Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 2 (2010) 2967–2972

Procedia Engineering

www.elsevier.com/locate/procedia

8th Conference of the International Sports Engineering Association (ISEA)

Validation of a live, automatic ball velocity and spin rate finder in tennis

J. Kelley[a]*, S. B. Choppin[a], S. R. Goodwill[a], S. J. Haake[a]

[a]*Sports Engineering Research Group, Centre for Sport and Exercise Science, Faculty of Health and Wellbeing, Sheffield Hallam University, Collegiate Crescent Campus, Sheffield, S10 2BP, United Kingdom*

Received 31 January 2010; revised 7 March 2010; accepted 21 March 2010

Abstract

Software designed to quickly and easily calculate the 3-dimensional speed and the spin rate of a tennis ball from high speed video footage from a single camera was validated. The software values were compared to speed values from light gates and spin rate values found by manually tracking the ball logo. The respective ranges were 18-31ms^{-1} and 65-165rad·s^{-1}. The speed values had a mean percentage error of 4.47% (1.08ms^{-1}). The spin rate values had a mean percentage error of 4.14% (4.71rad·s^{-1}).

Keywords: Tennis; Analysis Software; Validation; Ball speed, Ball spin rate

1. INTRODUCTION

There are several parties for which obtaining data on tennis ball speeds and spin rates is desirable. The International Tennis Federation (ITF) continually monitors many aspects of tennis match play. It is advantageous for them to obtain accurate data on the tennis ball as quickly and easily as possible. It could also be of use for players and coaches if ball speed and spin rate data was easy to obtain and readily available from matches and during practice. A method for obtaining both spin rates and speed values using simple equipment set up and calibration, and providing results quickly with minimum user input would be ideal. A method capable of producing live results would satisfy all parties; live results would be available when required and when analysis takes place after footage collection, such a method capable of giving live results would naturally enable fast and efficient analysis.

Previous work on obtaining ball spin rate data from match play has been carried out by Kelley et al. [1] at the 2007 Wimbledon Qualifying Tournament and Goodwill et al. [2] at the 2007 Davis Cup tie between Switzerland and Spain. Both studies were carried out on behalf of the ITF; examples of how the ITF monitor the game of tennis. Kelley et al. [1] and Goodwill et al. [2] recorded high speed video clips of tennis shots using Vision Research

* Corresponding author. Tel.: +44-114-225-5634; fax: +44-114-225-4356.
E-mail address: J.Kelley@shu.ac.uk

doi:10.1016/j.proeng.2010.04.096

Phantom high speed cameras. Manual analysis was used to measure ball spin rates, which is a time consuming process, and not suitable for live analysis. An automatic spin finding method is required in order to carry out live analysis or speed up analysis carried out after footage collection.

There are obvious methods for obtaining 3-dimensional ball speed. One of these is the use of a radar gun, as used by Mavvidis et al. [3] and often employed courtside at tennis tournaments to give speed values of Serves. However radar guns lose accuracy if the moving object is not moving in a direct line (on a collision course) with the radar gun. This is called the 'cosine effect' (Scientific American [4]). Essentially, radar guns just give the closing speed between the moving object and the radar gun. This restricts the radar guns use to shots that move on a direct line towards the radar gun. Another method for obtaining ball speed is three-dimensional reconstruction of footage from 2 cameras. Such a method was used by Choppin et al. [5] using 2 calibrated and synchronized high speed cameras. This method used a calibration procedure that requires a number (>20) synchronized images of a checkerboard from each camera once set up is complete. The calibration procedure and use of two cameras mean that this method is not suitable here.

Software was designed to calculate ball speed and spin rates using the footage from a single Vision Research *Phantom* high speed camera. The software can provide results within 15 seconds of the footage being recoded. The software requires only a simple calibration using a single image of a tennis ball a known distance from the camera. Ideally the ball should be approximately in the centre of the calibration image at a similar distance from the camera to the distance from the camera to the ball in the clips that are analyzed. The calibration image can be taken at any time, even away from the tennis court, as long as the camera lens settings remain the same for the calibration image and the recorded footage. The calibration procedure takes less than 1 minute. If no calibration is possible, the software can still give spin value results as the calibration is only required for speed calculation. This software was validated in this study.

2. METHOD

Tennis balls were projected from a pitching machine (BOLA) and video clips of the ball trajectory were recorded using a Vision Research *Phantom* high speed camera. Old tennis balls were used to reduce the likelihood that the ball properties would change during testing. The BOLA could be adjusted so that the ball speed and spin rate varied. Video clips were recorded at a frame rate of 1000fps. The ball speed calculated by the software was compared to the speed measured using light gates. The light gates were positioned at the start of the ball trajectory. The software measures the average speed over a specified number of frames. The clips were analyzed so that the ball position was 3m away from the light gates in the middle frame of the analysis. This point, 3m from the light gates, is referred to as point A and was the approximate ball position for which the average speed calculated by the software applies. The reduction in speed of the ball between the light gates and point A was estimated by comparing the velocities found when the light gates were at point A to those found when the light gates were in the set up position for. This test found that there was a consistent reduction in ball speed for each BOLA setting of approximately 6.5%. All light gate velocities were therefore reduced by 6.5% before they were compared to the velocities calculated by the software. Therefore the light gate speed values contained a certain amount of error due to the approximate 6.5% reduction. Another source of error was the error in the values given by the light gates. However this was assumed to be small in magnitude compared to the error in the reduction value.

The ball spin rates calculated by the software were compared to manually calculated spin rates using the same manual analysis method as Goodwill et al. [2]. The number of frames it took for the logo to rotate twice was counted. Dividing the frame rate by half the number of frames for two revolutions (essentially the number of frames for a single revolution) gives the ball spin rate in revolutions per second. This can be easily converted into $rad{\cdot}s^{-1}$. To assess the accuracy of the manual analysis method, five repeated manual analyses of 5 clips were carried out. The maximum variability between repeated analyses of the same clip was found to be 1.5%. There is no other method of obtaining spin rate values other than tracking the rotation of the logo or some other marker attached to the ball.