Explaining the Game: Network Science in Soccer

Keywords: network science, sports, spatial networks, multilayer networks, identifiability

Extended Abstract

Sport is a universal human activity that integrates physical performance, strategic decision-making, and complex social dynamics. Traditionally, sports science has relied on reductionist approaches that isolate individual attributes, biomechanical factors, or tactical elements. However, methodologies grounded in Complexity Science are offering new perspectives by revealing that sports are dynamic, interconnected systems characterized by emergent properties, collective behaviors, and intricate interdependencies among players, teams, and their environments.

In this paradigm shift, *Network Science* has become a central methodological framework. By modeling players, game events, or spatial zones as nodes, and their interactions—such as passes, movements, or communications—as edges, researchers can quantitatively assess team coordination, strategic organization, and the global dynamics of competition [1]. Network metrics such as centrality, modularity, community structure, and network efficiency have proven essential for dissecting both momentary game situations and broader seasonal patterns. Thus, Network Science is transforming both theoretical understanding and practical applications in sport, not only deepening our knowledge of its complex nature but also providing actionable insights for coaches, analysts, scientists, and decision-makers [2].

In this contribution, I focus on the application of Network Science to soccer, with particular attention to two concepts: network identifiability and tracking networks. First, I will present different approaches to constructing networks from player interactions [2,3]. Then, I will explain how to quantify the *identifiability* of a soccer team by analyzing its pitch passing networks. Identifiability refers to the ability to recognize a team based solely on the structure of its passing network. This methodology, adapted from neuroscience studies of brain network identifiability, is an example of the versatility of network science across domains. Results show that some teams are highly identifiable through their passing structure, while others are not. Interestingly, identifiability is positively associated with performance: teams at the top of the rankings are typically more identifiable than those at the bottom.

Most existing analyses in soccer have focused on either player-passing networks or pitch-passing networks (see Fig. 1 for a comparison). In the second part of my talk, I will discuss how tracking data enables the construction of *tracking networks* [4]. These networks are derived from professional competitions, where triangulated camera systems capture the positions of all players and the ball with sub-decimeter accuracy at 25 frames per second. Using this data with the purpose of constructing networks, different dynamical features of player behavior can be used to define links, leading to spatial networks whose structure evolves over time according to player position and speed. Examples include *marking networks*, which are bipartite structures linking players of opposing teams based on marking behavior, and *functional coordination networks*, weighted undirected networks capturing coordinated motion among teammates. Additionally, the movement of the ball can be projected into *flow networks*, constructed by dividing the pitch into regions and connecting them whenever the ball moves from one region to another. Unlike pitch-passing networks, flow networks also capture dribbles

and ball conductions, providing a richer picture of team dynamics. Analyzing their temporal evolution yields valuable insights into performance and playing style.
Finally, I will discuss how these methodologies extend beyond soccer to other team and individual sports, including boxing and badminton, emphasizing the broad applicability of network science in advancing the study of sport.

References

[1] Buldú, J. M., Busquets, J., Martinez, J. H., Herrera-Diestra, J. L., Echegoyen, I., Galeano, J., and Luque, J. (2018). Using network science to analyse football passing networks: Dynamics, space, time, and the multilayer nature of the game. Frontiers in Psychology, 9, 1900.
[2] Buldú, J. M., Busquets, J., Echegoyen, I., and Seirul.lo, F. (2019). Defining a historic football team: Using Network Science to analyze Guardiola's FC Barcelona. Scientific Reports, 9(1), 13602.
[3] Novillo, A., Gong, B., Martinez, J. H., Resta, R., del Campo, R. L., and Buldú, J. M. (2024). A multilayer network framework for soccer analysis. Chaos, Solitons & Fractals, 178, 114355.
[4] Buldú, J. M., Garrido, D., Antequera, D. R., Busquets, J., Estrada, E., Resta, R., and del Campo, R. L. (2020). Soccer tracking networks: Beyond event-based connectivity, in Conference on Analytics in Sports Tomorrow 2020, ed F.C. Barcelona., 1-13.

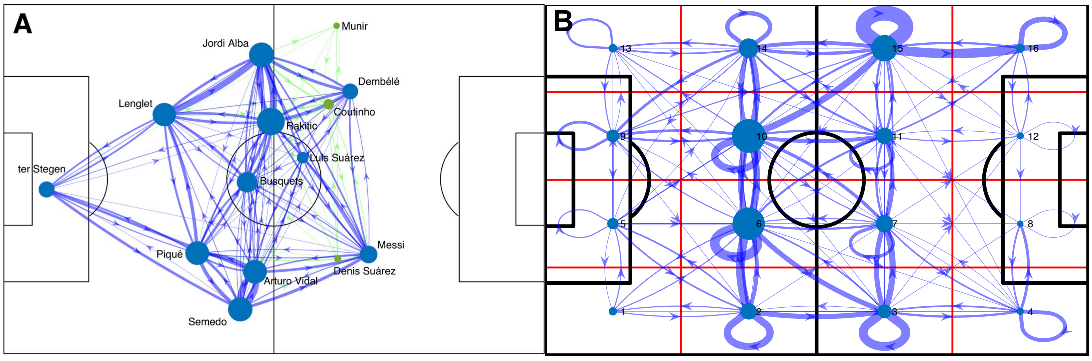

Figure 1. **Example of two kinds of (soccer) passing networks.** A) Player-passing network of a team during a single match. Players (nodes) are positioned at the center of mass of their passes, with node size proportional to eigenvector centrality. Link width is proportional to its weight, defined as the number of passes made from player *i* to player *j*. B) Pitch-passing network. The pitch is divided into *N* regions, and nodes correspond to these regions. The network is completed by counting the number of passes made from region *i* to region *j*. In both cases, the result is a weighted, directed network whose properties vary from match to match.