Service Fault Detection in Badminton

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***Abstract*— This paper proposes a computer-based method to automatically detect service faults performed by a badminton player in a game of badminton using computer vision, specifically focusing on service height violations.**

Methods used were object detection and faster R-CNNs (region-based convolutional neural networks) from detectron2. This was used to locate the positions of racket heads and shuttles in a video displaying legal and illegal backhand serves. The most up to date badminton service rules were implemented. Currently, service height faults are detected manually by service judges, leading to potential controversies and inaccuracies. The CNN model achieved an average confidence rating for detection of 0.997, although there were occasional false detections due to similarity between the racket grip and the shuttle. The proposed approach for fault serve detection had an 85% success rate and a 22% probability of false positives. Future research would include the detection of spin serves and the detection of foot movements during the serve.

By automating the detection of service height faults using computer technology, this approach aims to improve the fairness, accuracy, and spectator satisfaction in badminton matches.

Keywords—badminton, service, fault, object detection

I. INTRODUCTION

Badminton is a popular sport that requires precision, agility, and strategy. One of the most important aspects of badminton is the serve, which can give a player a significant advantage if executed properly. This is because it is the only shot in the whole game which can be controlled and determined completely by a player. However, because of its importance in the game, there are many specific rules and regulations that must be followed to make a badminton serve legal.

There are two main service styles: the "backhand serve" (Figure 1) and the "forehand serve". The main rules for a legal backhand serve from the 2022 BWF (Badminton World Federation) Statutes Section 4.1 Laws of Badminton [1] are as follows:

"9.1.4. some part of both feet of the server and the receiver shall remain in contact with the surface of the court in a stationary position;

9.1.5. the server's racket shall initially hit the base of the shuttle;

9.1.6. the whole shuttle shall be below 1.15 metres from the surface of the court at the instant of being hit by the server's racket;

9.1.7. the movement of the server's racket shall continue forwards from the start of the service until the service is delivered [1]."

This paper proposes a method of computer technology to detect a backhand service fault in badminton resulting from a service height fault (violation of rule 9.1.6); the shuttle is struck above 1.15m during the serve.

Figure 1 – Demonstration of a legal backhand serve and service judge [15]

Current methods of detecting this fault are purely manual and rely on the human eye. In competitive badminton history, this has led to many controversial service fault calls by service judges. By detecting this fault accurately and in real-time using computer technology, we aim to improve the fairness and accuracy of the game.

II. Background

A. Current detection method

The current method of detection for all forms of service faults is by a badminton referee, called a “service judge” (Figure 1). However, the service judge is the only referee in the game that can call a service height fault.

A service height measuring device (Figure 2) is positioned in front of the service judge, who sits opposite the umpire on the other end of the court. The device features two glass panels attached to either side, positioned at a height of 1.15m above the court. Two dark lines are marked on both glass panels. During a serve, the service judge observes the shuttle and makes a judgment based on the shuttle's position relative to the dark lines (Figure 3). If the shuttle is struck above the line, the service judge will deem it a fault. There is no specific thickness of the lines [14].

Figure 2 – Current manual service fault detection device [3]

The limitation of this method is that its results are highly susceptible to human error. Due to service faults being detected solely by humans, there is always bound to be some misjudgment. In a study on badminton refereeing performance, a BWF referee scores an average performance satisfaction value of 9.2 out of 10 [2]. This shows there is room for improvement. The implementation of computer and camera technology will decrease the game’s reliance on human judgement, resulting in increased fairness and consistency in the game, as well as overall spectator satisfaction [13].

Figure 3 – Viewing perspective of a service judge [10]

B. Hawk-Eye in badminton

Hawkeye is a system that uses multiple cameras placed in different areas around a court or field to capture images, which are then compared using computer vision techniques to obtain a comprehensive view of the court. The use of different camera angles allows the computer to determine the trajectory and landing position of the shuttle. Hawkeye is used in various sports including badminton, tennis, cricket, football, rugby, volleyball, and ice hockey [12]. However, its capabilities have not yet been tested on fault serve detection automation in badminton.

The Hawk-Eye technology utilizes multiple cameras placed in up to six different areas to capture images, which are then compared to obtain a comprehensive view of the court. By triangulating these images, the system can provide instant replay footage in 3D space [9]. Feature tracking: This algorithm tracks features of the sports object, such as its color and shape, to accurately predict its trajectory. Optical flow: This algorithm calculates the movement of pixels in a video sequence to determine the motion of the sports object. Kalman filter: This algorithm predicts the future position of the sports object based on its current trajectory and past motion. [11]

It was first introduced in 2001 by Sony and was first implemented in cricket. The technology allows sporting officials and referees to make quick and accurate decisions allowing the game to have minimal disruption. [5]

Figure 4 – Hawkeye system determines the landing point of a shuttle [7]

C. Fault serve detection in table tennis

Currently, service faults in table tennis are also made by umpires based on their experience and intuitive reaction; therefore, there tends to be much in-game controversy and players are not allowed the chance to challenge calls. Attempts at automated service fault detection using cameras and computer technology have been made [16].

Previous attempts have used an algorithm to analyse the trajectory of the ball toss. The algorithm is composed of several techniques such as YCbCr color space processing, morphological processing, circle Hough transform, and separation of moving and static components in an image sequence using the stable principal component pursuit method. Previous research has revealed that YCbCr color space performs better than HSV color space in recognizing ball color close to skin tone. It is also demonstrated that the positions of the ball and racket can be accurately located using color segmentation and stable principal component pursuit [16].

However, the limitation of these approaches is the camera placement. The fault detection method relies on the camera being front facing towards the player. This is not realistic for the game and is not a viable camera placement option in a professional match [17].

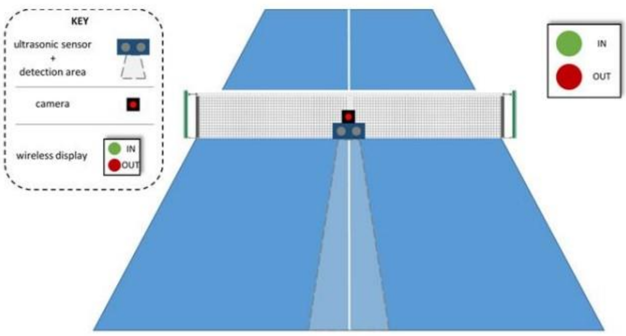

Figure 5 – Fault serve camera placement in table tennis [17]

III. Method

The approach I used to detect a backhand service height fault was to implement similar methods as the table tennis approach but with a less invasive camera set up and detection method.

A. Camera setup and footage

In badminton, the best place to view a serve is from the side of the court so that you can see the player's side profile and contact point of the shuttle. This is the position that service judges typically view the serve from (Figure 1).

The footage used was captured by setting up a camera on the side of the court parallel to the service line. It was positioned at a height so that the center of the frame was exactly 1.15m. The camera stayed stationary using a tripod and gyroscope. A gyroscope or some type of stabilizing device would be necessary in a real badminton game so that nearby vibration from the players' movement does not disrupt the camera input. This precalculated height setup removes the need for height calculations when processing the footage. However, this method for calculating height could be improved upon by adding a marker in the frame to use as a known relative length for calculating heights of other objects within the frame.

The background for the camera input was the plain grey background of the wall. This was helpful so that there were no other players or objects that may confuse the computer. I chose to wear a black badminton shirt and shorts to allow the camera to easily differentiate between objects in the video (Figure 6).

The camera input was 1920x1080p resolution. This was halved to 960x540p resolution for faster processing in the programming stage. A line was drawn across the middle of the frame using the frame coordinates (0, 270) to (960, 270). This was used as the threshold for the service height calculations.

B. Object Detection

The main method for detecting fault serves was to use object detection to recognise a shuttle and a racket-head. I trained a convolutional neural network (CNN) using over 60 photos of shuttles and rackets to detect a racket-head and a shuttle. I only used 60 photos as I had to manually label each photo. I used point labelling for the shuttles as this was the most accurate shape representation of the shuttle. I used elliptical labelling for the racket-head as this almost perfectly matched the shape of the racket-head.

The algorithm detectron2 used to train the CNN was Faster R-CNN (region-based convolutional neural network). This is a two-stage algorithm that uses a region proposal network (RPN) to generate potential object locations, and then performs classification and bounding box regression on those regions to predict the final detection [10].

The trained model was then tested on 60 more photos of shuttles and racket-heads. I then used various photos from Google Images of a badminton player performing a backhand serve for the validation step. The model detected both the shuttle and racket-head in the photos with an average 0.997 confidence rating.

Satisfied with the trained model, I moved on to testing it on the 5-minute video of me serving. I originally used the model to show all detections with a confidence level greater than 0.8. However, this caused many false detections to occur in some frames. Therefore, it was changed so that only the two detections with the highest confidence ratings were displayed. This improved the test method greatly.

C. Logic implementation

The way I measured a fault serve was by first defining the stages of a serve. The possible stages were simplified and categorized into 3 events:

1) *Preparing to serve*
2) *Legal serve*
3) *Fault serve*

Each event was defined by the position of the racket-head relative to the frame and the shuttle. The event “preparing to serve" was defined to be when the latest position of the racket-head and shuttle were both beneath the line, and they were more than 100 pixels apart.

The event “legal serve” was defined as when the latest position of the racket was beneath the line (the y coordinate of the top of the racket was greater than 270), and they were less than 100 pixels apart from each other in the x direction, as shown in **Figure 6**. This represents when the shuttle has left the face of the racket and is flying over the net. One way the definition of this event could be further improved is by measuring the velocity of the shuttle in each frame. If the shuttle’s velocity increased drastically, it means the player has served the shuttle.

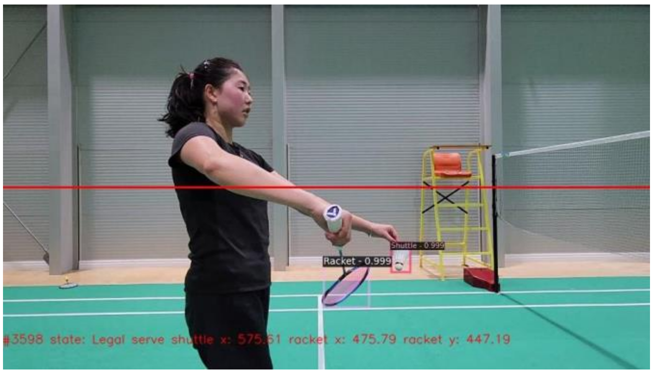

Figure 6 – Detection of a legal serve

Whenever the latest position of the racket was above the line (the y coordinate of the top of the racket was less than 270), and the racket and shuttle were less than 100 pixels apart from each other in the x direction, the person was considered to be performing a “fault serve” (Figure 7).

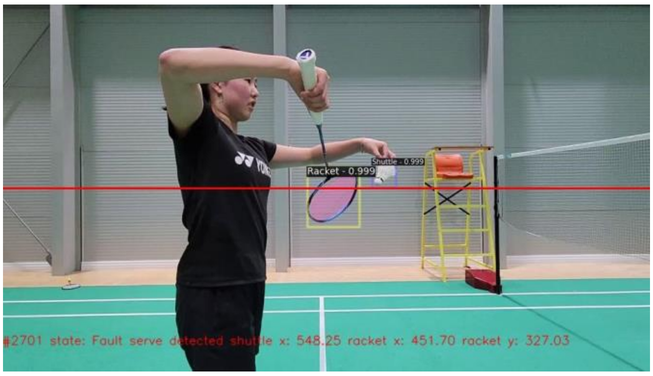

Figure 7 – Detection of a fault serve

The reason for using the most recent position of the racket and shuttle is because during some frames, the racket or shuttle would not be detected and therefore, there would have been no coordinates to compare against. To prevent this from happening, global variables were used to store the coordinates of the last detected racket and shuttle.

IV. Results

A. Environment

1) Input environment

The input that I used for testing and training the neural network was images sourced from Google Images. I used images of “backhand badminton serve”, “shuttle”, and “badminton racket”.

The video input that the fault detection system was tested on was a 60 frames per second (fps), 1080p camera input from a Samsung S22 in landscape mode. This input provided adequate quality data to test the system.

2) Software environment

The development environment used was as follows:

- Language: Python
- IDE: Visual Studio Code
- OS: Linux Mint
- CPU: i7-8550U
- RAM: 8 GB
- OpenCV Version: 4.5.1

B. Object Detection

Despite a small training data set (60 images) and testing data set (60 images) relative to typical trained CNN models, the detection results were successful. Each detection of a shuttle or badminton racket from the camera input had an average confidence rating of 0.997. This is incredibly high. The computer was able to detect a shuttle in over 92% of the relevant frames that had a shuttle. However, some detections were false since the computer also falsely identified the racket grip to be a shuttle at times.

In this camera footage used, a racket with a white racket grip was used caused the computer to confuse it with the shuttle since it was also white and of similar size to a shuttle in the video, as shown in Figure 8. Since the computer could not differentiate between the two and would often make this mistake, it would store the coordinates of the grip instead of the shuttle. The racket grip and racket head is far apart so the computer would identify the person to be "preparing to serve" instead of performing the serve. Therefore, the true success rate of the model's detection of a shuttle was lower than 92%.

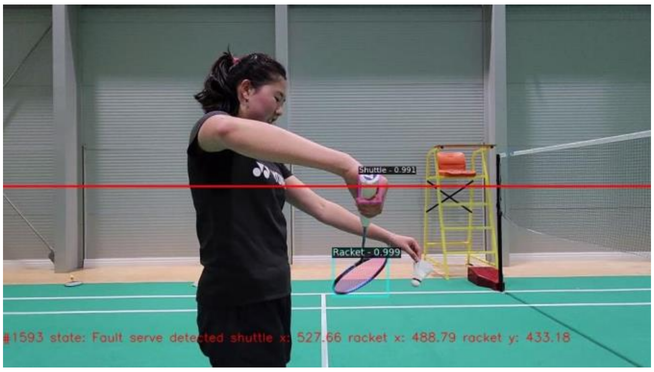

Figure 8 – False Detection of grip as a shuttle

Increasing the resolution of the video also caused the number of false detections of racket heads and shuttles to increase. Therefore, the frame resolution was reduced to 960x540p resolution. This decreased the number of false detections and also reduced the total processing time.

This problem could be solved by changing the colour of the racket grip used in the video. However, this is unrealistic since badminton players in real life use a wide variety of grip colours including white. They also wear different coloured clothing and often compete in diverse venues with different court colour, lighting, and background colours, therefore, the videoing environment is dynamic. The neural network could undergo more training to increase the detection accuracy and confidence rate.

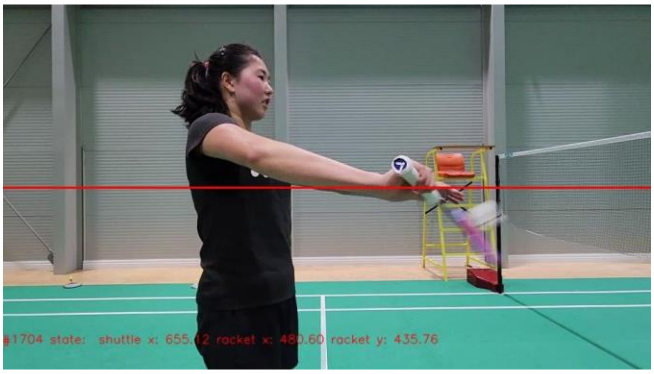
Figure 9 – No detection of racket-head or shuttle

Research has been conducted on different methods of service fault detection in other sports, but none have shown quantifiable results. This is because the research conducted by other sources primarily focused on theoretical approaches.

C. Fault serve detection

Figure 10 shows the results of testing the proposed approach. A total of 20 backhand serves were tested. Of those 20 serves, 10 legal serves were tested, and 10 height violation fault serves were tested. The approach gave an 85% success rate with 12.5% probability of detecting a false positive.

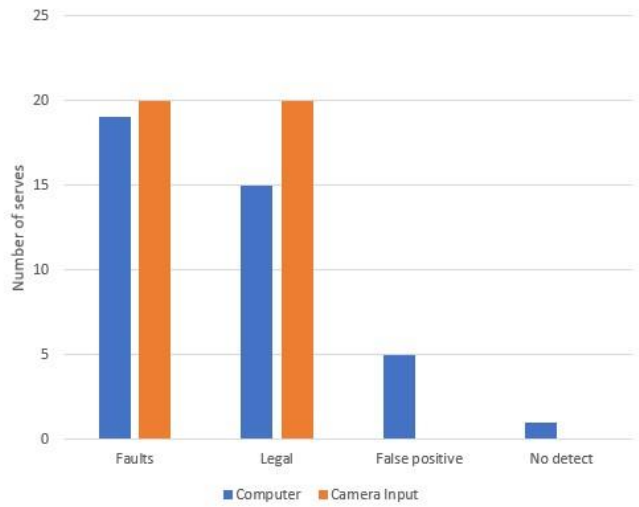

Figure 10 – Service detection results of trained model compared to the camera input.

V. Conclusion

A. Future research

Despite the challenges of limited training data and false positive detections caused by similar color and size characteristics of the objects in the footage, this approach of detecting fault serves achieved a satisfactory detection rate for shuttle position and fault serve identification. The results showed an 85% success rate with a low to medium probability of false positives.

This approach addresses the limitations of the table tennis fault serve detection method by using less invasive footage acquiring methods [16]. By positioning the camera outside the court, this mitigates any risk of interference with the game.

Recently, a new rule has been passed for the 2023 Sudirman Cup. This is an international mixed team tournament where players represent their countries. A new service technique was recently developed, called a "spin serve" [18]. This is when a player adds some spin to the shuttle before they serve, causing the flight pattern of the shuttle to be irregular. This has been banned. Although this ban is only provisional [19], the next step would be to implement a computer vision system to recognize a "spin serve". A spin serve would be detected by detecting if the feathers on the shuttle are rotating after release from the fingers and by tracking the flight pattern of the shuttle after contact with the racket.

Other service faults include detecting if the server's feet are moving. This would require a wider camera angle so that the feet are in the frame during the serve.

To solve the problem of false detections of the shuttle, filtering could be performed on the footage. The frames where the grip is falsely detected as the shuttle could be filtered out by removing all the frames where the shuttle position seems to jump sporadically away and a much further distance from the current position. For example, if the difference between the shuttle's x coordinate in the current frame is greater than 200 pixels from the shuttle's x coordinate in the previous frame, then remove the current frame.

The proposed approach could also be improved by adding a simple Kalman filter to predict the future position of the shuttle. This would increase the accuracy of the method. When an object such as the racket grip is falsely detected as a shuttle, a Kalman filter would help the computer identify if the detected object is indeed the same shuttle or not.

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