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Mixed Kalman/H∞ Filter for Multi-Object Tracking in Video Frames

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Abstract

In this paper, the mixed H-infinity and Kalman filter is proposed for multiple target tracking in the video arrangements. Here, the proposed system will be the joined execution of Kalman filter and the H-infinity filter. The Kalman filter is the best filter that is a linear combination of the measurements. That is why; it is widely used in tracking systems. The H∞ filter, also called the mini-max filter. The H∞ filter does not make any assumptions about the noise and it required only last time step and current state estimation for object tracking. Consequently, there would be no necessity for a high limit of computational stockpiling. This mixed filter uses a lower gain in order to obtain better performance, where as the pure H-infinity filter uses a higher gain because it does not take Kalman filter performance into account. The mixed H-infinity and the Kalman filter, used to find the location and speed of the objects when objects are moves with a certain motion law. The Kalman filter doesn't limit the mean square error. In this way, the H-infinity filter limits the mean square error and also utilized to limit the impact of unexpected noise whose insights are obscure. Usage of the proposed system was implemented in MATLAB and the execution of this system has better execution.

Keywords: *Multi-object tracking, Kalman filter, H-infinity filter, Mixed Kalman and H-infinity filter, Cost function.*

1. Introduction

Video object focuses on the picture and decides their location facilitates, along these lines to decide the path of the objects as time changes [4]. The single object tracking and the multiple object tracking is the two important tracking techniques in the object tracking. object tracking [1][2][3] alludes to the way toward measuring the constant areas of moving objects after some time. Amid the preparing time, there are two fundamental undertakings are utilized to recognize the objects in the video arrangements. In the underlying assignment, the location of the specific object is identified by the object recognition and the classification techniques. The second one is the significance of the object location of back to back picture outlines, which recognizes the single object tracking is the easyest way because it only detects the single object, so there is no collision and occlusion occurs at the time of tracking the single object. But the multiple object tracking is very crucial technique because it detects multiple objects in the meantime. Here,

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there is a chance for occurring collision and occlusion because all the objects in the video sequences have the various types of features. Sometimes the some objects contain the similar features. An alternate number of methodologies are utilized for settling this lightning variation, pose variation and intensity problem. In any case, that approach has its own particular points of interest and inconveniences [5][6][7].

In this paper, in section (3), the moving object detection technique is actualized. The mixed Kalman and H-infinity filter approach are presented in section (4). The result and the conclusion are explained in section (5) and (6).

2. Literature Review

W. Hu *et al.* [8] have bestowed an efficient methodology for the detection and tracking of multiple moving objects from a video sequence captured by a moving camera while not further sensors. In their methodology, moving objects are recognized utilizing a refinement theme and a minimum bounding box. Finally, moving object tracking was accomplished utilizing a Kalman filter in the view of the middle of gravity of a moving object region within the minimum bounding box.

A novel tracking rule was projected by J. Kwon *et al.* [9], which vigorously tracks an object by finding the state that limits the uncertainty.

Hui Li *et al.* [10] have bestowed a tracking technique of multiple pedestrians supported particle filters in video groupings. Throughout the method of tracking, the method processes severe occlusion condition to stop drift and loss phenomena caused by object occlusion and associates detection results with particle state to propose a discriminated methodology for object disappearance and appearance therefore to attain strong tracking of multiple pedestrians.

Xiong *et al.* [11] have exhibited a multi-object tracking of pedestrians in video sequences supported particle filters. Amid the way toward tracking, the technique uses the similarity between candidates and codebooks as perception probability capacity and processes severe occlusion condition to stop drift and loss occurrence caused by object occlusion.

Jan Timo Meyer *et al.* [12] have projected a hybrid tracking system that detects moving objects in videos compressed consistent with H.265/HEVC standard. The hybrid nature of their approach stems from the usage of a picture element domain technique that extracts the color information from the fully-decoded I frame and was updated solely once completion of every Group-of-Pictures (GOP).

Anton Milan et al. [13] have presented a multi-object tracking approach that expressly models each task as minimization of a unified discrete-continuous energy function. Trajectories are captured through global label costs, a recent idea from multi-model fitting that they have introduced to track.

3. Proposed Multi-Object Tracking Method

A multi-object tracking strategy fuses object region extraction and improvement of discriminative appearance model to depict video objects. Initially, the adaptive background subtraction and the Histogram equalization techniques are utilized to identify the object region. Then the features are extracted from that detected object region. After that, the multi-feature fusion method is utilized to find the matching degree of the features. Finally, the motion states are identified by this combined Kalman and the H-infinity filter. Figure 1, exhibits the object area extraction of the essential F frames.

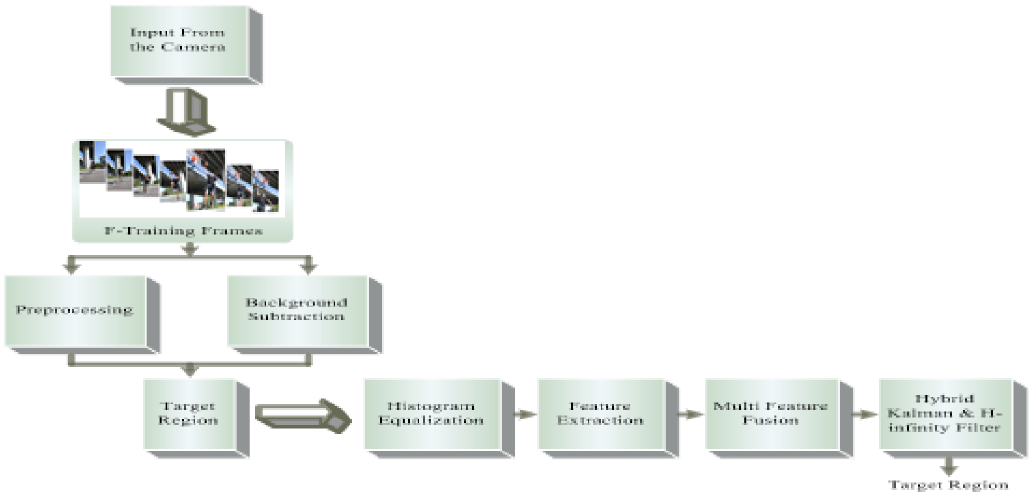

Figure.1. Block Diagram of Proposed System

To track the moving object in the video sequences, initially, the location and velocity of the objects are required. So in the proposed work, a combined Kalman and H-infinity filter is utilized for the multi-object tracking. The speed and position of the object in the video is varied by time. So, the mixed H-infinity and the Kalman filter is designed to find the location and speed of the objects when objects are moves with a certain motion law. In Figure 2, the upper left is the centre of the object and the position of the video object is represented as $P_a(t)$ and $P_b(t)$. Here, $P_a(t)$ is the horizontal position and $P_b(t)$ is the vertical position. The horizontal and the vertical velocity of the video object is represented as $S_a(t)$ and $S_b(t)$. The motion state of the object is given as follows,

$$A_t = [P_a(t) \;\; P_b(t) \;\; S_a(t) \;\; S_b(t)]^T \tag{1}$$

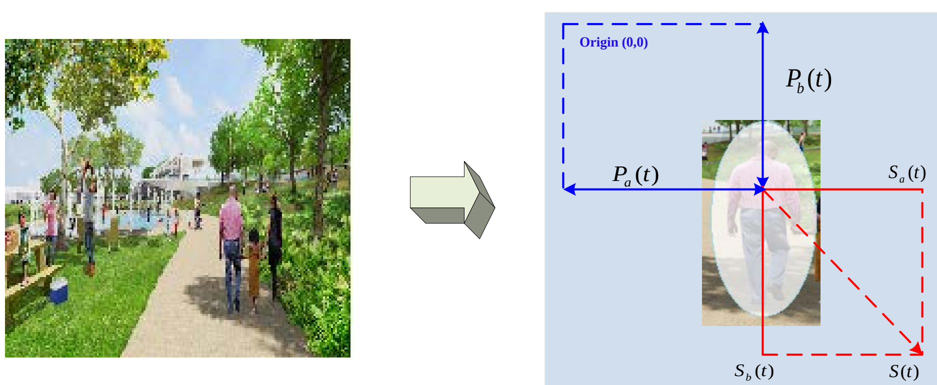

Figure.2. Motion State Representation

The centroid of the video object is given as follows,

$$P_a(t) = \frac{P_a(t-1) + S_a(t-1)T + T^2 S_a(t-1)}{2} \tag{2}$$

$$P_b(t) = \frac{P_b(t-1) + S_b(t-1)T + T^2 S_b(t-1)}{2} \tag{3}$$

The velocity of the video object is given as follows,

$$S_a(t) = S_a(t-1) + S_a(t-1)T \tag{4}$$

$$S_b(t) = S_b(t-1) + S_b(t-1)T \tag{5}$$

At time t and $t-1$ the horizontal and the vertical velocity of the object is represented as $S_a(t)$ $S_b(t)$ and $S_a(t-1)$ $S_b(t-1)$. At time t and $t-1$, the centroids are denoted as $P_a(t)$ $P_b(t)$ and $P_a(t-1)$ $P_b(t-1)$. The system model and the observation models are depicted from the above motion states equations.

$$A_t = \vartheta A_{t-1} + u_t \tag{6}$$

$$B_t = \mu A_t \tag{7}$$

In the above equation ϑ and μ is depicted as follows,

$$\vartheta = \begin{bmatrix} 1 & 0 & T & 0 \\ 0 & 1 & 0 & T \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \text{and} \quad \mu = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \tag{8}$$

Due to some uncertain noises, encompassing variety and jumbled background the above measurements are influenced, so the modified the above system model equation as follows,

$$A_t = \vartheta A_{t-1} + u_t + v_t \tag{9}$$

$$B_t = \mu A_t + w_t \tag{10}$$

In the above equation, the process noise and the measurement noise is represented as v_t and w_t the process noise and the measurement noise need the covariance matrix, so the covariance matrix is denoted as Ω_t and ϕ_t. Then,

$$v_t \sim N(0, \Omega_t),\ w_t \sim N(0, \phi_t) \tag{11}$$

The Kalman filter reduces the mean square error but this filter is not worked well in the non-Gaussian noise case, to compensate these problems the H-infinity filter is used in that place to minimize the non-Gaussian noises occurred at the time of tracking. The major benefit of the H-infinity filter is it does not require the previous information of the noises. But it requires the recursive equation of the Kalman filter. The predicted state and the updating phase are done based on the Kalman filter.

The predicted phase of the Kalman filter is computed as follows,

$$\tilde{A}_{t|t-1} = X\tilde{A}_{t-1|t-1} \tag{12}$$

The covariance of the predicted state is estimated by,

$$\Pr e_{t|t-1} = \text{cov}(A_t - \tilde{A}_{t|t-1}) = E\left[\left(A_t - \tilde{A}_{t|t-1} - E\left[A_t - \tilde{A}_{t|t-1}\right]\right) \times \left(A_t - \tilde{A}_{t|t-1} - E\left[A_t - \tilde{A}_{t|t-1}\right]\right)^T\right]$$

$$= X \Pr e_{t-1|t-1} \vartheta^T + \Omega_t \tag{13}$$

The measurement residual in the updating Phase of the Kalman filter is estimated as follows,

$$\tilde{K}_t = B_t - \mu\tilde{A}_{t|t-1} \tag{14}$$

4. Results and Discussions

The multi-object tracking accuracy and the performance of the system are evaluated by using robust filtering techniques. In this proposed method, a joined execution of the Kalman and the H-infinity filter is used to detect the velocity and centroid of the object. The performance, accuracy and the robustness of the proposed method is evaluated based on this motion states. In this method, the minimum mean square error is reduced by Kalman filter but this filter does not reduce error rate when the noises are in non-Gaussian cases. To overcome these problems the H-infinity filter utilized the game theory approach for computing the cost function. The H-infinity filter doesn't need prior knowledge of the noise but it needs the recursive equation of the Kalman filter.

4.1 Dataset Description

In the planned technique, test video sequences are taken from the PETS and CAVIAR database. This two database recorded a number of video shots and which is in different scenarios.The CAVIAR database with the resolution of 384 x 288 pixels, 25 frames per second and MPEG2 is utilized for the compression. A standard test video sequence 'PEST2001' with a resolution of 768×576. The proposed approach was executed in MATLAB by exploiting the available benchmark video files.

4.2 Performance analysis

The root means square error and the average root means square is computed for evaluating the error rate occurred at the time of tracking.

Where, the estimated location of the moving object is represented as K_t and the original location of the moving object is represented as $\tilde{K}_t$ and $\tilde{S}_0$.

Table 1. Parameter settings of proposed Multi-object tracking algorithm

Parameter	Video sequence 1	Video sequence 2	Video sequence 3
Total number of frames	950	175	1150
Number of training frames	25	20	35
Number of objects	6	7	8
Number of appearing objects	5	1	7
Number of disappearing objects	2	5	6

4.3 Comparison analysis

In this section, the performance of the proposed method is compared with the existing moving object tracking method. Here clearly illustrate, which method has the better tracking performance through the existing method. In the proposed method, a mixed Kalman and H-infinity filter utilized for the moving object tracking. The Kalman filter is utilized to measure the velocity and centroid of the object and the H-infinity filter utilized to minimize the estimation error.

Video Sequence 1: In the proposed technique, the test video arrangements are taken from the CAVIAR and PETS dataset. Table 2, demonstrates the root mean square error of the proposed strategy is contrasted and the current object tracking technique, for example, Kalman filter and the H-infinity filter. The video grouping 1 has six people on foot in the corridor and the filter tracks all the six walkers' root mean square error. In the proposed hybrid strategy, the RMSE is 3.08 in walker 1, in person on foot 2, 3 RMSE rate is practically same (3.1051 and 3.1861), the passerby 4 has the 3.21 RMSE, the RMSE rate in person on foot 5 and 6 is practically same (3.1865 and 3.1511). Contrasted and the current technique, the RMSE is less in the proposed strategy.

Table 2. Root Mean Square error for video sequence 1

	Kalman Filter	H-infinity Filter	Proposed mixed Kalman & H-infinity
Pedestrian 1	3.930	3.5161	3.0819
Pedestrian 2	4.103	3.7233	3.1051
Pedestrian 3	4.233	3.8521	3.1861
Pedestrian 4	4.289	3.9331	3.21
Pedestrian 5	4.268	3.9166	3.1865
Pedestrian 6	4.232	3.1865	3.1511

Video Sequence: In the proposed technique, the test video arrangements are taken from the PETS dataset. Table 3, demonstrates the root mean square error of our proposed strategy is contrasted and the current object tracking technique, for example, Kalman filter and the H-infinity filter. The video grouping 2 is the PET s09, this video sequence consist six pedestrian and the filter tracks all the six walkers' root mean square error. In the proposed hybrid strategy, the RMSE is 3.5938 in walker 1, in person on foot 4, 5 RMSE rate is practically same (4.2939and 4.2511), the passerby 2 has the 3.9618 RMSE; the RMSE rate in person on foot 3 and 6 is practically same (4.1906and 4.1208). Contrasted and the current technique, the RMSE is less in the proposed strategy.

Table 3: Root Mean Square error for video sequence 2

	Kalman Filter	H-infinity Filter	Proposed mixed Kalman & H-infinity
Pedestrian 1	4.9234	4.5948	3.5938
Pedestrian 2	5.1874	4.8943	3.9618
Pedestrian 3	5.2949	4.9682	4.1906
Pedestrian 4	5.2182	4.8997	4.2939
Pedestrian 5	5.1132	4.8073	4.2511
Pedestrian 6	4.8837	4.584	4.1208

5. Conclusion

A mixed Kalman and H-infinity filter are utilized in the proposed method to track the multiple objects in the video clip. Before tracking the object, initially, the adaptive background subtraction method is utilized to segregate the foreground and the background region separately. The false region and the exact object region are identified by the histogram equalization technique. Then, the feature extraction technique is implemented for extracting the features of the various types of the object after that the multi-feature fusion method computes the matching degree of the features. The position and the velocity of the object are detected by the mixed Kalman and H-infinity filter. There are two types of datasets are used to test this task. They are PETS and CAVIAR dataset. The current work is developed for the motion state detection and multi moving object detection. Usage of the proposed model and the techniques were completed in MATLAB and the execution of the proposed strategy has better execution and precision.

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