Developing an intelligent table tennis umpiring system

Conference or Workshop Item

DEVELOPING AN INTELLIGENT TABLE TENNIS UMPIRING SYSTEM

Dr. Patrick K. C. Wong
Department of Information and Communication Technologies, Open University
Walton Hall, Milton Keynes, MK7 6AA United Kingdom
k.c.p.wong@open.ac.uk

ABSTRACT

The aim of this research is to develop an intelligent system which is able to evaluate table tennis services independently and aid the umpire to make a more accurate decision. Table tennis is a fast sport. A service usually takes one to a few seconds to complete but there are many observations an umpire needs to take and makes a judgment before or soon after the service is complete. This is a complex and time-critical task and the author believes the employment of videography, image processing and artificial intelligence (AI) technologies could help evaluating the service. This paper outlines the idea and the plan of developing an intelligent assistant for table tennis umpire in evaluating services. The system is expected to be able to track the location of the ball from live video images and evaluate the service according to the service rules. In this pilot study, however, the focus is on the development of the techniques, rather than building a complete system. Various videography, image processing and artificial intelligence techniques will be experimented and evaluated. A prototype system is to be built. The system will be compared and tested against the judgements of a human umpire. Both the accuracy and rate of responses will be concerned. The ultimate goal is to further develop the system so that it can umpire and score table tennis matches autonomously. The system may also benefit players who want to have their services evaluated in real time without the need of having a human umpire present.

KEYWORDS

Artificial intelligence, Neural networks, Multi-agent systems, Image processing, Table tennis.

1. INTRODUCTION

This is a pilot study regarding the development of an intelligent system in aiding table tennis umpires to make accurate judgment about services. A table tennis service usually takes one to a few second to complete. However, there are over ten observations an umpire needs to take and make a judgment before or just after the service is complete. This is a very complex and time-critical task and requires a lot of judgments, even for an experience umpire [3]. With the help of image processing and artificial intelligent techniques, a computer system may be able to analyze the service and make a recommendation for the umpire to consider.

There are mainly six rules governing the service and they are listed in the International Table Tennis (ITTF) Handbook [2]. This paper focuses on two rules, 2.06.02 and 2.06.04. Rule 2.06.02 is notoriously difficult for umpires to judge. This could lead to inconsistent judgments between umpires. For the benefit of those who do not familiar with table tennis rules, the first four rules, of which this paper are concerned, are reproduced and listed in Table 1.

In rule 2.06.02, two points are particularly difficult for a human being to judge. Firstly, it is hard to determine whether the ball is projected near vertically upward. Furthermore, the wording of "near vertically upward" is quite ambiguous. It does not state what degree of deviations is acceptable. The second difficult point of this rule is that it is sometimes quite hard for a human being to determine whether the ball rises 16cm after leaving the palm. Moreover, a service usually takes a few seconds to complete. Within these few seconds, the umpire has to make over ten observations and judge whether all the actions comply with the rules. This is not an easy task and the author believes an intelligent system could help umpire to make a better judgment.

The aim of this research is to develop an intelligent system which is able to track the location of the ball from a live-fed video link, measure how many degrees the ball deviates from a vertical line and measure how high the ball rises after leaving the palm. The system should also be able to check whether the ball goes under the playing surface or is hidden from the receiver. This is a pilot study. The focus is concentrated on the

development of the techniques, rather than building a complete system. Therefore some of the details of a table tennis service will not be considered.

Table 1. Table Tennis rules regarding the service

Index	Description
2.06.01	Service shall start with the ball resting freely on the open palm of the server's stationary free hand.
2.06.02	The server shall then project the ball near vertically upwards, without imparting spin, so that it rises at least 16cm after leaving the palm of the free hand and then falls without touching anything before being struck.
2.06.03	As the ball is falling the server shall strike it so that it touches first his court and then, after passing over or around the net assembly, touches directly the receiver's court; in doubles, the ball shall touch successively the right half court of server and receiver.
2.06.04	From the start of service until it is struck, the ball shall be above the level of the playing surface and behind the server's end line, and it shall not be hidden from the receiver by the server or his doubles partner or by anything they wear or carry.

2. VIDEO IMAGES

As the system is primarily designed to aid umpires, the video should be taken at a position and an angle similar to the umpire's perspective. Figure 1a shows an example of the captured image, which was taken from the position of the umpire. The video should be filmed at a frame rate that is high enough to capture all the important movements of the ball but low enough to reduce processing time. A typical service takes one to three seconds to complete. The speed of the ball can go up to several meters per second during service. To determine the most suitable frame rate, several different frame rates will be experimented in this study. The resolution of the image is another important factor that needs to be optimized. Again, too high the resolution will require a lot of processing time, but too low the resolution will not show the details of balls and other objects. During the development phase, we only consider services from one end (umpire's left hand side) of the table although services can come from both ends of the table. Instead of using live-fed video images, recorded video clips are initially used to develop the system. The principle of analyzing images from a live video input is the same as that from a recorded video clips. When the system is developed, live video will be used to test the system.

3. IMAGE PROCESSING

The video taken will be analysed by the system. The main task is to locate and track the ball from the video images. In a table tennis match, before the service starts, the server is required to place the ball on the open palm of his/her stationary free hand (the hand that is not holding the racket). The ball usually stays on the open palm for one to a few seconds before the service starts. This short pause of stationary can be used to identify the start of the service. The ball should subsequently be tracked until it is struck.

For matches, the colour of the ball (usually white) is required to be distinguishable against the surrounding background. One way to make the ball "stand out" from the background is to convert the image into black and white. By applying a heavy threshold, any objects that do not have a similar colour of the ball will become black. Identifying the ball from the remaining white objects could be achieved by comparing each detected object's colour, shape and size against a typical real ball. However, if an object with similar characteristics of the ball presents in the scene, the system may wrongly recognise the object as the ball. Fortunately, during a service the real ball should be in motion whereas other objects which have similar characteristics are likely to be stationary. This feature can be used to identify the ball if several objects that have similar characteristics of the ball are detected. Artificial neural networks may also be employed to help identifying the ball. More descriptions of neural networks will be shown in next section.

Once the location of the ball is established from the first frame, the ball needs to be tracked from sequential frames. Similar technique can be used to detect the ball but the area of the frame needed to be concerned will be much smaller as the location of ball from the previous frame is known and the ball is expected to be in the neighbouring area. The tracking should be continued until the ball is struck.

When the ball reaches the highest point, the angle θ and the height of the rise should be measured. Figure 1 illustrates the above mentioned technique graphically. Firstly, Figure 1a shows when the ball is about to

leave the palm. Figure 1b is an image showing when the ball reaches the highest point of the service. Figure 1c shows the extraction of the ball from Figure 1b along with the ball from Figure 1a. Figure 1d illustrates the evaluation of the service, i.e. measuring the angle of the ball rise and height.

The challenge here is that the analysis must be conducted very quickly. Ideally, the system should be able to make a recommendation within a second after the service is complete because if it is a fault service, the umpire needs to call out as soon as it is detected.

Figure 1a. The ball is at its starting position (about to leave the palm).

Figure 1b. The ball reaches the highest point of the service.

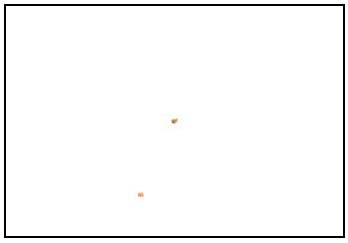

Figure 1c. The balls from Figure 2a and Figure 2b are extracted and combined in a picture.

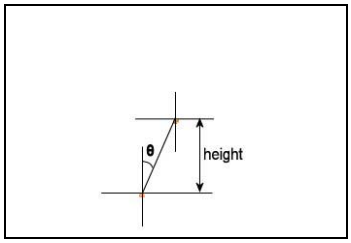

Figure 1d. Annotation are added to Figure 2c and showing how the angle and height are calculated.

[Source: These images are extracted from one of the demonstration video files in the web site of the Umpires & Referees Committee of the ITTF]

4. ARTIFICIAL NEURAL NETWORKS

Artificial neural networks (ANN) are particularly good at pattern recognition. They have been successfully applied to solve many real world classification and pattern recognition problems [1]. ANN may be considered as a greatly simplified human brain. The network is usually implemented using electronic components or simulated in software on a computer. The massively parallel distributed structure and the ability to learn and generalise makes it possible to solve complex problems that otherwise are currently intractable. In this study, it is to be employed to determine whether a detected object is a ball and whether the ball is on the palm or in mid-air. More description of ANN can be found in [1] and [4].

4.1 Application of ANN in detecting balls

In this study, the feasibility of employing ANNs to detect table tennis balls will be investigated. When several detected objects in the image are suspected to be a ball, the system should be able to inform whether each object is a real ball or a ball like object. If it is a real ball, the system should also state whether the ball is on the palm or in mid air. Characteristics of real balls and ball-like objects such as the colour, shape, size and average light intensity can be used to train an ANN. The ANN needs to be trained with a training set which contains large numbers of patterns which are derived from example images of real balls and ball-like objects that have slightly different characteristics. The sources of ball-like objects could be from the background of the match venue, spectators' clothes and advertising materials. Figure 2 shows example images of real balls that are on the palm and in mid air and ball-like objects that may be captured by the system.

Real ball in mid air					
Real balls rest on palm					
Ball-like objects	 logo	 text	 text	 logo	 logo

Figure 2 Example images of balls and ball-like objects that may be captured by the system.
[Source: Images of the balls are extracted from the photo gallery of the ITTF web site]

When a ball is rest on a palm, the bottom part of the ball will be slightly hidden by the palm. This will make the image of the ball captured by the system appeared to have a missing base. Whilst the ball is in mid-air, the image of the ball should be round and circular. The shadow of the ball casts on the palm will also affect the average light intensity of the ball. An ANN may be constructed to detect these differences.

The image of the balls captured by the system can be in different sizes if the distance between the video camera and the server varies. If the size of the image of the ball varies, it is difficult for an ANN to process as the number of input neurons of an ANN is usually constant. Hence, a preprocessing algorithm is required to convert an image of a ball into a training pattern which has fixed number of inputs. One way to achieve this may be to resize the image of the ball into a fixed size image, e.g. 20x20 pixels.

5. DISCUSSION

As table tennis umpiring is becoming more difficult (because of the new service rules), the author feels that computational technologies may be applied to aid umpires making more accurate decision on services. However, table tennis is a fast sport. If the system is to be of any use, it has to be able to evaluate a service through live video images in real time and produce an indication before the service is completed. This is a challenging task. The system has to be able to identify and track the ball, calculate the height of the ball rise and the angle and produce an indication within a second or so. Particularly, the image processing tasks as described in Section 3 have to be achieved very efficiently. Various filtering and enhancement techniques could help identifying the ball but they will increase the processing time. Likewise, the frame rate and resolution of the capturing video have an impact on the quality of the video and the processing time. These factors will be experimented and identifying the balance points of these factors will be attempted. AI techniques will be employed in this project. ANN will be used to check whether a ball-like object captured is indeed a ball. As there are many observations (sub-tasks for the system) have to be made during a service, it is desirable to implement the system as a multi-agents system (MAS). For example, one agent may be assigned to identify the ball, another agent for checking when the ball leave the play's palm, another agent for check when the ball reach the highest point etc. By working together, the agents system can simultaneously make several observations.

6. ACKNOWLEDGEMENT

The author would like to thank Atlanta Georgia Table Tennis Association for providing video samples about table tennis services at the ITTF web site. The author would also like to thank Ms. Cindy Leung, Chair of the Umpires & Referees Committee of the ITTF, for her support and kindness in this research.

7. REFERENCES

[1] Bishop C M, 1995, "Neural Networks for Pattern Recognition", Oxford University Press, New York.

[2] "International Table Tennis Handbook 2006/2007", http://www.ittf.com/ittf_handbook/ittf_hb.html, accessed on 20/10/2006.

[3] Salam A, "Practice to Keep it Simple", 2003, http://www.ittf.com/stories/Stories_Search_Detail.asp?ID=3449&s_Title=service+rule&, accessed on 20/10/2006.

[4] Wong K C P, Ryan H M, Tindle J, 1996 "Power System Fault Prediction Using Artificial Neural Networks", International Conference on Neural Information Processing, Hong Kong, 24-27September, 1996.