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Social Network Analysis of Football Communications by Finding Motifs

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ABSTRACT

Statistics, extraction, analysis are vital in sports science. Information technology and data science will significantly increase the quality of research and decisions of sports clubs and organizations. Currently, many coaches and sports institutions use analytics and statistics that are calculated manually. Sports science shows that winning a match depends on different factors.
The purpose of the research is to improve team performance by analyzing social networks, communication networks (such as players' passes and transactions during the match), and analyzing repetitive areas. These results are done by analyzing the data collected from 4 matches of the Persepolis team, including three matches from the first half of the Iranian Premier League in 2018-1399 and a Persepolis match against Al-Sharjah. This research examines the issue from two interconnected aspects: 1- Examining the performance of players individually and as part of a social network. 2- explore the communication network between players and land areas. This analysis uses the innovative method of identifying and classifying motifs.

Keywords: ***Social Network Analysis, Graph Analysis, Motif, Frequent Subgraph, Centrality.***

1. Introduction

Sports disciplines have spread rapidly, but a small percentage of research is related to sports science. Considering this issue, we realize that there is a research hole, or in other words, a need in sports organizations, which can be solved by expanding studies and research in sports science [1].

Information systems are currently used in most affairs. Sport is not a closed system. Sport is considered a mother information system that establishes connections between other subsets of information. Therefore, the use of information systems in these departments increases performance and efficiency and greatly accelerates and facilitates the activities of sports organizations[2].

With the continuous development of sports science, a helpful link between information technology and sports information management science is growing. Research, development, and analysis of sports information will be established as a trend in sports-related science [3]. A lot of information about sports can be obtained from the study of these sciences. Some of these data do not work until valuable information is extracted from them. Examining and identifying practical and valuable information from a large amount of data is called data mining.

Data mining has required data cleaning, integration, conversion, pattern evaluation, and presentation [4].

By examining the results of the analysis of the communication network of the passes, it is possible to identify possible ways to achieve a goal in a team. These reviews will help the technical staff analyze the match and choose the appropriate tactics, player selection, and order in future matches. A large part of the studies that look at the football sport from the point of view of the network theory show the passes as a basis for creating attack situations as a network in which the nodes represent the players, and the connection of the nodes means the pass. between players. The characteristics of players and teams are evaluated quantitatively by analyzing and examining the network of passes [5,6,7].

The relative importance of a node in the network is determined by different criteria of centrality, defined in graph theory and the science of network analysis. Social network analysis became a factor in developing a large part of centrality concepts in network science. Many topics and terms used to determine the indicators of centrality started many types of research in the field of sociological sciences [8].

The network analysis approach in the research showed that one of the most critical criteria of a team's performance is the interaction pattern between the team members.[5] An effective pattern connection can be created by identifying and examining these patterns.

The way players cooperate in team sports is critical. Analyzing the cooperation of players in these sports is very efficient and valuable for competitions. A review of research in this field showed that some studies had used the method of social network analysis to investigate the communication between players in the team [8,9,10]. The higher the coordination of the team, the better the performance and efficiency of the team, and finally, the output obtained from the team will be better. Coordination and appropriateness

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between teammates are essential for a strong and efficient team [11].

In a study, only successful passes, including throws, free kicks, corner kicks, and free kicks, were analyzed [12]. The players' communication must be clear to identify the passing process in a team. The method of passes in the cycle of consecutive passes is related to the way of communication between players and the group behavior of that team [13,14]. The main challenge is how to make individual and group decisions in the distribution of passes and communication between teammates in a match situation. [15, 16].

Collective behavior is characteristic of any living system, and the use of statistical physics methods (such as correlation functions) can help us understand their fundamental laws. In one research, five football matches were studied because football matches are unique but at the same time not usually studied example that is useful for studying the system of cooperation and collective competition [17].

Ball possession is another topic that has been researched and discussed; its impact on the match result has been. A comparison has been made between the two proprietary and direct styles competition. In this regard, studies have suggested that it is necessary to evaluate how teams use ownership related to effective offensive aspects. [18,19]. In another article, a result was obtained for scored goals, according to which 80% of the goals were scored with a sequence of three passes or less [20]. In this sense, the teams with a non-proprietary (direct) style were more successful, scoring goals in cycles of three passes or less. Another study showed that successful teams created more chances to achieve by using consecutive long passes. Finally, it was found that the ratio of direct style flowers was higher than using the possessive style. The number of shoots in long consecutive pass cycles was significantly higher for successful teams than in shorter consecutive cycles [21]. Another research showed that most results of losing or equalizing the top European football teams were when they used consecutive long passes. In most of the victories, they used consecutive short passes [22].

Another significant issue in this regard is the pass centrality network analysis. The match (and possibly the dangerous situations that result in one team scoring during the match) has to do with the centrality of the passing grid from different positions of the match during consecutive passes[23].

A study of players at the 2014 World Cup found that the central midfielder has the highest value of out-of-degree centrality, degree centrality of proximity, and centrality of distance in most teams. [24] Another study showed that the highest degree of centrality is in full-backs and defensive midfielders. These values indicate that the first step starts with the sequence of passes, full-backs, and defensive midfielders, and efforts are made to support the transfer of attack from the rear. They suggested that the style of play be ownership-based; No counterattack [25,26].

A review of some previous research in this field shows that in some teams that use a more straightforward playstyle, in general, the highest values of degree of centrality are found in attacking players [27]. In teams whose style of play is a sequence of passes in midfield players, the players who received the most passes from their teammates were midfielders; As a result, it is evident that these players are the goals of the team [26].

Another study uses an advanced algorithm to rank team performance and exploit key performance characteristics concerning the result of the competition based on the competition data set [28].

However, despite essential studies in this field, few studies have used centrality criteria to determine the prominent players who play a role in the communication network graph [26,29].

According to a recent article in the New York Times, football academies have traded $ 7 billion using various machine learning models and selling them to professional teams. For professional football clubs, the process of recruiting players has become very vital. The teams that fail to recruit the right players at the right time may endanger their next season [31], so it is essential to identify the players, their abilities, and situations in which the team is weak.

Research has been done to identify the attack tactics used by a team during a series of events. In one paper, regional classifications are used to examine interactions between regions. We achieve the aim locations and locations of all events and goals that have occurred in an area by classifying the event's positional coordinates of the beginning and end [30].

The purpose of this article is the scientific analysis of football to achieve accurate analysis to increase efficiency, and show how to improve the performance of teams by identifying the strengths and weaknesses of teams by examining the pass network and communications to find and categorize subgraphs Frequently, patterns and motifs are realized for a football team as an example (Persepolis). The designs of team playstyle, identifying strengths and weaknesses, critical paths, and strong communication of players The social network's attitude towards player communication is one of the innovations of this research.

2. Research Method

In this study, four matches of the Persepolis team are analyzed. First, three matches of this team in the 19th season of the Persian Gulf Premier League (against the teams of Gol Gohar Sirjan, Paykan, and Esteghlal of Tehran) are analyzed (some of the results of which are presented in the article [32]). Then, a match between Iran's Persepolis and the Al-Sharjah Emirates in the framework of the group stage competitions of the Asian Champions League 2019-2020 is analyzed and compared to the results of the team's three matches in the Iranian Premier League to examine the similarities and differences in the performance of this team in different conditions. Transactions during the game (such as shots, shots in the frame, loose balls, corners, etc.) as well as communications between the players of the Persepolis team were recorded as events and a database of these events was created. The necessary items for registering an event in the database include: origin, destination and the type of connection between the origin and the destination, which must be clear. Table 1 shows the statistical result of these communications.

2.1. Cycle

In the definition of the cycle, it should be stated that in this

research, the first stage in which the Persepolis players take possession of the ball in any way during the match, until the last stage when the ball is out of their control, is considered a ball turnover or cycle. Each cycle is finally classified into two categories, successful and unsuccessful, depending on the result of the last event. Successful cycles are cycles whose last communication destination includes one of the nodes: shoot, shot to the goal, etc., and unsuccessful cycles are cycles whose latest occurrence includes: ball leaking, etc.

2.2. Communication Graph

The communication network between team players was built based on transactions (events). The nodes include: players on the field (the name of the node is the number of the player in the match), shot on goal(as ShootDarvazeh), shoot(as Shoot), cross(as Santr), throw-in(as Out), corner, ball leak(as Lo), faults of the Persepolis players(as Khata1), and faults of the opposing team(as Khata2). This network was created as a directed graph. This graph was illustrated in "Gephi" software. A unique communication graph was created for each match. An example of the communication graph was shown in Figure 1.

2.3. Degrees Distribution

In the sciences related to networks and graphs, the degree sum for each node expresses the sum of input and output edges. The degree distribution can be obtained by drawing the graph of the frequency distribution of the node degrees from the set of node degrees of a graph. The degree of each node can be one of the criteria for measuring the individual activity of the players in such a way that the degree of a node indicates the participation rate of that node (player) in the competition transactions. From the aspect of mathematics in graph analysis, in the research, G was considered a directed graph of communication, and $V(G)$ was viewed as the set of vertices of this graph. If $v \in V(G)$, the sum of the edges leaving and entering the vertex v is the degree of this vertex.

2.4. Graph Density and Average Degrees

The graph density, along with the average degree of the nodes, was calculated as one of the criteria for measuring the cooperation of the team players with each other. The statistics obtained from criteria including average degrees (obtained from Eq.(1)), weighted average degrees (obtained from Eq.(2)), and graph density (obtained from Eq.(3)) from the graph of all four competitions were displayed in Figure 2. To calculate the node's weighted degree node, a weight was assigned to each event (in the access centrality section). In the following formulas, L' is the total number of edges without considering duplicate edges, N is the total number of nodes, and W is the total weight of nodes (weights assigned in the access centrality).

$$\text{Average degrees} = \frac{L'}{N} \qquad (1)$$

$$\text{Average weighted degrees} = \frac{W}{N} \qquad (2)$$

$$\text{Graph density} = \frac{L'}{N*(N-1)} \qquad (3)$$

2.5. Motif - Correlation

The frequent subgraphs were extracted from all the subgraphs in the communication graph (network of players/areas). From these frequent subgraphs, meaningful (frequent) sequences of race events or motifs were extracted.

Table 1. Statistics of the Total Number of Nodes and Connections in Each Match

Persepolis vs. Gol gohar	Total number of nodes (N)	23	Win 2-1
	Total number of edges (L)	657	
Persepolis vs. Paykan	Total number of nodes (N)	23	Win 2-1
	Total number of edges (L)	589	
Esteghlal vs. Persepolis	Total number of nodes (N)	23	Win 0-1
	Total number of edges (L)	374	
Persepolis vs. Al-Sharjah	Total number of nodes (N)	24	Win 4-0
	Total number of edges (L)	594	

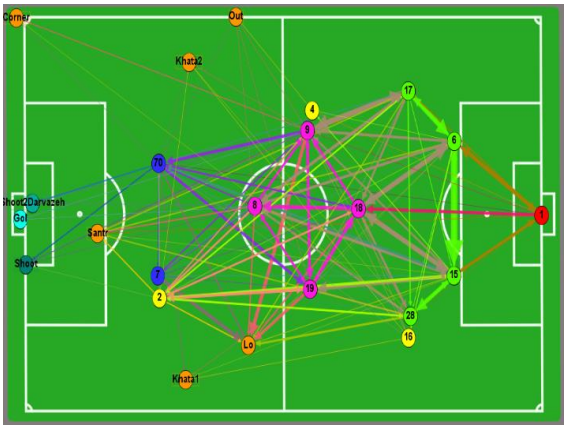

Figure. 1. Example of the network: communication graph of the Persepolis team in the match with Paykan

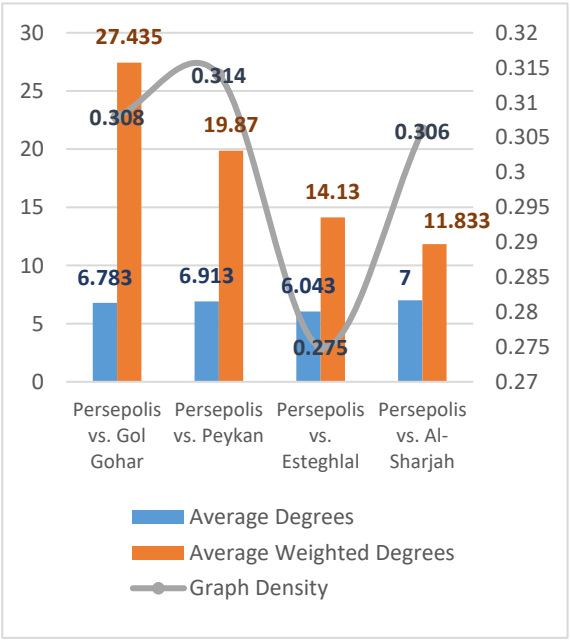

Figure. 2. Analyzing cooperation and comparing the points of nodes degree and graph density

The motifs obtained in this research show the strong connections of the existing nodes (in the sequence) with each other. Each of these motifs is analyzed as a correlation path. Motifs can be used to formulate the strategy of selecting players, to arrange the team, and making the players' solidarity by their capabilities (before the matches). It is also possible to use motifs to analyze the path of solidarity between the players of the rival team (in previous rival matches) and plan and provide solutions to deal with these connections. Motif analysis can also be used during a match.

Investigating the correlation paths formed during a match can reveal part of the team's strategy. The number of repetitions and nodes in each subgraph is essential.

2.6. Transactions Distribution per the Area Graph

Figure 3 shows the communication network relative to the position on the field of play (areas on the field). This graph as to the match between Persepolis and Al-Sharjah, which shows the activity and strategy of the team to rotate the ball or try to penetrate from the middle and in the next dimension of the left-wing.

2.7. Reach Centrality

Each event in this section was assigned a proportional weight, which is explained. First, all occurrences were given a weight of 1. In the next step, the cycles were categorized into successful and unsuccessful. Then the cycles were examined separately, and the weight was assigned to the events within a cycle. In the cycles of the successful category, a positive weight (variable depending on the type of cycle) was given to the last event. From last to first, a fraction of that positive weight was given in descending order to our other events. For unsuccessful cycles, a negative weight (variable depending on the type of cycle) was given to the last event of the cycle, and only the last two events (from the last to the previous) were given as a fraction of the negative weight to the rest of the events in the cycle.

Finally, the total weight of the edges in different cycles is obtained, which indicates the suitability or non-suitability of each path (from the source player to the goal that is successful in reaching the events of the cycle) by considering the influential players.

Finally, a proportional weight is assigned to each edge, according to which the total weight of the edges in different cycles is obtained. The total weight of each cycle shows whether or not each path is suitable. In this way, from the beginning (which is the origin player of the cycle) to the goal (which is to reach the final events of the successful cycle) by considering the effective players (intermediate nodes in the cycle), they are examined.

3. Results

3.1. Average degrees

The results of the analysis of the three criteria of average degrees, weighted average degrees, and graph density show that:

The weighted average score in the match of the Persepolis team vs. Golgohar team was higher than the rest of the matches, which indicates better statistical performance in obtaining access centrality points (good results in scoring cycles and proper use of communications).

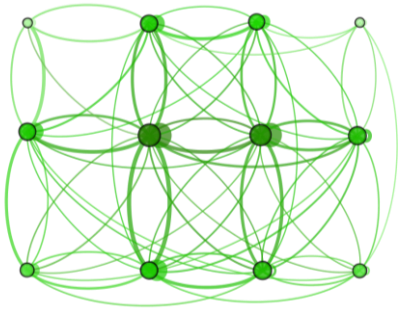

Figure. 3. Frequent subgraph - area correlation

The match between Persepolis and Al-Sharjah teams has the highest average score. This point advantage shows the cooperation of the players in this match compared to the other three matches.

Persepolis match against Al-Sharjah team got the lowest score in this analysis. This issue shows the failure to achieve the desired results in cycles compared to other competitions.

3.2. Motifs - Player Correlation [32]

Meaningful, frequent subgraphs or motifs and correlation paths were obtained in all four matches. A few of them were mentioned. For example, in the match between Persepolis and Paykan, some correlation paths are shown in Figure 4.

The motifs in Figure 4 show the attempt to penetrate from the right side (using players from the right side of the field, for example, player number 17), which is the strategy of the Persepolis team in this match.

The motifs in Figure 5 in the Persepolis-Esteghlal match show the proper relationship between the defense and the midfield. The middle line will not be able to communicate with the offensive line to complete the correlation path.

The motifs in Figure 6 in the Persepolis vs. Al-Sharjah match show the lack of control and improper communication between players 88 and 5. This lack of control leads to the loss of possession of the ball, which repeatedly happened during the match.

Correlation paths with at least three players and three repetitions of the total events of the three matches of the Persepolis Premier League were collected and given in Figure 7. paths were categorized according to whether the beginning and end were in one line (defense, midfield, and attack) (corresponding to the player's position, not the player's current position) or first in one line and end in another. paths that went first on one line, then to another, and finally back to the starting line were considered "other." (For example, in Figure 4, paths 1 to 6 to 17 is regarded as a line of defense.).

In contrast, correlation paths with at least three players and three repetitions of the total events of the Persepolis vs. Al-Sharjah match were obtained, which were given for comparison in Figure 8. It is clear that the communication between the defensive and midfield lines and the attacking line players is weak, and these players are not present in the process of correlation paths of the players. This weakness is exacerbated by the lack of strong communication between

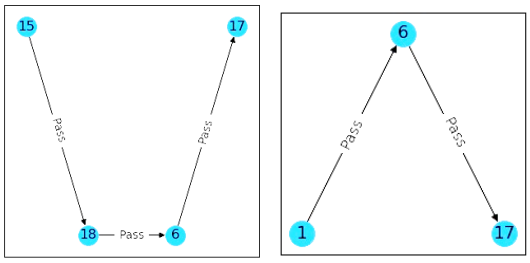

Figure. 4. Motifs - Node Destination 17

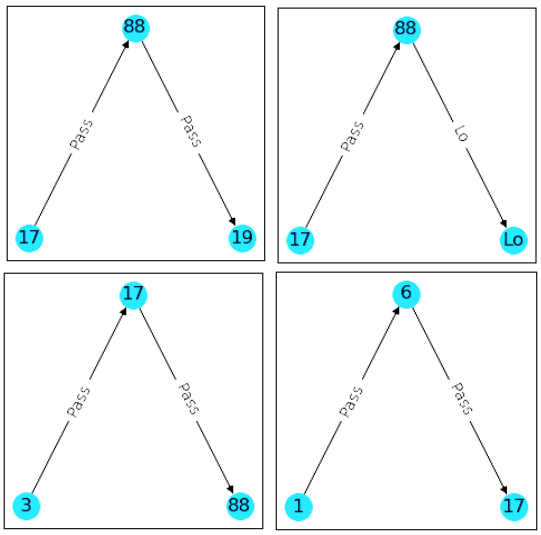

Figure. 5. Motifs - Weakness in attack

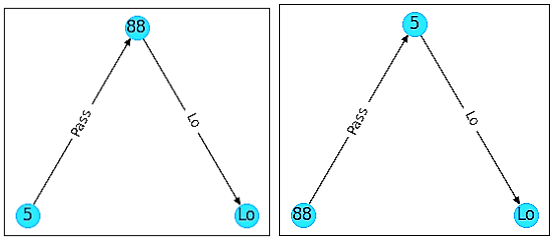

Figure. 6. Motifs - Leaking the ball

attacking players and the lack of correlation paths on the offensive line. Comparing this statistic from the Premier League matches with the sample of this statistic in the match against Al-Sharjah, results that the mentioned weakness persists.

3.3. Motif - Area Correlation

By extracting the correlation of the areas from repetitive transactions and obtaining the patterns of Persepolis vs. Al-Sharjah match and classifying them, the following results are determined:

Figure 9 shows the correlation paths with the criterion of dividing the field of play into Persepolis vs. Al-Sharjah fields and the frequent rotation of the ball in these areas.

Figure 10 shows the correlation paths with the criterion of dividing the playing field into defensive-midfield-offensive lines and frequent rotation of the ball in these areas.

Figure 11 shows the correlation paths with the criterion of dividing the playing field into left-right-middle wings and frequent rotation of the ball in these areas.

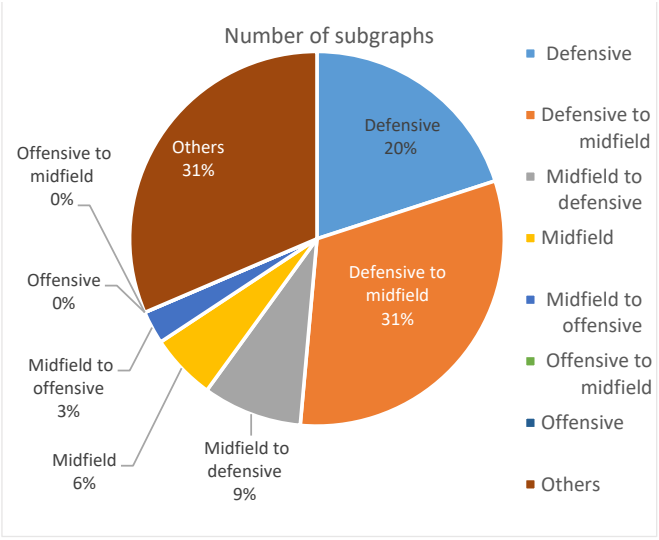

Figure. 7. Categorizing Persepolis motifs

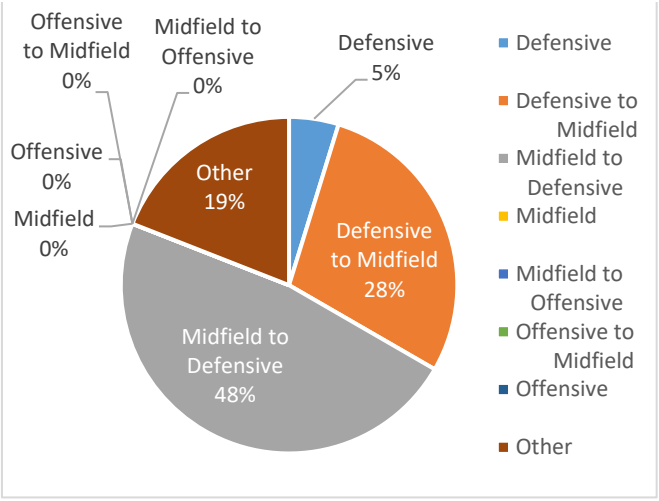

Figure. 8. Categorizing Persepolis repetitive motifs

Figure 11 shows the correlation paths with the criterion of dividing the playing field into left-right-middle wings and frequent rotation of the ball in these areas.

As a result, the frequent correlation of different areas shows that Persepolis (48% of the cases inside the opponent's field) is playing against Al-Sharjah and the strategy of direct and right-side penetration (39%).

3.4. Centrality

Reach centrality is calculated and illustrated with Gephi visualization software. The Figures 12-15 show the players based on dark blue, light blue, and cream colors from high to low degree of centrality.

In Figures 12-15, graphs are displayed where the color of the players' nodes indicates the result of the hits they hit the ball and their impact on the match process. The darker the color of the knot, it means that he sent valuable balls (shots, crosses, assists, etc.) and was an effective player in the match. Finally, one of the strategies according to this analysis is to deliver the ball to these players.

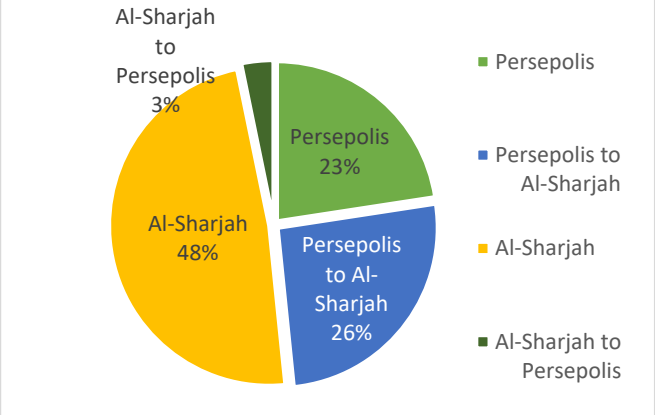

Figure. 9. Categorizing the ball rotation in repetitive patterns in ground

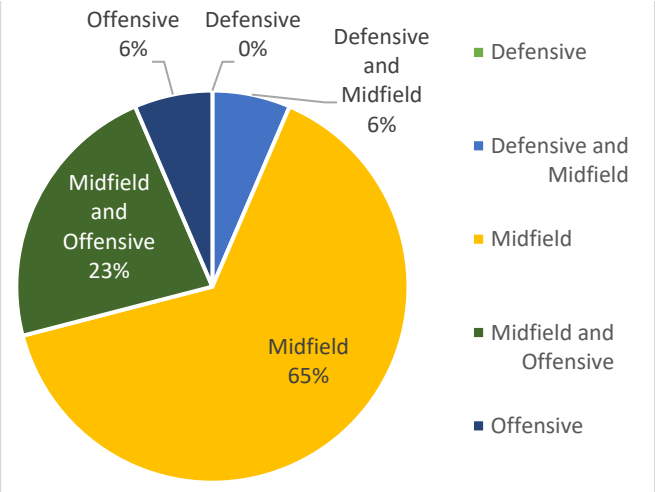

Figure. 10. Categorizing the ball rotation in repetitive patterns in lines

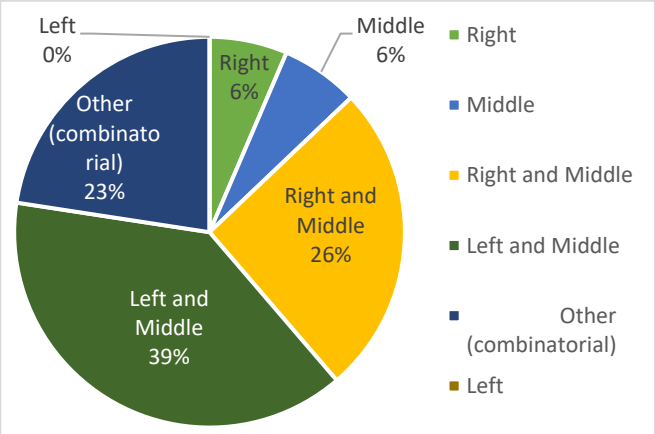

Figure. 11. Categorizing the ball rotation in repetitive patterns in sides

3.5. N-pass cycle

During the competition, the cycles obtained different results with different points, which were obtained from the sum of the points of the routes in the access center. Each cycle was labeled based on the total number of passes in that cycle. Cycles were categorized based on labels. (1P: cycle with pass length 1).

The diagram in Figure 16 shows the ratio of the total points obtained in each type of cycle to the number of cycles of that type. The diagram in Figure 16 is divided into two parts,

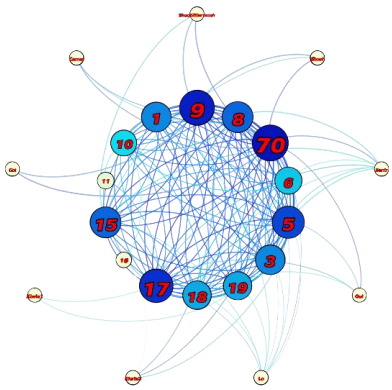

Figure. 12. Displaying the performance of Persepolis players vs. Gol Gohar in terms of points gained in the match

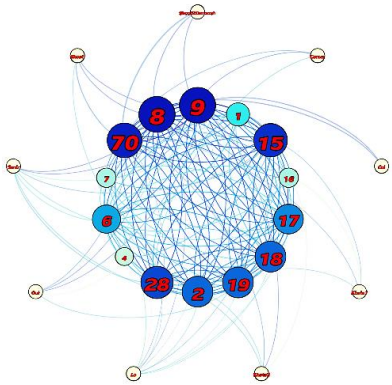

Figure. 13. Displaying the performance of Persepolis players vs. Paykan in terms of points gained in the match

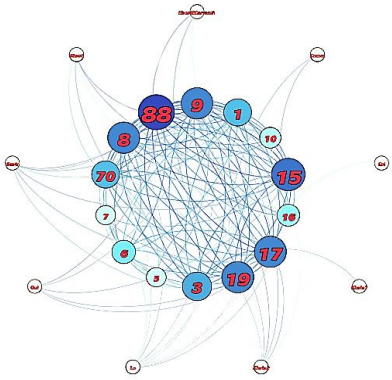

Figure. 14. Displaying the performance of Persepolis players vs. Esteghlal in terms of points gained in the match

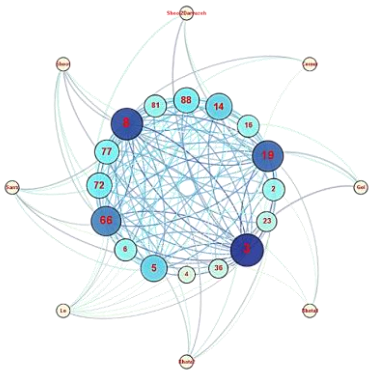

Figure. 15. Displaying the performance of Persepolis players vs. Al-Sharjah in terms of points gained in the match

including the three matches of the Persepolis team in the Premier League of the Persian Gulf and the Asian match of the Persepolis team against the Al-Sharjah team. The results show better results in the 7-pass and 8-pass cycles for the Persepolis team. Therefore, this team has performed better (relative to the total number of cycles) in long cycles. In contrast, this team shows poor performance in short pass cycles. This analysis shows the strategy of Persepolis in the matches to take possession of the ball and possessive play and create opportunities from the opponent's closed playing style.

4. Conclusion

Team success depends on many factors. This study analyzed the communication patterns of players in previous matches to analyze social networks of passes and in-game transactions. The strong interaction of team members and the cooperation of these people as a complete network makes the team dynamic and improves performance. This research has looked at sports from an innovative and networked perspective, which has provided results, claims, and solutions.

A database of matches was created to perform the analyzes performed in this research. The database included three matches of the Persepolis team in the Premier League of the Persian Gulf and one match in the Asian League from this team. The analyzes were done from two perspectives:

• Detailed view at the level of nodes: In this view, players were considered as part of a social network, and factors such as types of node degrees, points of each node, etc., were investigated.

• Network generalities: In this view, the players' communication network analysis from a macro perspective and the investigation of network characteristics were done. The network was illustrated as a graph, and the following factors: correlation path, n-pass cycle, critical path, etc., were calculated and analyzed.

In the first part, degree types, total degree-score of nodes, and graph density were calculated. On average, each player (node) was connected with 6 or 7 other nodes. Also, the density of the communication graph in the match with Al-Sharjah has increased unexpectedly compared to the average grades (both weighted and weightless).

In the second part, the correlation paths of players and areas of the field were identified and categorized. Most of the players' paths of solidarity among the players were with the position of the defensive line or the connection of the defensive and midfield line. In contrast, these routes did not exist in the offensive line and midfield to attack. On the other hand, for the game between Persepolis and Al-Sharjah, the correlation paths of more areas in the middle and the left regions inside the opponent's field were obtained, which showed that the team played and played forward in this match. Reach centrality, critical path, and n-pass cycles were calculated, which showed that the 8-pass cycles were effective for Persepolis. Finally, due to the lack of communication and strong correlation with the offensive line and in the offensive line, the existence of a problem within this line or effective communication with it was concluded in this team. This problem was seen both in the Premier League matches and in the Asian game of the Persepolis team. However, the team's victory in the tournament despite this problem can depend on the following two

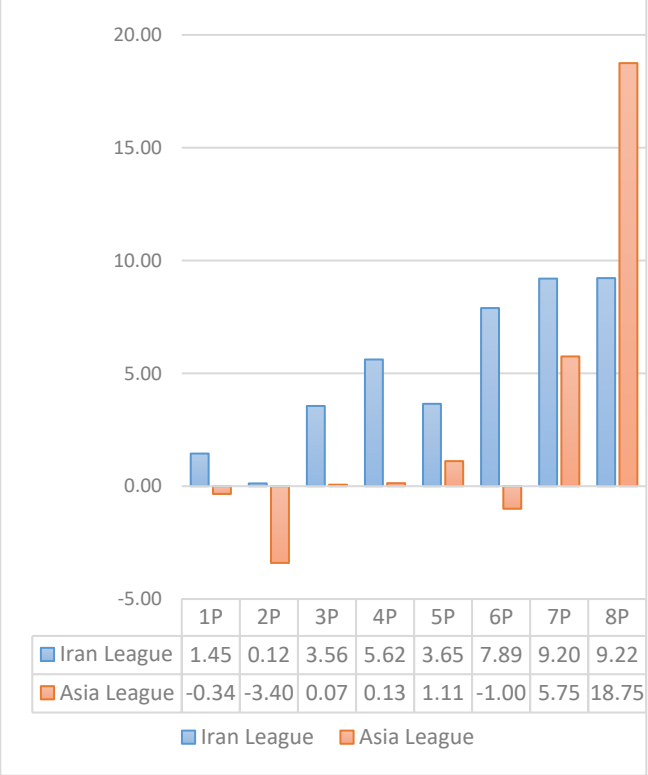

Figure. 16. Displaying the ratio of the total points earned per cycle to the number of cycles

influential factors:

1. The skill of individual players to play as nodes outside the communication network.

2. Support and replace players from other lines (except the offensive line) to achieve the desired result during matches.

Declarationss

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Authors' contributions

AA: Study design, acquisition of data, statistical analysis, interpretation of the results, drafting the manuscript, revision of the manuscript; BT: Study design, Supervision, revision of the manuscript; MM: Study design, acquisition of data, drafting the manuscript;

Conflict of interest

The authors declare that there is no conflict of interest.

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