Passing Networks in Football

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1 Introduction

Possession-based football focuses on keeping the ball and moving it around with short, controlled passes. One useful way to study this style is to think of the team as a network. Each player becomes a node, and every pass creates a link between them.

In this essay, I explain how passing networks can be represented using matrices, and how these matrices help reveal patterns in how a team builds play.

2 Graphs and Passing Networks

A passing network can be written as

$$G = (V, E),$$

where V is the set of players and E is the set of passes between them.

A pass from player i to player j is written as (i, j). Because passes have direction, this forms a directed graph. Each edge also has a weight, which is simply the number of passes.

We define

$$f : V \times V \to \mathbb{N}_0,$$

where $f(i, j)$ counts how many passes go from player i to player j.

3 Adjacency Matrices

Label the players $v_1, v_2, \ldots, v_n$. The adjacency matrix is

$$A_{ij} = f(v_i, v_j).$$

Each row shows the passes made by a player, and each column shows the passes they receive.

Row and Column Sums

Let $\mathbf{1} \in \mathbb{R}^n$ be the vector with all entries equal to 1:

$$\mathbf{1} = \begin{pmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{pmatrix}.$$

Then

$$(A\mathbf{1})_i = \sum_{j=1}^{n} A_{ij}.$$

This gives the total number of passes made by player i.

Similarly,

$$(A^T\mathbf{1})_j = \sum_{i=1}^{n} A_{ij},$$

which gives the total number of passes received by player j.

4 Example

Let

$$A = \begin{pmatrix} 0 & 4 & 1 & 0 \\ 2 & 0 & 3 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix}.$$

Then

$$A\mathbf{1} = \begin{pmatrix} 5 \\ 5 \\ 1 \\ 1 \end{pmatrix}, \quad A^T\mathbf{1} = \begin{pmatrix} 2 \\ 5 \\ 4 \\ 1 \end{pmatrix}.$$

5 Powers of the Matrix

The entry (i, j) of A^2 counts how many two-pass sequences go from player i to player j.

This shows indirect links between players and gives extra insight into how the team moves the ball.

6 Centrality

Eigenvector Centrality

We take the eigenvector corresponding to the largest eigenvalue of A. Since A has non-negative entries, the Perron-Frobenius theorem guarantees an eigenvector with all non-negative components. This vector x satisfies

$$A\mathbf{x} = \lambda\mathbf{x}.$$

Each value x_i gives a score for how central player i is in the network.

A player becomes important if they are connected to other important players. This captures how influence spreads through the team.

7 Real Example: El Classico

These ideas are used in real football analysis, not just in theory.

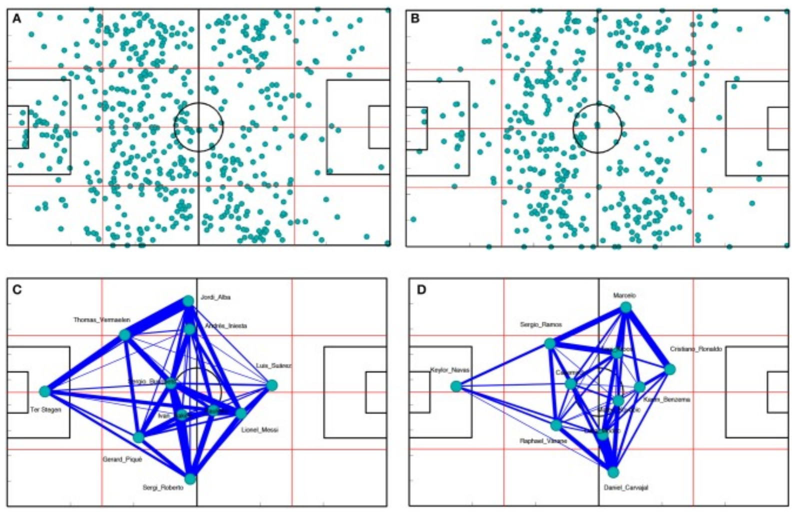

Figure 1: Passing network from El Classico match in the 2017/18 season. Node size reflects importance, and edge thickness shows number of passes.

In diagrams like this: - Players are placed roughly where they play on the pitch - Thicker lines show more frequent passes - Bigger nodes represent more central players

Teams like Barcelona often show very dense networks, especially in midfield, which matches their possession-heavy style with which they played with especially during the 2010s.

Lionel Messi was a big part of this, which is shown through his many strong connections with the whole team, even with Jordi Alba despite them playing on opposite sides of the pitch - this displays how common it was for him to drift inwards and receive the ball from an overlapping Jordi Alba (which is how the famous last minute winning goal was created) . The network also shows how Luis Suarez was rarely involved in the build-up of play, and if he were ever to receive any passes, it would be from Lionel Messi, the "magician".

From these networks alone you can see the strengths and weaknesses of each team and how they built up play, Barcelona's network suggests a highly interconnected structure, showing that they would break down teams through possession, and Real Madrid having noticeably stronger connections on the wings, showing their reliance on their Fullbacks and Ronaldo, and how they would score through counter attacks.

8 Other Measures

Other useful metrics include:

Degree: total passes made or received

Betweenness: how often a player acts as a link between others

Closeness: how quickly a player can reach everyone else in the network

9 Limitations

This model does not include positioning, pressure, or decision-making. It shows structure, but not the full complexity of football.

10 Conclusion

Passing networks give a clear mathematical way to describe how a team plays. The adjacency matrix records all passing relationships, and further analysis helps reveal deeper patterns in the team's structure, which could even help opposing teams spot strengths and weaknesses and exploit them