Badminton Hawkeye System

Anu Ahuja
Department of Computer Science and Software
University of Canterbury
Christchurch, New Zealand
aah109@uclive.ac.nz

***Abstract*—This paper proposes a method to create an automatic linesman system to make accurate in/out judgement calls in badminton with real time tracking of the shuttle and its flight trajectory. In professional badminton the use of a hawk-eye system has been in place since 2014, however due to its incredibly high hardware cost, its application into amateur badminton is not yet possible. In this paper we look at an implementing an instant review system which will be able to run on an iPhone camera, and using image processing software be able to determine accurately the position of the shuttle and therefore whether the shuttle lands in or out.**

***Index Terms*—Computer Vision, Hawk-eye, Badminton**

I. Introduction

The Badminton World Federation (BWF) has been using a high quality instant review system (IRS) since 2014 called Hawk-Eye [1]. Badminton is the worlds fastest sport, with the shuttle being the fastest object ever recorded in sports [2]. The Guinness World Record for the fastest badminton smash was recorded at 565 km/h, to put this into context, the fastest speed recorded by a Formula 1 car is 397.48 km/hour while the fastest tennis serve maxes out at 263 km/hour [3]. Because of this the IRS used in badminton is required to be of the highest quality and uses top of the line hardware to track the shuttle at such high speeds. At the worlds highest stage, this IRS uses six high speed cameras located at strategic points which calculates trajectory and positions. These calculations are then used to determine the exact position of the shuttle with only a 3.6mm margin of error. This technology has greatly improved the sport and has added a layer of accuracy and precision to aid the technical officials in determining whether the shuttle was in or out. However this technology comes at a very expensive price point and because of this the application of this technology is only available to badminton at the highest level. Developing a much cheaper version of this IRS using phone cameras would be of high benefit to badminton players who play at a club level or in countries where Badminton is not as popular such as New Zealand. To develop an IRS which is accessible for everyone, the use of a phone camera would be advantageous as everyone has access to one. The phone camera would have to be calibrated to eliminate distortion, the footage captured by the camera will need to be processed using software along with the use of trajectory tracking algorithms to predict where the shuttle will land [4]. Calculating the shuttle position in relation to the lines on the court will determine whether the shot is in or out. This system may not be as accurate as the top of the line Hawk-Eye, however at a fraction of the price it may still produce accurate results while being accessible to almost everyone who plays the sport.

II. Background

A few studies have delved into this topic of building a hawk-eye system for badminton at an amateur level.
One particular study proposes a convolutional neural network (CNN) designed with feature pyramid structure for badminton detection [5]. The model combines MobileNetV3 architecture and an improved CSP structure that reduces redundant computation and memory access to create a small and fast model. Due to the shuttle being small, it is often difficult to detect. For this the study proposes a loss function based on the combination of Normalized Wasserstein Distance (NWD) loss and Intersection over Union (IoU) loss is redesigned to improve detection performance for small badminton targets.The proposed model achieves a precision of 82.8% and a recall of 68.2%, indicating high accuracy in detecting badminton-related objects.
Another study also builds an IRS with a different methodology [6]. It details an architecture, which includes differential imaging, cumulative frame generation, neural network detection, Kalman filtering, and trajectory analysis to determine whether the shuttlecock landed inside or outside the court. Specifically this included a camera calibration, court recognition using Mask R-CNN to predict segmentation, Shuttlecock Detection and Tracking by generating a set of shuttlecock candidates (blobs) and, using a set of filters, then selecting the one most likely to be a shuttlecock. Shape segmentation made it easy to distinguish a shuttlecock from another moving object. To find the frame where the shuttle hits the ground they utilize the shuttlecock blurriness measure as its rapidly changes when the shuttlecock hits the ground. After this they are able to determine whether the shuttlecock landed inside or outside the court. The study elucidates the system's performance evaluation, indicating promising levels of accuracy in detecting shuttlecock visibility and ground touch. Challenges such as occlusion handling and system reliability are discussed, along with potential avenues for improvement through technological advancements.
One other study implements and tests two potential approaches, one uses a retrospective method using motion detection and the other uses a non-retrospective method employing Support Vector Machines (SVM) [7]. The retrospective ap-

proach achieves higher accuracy (85%) compared to the SVM approach. Challenges such as irregular shuttlecock shape, high-speed movement, occlusions, and background interference are addressed. In the proposed system, the boundary of the badminton court is detected using color segmentation and edge detection. Shuttlecock localization involves preprocessing, scene context elimination, player detection, motion detection, and trajectory extraction. The retrospective approach employs multi-scale tracking, while the non-retrospective method utilizes SVM with feature extraction from black-white images and differentiated maps. The study emphasises the future work which needs to be conducted which were extracting the temporal correlation in a more efficient way to improve the robustness of the proposed learning algorithm.
There have been other similar studies which use similar methodologies to develop an automatic linesman system for badminton. One of which presents an algorithmic approach to model the shuttlecock's position, track its trajectory, and make decisions regarding its landing point [8]. The proposed system uses computer vision techniques, including background subtraction in hue space and analysis of the shuttlecock's trajectory, coupled with a decision-making process. The performance of the system is evaluated based on accuracy, sensitivity, and specificity metrics. They use a fixed camera position and the shuttles' x and y coordinates when it lands in an equation to determine whether the shuttle is in or out. The study also highlights that the speed of the shuttlecock and illumination condition of the court heavily influence the performance of the system. As such, further research is needed address these problems through better modelling and a more accurate detection scheme.

III. Proposed Method

The method proposed to develop a Hawkeye-like system for badminton using computer vision is conducted using an iPhone 12 camera. Which has a resolution of 12 Megapixels and a frame rate of 30fps, the software is written in Python 3.9 and uses image processing libraries such as OpenCV version 4.9.0.

A. Camera Calibration

Before implementing the Hawk-eye system, the iPhone 12 camera needs to be calibrated to remove any tangential or radial distortion coming from the camera lens [9]. To do this the intrinsic and extrinsic properties of the camera will need to be determined using a checkerboard pattern and corner detection algorithms. Using the parameters calculated, the distortion coefficients are then used to undistort the camera lens.

B. Data collection

Data is collected using the calibrated iPhone camera positioned on a tripod with the view of the back line of the badminton court. Several videos are taken of back line with a shuttle falling around the back court area. Few videos are recorded of the shuttle landing in, and a few videos are recorded of the shuttle landing out. This data is the preprocessed to get ready for detection.

C. Preprocessing

Frames from the recorded videos are then extracted and image processing techniques are applied to them to enhance the visibility of the court lines and shuttlecock in each frame. First we convert to frame from RGB space to HSV as it removes the inaccuracies causes by any background light and brightness. The system will then be reduced to the area of interest which is area around the back court line to reduce background noise. Background subtraction may also be used to single out the shuttle, further contrast adjustments and edge detection may be used to enhance the court line features.

D. Court Line Detection

To detect the line on the court, computer vision edge and corner detection algorithms are used such as Canny Edge Detector [10]. As well as this methods like Hough Transform for line detection or template matching may also be used. Once the lines of the court are detected, their x and y coordinates are stored for reference during the shuttlecock detection.

E. Shuttle Detection

To detect the shuttle an object detection algorithm is used. The trajectory of the shuttle can also be tracked using techniques such as Kalman filtering or optical flow. The algorithm needs to consider the speed and trajectory of the shuttle to predict its future position accurately.

F. Decision Making

Once the position of the shuttle is determined in each frame. The frame when the shuttle lands on the ground can be used to compare with the coordinates of the court lines to determine if it is ”in” or ”out.” A geometric calculation will be required to determine if the shuttle's position overlaps with the court lines, indicating whether it is in or out. Furthermore there may be a need to develop algorithms to handle occlusions caused by players or temporary obstructions on the court.

This proposed method works to develop a Hawkeye-like system using computer vision for badminton, enabling users to accurately determine whether the shuttlecock falls within the court lines during matches.

IV. Results

V. Conclusion

A. Future Research

- using deep/machine learning to improve accuracy
- multiple camera angles
- better camera, higher resolution

REFERENCES

[1] BadmintonBites, "How Does Hawk-Eye Technology Work in Badminton?," BadmintonBites, Apr. 09, 2022. https://badmintonbites.com/how-does-hawk-eye-technology-work-in-badminton/

[2] "Speedy Birdie—The Fastest Projectile in Sport," Engineering.com. https://www.engineering.com/story/speedy-birdiethe-fastest-projectile-in-sport

[3] International Olympic Committee, "Satwiksairaj Rankireddy smashes Guinness world record for fastest badminton hit," https://olympics.com, Jul. 19, 2023. https://olympics.com/en/news/fastest-badminton-smash-hit-satwiksairaj-rankireddy-india-guinness-world-record (accessed Mar. 24, 2024).

[4] "Hawkeye Technology Alters Badminton: Fortify Accurate Calls," Feb. 09, 2024. https://thebadmintonpost.com/hawkeye-technology-alters-badminton-fortify-accurate-calls/ (accessed Mar. 23, 2024)

[5] H. Jiang, Z. Qiang, Y. Jin, X. Zhang, and C. Wang, "Badminton Hawk-Eye Challenge: A Lightweight Badminton Detection Network Based on Feature Pyramid," Research Square (Research Square), Aug. 2023, doi: https://doi.org/10.21203/rs.3.rs-3238350/v1.

[6] M. Kopania, J. Nowisz, and A. Przelaskowski, "Automatic Shuttlecock Fall Detection System in or out of a Court in Badminton Games—Challenges, Problems, and Solutions from a Practical Point of View," Sensors, vol. 22, no. 21, p. 8098, Jan. 2022, doi: https://doi.org/10.3390/s22218098.

[7] E. McGee, "Automatic Linesman System for Badminton Games - PDF Free Download," docplayer.net, 2018. https://docplayer.net/49133651-Automatic-linesman-system-for-badminton-games.html (accessed Mar. 25, 2024).

[8] L. H. Leong, M. A. Zulkifley and A. B. Hussain, "Computer vision approach to automatic linesman," 2014 IEEE 10th International Colloquium on Signal Processing and its Applications, Kuala Lumpur, Malaysia, 2014, pp. 212-215, doi: 10.1109/CSPA.2014.6805750.

[9] OpenCV, "OpenCV: Camera Calibration," docs.opencv.org. https://docs.opencv.org/4.x/dc/dbb/tutorial_py_calibration.html

[10] V. M, "Comprehensive Guide to Edge Detection Algorithms," Analytics Vidhya, Aug. 06, 2022. https://www.analyticsvidhya.com/blog/2022/08/comprehensive-guide-to-edge-detection-algorithms/