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Applying graphs and complex networks to football metric interpretation

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ABSTRACT

This work presents a methodology for analysing the interactions between players in a football team, from the point of view of graph theory and complex networks. We model the complex network of passing interactions between players of a same team in 32 official matches of the Liga de Fútbol Profesional (Spain), using a passing/reception graph. This methodology allows us to understand the play structure of the team, by analysing the offensive phases of game-play. We utilise two different strategies for characterising the contribution of the players to the team: the clustering coefficient, and centrality metrics (closeness and betweenness). We show the application of this methodology by analyzing the performance of a professional Spanish team according to these metrics and the distribution of passing/reception in the field. Keeping in mind the dynamic nature of collective sports, in the future we will incorporate metrics which allows us to analyse the performance of the team also according to the circumstances of game-play and to different contextual variables such as, the utilisation of the field space, the time, and the ball, according to specific tactical situations.

1. Introduction

The analysis of sport competitions aims to provide reliable performance tools, that can assist the coaching staff to better understand the behaviour of the team and players. This way, the staff can properly adapt the game-play strategies, or to define more efficient training methodologies. Due to the high volume of information currently available for coaches, it is necessary to know how to recognise the relevant information and, then, to properly use the selected information. This is a complicated or even impossible task, if the right methodology is not applied, or when no adequate tool is available.

The utilisation of methodological criteria, which are similar to those utilised in complex network analysis, is an innovative solution in sports analysis. These criteria have been already utilised in different applications for cooperation-opposition sports (Cotta, Mora, Merelo, & Merelo-Molina, 2013; López-Peña & H. Touchette, 2012; Passos et al., 2011). Network theory is a field of study derived from mathematics and computer science, which provides a coherent theoretical framework to those complex systems focused on studying the principles governing their structure (topology or configuration). A network can be represented as a graph, consisting of directly or indirectly interconnected elements or nodes (Newman, 2003). In our study, each node will represent a player, and the

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connections are generated from a measurement parameter representing an interaction in the play-field. The number of nodes, and the interconnection degree and type between them will determine the complexity degree of the network and its evolution potential (only in case of dynamic or evolutionary networks).

In any case, it is always important to consider that, as in football, not every node in the network has to necessarily be directly connected. In sports, non-linear relations are important, as they directly influenciate the behaviour and evolution of game-play (De Saá Guerra et al., 2013). The way the nodes are related and their potential evolution are among the main aspects that determine the complexity degree of a network. The team behaviour in collaboration-opposition collective sports is sustained by the team play configuration, which is particular, characteristic, evolutive and highly complex (Greihaine, Godbout, & Zerai, 2011), and which represents the way that the team decides to distribute in the field and to plan the competition (Seabra & Dantas, 2006). This will depend, among other variables, on the tactical design proposed by the opposite team and on the conditions occurring during the game-play itself (partial score, partial time, domain, ball possession, etc.). This game-play planning, necessarily requires the establishment of a network of interactions among teammates, which receive and deliver information, develop and adapt the collaboration and coordination, that finally helps on mapping and configuring the social structures within the collective behaviour (Passos et al., 2011). This way, a *graph representation* can signal fundamental behaviours of the game-play dynamics, as field positioning, player rotation, relevance of a player in the tactical schema, number of interactions, strong and weak zones in the field, and frequency on passing direction (Yamamoto & Yokoyama, 2011). Nevertheless, one of the main features that make graph representation relevant is that it allows to contextualise the team behaviour, avoiding that the analysis only focus on mere reproductions or quantification of the number of passes, the quality of them, or other variables. Graph representations allow to better approximate to the understanding of the functionality and adaptability of a team, in the context provided by the competition (Ribeiro, Silva, Duarte, Davids, & Garganta, 2017). For this kind of game-play view, and several of the underlying principles of the competition dynamics, mechanisms such as the graph theory and reciprocity networks (Nowak & May, 1992), free of scale complex networks and small world (Chen, Fu, & Wang, 2008; Santos & Pacheco, 2005; Santos, Pacheco, & Lenaerts, 2006), have allowed to better explain the importance of collaboration and co-evolution of the strategy and the strength of the network (Wu et al., 2010), specially when trying to explain the inherent emergent processes in complex systems with biological and social properties (Warner, Bowers, & Dixon, 2012).

In consequence, at each instant of game-play, its evolution will be unpredictable, but it will contain underlying deterministic behaviours (chaotic behaviour). In every case, each node holds a relative importance according to its connectivity degree, which results in a network presenting different types of nodes with equivalent, different, or shared functions. Those nodes with the more significant interactions (strongest nodes), will be defined as *dominant attractors*. These nodes are those which rule the system and orient the vector of system evolution. Also, when the self-organisation is a relevant feature of a system, the dominant attractors are those which generate recurrent behaviours. The auto-organisation can be expressed in game-play through different clustering levels of players. That is to say, there is a high chance that if a player is connected to other two players, these will also be connected between each other, but with different intensity according to their function. *Assortative mixing* is an interesting concept to be evaluated in complex networks, which consists in measuring the connectivity level of the nodes of higher degree, which are also responsible of forming clusters in the network. The tendency of a network to non-randomly form clusters between highly connected nodes, can be evaluated using the *clustering coefficient* (López-Peña & Touchette, 2012). In order to properly characterise the node, we can use the *centrality* values and clustering coefficients, as described in Methods Section.

The objective of this work is to apply network theory for modelling the behaviour of a professional football team in real competition conditions, and to analyse these behaviours to understand game-play of the team in practice. Moreover, we propose a new methodology for discovering the game-play features of a team in terms of possession of the ball.

2. Methods

2.1. Sample

36 matches of a professional football team of the first Spanish division (LFP – Liga BBVA) were analysed (14 won, 12 lost, and 10 tied). In order to respect players confidentiality, the data has been considered anonymously before the analysis, by assigning a random number to each player.

2.2. Materials

The analysis of the matches was performed using the Amisco Pro® system (version 1.0.2, Nice, France). This tool is a semi-automatic video tracking system, with specific software for evaluating the different variables of the match.

2.3. Participation in game-play and player connectivity

Initially, players connectivity during offensive game-play was determined. For this purpose, for each player, the number of passes and receptions was utilised as parameter (number of events). The place in the field where these events were produced was also registered, together with the players related in the event, and the consecutive pass sequence (ball posessions). These parameters allow to understand the internal dynamics of the team.