

Chapter 2

How to Use the Dots to Analyze the Behavior and the Collective Organization

Abstract Position data can be obtained from different approaches and techniques. Based on that, the aim of this chapter is to briefly present the main methods that have been used to track players during the games and training sessions and to discuss which kind of information can be used to analyze the individual and collective behavior. The introduction to the uPATO software will be also executed. This software allows to import position data from multi-camera tracking systems or Global Positioning System (GPS) and to compute tactical and collective measures representing group behavior.

Keywords Position data · Georeferencing · Tracking systems · GPS · uPATO · Soccer

2.1 Following the Players? Tracking Systems to Determine the Data Position

Tracking the movement of players during a match has become a common practice in sports [6]. The use of position data of players allows coaches to better understand the performance of players and of the team, giving them a competitive advantage over other teams. From position data, it is possible to calculate different metrics, both individual and collective, that give a better comprehension on training exercises and real game situations performance. From these measurements, match dynamics and team dependencies and coordination (both intra-team and inter-team) can be analyzed, as well as tactical patterns and their changes with regard to game moments, giving coaches and teams a powerful tool for performance analysis and data for metrics calculation [11].

Different tracking mechanisms and systems exist, each with their advantages and disadvantages. From multiple camera systems to local position systems or GPS systems, it is possible to track the position of players with good accuracy, and extract position data on every measured instant across a defined time interval. From the data, it is possible to calculate metrics and extrapolate information on the players and the team, which allows for a more comprehensive analysis of a game [12].

The following sections give some insight on different tracking systems for the position of players on set time instants.

2.1.1 Camera Systems

Camera systems record live footage of a game, which is then processed to detect each player on the field. Object detection can be made with different procedures, such as background subtraction or shape detection. From this, it is then possible to obtain location data of the players for that frame, which represents a time instant. For improving coverage of the field, some systems utilize multiple cameras, placed at different angles, where each camera covers an area of the field [12]. Another possibility is the use of rotating and zoom-enabled cameras (such as Pan-Tilt-Zoom (PTZ) cameras) [7, 8]. The full camera set captures the entire playing field. Captured frames are either fused first for detection, or first individually analyzed on each camera, and then the detected players on each camera are joined. From the detected players, tracking algorithms are used to compute the movement of the players across frames and, from there, calculate the positions of each player across the frames.

Camera systems provide some significant advantages over other tracking methods, mainly the possibility of tracking official games, since players are not allowed to have devices on them during these matches. Some systems, such as Datatrax and Feedbacksport, allow for cameras to be moved to different fields, but the majority of camera systems require a fixed installation, meaning that teams only have data on their home matches [6]. However, these systems also have some issues and disadvantages, mainly in terms of occlusion, change in light conditions, the need to install and calibrate cameras, the computational weight of the image processing and the time it takes to have all data registered [6].

2.1.2 GPS Systems

Global Positioning System is most commonly used in military or commercial applications for location tracking and orientation. It is a system composed of 27 satellites, orbiting the Earth. Time information is sent from the satellites to a GPS receiver, and through time comparison (of the clock on the satellites with the clock on the receiver) a position is triangulated. A minimum of four satellites is required to triangulate the position accurately [9, 10].

This system can also be adopted as a position data tracking device for players. Each player is accompanied by a GPS receiver, which tracks its position at every measured instant. With this, it is possible to measure performance in sports in less restricted environments, and analyze real game situations through the gathered data [10]. Some systems also add other sensors to the GPS receiver, to track physiological data, such as heart rate or hydration.

Previous GPS units had several disadvantages when compared to other architectures, due to high acquisition cost, lack of precision and low report frequency, which made it difficult to gather reliable speed and acceleration data. Nowadays, most GPS devices have improved on these previous points, but maintain other disadvantages, such as the size of the devices, battery life, the amount of data generated due to the better reporting rate, and the inability to use GPS indoors, making the system unusable in indoor sports. GPS remains heavily dependant on satellite connection, making even outdoors unreliable in certain low coverage situations.

GPS devices have an average reliability on reported distance, which is reduced with the increase of velocity or changes in direction. When measuring longer movements, in time and distance, the error in measurement stays below 5%, but when measuring sprints the error can be as high as 77% for a 10m sprint on a 1 Hz GPS device (1 Hz signifies that one report is made each second) [4].

GPS devices have other advantages though. They are not affected by lighting conditions, and can track players even when grouped up. They are also portable, not being restricted to a single field, and require practically no setup when compared with camera-based systems.

GPS tracking was the used method for the position data of players used on the uPATO framework, with recourse to GPS units (10Hz, Accelerometer 1 kHz, Field-Wiz, Paudex, Switzerland).

2.1.3 Other Systems

Other types of tracking systems exist, albeit not as popular as the ones presented in the previous sections. The first methods used for capture were through the recording of the match, and then manually measuring and annotating positions and movements, and comparing with videotaped movements of players (e.g., sprinting) to provide some measures of calibration and comparison [6]. Other, more recent techniques, include, for example, the TrakPerformance (Sportstec, Warriewood, NSW, Australia) system, where a pen is used on a drawing tablet to register the movement of a single player on the field [6], or the Local Position Measurement (LPM) system (Inmotio Object tracking v2.6.9.545, 45 Hz, Amsterdam, the Netherlands), where players wear a vest transmitter and several base stations are placed to capture the signals of the vests [5]. The first system has the advantage of being highly portable, inexpensive and usable virtually on any field, but it can only track one player, requires continuous operation and is dependent on the skill of who is registering the movement. The second system has the advantage of being usable both indoors and outdoors, when compared with a traditional GPS, but requires installation of the base stations and is, therefore, not portable between fields.

2.2 Introducing the uPATO Software: From GPSs to Data Import

The uPATO is a tool developed with the objective of providing users with an easy way for analyzing the performance of players at a collective and individual level, in team sports. It is composed of three major modules: a GPS module for analyzing GPS data, a module for analyzing matrices containing data from passes and goals and a module providing representations for comparing metrics. The subject of this book focuses on position data, thus centering the discussion around this tool's GPS module and omitting the other two modules.

The GPS data is organized and stored in a database, which requires the installation of MySQL, creation of a database and configuration of a user with access to it. In order to access the database and its data, the application presents a login menu, requiring the introduction of the username and password previously configured. After the login menu, the user has access to all the functions of the module: introduce/import data, calculate metrics and process data, visualize representations of the metrics and game animations.

The first step is then importing data to the database for future processing and consulting. An overview of the importation process is described in Sect. 2.2.1. While Sect. 2.2.2 briefly introduces the process of calculating the available metrics in this tool and Sect. 2.2.3 discusses how the results are presented to the user and how they become available for exportation.

2.2.1 *Importing Data*

A database was designed with team sports in mind, being organized into the following main tables:

- Location—consists in a field or location where a game took place;
- Team—consists in a team of players;
- Game—a combination of two teams, a location and a date;
- Player—each of the players;
- Data—the location of a player at each instant during a game.

Before importing data into the system, the involving structure needs to be created, including the location, teams, game and player. Each of these entities is created in a separate menu, through the submission of a specific form such as the one shown in Fig. 2.1, used in the submission of a new field (or location). In this case, the user fills the form with a name and, either with the width and height of the field, or with the GPS coordinates of the four corners of the field. The order of the corners does not matter, as long as they are inserted following any circular direction.

Another example of a form is displayed in Fig. 2.2 for the creation of a new player. In this case the required data include the name, number, position and team.

Fig. 2.1 Image of the form used in the creation of a new location

The screenshot shows a window titled "uPato" with a form titled "New Location". The form contains the following fields and controls:

- A "Name" text input field.
- An "and" label.
- A "Field Dimensions" section with "Width (m)" and "Height (m)" text input fields.
- An "or" label.
- A "Field Corners' Coordinates" section with four rows, each containing "Lat" and "Long" text input fields.
- A "Browse" button next to each "Long" input field.
- A "Submit" button at the bottom center.
- A "Back" button at the bottom center.

Fig. 2.2 Image of the form used in the creation of a new player

The screenshot shows a window titled "uPato" with a form titled "New Player". The form contains the following fields and controls:

- A "Name" text input field.
- A "Number" text input field.
- A "Position" dropdown menu with "GK" selected.
- A "Team" dropdown menu.
- A "Submit" button at the bottom center.
- A "Back" button at the bottom center.

The system currently recognizes four different file formats of GPS data: the first two are similar, with the file describing the positions of a single player, where each row contains the instant of time and the position of that player (file formats obtained from the FieldWiz system [1]). The only difference between the two file formats is that one of them contains an initial matrix with the dimensions of the field before the rows with the actual data; the three other file formats include data from multiple players in a single file. One of them contains, in each row, the instant, position and name of the corresponding player (multiple players per file) and the other one describes files where each row contains an instant and the positions of a set of players in that instant (multiple players per row) (which is the file format used in the Johan system [2]).

The image shows a software window titled "uPato" with a subtitle "New Multiple Data". Inside the window, there are four input fields arranged vertically. The first field is labeled "Game" and contains the text "2016-02-02 02:22:22 - test1 vs test1". The second field is labeled "Team" and contains the text "test1". The third field is labeled "Format" and contains the text "Multiple Players for File". The fourth field is labeled "File" and is currently empty. To the right of the "File" field is a button labeled "Browse". Below the "File" field, there are two buttons: "Submit" and "Back".

Fig. 2.3 Image of the form used in the importation of new data in one of the multiple players per file format recognized

Data from the TraXports system [3] are also recognized by the uPATO, even though its data isn't GPS based.

The introduction of data is divided into individual and multiple data formats, displaying a form for the selection of the game, player and specific file format in the first case and game, team and specific file format in the second. Fig. 2.3 presents the form used in the importation of data from a file from one of the multiple players per file format recognized, as previously described.

2.2.2 Processing Data

After inserting the data into the system, the user is able to calculate several metrics on the data. The uPATO divides metrics into two different sets: collective metrics, which involve data from all the players in a team; and individual metrics, referring to metrics calculated on the specific data of a player. A complete list of the metrics available for computing is presented in Appendix A.

In order to calculate the available metrics, two menus are available, one for each type, containing a specific form for selecting the data for processing, with the remaining steps being performed automatically by the system.

2.2.3 Results and Representations

When the calculation of the metrics is complete, representations are created with the results and presented to the user. The presented data is available for exportation at the press of a button, saving all data into .csv files and the representations into image files. With the data in .csv files, they can then be imported and analyzed in other systems or, in some cases, depending on the format, be passed to the data comparison module, which will then create barplots or boxplots of the data, allowing for a visual comparison and analysis.

Another function provided by uPATO is the creation of game animations with the position data of players. This option is available through the submission of a form selecting the data of interest, in the `Game Animation` menu. The game animation presents an animation of the selected period of time, where each player is represented by a dot positioned accordingly in the field and updated in real time. The animation also calculates most collective metrics, allowing users to visualize these metrics and some of their values at the same time as watching the game.

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Computational Metrics for Soccer Analysis

Connecting the dots

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