

Original Research Paper

Multiple Vehicle Tracking using Adaptive Gaussian Mixture Model and Kalman Filter

Fandy Setyo Utomo

Department of Information System, STMIK AMIKOM Purwokerto, Purwokerto, Indonesia

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Email: fandy_setyo_utomo@amikompurwokerto.ac.id

Abstract: Based on data from the Central Statistics Agency (BPS) of the Republic of Indonesia in catalog Crime Statistics in 2014, the number of crimes of theft of motor vehicles has increased since 2010 until 2013. Recorded in 2013 the number reached 42.508 cases of theft. In this study, we made a prototype application using Adaptive Gaussian Mixture Models algorithms and the Kalman Filter to detect the movement of the vehicle in order to prevent vehicle theft. Adaptive Gaussian Mixture Models were used for image segmentation foreground and background, while the Kalman Filter was used to track the vehicle. Stages in this study consisted of two phases, namely the manufacture of prototype and testing of prototype applications. Testing was done by observing the resource usage of memory (RAM) and the processor when the application was executed and the speed and degree of vehicle motion detection accuracy. The test results showed that the prototype application using Adaptive Gaussian Mixture Model and Kalman Filter had an accuracy rate of 90% and a high speed in detecting motion with the use of vehicles under 65000 KB RAM and processor work load below 27% on condition vehicles that have mutual occlusion.

Keywords: Vehicle Detection, Vehicle Tracking, Adaptive Gaussian Mixture Model, Kalman Filter

Introduction

Based on data from the Central Statistics Agency (BPS) in 2014, number of motorists increased quite rapidly on the number of users of cars and motorcycles in Indonesia. In 2013, there were 11.484.514 units and 84.732.652 units of motorcycles. It was directly proportional to the increase in the number of motor vehicles, the increase in the number of crimes of theft of motor vehicles according to BPS in catalog Crime Statistics in 2014, also increased. In 2010 there were 35.688 cases, in 2011 there were 39.217 cases, in 2012 there were 41.816 cases and in 2013 there were 42.508 cases of theft.

An increasing number of crimes of theft of motor vehicle become a social problem that must be resolved. In this study, we aimed to make a prototype vehicle tracking applications using Adaptive Gaussian Mixture Model and Kalman Filter Algorithm to prevent theft of vehicles. Adaptive Gaussian Mixture Model is used for image segmentation foreground and background, while Kalman Filter is used for tracking vehicles.

Researches conducted by (Barcellos *et al.*, 2015; Sutjiadi *et al.*, 2015; Han *et al.*, 2015) used a Gaussian Mixture Model (GMM) to detect the object vehicle. According to Zivkovic (2004), GMM weaknesses are not able to adapt to changing lighting environments, such as the lighting changes when the weather changes, changes due to lighting in the indoor environment and the time change from daylight to night. Due to changes in ambient lighting can cause the appearance of new objects in the scene, for example, the shadow image of the foreground. Research conducted by Ma and Zhang (2015) developed a model to detect vehicle with GMM. They combined GMM with frame difference. However, based on research by Benezeth *et al.* (2010), the frame difference algorithm had shortcomings, namely the foreground and the background image segmentation had less good results on a video that had a high noisy. In addition, the algorithm had a low level of precision in grayscale videos. The development of GMM algorithm to detect objects was carried also by Hu and He (2016). They combined GMM algorithm with Three-Frame

differencing techniques that had been modified to image segmentation foreground and background. Then, the shadow removal of the foreground image used technique of HSV Space. Adaptive GMM used in this study was to image segmentation foreground and background. Adaptive GMM is proposed by Zivkovic (2004). Adaptive GMM advantages compared with GMM, the Adaptive GMM has the ability to identify and eliminate the shadow of the foreground image, have the result of the foreground and background image segmentation better with time computing faster than GMM (Zivkovic, 2004; Zivkovic and van der Heijden, 2006). Based on research conducted by Alavianmehr *et al.* (2015) concerning the application of Adaptive GMM to detect vehicles in highway traffic surveillance, the result showed that Adaptive GMM had a high degree of accuracy with low resource used in detecting the vehicle.

Research on Multiple Vehicle Tracking, had been conducted by Lin and Chen (2014) using the Kalman Filter algorithm and GMM. GMM was used for image segmentation, while the Kalman Filter was used for tracking vehicles. Their results showed that the use of two algorithms was less accurate in detecting vehicles in different conditions of mutual occlusion. The approach was done by Srilekha *et al.* (2015). They used Kalman filter for detecting and tracking vehicles. The test results showed that the algorithm had reached 97.5% accuracy rate in detecting and tracking vehicles in conditions without mutual occlusion with normal lighting.

Adaptive GMM and Kalman filter algorithm is proposed in this study for detecting and tracking vehicles. In this study the measurement was done by the level of accuracy and speed of vehicle motion detection and the use of processor resources and Physical Memory (RAM) that was used when the algorithms were executed.

Research Method

Research Method Stages

Some stages of the research, described in Fig. 1.

Starting from the research stage to build prototype applications to test the prototype. First Prototype application used GMM algorithm and Kalman Filter, second prototype application used the Kalman Filter algorithms and third prototype application used Adaptive GMM and Kalman Filter. The third prototype application is the model proposed in this study. The third prototype was then tested to observe the performance of each in detecting and tracking vehicles.

Proposed Mechanism of Prototype

Proposed mechanism began with a working prototype application foreground and background image

segmentation using Adaptive GMM. Next, the shadow of the object in the foreground image was eliminated using the algorithm. Detection and tracking of vehicle movements were performed by utilizing the Kalman Filter algorithm. Figure 2 describes in detail the working mechanism of the proposed method.

Gaussian Mixture Model

Gaussian Mixture Model (GMM) algorithm is used to perform background subtraction operations or separation between foreground and background images. This algorithm was proposed by Stauffer and Grimson (1999). The concept of background image on GMM algorithm, that background was parametric each pixel location which was represented by a number of functions that combine to form a Gaussian probability distribution function (Stauffer and Grimson, 1999; Genovese *et al.*, 2010; Zhu, 2011):

$$F(X_N) = \sum_{j=1}^k W_j \cdot \eta(X_N; \theta_j) \quad (1)$$

where, F is a probability distribution, W_j is the weight parameter of j^{th} which is a component of the Gaussian. $\eta(X_N; \theta_j)$ is a normal distribution of the j^{th} which can be represented by Equation 2:

$$\eta(X_N; \theta_j) = \eta(x; \mu_j; \sum_j) = \frac{1}{(2\pi)^{\frac{D}{2}} \left| \sum_j \right|^{\frac{1}{2}}} e^{-\frac{1}{2} (x - \mu_j)^T \sum_j^{-1} (x - \mu_j)} \quad (2)$$

where, μ_j is mean, $\sum_j = \sigma_j^2 I$ is covariance from j^{th} .

Gaussian sorted based on the value of $\frac{W_j}{\sigma_j}$; then the distribution and the first chosen as a model background, where:

$$B = \arg \min_b \left(\sum_{k=1}^b > T \right) \quad (3)$$

Threshold T is earlier minimum probability when the background is in the scene.

Adaptive Gaussian Mixture Model

Research conducted by Zivkovic (2004), to increase the ability of Gaussian Mixture Model to adapt to changes in ambient lighting. Adaptive GMM will update the background model by adding a new sample and replace the old ones. Probability distribution function in Equation 2 recomputed for each pixel (Kumar and Agarwal, 2013).

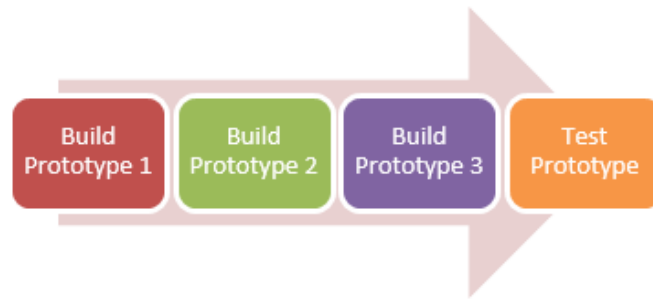


Fig. 1. Research stages

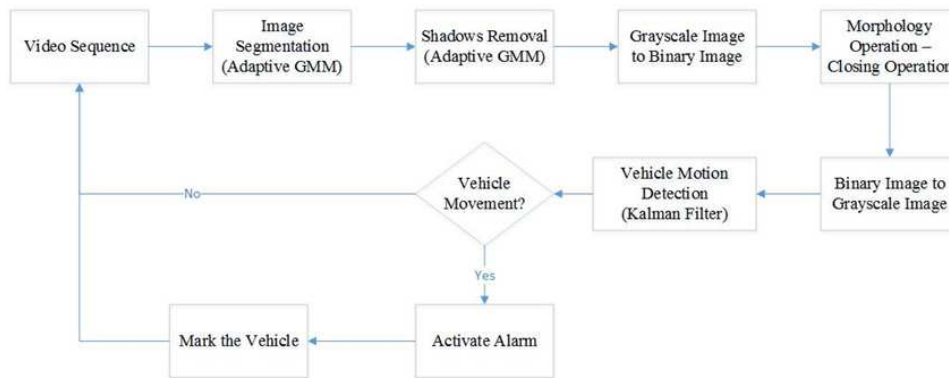


Fig. 2. Proposed method

Table 1. Dataset

File	Envi	Duration (Second)	Camera angles	Lighting
Street .avi	Street	12	Top View	Normal
highway_two.avi	High-way	30	Front View	Normal

Kalman Filter

Kalman filter algorithm is used to estimate the discrete-linear process and tracking the movement of objects. The algorithm consists of two stages, namely time updates and measurement update (Jeong *et al.*, 2013; Najafzadeh *et al.*, 2015). Kalman Filter is modeled by Equation 4 and 5 (Huang and Hong, 2011; Pokheriya and Pradhan, 2014):

$$X_k = F.X_{k-1} + W_k \quad (4)$$

$$Z_k = F.X_k + V_k \quad (5)$$

where, W_k and V_k is the movement and noise measurement vector based on a Gaussian distribution $Gaussian\ p(w) \sim N(0, Q)$, $p(v) \sim N(0, R)$. F is the transition matrix and H is the measurement matrix. Covariance matrix Q and R are assumed to be the identity matrix.

Dataset

Dataset consist of two video files Table 1 describes the characteristics of the dataset used in testing.

Based on the explanation in Table 1, there are two video files used in the test prototype application. Street.avi file size of 30.1 MB with conditions non mutual occlusion and vehicle traffic in one direction, while the highway_two.avi file size of 82.4 MB with mutual occlusion condition of the vehicle and traffic in two ways direction. Street.avi has a frame rate of 30 frames per second (fps), whereas highway_two.avi file has a frame rate of 25 fps.

Prototype Testing

The third prototype testing applications used four parameters, namely the allocation of physical memory (RAM) in KB and percentage of the workload of the computer processor that is used to operate the prototype, speed in detecting motion of the object, as well as the accuracy of detection of vehicle movements.

Tools

In this study, we used a computer with specs Intel Core i3-2120 CPU @ 3.3 GHz, 4 GB RAM to implement an application prototype and test prototype, whereas the Software we used for implementation were Visual Studio. NET 2010, open CV v2. 4.10 and Emgu CV 2.4.10.

Visual Studio was used to build prototype applications. Open CV is a computer vision library used in this study. Gaussian Mixture Model, Adaptive Gaussian Mixture Model and Kalman Filter Algorithm used in this study contained in Open CV. Emgu CV is a library that serves as a wrapper for Open CV so that application development can be done in the NET Framework environment.

Results

The test results of the three prototype can be described in Table 2 and 3. Table 2 describes the results of prototype testing with street.avi file dataset, while Table 3 describes the results of prototype testing with highway_two.avi file dataset.

Based on the test results in Table 2, it can be concluded that the best performance was shown by Kalman Filter algorithms in detecting and tracking vehicles. Execution of the algorithm using the resources of physical memory (RAM) and processor was the smallest among others.

Based on the test results in Table 3, it can be concluded that the proposed model using Adaptive GMM algorithm and Kalman Filter had the best accuracy rate and speed of vehicle movement detection was best than the other models.

Discussion

Based on the test results of the three models in Table 2, it can be explained that the three models showed the maximum degree of accuracy in detecting the movement of the vehicle. The results achieved in non mutual occlusion condition of the vehicle. However, the test results in Table 3, the proposed model using Adaptive GMM and Kalman Filter had a level of accuracy and speed of the vehicle motion detection highest compared to the other models. The proposed model was able to work well in conditions of mutual occlusion vehicle. Speed is measured vehicle speed detection models to identify vehicle movement in the video.

The use of Adaptive GMM algorithm in the proposed model was able to improve the accuracy of detection and tracking vehicles compared with the model proposed in the study Srilekha *et al.* (2015) which only used Kalman Filter. Adaptive GMM was able to detect objects better vehicle than the GMM. This is consistent with the theory of the research results Zivkovic (2004). Figure 3 describes the comparison of the foreground image segmentation using Adaptive GMM and GMM to detect vehicles.

Based on Fig. 3, it appears that Adaptive GMM has a foreground image segmentation results are better than GMM.

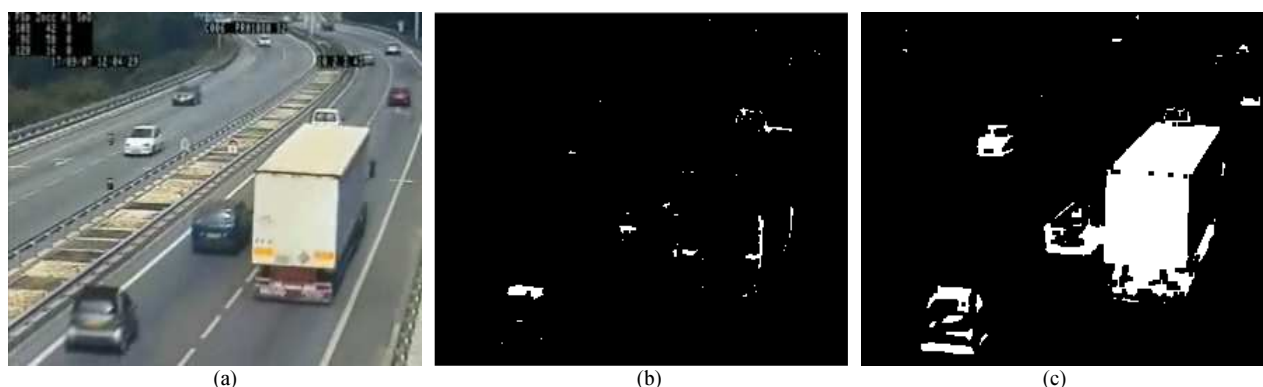


Fig. 3. Comparison of image segmentation results, (a) Original Video, (b) GMM, (c) Adapt. GMM

Table 2. Testing results on File street.avi

	RAM (KB)	Processor (%)	Speed of motion detection	Motion detection accuracy (%)
GMM and Kalman Filter Lin and Chen (2014)	65898.20	36.3	High	100
Kalman Filter Srilekha <i>et al.</i> (2015)	52472.02	13.86	High	100
Adaptive GMM Kalman Filter	56874.40	23.55	High	100

Table 3. Testing results on file highway to.avi

	RAM (KB)	Processor (%)	Speed of motion detection	Motion detection accuracy (%)
GMM and Kalman Filter Lin and Chen (2014)	72908.15	25.03	Low	61.12%
Kalman Filter Srilekha <i>et al.</i> (2015)	54715.57	33.97	Low	75.93%
Adaptive GMM and Kalman Filter	63563.63	26.12	High	90.74%

Conclusion

Adaptive GMM algorithm and Kalman Filter had an accuracy rate of detection and tracking of vehicles with good performance with vehicles that have mutual occlusion. Application of Adaptive GMM algorithm in the proposed model, was able to improve the accuracy of detection and tracking of vehicles.

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Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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