



Player Analysis Technology Approval report

Hawk-Eye

Test code: PAT-13-002

Serial no: n/a

Software version(s): n/a

Firmware version: n/a

Issue date: 24 December 2013



Objective: To test and evaluate Hawk-Eye Player Analysis Technology according to Rule 31 of the 2014 Rules of Tennis.

Result: Approved

SUMMARY

Multiple cameras fixed around the court are used to capture images of play. The cameras are connected to personal computers (PCs) on a wired, isolated network. Software, on the network, is used to reconstruct 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 the flight of the ball and movement of the players, and match statistics.

The event owner/sanctioning body/customer determines the information that can be distributed by Hawk-Eye. Information can be sent to the in-stadium display, TV broadcast and internet-enabled devices. The provision of line call replays to the in-stadium display is controlled by the chair umpire (and review official).

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

COMPONENT	NO COACHING	COACHING
Video cameras	Permitted	Permitted
Two-way radio	Not permitted	Permitted
In-stadium display	Permitted	Permitted
Auxiliary device (e.g. smartphone)	Not permitted	Permitted

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, store, process, transmit and display 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
Two-way radios (optional)	Communicate with chair umpire, TV broadcaster
In-stadium display (optional)	Display match statistics and virtual replays
Auxiliary device, e.g. smartphone (optional)	Display match statistics and virtual replays

Table 1. Description of the components of the Hawk-Eye system.



Figure 1. Components of the Hawk-Eye system (from left to right): Video camera; PC; two-way radio (talkback panel); in-stadium display; auxiliary device (smartphone).

DATA CAPTURE AND PROCESSING

Multiple (typically 8-10) high frame rate (typically 50/60 Hz) cameras are mounted at fixed locations around the court. Each camera is connected via Ethernet cable to a dedicated PC, which performs image processing on (and optionally stores) the raw image data. The PCs are connected on an isolated network, which includes an additional 'control' PC.

The control PC is used to start and stop data capture and process the data provided by each camera PC. Proprietary software on the control PC reconstructs the trajectories (in three

dimensions) of the ball and the players relative to the court. Additional proprietary software is used to create a virtual replay of the ball and player trajectories on the court and match statistics (derived from the trajectory data). Typically, the two software packages are run by designated operators on separate PCs.

Data generated includes time histories of: position of the ball and players in three dimensions; instantaneous speeds of the ball and players; locations and times of each shot; estimation of ball spin; classification of winners, errors, forehands, backhands.

Trajectory data (for the ball and players) are stored on a password-protected server. The data are sent from the control PC to a centralised server using file transfer protocol (FTP).

COMMENTS

The system functions independently of the players (does not require any player input). It is typically run by 2-3 operators.

Transmission of data between data capture and processing components is on wired, isolated network, limiting its susceptibility to hacking. Transmission of data from the isolated network to the Hawk-Eye server is done via FTP.

DATA COMMUNICATION

The event owner/sanctioning body/customer determines the information that can be distributed by Hawk-Eye.

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

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

Transmission of information to the in-stadium display is dictated by the chair umpire, via radio communication with the Hawk-Eye operator(s) and review official. The information requested by the chair umpire (which comprises challenged line calls only) is sent by the Hawk-Eye 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.

Transmission of information to TV broadcast is dictated by the TV producer/director, via radio communication with the Hawk-Eye operator. Information is typically offered by the Hawk-Eye operator and sent from their PC to TV via coaxial video cable when desired by the producer.

The event owner/sanctioning body selects the information that is transmitted via the internet (typically ahead of the event). Information is displayed on an auxiliary device, such as smartphone or laptop, via a web-based application (Pulse). The data for Pulse are provided by a dedicated PC connected to the isolated network.

COMMENTS

The event owner/sanctioning body determines the information that can be distributed by Hawk-Eye.

The transmission of information from Hawk-Eye to the in-stadium display is at the request of the chair umpire and subject to approval by a review official.

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.

Coaching information is available through a web-based application (Pulse). Therefore, players must not have access to internet-enabled devices, e.g. smartphone, laptop, when coaching is prohibited.

ADDITIONAL INFORMATION

Client:

Hawk-Eye Innovations Ltd
Sony Europe
Jay Close
Viables
Basingstoke RS22 4SB
UK

Date tested: 6 December 2013

Report prepared by: Jamie Capel-Davies

Report authorised by: Stuart Miller

Revision number: 0