The Dutch Soccer Team as a Social Network

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Abstract

Although being very popular all around the globe, soccer has not received much attention from the scientific community. In this paper we will study the Dutch Soccer Team from the perspective of complex networks. In the DST network every node corresponds to a player that has played an official match for the Dutch Soccer Team. A node is connected with another node if both players have appeared in the same match. The aim of this paper is to study the topological properties of the Dutch Soccer Team network. The motivation for studying the DST network is twofold. The first reason is the immense popularity of the DST, in the Netherlands. Through our study we obtain all kind of new statistics about the DST. Secondly, our results could also be used by the coach of the DST, for instance by determining the optimal line-up. Using data available from a public website we have computed the topological metrics for the DST. Furthermore, we have looked at the evolution of the topological metrics over time and we compared them with those of other real-life networks and of generic network models. We found that the DST is a small world network and that the player with the highest degree also has the lowest clustering coefficient.

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Introduction

Soccer is a very popular sport in many countries. According to the coach of the successful AC Milan in the 1990's, Arrigo Sacchi, "it is the most important of the unimportant things in life." Bill Shankly, legendary former manager of Liverpool, made an even more pronounced statement: "Some people say soccer is a matter of life and death. But it is more important than that!"

The popularity of soccer is also reflected in some numbers related to the 2006 World Cup held in Germany. This tournament attracted a cumulative television audience of 27 billion viewers. The global TV coverage was over 73,000 hours (FIFA, 2006).

Although being very popular all around the globe, soccer has not received much attention from the scientific community. For instance, the World Congress on Science & Football, is held only once every 4 years (WCSF, 2007). The edition of this Congress, held in 2007, only attracted 477 attendees, which is not considered a high number for an important scientific Congress.

A nice overview of scientific aspects of soccer is given by Ken Bray (Bray, 2006). In this book, and related references, the following subjects are typically dealt with: physics of the ball, training schemes, performance statistics, medical and physiological aspects, penalty shoot-outs, and the role of electronic devices. Another interesting book, albeit from a completely different perspective, was written by David Winner. In Brilliant Orange, he explores the relation between the Dutch, their history and architecture, their culture and politics, and the influence of each on Dutch Soccer (Winner, 2001).

In this paper, we will study the Dutch Soccer Team from the perspective of complex networks. Our study is inspired by a paper by Onody and De Castro from 2004, who studied a network comprised of Brazilian soccer players (Onody et al., 2004). In this paper, we will study the Dutch Soccer Team (DST) as a social network. In the DST network every node corresponds to a player that has played an official match for the Dutch Soccer Team. A node is connected with another node if both players have appeared in the same match. The aim of this paper is to study the topological properties of the Dutch Soccer Team network.

Studying the topology of real-life networks is important for two reasons. First, it helps us to understand the structure of networks that occur in real-life. Secondly, it can help us to predict how processes on networks evolve. Examples of the latter point include the efficiency of Internet search engines and the spread of viruses on computer networks.

The motivation for studying in particular the DST network is also twofold. The first reason is the immense popularity of the DST in the Netherlands. In particular, Dutch people are very interested in all kinds of facts and statistics related to the DST. Through our study, we obtain many new statistics about the DST. An example of this is "which player had the most co-players?" Secondly, our results could also be used by the coach of the DST, for instance, by determining a line-up where certain aspects of the team are optimal. For instance, a team could be organized so that as many players as possible who have already played together can be on the same team.

The paper is organized as follows. Section 2 describes the topological metrics that will be considered throughout this paper. In Section 3, we describe how we obtained the data and give a visual impression of the DST network. Section 4 discusses results on the topological metrics for the DST network. In Section 5, we give non-network related results that were obtained form the data. Section 6 summarizes our main results and gives some suggestions for further research.

Background

In this section, we provide a set of topological metrics, which is considered relevant in the networking literature (Newman, 2002[a]). A graph theoretic approach is used to model the topology of a complex system as a network with a collection of nodes V and a collection of links E that connect pairs of nodes. A network is represented as an undirected graph $G(V;E)$ with $N = |V|$ nodes and $L = |E|$ links.

Link density
The link density S is the ratio of the number of links and the total number of possible links, given by:

$$S = \frac{2L}{N(N-1)}.$$

Degree
The degree d_i of a node i denotes the number of neighbours a node has. The average degree can be easily obtained from the total number of nodes and links:
$E[d_i] = 2L/N$.

Assortativity coefficient
A metric that quantifies the correlation between pairs of nodes is the assortativity coefficient r ($-1 < r < 1$). Networks with $r < 0$ are disassortative, which means that the nodes connect to other nodes with various degrees. In networks with $r > 0$ (assortative networks) the nodes are more likely to connect to nodes with similar degree (Newman, 2002[b]).
The assortativity coefficient r is given by:

$$r = \frac{L^{-1}\sum_i j_i k_i - \left(L^{-1}\sum_i \frac{1}{2}(j_i + k_i)\right)^2}{L^{-1}\sum_i \frac{1}{2}(j_i^{\,2} + k_i^{\,2}) - \left(L^{-1}\sum_i \frac{1}{2}(j_i + k_i)\right)^2},$$

where j_i and k_i are the degrees of the nodes at the ends of the i-th link, with $i = 1 \ldots L$.

Distance
The distance between a pair of nodes i and j is the length of the shortest path between the nodes. The average distance is the distance averaged over all pairs of nodes.

Diameter
The diameter is the largest distance between any pair of nodes.

Eccentricity
The eccentricity of a node is the largest distance to any other node in the graph. The eccentricity of the graph is the average of eccentricities of all nodes.

Clustering coefficient
The clustering coefficient C_i for a node i is the proportion of links between the nodes within its neighbourhood divided by the number of edges that could possibly exist between the nodes. The clustering coefficient for the whole network is the average of the clustering coefficient for each node.

Closeness
The closeness of a node is the average distance to the other nodes in the graph. Note that some define closeness to be the reciprocal of this quantity. Closeness can be regarded as a measure of how long it will take information to spread from a given node to other reachable nodes in the network. The closeness of a node is a measure of centrality. The node with the lowest closeness is called the most central node.

Algebraic connectivity
The Laplacian matrix of a graph G with N nodes is an NxN matrix $Q = \Delta - A$, where $\Delta = \mathrm{diag}(d_i)$, d_i is the degree of node i and A is the adjacency matrix of G. The second smallest eigenvalue of the Laplacian matrix is called the algebraic connectivity. The algebraic connectivity plays a special role in many problems related to graph theory (e.g. Chung, 1997). The most important is its application to the overall connectivity of a graph: the larger the algebraic connectivity, the more difficult it is to cut a graph into independent components.

Dutch Soccer Team network

The data used to construct the DST network are available at www.voetbalstats.nl. This site contains information about all official soccer matches by the Dutch Soccer Team and about all European matches played by Dutch league teams. A screen shot of this site, which is only available in the Dutch language, is given in Figure 1.

Figure 1: Screen shot of www.voetbalstats.nl

The site gives the line-ups for all official DST matches. We have considered all matches up until Russia - The Netherlands (21 June 2008), which was match number 670. The first match ever of the DST was Belgium – The Netherlands (30 April 1905). As an example we show the line-up of match number 331, The Netherlands – Belgium (18 November 1973), in Figure 2.

Nr. 331

Nederland	0 - 0	België
WKKW	18-11-1973	Toeschouwers: 62000
Stadion: Olympisch Stadion	Bondscoach: Frantisek Fadrhonc	Scheidsrechter: Pavel Khazakov

Speler	Club	Gesc.	Strafs.	In	Uit	e.d.	Int.	Doelp.
Schrijvers Piet	FC Twente						4	
Suurbier Wim	Ajax						25	3
Hulshoff Barry	Ajax						14	6
Mansveld Aad	FC Den Haag						6	
Krol Ruud	Ajax						17	
Haan Arie	Ajax						8	1
Neeskens Johan	Ajax						14	6
Mühren Gerrie	Ajax						10	
Rep Johnny	Ajax						3	1
Cruijff Johan (c)	Barcelona						26	22
Rensenbrink Rob	Anderlecht						10	

Figure 2: Line-up of Match Number 331

All players in Figure 2 appear as nodes in the DST network and are all mutually connected. So, as an example, Aad Mansveld is connected to Rob Rensenbrink.

By working our way through all 670 matches of the DST until June 2008, we have been able to construct the adjacency list of the DST network. In 670 matches, a total number of 691 players appeared. Every individual player was given an ID from 1 to 691. The ID ranking was based on the number of matches played. The adjacency list is the representation of all links in the network as a list. For instance, because Aad Mansveld has ID 294 while Rob Rensenbrink has ID 41, the adjacency list of the DST network contains the entry 41 – 294. We have found that the total number of links in the DST network equals 10,450.

In Figure 3, we have visualized the DST network by importing the adjacency list to the Pajek program (Pajek, 2007).

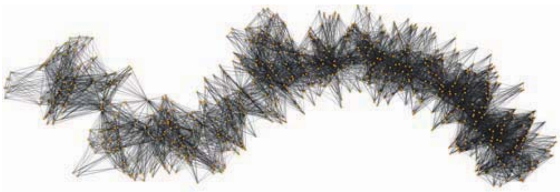

Figure 3: Visualization of the DST network

Nodes on the far left of the graph denote players that played in the beginning of the previous century. Nodes on the far right represent players that were playing in recent years or are still active.

Results

In this section we present the values of the topological metrics introduced in Section 2 for the DST network. We have computed the metrics using Pajek and dedicated Matlab functions. The results are given in Table 1.

Metric	Value
Number of nodes	691
Number of links	10450
Density	0.044
Average degree	30.25
Assortativity coefficient	-0.063
Average distance	4.49
Diameter	11
Eccentricity	8.59
Clustering coefficient	0.75
Algebraic connectivity	0.16

Table 1: Topological Metrics for DST Network

First, we conclude that the DST network is connected, i.e. between every pair of players a path exists. As an example, consider Johan Cruijff and Marco van Basten. These two players never played in the same game. However, they have both played with Willy van de Kerkhof, hence the distance between Cruijff and van Basten is 2.

Because the average distance between players is small (4.49), the DST network exhibits, like many other social networks, the small world phenomenon. In addition, because the clustering coefficient is high (0.75) the DST network is a small world network (Watts, 1999). More detailed information is given in Table 1.

For instance, we are now capable of answering the question "which player had the most co-players?" It turns out that the player with the highest degree is Harry Dénis. In fact, Dénis occurred in matches with 117 other players. On the other hand, Edwin van der Sar, who played the most matches of all players, only has a degree of 97. Interestingly enough, Dénis also has the lowest clustering coefficient (0.17) of all players.

According to Table 1, the diameter of the DST network is 11. For instance, the shortest path between Rafael van der Vaart (who is still an active player) and Jan van Beek has length 11.

Note that the DST network has many other shortest paths of length 11. For instance, any player that only played with Edwin van der Sar after 2000, has a shortest path of length 11 to Jan van Beek. In fact, by using Pajek, we have found that the DST network has 324 shortest paths of length 11.

By computing the closeness of all players, we have been able to determine the most central player in the DST network.

Table 2 shows the top 5 of players with the lowest closeness. The most central player in the DST network is Roel Wiersma, who was active from 1954 to 1962 and played 53 matches. Note that it is not surprising that the most central players were active about 50 years ago, because the Dutch Soccer Team has a history of about 100 years. Of the players still active today, Edgar Davids is most central, with an average distance to the other players of 4.73.

	Player	DST career	Closeness
1	Roel Wiersma	1954-1962	3.119
2	Faas Wilkes	1946-1961	3.213
3	Bertus de Harder	1938-1955	3.217
4	Kees Rijvers	1946-1960	3.222
5	Mick Clavan	1948-1965	3.230

Table 2: Top 5 Most Central Players (lowest closeness)

The evolution of the topological metrics for the DST network over time is given in Table 3.

Metric	1926	1946	1966	1986	2008
Number of nodes	181	282	427	556	691
Number of links	1956	3170	5190	7575	10450
Density	0.12	0.080	0.057	0.049	0.044
Average degree	21.61	22.48	24.31	27.25	30.25
Assortativity coefficient	- 0.17	-0.16	-0.16	-0.11	-0.063
Average distance	2.32	2.70	3.37	3.88	4.49
Diameter	4	6	8	10	11
Eccentricity	3.48	4.58	6.16	7.54	8.59
Clustering coefficient	0.77	0.76	0.76	0.75	0.75
Algebraic connectivity	1.13	0.68	0.31	0.21	0.16

Table 3: Evolution of the DST Network in Time

For the DST network, the number of nodes and links increase over time. It can be observed from Table 3 that also most of the other topological metrics for the DST network increase over time. In fact, the average degree, the average distance, and the diameter all exhibit an almost linear increase in time. Looking at the assortativity coefficient, we conclude that the DST network becomes less disassortative in time. The link density is decreasing in a nonlinear fashion, while the clustering coefficient remains almost constant.

Next, we will compare the topological metrics for the DST network with other real-life networks from nature and society, i.e. technological, social, biological and linguistic networks. For this comparison, which was also reported in Jamakovic et al. (2007), we have considered the following real-life networks:

- Brazilian Soccer Players network (BSP) (Onody et al., 2004)
- the western states power grid of the US (Pow) (Watts et al, 1998)
- American air transportation network (Air) (Colizza et al., 2007)
- the Internet at the autonomous system level (Int) (CAIDA, 2007)
- actors co-appearing in movies (Act) (Barabasi et al., 1999)
- network representing frequent associations between dolphins (Dol) (Lusseau et al., 2003)
- network representing protein interaction of the yeast Saccharomyces cerevisae (Pro) (Jeong et al., 2001)
- network representing word adjacencies in Spanish (Spa) (Milo et al., 2004)

In Table 4, topological metrics for various real-life networks are shown. Some entries in the BSP column are empty because these metrics were not reported in Onody et al. (2004).

Metric	DST	BSP	Pow	Air	Int	Act	Dol	Pro	Spa
Number of nodes	691	13411	4940	2179	20906	10143	62	4713	11558
Number of links	10450	315566	6594	31326	42994	147907	159	19528	43050
Density	0.044	0.0035	0.00054	0.013	0.0002	0.0029	0.084	0.0018	0.00064
Average degree	30.25	47.10	2.67	28.75	4.11	29.16	5.10	8.29	7.45
Assortativity coeff.	-0.063	0.12	0.0036	-0.046	-0.20	0.026	-0.044	-0.13	-0.28
Average distance	4.49	3.29	18.54	3.03	3.89	3.71	3.40	3.16	2.92
Diameter	11	-	46	8	11	13	8	4	10
Eccentricity	8.59	-	34.06	5.87	8.03	9.57	6.50	3.99	7.59
Clustering coeff.	0.75	0.79	0.080	0.48	0.21	0.76	0.26	0.11	0.38
Algebraic conn.	0.16	-	0.0009	0.21	0.015	0.0004	0.17	0.12	0.078

Table 4: Topological Metrics for Various Real-Life Networks

Many observations can be made from Table 4. Here we confine ourselves to just a few. The average degree of the DST network (30.25) has the same order of magnitude as that of the air transportation network and the actor network. On average, a player in the Brasilian league, played with 50% more players, than a player in the DST. The reason for this is probably that far more games are played in a league competition than in a national team. Apart from the power grid network, the DST network has the highest average distance (4.49) between nodes. The clustering coefficients of the DST, the BSP, and the actor networks are comparable and much higher than the other networks considered in Table 4. Next, we compare the topological metrics for the DST network with those of generic network models, such as the random graph of Erdös-Rényi (ER), the small-world graph of Watts-Strogatz (WS), and the scale-free graph of Barabási-Albert (BA) (Bollobás, 2001; Watts, 1999; Barabasi, 2002).

The ER graph is the most investigated topology model (Bollobás, 2001). The most frequently occurring realization of this model is $G_p(N)$, in which N is the number of nodes and p is the probability that there is a link between any two nodes. The major characteristic of $G_p(N)$ is that the existence of a link is independent from the existence of other links. The total number of links in $G_p(N)$ is on average equal to pL_{max}, where $L_{max} = N(N-1)/2$ is the maximum possible number of links. Hence, the link density $q = L/L_{max}$ equals p.

The WS graph captures the fact that, despite the large size of the topology, in most real-world networks, there is a relatively short path between any two nodes. Initially, the WS graph is built on the ring lattice $C(N, k)$, where each of the N nodes is connected to its first $2k$ neighbors (k on either side). Subsequently, a small world is created by moving, for every node, one end of each link (connected to a clockwise neighbor) to a new location chosen uniformly with rewiring probability p_r, such that no double links or loops are allowed. The number of links L in the WS graph, irrespective of p_r, is always equal to $L = Nk$. Hence, the link density satisfies $q = \frac{2k}{N-1}$.

The BA graph gives rise to a class of graphs with a power-law degree distribution. The BA graph is based on two ingredients: growth and preferential attachment of nodes, which implies that nodes with larger degree are more likely candidates for attachment of new nodes. The BA algorithm starts with a small number m_0 of fully-meshed nodes, followed at every time step by a new node attached to $m \leq m_0$ nodes already present in the system. After t timesteps, this procedure results in a graph with $N = t + m_0$ nodes and $L = m_0(m_0-1)/2 + mt$ links. Hence, the link density is

$$q = \frac{m_0(m_0-1)+2mt}{N(N-1)}.$$

Table 5 compares the topological metrics of the DST network and the three considered network models. The values for the metrics for the generic network models are averaged over 1000 simulation runs. The parameters p, k, m, and m_0 are chosen such that all three network models have link density almost identical to that of the DST network. This means that for the WS graph we set k = 15, while for the BA graph we choose m = 15 and m_0 = 31.

Metric	DST	ER	WS $p_r = 0.1$	WS $p_r = 0.2$	BA
Number of nodes	691	691	691	691	691
Number of links	10450	10450	10365	10365	10365
Link density	0.044	0.044	0.044	0.044	0.044
Average degree	30.25	30.19	30.00	30.00	30.00
Assort. coeff.	- 0.063	- 0.005	0.38	0.34	- 0.005
Average distance	4.49	2.22	8.12	6.51	2.19
Diameter	11	3.00	18.39	14.75	3.00
Eccentricity	8.59	3.00	15.30	11.88	2.96
Clust. coeff.	0.75	0.044	0.72	0.71	0.13
Algebr. conn.	0.16	13.46	0.15	0.21	12.10

Table 5: Comparing the DST Network with Generic Network Models

The main conclusion from Table 5 is that, with respect to the considered topological metrics, the DST network most resembles a WS graph, with rewiring probability p_r = 0.2. The only exception is the assortativity coefficient, which is much higher for the WS graph than for the DST network. Note that both the ER and BA graph have a much smaller diameter and clustering coefficient than the DST network.

Non-Network Results

In this next section we give a number of non-network related results about the Dutch Soccer Team. Figure 4 shows the number of matches played by the DST per year.

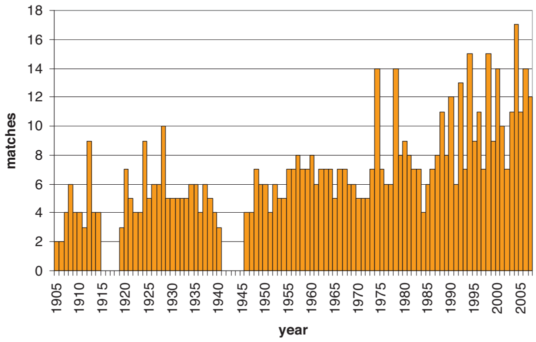

Figure 4: Number of Matches of the DST per Year

A visual inspection of Figure 4 reveals, amongst others, the occurrence of two world wars, local maxima when the DST reached the World Cup final (1974 and 1978), a local minimum when the DST failed to quality for the World Cup (2002) and the trend that the number of matches played per year is increasing.

Because goals are the quintessence of soccer, we will now focus on some goal statistics.
The 10 players that have scored the most goals for the DST are given in Table 6.

	Player	Matches	Goals
1	Patrick Kluivert	79	40
2	Dennis Bergkamp	79	37
3	Faas Wilkes	38	35
4	Abe Lenstra	47	33
5	Johan Cruijff	48	33
6	Ruud van Nistelrooy	64	33
7	Beb Bakhuys	23	28
8	Kick Smit	29	26
9	Marco van Basten	58	24
10	Leen Vente	21	19

Table 1: Leading scorers for DST

Table 1 shows that Patrick Kluivert has scored most goals for the DST. However, we can also see that Kluivert needed more than twice as many games as Faas Wilkes, to score only 5 more goals. For this reason we have also looked at the goal ratio per player, i.e. the number of goals scored by a player per 90 minutes. We only considered players who played 20 matches or more. The result is shown in Table 7.

	Player	Goals	Matches	Minutes	Goals per 90 minutes
1	Beb Bakhuys	28	23	2070	1.22
2	Pierre van Hooijdonk	14	46	1295	0.97
3	Leen Vente	19	21	1870	0.91
4	Faas Wilkes	35	38	3450	0.91
5	Kick Smit	26	29	2587	0.90
6	John Bosman	17	30	1968	0.78
7	Mannes Francken	17	22	2010	0.76
8	Ruud Geels	11	20	1310	0.76
9	Tonny van de Linden	17	24	2138	0.72
10	Abe Lenstra	33	47	4260	0.70

Table 2: Goal Ratio for Players with 20 Matches or More

Of all players that played 20 matches or more, Beb Bakhuys has the highest goal ratio. On this list, Patrick Kluivert is only ranked 14, with a goal ratio of 0.62. It should be noted that Piet de Boer has a goal ratio of 3. He only played once for the DST (match 148 in 1937) and scored three times in this match. The reason that Piet de Boer did not play a second match for the DST is unknown.

Conclusions

In this paper we have studied the topological characteristics of the Dutch Soccer Team network. Taking all matches until June 2008 into account, the main conclusions are as follows:

- The DST network consists of 691 players with 10,450 connections between them.
- The DST network is connected, i.e. between any two players a path exists.
- The DST network is a small world network, because the average distance between players is small (4.49), while the clustering coefficient is high (0.75).
- The player with the most co-players is Harry Dénis, who played together with 117 others.
- Of all players Harry Dénis has the lowest clustering coefficient, i.e. he is the player whose co-players are the least mutually connected.
- The diameter of the DST network is 11, i.e. the longest shortest path has length 11.
- The most central player in the DST network is Roel Wiersma.

Furthermore, we have looked at the evolution of the topological metrics over time. Then, we compared the topological metrics of the DST network with those of other real-life networks and of generic network models.

Finally we have discussed some non-network related results:

- The largest number of matches played by the DST per year is 17. This took place in 2004.
- Of all players that played 20 matches or more, Beb Bakhuys has scored the most goals per 90 minutes (1.22).

Our study reveals a lot of new, interesting statistics, which would best be utilized by the coaches of the DST. The first step towards the development of a decision support tool for coaches would be to examine the topological metrics of players who participated in a particular match and the outcome of the match. The coaches could then determine the line-up for upcoming matches in such a way that certain properties of the team are optimal. For instance, they could choose a line-up so that as many players as possible have already played together. We assume that a team becomes better when enough players have played together before, e.g. because they can anticipate better what the other players are going to do or how they want the ball to be passed to them. Further research could include conducting the same study for the national soccer teams of other countries, the automatic collection and visualization of the DST network, and the development of an interactive tool, which would allow the user to navigate through the DST network, for instance to obtain quickly statistics of a favorite player.

A final possible application of our study is the generation of questions for soccer quizzes.

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