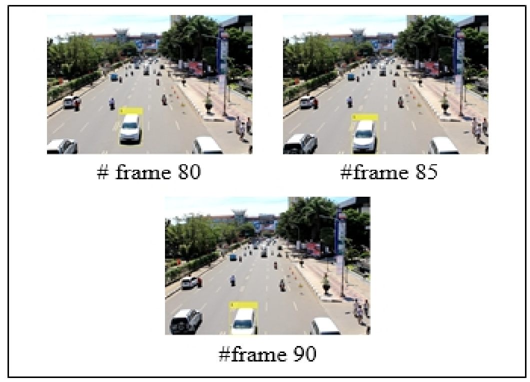

FIGURE 9. DETECTED VEHICLE IN EACH FRAME

Figure 9 shows the detected vehicle in each frame. The vehicle began to be detected on frame 80 until frame 90. With using the tracking object so will be known that detected object on the first frame is the same with detected object on the next frame.

Validation of tracking object is calculated by the consistency of tracking object ID prediction in percentage that calculated using the formula as follows.

$$\%\,consistency = \frac{\sum_{n=1}^{N}\left(\frac{P_n}{D_n} \times 100\%\right)}{N} \quad \ldots\ldots\ldots\ldots (5)$$

where :

P_n = Number of n[th] ID prediction consistency
D_n = Data number of n[th] ID
N = ID total in video

Test result of tracking object system for seeing the consistency prediction using Kalman filter method is showed in Table II.

TABEL II. THE RESULT OF TRACKING OBJECT SYSTEM

No	Frame	Object ID		Consistency %
		Actual ID	Predict ID	
1	80	1	1	100
2	85	1	1	
3	90	1	1	
4	95	1	1	
5	100	1	1	
6	210	2	4	100
7	215	2	4	
8	220	2	4	
9	225	2	4	
10	230	2	4	
11	285	3	5	100
12	290	3	5	
13	295	3	5	
14	300	3	5	
15	305	3	5	
16	340	4	7	100
17	345	4	7	
18	350	4	7	
19	355	4	7	
20	360	4	7	
Average				100

Tabel II shows that the percentage of consistency prediction using kalman filter method reaches 100%. This proves that this method is appropriate to used for tracking object.

IV. CONCLUSIONS

The research is conducted using data of vehicle video and divided into two conditions i.e. light traffic and heavy traffic. The detection object uses Gaussian Mixture Models method and the tracking object uses Kalman filter method. System validation for detection object is conducted with using ROC analysis the parameters of precision, sensitivity, specivisity and accuracy. Light traffic condition obtains the precision of 100%, sensitivity of 94.44%, specificity of 100% and accuracy of 97.22%. While for heavy traffic condition obtains the precision of 75.79%, sensitivity of 88.89%, specificity of 70.37% and accuracy of 79.63%. The consistency of tracking object reaches 100%. The results show that GMM method working properly in light traffic.

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