Moving Object Detection and Tracking under Different Occlusion Conditions in Video Sequences

Arjun Nelikanti, G. Karuna, G. Venkata Rami Reddy

***Abstract*: This paper proposed a novel method for the detection and tracking of hand-thrown object in a video sequence in real time sports events. This paper mainly aimed to detect regions of the object in a set of outdoor and indoor videos in different occlusion conditions, and used Kalman filter to detect object on different trajectories over a fixed time window. This approach proved that the thrown object is successfully detected in various cases under occlusion and non-occlusion conditions with different backgrounds. To evaluate the accuracy, two different types of performance evaluations metrics are used based on object detection and tracking. The results shows that significant performance, the average accuracy of the object detecting is 97.89% and tracking is 98.35%.**

***Keywords* : Kalman Filter , Object detection, Object tracking, Occlusion.**

I. INTRODUCTION

Methods for detection of thrown object in video sequences have direct applicability in the domains of sports video analysis and general human activity monitoring applications. We present one such method, intended for use in sports video analysis system that detects and tracks an object, throwing of object is an example. In addition to detecting the throwing activity, the system must initialize automatic tracking of the object, so the thrown object's trajectory must be recovered and if necessary extrapolated in order to determine the object of the throwing activity.

Few difficulties associated with detection of the ball in sports video analysis are the size of the ball with respect to the field of view, vary in the size with the change in distance from the camera position or view, the presence of many other objects that match the ball features in the frame, occlusions by different objects in the scene and the shape, color or size of the ball changes in frames due to motion of ball and varying lighting conditions. For detection and tracking the object's trajectory is the strongest cue, which remains parabolic in nature and the length of trajectory is large than other moving objects in the video sequence.

The rest of this paper is organized as follows: Section II describes related work. Section III describes our method to track and find the trajectory of the object identified. Section IV describes how the experiments are performed in different situations, Section V presents our results on a set of test videos, and our conclusion is presented in Section VI.

II. RELATED WORK

Many algorithms have been developed in the recent years to detect and track the ball in the sports. S. Zhao, et al[1] proposed a novel single object tracking with moving cameras and handling the ambiguity between appearance change and occlusions. M. Gnanasekera and C. Kulasekere[2] proposed a method based on Kalman Filter to filter out the noise components of the Kalman's Estimation method, which is used to the object's position during occlusions.

G. Waghmare, et al[3] developed a system for shuttlecock detection and prediction of trajectory in real time environment using two 2-D laser scanners. The results obtained by two scanners are used to predict the end point of shuttlecock trajectory. The use of two laser scanners minimized the computational latency over traditional camera.

N. Funde, et al[4] proposed a system for object tracking in environments with the static camera and simple background where no objects are identical to the target object. the main focus of this system is to minimize the effort of manual processing and improve the response time to forensic events. Using segmentation techniques region of interest is cropped in the videos taken from network of cameras. The tracking of target object is done by using the time stamp on the segmented regions of objects.

R. G. Nieto, et al[5] constructed a database called Distorted Video Surveillance Database (DSDV) which are affected by in-capture distortions like low exposure and out-of-focus and performed an analysis of seven eminent trackers using the constructed database with A-R plot performance as measure. The algorithms created depending on perceptual features can improve video object tracking which are affected by these distortions. M. Heimbach, et al [6] proposed an application to improve the accuracy of object tracking in video sequences which are affected by noise and occlusion. Kalman filter is used to improve the accuracy of tracking where covariance parameters are tuned continuously using maximum histogram oriented gradients (HOG) response as a confidence level measure.

J. Kim and M. Kim [7] proposed a vision system for soccer training using multi-exposure cameras to capture high-speed motion images of soccer ball. To detect the soccer ball regions and analyze the motion parameters of soccer ball, a new detection system and motion analysis is used.

A. Kumar, et al [8] proposed an algorithm for visually tracking a tennis ball in 3D.

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This approach uses 2D tracking methods to obtain tracking data of 2D ball from multiple camera views and uses automatic feature-based video synchronization methods. To obtain the 3D trajectory, temporal 3D locations of the ball is determined using 2D locations obtained from synchronized videos and camera calibration information. This approach also presents a physics-based modeling to improve the tracking continuity when cameras have overlapping views. E. Ribnick, et al[9] trajectories of thrown objects are estimated using the Expectation-Maximization (EM) algorithm. Y. Kim and K. Cho [10] proposed a robust multi-object tracking algorithm for acquiring object oriented multi-angle videos of indoor sport play by combining subdivided color histogram based tracking and labeling based tracking. The color histograms are used to distinguish similar color areas and labeling based tracking uses background subtraction and matches labels by comparing past tracking result with the detected object locations for automatic detection.

Mengze Li, et al[11] proposed an algorithm for estimating the position and trajectory of a ball with a RGBD (RGB and Depth) sensor. A ball trajectory detected using color-based back projection method is proposed. The k-means clustering is also employed in order to track the ball even in noisy background. H. Liu, et al[12] 3D location of table tennis ball and velocity is estimated simultaneously using blurred image pair and weighted least-square method is used to estimate flying trajectory of table tennis ball. Wei-Ta Chu, et al[13] introduced Kalman filter based approach which is used to track baseball position and trajectory segments from single view video scene. Using physical model a final trajectory candidate is generated based on trajectory segments.

III. METHODOLOGY

In this paper, we proposed a system model to detect and track the object under different situations is represented in the flow chart below Fig.1.

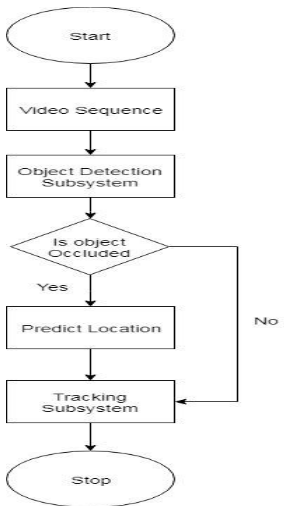
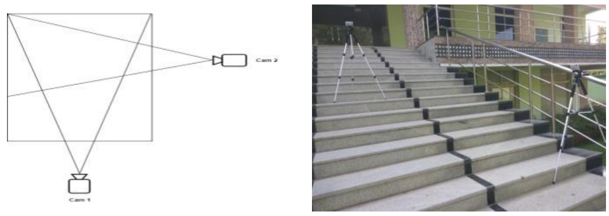


Fig. 1. System overview

A. Image Acquisition

Camera Specifications**:** We have setup two cameras using a standard tripod. Canon Power Shot A4000 IS. The size of captured image is 1280x720 at the frame rate 25fps. The second camera is SonyDSC-T70 which has 640 x 480 video resolution and number of frames per second or capture rate is 30fps.

Camera Views: In our work we have used two cameras in two different positions i.e. in side view and front view. The cameras are placed approximately 0.2 m to 1 m high and 4m apart on either side as shown in fig 2.



(a) (b)

Fig. 2. Hall of fame

B. Dataset

The proposed tracking system was tested using video sequences captured using cameras specified in section III-A. The experiments are conducted with the data sets of varying speed of the object and background scene. The performance of the tracking system was evaluated using these video scenes with different performance metrics shown in section IV. In this paper the object is a cricket ball where the motion of the ball is tracked in different situations. We have considered many cases where the ball undergoes occlusion in different situations. The detection of ball is done in the following different situations where the ball is being as follows:

a. Rolled on the ground: In this case two views are used i.e. front and side view. The object is being occluded at three different places: at release, in middle of the path and at the point where the object hits the wall.

b. On steps: In this case camera positions are at side and front. Occluded at the release and in the path of object moving down. The ball speed may vary depending on the slope of the steps.

c. Thrown in the air: While the ball is moving in the air, it is affected by the earth's gravitational force and air resistance. In this paper we have ignored air resistance.

d. Free fall along with gravity: The ball is released from a certain height. Occluded at release, before hitting the ground and at the point of contact with the ground. The camera positions are at side where the ball can be seen falling towards ground which might make a curve.

e. Thrown against gravity: The ball is thrown from a certain height towards the wall and which bounces back towards the position of release and later to the ground. The other case for throwing is a ball towards the ground which in turn makes a bounce towards wall and hits the wall, later to release position. Occluded at middle of the ball’s flight.

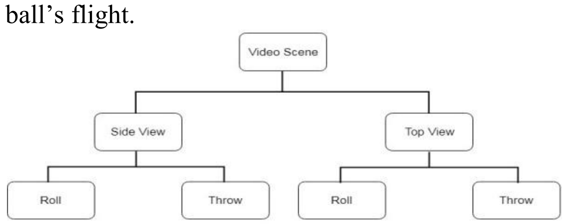


Fig. 3. Test cases

We have considered all these cases as shown in the fig. 3, for evaluating the detection and tracking of the ball under different occlusion conditions in scenes. The below table-1 shows the number of video sequences with approximately 1 to 4 seconds of duration which are considered as primary data for the experimental analysis.

Table-1: Datasets for all cases

Views		Roll	Step	Throw
Front view	Occluded	39	38	24
	Not occluded	69	32	123
Side view	Occluded	39	38	24
	Not occluded	69	32	123

C. Object Detection Subsystem

First the input video stream is converted into a sequence of frames. In each frame of video scene the object is detected and tracked. In this section the object details and detection are covered.

- Object details: The object in our datasets is cricket ball of two colors: Red and White. The shape of the object is round, weighs > 5.5 ounces/155.9 g, <5.75 ounces/163 g, and the circumference shall measure > 8.81 in/22.4 cm, < 9 in/22.9 cm [14]. The speed of ball in the motion is approx to 5m/s to 20m/s used in the dataset.

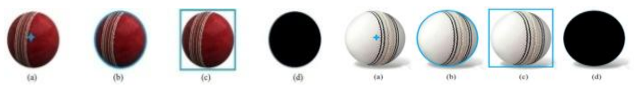
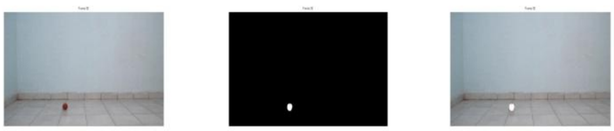


Fig. 4. Object Representation (a) point (b), (c) geometric (d) silhouette

The above fig. 4 shows different ways of object representation [15]. a: point b, c: geometric d: silhouette.



(a) (b) (c)

Fig. 5. Object detection: highlighted ball with white pixels

The detection of moving object uses a background subtraction which only finds a portion of the object as the contrast of the object and the background which produces noise. The intensities which are most probably of the background are determined by a simple heuristic. Then the pixels which do not match to these are called the foreground pixels, these pixels are grouped using 2D connected component analysis. The object is highlighted with white region using foreground detector shown in figure 5, which compares the frame to a background model. In our experiment we have used 10 initial video frames for training background model to determine whether individual pixels are part of the foreground or the background and computes foreground mask.

The value of (x_0, y_0)'s, at any instance is:

$X_1,..., X_t = \{V(x_0,y_0,i): 1 \leq i \leq t\}$

This history is modeled by a mixture of K Gaussian distributions:

$$P(X_t) = \sum_{i=1}^{K} \omega_{i,t} N(X_t|\mu_{i,t}, \Sigma_{i,t}) \quad (1)$$

$$N(X_t|\mu_{i,t}, \Sigma_{i,t}) = \frac{1}{(2\pi)^{D/2}} \frac{1}{|\Sigma_{i,t}|^{1/2}} \exp\left(-\frac{1}{2}(X_t - \mu_{i,t})^T \Sigma_{i,t}^{-1} (X_t - \mu_{i,t})\right) \quad (2)$$

Where, K is the number of distributions, ω is a weight associated to the i^{th} Gaussian at time t and μ, Σ are the mean and standard deviation of said Gaussian respectively.

The association of detections to the same object is based on motion. The Kalman filter [16] is used to estimate the track of the ball motion.

D. Object Tracking Subsystem

The next step after detection of the object in different scenarios is tracking the object. This is the most important step as it gives the exact object behavior and properties if we have high success rate in tracking the object. The needed properties have been evaluated in the section IV. Tracking is defined as the problem of estimating the trajectory of an object in an image plane as it is under motion in a scene. Tracking an object in the video scene is a crucial issue. Analysis and tracking the moving object is one of the most popular researching areas in many kinds of sports for the analysis of tactics and of object's moving pattern in the games such as soccer, baseball, volleyball, cricket, tennis, etc,. Tracking of an object isn't easy all the time; there are few challenges while tracking in a video sequences like occlusions, complex background, scale variation, large illumination changes, etc. Tracking happens in the different situations as: no occlusion, partial occlusion and full occlusion.

In this paper we have used the most popular and widely used tracking algorithm i.e. Kalman filter which best suits for tracking smaller size objects.

- Kalman Filter

The Kalman filter[16] is valuable for tracking distinct types of moving objects. It was initially created by Rudolf Emil Kalman to track the path of spacecraft at NASA. Kalman filters can be utilized by various different types of linear dynamical systems. The Kalman filter is a recursive 2-stage filter. The two phases are predict and update. In the predict phase, present location of the moving object is estimated or predicted based on the previous observation made. For illustration, if an object is moving with consistent dispatch, current location of an object at X_t can be based on its prior location, X_{t-1}. In the update phase the capacity of the object's present location is pooled with the predicted location and acquires the posteriori projected current position of the object.

The two stages of Kalman Filter : prediction and correction,

Prediction:

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

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

Updation:

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

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

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

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

- Trajectory Generation

A trajectory T_i is a sequence of the state parameters of an Object i along the frames k = 1,2,…,n from its detection to the end of tracking.

$T_i = \{ (t, p)_k | \ k = 1, . . . , n\}i$

Where t_k is the time of frame k and p_k is the centroid of object i at the frame.

The two main steps in any object tracking in a video scene are:

(i) Detecting of the moving object in every frame.
(ii) Associating the detections corresponding to the same object in video sequence.

In video scene, few detections of the object may be assigned to tracks, while other detections may not be assigned. The tracking locations are updated using the corresponding detections. The tracks which are not assigned are marked invisible. If tracker does not detect the ball in the frame till the video scene ends then it assumes that the object moved away from the field of view and the track gets deleted till last successful track location. The trajectory of an object in few video scenes is shown in section IV.

The challenging problems investigated in this work mostly occur due to:

- lack of camera view
- fast ball kinematics
- small size of the object
- occlusion

IV. IMPLEMENTATION

We have implemented the proposed method and executed on the PC that has Intel(R) Core^{TM} i5 CPU and 6,144 MB memory running MATLAB R2014a. MATLAB has an Image Processing Toolbox for handling images and videos efficiently.

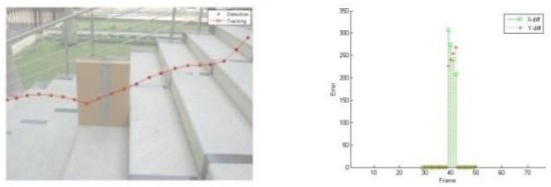
A. Detection and tracking of ball

The process of ball presence calculation algorithm in the video sequences is summarized as follows.

Algorithm 1: Ball Presence
Result: Ball visibility in video
while (VideoIsPlaying) **do**
  readEachFrame();
    if*isempty(detectedBallLocation)***then**
      NonBall++
else
      BVisible++
    end
    if*trackedBallLocation ≤framesize***then**
      BTracked++
    else
      Bnt=Bnt++
    end
end
occluded=BallTracked-BallVisible;

The above algorithm is implemented and the results obtained are shown in table III discussed in section V.

The figure 6(a) shows the detection and tracking of the cricket ball in a image sequence and the ball occluded when it passes behind the box at the frames (39 to 42) which is shown in figure 6(b), the difference of (x,y) of detection and tracking shown on y axis and frame numbers on x axis when the ball undergoes occlusion.



(a) (b)

Fig. 6. Ball occlusions in (a) Trajectory and (b) error difference of detection and tracking

The figure 7 shows 3 frames of the test sequence in ball being rolled on ground under occlusion with the ball (a) completely visible before it undergoes occlusion, (b) partially occluded ball and (c) completely occluded ball which cannot be seen in the image.

(a) (b) (c)

Fig. 7. Three frames of the test sequence (a) Complete visibility (b) Partially visible or occluded (c) Complete occlusion and/or not visible in the scene.

The fig. 8 shows the trajectory of ball tracked in different conditions in both side and front views as described in section III-B.

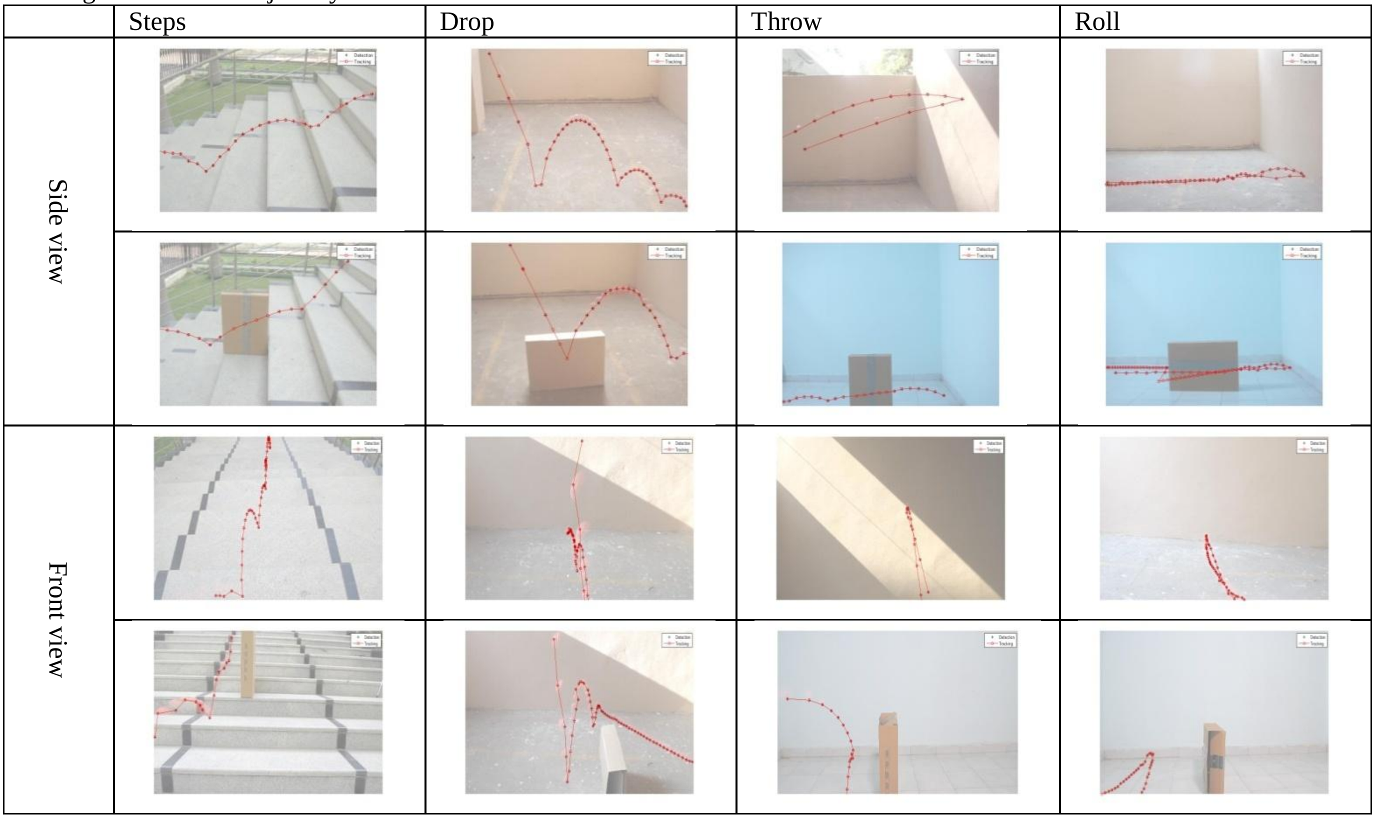


Fig. 8. Trajectory of detected ball

The velocity and the throwing angle of the ball [17] are calculated once the cricket ball locations are detected in the image sequence utilizing the tracking information.
These two parameters are used to further analyze the ball motion and the results are shown in table 4.

- Calculation of Ball Throwing Angle

The ball throwing angle (θ_{bt}) is calculated by using the below equation

$$\theta_{bt} = \tan^{-1}\frac{(y_{i+1}-y_i)}{(x_{i+1}-x_i)} \quad (10)$$

where, (x_i, y_i) and (x_{i+1},y_{i+1}) are the coordinates of ball location for i and (i+1) frames respectively.

- Velocity Estimation of Thrown Ball

The velocity of throwing ball can be calculated as,

$$v_{throw} = 4.9.\frac{t_{throw}}{\sin(\theta_{bt})} m/s \quad (11)$$

where, t_{throw} is ball flight duration in the video scene which can be calculated as,

$$t_{throw} = \frac{T_l}{f_r} sec \quad (12)$$

Where, T_l is length ball tracked in video scene and F_r is frame rate of video captured.

Table-2: Estimated results of ball in motion.

Video Sequence	Fr in fps	T_{throw} in sec	θ in deg	V_{throw} in m/s
s7-1	30	1.37	74.29	7.49
so4-7	30	0.70	47.73	6.05
so4-11	30	1.43	61.56	7.34
suo2-4	30	0.80	35.22	6.39
f7-1	25	1.76	1.06	9.88
fo4-7	25	0.96	87.40	8.76
fo4-11	25	1.32	86.57	6.57
fuo2-4	25	0.92	67.38	4.57
s3a	30	2.07	3.95	14.07
s8a	30	2.37	2.20	14.37
so4w	30	2.27	39.40	11.20
so8a	30	1.73	14.04	8.54
f3a	25	1.80	18.00	11.79
f8a	25	2.28	42.77	11.93
fo4w	25	1.52	88.49	14.78
fo8a	25	2.00	51.34	11.14
d3	30	1.17	70.20	6.46
d5	30	1.80	66.28	29.26
so4da-1	30	1.50	61.80	8.56
d3-1	25	2.56	82.58	16.07
d5-1	25	2.24	76.64	11.61
fo4da-1	25	2.84	84.06	20.24
sro-4	30	1.50	1.49	7.37
fro-4	25	2.08	65.10	13.24
s1-1	30	0.73	16.23	7.18
s3-6	30	0.57	27.47	3.87
s6-1	30	0.90	9.83	11.09
f1-1	25	1.52	73.19	9.26
f3-6	25	1.08	71.43	7.18
f6-1	25	1.08	75.05	15.61

B. Evaluation Protocol

The two metrics for tracking evaluation are: recall and precision. Precision measures the average distance between the track and the ground truth while recall measures overlap.

$$\text{Precision} = \frac{\#\text{true positives}}{\#\text{true positives}+\#\text{false positive}} \quad (8)$$

$$\text{Recall} = \frac{\#\text{true positives}}{\#\text{true positives}+\#\text{false negative}} \quad (9)$$

The figure 9 shows the accuracy, precision and recall of ball tracking in different cases of moving ball under different situations.

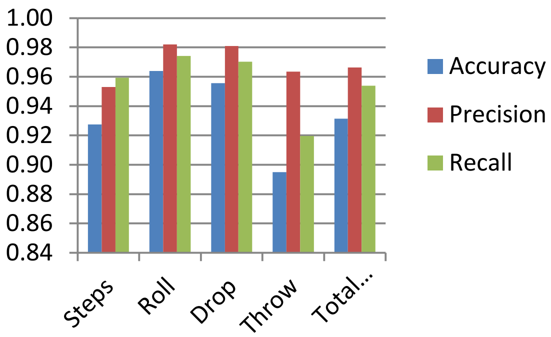


Fig. 9.Evaluation of ball tracking

- System Limitations:

Speed of the object: Shape deformation due to fast speed, so limiting speed in this paper.

Camera specifications: camera lenses which affect the quality of video captured and zooming capacity due to which the field of view area is maximum 12ft X 12ft.

However, the occlusions are still cannot be avoided in the moving object tracking context which constraints accuracy. The proposed system model ignores air friction, cannot model some complicated movements of the ball under occlusion and shadow of the object.

V. RESULTS AND DISCUSSIONS

In this section we discuss the results obtained by implementing our method for detection and tracking of a cricket ball in the test sequences.

Table-3: Presence of cricket ball

Video sequence	Ball present		Ball not present
	Ball frames	Ball occluded	Non ball frames
s6-1	15	0	21
so3-2	13	4	40
su1-1	26	0	56
suo2-6	17	4	73
f6-1	14	0	75
fo3-2	12	0	75
fu1-1	55	0	7
fuo2-6	21	0	118
s1	54	0	9
s3a	38	0	6
so1a	61	4	42
so4w	61	3	16
f1	45	0	41
f3a	39	0	24
fo1a	52	7	36
fo4w	28	3	45
d2	35	0	12
so4da-1	25	3	33
d2-1	45	0	12
fo4da-1	62	0	43
s1-1	20	0	11
s3-2	17	0	5
f1-1	16	0	31
f3-2	17	0	23

The table 3 shows the cricket ball presence situation in the test scenes. This situation is classified as: the ball has been considered visible if the ball is occluded < 25% of its surface area and it has been considered occluded if the ball visibility vary between the 25% and 50%. Non-Ball cases include both where the ball is occluded for > the 50% of its area and where the ball is absent.

Table- 4: Performance of cricket ball detection and tracking

Video	Ground Truth		Cricket Ball Detection			Cricket Ball Tracking		
	Total frames	Ball frames	Correct Frames	False Frames	Accuracy (%)	Correct Frames	False Frames	Accuracy (%)
s6-1	36	15	36	0	100.00	36	0	100.00
so4-2	57	13	55	2	96.49	57	0	100.00
su1-3	68	34	68	0	100.00	68	0	100.00
suo2-6	94	17	94	0	100.00	94	0	100.00
f6-1	89	14	88	1	98.88	89	0	100.00
fo4-2	84	10	84	0	100.00	84	0	100.00
fu1-3	100	61	100	0	100.00	99	1	99.00
fuo2-6	139	21	139	0	100.00	139	0	100.00
s2	72	34	69	3	95.83	72	0	100.00
s4a	127	77	127	0	100.00	126	1	99.21
so1a	107	61	107	0	100.00	107	0	100.00
so4w	80	61	80	0	100.00	80	0	100.00
f2	70	27	70	0	100.00	70	0	100.00
f4a	125	82	124	1	99.20	124	1	99.20
fo1a	98	52	95	3	96.94	97	1	98.98
fo4w	76	28	76	0	100.00	76	0	100.00
d5	61	42	61	0	100.00	61	0	100.00
so4da-1	61	25	60	1	98.36	60	1	98.36
d5-1	71	51	71	0	100.00	71	0	100.00
fo4da-1	105	62	105	0	100.00	105	0	100.00
s3-4	27	16	27	0	100.00	27	0	100.00
s3-5	26	16	25	1	96.15	25	1	96.15
s4-2	30	15	30	0	100.00	30	0	100.00
f3-4	35	14	35	0	100.00	35	0	100.00
f3-5	39	14	39	0	100.00	38	1	97.44
f4-2	58	16	58	0	100.00	58	0	100.00

The experimental findings of the ball detection-and-tracking for different said cases are shown in Table 4.

In above table 4, the ball frames are manually counted in ground truth which refers the ball present in video sequence except occluded ball frames (the frames where the ball visibility is more than 25%), "Correct Frames" refers to those frames where the ball has been detected and tracked in ball frame and does not detect and track the ball in a non-ball frames where "False Frames" refers to wrongly detected ball frames in a non-ball frame and/or the ball is detected and tracked in a ball frame.

The accuracy is the ratio between the correct detection to the number of ball frames in the video sequence.
The figure 10 shows accuracy of ball detection and tracking in different said cases, it can be seen that the accuracy of the detection and tracking is low in the ball thrown case and ball tracking accuracy is high in ball rolling case. this is due to the speed of the ball, in rolling case the ball moves in a uniform direction with a less speed when compared to the ball thrown in the air towards the wall which bounces back to the point of release. In this case the ball takes non uniform trajectory shape as shown in the figure 8.

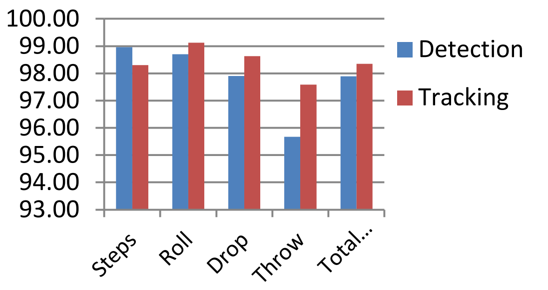


Fig. 10. Accuracy of ball detection and tracking

VI. CONCLUSION

The experimental results demonstrated that the Kalman filter can distinguish the occurrence of occlusion and track the target through appearance changes and complex occlusions. The main contributions in this paper are, Firstly, a two-camera base hardware configuration is presented with different specifications to analyze the detection, tracking ball and trajectory acquisition. Second, cricket ball detection based on background subtraction is used for fast and precise detection of cricket ball. Third, a novel model in the prediction process is proposed which generates trajectory of the ball tracking using the Kalman filter. The emergence velocity of the ball can be derived if the incidence velocity and the angle are known, which is vital for predicting the trajectories of moving ball. In the results shown the velocity of the ball varies from 3 to 30 m/s.
In future, we would like to develop a framework model which can be utilized for further investigation of the sports video taking into consideration about the other factors like earth's gravity, ball spin etc, using two cameras with high configuration for high speed 3-D trajectory projection to enlarge the precision without speed sacrifice.

REFERENCES

1. S. Zhao, S. Zhang and L. Zhang, "Towards Occlusion Handling: Object Tracking With Background Estimation," in *IEEE Transactions on Cybernetics*, vol. 48, no. 7, pp. 2086-2100, July 2018. doi: 10.1109/TCYB.2017.2727138.
2. M. Gnanasekera and C. Kulasekere, "A Kalman filter based occlusion handler for lengthy occlusions," 2016 International Conference on Microelectronics, Computing and Communications, Durgapur, 2016, pp. 1-4. doi: 10.1109/MicroCom.2016.7522545.
3. G. Waghmare, S. Borkar, V. Saley, H. Chinchore and S. Wabale, "Badminton shuttlecock detection and prediction of trajectory using multiple 2 dimensional scanners," IEEE First International Conference on Control, Measurement and Instrumentation, Kolkata, 2016, pp. 234-238.doi: 10.1109/CMI.2016.7413746
4. N. Funde, P. Paranjape, K. Ram, P. Magde and M. Dhabu, "Object Detection and Tracking Approaches for Video Surveillance Over Camera Network," 2019 5th International Conference on Advanced Computing & Communication Systems, Coimbatore, India, 2019, pp. 1171-1176. doi: 10.1109/ICACCS.2019.8728518
5. R. G. Nieto, H. D. B. Restrepo and I. Cabezas, "How Video Object Tracking Is Affected by In-capture Distortions?," ICASSP 2019 - 2019 IEEE International Conference on Acoustics, Speech and Signal Processing, Brighton, United Kingdom, 2019, pp. 2227-2231. doi: 10.1109/ICASSP.2019.8683625
6. M. Heimbach, K. Ebadi and S. Wood, "Improving Object Tracking Accuracy in Video Sequences Subject to Noise and Occlusion Impediments by Combining Feature Tracking with Kalman Filtering," 2018 52nd Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, USA, 2018, pp. 1499-1502. doi: 10.1109/ACSSC.2018.8645175
7. J. Kim and M. Kim, "Smart vision system for soccer training," International Conference on Information and Communication Technology Convergence, Jeju, 2015, pp. 257-262. doi: 10.1109/ICTC.2015.7354543
8. A. Kumar, P. S. Chavan, V. K. Sharatchandra, S. David, P. Kelly and N. E. O'Connor, "3D Estimation and Visualization of Motion in a Multicamera Network for Sports," 2011 Irish Machine Vision and Image Processing Conference, Dublin, 2011, pp. 15-19. doi: 10.1109/IMVIP.2011.12
9. E. Ribnick, S. Atev, N. Papanikolopoulos, O. Masoud and R. Voyles, "Detection of thrown objects in indoor and outdoor scenes," 2007 IEEE/RSJ International Conference on Intelligent Robots and Systems, San Diego, CA, 2007, pp. 979-984. doi: 10.1109/IROS.2007.4398962.
10. Y. Kim and K. Cho, "Robust multi-object tracking to acquire object oriented videos in indoor sports," 2016 International Conference on Information and Communication Technology Convergence, Jeju, 2016, pp. 1104-1107. doi: 10.1109/ICTC.2016.7763379
11. M. Li, A. Ravankar, A. A. Ravankar, Y. Kobayashi and T. Emaru, "Estimation of position and trajectory of a flying ball in 3-D space," IEEE/SICE International Symposium on System Integration, Nagoya, 2015, pp. 443-448.
12. H. Liu, Z. Li, B. Wang, Y. Zhou and Q. Zhang, "Table tennis robot with stereo vision and humanoid manipulator II: Visual measurement of motion-blurred ball," IEEE International Conference on Robotics and Biomimetics, Shenzhen, 2013, pp. 2430-2435. doi: 10.1109/ROBIO.2013.6739835.
13. Chu, Wei-Ta, Chia-Wei Wang and Ja-Ling Wu. "Extraction of baseball trajectory and physics-based validation for single-view baseball video sequences." 2006 IEEE International Conference on Multimedia and Expo. IEEE, 2006.
14. https://www.lords.org/mcc/laws/the-ball
15. A. Yilmaz, O. Javed and M. Shah, “Object tracking: A survey”, ACM Computing Surveys CSUR, vol. 38,pp. 1–45, Dec. 2006.
16. 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.
17. B. Chakraborty and S. Meher, "A trajectory-based ball detection and tracking system with applications to shooting angle and velocity estimation in basketball videos," 2013 Annual IEEE India Conference, Mumbai, 2013, pp. 1-6.

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