FIFA

Semi-Automated Offside Technology

Component Testing Overview

October 2022

Introduction

FIFA has introduced semi-automated offside technology to support its video assistant referees (VARs) during the FIFA World Cup 2022™ and FIFA Women's World Cup 2023™. A significant amount of research has gone into understanding semi-automated offside technology, with the results providing evidence that the underlying systems are both accurate and reliable. Due to the impending development of new technologies, FIFA has developed a testing protocol that outlines the certification path for such technologies to be used in games.

The core components of semi-automated offside technology that require validation are:

1. virtual offside line (VOL) technology capable of automatically generating offside lines in all areas of the pitch;

2. ball-tracking capability that can automatically identify the location of the ball and the moment the ball is kicked;

3. a valid skeletal-tracking system capable of automatically and accurately identifying skeletal points on multiple players simultaneously; and

4. an alert system capable of automatically displaying messages when offside incidents occur.

In addition to the individual component tests, additional assessments will be conducted to ensure that the logic behind the semi-automated offside technology can deal with specific edge cases that are known to cause challenges to the relevant system and that all components are able to work together simultaneously in a full match environment.

This document summarises the additions and amendments made to the existing 'Offside Technology Test Manual' and the new 'Skeletal Tracking Test Manual' while also outlining the required stand-alone tests.

Testing requirements

An overview of the required tests is listed below.

Component	FQP Test Location	Test	Requirements
1	**Offside Technology**	2D line placement	Pass/fail as per manual
1	**Offside Technology**	3D manual line placement	Pass/fail as per manual
2	**Offside Technology**	Kick-point detection	Check
2	**EPTS**	Ball tracking	Check
3	**EPTS**	Skeletal tracking	Pass/fail as per manual
4	**Offside Technology**	System alert	Check
5	**Offside Technology or EPTS**	Logic & match test	Check

Explanation of each individual test component can be found in the next sections of this document.

Various additions and amendments have been made to the Offside Technology Test Manual (previously known as the 'Handbook of Test Methods for Virtual Offside Line Assessment') to facilitate the testing of semi-automated offside technology components. These are listed below and explained in detail in the Handbook.

Additional Tests

Kick point

To establish the kick-point detection accuracy, an additional check will take place during the offside scenarios. Due to the difficulty in syncing different camera systems and sensors, as well as establishing a ground truth over which system is more accurate, a visual check will be deemed sufficient. This visual check will be carried out by the FIFA representative acting as the VAR. This visual check will establish whether or not the kick-point that best reflects the first point of contact has been automatically selected. There are many factors that contribute towards the difficulty of kick-point identification and therefore multiple camera angles can be used as part of the assessment.

The checks will take place during the assessment; however, a screen recording must also be taken in case later checks are needed. In each scenario, a member of the testing team will request that once the kick point is automatically detected, the operator rewind one frame and then forward two frames (more frames can be checked if necessary). This will show the three frames that could have been used for the kick point and help determine whether the frame that best represents the first point of contact with the ball had been selected. Due to the discrete nature of using camera footage for kick-point identification and the short contact time between player and ball, there is no gold standard.

Alert system

In addition to the kick-point check, an alert check will be conducted to ensure that alerts are correctly issued for offside scenarios. This alert system can be a visual aid embedded into the system or a separate application providing real-time information to a match official (the VAR by default). While other settings are possible, the default should be:

- X values <1m apart: "close onside" or "close offside"
- X values >1m apart: only indicate "clear offside"

A simple checklist answering 'yes' or 'no' will be undertaken to understand if the system automatically created an alert for onside decisions of <1m and for all offside decisions within 5 seconds of the attacker receiving the pass.

Amended VOL Tests

Data collection

Due to semi-automated offside technology requiring a minimum number of players to automatically detect offside, blocks 1 and 3 have been updated to include a minimum of four players: one goalkeeper, one defender and two attackers. Two of these players will be in known locations, with the others in controlled positions away from the offside lines. Each scenario will require providers to generate both the attacking and defending line. One randomised line will be selected from each scenario to be analysed for accuracy.

Mannequins and football boots previously used for 3D offside points will be replaced with stationary players. A total station will be used to position players so that the leading and trailing goalscoring parts of the body of both the attacker and second-last defender are in line with a known pitch location. Research will be conducted to identify the variation of this position in application.

Data submissions

Due to semi-automated offside technology systems using their own tracking cameras to inform player skeletal positions, a pre-agreed electronic performance and tracking system (EPTS) camera must be used to submit images of the offside scenarios. The default approach should be that VOLs should only be generated on the EPTS feeds, with broadcast gaining access to these through the VAR system. Semi-automated offside technology providers who wish to integrate broadcast cameras into their EPTS system can raise this topic with FIFA, but this is currently not recommended.

Semi-automated offside technology providers will be required to submit the 3D coordinates, the decision and the distance between attacking and defending coordinates for each scenario.

Semi-automated offside technology providers are required to provide a regular manual offside tool for VARs in addition to the automated tool in order to amend the VOL in the event of edge cases where VAR interpretation is needed or under the request of the VAR. Block 1 will use players, and providers must use their fully automated system. Block 2 will require that providers use their manual line generation. Block 3 must be conducted using the automated system.

Data analysis

Analysis will be conducted on the agreements between the criterion data collected by the test institute and the semi-automated offside technology provider. This includes the final decision and the 3D coordinates of both attacking and defending skeletal coordinates.

For certification, the semi-automated offside technology values will be compared to the criterion data set. Root-mean-square difference (RMSD) – which serves to aggregate the errors from multiple data points into a single value – will be used to determine the accuracy of the system. Certified systems must have an RMSD value of well above industry standard for the X coordinates (where the X axis represents the axis perpendicular to the goal line).

EPTS Test Protocol - SAOT

A new skeletal-tracking protocol has been designed to assess the accuracy of skeletal-tracking systems. Whilst the set-up and protocol are very similar to the existing EPTS test protocol, nuances between the capture and the set-up have led to the decision to keep this manual separate from the existing centre of mass testing protocol. Skeletal tracking for officiating purposes, such as semi-automated offside technology, must meet the minimum pass/fail requirements, whilst limb tracking not intended for the use of semi-automated offside technology has no such requirements.

Providers of semi-automated offside technology must take part in two days of testing. The first day involves data capture related to the validation of player (centre of mass) and ball-tracking data, whilst the second day involves skeletal-tracking validation. Due to the nature of semi-automated offside technology, the provider must upload live tracking data to a pre-defined server to allow for analysis to be conducted on raw data rather than cleaned and processed post-match data.

An overview of the test protocol can be found below, but for full details please refer to the Handbook of Test Methods for Skeletal Tracking.

Skeletal tracking for SAOT

- Criterion tracking data collected through Vicon motion capture
- Participants marked with specific skeletal markers
- Data capture includes a combination of individual player trials with specific calibration movements, multiple player trials with football-specific movements and some offside-specific trials
- Live data collected through online message server
- Post collection – temporal and spatial alignment of data
- Quantified levels of agreement calculated between provider and Vicon skeletal points
- Root-mean-square difference (RMSD) between X coordinates (where the X axis represents the axis perpendicular to the goal line) must be well above industry standard to pass the certification

Ball tracking

- Due to the importance of understanding the ball position for offside scenarios, specifically to understand whether the ball has been played forwards or backwards, it is important to understand the quality of the ball-tracking data of the provider. The ball-tracking validation takes place in the regular EPTS test protocol and compares the provider ball data to criterion data collected through Vicon and known pitch locations measured using pitch topography equipment.

- Whilst there is no pass/fail requirement for this assessment, an initial recommendation is that the position difference between the criterion data and the provider data is no greater than 25cm – a value that represents the approximate diameter of the ball.

Logic & Test Match Protocol - SAOT

The final third component for approval of semi-automated offside technology systems is carried out in the form of a logic test match. During this test, the functionality and logic of the system is tested in a match-like scenario. FIFA will organise such a test on an annual basis either in connection with the Offside Technology test event or the EPTS Skeletal Tracking test event depending on the availability of access to the stadiums. In the event that a technology provider does not participate in the test organised by FIFA, technology providers have the possibility to organise a separate test considering that all costs need to be covered by the provider.

The logic and test match serves two purposes:

1. To identify whether the system can apply all elements of a SAOT system together in a match-like scenario

2. To identify key limitations to the system by presenting scenarios that specifically challenge the logic of the system. Some examples are listed below:

    - What does the system do when the goalkeeper is the second last defender?

    - What does the system do when a player is off the pitch?

During this test match, offside scenarios will be organised by a FIFA representative on the pitch with a second FIFA representative observing the technology at the VAR station. The Offside Technology provider will use their system as they would in a regular game and where possible generate virtual reality replays for the offside scenarios. The test match will take place over two 45 minutes windows: the first window will focus on dead ball incidents, and the second will be built around open play. The following data must be recorded and submitted to FIFA for analysis:

- Live skeletal and ball tracking data submitted to Rabbit MQ

- Screen recording of Offside Technology station for the entirety of the test match

- Video output recordings from all cameras for the entirety of the test match

Based upon the performance of the system in the logic & match test, FIFA deserves the right to request another test in case of issues in the logic of the system. Successful completion of the test will result in a passed test report issued by FIFA. The report will contain elements from both the offside technology and skeletal tracking test events and a summary of the observations from the Logic & Test Match.