Player Analysis Technology Approval report

Sentinel

Test code: PAT-23-027

Serial no: n/a

Software version(s): n/a

Firmware version: 22.04

Issue date: 24 August 2023

Objective: To test and evaluate Sentinel Player Analysis Technology according to Rule 31 of the 2023 Rules of Tennis.

Result: Approved

SUMMARY

Multiple cameras fixed around the court are used to capture images of play. The cameras are connected to a network switch which uploads the images to a cloud server. Personal computers (PCs) are connected to the cloud server, which runs software that reconstructs the ball and player trajectories in three dimensions from the camera images and a virtual model of the court.

The trajectory information is used to generate virtual replay graphics of ball flight, player movement, and match statistics.

The event owner (customer) and sanctioning body determine the information that can be distributed by Sentinel. Information can be sent to the in-stadium display and/or TV broadcast. The provision of line call replays to the in-stadium display is controlled by the Chair Umpire.

Restrictions on the access by a player to Sentinel components during periods when coaching is and is not allowed are as follows:

COMPONENT	NO COACHING	COACHING
Video cameras	Permitted	Permitted
Loudspeaker	Permitted	Permitted
In-stadium display	Permitted	Permitted

NOTE: Approval does not attempt to, nor does it in fact, establish the accuracy or reliability of data or fidelity of its transmission, including (but not limited to) the provision of 'in'/ 'out' decisions for the purposes of line-calling.

MAIN COMPONENTS

The main components of the system are described in table 1 and depicted in figure 1.

COMPONENT	FUNCTION(S)
Video cameras	Capture images of play
Personal computers (PCs)	Start/stop data capture, transmit and display data
Cloud servers	Receive, store, analyse and transmit data
Computer vision software	Reconstruct the ball and player trajectories from camera images
Data analysis and modelling software	Generate match statistics and virtual replay of each point
Loudspeaker	Communicate 'out' calls
Two-way radios (optional)	Communicate with Chair Umpire, TV broadcaster
In-stadium display (optional)	Display match statistics and virtual replays

Table 1. Description of the components of the Sentinel system.

Figure 1. Components of the Sentinel system (from left to right): Video camera; PC display monitor; in-stadium display.

DATA CAPTURE AND PROCESSING

Multiple (typically 10-14) high frame rate (typically 75 Hz) cameras are mounted at fixed locations around the court. Each camera is connected via Ethernet cable to a courtside network switch which uploads the camera images to a cloud-based server. Authorised users can log into the cloud platform from anywhere worldwide with an internet connection. This allows the operator to view the live images and alter the camera and software settings.

Data is captured continually with ball-surface impact points identified and marked by the software. Ball trajectories and player positions are reconstructed in three dimensions and plotted relative to the court. The system can provide outputs for both challenges and live (real-time) electronic line calling. Virtual replays of shot trajectories and ball impact marks relative to court lines can be produced for in-stadium displays.

Data generated includes time histories of the position of the ball and players in three dimensions; instantaneous speeds of the ball and players; and locations and times of each shot. All data is stored on a password-protected cloud-based server.

COMMENTS

The system functions independently of the players (does not require any player input). It is typically run by a minimum of two trained operators who can be based on- or off-site.

Transmission of data from the cameras is on a wired, isolated network, limiting its susceptibility to hacking. Transmission of data from the camera network to the cloud and from the cloud to the operator PCs is encrypted and access to the cloud server is password protected.

DATA COMMUNICATION

The event owner (customer) and sanctioning body determine the information that can be distributed by Sentinel.

Match statistics and virtual replays can be sent to multiple recipients. These include:

1. In-stadium display
2. TV broadcast
3. Internet end points

Transmission of visual information to the in-stadium display is dictated by the Chair Umpire, via radio communication with the Sentinel operator(s) and the Review Official. The information requested by the Chair Umpire (which comprises line calls only) is sent by the Sentinel operator from their PC to a machine controlling the in-stadium display (typically manned by a third-party operator) via coaxial video cable, following authorisation by the Review Official.

When the live system is in use, an audible 'out' call is communicated by a loudspeaker near the court when the ball lands 'out'.

Transmission of visual information to TV broadcast is dictated by the TV producer/director, via radio communication with the Sentinel operator.

COMMENTS

The event owner (customer) and sanctioning body determines the information that can be distributed by Sentinel.

The transmission of visual information from Sentinel to the in-stadium display is at the request of the Chair Umpire and subject to approval by a Review Official. When the live system is in use, an audible 'out' call is communicated by a loudspeaker near the court.

TV broadcast may show coaching information. Therefore, it is important that players do not have access to TV when coaching is prohibited.

Data output by the control PC to the in-stadium display and TV is sent as video over coaxial cable, which is one directional and ensures the recipient cannot access or affect any part of the system.

ADDITIONAL INFORMATION

Client:
Bolt6
Runway East Shoreditch
52 Tabernacle Street
London
EC2A 4NJ

Date tested: 25 January 2023

Report prepared by: David Cole
Report authorised by: Jamie Capel-Davies
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