Cricket Ball Detection using Computer Vision

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***Abstract*—Cricket is such a popular game worldwide that people relate to it while watching it. In India, people are connected to the game through their emotions. In such games, there must be a need for a system that supports the umpire in critical decisions as there is plenty of scope for errors, which can sometimes be controversial. This paper proposed a system based on computer vision that can assist the umpires. There is a rule called LBW in cricket, which states that if a ball can hit the wicket but instead gets obstructed by the batter's body part, then it can be given out on the appeal of the fielding team; thus, this software can help in making LBW decisions by tracking the ball. The team can also employ it to detect the batsman's weak and strong zones. The proposed paper focuses on two approaches viz The Sliding Window technique and Segmentation by Colour technique; these two approaches are used to detect the object (in this scenario, the object is the ball). A high accuracy level in detecting and tracking the ball has been observed in the results.**

Keywords—cricket, video feed, computer vision, object detection, image segmentation, sliding window, ball tracking

I. Introduction

Watching Cricket is fun but when the things come to such critical decisions where the single decision impacts the final result of the game, there is a requirement of such a system which can give accurate decisions. Relying on decisions of umpires is not justice for teams as they are not accurate because there is a scope of human error. Also it is not possible to track the ball precisely which is blowing from speed of 130 kmph to 160 kmph. In such a case there is a need for a system which can assist the proper tracking of the ball and give accurate decisions.

Cricketers like Sachin Tendulkar have received the highest civilian award in India, i.e., The Bharat Ratna, for their contribution to the game. This very much proves the craze of the game for the people of the country. When such importance is given to something by the people, their decisions also affect them. There are times when things come to such critical decisions where the single decision impacts the result of the game. The law of LBW is the most significant example of that. It has sparked quite a lot of controversies in the past. There is also a scope of error in detecting fours and sixes accurately, as even a single run can cost the batting side the whole match. Nowadays, teams rely heavily on the DRS, i.e., the Decision Review System or the Umpire Decision Review System, where teams can challenge the on-field umpire's decision and ask for the third umpire's help, known as the TV umpire.

The system proposed in paper consists of such a model that helps in hotspot detection of players. It helps at two places. One is during LBW(Leg Before Wicket) which is such a critical decision that a minute direction or position of the ball can impact the result which can not be detected by the human eye. There is a need for assistance in deciding whether the ball has pitched inside or outside the stumps. Second benefit is it helps in detecting strong and weak zones of the player. Each player has some weak zone where they can be stumped easily. It helps in identifying such zones of players and players can perform better in upcoming matches using this data.

It is possible for systems using different approaches to the ball tracking system by computer vision. One popular approach is Sliding window. In this the complete image frame is divided into a number of patches of 3 by 3 or 5 by 5 grid into two classes one class consisting of an object and another not consisting of an object. This method is simple and efficient but one drawback is that it is expensive as it considers every patch of an image. Another approach is segmentation by colour. In this technique, instead of considering every patch we focused on patches containing the similar colour of our ball and segment these patches.

Some of the components of DRS are:

- *Hawk Eye:* It is used in International Cricket to find whether the ball would have hit the stump, which initially gets stopped by the batter's body. The no. of cameras used for hawk-eye is six, and the framerate for each is 340 fps.
- There is a replacement for Hawk Eye, which is the Virtual Eye. It has four cameras, and the framerate for each is 230 fps.
- Slow Motions, video replays, zoom, pause, etc.
- *Snickometer:* It is used to detect sounds. It is used to distinguish whether the ball hits the bat or not. If the ball edges the bat, then an audio spike can be seen on the graph.

- *Hot Spot:* It is a system for infrared imaging. Very high-power cameras are used for the same. The third umpire can see whether or not the ball has made contact with the bat.

Thus, for TV umpires, such a system is required to be accurate. Relying on umpires' decisions is not justice for teams as they are inaccurate because there is a scope of human error. Also, it is impossible to track the ball blowing from 130 kmph to 160 kmph. In such a case, there is a need for a system to assist in adequately tracking the ball and making accurate decisions.

Fig.1. Cricket Hotspot detection at play

The proposed system in the paper consists of a model that helps ball tracking. LBW (Leg Before Wicket) is a critical decision that a minute direction or ball's position can impact the result, which the human eye cannot detect. There is a need for assistance in deciding whether the ball has pitched inside or outside the stumps. The second benefit is that it helps see the player's strong and weak zones. Each player has some weak zone where they can be stumped easily. It helps identify such zones of players, and players can perform better in upcoming matches using this data.

Systems can use different approaches to ball-tracking systems by computer vision. One popular approach is a Sliding window. In this, the image frame is divided into several patches of 3 by 3 or 5 by five grids into two classes, one consisting of an object and another, not a thing. This method is simple and efficient, but one drawback is that it is expensive as it considers every patch of an image. Another approach is segmentation by colour. In this technique, instead of considering every patch, we focused on patches containing a similar colour to our ball and segmented these patches.

II. Literature Survey

[1] To detect overstepped no-balls in a cricket match, the paper has used a variety of computer vision-based methodologies. The effective and efficient proposed approach established a template frame for each camera that detects the popping crease marker, and then it applied a subtraction analogy for photos between the video and template frames from the umpire's selected camera. The proposed method has eliminated human perceptions' shortcomings in deciding to overstep the ball on wiped-out opportunities. [2] This model categorises the data to make fair and impartial judgments to enhance the game's quality. While the existence of genuine, original datasets would have been more beneficial in these classification issues, the models lower the overhead costs of making these judgments and preserve the game's rhythm. With synthetic data, it was possible to analyse the photographs, and the model better than SVM was CNN. [3] The research investigated strategies for identifying actions such as no-ball. The system presented in the article automates many actions throughout a cricket match; these would assist the umpire and coach in making precise decisions during the contest. A database may be utilised to make judgments using various approaches. They make the choices that land the umpire in hot water. [4] This project recognises acceptable movements in the game of cricket without the need of any specialised sensor or gloves; instead, a static camera on the umpire is required because the background is mainly stationary; nonetheless, this approach works better for static motions such as out, no six wides, and so on. This project involves the training of multiple classifiers. [5] After obtaining the maximum correlation threshold, the Mach filter was used to correlate the test video with the Mach train set. Several vision-based tracking algorithms and their thorough implementation in a consistent manner are discussed as a method of detecting unique cricket plays. Real-world cricket shots have been used to support the precision of the suggested approach. [6] Because of its high cost and limited code transparency, the cricket control system is now only used in a few college teaching scenarios to investigate or validate specific algorithms. However, the system design cost is relatively cheap in this work. Compared to other cricket control systems, this system has the benefit of integrating computer vision technology, which can display the real-time movement of the ball. The selection of device materials is rather versatile, and the algorithm program is simple to grasp. [7] In this study, cricket players' career statistics datasets were subjected to several unsupervised machine learning approaches, such as k-means clustering density estimation and outlier detection. It's done to identify standout players and commanding team members by automatically classifying the players according to their level of batting and bowling output. The results are consistent with expert-generated rank lists that ranked the players using a different qualitative methodology. [8] The critical contributions to cricket sports analytics are automated stroke classification and overlay annotation to obtain objective diagnostic measures or quantities from data. ML and AI are used to analyse game actions, research ACST development, and analyse the feed of broadcast sporting events. [9] In a snickometer, five audio samples were wirelessly communicated to the processing unit where features were collected; these characteristics were further integrated to develop the model. An accuracy of 97.5 was obtained for samples of 260 data points and testing samples of 40 data points. [10] The suggested framework depends on the pre-trained CNN to segregate representations through the model's three auxiliary components. The research provides a unique way to recognize various shots in the area of cricket sport. The network outperformed any previously employed flagship descriptors and had accurate classifiers that effectively detect anomalies. [11] This work used various IMU sample frequencies to see if machine learning models could correctly measure rapid bowling events. No matter how many bowling phases were employed or the sampling frequency, all models had high accuracy of 95%. Gyroscope sensor properties contributed significantly to each model's accuracy, an important discovery for future event-detection work. [12] This study discusses three convolution layers of a CNN model's method for classifying cricket shots. Maximum polling layers are three-four layers with dropouts.

Two thick layers and one flattening have been used. Using functional layers for coaching and enhancing bowling and batting abilities reduces overfitting. [13] In the intended method, the cricket video frames may be distinguished into three class forms using a cricket play differentiator methodology based on optical observation methods. The technique has demonstrated strong performance in identifying the enlarged frames' pitch and distance view shot types. [14] Localization methods are implemented using fingerprinting, and inexpensive approaches such as WLAN are often used. These solutions use conventional wireless architecture and do not require hardware; nonetheless, RFID is appropriate for congested situations. There are no prerequisites for indoor localisation; the precision needed for the surroundings determines the choice of this approach. [15] The covariance descriptor has been proposed as a tool for recognising tasks in an online context. The proposed descriptor encodes the statistics of temporal shape and motion changes in a low dimensional space; the method was successfully tested on a privately collected dataset using quality measures such as latency that were specially designed for the online scenario. The descriptor was evaluated on standard gesture recognition datasets, demonstrating performance comparable to the state-of-the-art despite its relative simplicity and compactness. [16] This essay has covered some of the current challenges and some of the existing applications of computer vision in sports. Currently, there are reputable commercial applications utilising innovations like multi-camera ball tracking to provide inside depth information for analysis, coaching, and referee support for TV watchers. Systems for tracking broadcast cameras based on vision Erasers enable the integration of overlays into the image. [17] This research addresses the issue of localising the temporal activity of cricket strikes in match broadcast videos. We build two pipelines for this work based on whether or not the perspective invariance labelling assumption (Constrained) is taken into account (Unconstrained). On the Generic dataset, the Constrained model, which depends on additional CUT annotations and perspective starting frames, performs the fastest and most accurately. [18] The presence of public emotions in social media data presents special difficulties and opportunities for decision-making across several fields. The main contribution of this study is to demonstrate that clever computational tools may be used to recognise and categorise different emotional states in texts. [19] The presence of public emotions in social media data presents special difficulties and opportunities for decision-making across several fields. The main contribution of this study is to demonstrate that clever computational tools may be used to recognise and categorise different emotional states in texts. [20] In this study, we add two new techniques to the rank pooling method. First, we present an efficient, clear, and fundamental temporal encoding technique based on the discriminative rank pooling framework that can be used for action classification tasks with vector sequences or video sequences generated by convolutional neural networks. [21] In most cricket matches, the hotspot is one of the most widely acknowledged and accurate technologies. Despite the accuracy of this technology, ICC has not made it officially available. This gadget informs hitters whether the ball has struck their pad, making the umpire's work easier. In the future, this may pose a risk for umpires since they may be replaced, causing them to lose employment. Anyone may readily estimate that the ball misses the off stump with the help of this hot location. [22] The neural network performed extraordinarily well, with an accurate classification rate of 97.5% for data that had never been seen before. It is thought that improving the characteristics retrieved from the wavelet transform and utilised to train the neural network will yield better outcomes. [23] Techniques for automating the categorization of cricket pitch frames are proposed in this research. The grayscale histogram statistical modelling has been discovered to be a forgiving classifier with a good recall. Experiments on four films with varying content and quality confirmed the algorithms' usefulness and deployment in sequence. The algorithm's retrieved pitch frames can be utilised for additional processing, such as segmenting important players on the pitch. Accounting for shadow effects and topological irregularities of the players discovered in the pitch frames can enhance the outcomes. [24] Computation has been developed that accurately identifies the cricket video's events. Because K-implies division computation is simple, it completes the full division operation of the video without breaking a sweat, adding to the overall impact of the study. Since the job manages several Umpires' signs, multiple classes are distinguished by these signs. For scene characterisation, these classes need a multiclass outfit classifier. [25] A real-time technology was presented to update the cricket scoreboard without requiring human intervention. After key incidents, the system recognises the indication indicated by the match umpire. The sole disadvantage of this method is that scorers must still pay attention to the batters' runs taken by sprinting between the wickets because the umpire does not indicate 1s and 2s. [26] The primary advantage of the acoustically based highlight and key event recognition presented in the study for television broadcasters is the automatic generation of a highlight package. We were able to eliminate the requirement for developing a heuristic set of criteria to identify critical event detection by applying Hidden Markov Model-based classifiers to the data set, avoiding a two-class method that was proved to be ineffective. [27] Results showed that when adjudicators needed to distinguish between crucial cricket sounds like a ball hitting a bat and a ball hitting a pad, seeing a sound file in the time domain proved to be unclear. The correlation values of the wavelet transform and the accompanying pseudo-frequency at the points of interest demonstrate distinct discrepancies between the two signal classes when the sound files are analysed using the wavelet transform. [28] The experimental findings showed that the Kalman filter can identify when an obstruction occurs and can keep track of the target despite changes in appearance and complicated obstructions. [29] The paper presents a straightforward method for cricket wide-cast video analysis. The method operates on three levels: a) categorising the kind of perspective b) recognising the shots where effective play occurs; and c) determining the stroke direction. We had good success (80%) in identifying the stroke's direction. [30] The study offers a simple technique for wide-cast cricket video analysis. The technique works on three different levels: a) classifying the perspective; b) identifying the shots where effective play happens; and c) establishing the direction of the stroke. We were able to determine the direction of the stroke with good success (80%).

III. Methodology

A ball detection system based on computer vision that can assist the umpire is introduced. There is a rule called Leg Before Wicket (LBW) in cricket, which states that if a ball can hit the wicket but instead gets obstructed by the batter's body part, it can be given out on the appeal of the fielding team. As it is impossible to track the ball precisely, which is coming at a speed of 130 kmph to 160 kmph, in such cases, there is a need for a system that can assist in the proper tracking of the ball and give accurate decisions.

The system proposed in the paper consists of such a model that helps in the hotspot detection of players. It helps in two places. One is during LBW, which is such a critical decision that a minute direction or position of the ball can impact the result, which the human eye cannot detect. There is a need for assistance in deciding whether the ball has pitched inside or outside the stumps. The second benefit is that it helps detect the player's strong and weak zones. Each player has some weak zone where they can be stumped easily. It helps identify such zones of players, and players can perform better in upcoming matches using this data.

Algorithm 1 Algorithm for object tracking with a sliding window and segmentation by colour

Input: Path to the video file for its comparison with the data-set.

Output: A classification report for the selected frame based on the object detected.

Initialisation :

1: Create a Video-Capture object and read from the input file.
2: Capture and crop the video frame-by-frame.
3: Read and initiate a binary threshold on all the frames.
4: Apply Gaussian blur to the specified frame.
5: Create a grey mask and obtain the contours based on the specified HSV values.
6: Create labelled patches that presumably contain the object.

Fig. 2. Algorithm

Systems can use different approaches to the ball-detecting system by computer vision. One popular approach is a Sliding window. In this, the image frame is divided into several patches of 3 by 3 or 5 by five grids into two classes, one consisting of an object and another, not an object. This method is simple and efficient, but one drawback is that it is expensive as it considers every patch of an image. Another approach is segmentation by colour. In this technique, instead of considering every patch, we focused on patches containing a similar colour to our ball and segmented these patches. The proposed work focuses on two approaches viz the Sliding Window technique and Segmentation by Colour technique; these two approaches are used to detect the object (in this scenario, the object is the ball). A high accuracy level in detecting the ball can be achieved using this technique.

IV. Flow Chart

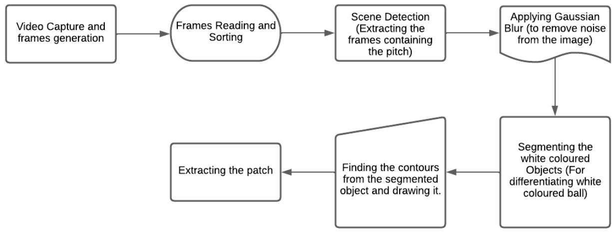

Fig. 4. Pre-processing

V. Result

To read the input file, the program creates a Video-Capture object. It crops the video frame-by-frame, and the progress of capture is showcased with a playback of the video, as shown in Fig. 5.

Fig 5. Input Video Screenshot

Fig. 6. Extracted Frame

A mask variable holds the absolute difference between 2 images at the same time. To differentiate the object from the background, the threshold operation is applied. In this operation, one value is considered as the threshold value, and compares these values with pixel difference. If the pixel is less than the threshold it sets to zero and if it is greater than the threshold it is set to 255 i.e., maximum value.

To get the image size in its original form, Ravel() operation is performed after the threshold operation. It can also be seen as the way to detect the scene change as shown in Fig. 7. The outlier point shows the point where the scene changes as the difference is higher at that point of time.

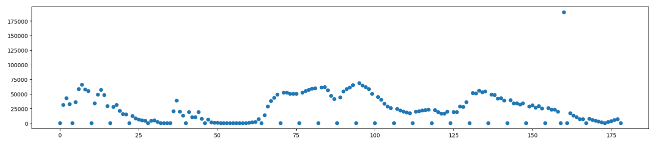

Fig. 7. Scene Changes

Gaussian blur is applied to the specified frame as shown in Fig. 8. Contours are obtained using a grey mask (Figs. 9 and 10), which are directly linked to the HSV colour values specified in the code. Primarily, the cricket ball is white; hence, the HSV values of white are used, i.e., 0-255, 0-255, 255.

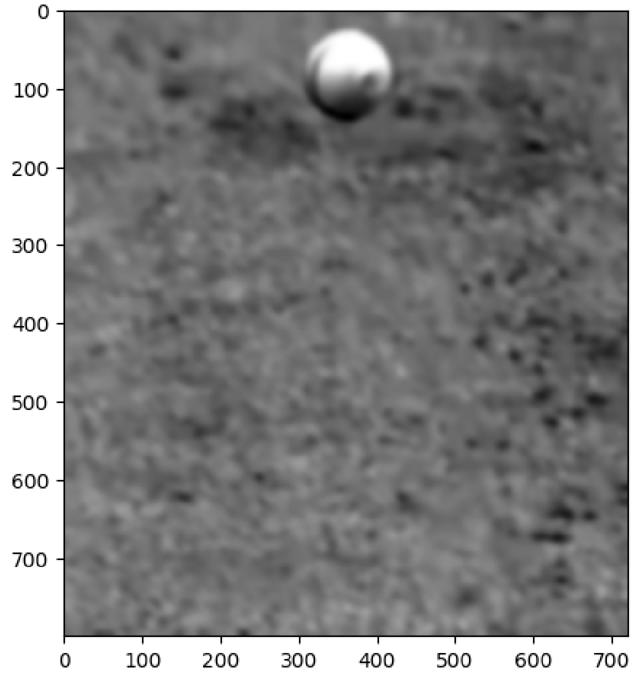

Fig 8. Gaussian Blur

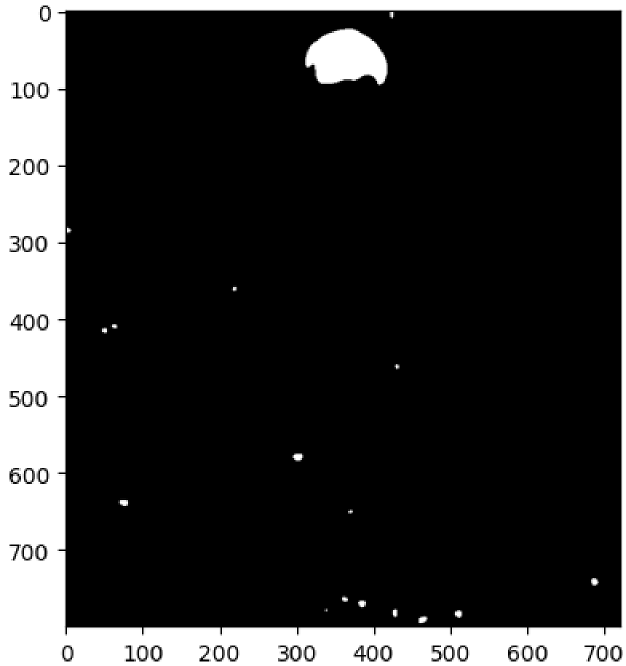

Fig. 9. Grey Mask

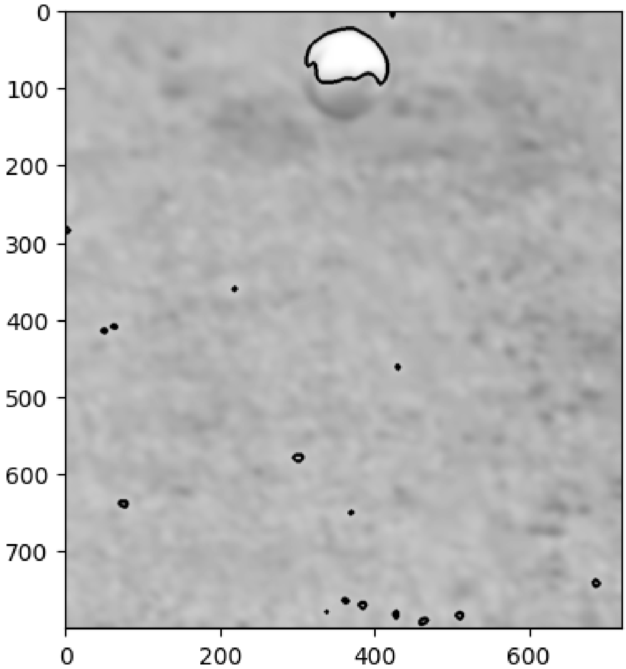

Fig 10. Contours

The program creates patches of the frame that match the HSV values. These patches have a high chance of containing the ball. The ball is visible in the patch created in Fig. 11.

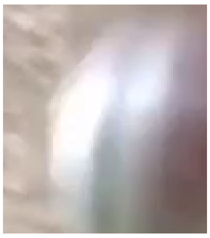

Fig 11. Patch

Patch Count	X Coordinate	Y Coordinate	W (Width)	H (Height)
0	506	780	9	9
1	425	778	6	10
2	337	778	3	3
3	380	767	10	9
4	359	762	8	6
5	683	738	9	9
6	368	649	5	5
7	428	460	5	6
8	47	413	7	6
9	60	408	7	5
10	217	359	5	5
11	0	282	7	7

Table 1. Coordinates and Dimensions of Patches

Table 1 dictates the coordinates and dimensions of the patches generated by the program. The coordinates are calculated based on the contours formed which lie within the frame extracted from the input video. A total of 11 patches were created, representing the 11 different points on the extracted frame where the program thinks the ball is present.

VI. Conclusion

A computer-based program is developed for detecting objects from the video frame. In this case, the cricket ball is considered an object. Detection of the ball helps assist in making crucial decisions in the game. Similar object detection can be used in other sports and many real-life scenarios. This object detection can also be used in making AI-based cars, robots, and other devices. It can be used for security purposes at sensitive places for detecting and alerting prohibited objects. Then, there is no need to assign a particular workforce to supervise the system that can be made self-sufficient to detect objects on its own. This way, a specific object can be separated from all surrounding objects from the frame.

References

[1] Chowdhury, AZM Ehtesham, Md Shamsur Rahim, and Md Asif Ur Rahman. "Application of computer vision in Cricket: Foot overstep no-ball detection." In 2016 3rd International Conference on Electrical Engineering and Information Communication Technology (ICEEICT), pp. 1-5. IEEE, 2016.

[2] Iyer, Ganesh Neelakanta, Vignesh S. Bala, Bommidi Sohan, R. Dharmesh, and Vishal Raman. "Automated third umpire decision making in cricket using machine learning techniques." In 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), pp. 1216-1221. IEEE, 2020.

[3] Chauhan, Anuj, and Vandana Bhatia. "Cricket Activity Detection Using Computer Vision." In 2020 Sixth International Conference on Parallel, Distributed and Grid Computing (PDGC), pp. 428-433. IEEE, 2020.

[4] Shahjalal, Md Asif, Zubaer Ahmad, Rushrukh Rayan, and Lamia Alam. "An approach to automate the scorecard in cricket with computer vision and machine learning." In 2017 3rd International Conference on Electrical Information and Communication Technology (EICT), pp. 1-6. IEEE, 2017.

[5] Karmaker, D., A. Z. M. E. Chowdhury, M. S. U. Miah, M. A. Imran, and M. H. Rahman. "Cricket shot classification using motion vector." In 2015 Second International Conference on Computing Technology and Information Management (ICCTIM), pp. 125-129. IEEE, 2015.

[6] Huang, Rui, Hui Wang, Feng Liu, and Wei-wei Guo. "Design of cricket automatic control system based on computer vision technology." In 2019 International Conference on Robots & Intelligent Systems (ICRIS), pp. 26-29. IEEE, 2019.

[7] Parameswaran, Kamalaruban. "Vector quantization, density estimation and outlier detection on cricket dataset." In 2013 International Conference on Computer Communication and Informatics, pp. 1-5. IEEE, 2013.

[8] Bandara, Ishara, and Boris Bačić. "Strokes classification in cricket batting videos." In 2020 5th International Conference on Innovative Technologies in Intelligent Systems and Industrial Applications (CITISIA), pp. 1-6. IEEE, 2020.

[9] Pavuluri, Kumar Raja, Nilay Aishwarya, Arvind Kumar, and Kamlesh Kishore. "Smart Snickometer for assisting Cricketing Umpires." In 2020 5th International Conference on Computing, Communication and Security (ICCCS), pp. 1-5. IEEE, 2020.

[10] Semwal, Archit, Durgesh Mishra, Vineet Raj, Jayanta Sharma, and Ankush Mittal. "Cricket shot detection from videos." In 2018 9th international conference on computing, communication and networking technologies (ICCCNT), pp. 1-6. IEEE, 2018.

[11] McGrath, Joseph W., Jonathon Neville, Tom Stewart, and John Cronin. "Cricket fast bowling detection in a training setting using an

inertial measurement unit and machine learning." Journal of sports sciences 37, no. 11 (2019): 1220-1226.

[12] Foysal, Md, Ferdouse Ahmed, Mohammad Shakirul Islam, Asif Karim, and Nafis Neehal. "Shot-Net: A convolutional neural network for classifying different cricket shots." In International Conference on Recent Trends in Image Processing and Pattern Recognition, pp. 111-120. Springer, Singapore, 2018.

[13] Ravinder, M., and T. Venugopal. "Content-based cricket video shot classification using bag-of-visual-features." In Artificial Intelligence and Evolutionary Computations in Engineering Systems, pp. 599-606. Springer, New Delhi, 2016.

[14] Deak, Gabriel, Kevin Curran, and Joan Condell. "A survey of active and passive indoor localisation systems." Computer Communications 35, no. 16 (2012): 1939-1954.

[15] Kviatkovsky, Igor, Ehud Rivlin, and Ilan Shimshoni. "Online action recognition using covariance of shape and motion." Computer Vision and Image Understanding 129 (2014): 15-26.

[16] Thomas, Graham, Rikke Gade, Thomas B. Moeslund, Peter Carr, and Adrian Hilton. "Computer vision for sports: Current applications and research topics." Computer Vision and Image Understanding 159 (2017): 3-18.

[17] Gupta, Arpan, and Sakthi Balan Muthiah. "Viewpoint constrained and unconstrained Cricket stroke localization from untrimmed videos." Image and Vision Computing 100 (2020): 103944.

[18] Jain, Vinay Kumar, Shishir Kumar, and Steven Lawrence Fernandes. "Extraction of emotions from multilingual text using intelligent text processing and computational linguistics." Journal of computational science 21 (2017): 316-326.

[19] Shingrakhia, Hansa, and Hetal Patel. "SGRNN-AM and HRF-DBN: a hybrid machine learning model for cricket video summarization." The Visual Computer 38, no. 7 (2022): 2285-2301.

[20] Fernando, Basura, and Stephen Gould. "Discriminatively learned hierarchical rank pooling networks." International Journal of Computer Vision 124, no. 3 (2017): 335-355.

[21] Jain, Mr. Piyush, and Mr. Rajesh Chakrawati. "'Improvement in Hot Spot Technology in Cricket' Technique for the Best." International Journal of Scientific & Engineering Research, ISSN 2229-5518, 5, no. 10 (October 2014): 257–62. https://www.ijser.org/researchpaper/Improvement-in-Hot-Spot-Technology-in-Cricket.pdf.

[22] Udayagiri, Hariteja, Muhammad Arbaaz Hussain, and Shruti Bhargava Choubey. "HOTSPOT TECHNOLOGY IN CRICKET."

[23] Jayanth, Sandesh Bananki, and Gowri Srinivasa. "Automated classification of cricket pitch frames in cricket video." ELCVIA: electronic letters on computer vision and image analysis 13, no. 1 (2014): 33 49.

[24] Huggi, Sanjeev Kumar, and Suvarna Nandyal. "Detecting events in cricket videos using RF classifiers." Int. J. Adv. Res. Found 3 (2016): 1-5.

[25] Nair, Vaishnavi K., Raakhi Rachel Jose, Parvathy B. Anil, Minnu Tom, and Lekshmy PL. "Automation of Cricket Scoreboard by Recognizing Umpire Gestures."

[26] Premaratne, S. C., A. Gamanayake, K. L. Jayaratne, and P. Sellappan. "Improving Event detection in Cricket Videos Using Audio Feature Analysis."

[27] Rock, R., Adrian Als, P. Gibbs, and Carlos Hunte. "The 5th Umpire: Cricket's Edge Detection System." In Proceedings of the International Conference on Scientific Computing (CSC), p. 1. The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (WorldComp), 2011.

[28] Nelikanti, Arjun, G. Karuna, and G. Venkata Rami Reddy. "Moving Object Detection and Tracking under Different Occlusion Conditions in Video Sequences."

[29] Kumar, Ashok, Javesh Garg, and Amitabha Mukerjee. "Cricket activity detection." In International Image Processing, Applications and Systems Conference, pp. 1-6. IEEE, 2014.

[30] Velammal, B. L., and P. Anandha Kumar. "An Efficient Ball Detection Framework for Cricket." International Journal of Computer Science Issues (IJCSI) 7, no. 3 (2010): 30.