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***Abstract*—Moving object tracking is a method used to estimate the trajectory, detect and analyze changes that occur in an observed object in a video. The moving observed object can be a single object or plural objects. This research focused on a single object within dataset video consists of several moving objects, object difference to the background, nonlinear object movement, camera movement, and object zoom in/out. Sometimes the object being tracked is obvious, but the tracking result is less precise. Some of the reasons are low quality video, system noise, small object, and other factors. In order to improve the precisions of the tracked object especially with dataset video above, we propose a new hybrid method for better and faster tracking result. The object tracking process used a hybrid method of Camshift method as the main tracking technique and Kalman filter for prediction and correction. The Camshift method has several advantages including tracking in various histogram condition and varying object color. Kalman Filter method has advantages to predict object movement in next frame based on previous frame. The computational complexity and large memory requirements for the implementation of tracking were reduced and the precision of the tracked target was good. Based on the trial of tracking the whole video, we can conclude that by adding prediction process with Kalman Filter makes object tracking results become more precise. The addition of Kalman Filter also makes the average tracking time faster than the tracking time using the Camshift method only in the whole video.**

***Index Terms*—object detection, Kalman filter, Camshift method, object tracking**

I. INTRODUCTION

Moving object tracking is a method used to to estimate the trajectory, detect and analyze changes that occur in an object from a frame to the next one in a video [1] [3]. The aim of moving object tracking is to estimate the trajectory of an object in the image plane as it moves around a scene. Moving object tracking may help to detect, identify, and analyze the object [7]. There are three basic steps in tracking a moving object. The first step is the detection or select Region of Interest (ROI) of a moving object in a video. The second step is tracking an object that has been selected from the first step of several parts of the frame. The third step is the analysis of movement of the object to identify the object's behavior [8].

In the military field, automatic surveillance video tracking is used to monitor a certain location. For instance, it can be used either to guard the state boundary or to monitor the enemies movement on the battlefield. CCTV also works in the same manner in monitoring the crowds such as campus, mall, market, etc. In soccer video, object tracking is used to know a player real-time position. Thus, a sports analyst will be able to inform the game pattern, the formation, and the strategy that should be done. Overall, the game should involve moving object tracking. The observed object is relatively small compared to the relatively big video size.

The methods or approaches used to track the moving object are SIFT, Mean-Shift, Camshift, Kalman Filter, and Particle Filter. Each method has their own advantages and disadvantages. For example, Kalman Filter can only be used in a linear or stable system with noise distributed normally (Gaussian) [2]. The Camshift method is a development of Mean-shift. Camshift can be used for the general purpose of moving object tracking [5]. However, this method cannot detect an object hindered by another object within a frame. Otherwise, Kalman Filter is able to predict such an object. Thus, a combination of Camshift and Kalman Filter are expected to ease the moving object tracking in various situation and condition [4].

A research on moving object tracking using Kalman Filter had been conducted with the title Moving Object Tracking Using Kalman Filter [6]. This work was done on an object having various background targeting a single object. Another work titled Moving Target Tracking Based on Camshift Approach and Kalman Filter [4] succeeded in combining Camshift and Kalman Filter. In this work, Kalman Filter is used as the tracking method and fixed by the Camshift method.

This paper discuss new method, called hybrid method, of moving single object tracking in a video with Camshift method as the main tracking and Kalman filter for prediction and correction. This method is believed to give better result in tracking and also better in computation time. Obstacles were found in the video including objects moving together, the similar color of the object and the background, and moving camera. Video acquisition process obtained in State Islamic Institute of Tulungagung and video dataset [7] from a valid source.

II. CAMSHIFT AND KALMAN FILTER

This section explains the two main methods used in this work. The Camshift method and Kalman filter each have their own superiority. These methods also have combinational similar input and output. Thus, both of them are able to provide a new method for tracking.

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A. *Camshift Method*

The Camshift method is an improvement of the Mean-Shift method [4]. It can be used for general purposes related to moving object tracking. Moreover, it also can be used in various histogram condition and object color [5]. Another advantage of Camshift method is it has no dependency on the type of the objects either it is rigid or nonrigid. Camshift method procedure is shown in Figure 1.

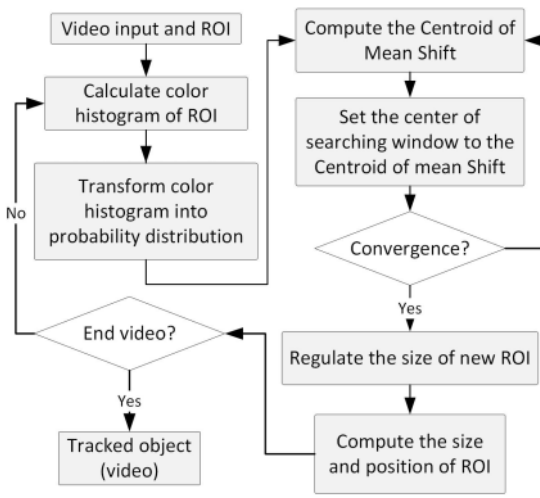


Fig. 1. Camshift method [7].

For color probability distributed image, mean region (centroid) in a search window can be determined using several equations.

The 0^{th} moment:

$$M_{00} = \sum_x \sum_y I(x,y) \tag{1}$$

The 1^{st} moments for x and y :

$$M_{10} = \sum_x \sum_y xI(x,y) \tag{2}$$

$$M_{01} = \sum_x \sum_y yI(x,y) \tag{3}$$

The centroid of search window:

$$x_c = \frac{M_{10}}{M_{00}}; y_c = \frac{M_{01}}{M_{00}} \tag{4}$$

where $I(x,y)$ is a pixel color value at position (x,y) in the image and (x,y) are in the search window. M_{10} is the first moment for x, while M_{01} is the first moment for y.

B. *Kalman FIlter*

Kalman Filter is used for predicting a linear system and Gaussian distributed system. Kalman filter is a statistical method based on point tracking. This method always gives an optimum solution in tracking objects in the form of precise prediction results [6]. Kalman filter method predicts the most probable object location in the current frame based on target tracking from the previous frame. Next, this method searches target location around the previous one [5]. Primary steps of Kalman filter are prediction and correction [4]. Figure 2 shows the discrete cycle of Kalman filter in image processing.

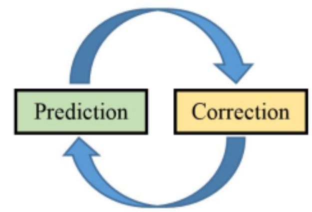


Fig. 2. The discrete cycle of Kalman filter [6].

Define vector state $X_k = [x, y, v_x, v_y]$, vector measurement $Z_k = [x, y]^T$, where x and v_x are target images and their displacement in the direction of the horizontal position. Meanwhile, y and v_y are target images and their displacement in the vertical direction. Prediction and correction equations of Kalman filter method are.

a. Prediction stage

Prediction equation 1:

$$X_{pred_k} = A.X_{k-1} \tag{5}$$

Prediction equation 2:

$$P_{pred_k} = A.P_{k-1}.A^T + Q \tag{6}$$

b. Correction stage

Kalman-gain equation:

$$K_k = P_{pred_k}.H^T.(H.P_{pred_k}.H^T + R)^{-1} \tag{7}$$

Update equation 1:

$$X_k = X_{pred_k} + K_k.(Z_k - H.X_{pred_k}) \tag{8}$$

Update equation 2:

$$P_k = P_{pred_k} - K_k.H.P_{pred_k} \tag{9}$$

The values of transition matrix A, measurement matrix H, process noise covariance matrix Q, and measurement noise covariance matrix R are.

$$A = \begin{matrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}, Q = \begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}, H = \begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{matrix}$$

$$R = \begin{matrix} 1 & 0 \\ 0 & 1 \end{matrix}$$

III. Single Object Tracking Using Hybrid Method

This section discuss an object tracking within a video using the Camshift method and predicted by Kalman Filter, we called it hybrid method. First step is converting video into frame sequences, then choosing ROI (Region of Interest) from first frame. In this case, the object marked with rectangle. Camshift and Kalman filter combined simultaneously for

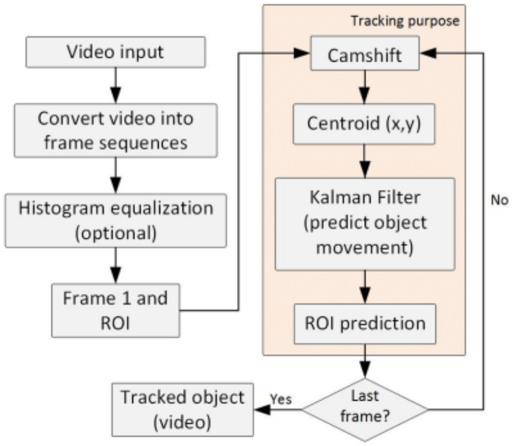


Fig. 3. Sequences of a hybrid method tracking diagram.

tracking approach. Figure 3 shows a block diagram of the tracking system.

There are two ways in combining the Camshift method and Kalman filter. This work used one of them where the Camshift method is used as the main tracking method and enhanced by Kalman filter as shown in Figure 4. This hybrid method is believed to be more superior than several methods that uses Kalman filter as the main tracking method. Moreover, the Camshift method is based on HSV color-based simple calculation that uses its histogram for several condition having various object color. This characteristic of the Camshift method could be its additional advantage [7]. Besides, the Camshift method is independent to the camera movement and object transformation within a video data.

Kalman filter has an advantage related to its capability in predicting image movement accurately. Kalman filter also keeps on giving optimum solutions in conducting tracking [6]. Nevertheless, Kalman filter drawback is it can only work in a linear system which means only in a static video. Considering both the advantage and disadvantage of the Camshift method and Kalman filter, both method could be combined into a new method capable to be used for general aiming tracking.

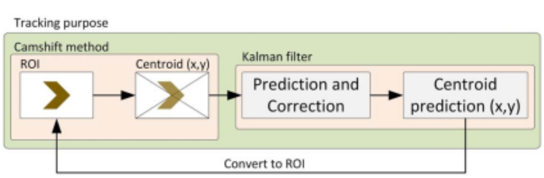


Fig. 4. Sequences of a hybrid method.

The Camshift method was the basis of the hybrid method as shown in Figure 4. The Camshift method input was the processed ROI coordinate yielding the centroid (x,y) of a rectangle wherein the tracked object was included. The centroid (x,y) became the Kalman filter input to predict and correct the object location in the next frame. Kalman filter results are shown in the form of (x,y) prediction point which would be processed by the Camshift method in the next step.

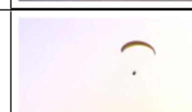
IV. Result and Discussion

This section explains object tracking trial using five videos. The first trial was testing the tracking object using the Camshift method. The second trial was testing the tracking object using the hybrid method of Camshift and Kalman filter. The last trial was comparing the effect of adding Kalman filter method to the tracking process.

The precision criterion was the tracked object inside the rectangular marking area. Meanwhile, the non-precise criterion was the tracked object outside the rectangular marking area. Object marking area was formed from the tracked object centroid calculation coordinate.

The program trials were done to the videos with .avi or .mp4 extension. The trial videos had been saved in computer directory. They had been obtained from manual acquisition around State Islamic University of Tulungagung and valid source of video dataset [7]. The list of the trial videos is shown in Table I below.

TABLE I
Tracking Trial Video Dataset

	Name	Numbers of Frames	Video Screenshot
1	sepeda-motor.avi	264	
2	jalan-kaki.avi[a]	495	
3	sepeda.avi[a]	151	
4	paralayang.avi	167	
5	jogging.avi	237	

[a] Camera movement.

Video screenshots in Table I have different sizes. Sepeda-motor.avi and jalan-kaki.avi videos are 848×480 pixels. Sepeda.avi video is 320×240 pixels. Paralayang.avi video is 640×360 pixels. The last trial video jogging.avi is 1280×720 pixels. Each video has different characteristics including object difference to the background, nonlinear object movement, camera movement, the number of moving object in one frame, and object zoom in/out.

A. Native Tracking

Comparison of tracking results between before and after adding Kalman Filter to the videos was necessary to know whether the proposed method would yield better results or not. Thus, object tracking will be conducted in each dataset video without Kalman filter. Table II shows object tracking results using the Camshift (Native) method.

TABLE II
OBJECT TRACKING RESULTS USING NATIVE METHOD

	Name and Frames	Tracking Results		Average Time (sec)
		Precise	*Non-Precise*	
1	sepeda-motor.avi (264)	250	14	0.3424
2	jalan-kaki.avi (495)	342	153	0.3928
3	sepeda.avi (151)	84	67	0.0748
4	paralayang.avi (167)	53	114	0.1963
5	jogging.avi (237)	195	42	0.1308

B. Tracking Using Hybrid Method

Tracking results using the Camshift method are still less precise than what they are expected to be. These phenomena were proven by numerous objects that cannot be tracked. The proposed method gave a better solution to the tracking results by adding prediction step using Kalman filter to track objects. Table III shows object tracking results using Hybrid method.

TABLE III
OBJECT TRACKING RESULTS USING HYBRID METHOD

	Name and Frames	Tracking Results		Average Time (sec)
		Precise	*Non-Precise*	
1	sepeda-motor.avi (264)	264	-	0.3101
2	jalan-kaki.avi (495)	348	147	0.2983
3	sepeda.avi (151)	106	45	0.0658
4	paralayang.avi (167)	53	114	0.1743
5	jogging.avi (237)	206	31	0.1279

C. Discussion

This section focused on tracking accuracy level between tracking using native method (Camshift) and tracking using Hybrid method. Figure 5 and 6 show several frame sequences before and after Kalman filter addition.

Fig. 5. Missed rectangle in result of sepeda-motor.avi tracking (frame 151, frame 152, and frame 153) before adding Kalman filter.

More detail comparison between the native tracking and the hybrid tracking methods can be seen in Table IV.

Figure 7 shows precision level improvement in tracking using the CamShift method and the Hybrid method. Object

Fig. 6. Correct rectangle in result of sepeda-motor.avi tracking (frame 151, frame 152, and frame 153) after adding Kalman filter.

TABLE IV
COMPARISON TRACKING RESULT

Frame	Native	Hybrid
151		
152		
153		

tracking using the Camshift method without Kalman filter resulting in success percentage value as much as 56% for sepeda.avi video. Meanwhile, the success percentages were 95% and 69% for sepeda-motor.avi and jalan-kaki.avi respectively. Sequentially, paralayang.avi and jogging.avi reached 32% and 82% for their success percentage.

Object tracking using the Camshift method with Kalman filter resulting in tracking success percentage as much as 70% for sepeda.avi video. Meanwhile, for sepeda-motor.avi and jalan-kaki.avi each reached 100% and 70% respectively. Sequentially, paralayang.avi and jogging.avi reached 32% and 87%.

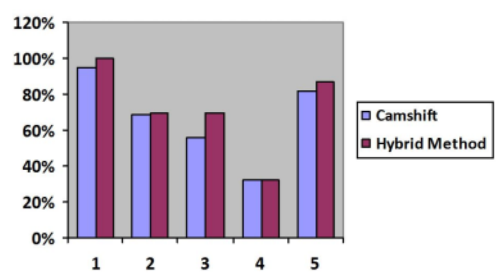


Fig. 7. The tracking precision level using the Camshift and Hybrid method.

Sepeda.avi video tracking used the Camshift-Kalman hybrid method and yielded more precise tracking than the previous work results done by the author. Previous work yielded as much as 84 frames out of 151 frames or 56% using the Camshift method [7]. The Kalman filter prediction process gives more precise tracking results.

TABLE V
LOOPING PROCESS IN DETERMINING THE OBJECT TRACKING PROCESS CENTROID

	Name and Frames	Total Looping Centroid	
		Camshift	***Hybrid***
1	sepeda-motor.avi (264)	285	271
2	jalan-kaki.avi (495)	527	511
3	sepeda.avi (151)	237	203
4	paralayang.avi (167)	211	188
5	jogging.avi (237)	245	238

Table V shows looping process data to determine the centroid of object tracking results. Prediction and correction by Kalman filter makes Camshift method centroid calculation faster than before. The Camshift method centroid calculation will be stopped when the difference between the i^{th} frame and the $(i-1)^{th}$ frame search window is convergent. In this work, convergence means the difference is less than the determined threshold value 1. The threshold value 1 was obtained from the previous works done by the researchers.

V. CONCLUSION

In this paper we have presented an integration method between Camshift method and the Kalman filter to track objects called Hybrid method. This approach significantly improves the overall tracking system. Thus, by adding the prediction process to the Kalman filter made the object tracking results became more precise.

By adding prediction process using Kalman filter made the tracking results became more precise with the increasing percentage as much as 14% in the sepeda.avi video. In the other videos, this addition didn't give significant impact. It also made the hybrid method in each frame became faster than using the Camshift method only. The highest average tracking time per frame increase was 0.0945 seconds in jalan-kaki.avi video. It was because of the faster centroid finding looping process.

The developed program was still imperfect and needed development related to its less than 100% results precision. Thus, the next work should be developed by combining or comparing with another existing method. The next work also may develop multiple object tracking using the same or different method in hopes that in a video frame the whole moving object can be accurately tracked. Related to the place where the data acquisition took place, this work results can be studied and developed to enhance the CCTV camera surveillance system either in the real-time or offline system.

REFERENCES

[1] X. Chen, X. Li, H. Wu, and T. Qiu, "Real-time object tracking via camshift-based robust framework," in *2012 IEEE International Conference on Information Science and Technology*, March 2012, pp. 527–530.

[2] B. Deori and D. M. Thounaojam, "A survey on moving object tracking in video," *International Journal on Information Theory (IJIT)*, vol. 3, no. 3, pp. 31–46, 2014.

[3] Y. Habibi, D. R. Sulistyaningrum, and B. Setiyono, "A new algorithm for small object tracking based on super-resolution technique," *AIP Conference Proceedings*, vol. 1867, no. 1, p. 020024, 2017. [Online]. Available: http://aip.scitation.org/doi/abs/10.1063/1.4994427

[4] K.-h. Hsia, S.-F. Lien, and J.-P. Su, "Moving target tracking based on camshift approach and kalman filter," *Int J Appl Math Inf Sci*, vol. 7, no. 1, pp. 193–200, 2013.

[5] S. Huang and J. Hong, "Moving object tracking system based on camshift and kalman filter," in *Consumer Electronics, Communications and Networks (CECNet), 2011 International Conference on*. IEEE, 2011, pp. 1423–1426.

[6] H. A. Patel and D. G. Thakore, "Moving object tracking using kalman filter," *International Journal of Computer Science and Mobile Computing*, vol. 2, no. 4, pp. 326–332, 2013.

[7] G. Swalaganata, D. R. Sulistyaningrum, and B. Setiyono, "Super-resolution imaging applied to moving object tracking," *Journal of Physics: Conference Series*, vol. 893, no. 1, p. 012062, 2017. [Online]. Available: http://stacks.iop.org/1742-6596/893/i=1/a=012062

[8] A. Yilmaz, O. Javed, and M. Shah, "Object tracking: A survey," *Acm computing surveys (CSUR)*, vol. 38, no. 4, p. 13, 2006.

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