Detection and Tracking of an Object in a Video Sequence Using Kalman Filter: A Survey

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Abstract **Object detection and tracking are the important and more challenging tasks in video sequence and computer vision applications. Object detection is the procedure of finding the non-stationary entities in the image sequences. Detection is the first step towards tracking the moving object in the video sequence. The representation of the detected object is the next important step to track. Tracking is the method of identifying the position of an object in motion in the video sequence. Difficulties in identifying the dynamic positions is much more challenging task than detecting the object due to motion of the object, changing appearance patterns of objects and the scene, and most significantly is handling occlusion of tracked object. Tracking of an object is applied in numerous applications like in, monitoring the traffic, video indexing, human-computer interaction, Video surveillance, Robot vision, Sports and Simulations. Here we are going to present a brief review of numerous object detection, object classification and object tracking algorithms available. Therefore, the goal of this paper is to discuss the problem of object tracking and classify them into different categories, and identify new trends. In this survey we will discuss about detection and tracking of the object using Kalman Filter [1] in different applications. Moreover, we discuss the important issues related to occlusion handling using image features and use of multiple cameras.**

Keywords* — *Computer Vision, Kalman Filter, Object classification, Object detection, Object Tracking and Occlusion.

I. INTRODUCTION

Videos are the sequences of images, which are called frames, show the frequency fast enough so that human eyes can perceive the continuity of its contents. It is clear that all image processing techniques to be applied to individual frames. Moving object detection is the initial step for the process of analyzing a video. This is done either in each and every frame or when the object first appears in the video. A general algorithm for object detection may be desirable, but it is extremely difficult to treat properly objects or objects unfamiliar with significant variations in color, shape and texture.

Therefore, many practical computer vision systems require a fixed camera environment, which makes the detection process more open objects. Objects can be represented [2] by their shapes and appearances. Object tracking is a process of monitoring an object's spatial and temporal changes during a video sequence, including its presence, position, size, shape, etc. Object tracking algorithms have acquired priority due to the availability of highly sophisticated computers, good quality and inexpensive cameras. The process of tracking an object which undergo different phases is shown in the Figure 1.

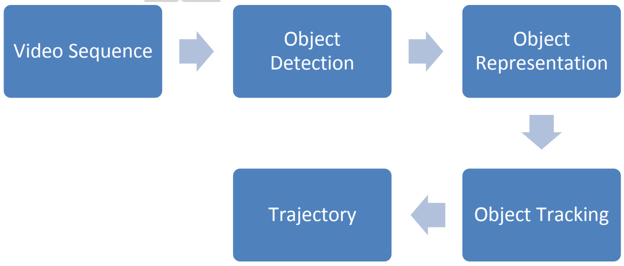

Figure 1: Phases

- Object Detection

Each tracking strategy requires an object detection component either in each frame in the scene or when the object initially appears. A typical methodology for object detection is to utilize data in a video from one frame to next for further analysis.

- Object Representation

After detection of an object, for further analysis in any tracking scenario the object can be represented by their appearances or shape. For example, vehicle, ball, human, or plane in the air will be represented for tracking in video sequence using any shape representation of interest.

- Feature Selection For Tracking

In order to track any object in a video sequence feature selection of the target plays a crucial role. Both object

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representation and feature selection are related to each other for example color is used as feature for histogram representation, for contour or silhouette based representation the object edges or boundaries are used as features. In many tracking approaches the algorithms used may use combination of more than one feature.

- Object Tracking

Tracking of an object involves many steps before finding the trajectory of the object, which includes detection, representation and feature extraction. The main aim of a tracker is to generate the trajectory of an object being tracked in a video sequence by finding the position of it in every frame of the video scene. In tracking approaches the objects are represented using the shape or appearance models. The model selection depends on the type of object, for example, point and geometric shape representation can be used for tracking of rigid objects in the video sequence. For non rigid objects, contour or silhouette representations are more suitable description used for their motion.

The rest of the paper is systematized as follows. Section II presents motivation. Section III presents related work in which object detection, representation and tracking under different occlusion conditions is illustrated. Conclusion about the paper is presented in Section IV.

II. Motivation

The motivation of this survey paper is to provide an overview of the most recent trends and of the future research directions in object tracking and video processing. Rather than covering all aspects of the domain in detail, this survey covers issues related to occlusion handling in tracking objects. Why is occlusion handling so important? Objects tracking while occlusion gives much information which is useful in analysis of the object being tracked as humans cannot directly detect with his own eyes when occlusion happens. This can be further used in many applications like sports, entertainment and military aircraft navigation and targeting.

III. Related Work

Object detection in the video scene is the fore most step in tracking of moving object. There are many object detection methods shown in Figure 2, which is to find the moving object in every frame during a video scene.

A. Detection

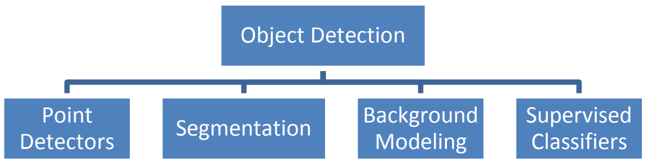

Figure 2: Object Detection

- Point Detectors

In an image the point detectors are used to find the interest points. In terms of application the interest points are being used in context of view-based object recognition, image matching, tracking and motion problems.

- Segmentation

Another widely used process for detection of an object in an image or a video sequence is segmentation. The process is to divide an image into multiple parts or similar regions which is used to identify relevant information in digital images using different methods.

- Background Subtraction

Detection of an object by building a representation of the scene in a video called the background model and detecting variations from the model for every frame in video. The object can be identified in an image region if there is any significant change from background model. These regions are used for further processing, this process is called as the background subtraction.

- Supervised Learning

Other object detection approach which requires a set of templates which takes set of examples as learning sets, the supervised learning methods maps inputs to outputs by generated function .A standard formulation of supervised learning is the classification problem where the learner approximates the behavior of a function by generating an output in the form of either class label or regression which is known as classification. The learning examples take object features and object class associated with it which are manually defined.

B. Representation

In the process of tracking, an object can be anything of interest in a video scene for analysis. After detection of the object, it's representation is employed for tracking in video scene. This section will outline the object representation types shown in below Figure 3.

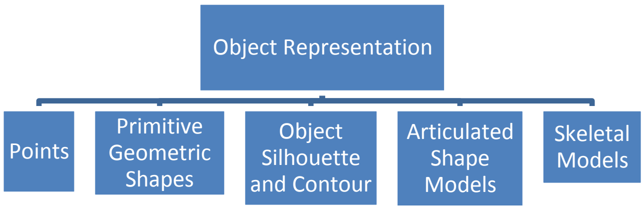

Figure 3: Object Representation

Table 1 shows few algorithms used for suitable applications for object representation.

Table 1: Object Representation

Type	Suitable Applications	Algorithms	Example
Centroid [3]	Rigid objects, Sports	Kalman Filter,	Object tracking

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	activities	Particle and Multiple Hypothesis Tracking	
Multiple points [4]	Rigid objects, Sports activities	Greedy Optimal Assignment (GOA), SVM and Mean-shift	Object tracking and measurement
Rectangular or Elliptical patch [5]	Surveillance, Non-rigid objects	Kalman Filter, KLT and Eigen tracking	Object identification and tracking
Object skeleton [6]	Detect and track Human body parts and human action	CAMShift and Particle filter	Object measurement and shape of region
Object contour and silhouette[7]	Shape representation and Surveillance	Gradient descent and Particle filtering	Object detection

C. *Object Tracking*

Object tracking is mainly defined as estimating the trajectory of an object as it moves in a image sequences or in the video scene. For further analysis of the object being tracked the one can define more information like shape, area, speed and orientation. The tracking becomes complex due to few reasons:

-- Noise in videos
-- Speedy and Complex motions of object
-- Partial or Full Occlusions
-- Variation in light effects
-- Complex shapes of object.

Object tracking methods are mainly categorized into three as shown in Figure4. We briefly introduce the point tracking method and related work for this category.

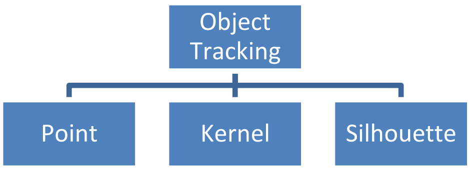

Figure 4: Object Tracking

- Point Tracking

In point tracking the objects detected in consecutive frames in the video scene are represented by points at the centroid of the object, and the association of the points is based on previous state which takes object motion and position. In point tracking the methods is categorized mainly into two types:

-- Deterministic methods
-- Statistical methods

Statistical methods solve the tracking problems by taking measurement into account during object state estimation and model the object properties such as position velocity and acceleration. Point tracking methods can be evaluated on the basis of whether they generate correct point trajectories. Given a ground truth, the performance can be evaluated by computing precision and recall measures. In the context of point tracking, precision and recall measures can be defined as:

$$Precision = \frac{\#\ of\ correct\ correspondences}{\#\ of\ established\ correspondences} \quad (1)$$

$$Recall = \frac{\#\ of\ correct\ correspondences}{\#\ of\ actual\ correspondences} \quad (2)$$

correspondences available in the ground truth are the actual correspondences in equations (1) and (2). Additionally, a qualitative comparison of object trackers can be made based on their ability to deal with entries of new objects and exits of existing objects, handle the missing observations (occlusion), and provide an optimal solution to the cost function minimization problem used for establishing correspondence. One of them is Kalman Filter, a recursive predictive filter that is based on the use of state space technique and recursive algorithm. The predict equations (3), (4) and update equations (5), (6), (7) as below:

Predict:

$$\hat{X}_{t|t-1} = F_t \hat{X}_{t-1|t-1} + B_t u_t \quad (3)$$

$$P_{t|t-1} = F_t P_{t-1|t-1} F_t^T + Q_t \quad (4)$$

Update:

$$\hat{X}_{t|t} = \hat{X}_{t|t-1} + K_t(y_t - H_t \hat{X}_{t|t-1}) \quad (5)$$

$$K_t = P_{t|t-1} H_t^T (H_t P_{t|t-1} H_t^T + R_t)^{-1} \quad (6)$$

$$P_{t|t} = (I - K_t H_t) P_{t|t-1} \quad (7)$$

where
$\hat{X}$: Estimated state.
F : State transition matrix.
u : Control variables.
B : Control matrix.
P : State variance matrix.
Q : Process variance matrix.
y : Measurement variables.
H : Measurement matrix.
K : Kalman gain.
R : Measurement variance matrix.
Subscripts are as follows: t|t current time period, t-1|t-1 previous time period, and t|t-1are intermediate steps.

The filter estimates the state of a dynamic system, even if the precise form of the system is unknown. The filter supports estimations of past, present and future states. Kalman filter tracks a single object, cannot handle object entry and exits and handles occlusion and provides optimal solution. Few of such applications where Kalman filter is used are as follows:

In [8] proposed a novel real-time 3D hand tracking

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method in depth space using a 3D depth sensor and using Kalman filter. Detection of hand candidates using predefined wave motion and motion clusters, and using Kalman filter hand locations were tracked.

In [9] a novel approach is proposed to estimate lane for robust curvature information with Kalman filter. In this paper the target is lane on a real road environment.

In [10] for human body tracking in video surveillance system a human skeleton model is proposed. Two techniques were used to locate eight human body points. The first, uses gait study to find the ankle and keen points. To track the remaining body points Kalman filter was used as second technique.

In [11] proposed an approach which detects a single object using Median approximation technique in a video scene. After detection of the object Kalman filter is combined with Template Matching algorithm used for tracking the object.

In [12] proposed a model which assigns weight to object using 2D Gaussian function to increase the observation of the object and Kalman filter is used to track the object in the soccer game video scene.

In [13] proposed an approach which combines Field of View(FOV) lines method and Kalman filter for tracking of single human moving under multi camera video scene with a static video background.

In [14] proposed a method using Kalman Filter combined with Mean Shift for handling real time occlusion situations. Mean Shift algorithm is used to track using similarity measure and when it fails in handling occlusion Kalman filter is employed for tracking the object under occlusion conditions.

In [15] proposed a model-based approaches for tracking real-time 3D soccer ball in video sequence captured from multiple fixed cameras. The Kalman filter is used to filter merged and noisy objects in image plane as the occlusion caused by players and the ball.

In [16] proposed a state-space model applied to an Extended Kalman Filter which is used to estimate and track the Euler angles and translation parameters of the object in 3D using its 2D image projection.

In [17] proposed content-adaptive progressive occlusion analysis (CAPOA) algorithm that is used to analyze the occlusion situation. To rectify target location the occlusion situation within Region of interest(ROI) using the CAPOA algorithm and then perform the variant-mask template matching(VMTM) based on this result VMTM yields a new ROI whose occlusion situation is analyzed by the CAPOA algorithm again. The final ROI is obtained by template matching of the result of previous ROI and analyzed again by CAPOA algorithm to get final template mask. The non-occluded part of template is updated to Kalman filter.

In [18] proposed a method for detection and tracking small objects using background removal by subtraction of row-mean then the objects are tracked using morphological filters and by Kalman filter after identification the targets.

In [19] proposed a method for smoothing the trajectory of an object in video sequence. They used Kalman filter for reducing the vibrations in trajectory in both vertical and horizontal directions.

In [20] proposed an algorithm for tracking of objects in video scene by combining Kalman filter and superpixel method. Kalman filter is used for occlusion handling and superpixel method for finding real position of the object in the video sequences.

In [21] proposed a model for the description and inference of motion of segmented regions is presented, using the Kalman filter without requiring a priori information of the scene. Segmentation of moving objects is done through the clustering of optical flow vectors for similarity.

In [22] proposed a method which combines extended Kalman filter with color information. Spatio-temporal Gaussian mixture model is used to detect the multiple objects and for tracking the object under partially occlusion extended Kalman filter is used and under complete occlusion color and size were integrated to extended Kalman filter with past information.

In [23] proposed a approach which uses Scale Invariant Feature Transform(SIFT) for tracking the objects in the non occluded frames and when the objects undergo occlusion Kalman filter is used to track in further frames.

In [24] proposed an adaptive Kalman filter for tracking of an object. The modifications for the Kalman filter are done by combination of adaptive estimation, memory attenuated filtering and maximum likelihood estimation for state estimation.

In [25] proposed a method for tracking of vehicles under light and heavy traffic conditions. Gaussian Mixture Model (GMM) used for detection of vehicle and for tracking of the vehicles Kalman Filter was used.

In [26] proposed a modified steady-state gain of the Kalman filter by adding a fractional feedback loop across the Kalman filter gain. This modification of Kalman gain is estimated by minimizing the cost function of the filter. This method was used for tracking of vehicles in a video sequence.

In [27] proposed a method for target detection using single-double side constant false alarm rate(SD-CFAR) and for enhancing the Kalman filter they used Auto Regression model based on interrupt prediction and multi-track method to initialize and track the target.

In [28] proposed an on-line targlet framework for

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tracking of pedestrians. The detection of people is computed based on classifier running on Movement Feature Space(MFS), the outputs generate trajectories of the people in the scene and are concatenated by using Kalman filter approach.

In [29] proposed a neural network based on phase correlation to recognize the object and Kalman filter to track the objects in moving plane. And used to distinguish identical objects based on Kalman filter estimates of the position and velocity.

In [30] proposed multiple objects tracking using Kalman filter simultaneously where several objects occlude one another either partially or fully in dynamic surveillance environment.

In [31] proposed an algorithm by combining adaptive least square and Kalman filter for tracking the object under occlusion. When the object is occluded, the appropriate fitting curve is selected after smoothing trajectories and to predict the object location the least square method is used to fit the object trajectory.

In [32] techniques for generating trajectory of a soccer ball from soccer game video scene using fixed cameras were introduced. Image differencing is used for moving ball detection, for tracking of ball under occlusions Kalman filter is used in each individual camera.

In [33] proposed an adaptive approach which estimates 3D position of soccer ball in soccer game video sequences using two camera viewpoints. The Kalman Filter is used to estimate the 3D position of the soccer ball for the frames when the ball position cannot be detection in the two cameras.

In [34] performed experiments which analyzed the performance of Kalman filter under occlusion by tuning the parameters. The performance of prediction model of the object trajectories are shown under different occlusion conditions.

In [35] proposed a system which is capable of detecting court region in basketball game videos and player extraction. The Kalman filter is used to compute player trajectories and mapped onto court coordinates for identification of tactics of players performing any offense while playing.

In [36] proposed a method for detection and tracking of soccer ball from real soccer video scenes. Tracking and matching of ball process is employed by Kalman filter for solving occlusions when occluded by players in the field. Later 3D ball positions are provided as input in 2D processing for robust and efficient soccer ball detection and tracking.

In [37] proposed a trajectory-based ball detection and tracking algorithm for tennis video scenes. For detection of the ball it uses the location relation of player and the ball to improve the ball candidate. From the ball candidate images the candidate trajectories are produced using Kalman filter in three steps: evaluation of each trajectory, identification of ball trajectory and extending the ball trajectory according to ball hitting points and player location.

In [38] designed a video processing pipeline in a snooker video sequence based on the generalized symmetry transform to estimate the radii and centers of the balls and segmentation. For tracking the balls they have used linear Kalman filter, and based on pixel colors in their area have classified accordingly. Similarly segmentation and classification is done for the black-white cue ball.

In [39] proposed an online multi-object tracking approach by Kalman filter and Hungarian algorithm. The moving objects in the video sequence are segmented by frame difference and labeled those objects by adaptive labeling method. The labeled objects are tracked using Kalman filter and association between them is done by Hungarian algorithm.

- Occlusion Handling

In video object tracking, occlusion happens when a tracked object is not available in camera sequence to continue tracking its spatial state while the object is as yet present at the scene. Occlusion can be classified into three categories: self occlusion, interobject occlusion, and occlusion by the background scene. Once in a while, occlusion happens when one piece of the object occludes another, this is known as self-occlusion. This situation most frequently arises while tracking articulated objects. Inter object occlusion happens in multiple object tracking where the objects occludes each other. And occlusion by the background scene structure happens when a structure out of sight blocks the tracked object. Occlusion handling is an unavoidable problem in object tracking. The main problem occurs during and after the occlusion. There may be mainly two challenges occur while object is under occlusion. Firstly, when two objects occlude each other in multiple object tracking video scene, the foreground blob of the objects will gather together and it will end up testing to characterize the pixels in the blob to particular object precisely. Second, the real location of the tracking object is challenging to decide since the perceivability of the tracked object end up completely absent or constrained while the object is under occlusion. After the object occlusion event ends, particularly the full occlusion, it is hard to decide if the object is another object appear to the scene or it is the same object which undergone and returned after occlusion. This issue becomes more complex particularly when tracking of multiple objects with features like same color or texture. The answers for this issue are regularly known as occlusion recovery techniques. For handling occlusions issue, different strategies has been proposed. We have summarized a few state of the art methods based on the nature of the problem each of the methods tried to solve.

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In [40] proposed a method for tracking an object in video sequence using template matching. Using the Mahalanobis distance and robust error norm for down-weighting outliers due to partial occlusions by an observation mode. The shadow and abrupt changes of lighting conditions are handled by photometric invariants.

In [41] proposed a strategy for tracking multiple objects and their occlusion behavioral relationship while moving in a group under occlusion conditions. The method explicitly defines the occlusion relationships between multiple objects and integrated into tracking framework after deduction of the occlusion relationships. And based on graph embedding framework the joint state estimation problem is deduced in multi-object tracking.

In [42] proposed clustering strategy on object candidates, using spatiotemporal RGB-D video segmentation produced mask for objects in key-frames through the whole video. For solve inconsistency under occlusion they used bilateral representation and scale-invariant feature transform flow. The proposed method extracts multiple objects and tracks them without any user input cue.

In [43] proposed a anti-occluding objects tracking with Dezert-Smarandache Theory (DSmT) in complex background based on occlusion judgment prediction under different occluding conditions and generation of hyper power sets.

In [44] proposed a novel method to segment and track multiple when objects are subject to occlusion by combining spatial-color Gaussian mixture model (SCGMM) with an energy minimization framework which uses multi-label graph cut algorithm. When objects doesn't undergo occlusion, a SCGMM is learned for all such objects.

In [45] introduced a super-trajectory representation based semi-supervised video segmentation approach. And demonstrated that, based on the density peaks based clustering, compact trajectories were grouped into super-trajectories. Occlusion and drift are naturally handled by the trajectory generation method using the probabilistic model showed in their context.

In [46] an object tracking method is proposed where the dominant color of the object is extracted from the segmented target which is selected by the user. A motion model is constructed to set the system model of adaptive Kalman filter firstly. The dominant color of the moving object in HSI color space will be used as feature to detect the moving object in video sequence. The result of detected object is supplied back as the measurement of adaptive Kalman filter and the estimate parameters are adjusted by occlusion ratio adaptively of adaptive Kalman filter.

IV. Conclusion

In this paper, we present a survey of object detection, object representation and object tracking and mainly focused on object tracking using Kalman filter. We have discussed different object detection techniques which is the first step for any object tracking in a video sequence with their merits and demerits of each. For object representation we have summarized algorithms in table 1, suitable for different representations in different object tracking applications where object differs in each of it. In object tracking the widely used tracking algorithm is Kalman filter tracking and we have summarized different works where Kalman filter and other algorithms combined in few cases for object tracking. This paper also provides summaries of occlusion handling while tracking an object in a video sequence, where the occlusion handling issue is still a concern. We believe that this article can give a reliable insight in object tracking under different occlusion conditions using Kalman filter and will be helpful in this particular research topic.

References

[1] R. E. Kalman, “A new approach to linear filtering and prediction problems”, *Transactions of the ASME–Journal of Basic Engineering*, vol. 82, pp. 35–45, 1960.

[2] A. Yilmaz, O. Javed and M. Shah, “Object tracking: A survey”, *ACM Computing Surveys CSUR*, vol. 38,pp. 1–45, Dec. 2006.

[3] J. C. Nascimento, A. J. Abrantes, and J. S. Marques, “An algorithm for centroid-based tracking of moving objects”, *IEEE International Conference on Acoustics, Speech and Signal Processing. Proceedings.*ICASSP99 (Cat. No.99CH36258), vol. 6, Mar.1999,3305-3308.

[4] C. J. Veenman, M. J. T. Reinders, and E. Backer, “Resolving motion correspondence for densely moving points”, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 23, no. 1, pp. 54–72, Jan.2001,ISSN: 0162-8828.DOI: 10.1109/34.899946.

[5] D. Comaniciu, V. Ramesh, and P. Meer, “Kernel-based object tracking” ,*IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 25, no. 5, pp. 564–577,May 2003,ISSN: 0162-8828.DOI: 10 . 1109 / TPAMI .2003.1195991.

[6] A. Ali and J. K. Aggarwal, “Segmentation and recognition of continuous human activity”, *in Proceedings IEEE Workshop on Detection and Recognition of Events in Video*, Jul. 2001, pp. 28–35.DOI: 10.1109/EVENT.2001.938863.

[7] I. Haritaoglu, D. Harwood, and L. S. Davis, “W4:Real-time surveillance of people and their activities”, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 22, pp. 809–830, 2000.

 DOI : 10.35291/2454-9150.2019.0038

[8] Park, Sangheon, et al. "3D hand tracking using Kalman filter in depth space." *EURASIP Journal on Advances in Signal Processing* 2012.1 (2012): 36.

[9] Song, Moon-Hyung, et al. "A novel approach to the enhancement of lane estimator by using Kalman filter." *Control, Automation and Systems (ICCAS), 2017 17th International Conference on*. IEEE, 2017.

[10] Kong, Win, Aini Hussain and Mohd Hanif Md Saad. "Essential human body points tracking using kalman filter." *Proceedings of the World Congress on Engineering and Computer Science*. Vol. 1. 2013.

[11] G. Mallikarjuna, and Ch Satyanarayana, "Object Tracking System Using Approximate Median Filter, Kalman Filter and Dynamic Template Matching." *International Journal of Intelligent Systems and Applications* 6.5 (2014): 83.

[12] Najafzadeh Nima, Mehran Fotouhi, and Shohreh Kasaei. "Object tracking using Kalman filter with adaptive sampled histogram." *Electrical Engineering (ICEE), 2015 23rd Iranian Conference on*. IEEE, 2015.

[13] Purnama Bedy, Bayu Erfianto, and Yusfia Hafidz. "On the experiment of multi camera tracking using kalman filter and FOV lines." *Information and Communication Technology (ICoICT), 2014 2nd International Conference on*. IEEE, 2014.

[14] Panahi, Rahim, Iman Gholampour, and Mansour Jamzad. "Real time occlusion handling using Kalman Filter and mean-shift." *Machine Vision and Image Processing (MVIP), 2013 8th Iranian Conference on*. IEEE, 2013.

[15] Ren Jinchang, et al. "Real-time modeling of 3-d soccer ball trajectories from multiple fixed cameras." *IEEE Transactions on Circuits and Systems for Video Technology* 18.3 (2008): 350-362.

[16] Hajimolahoseini H, R. Amirfattahi, and S. Khorshidi. "Real-time pose estimation and tracking of rigid objects in 3D space using extended Kalman filter." *Electrical Engineering (ICEE), 2014 22nd Iranian Conference on*. IEEE, 2014.

[17] Pan Jiyan and Bo Hu, "Robust occlusion handling in object tracking." *Computer Vision and Pattern Recognition, 2007. CVPR'07. IEEE Conference on*. IEEE, 2007.

[18] Dehghani Abbas, and Ali Pourmohammad. "Small target detection and tracking based on the background elimination and Kalman filter." *Artificial Intelligence and Signal Processing (AISP), 2015 International Symposium on*. IEEE, 2015.

[19] Ruan Tao, et al. "Stabilizing Object Tracking Trajectory on the Basis of Kalman Filter." *Multimedia Big Data (BigMM), 2017 IEEE Third International Conference on*. IEEE, 2017.

[20] Faghihi Mohammad, Mehran Yazdi and Sara Dianat, "Superpixel tracking using Kalman filter." *Pattern Recognition and Image Analysis (IPRIA), 2017 3rd International Conference on*. IEEE, 2017

[21] Sanchez-Garcia, Angel Juan, et al. "Tracking and prediction of motion of segmented regions using the Kalman filter." *Electronics, Communications and Computers (CONIELECOMP), 2014 International Conference on*. IEEE, 2014.

[22] Khan Malik M, et al. "Tracking Occluded Objects Using Kalman Filter and Color Information. " *International Journal of Computer Theory and Engineering* 6.5 (2014): 438-442.

[23] Mirunalini P, S. M. Jaisakthi and R. Sujana, "Tracking of object in occluded and non-occluded environment using SIFT and Kalman filter." *Region 10 Conference, TENCON 2017-2017 IEEE*. IEEE, 2017

[24] Tripathi Ravi Pratap, Soumyabrata Ghosh, and J. O. Chandle, "Tracking of object using optimal adaptive Kalman filter." *Engineering and Technology (ICETECH), 2016 IEEE International Conference on*. IEEE, 2016

[25] Bakti Rizki Yusliana, Intan Sari Areni, and A. Ais Prayogi. "Vehicle detection and tracking using Gaussian Mixture Model and Kalman Filter." *Computational Intelligence and Cybernetics (CYBERNETICSCOM), 2016 International Conference on*. IEEE, 2016.

[26] Kaur Harpreet and J. S. Sahambi. "Vehicle tracking in video using fractional feedback kalman filter." *IEEE Transactions on Computational Imaging* 2.4 (2016): 550-561.

[27] Qian, Y. Chen, X. Cao, J. Wu, and J. Sun, "An underwater bearing-only multi-target tracking approach based on enhanced kalman filter*", IEEE International Conference on Electronic Information and Communication Technology (ICEICT)*, Aug. 2016, pp. 203–207.DOI: 10.1109/ICEICT.2016.7879684.

[28] P. Negri and D. Garayalde, "Concatenating multiple trajectories using kalman filter for pedestrian tracking", *IEEE Biennial Congress of Argentina (ARGENCON)*, Jun. 2014, pp. 364–369.DOI: 10 . 1109 /ARGENCON.2014.6868520.

[29] F. Noor and M. Alhaisoni, "Distinguishing moving objects using kalman filter and phase correlation methods", *IEEE International Multi Topic Conference 2014*, Dec. 2014, pp. 299–304.DOI: 10 . 1109 /INMIC.2014.7097355.

[30] J. M. Jeong, T.-S. Yoon, and J.-B. Park, "Kalman filter based multiple objects detection-tracking algorithm robust to occlusion*", Proceedings of the SICE Annual Conference (SICE)*, Sep. 2014, pp. 941–946.DOI: 10.1109/SICE.2014.6935235.

 DOI : 10.35291/2454-9150.2019.0038

[31] X. Mu, J. Che, T. Hu, and Z. Wang, "A video object tracking algorithm combined kalman filter and adaptive least squares under occlusion", *9th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI)*, Oct.2016, pp.6–10.DOI: 10.1109/CISP-BMEI.2016.7852673.

[32] J. Ren, J. Orwell, and G. Jones, "Generating ball trajectory in soccer video sequences", *in CVBASE '06: ECCV Computer Vision Based Analysis in Sport Environments workshop*, 2006.

[33] N. Ishii, I. Kitahara, Y. Kameda, and Y. Ohta, "3d tracking of a soccer ball using two synchronized cameras", *Advances in Multimedia Information Processing-PCM2007, Berlin, Heidelberg: Springer Berlin Heidelberg,2007*, pp. 196–205,ISBN: 978-3-540-77255-2.

[34] L. Y. Ong, S. H. Lau, V. C. Koo and X. P. Khoo, "Experimental analysis of object tracking during occlusion", *Journal of Engineering and Applied Sciences*, vol. 13, pp. 820–826, 2018.

[35] T. Fu, H. Chen, C. Chou, W. Tsai and S. Lee, "Screen-strategy analysis in broadcast basketball video using player tracking", *Visual Communications and Image Processing (VCIP)*, Nov.2011, pp.1–4.DOI:10.1109/VCIP.2011.6115927.

[36] J. Ren, J. Orwell, G. A. Jones and M. Xu, "Tracking the soccer ball using multiple fixed cameras", *Computer Vision and Image Understanding*, vol. 113, no. 5,pp. 633–642, 2009,ISSN: 1077-3142.DOI: https://doi.org/10.1016/j.cviu.2008.01.007.[37]

[37] X. Yu, C. Sim, J. R. Wang and L. F. Cheong, "A trajectory-based ball detection and tracking algorithm in broadcast tennis video", *International Conference on Image Processing*. ICIP '04.,Oct. 2004,1049–1052 Vol.2. DOI:10.1109/ICIP.2004.1419482.

[38] M. H¨oferlin, E. Grundy, R. Borgo, D. Weiskopf, M.Chen, I. W. Griffiths and W. Griffiths, "Video visualization for snooker skill training",*12th Eurographics/IEEE-VGTC Conference on Visualization, EuroVis'10, Bordeaux, France: The Eurographs Association; John Wiley; Sons, Ltd.*, 2010,pp.1053–1062.DOI:10.1111/j.1467-8659.2009.01670.x.

[39] Z. Wang, X. Jiang, B. Xu, and K. Hong, "An online multi-object tracking approach by adaptive labeling and kalman filter", *Conference on Research in Adaptive and Convergent Systems, Prague, Czech Republic: ACM, 2015*, pp. 146–151,ISBN: 978-1-4503-3738-0.DOI: 10 . 1145 / 2811411 .2811491.

[40] H. T. Nguyen and A. W. M. Smeulders, "Fast occluded object tracking by a robust appearance filter", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 26, no.8, pp.1099–1104, Aug.2004,ISSN:0162-8828.DOI: 10.1109/TPAMI.2004.45.

[41] J. Gao, J. Xing, W. Hu, X. Zhang and R. Hu, "Multi-object tracking under occlusion using dual-mode graph embedding", *in2013 2nd IAPR Asian Conference on Pattern Recognition*, Nov. 2013, pp. 547–551.DOI: 10.1109/ACPR.2013.77.

[42] Q. Xie, O. Remil, Y. Guo, M. Wang, M. Wei, and J. Wang, "Object detection and tracking under occlusion for object level rgb-d video segmentation", *IEEE Transactions on Multimedia*, vol. 20, no.3, pp. 580–592, Mar. 2018, ISSN: 1520-9210.DOI: 10.1109/TMM.2017.2751965.

[43] J. Sun and Y. Wang, "Research on moving object tracking under occlusion conditions", *International Conference on Management and Service Science*, Sep.2009, DOI: 10.1109/ICMSS.2009.5302296.

[44] M. Wu, X. Peng, Q. Zhang and R. Zhao, "Segmenting and tracking multiple objects under occlusion using multi label graph cut", *Computers & Electrical Engineering*, Volume 36, Issue 5, 2010, 927-934, ISSN 0045-7906.

[45] W. Wang, J. Shen, F. Porikli and R. Yang, "Semi-supervised video object segmentation with super-trajectories", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2018, ISSN: 0162-8828.DOI:10.1109/TPAMI.2018.2819173.

[46] S. K. Weng, C. M. Kuo and S. K. Tu, "Video object tracking using adaptive kalman filter", *Journal of Visual Communication and Image Representation*, Volume 17, Issue 6, 2006, Pages 1190-1208, ISSN 1047-3203, https://doi.org/10.1016/j.jvcir.2006.03.004.

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