Handbook of test methods for EPTS devices

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1. Introduction

As a result of an extensive research and consultation period FIFA has developed a Quality Programme for Electronic Performance Tracking Systems (EPTS). This programme has been developed as a method to quantify the accuracies of the various systems available. As with the other Quality Programmes, the aim is neither to promote specific products nor to interfere in the market and block innovation, but to describe EPTS in a technical way that are best suited for use in football. This programme will be iteratively improved and developed based on data driven decisions in order to increase the quality of the output data over time.

The method for the testing includes testing against two systems. The first system is a globally recognised gold standard for motion capture (VICON) which will be used for testing specific football movements in a 30x30 m area. The second system that will be used will be the Vision Kit system developed by Victoria University which utilises labour intensive methods to track players over the full size of the pitch. Together this ensures that the accuracy of the system can be assessed whilst ensuring that manufacturers have their systems prepared for a real life game scenario.

This Test Manual is suitable for all types of EPTS including Global Positioning Systems (GPS), Local Positioning Systems (LPS) and Optical Tracking Systems (OTS). This document outlines the method for data collection, processing and analysis.

2. Test Protocol

2.1. Testing Venue

The testing shall be undertaken in a football stadium with pitch dimensions according to the official FIFA regulations. The venue must allow the concurrent operation of GPS, LPS, and optical systems, and therefore shall have sufficient height for optical systems’ cameras to be installed.

2.2. Participants

It is recommended for the participants to be at least 16 years of age, to ensure that the movements performed during the testing tasks are representative of those found in a typical football match. As well as ensuring that the participant size is representative of the final user.

2.3. Test Area

The test area shall consist of:

A 30 x 30 m area for tasks a) b) & c) (see 2.4) in which the players’ movements are captured with a motion capture system. This test area shall have the dimensions of 30 x 30 m and shall be set up in one of four possible quadrants originating from the centre circle (Figure 1).
The full size of the pitch for task d) (see 2.4) in which the players’ movements are captured with a computer vision system.

2.4. Testing Protocol Overview

Participants shall be asked to complete the following tasks, in this order:

a) A circuit, designed as demonstrated in

b) Figure 2, within an area with dimensions 25 x 25 m, which shall include:

i. Self-paced walking

ii. Self-paced jogging

iii. Maximal accelerations

iv. Changes of direction

The circuit shall have a minimum duration of 4 minutes per participant.
Figure 2. Schematic of the circuit; green indicates walking, orange indicates jogging, red indicates maximal acceleration

c) A 2 v 2 small-sided game, played in an area with dimensions 25 x 25 m, in which players attempt to maintain ball possession without the possibility of scoring. The game should have a minimum duration of 4 minutes.

d) A 5 v 5 SSG small-sided game, played in an area with dimensions 25 x 25 m, in which players attempt to maintain ball possession without the possibility of scoring. The game should have a minimum duration of 4 minutes.

e) A series of five maximal sprints over a distance of 40 m, commencing outside and concluding inside the 30 x 30-m test area for motion capture.

f) In addition to the sprints mentioned in d above, players will be asked to jog along internal lines of the pitch to ensure the full pitch is covered by manufacturers.

2.5. Computer Vision Set Up

The cameras used to collect the video for computer vision analysis should have a minimum quality of full HD.

The cameras set up shall keep in consideration the following aspects:

a) The exact dimensions of the test area shall be recorded. This must be as accurate as possible, as dimensions are then used to calibrate the computer vision software during analysis phase.
b) Cameras shall be placed on a solid surface, ideally a tripod.

c) The exact number of cameras to be used will depend on the dimensions of the area to be captured. For the abovementioned test area, it is recommended that at least 4 cameras shall be used.

d) Cameras shall be positioned as high as possible around the test area (e.g. on the stadium stands).

e) Once cameras are in position, the zoom shall be moved to the furthest possible setting, until the horizontal picture appearing in the camera’s display contains the outer borders of the test area, as illustrated in Figure 3. This process is repeated with each camera until the entire playing area is covered.

f) When all cameras are set up and covering the entire test area, video capture can commence.

2.6. Motion Capture Set Up

It is recommended that a variety of infrared cameras with different types of lenses are employed for data collection. This variety in the field of view provides both the depth and width required for the task being captured. Cameras with high megapixel sensors but also suitable for outdoor capture are recommended, due to the optical filter fitted which attenuates wavelengths of other light and only lets in the specific Infrared wavelength.

Cameras shall be laid out evenly spaced around the perimeter of the 30 x 30 m test area, to allow for a minimum 25 m x 25 m area to be captured (Figure 4). The cameras shall be powered by POE switches connected through Cat 5E Ethernet cables, which are then connected to a central hub switch.
Once camera setup is complete, the system shall be calibrated. The error values shall be checked by the researchers to ensure that they fall within suitable values (less than 1 mm). If error values are not acceptable, another calibration wave shall be conducted. A further test shall be conducted to determine the consistency of the calibrated space with the active wand being passed through the test space, but collected as test data (rather than as part of the calibration process).

Five reflective markers with a 28 mm diameter shall be placed on each participant prior to testing. Markers shall be located on the left and right anterior superior iliac spine, the sacrum and one on each of the shoulders (Figure 5). Markers shall be secured with a combination of double-sided tape between the marker base and the skin and with strapping tape placed on top of the base but not obscuring the marker. The same testers shall apply the markers each day to provide consistent marker locations for each participant.
Data shall be collected at 100 Hz for each player and task using dedicated software. Data shall then be labelled and transferred to Visual 3D software for further analysis. Gaps of less than 10 frames shall be filled using an interpolation function. Where gaps are too large to fill, these data shall not be included in the dataset. The XY coordinates for each player and marker shall be smoothed using a 5-Hz Butterworth digital filter (the 5 Hz cut-off is chosen based on extensive signal processing including residual analysis, wavelet analysis and visual inspection of data). To approximate the centre of mass, the average of the three pelvis markers is calculated for the entire time series then differentiated (three-point central differences method) to velocity. These data shall then be transferred for each individual and each task to the analysis software to compare with the appropriate manufacturer data.

3. Data Analysis

3.1. Data analysis processes

All manufacturers shall be assessed at 10 Hz

3.2. Motion Capture Data Preparation

Motion capture data shall be provided as individual drill files for multiple players sampled at 100 Hz. Files contain X and Y coordinates as well as velocity in X and Y. Files shall be firstly split into individual player and drill files. Velocity shall then be established from the velocity in the X and Y planes. To allow comparison of motion capture data with both 10 Hz and 25 Hz manufacturers data, the X, Y and velocity data shall be linear interpolated to 50 Hz, smoothed using a 5-point moving average, smoothed using a 2nd order, low pass Butterworth filter, with a 1 Hz cut-off. Data shall then be down-sampled to either 10 Hz or 25 Hz.

3.3. Computer Vision Data Preparation

Computer vision data shall be provided as X and Y coordinates at a sample rate of 25 Hz. The file shall be sorted by player and frame number. A change of greater than 1 in the frame count indicates a change of drill within a session. Files shall be split into separate drills for each individual player. Individual 25-Hz X and Y coordinates shall then up-sampled to 50 Hz using linear interpolation and smoothed using a 5-point moving average. Displacement shall then be established from the X and Y coordinates using the 3-point centrum method, subsequently allowing the calculation of velocity. Velocity shall then smoothed using a 2nd order Lowpass Butterworth Filter with a 1 Hz cut-off. X, Y and velocity data shall then be down-sampled to either 25 Hz or 10 Hz by extracting every 2nd or 5th data point respectively.

3.4. Manufacturers Data Preparation

Manufacturers’ data shall be provided using the FIFA EPTS Standard Data Format. Where provided, the Unix time shall be recorded as the reference time. Manufacturers files provided at 10 Hz shall be checked for consistency of sample rate (i.e., dropped data points, inconsistent sample rate) and shall be resampled
at 10 Hz using linear interpolation to ensure synchronisation with motion capture and Computer vision data.

Manufacturers files provided at 18 Hz shall be checked for consistency of sample rate (i.e., dropped data points, inconsistent sample rate) and shall be resampled at 20 Hz using linear interpolation to ensure synchronisation with motion capture and Computer vision data. Data shall then be smoothed using a 3-point moving average and then down-sampled to 10 Hz.

Manufacturers files provided at 25 Hz shall be checked for consistency of sample rate (i.e., dropped data points, inconsistent sample rate) and resampled at 50 Hz using linear interpolation. Data shall then smoothed using a 5-point moving average and then down-sampled to 10 Hz.

Further to the raw data provided by manufacturers, a 2nd order Low Pass Butterworth Filter with a 1 Hz cut-off will be applied to all manufacturers’ velocity data.

3.5. Motion Capture and Computer Vision Synchronisation

Individual Computer vision 10 Hz data or 25 Hz files and motion capture 10 Hz and 25 Hz data shall be imported and synchronised using cross correlation of the speed values. Once synchronised, files shall be trimmed and combined, and stored as individual player and drill files containing both sets of data.

3.6. Motion Capture and Manufacturers Data Synchronisation

The individual player and drill files (Motion capture and computer vision data) shall be imported and synchronised with individual manufacturer data. Synchronisation shall then be established between the manufacturers speed data using cross correlation with the motion capture velocity data. Cross correlation establishes the best shifting of the two data signals that results in the highest relationship (correlation) between the manufacturers speed data and the motion capture speed data. The resulting data shall be trimmed and combined. The manufacturers speed data will then be further synchronised by shifting the speed trace forwards and backwards by 50 data points in intervals of one, with the Root Mean Squared Difference (RMSD) at each point established. The shifting of the manufacturers data that results in the lowest RMSD will be used for analysis. The final file for statistical analysis contains the motion capture data, Computer vision data, and the manufacturers data.

3.7. Position Alignment

Prior to assessing X and Y position differences, any GPS manufacturers providing Latitude and Longitude data shall be converted to X and Y position data using the “geosphere” package within R. The programming language R is free software for statistical computing (for more information see r-project.org) and includes a variety of “packages” that can be used to process large time series files similar to those provided from VICON analysis and player tracking manufacturers. To examine the difference in position data, X and Y co-ordinates shall be rotated to match the X and Y co-ordinates from motion capture data. This will be achieved by rotating the manufacturers data by 1 degree through 360 degrees until the lowest error in position data is achieved. Once the closest 1-degree rotation is known the manufacturers X and Y
co-ordinates will be further adjusted to the closest 1/100 of 1 degree either side of the best alignment. Once aligned, data shall then be shifted left or right, up or down to ensure X and Y position data are synchronised. The difference between the manufacturer X and Y coordinates and motion capture X and Y coordinates shall be quantified as the straight-line difference between the coordinates.

3.8. Statistical Analysis

The differences between manufacturer’s and motion capture/computer vision data for both position (in m) and velocity (m.s\(^{-1}\)) will be assessed using both absolute and relative measures. For absolute measures, the mean difference between the two data sources will be obtained to provide an indication of any systematic differences between the two data sources.

A 95% (or similar range) confidence interval should also be reported. This serves to display the range of values that the reader can be 95% certain contains the true mean of the sample population. To determine the level of agreement between the two sources, for the velocity, the root-mean square difference (RMSD) will be obtained between the two forms of the raw data. This represents the sample standard deviation of the differences between the two sources. For position, mean absolute error is suitable for the same purpose. As a relative measure, standardised effect sizes can be used, or typical error of the estimate. It is worth noting that the above absolute measures rely on an assumption of normally-distributed differences between the two data sets. In the event of heteroscedasticity in overall differences, comparisons may be delimitied to those velocity bands whereby normality is present.

Values will be presented at an overall level (all data combined from the SSG and circuit), and divided by velocity bands as per FIFA velocity bands. Visual representation of the data can further aid interpretability of results. We recommend two types of figures for this purpose; however, others also exist. First, visualisation of the distribution of differences via a histogram can be undertaken for both velocity and position data (Figure 6).
Second, a grid of the capture space using 1 m x 1 m bins can be useful for the purpose of identifying any areas of the capture space that are problematic for agreement Figure 7.
Figure 7. Example of grid visualisation of the differences in velocity and position
4. **Criteria for Product Accreditation**

Manufacturers will be evaluated for velocity and where relevant, position using a five-level scale. The scale will use colour coding rather than stating specific velocity or position differences. Box plot values have been used to develop thresholds to inform this grading based on current industry standards; these are as follows:

a) Well Above: Q1 minus 1.5*IQR to 25\textsuperscript{th} percentile

b) Above: 25\textsuperscript{th} percentile to median

c) Standard: Median to 75\textsuperscript{th} percentile

d) Below: 75\textsuperscript{th} percentile to Q3 + 1.5*IQR

e) Well-below: Everything greater than Level 4

The resulting colour coding is as follows:

<table>
<thead>
<tr>
<th>Legend</th>
<th>Well-above</th>
<th>Above</th>
<th>Standard</th>
<th>Below</th>
<th>Well-below</th>
</tr>
</thead>
</table>

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