The overview, outcome, and outlook of GIS-based football visualization

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Abstract. The purpose of this article is to demonstrate that the importance of GIS visualization in football analysis. GIS-based football analysis is not only fantastic toy, but also tangible outcome. This article is about the overview and outcome of GIS-based football game visualization in general and focusses on the outlook of football animated visualization. We first described the concept of the tracking and event data. Afterwards, four types of outcomes were summarized with their strengths and drawbacks. The outcomes with spatial-temporal framework have a better visualization and tactical instructions effect than non-spatial graph. Due to the limitation of traditional and conventional methods, it is of great importance to highlight the possibilities of football animated visualization as well as its advantages and development trend. With the development of data acquisition hardware and computing power, continuous panel data can be obtained and analysed during the game. Multi-dimension analysis is one of the key advantages of animated analysis comparing to the graphic visualization. Automated workflow should be created in such as spatial-temporal limited structure. This short paper could pave the way to a better understanding of GIS-based football visualization, which is of great interest in the case of Geovisualization.

Keywords. *GIS-based football analysis, football animated visualization, GIS, geovisualisation; spatial-temporal analysis*

1 GIS-based football analysis: fancy toys, tangible outcomes, or both?

Football is a sport limited by a specific spatial-temporal framework. Conventional methods of football match statistics often fail to analyse and visualise the complex spatial-temporal patterns of the football sufficiently. As football is a spatial-temporal phenomenon, it is obvious to visualise its analysis outcomes in the form of a map. To better convey football players with adequate tactical instructions, Geographical Information Systems (GIS) is applied in the field of football game analysis in an appropriate manner. The relevance of space and time is increasingly acknowledged by professional football clubs. Without continual improvement of their performance, professional football teams would be uncompetitive soon. These circumstances lead to a vast amount of football geospatial data and a rising demand for understandable visualization (Kotzbek & Kainz, 2014). Therefore, it is crucial to specify and highlight the usage of GIS visualization can significantly enhance the game analysis by taking the spatial-temporal perspective of football and visualization sufficiently into account.

2 Overview of GIS-based football visualization

GIS-based football analysis is a union of space, time, and football. During entire football game, almost every single action between the players on the field is being recorded by some specific censors. A vast amount of raw data, especially tracking data, is created through this process. The outcome of this process is visualized graph, map, and video.

2.1 Data type

Definition of the term "football-specific geo data" was first introduced in 2014 and refers to a special kind of geo data that encompass all spatio-temporal data which directly represent the entire gameplay of a football game (Kotzbek & Kainz, 2015). A typical data set for one game consist of general match information, teams information about the intended positions on the pitch and substitutions, positional data (2D or 3D coordinates of the ball, players and, sometimes, referees) and event-specific characteristics (Andrienko et al., 2021). Event data and tracking data are two types of geo data regarding football development. Both can be regarded as vector data with attribute data. This could serve as an input to further intersection analysis, for instance.

2.1.1 Event data

The position-based specific behaviours of football players on the field are called events, such as shots, passes, cross, tackles, offside, etc. Each row of event data should contain information about the time, space, specific players, and event characteristics. Event data is captured manually from every game scene of the recorded video. The subjective perceptual processes of the data capture procedure are susceptible to errors. To minimize the expected error, all records are cross validated. An average error of 3.6 m was observed but the reliability is still reliable for coaching (Bradley, O'Donoghue, Wooster, & Tordoff, 2007). The key to overcomes the comparatively high spatial error problem is a joint connection between tracking and event data.

2.1.2 Tracking data

Comparable to event data, tracking data in football corresponds to consecutive point data linked with a dense timestamp. Whereas tracking data is directly linked to the players and the ball, event data represents connected dynamic interactions among the players. Tracking data can be correlated with the event data as an attribute. All this information is separately available for each player as well as the ball. To reconstruct the 3D football trajectory, z-coordinate is also common for the ball's path.

2.2 Outcome

The analysts can visualize the prepared data in different kinds of outcome. According to the temporal attribute, the outcome could be separated into cross sectional or panel outcome. And the outcome style contains non-spatial graph or field map. Combined with cluster analyses, proximity analyses, and buffering, complex spatiotemporal network during football matches could be understood and applied from many issues, such as analysing spheres of action (Kotzbek & Kainz, 2014).

2.2.1 Statistic graph

With a history more than one hundred years, statistic graph is the basic visualization style in sports analysis. Simple data can be compared by this way directly, as shown in Figure 1. However, non-spatial graph is hard to contain any spatial information, which may damage its tactical instruction value and lose some key information.

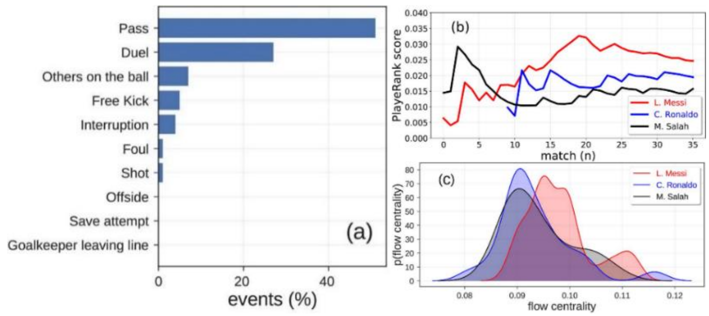

Fig. 1 Statistic graph. (a) Frequency of events per type. (b) Performance quality calculated as the PlayeRank score. (c) Distribution of the flow centrality. (Pappalardo et al., 2019)

2.2.2 Pass map

Pass map consists of the football passing data between players, including players and direction. Only one pass could happen at a specific moment. However, there are 1000 passes in a match on average. Therefore, it's hard to visualize all the passing data in a match into one map. Most of the pass maps are visualized by selected time period. The length of the arrow often represents the distance of the pass, as shown in Figure 2. It's hard to visualize the passing speed in 2-D dimension.

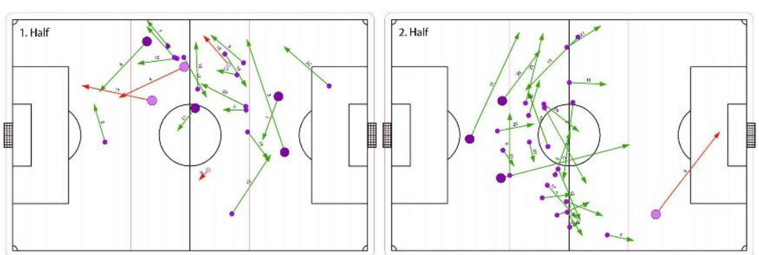

Fig. 2 Pass map (Kotzbek & Kainz, 2017)

2.2.3 Heat map

Heat Maps are used to identify the frequency of events spread in particular parts of a football pitch, as shown in Figure 3. The part of the map will be heated up and turn into red in the areas that the player can cover in a football match. The creation of color-coded heat maps must be combined with spatial-temporal data. Heat maps help the analysts know more about the players and the best positions to be placed.

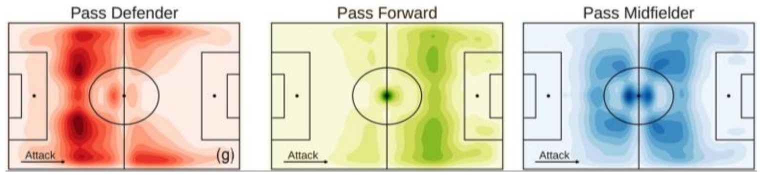

Fig. 3 Heat map (Pappalardo et al., 2019)

2.2.4 Positioning map

Positioning maps show the locations of one or more players at a particular time, as shown in Figure 4. Positioning maps can be created by cross sectional data or continuous panel data, depending on the analysing need. The moving path of the players are depicted as single tracking point features. Applying tracking analysis tools, covered paths can be displayed as lines. If the tracks of all players are presented, a differentiation would be impossible. The length of the lines between two points are depended on the speed of the players and the sampling rate.

Fig. 4 Positioning Map (Beernaerts, De Baets, Lenoir, & Van de Weghe, 2020)

3 Outlook: Football animated visualization

Map analysis is a good method to convey adequate tactical instructions. However, the dynamic factors of football decide its complex spatio-temporal structure, which is hard to be visualized by the maps. Thus, football animated visualization with video analysis becomes more popular in recent years. Figure 5 shows some screenshot of football video analysis. Such measures can assist to understand the course of the game in retrospect. The trend and advantages of football animated visualization are listed in this research.

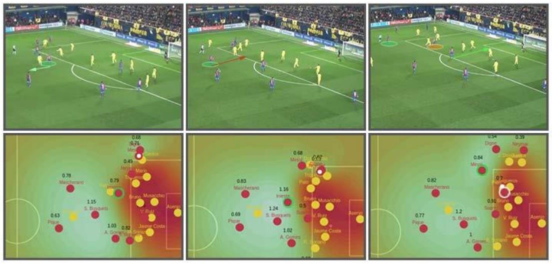

Fig. 5 Screen shot of football animated video (Fernández & Bornn, 2018)

3.1 Cross Sectional visualization to continuous panel visualization

Most of the football map analysis can only present the cross-sectional data or time series data in a short term. It is good enough when the analysts only highlight some short-term event. However, if the coach and players hope to know more about the development of specific event, cross sectional analysis can not support this demand immediately. Visualizing the continuous panel data in the whole match can solve this problem. Although the data volume is larger than cross sectional analysis, the newest rendering technology is qualified in this kind of animated analysis.

3.2 Post-game review to real-time analysis

Due to the limitation of data acquisition speed and computing power, post-game analysis is the main method in previous football analysis. However, with the upgradation of newest data transmission technology, real-time analysis is coming to reality. Map analysis is suitable for statistics review work. But for the real-time analysis, animated video analysis is easier to present what happened in a short time.

3.3 Few-dimension analysis to multi-dimension analysis

Due to the limitation of the field map canvas, it is hard to examine more than five attribute at a map. Animated visualization video makes it possible to examine more spatio-temporal distribution of certain events during the game. Beyond that, it is of particular interest, if tracking and event data are being combined by an attributive join via the long timestamp. Multi-dimension analysis will facilitate manifold analysis opportunities.

3.4 Manual workflow to automated workflow

The data format, pre-processing work, and the adaptability between the hardware and the software increase the manual workflow of analysts. Therefore, the standard of the data should be published, and the pre-processing work should be packaged into a standard and automated workflow. This will alleviate the burden of the football video analysts and release their time to do more tactical analysis work.

4 Conclusion and discussion

Football is an amalgamation of spatiotemporal components and phenomena. The relevance of space and time in football is increasingly acknowledged by football clubs. Owing to spatial-temporal structure, football data is applicable for GIS analysis. The primary aim of this paper was to present the overview of GIS-based football visualization. We first described five kinds of outcome are introduced with their features and advantages. It is of great importance to highlight the possibilities of football animated visualization as well as its advantages over traditional and conventional methods respectively. This could pave the way to a better understanding of football visualization, which is of great interest in the case of football game analyses.

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