Turkish Journal of Sport and Exercise /Türk Spor ve Egzersiz Dergisi
http://dergipark.gov.tr/tsed
Year: 2020 - Volume: 22 - Issue: 2 - Pages: 296-304
DOI: 10.15314/tsed.671489

ISSN: 2147-5652

Modularity In Football Passing Networks

Necmi GÜRSAKAL [1A] , Halil Orbay ÇOBANOĞLU [2B]
Bülent BATMAZ [3C] , Sandy ÇAĞLIYOR [4D] , Fırat Melih YILMAZ[5E]

[1]*Fenerbahçe University, Faculty of Economics and Administrative Sciences, İstanbul, Turkey.*
[2]*Alanya Alaaddin Keykubat University, Faculty of Sport Sciences, Alanya/Antalya, Turkey.*
[3]*Anadolu University, Open Education Faculty, Eskişehir, Turkey.*
[4]*Haliç University, Faculty of Economics and Administrative Sciences, İstanbul, Turkey.*
[5]*Dokuz Eylül University, Department of Data Science, İzmir, Turkey.*

Address Correspondence to H. O. ÇOBANOĞLU: e-mail: orbay.cobanoglu@alanya.edu.tr

(Received): 07.01.2020/ (Accepted): 31.08.2020

A:Orcid ID: 0000-0002-7909-3734 B:Orcid ID: 0000-0002-1305-9496 C:Orcid ID: 0000-0003-4706-5808

D:Orcid ID: 0000-0003-1106-5531 E:Orcid ID: 0000-0001-5816-4321

Abstract

In recent decades, within the boundaries of complexity sciences, network science has been used to analyze many kinds of networks. A complex system is formed by smaller subsystems which can be designed independently yet function together as a whole. Modules of a network can be called as groups, clusters or communities and modularity can be defined as a measure of the structure of networks or graphs. If it has dense connections within a network's modules and sparse connections between nodes in different modules, in this case networks have high modularity. At the end of each football match, successful pass networks can be achieved. These modular structures can be thought as "independent yet function as a whole" football modules. Generally so called modules in the technical directors' thoughts can be listed as defense, midfielders area and strikers area. If they want to know how modules are generated and how their disconnection leads to functional decay they should analyze the modularity formed as a result of a football match. The aim of this study is to examine to what extent the football teams' managers have implemented their strategies in games. First, 10 matches with the e-analysis football program were analyzed. And then modularity analysis began with transforming the video of a football match into a pass network. Using this pass network, network metrics was to be computed and then these metrics was to be used to make a modularity analysis using Gephi. After modularity analysis using Gephi, modularity classes of these networks were found for all networks. When the results obtained from the modularity analysis were examined, it was observed that the number of modules varied between 2 and 4. Consequently, it was observed that the systems found as a result of the modularity analysis were very different than the planned systems.

Keywords: Network Science, Network Metrics, Modularity, Football.

INTRODUCTION

In recent decades, within the boundaries of complexity sciences, network science has been used to analyze many kinds of networks. A complex system is formed by smaller subsystems which can be designed independently yet function together as a whole (1). "Biological and technological systems both exhibit a common pattern of modular organization. A modular system is formed by quasi-independent parts that are tightly integrated within themselves but also exhibit a certain degree of interdependency among them" (2). For example, "Muscle coordination of isometric force production can be explained by a smaller number of *modules*" (3).

To provide and form communication platforms, to detect the similarities and differences, we classify living organisms, objects and relations in science. We know that biological *networks* are generally *modular* and many social networks and complex systems are found to be naturally divided into clusters of densely connected nodes, and it is called as community structure (CS). Also brain networks can be examined and analyzed with a large variety of graph theory tools, "Methods for detecting modules, or network communities, are of particular interest because they uncover major building blocks or subnetworks that are particularly densely connected, often corresponding to specialized functional components" (4).

Modules may correspond to groups of individuals in social networks, ensembles of interacting proteins (5), or coregulated genes in cellular networks and building blocks in the brain networks (6). Modules of a network can be called as groups, clusters or communities and modularity can be defined as a measure of the structure of networks or graphs. This means that nodes of a network can be partitioned into internally dense and externally sparse subnetworks and these are called modules or communities (7). If we have dense connections within a network's modules and sparse connections between nodes in different modules, in this case we have high modularity. In Figure 1 we see the modularity and community structure in a network.

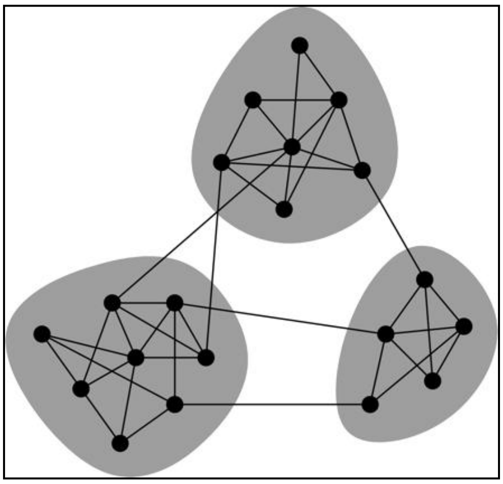


Figure 1. Modularity in a network (8).

In general we use large-scale network data sets, such as social networks, internet and web data, or biochemical networks to divide a complex network into clusters. Modularity also can be seen in networks include the webs of interactions among proteins, genes, enzymes and metabolites or signaling molecules (9). According to Valverde, "A modular architecture allows independent changes in different parts of the system without affecting the whole. Well-adapted modules are conserved and provide a robust infrastructure for future adaptation" (6) and, "Modules are also expected to play a key role in providing a source of specialization, while their proper interconnection guarantee integration at the system-level scale. Both are needed in order to sustain proper functionality and we need to understand both how modules are generated and how their disconnection leads to functional decay" (6). As a result of faulty intermodule communication we get breakdown of modularity. At the end of every football match, we can get resulting pass networks. Although we have mentioned that modularity can be used in large scale networks, it can also be used in small scale pass networks in football. In this article, we have used network science tools to analyze these pass networks that can be transformed into modular structures. Football players (nodes in network terms) in such modules should be homogeneous according to their talents. These modular structures can be thought as "independent yet function as a whole" football modules. In general so called modules in the technical directors' thoughts can be listed as defense, midfielders area and strikers area. If they want to how modules are generated and how their disconnection leads to functional decay they should analyze the modularity formed as a result of a football match.

MATERIALS AND METHODS

The research sample was composed of 10 matches made by Turkish National Football Team in 2014 World Cup qualifiers. As seen In Figure 2, our modularity analysis begins with transforming the video of a football match into a pass network. Using this pass network, network metrics are to be computed and then these metrics are to be used to make a modularity analysis using Gephi. The spearman correlation test was used to determine the relationship between the number of modules in the competitions of the Turkish National Football Team and the goals scored and scored ($p<0.05$).

Necmi GÜRSAKAL Orcid ID: 0000-0002-7909-3734 / Halil Orbay ÇOBANOGLU Orcid ID: 0000-0002-1305-9496 / Bülent BATMAZ Orcid ID: 0000-0003-4706-5808
Sandy ÇAGLIYOR Orcid ID: 0000-0003-1106-5531 / Firat Melih YILMAZ Orcid ID: 0000-0001-5816-4321

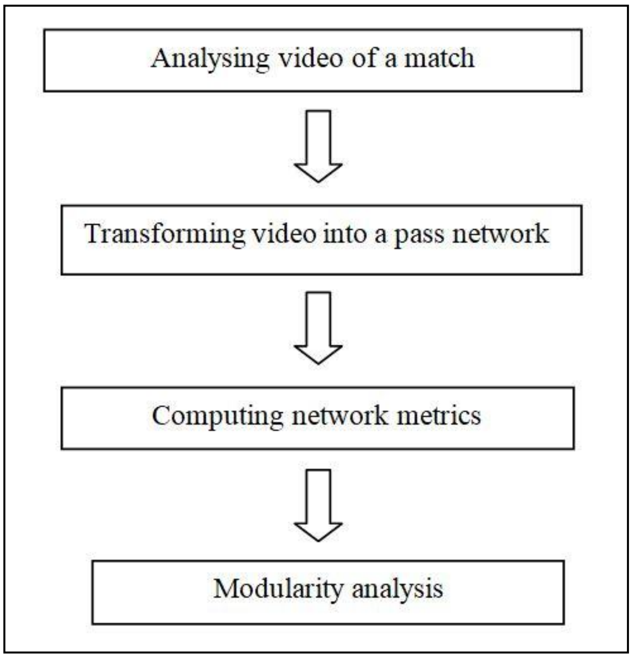
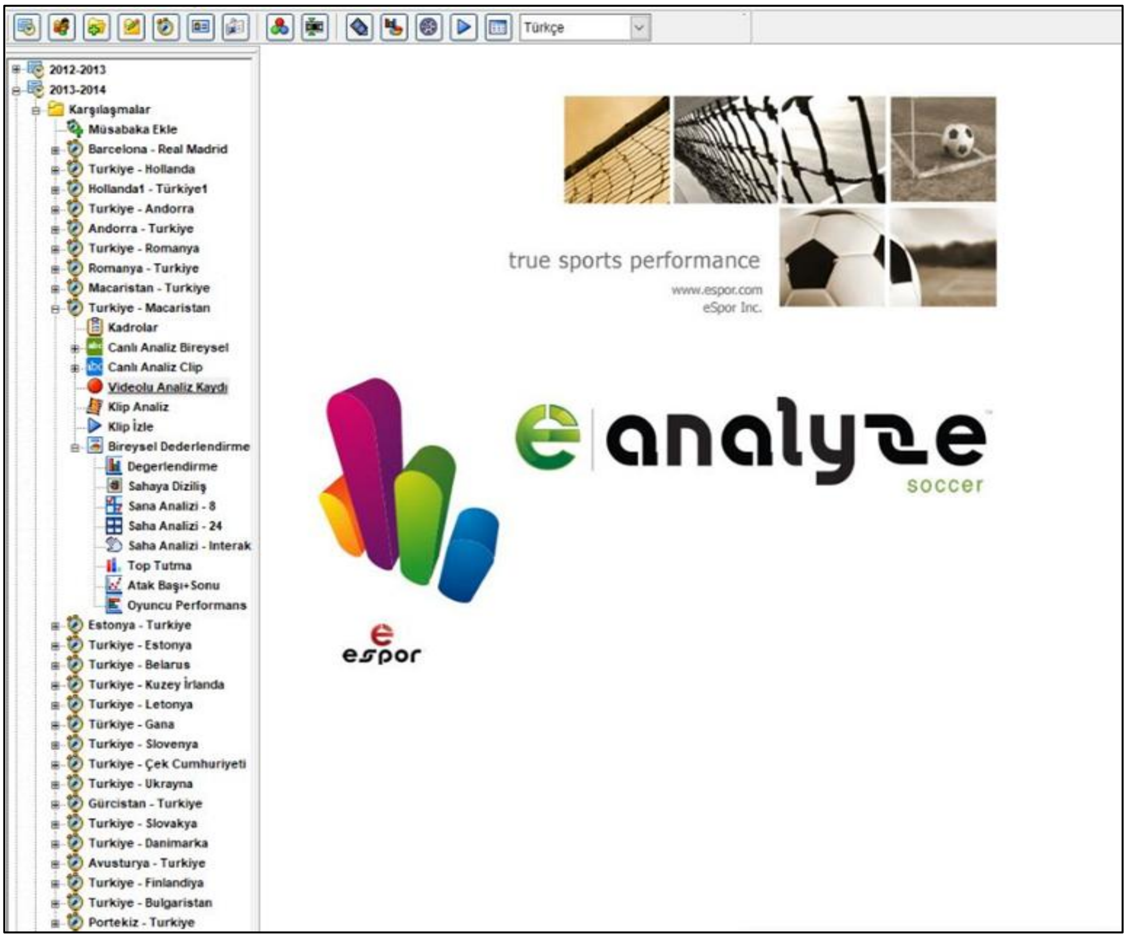


Figure 2. Modularity analysis process of a football match

Analysing Video Of A Match

The 10 matches were analyzed with the e-analysis soccer program (Figure 3).



1027	T21	T6
1028	T6	T21
1029	T21	T2
1030	T2	T3
1031	T3	T14
1032	T14	T8
1033	T8	M3
1034	M3	T4
1035	T4	T2
1036	T2	T6
1037	T6	T2
1038	T2	T19
1039	T19	T21
1040	T21	M17
1041	M17	M12
1042	M12	M13
1043	M13	T4
1044	T4	T8
1045	T8	T21
1046	T21	T8
1047	T8	T2
1048	T2	T17
1049	T17	T19
1050	T19	T6
1051	T6	T8
1052	T8	T14
1053	T14	M3
1054	M3	T4
1055	T4	T23
1056	T23	T2
1057	T2	M3
1058	M3	T3
1059	T3	T14
1060	T14	T21
1061	T21	T3
1062	T3	T21
1063	T21	M16
1064	M16	T6
1065	T6	M12
1066	M12	M13
1067		

Figure 4. Pass Actions Excel File

Computing Network Metrics

The obtained Excel pass files were processed to open source Gephi 0.9.1 program and the networks of the competitions were measured.

Modularity Analysis

Modularity analysis was performed using Gephi 0.9.1 program.

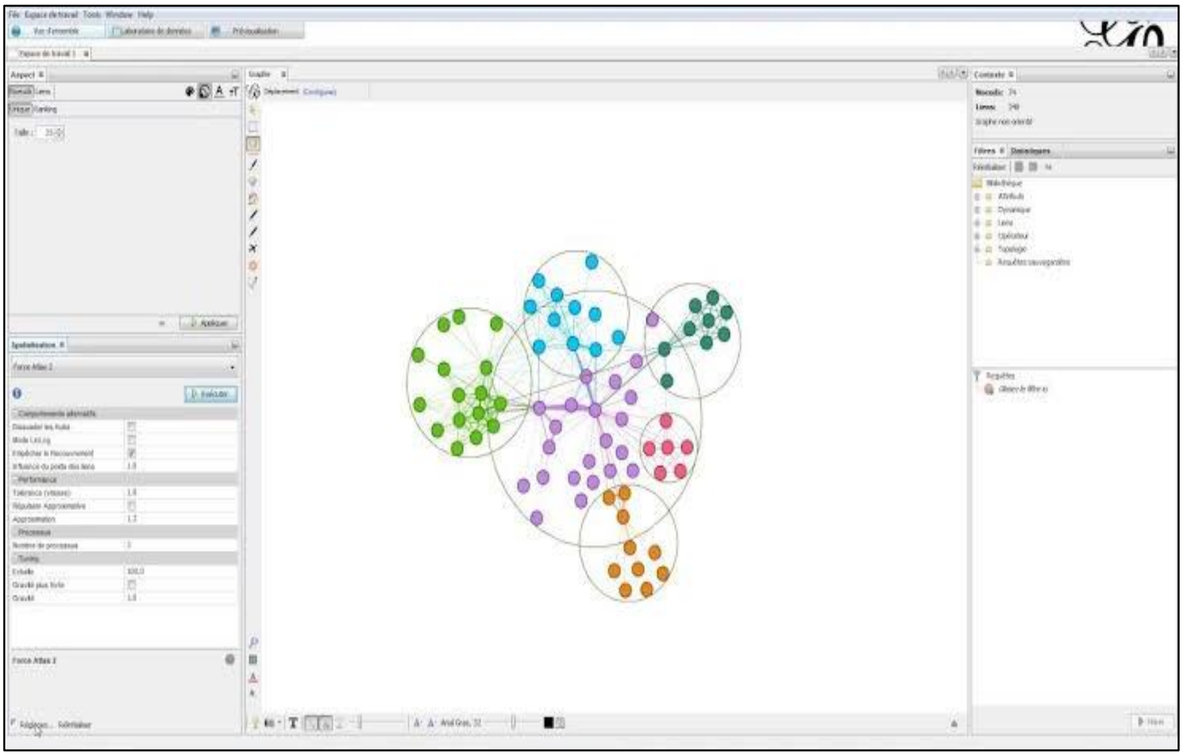
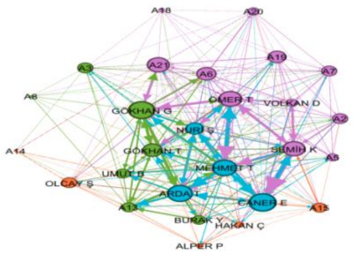
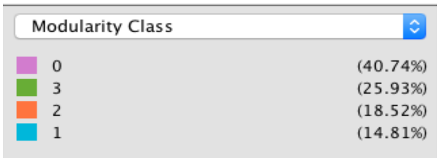
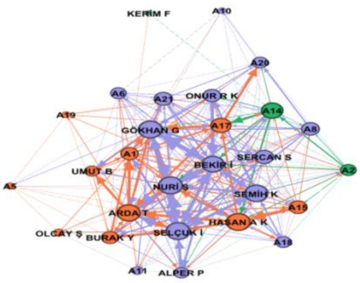
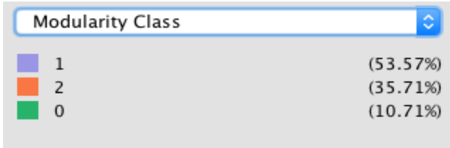
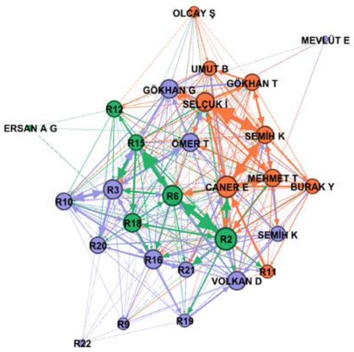
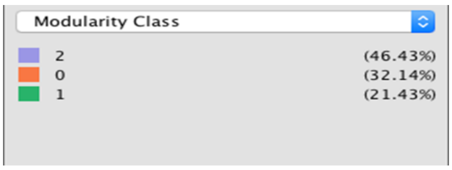


Figure 5. Gephi 0.9.1 Programme

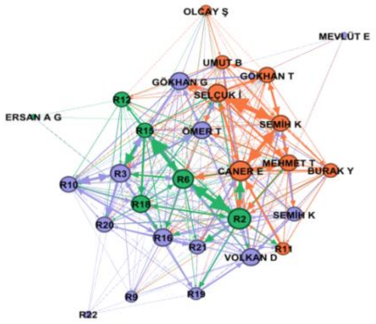
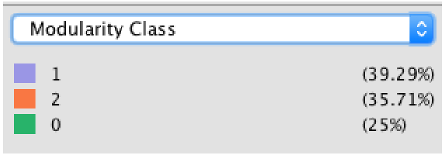
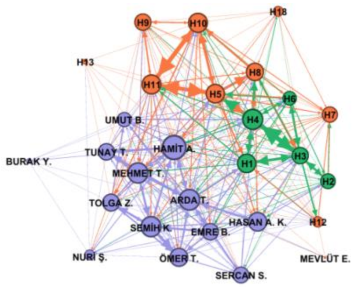
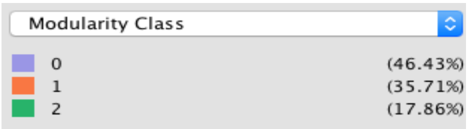
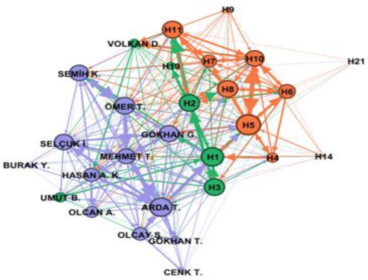
Necmi GÜRSAKAL Orcid ID: 0000-0002-7909-3734 / Halil Orbay ÇOBANOGLU Orcid ID: 0000-0002-1305-9496 / Bülent BATMAZ Orcid ID: 0000-0003-4706-5808
Sandy ÇAGLIYOR Orcid ID: 0000-0003-1106-5531 / Firat Melih YILMAZ Orcid ID: 0000-0001-5816-4321

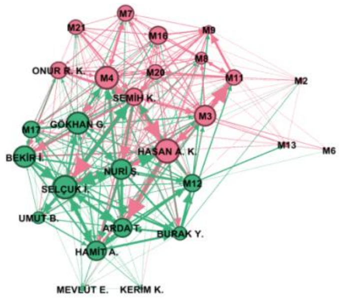
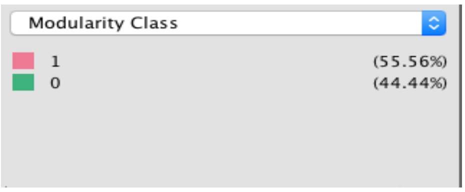
RESULTS

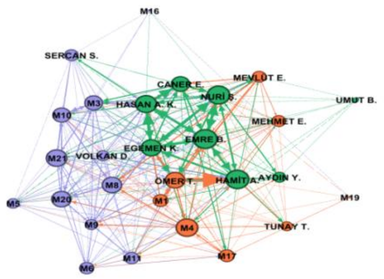
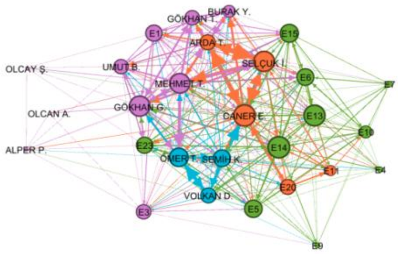
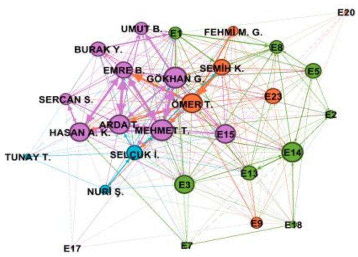
In this study, 10 of Turkish National Football Team's 2014 World Cup Qualifying matches are used. With various algorithms for modularity analysis, open source Gephi's algorithm for network analysis is used. The results obtained are shown in Table 1 and Table 2.

<table>
<tr><th colspan="2">Table 1. Pass networks and modularity classes of these networks</th></tr>
<tr><td>Turkey-Andorra (06.09.2013)</td><td>4-4-2 (4mod)</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Andorra-Turkey (22.03.2013)</td><td>4-4-2 (2 mod)</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Turkey-Romania (12.10.2012)</td><td>4-2-3-1 (2mod)</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Romania-Turkey (10.09.2013)</td><td>4-4-2 (3mod)</td></tr>
</table>

Necmi GÜRSAKAL Orcid ID: 0000-0002-7909-3734 / Halil Orbay ÇOBANOGLU Orcid ID: 0000-0002-1305-9496 / Bülent BATMAZ Orcid ID: 0000-0003-4706-5808
Sandy ÇAGLIYOR Orcid ID: 0000-0003-1106-5531 / Fırat Melih YILMAZ Orcid ID: 0000-0001-5816-4321

<table>
<tr><td></td><td></td></tr>
<tr><td>Holland-Turkey (07.09.2012)</td><td>4-2-3-1 (1 mod)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Turkey-Holland (15.10.2013)</td><td>4-4-2 (2 mod)</td></tr>
<tr><td></td><td></td></tr>
</table>

<table>
<tr><td>Turkey-Hungary (26.03.2013)</td><td>4-2-3-1 (2mod)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Hungary-Turkey (16.10.2012)</td><td>4-2-3-1 (3mod)</td></tr>
</table>

	
Estonia-Turkey (11.10.2013)	4-4-2 (3mod)
	
Turkey-Estonia (11.09.2012)	4-2-3-1 (3mod)
	

When we examine the results obtained from Table 2, we see that the number of modules varies between 2 and 4. The general the three-module layout (4-4-2) is observed in 6 of the 10 games. Moreover, even if the 3-module layout occurs in the field, the number of players in the modules has no remote or close relationship with the number of players within the module considered before the game. Table 2 shows us clearly that in football things may not always go as planned. In addition, the modularity measures in Table 2 explain to us how good the adaption to modularity level is. Another striking point is that the distribution of modularity measurements is close to normal distribution (n = 10, KS = 0.273, p-value = 0.04). In the matches of the same two teams, the proximity of the modularity measurements can be viewed in the column titled "Modularity difference of the same teams (Absolute value)".

Table 2. Summary of results

Matches	Results	Modularity	Modularity difference of the same teams (Absolute value)	Number of modules (Turkey's modules)	Number of nodes in modules
Turkey-Andora (06.09.2013)	5-0	0,108	0,027	4 (4)	11-4-5-7
Andora - Turkey (22.03.2013)	0-2	0,081		3 (2)	3-15-10
Turkey-Romania (12.10.2012)	0-1	0,137	0,003	3 (2)	7-11-10
Romania-Turkey (10.09.2013)	0-2	0,140		3 (3)	9-6-13
Holland-Turkey (07.09.2012)	2-0	0,163	0,011	3 (1)	13-10-5
Turkey-Holland (15.10.2013)	0-2	0,152		3 (2)	9-7-12
Turkey-Hungary (26.03.2013)	1-1	0,138	0,012	2 (2)	12-15
Hungary-Turkey (16.10.2012)	3-1	0,150		3 (3)	8-8-12
Estonia-Turkey (11.10.2013)	0-2	0,135	0,003	4 (3)	10-3-10-5
Turkey-Estonia (11.09.2012)	3-0	0,132		4 (3)	6-10-9-3

When we examine the number of players in the modules, we see that these numbers change between 3 and 15 and the value is 10 (Figure 6).

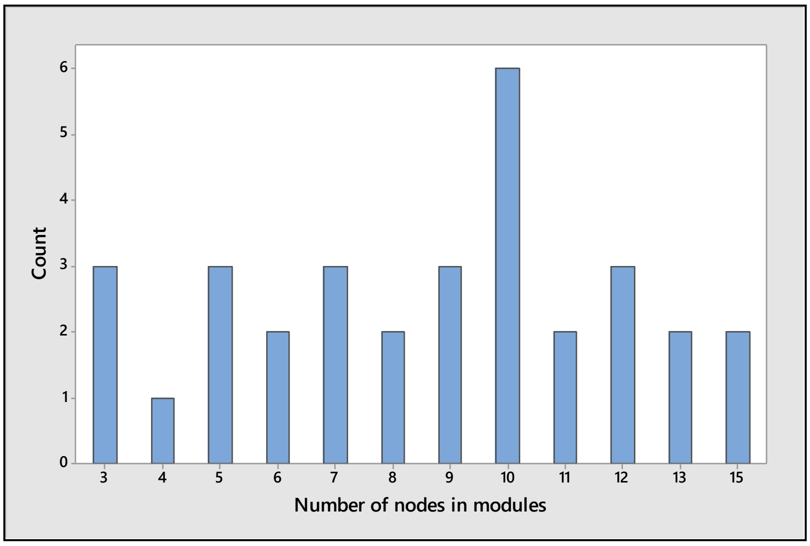


Figure 6. Number of nodes in modules

8,688, which is found the average number of players in the modules, also tells us that there is a big difference between what was planned and what is occurring in football.

Table 3. Descriptive Statistics

	Mean	Std. Deviation	N
Goals	1,6000	1,57762	10
Goals allowed	,9000	1,10050	10
Modules Numbers	2,5000	,84984	10

Table 4. Correlations

			Modules Numbers
Spearman's rho	Goals	Correlation Coefficient	,798**
		Sig. (2-tailed)	,006
		N	10
	Goals Allowed	Correlation Coefficient	-,497
		Sig. (2-tailed)	,144
		N	10

**.Correlation is significant at the 0.05 level (2-tailed).

In our study, the relationship between the number of goals and goals allowed and the number of modules in the match was investigated with Spearman correlation coefficient. With the obtained value 0.006 it was seen that this relation is strong (0.798) and significant (Table 3 and Table 4).

DISCUSSION AND CONCLUSION

Modularity is a widely-used criterion for evaluating the quality of the detected community structures. The modularity is computed as a summation of the difference between the actual number of links and the expected number of links of a node-node pair over all pairs. The larger the modularity, the better the quality of the detected community structures (10). In this study, the game tactics (systems) used in football are explained with the concept of modularity.

Today, the basic system implemented in football matches is the 4-4-2 system. In the 4-4-2 system, the defense with a four-defensive defense is usually a self-defense. When we divide the field into three equal areas, it is inevitable for the success of the 4-4-2 system that each player in the number one field will have the defense block installed. The most important point in the wing is the harmony between the two in the middle of the defender. The 4-2-3-1 system is a transformed form of 4-4-2. Defense principles and understanding are the same as 4-4-2. With five midfielder teams using teams 4-2-3-1, they can control the game by forcing defenses to move away from the margins.

Our data set is limited to 10 games. It is noteworthy that the number of players in the modules is sometimes 10. Although the results obtained in 10 games as the number of modules are not far from the 4-4-2 system, it is seen that there is a big difference between the ones planned before the match and the ones taking place in terms of the number of players in the modules. When we examine the pass network of the match Holland-Turkey (07.09.2012) in Table 1, this network has three modules, one module of the Turkish National Football Team and two modules of the Netherlands national team. In particular, the strength of the ties between the modules of the Dutch national team connecting H5 and H8 to each other, explains the fact that the Dutch National Team wins the match.

One of the interesting points is that in Hungary-Turkey (16.10.2012) match, Hungary won the match despite it has only one module. In the Turkey-Holland (15.10.2013) match Turkey played as a single module, but Turkey has lost the match this time. Turkey-Hungary (26.03.2013) match is also a two-moduled match with one small exception. All of these also confirm that there is no relationship between the number of goals scored in a match and the number of modules in the match. As a result, we can say that there is a significant problem in the reflection of the systems that the managers designed in their minds, even if we have a limited data set.

REFERENCES

1. Gharajedaghi J. Systems Thinking Managing Chaos and Complexity: A Platform for Designing Business Architecture. 2nd ed. Butterworth-Heinemann, 2005.
2. Schlosser G, Wagner GP. Modularity in Development and Evolution. Chicago: Chicago University Press; Chicago, IL, 2004.
3. Roh J, Lee SW, Wilger KD. Modular Organization of Exploratory Force Development Under Isometric Conditions in the Human Arm. Journal of Motor Behavior, 2019; 51(1): 83-99.
4. Sporns O, Betzel RF. Modular Brain Networks. Annual Review of Psychology, 2016; 67(Jan 4): 613-640.
5. Luo F, Yang Y, Chen C, Chang R, Zhou J, Scheuermann RH. Modular Organization of Protein Interaction Networks. *Bioinformatics*, 2007; 23(2): 207-214.
6. Valverde S. Breakdown of Modularity in Complex Networks. Frontiers in Physiology, 2017; 8(497): 1-8.
7. Newman MEJ. Communities, Modules and Large-Scale Structure in Networks. Nature Physics, 2012; 8: 25-31.
8. Newman MEJ. Modularity and Community Structure in Networks. PNAS, 2006; 103(23): 8577-8582.
9. Sol´e RV, Valverde S. Spontaneous Emergence of Modularity in Cellular Networks. Journal of The Royal Society Interface, 2008; 5(18): 129-33.
10. Ding J., Sun Y., Tan P., Ning Y. Modularity Maximization for Community Detection in Networks Using Competitive Hopfield Neural Network. International Journal of Innovative Computing, Information and Control, 2019; 15(4): 1455-1467.