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ScienceDirect

Procedia Engineering 147 (2016) 584 – 589

Procedia Engineering

www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

Validation of football's velocity provided by a radio-based tracking system

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Abstract

Nowadays, many tracking systems in football provide positional data of players but only a few systems provide reliable data of the ball itself. The tracking quality of many available systems suffers from high ball velocities of up to 34 ms^{-1} and from the occlusion of both the players and the ball. Knowledge about the position and velocity of the football can yield valuable information for players, coaches and the media.
To assess the accuracy of the football's velocity provided by the radio-based tracking system RedFIR, we used a ball shooting machine to repeatedly simulate realistic situations at different velocities ranging from 7.9 ms^{-1} to 22.3 ms^{-1} in an indoor environment. We then compared velocity estimates for 50 shots at five speed levels with ground truth values derived from light gates by way of mean percentage error (MPE) and Bland-Altman analysis. The speed values had an MPE of 2.6% (-0.49 ms^{-1}).
These results suggest that RedFIR is capable of providing accurate information about the kinematics of a football.

Peer-review under responsibility of the organizing committee of ISEA 2016

Keywords: RTLS; Football Tracking; Accuracy; Speed

1. Introduction

Nowadays, there are different tracking systems available that provide positional and velocity data of football players and the ball. In official matches camera-based systems are used frequently as game rules do not yet permit GPS- and radio-based systems that need to integrate sensors into the ball or to attach them to players. Hence, the latter are more common in training environments [1]. However, the tracking performance of camera-based systems suffers from considerable shortcomings: ball velocities of up to 34 ms^{-1}, instantaneous movements, changing weather and illumination conditions and the occlusion of both the players and the ball are common challenges for these systems [2]. The RedFIR radio-based local positioning system uses sensors integrated into the ball and located near the players' shoes to avoid such issues and provides positional, velocity and acceleration data on the players and the ball with high update rates and high precision that could be used in training and match play.

Knowledge about the movements (position and velocity) of players and playing objects (e.g.; a tennis ball or football) allows for assessing tactical and technomotorical skills quantitatively and qualitatively without the need of subjective expert ratings and forms an important part of performance analysis. Kinematic data of football player movements can also help to analyze the players' physiological demands during matches and to show additional information about the performance of players to spectators. In game sports, like football or tennis, the target or goal for each party is to handle the ball in such a way to score a goal (or point) and simultaneously prevent the opponent from scoring [3]. Hence, knowledge about the movement and speed of the playing object is of utmost importance to analyze tactical performance in game sports.

Moreover, it can also be helpful when analyzing technomotorical skills: In sports like baseball, exerting force directly onto the ball is crucial for pitchers in order to accelerate it to high speeds which is an important factor of pitching performance [4,5]. Typically, technique-related studies have been conducted in laboratory scenarios on volleyball serves [6,7] as well as ball speed in table tennis [8] and football [9].

In a match or training environment some investigations based on ball speed have been carried out using radar guns, such as in football [10], tennis [11] or handball [12], others have used light gates and/or (high speed) cameras in tennis [13] and baseball

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1877-7058
Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.244

[14]. Nevertheless, none of these methods provides an easy way to obtain ball speed that is applicable for every pass and shot on the whole football pitch: a radar gun just gives the closing speed between the moving object and the radar gun and is thus limited to goal shots when being placed behind a goal. Light gates require a fixed setup and the ball to intercept both light beams which makes their use non-practical in training and prohibits their use in actual match play. Obtaining ball speed from video cameras is possible in training and match play with the before mentioned shortcomings.

However, there is a lack of scientific research regarding the validity of methods for acquiring kinematic data of the football that are applicable in training and match situations since there are almost no studies concerned with the accuracy of ball speed estimates in sport. Kelley et al. [13] validated an automated software tool based on high-speed video for estimating ball speed and spin rate in tennis. They assessed its accuracy by comparing speed obtained by the software to the ones based on light gates. For this study we adapted their setup to football.

This study aims at validating the estimate of football speed obtained by the radio-based locating system RedFIR. See Seidl et al. [15] for a validation study dealing with the positional accuracy of the ball tracking. Hence the current study complements the validation of kinematic data of a football obtained by a radio-based tracking system.

2. Methods

2.1. The RedFIR Real-Time Locating System

The RedFIR Real-Time Locating System (RTLS) is based on time-of-flight measurements, where small transmitter integrated circuits emit burst signals. Antennas around the pitch receive these signals and send them to a centralized unit which processes them and extracts time of arrival (ToA) values. ToA values are the basis for time difference of arrival (TDoA) values, from which x, y, and z coordinates, (and subsequently three-dimensional velocity and acceleration) are derived using hyperbolic triangulation.

The RedFIR system operates in the globally license-free ISM (industrial, scientific, and medical) band of 2.4 GHz and uses the available bandwidth of around 80 MHz. Miniaturized transmitters generate short broadband signal bursts together with identification sequences. The locating system is able to receive an overall of 50,000 of those signal bursts per second. An installation typically provides 12 antennas that receive signals from up to 144 different transmitters. Balls emit around 2,000 tracking bursts per second whereas the remaining transmitters (61 mm × 38 mm × 7 mm) emit around 200 tracking bursts per second. The miniature transmitters themselves are splash-proof (in case of the player transmitters) or integrated into the football. Figure 1b) shows a glass model of a ball transmitter. For a more detailed description of the RedFIR system and the generated data streams see von der Grün et al. [16] and Mutschler et al. [17].

2.2. Hardware setup

We conducted our experiments in the Fraunhofer Test and Application Center L.I.N.K. in Nuremberg, where – within an area of 30 m × 20 m × 10 m – a RedFIR system is installed [18]. To repeatedly simulate realistic shots we placed a ball shooting machine (Seattle Sport Sciences, Inc., Redmond, WA, USA) in front of two light gates (Tag Heuer, Chronoprinter CP505) at known distances to obtain ground truth values for mean velocity. Since different speed levels resulted in slightly different ball trajectories we had to adjust the position of the second light gate to guarantee that the ball would interrupt both light gates and to increase the accuracy of the reference system based on rounding errors as outlined in 2.3.

We shot the ball ten times at each speed level 0 (2, 4, 6, 10), i.e., with approximately 7.93 ms^{-1} (9.75 ms^{-1}, 15.04 ms^{-1}, 20.17 ms^{-1}, 22.32 ms^{-1}) resulting in a total of 50 shots. Only the ball's transmitter and two reference transmitters were activated. Twelve receivers were active during our tests. Figure 1a) shows the setup detailing the placement of the ball shooting machine and light gates.