Problem Chosen	2020	Team Control Number
E	MCM/ICM Summary Sheet	2017209

A Network Dynamic Analysis of Football Strategies

Summary

Football is one of the most popular sports in the world. In order to analyze the dynamic characteristics of the team and improve the winning rate, we set up a series of models to determine the teamwork performance of Huskies from multiple angles, and gave our advice.

In task 1, for the sake of exploring structural and dynamical features of Huskies, we introduce average position and eigenvector centrality to define the passing network of a team. Furthermore, 3 indicators are selected to measure the degree of cooperation, and then we endow the indicators weights and integrate them into a comprehensive index to identify the team configuration. Moreover, Q-clustering analysis is employed to clarify the team formation. Then, social network analysis is applied to obtain the micro and macro network properties.

In task 2, we select 11 indicators to measure the performance of teamwork, and then entropy weight method is applied to integrate the indexes into the from 6 aspect. When Huskies's performance is better in more aspects, the more successful its team cooperation. The evaluation results matches the game results well, which indicates the universality. Then we regroup these indicators into Comprehensive Structural Performance (CSP), Comprehensive Configurational Performance (CCP), and Comprehensive Dynamic Performance (CDP), applying entropy weight method again to capture different aspects of the teamwork.

In task 3, according to the application of Team Properties Capture Model, we find that the more team configurations, the more likely to win. And Huskies has a weak backcourt since opponents take possessions many times and shoot. Then, we propose advice aiming at the performance of Huskies. 1) strengthen cooperation and grasp opportunity, 2) improve the defense of the left rear, and 3) develop the ability of long pass.

In task 4, based on the analysis and findings of Huskies performance, we advise to pay attention to three aspects when design more effective teams: 1) focus on effective communication between team members. 2) according to the team foundation to determine the team development plan. 3) be able to adjust the direction of the team in time. Besides, designers are also supposed to take leadership style, team atmosphere, and external environment into account.

Keywords: Football game, Social network analysis, Entropy weigh method.

Contents

1. Introduction

1.1 Background

As time advances, the development of societies ties between the increasingly closer. We have been solved many challenging problems relying on interdisciplinary teams and the most representative is in the field of sports. Soccer is widely thought as the most popul ar sport around the world, which must obey strict rules including the number of players, their roles, allowable contact between players, points earned and so on. But team success is much more than the sum of the abilities of individual players. Rather, it is based on many other factors that involve how well the teammates play together. In the current researches, social network analysis and other quantitative methods are widely used to analyze team interaction and individual performance, and remarkable results have been achieved.[1]

In this paper, we focus on quantifying and formalizing the structural and dynamical features to explore how the complex interactions among the players on the field impacts their success. The goal is not only to examine the interactions that lead directly to a score, but to explore team dynamics throughout the game and over the entire season.

1.2 Our Work

To explore the structural and dynamical features of Huskies throughout the game and over the entire season, we establish a passing network and apply weighting method and Q-clustering analysis to identify the network patterns. Then, social network analysis is employed to analyze the teamwork performance macroscopically and microscopically. After that, indicators are selected to capture different aspects of the teamwork and we have to inform the coach effective strategies based on our findings.

We will proceed as follows for the sake of tackling the problems.

- Create a passing network to identify network patterns and other structural indicators and network properties throughout the games dyadic and triadic configurations, team formations, micro to macro when looking at interactions, and time such as short to long .
- Identify performance indicators that reflect successful teamwork and clarify whether strategies are universally effective or dependent on opponents ’ counter-strategies. Use the performance indicators and team level processes to create a model that captures structural, configurational, and dynamical aspects of teamwork.
- Use the insights gained from the teamwork model to inform the coach about what kinds of structural strategies have been effective for the Huskies. Advise the coach on what changes the network analysis indicates that they should make next season to improve team success.
- Generalize our findings and advise how to design more effective teams and what other

aspects of teamwork are worth being noticed.

2. Assumptions and Notations

2.1 Assumptions

For the sake of the limitation of our knowledge and the lack of the data, we make the following assumptions to help us construct the model and simplify the given problem.

● The members of Huskies and its opponents will not change in the future and their abilities, strengths, weaknesses and characteristics also will not change significantly.

● New tactics and strategies will not be developed.

● Huskies and their opponents try their best to win the game in every game.

2.2 Notations

We list the symbols and notations used in this paper in Table 1.

Table.1 Notations

Symbols	Definition
CD	Configuration Degree
CSP	Comprehensive Structural Performance
CCP	Comprehensive Configurational Performance
CDP	Comprehensive Dynamical Performance
l	The reciprocal distance of a pass
t	The reciprocal of the time interval between two passes
C_B	Betweenness Centrality

3. Coordinate System and Node Number

For better structure and description of this paper, coordinate system construction and naming principle of node number have to be introduced at first.

● Coordinate System Construction

According to the illustration in the data set, Huskies and its opponent have different coordinate system when getting possession as shown in figure 2. For the sake of better description of the relative position of the two teams, we will show them in one coordinate system.

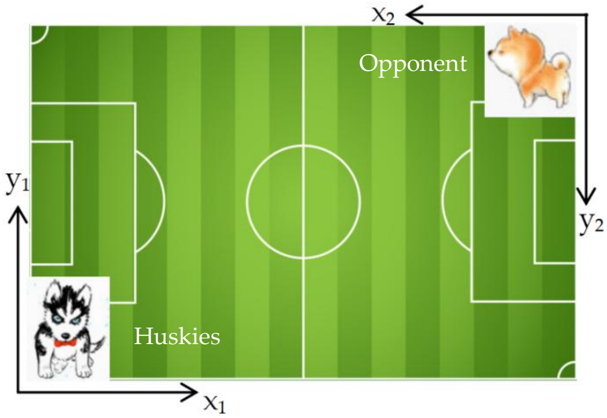

Figure.1 Coordinate System

● Naming Principle of Node Number

Since we don't know the the number on player's uniform and it's inconvenient to use the player ID in data set for program calculation and chart expression, so we need to renumber the player member. If there are m forwards, n defenders, k midfielders and j goalkeepers , then the naming rule is as follows:

Table.2 Naming principle of node number

Player ID	F_1,...,F_m	D_1,...,D_n	M_1,...,M_k	G_1,...,G_j
Node Number	1,...,m,	m+1,...,m+n	m+n+1,...,m+n+k	m+n+k+1,...,m+n+k+j

4. Team Dynamics

To identify the team dynamics, a passing network is established and we figure out the team configurations by endowing target weights and combine them to realize comprehensive index. Furthermore, Q-clustering analysis is used to identify the team formation. After that, social network analysis is applied to analyse macro and micro features.

4.1 Passing Network of Football Teams

For the sake of exploring the net patterns of Huskies, we define the passing network of a team as the network containing the team's players as nodes and connecting arrows between two players.[8] (See Figure.2)

Eigenvector centrality: The eigenvector centrality of a player i is a measure of node importance that is obtained by calculating the eigenvector v_1 associated to the largest eigenvalue λ_1 of the weighted adjacency matrix A. The eigenvector centrality is a measure of node importance that takes into account the number of all directed connections a player (node) has. Furthermore, two factors contribute to increase the value of eigenvector centrality: (i) a higher number of direct connections to other players (note that connections are weighted) and (ii) to be connected to other nodes that, in turn, also have a high centrality. In this way, important players are those that are (highly) connected to other important players of the team.[3]

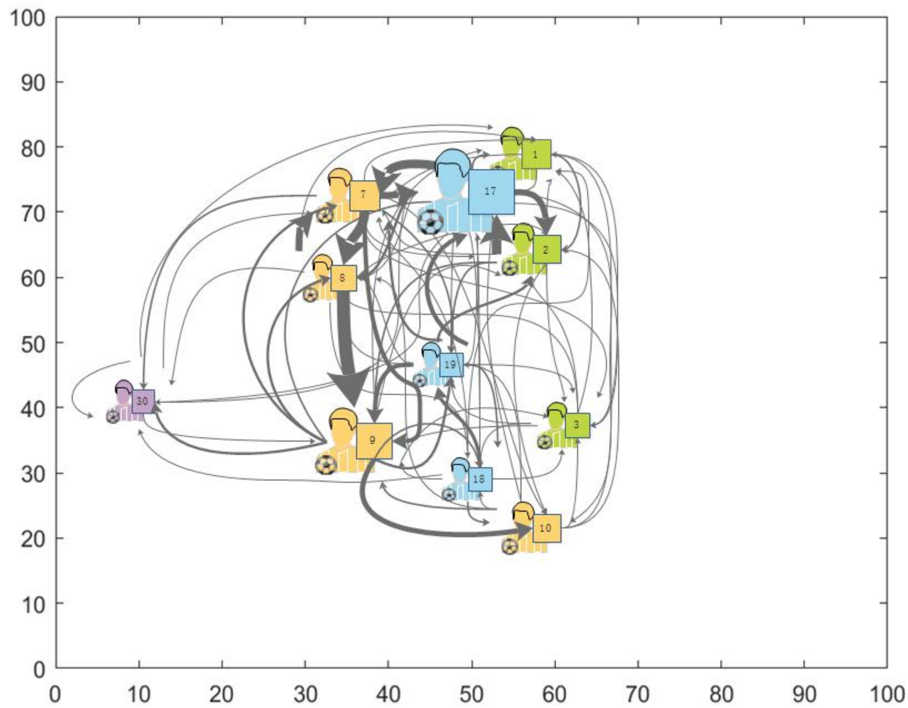

Figure.2 Schematic illustration of a football passing network. In the plot, players are represented by the nodes, whose size is proportional to their eigenvector centrality, a measure of importance in the network structure. The position of each player is given by the average of the positions of all passes made by the player along the match. The width of the links is proportional to their weights, which account for the number of passes between players [3]. Green, blue, orange and purple nodes are forward, midfielder, backfielder, and goalkeeper respectively.

The players do not stay at static positions during games, but the network with its arrows represented in various thickness helps us to compare the performance and characteristics of Huskies and Opponent 1 and identify the players with the most important roles during the match. Moreover, as the individual players' positions remain constant across networks, the different match networks can be easily compared to extract the general features of the play of a team, such as the efficiency of a particular team strategy.[2]

4.2 Team Configurations

After transforming team interaction into a passing network, our initial attempt at using clustering coefficient to figure out the net patterns has not provided much useful information, so some indicators are selected and we endow target weights and combine them to realize some comprehensive indexes to determine whether the dyadic and triadic configurations exist.

First of all, we counted the number of player in a possession round, but considering that not all player are eligible for dyadic and triadic configuration, so we select three indicators and get an index, Configuration Degree (*CD*), by weighted summation to determine the configuration.

$$CD_i = \sum_{i=1} n(\omega_1 l_i + \omega_2 t_i) + \omega_3 p_i \ , \tag{1}$$

$$p_i = \frac{n}{s}, \tag{2}$$

where n is the number of passes for player i and s is the number of total passes, l_i is the reciprocal of distance, and t_i is the reciprocal of the time difference of passing. After that, rank the *CD*. If the sum of the first m players' degree is greater than a certain threshold, then m players are cooperating in this passing round. If the degree of all players is still less than the threshold, then there is no cooperation.

After bringing in groups of data, we determine that $\omega_1 = 1/3$, $\omega_2 = 1/300$, $\omega_3 = 1/50$ and threshold value is 0.15 for a reasonable order of magnitude. Here is the outcome in match 1.

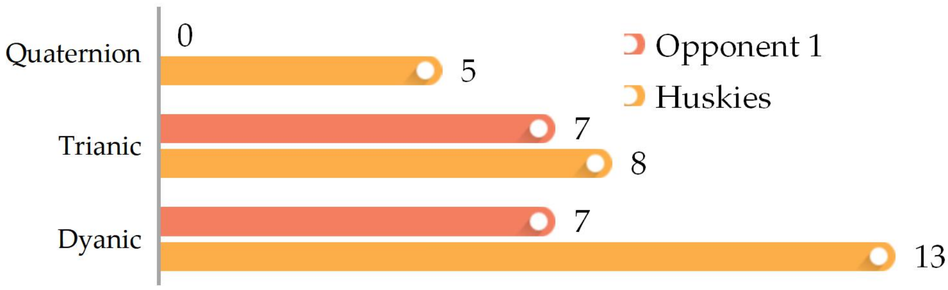

Figure.3 Huskies - Opponent 1. Team Configurations.

After we obtain the team configurations, we can also find out the micro information, that is, pairwise, but we will show the results later.

4.3 Team Formation

In this section, we are going to identify another network pattern, team formation. The position of each player is given by the average of the positions of all passes made by the player along the match. Since the determination of football team formation is only related to the X coordinate, clustering tree formed by the X coordinate of "average position" helps us identify the formation of teams. (See Figure.)

It can be seen from the formation that Huskies attaches great importance to the midfield, where a large number of players are arranged. From the perspective of strategy, the attack is mostly planned from midfield, and the through ball is also from midfield.

4.4 Micro and Macro Analysis Based on Social Network

Social network is a kind of social organization based on "network" rather than "group" and is widely used in the analysis of football performance. It not only discusses the static and dynamic characteristics of player interaction, but also forms the micro, meso and macro analysis perspectives.[1] However, we ignore the whole networks due to the little dynamic information involved and do macro analysis according to the LAN networks. (See Figure.5)

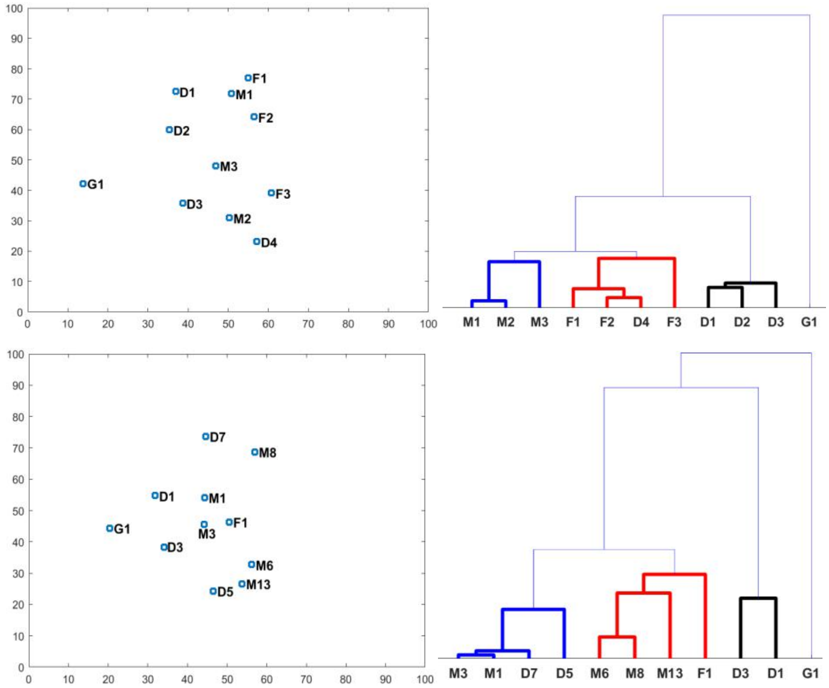

Figure.4 Clustering tree of Huskies in match 1 and 21. Upper graphs - Match 1. The team formation is 3-3-4, [D3,D2,D1]-[M3,M2,M1]-[F1,F2,F3,D4]. Lower graphs - Match 21. The team formation is 2-4-4, that is, [D1,D3]-[M1,M3,D7,D5]-[M6,M8,M13,F1]. Notice that the goalkeeper is not involved in the formation.

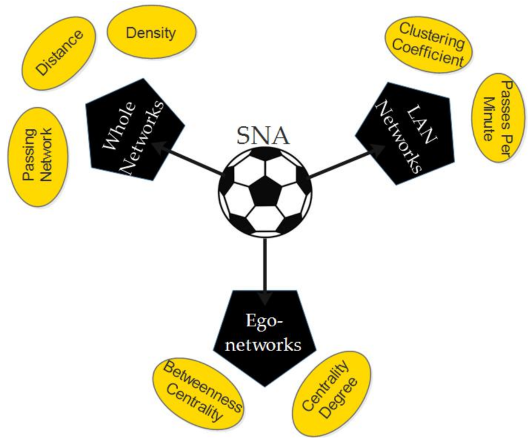

Figure.5 Process flow for the SNA (Social Network Analysis).

4.4.1 Local Area Networks

In the following we can capture macro and time information from the perspective of local area networks (LAN). Particularly, we pay attention to the two features: passes per minute and clustering coefficient.

1) Passes Per Minute

Number of passes per minute provides an indication of the speed of the game. (See Figure 6)

2) Clustering Coefficient

Clustering coefficient is an indication of the extent to which players tend to luster together when passing the ball. To compute this coefficient, we symmetrize the network and compute the local coefficient γ_i fro each node i with more than two vertices as

$$\gamma_i = \frac{N_i}{\delta_i(\delta_i - 1)/2}, \tag{3}$$

where δ_i is the degree of node i and N_i is the number of links between nodes j, k connected to i. Subsequently, the clustering coefficient γ_G of the network G is

$$\gamma_G = \frac{\sum_{i \in V \setminus V^{(1)}} \gamma_i}{|V \setminus V^{(1)}|}, \tag{4}$$

where V is the total number of the nodes while $V^{(1)}$ represents the number of nodes not involved in.[4]

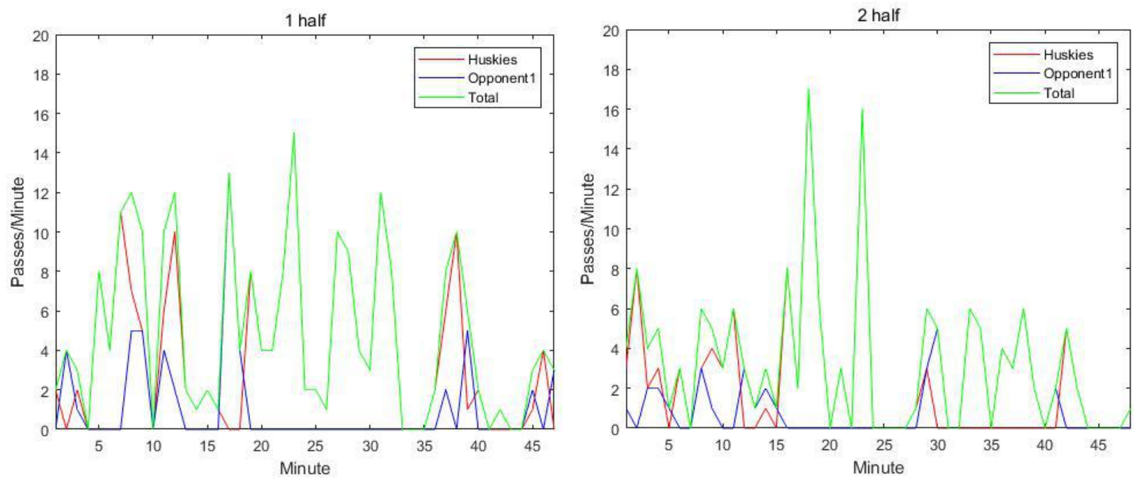

Figure.6 Huskies-Opponent 1. Passes per minute.

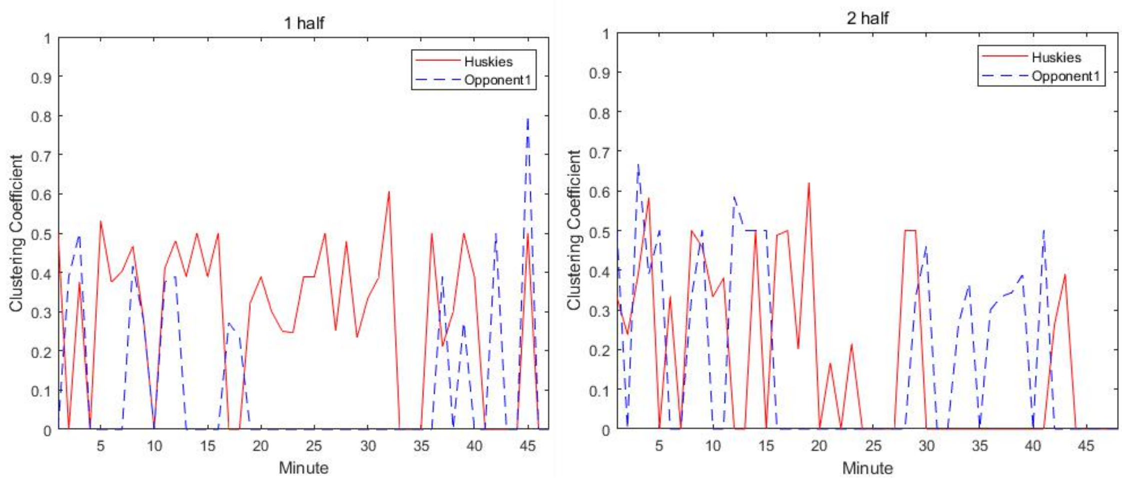

Figure.7 Huskies-Opponent 1. Clustering Coefficient.

3) Conclusion

It can be seen from Figure.6 that from the entire game the passing speed in the first half was significantly higher than that in the second half, and most of the time Huskies was in charge of the ball. The 17-23 minutes in the first half and 18-23 minutes in the second half is the fastest period.

As shown in Figure.7, the clustering coefficient of Huskies during the first half is much larger than that of Opponent 1 and stays at a high level consistently. This accords with the pass per minute above of Huskies, and indicates that Huskies settles into its combinative game but it is very irregular for Opponent. But clustering coefficient of Opponent 1 performances better in terms of the density and continuity while Huskies is the opposite, which is consistent with a less structured development of the game for Huskies.

4.4.2 Ego-networks Analysis

In this section, we combine centrality with configuration in section 4.1 to obtain the micro information about individuals and pairs respectively.

- **Centrality[2][5]**

1) Betweenness Centrality

Betweenness centrality measures the extent to which a node lies on paths between other nodes. This quantity is defined as the percentage of shortest paths that go through player *i*:

$$C_B^{(i)} = \frac{1}{90} \sum_{j \neq k \neq i} \frac{n_{jk}^i}{g_{jk}}, \tag{5}$$

where n_{jk}^i is the number of geodesic paths from j to k going through i and g_{jk} is the total number of geodesic paths. The normalization factor 1/90 ensures $0 \leq C_B^{(i)} \leq 1$.

Betweenness Centrality measures how much the player controls the interaction between others. More specifically, a node shoots a high betweenness centrality score when it is on the ball-flow of many other pairs of nodes. If a node is between many pairs of nodes, even if its degree is relatively low, it may play an important betweenness role. Thus, it is in the centre of the network. Particularly, a betweenness score of 0 means that a player is not engaged in the match, who so can be removed without much effect.[2][5]

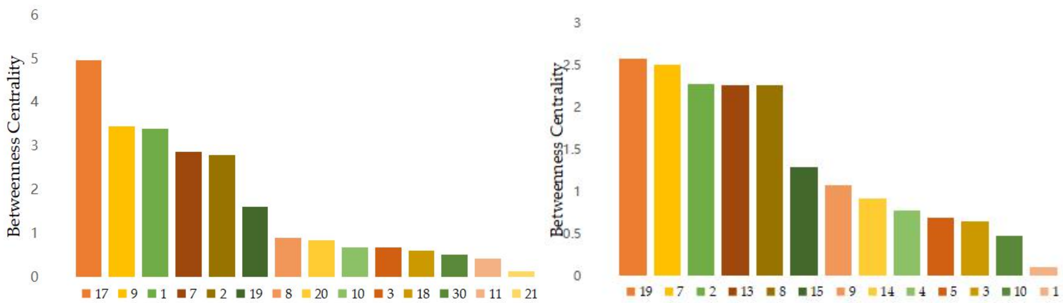

Figure.8 Huskies-Opponent 1. Left graph - Betweenness Centrality of each player in Huskies. Right graph - Betweenness Centrality of each player in Opponent 1. The number on the horizontal axis indicates the node number of the corresponding player.

As shown in Figure 8, the betweenness centrality of No.17 player in Huskies team is the largest, followed by No.9, No.1, No.7 and No2, indicating that these players are in the center of the pass network. Most of the players pass the ball to them, and the their pass coverage is also large, which can pass the ball to most of the players on the field. On the other hand, the betweenness centrality of Opponent 1 performs poorly, with a maximum of only 2.6.

2) Centrality Degree

Centrality degree is a concept proposed by Freeman (1979). It refers to the degree to which a node is located in the middle of other "point-to-point". When the connection has a direction, it can be divided into in-degree and out-degree[5].

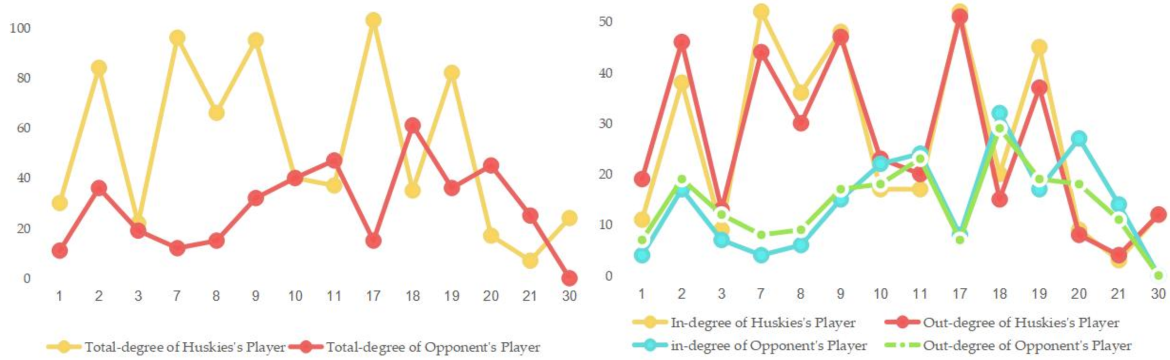

Figure.9 Huskies-Opponent 1. Degree centrality. Right graphs - In-degree and out-degree of two teams. Left graphs - Total degree of two teams.

In terms of the total-degree of players, No. 17 in Huskies has the largest degree, followed by No. 7, No. 9, No. 2 and No. 19, while No. 18 in Opponent 1 is ranked first, followed by No. 11 and No. 20. Combined with the Table 2, it is found that most of players ranking ahead in Huskies are guards and midfielders, while those Opponent 1 are all midfielders.

Generally speaking, the defensive player's out-degree is greater than in-degree, which means more successful intercepts while the offensive players are the opposite. The out-degree of midfield players in both teams is greater than the in-degree, and the in-degree of forward players is greater than the out-degree. The average in-degree of Huskies's offense is 42.6, while that of Opponent 1's offensive players is 13. This shows that although the same number of offensive players, players in Huskies receive more effective passes and have more opportunities to form a through pass.

4.5 Micro and Macro Analysis

● Pairwise

According to the statistics of players with high frequency in the cooperation times (in section 4.2), we can find that No.9, No.4 and No.6 prefer to cooperate with others in Huskies, and No.4 and No.6 often cooperate with each other. No.9 will cooperate with many players.

● All players

Divide the stadium into 10×10 areas, count the sum of the passing times of the two teams in each area in the first half and the second half of the first match, draw the corresponding thermal depth map to reflect the tactical situation of the team in this period of time. It can be seen from the figure that in the first half, the darker part of Huskies's team is more and close to the goal of Opponent 1, while the darker part of opponent 1 is smaller and concentrated near the midfield, which shows that Huskies's team occupies the offensive advantage in the first half, and opponent 1 is mainly in the defensive state. In the second half, the attack of Huskies was weaker than that of the first half, while the attack of opponent 1 was strengthened. The number of passes of opponent 1 near the goal of Huskies became more and the attack was mainly distributed on the left side.

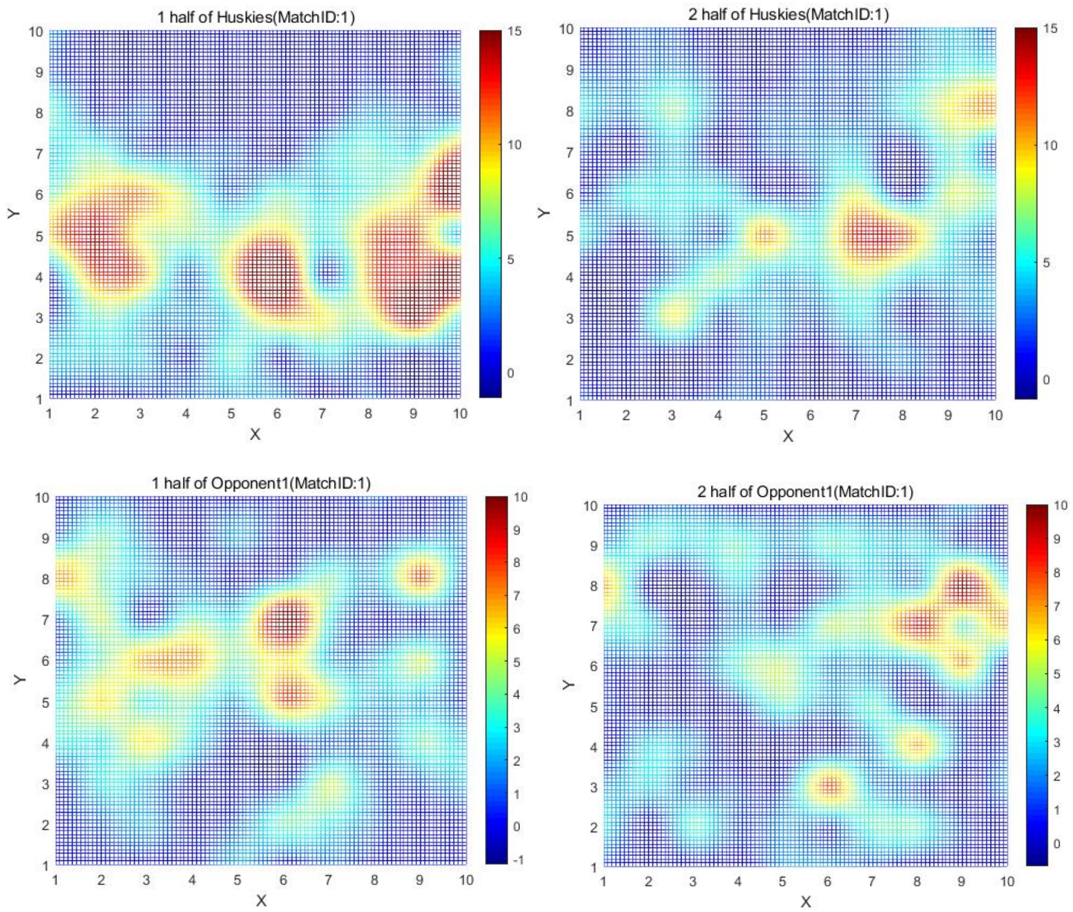

Figure.10 Heat depth map of pass distribution of two teams in match 1

5. Teamwork Property Capture Model

In this section, 11 indicators are selected to capture the structural, configurational, and dynamic features of the teamwork. Selected indicators are calculated and compared with the game results for the sake of proving feasibility.

5.1 Team-Level Performance Indicators

As required, we select 11 indicators from the perspective of Successful Teamwork, Diversity, Coordination/ Contribution, Tempo, Flexibility and Adaptability to help develop a strong relationship between the teamwork performance and collected data.

(See Figure.11) Because the meaning of many indicators are easy-to-understand or have been mentioned before, so only definitions of Passing deviation and Possession percentage will be explained as below and the meaning of others are

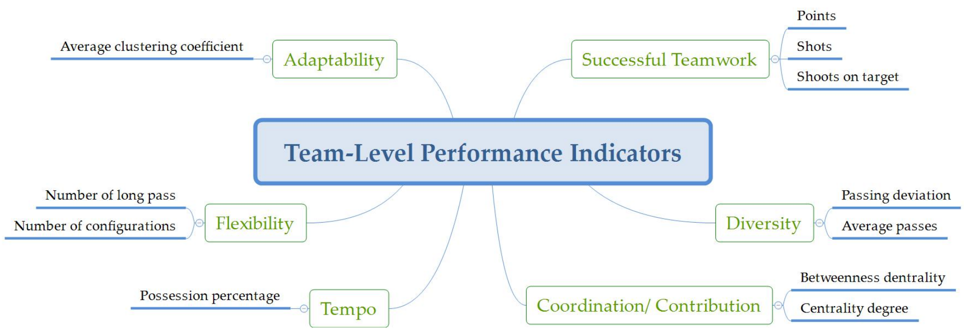

Figure.11 Team level performance evaluation index system.

● Passing deviation. The more kinds of passes, the more diverse the game. We count the numbers of head pass, hand pass, smart pass, cross, high pass, and launch respectively and calculate the deviation. The bigger the deviation, the more diverse the game. But simple pass is so frequently that it is not involved in.

● Possession percentage. The time ratio of a team to control the football in the process of the game. The sum of the possession percentage of the two teams is 100%. The higher the indicator, the better the tempo.

5.2 Universality Of the Strategy

To clarify the universality of the strategy, the lower indicators are integrated into a relatively comprehensive indicator by **Entropy Weight Method**, and the differences between the two teams are compared from six aspects of Diversity, Coordination/ Contribution, Adaptability, Flexibility, Tempo and Successful Teamwork.

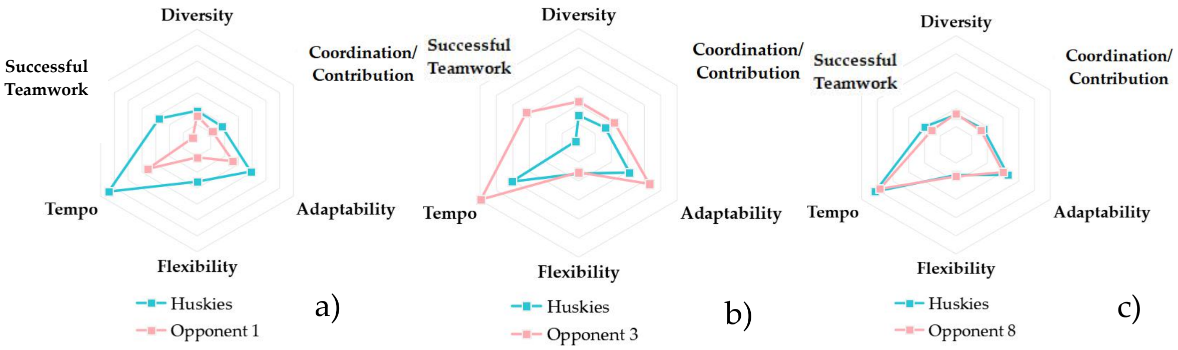

Figure.12 Comparison of successful teamwork and team-level process between Huskies and its opponents. The radar charts show the difference between two teams in the same aspect, instead of the performance of one team in different aspects. a) Huskies - Opponent 1. Huskies wins 1:0 against Opponent1. b) Huskies - Opponent 3. Huskies loses to Opponent 3 with 1-2. c) Huskies - Opponent 13. The game is a 1:1 draw.

When Huskies's performance is obviously better in more aspects, the more successful its team cooperation and team level process are, and the more likely Huskies is to win. In order to verify that this method is generally applicable, we bring in relevant data of matches for verification, and show as shown in Figure 12. It is found that the evaluation results are consistent with the final competition results, which means universally effective.

5.3 Teamwork Properties Capture

To capture the characteristics of different aspects of teamwork, we regroup the 11 indicators above into three categories: structural, configurational, and dynamical aspects.

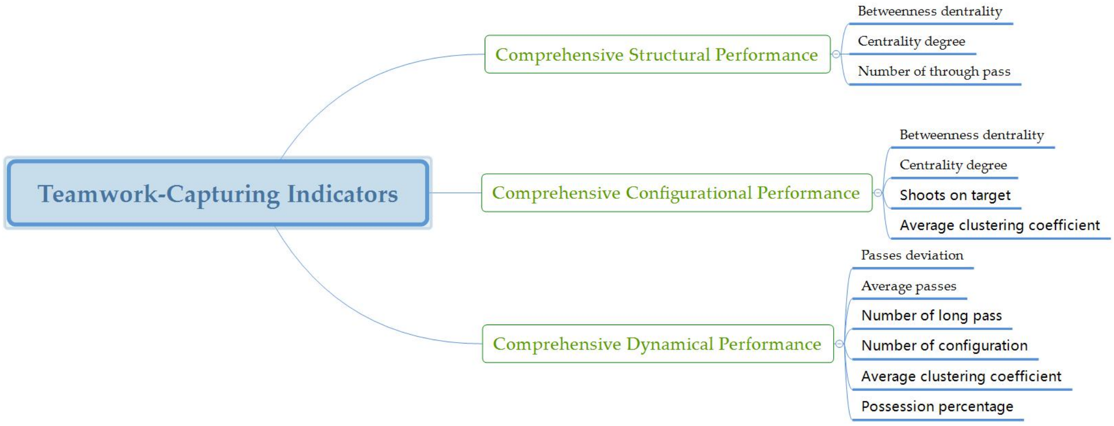

Figure.13 Teamwork-Capture evaluation system

Then, we integrate the indicators into Comprehensive Structural Performance (CSP), Comprehensive Configurational Performance (CCP), and Comprehensive Dynamical Performance (CDP) respectively by using entropy weight method (EWM).[6] After visualizing, we find that when Huskies's performance is obviously better in CSP, CCP, and CDP, the more successful its team cooperation and team level process are, and the more likely Huskies is to win, which means the capture results accord with the final game results.

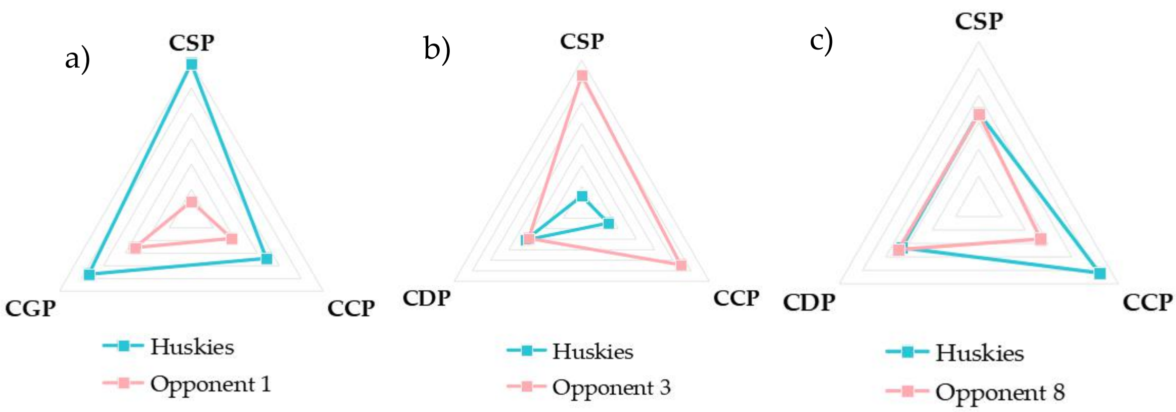

Figure.14 Comparison of CSP, CCP, and CDP between Huskies and its opponents. a) Huskies - Opponent 1. Huskies wins 1:0 against Opponent1. b) Huskies - Opponent 3. Huskies loses to Opponent 3 with 1-2. c) Huskies - Opponent 13. The game is a 1:1 draw.

5.4 Maps to Capture

1) Depth heat map

The distribution heat map of passing can be obtained through the statistics of players' passing position information in a certain period of time. The depth of the color reflects the number of times the area has passed in this period. It can reflect the tactical arrangement of the team from a macro perspective. Section 4.6 has shown the distribution of the pass of Huskies and opponents in the first half, and Figure.14 has drawn the heat depth map of Huskies in the whole game. It reflects that the main tactics of Huskies in the first match is mainly attack, and mainly concentrated in the middle.

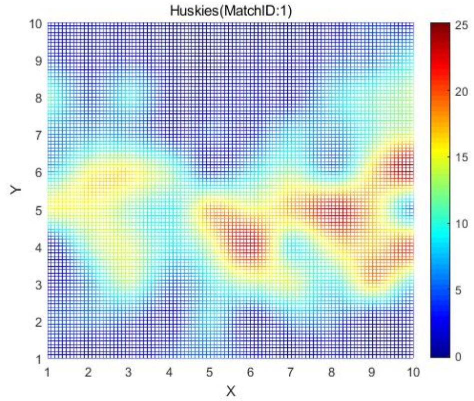

Figure.15 Heat depth map of pass distribution of Huskies in match 1

5.5 Attack track map

We can get the corresponding passing point when the passing position is near the opponent's forbidden area through screening . Based on these points, a track map as shown in the Figure.15 can be drawn, in which the number represents the player number at the time of passing. It can show the structure of team cooperation at a macro level.The lines of four different colors in the Figure.15 show that there are four main attack routes.

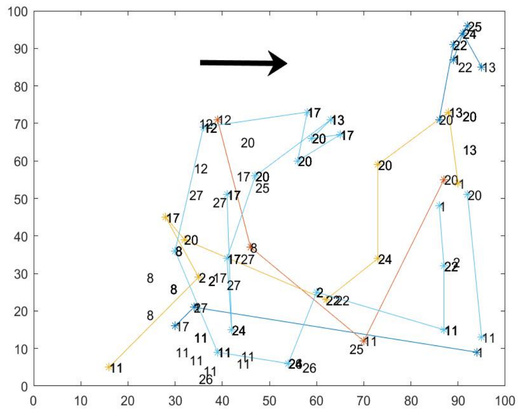

Figure.16 An example of attack trajectory

6. Effective Strategy Suggestions

According to the application of Team Properties Capture Model, we propose some advice aiming at the performance of Huskies: strengthen cooperation and grasp opportunity, improve the defense of the left rear, develop the ability of long pass.

1) Strengthen cooperation and grasp opportunity

After counting the passing of the whole game, we can get the comparison of dyadic configuration, triadic configuration and multi-player configuration (≥ 4 players) times between the two teams the whole game. The statistical results of 5 matches is shown in Table.3.

Table.3 Times of configuration in match 1, 3, 8, 14, and 38.

Team	Match_ID	Dyadic	Triadic	Multi-Player	Total times	Result
Huskies	1	13	8	5	26	win
Opponent 1	1	7	7	0	14	
Huskies	3	10	5	2	17	loss
Opponent 3	3	19	3	1	23	
Huskies	8	12	7	2	21	tie
Opponent 8	8	4	7	2	13	
Huskies	14	13	8	4	25	win
Opponent 14	14	18	6	2	26	
Huskies	38	8	7	2	17	loss
Opponent 14	38	14	8	1	23	

It can be observed that the total times of Huskies exceeds 20 in the winning two games and the draw game, while that in the losing game is less than 20. At the same time, dyadic configuration times maintains a relatively stable level. These characteristics indicate that if Huskies wants to achieve better results, it needs to strengthen cooperation, so as to play the team's level. In addition, although the cooperation times of Huskies is more than that of its opponent in match 3, but Huskies still loses the game, which shows that the ability of Huskies to seize the opportunity needs to be improved because the configurations are not converted into effective shoots.

2) Improve the defense of the left rear

The two matches of Huskies and Opponent 14 are selected to analyse the weakness of Huskies, each of which has its own win or loss and the score gap is large. First of all, by comparing Huskies's heat map of the two matches, we can see that the strength of Huskies's midfield in the first match is greater than that in the second. The distribution of players is relatively concentrated, especially in the midfield and backfield. But in the second game, the players move forward as a whole, reducing their defensive strength.

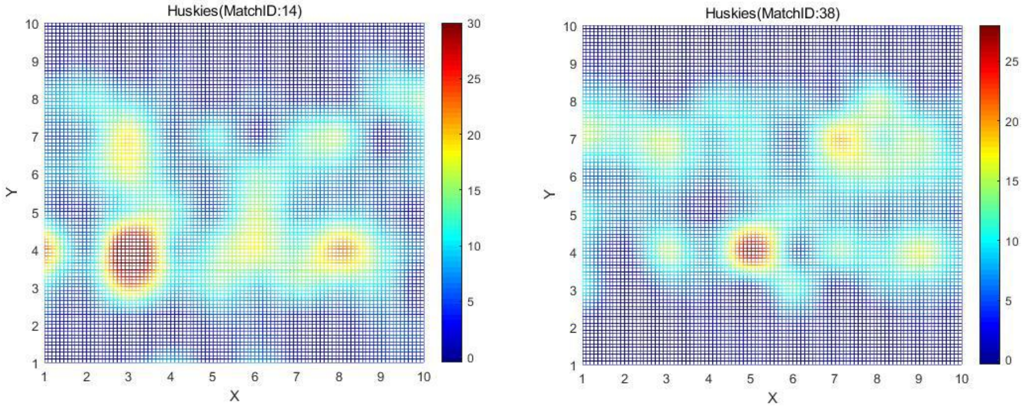

Figure. 17 Player density heat map of Huskies in match 14 and 38.

Then, we find that the possession percentage of Huskies decreases from 49.1% to 41.7%. In addition, as shown in Figure.17, the attack strategy of Huskies is to plan the attack with midfield passes, and then move forward to the right to provide the shot opportunity through Teamwork-Properties-Capture Model.

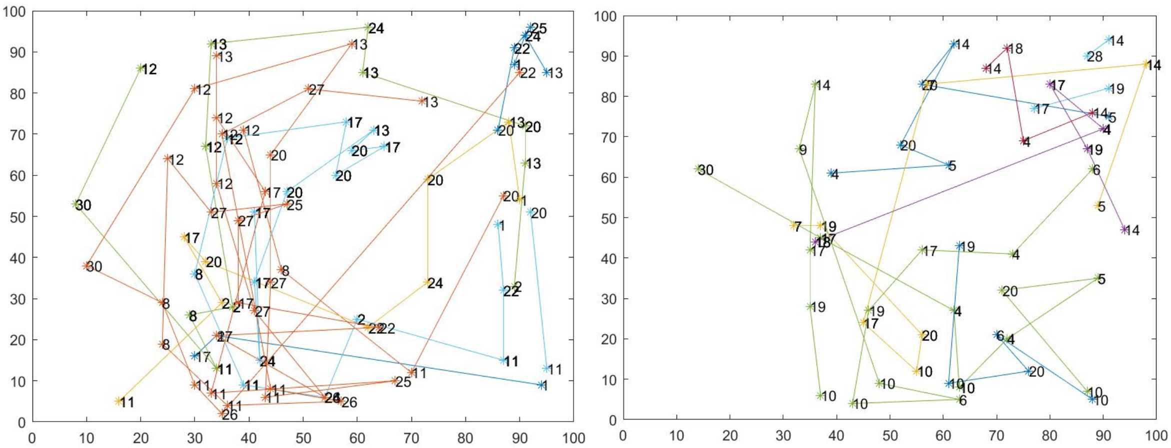

Figure.18 Attack track chart. Left picture shows the first field data of husky team, and the right picture shows the second field data.

As shown in the figure above, we can see that the team has reduced the passing in the middle and back of the court and directly attacked in the front court.

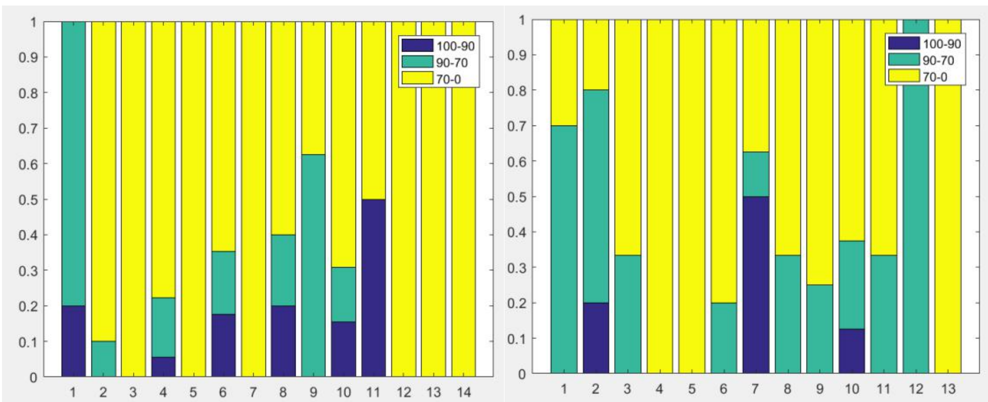

Figure.19 Distribution of attacking players.Left picture shows the first field data of husky team, and the right picture shows the second field data.

It can be seen from the distribution of players that, compared with the left figure, the green parts increases, while the yellow decreases, indicating that the team's attack will be planned in the front court and this is consistent with the analysis result of thermodynamic diagram.

In order to analyze the team's defeat match 38, we visualize the opponent's goal track, and then find the defense weakness of Huskies is left rear because opponent take possession here most of the time.

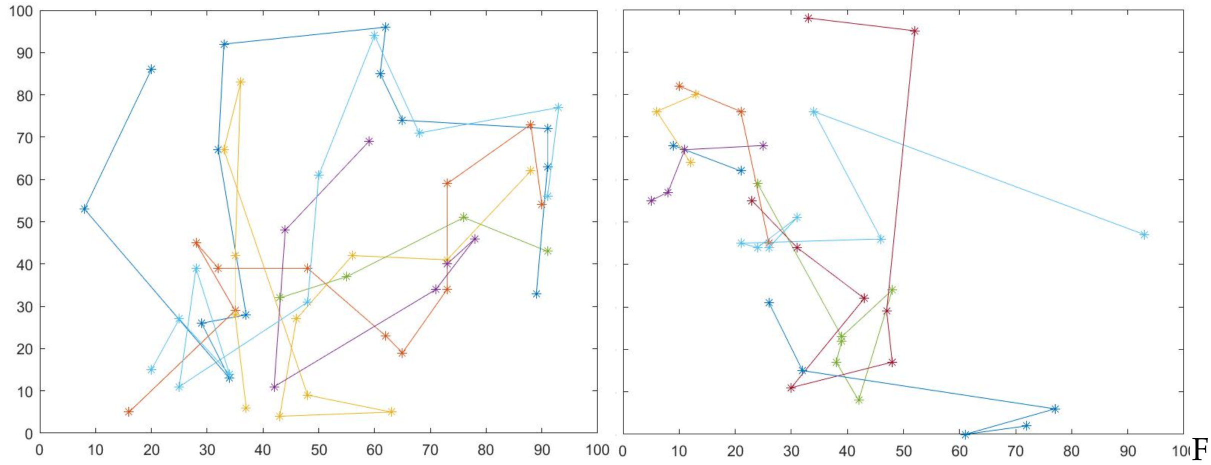

Figure.20 Shot trajectory

So we advise Huskies to pay attention to midfield and backfield in order to strengthen the defense and also support the forwards with a wide range of transfers, causing a greater threat. Take player Huskies F2 as the core when attacking and conduct multiple passing before that to improve the efficiency and threat of attack. Besides, Huskies are supposed to improve the defensive strength of the left rear to prevent the opponent from taking possession and shooting.

3）Improve the ability of long pass

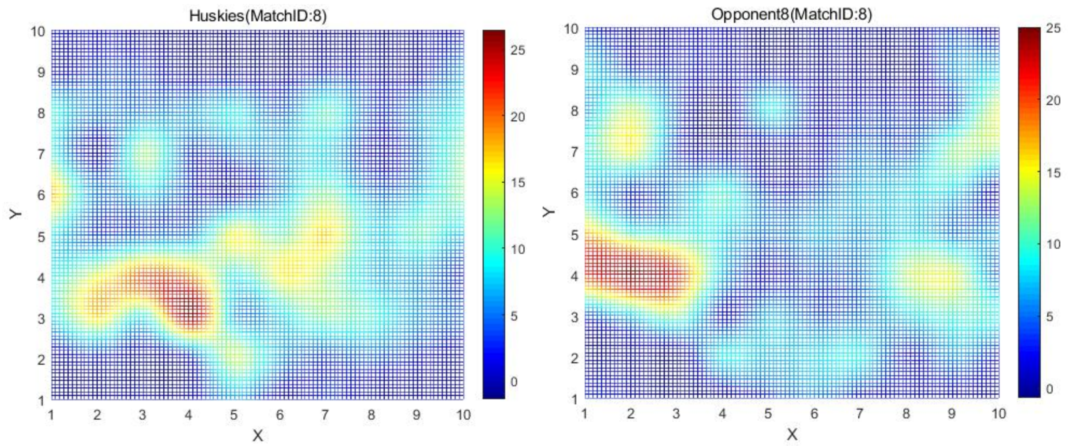

Figure.21 Heat map of players distribution of two teams in match 8

It is observed from Figure 21 that the players of the two teams are mainly concentrated in the back court in match 8, which shows that the key of the whole game is to attach importance to defense. Both teams use the similar tactics and the final result is a 1-1 draw. Therefore, we think that although it is not easy to form a large-scale offensive situation, the team can rely on the opponent's faults liking muffing the ball, and then achieve a rapid defensive counterattack through long pass, which poses a great threat to the opponent. Therefore, it is suggested that Huskies should send players who are good at completing long pass to cooperate with those who have strong individual attack ability when using the defensive tactics focused on the backcourt, so that it is easy to use the opponent's mistakes to score.

7. How to Design A Effective Team

In social life, there are more and more problems related to the team that need to be solved. Football match can be regarded as a small society. The cooperation between players and teams is similar in fact. It is helpful to analyze players' performance and improve the team's performance by building a network of players' passing. Similarly, looking at communication among team members as a network of passing can help build a more effective team.

7.1 Design a more effective team

1) Focus on effective communication between team members.

According to our previous model analysis, when the number of effective matches of Huskies team reaches a certain number of times, the team is more likely to win. In the actual team work, the effective communication among members is helpful to improve the work efficiency.

2) According to the team foundation to determine the team development plan.

In the football match, the tactics of the team are determined based on the strength of the team and the opponent's situation. Different teams have different types and levels of players, different styles and different ideas of coaches, which also creates many teams with different styles. When building a team, it is necessary to determine the development plan according to the actual basis of the team.

3) Be able to adjust the direction of the team in time.

In the football match, when the situation on the spot changes, the coach will adjust the tactics in time according to his own judgment to help the team open the situation. As shown in Figure 22 and Figure 23, in the 14th round of competition, Huskies paid attention to attack in the first half, while in the second half, the opponent's attack strength increased,Huskies adjusted the tactics in time, changed from active attack to focus on defense, and finally won the game successfully. In reality, team cooperation is the same. Only by constantly adjusting the direction according to the current situation, can team development be more smooth.

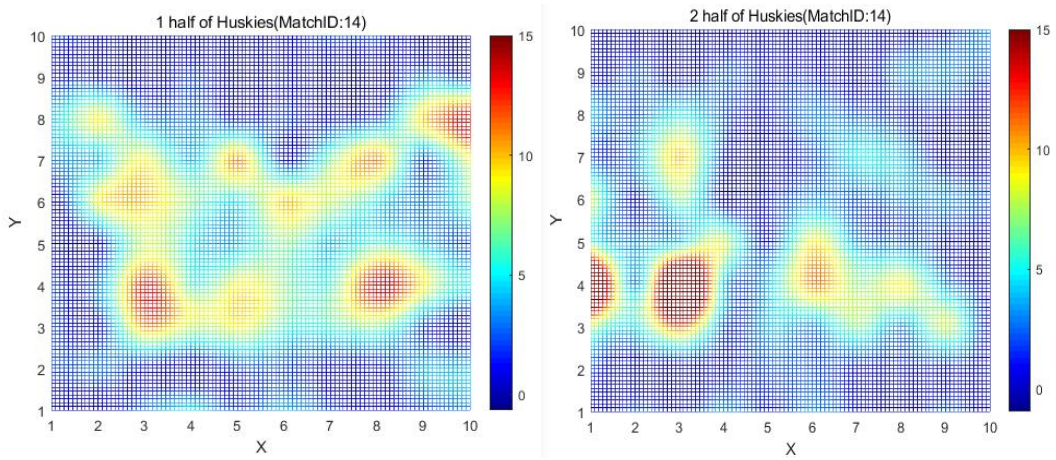

Figure.22 Match 14 heat map of the first half and the second half of Huskies

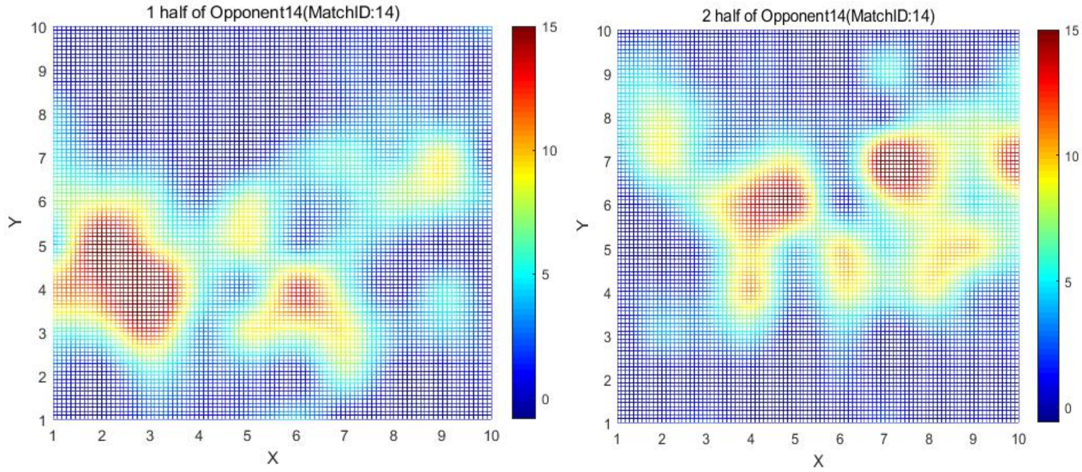

Figure.23 Match 14 heat map of the first half and the second half of opponent 14

4) Match team members properly. In the previous model, We suggest that a backcourt player who is good at long range passing should be matched with a fast and sharp striker. Only when the team members are grouped reasonably according to their characteristics, can the team members deal with all kinds of problems more efficiently; on the contrary, if the people with style conflict are grouped together, it is easy to cause conflicts and the team atmosphere will be affected.

7.2 Other aspects of teamwork

1) Leadership style [7]:Autocratic, democratic and laissezfaire. Scientific and reasonable leadership style is conducive to the development of the team.

2) Team atmosphere: whether it’s harmony, inclusiveness and openness, and high morale of members.A good atmosphere helps team members communicate and improve work efficiency.

3) External environment: the general term of external political environment, social environment, technical environment, economic environment, etc.National and industrial policies and other factors may have a certain impact on the completion of team work.

8. Sensitive Analysis

It can be seen from Figure.24 that the influence of threshold change on the calculation of opponent1's long pass times is nearly linear. In [40,80], the number of long pass times decreases about 7.5 times when the threshold increases by 10, while the influence of threshold change on the calculation of Huskies team's long pass times is large. In [40,60], the number of long pass times decreases about 25 times when the threshold increases by 10, and in [60,80], the number of long-distance transmissions decreases about 10 times with the threshold increasing by 10.

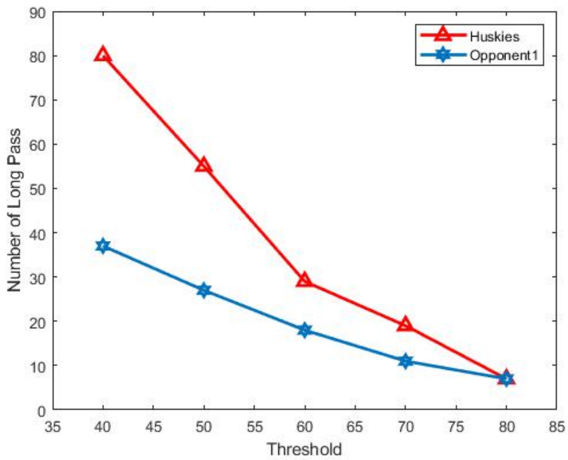

Figure.24 Sensitive analysis. Number of long pass under different threshold.

9. Strengths and Weaknesses

9.1 Strengths

● The network dynamic model analyzes the players' passing from multiple angles. There are both macro comparison and micro analysis.

● The team's attack track is visualized, which is convenient for readers to observe and analyze. The team's strategy, style and other abstract concepts are graphical, so that readers can understand the team in a deeper level.

● Screening effective passing data, involving everyone involved in passing, reflecting the team's operation process in the game.

9.2 Weaknesses

● Because most of the data are ball holder data, it is impossible to accurately evaluate the strategies when the team loses the ball right.

● Time discretization: because the data provided are discretized in time, the model can not accurately show the continuous change state of team strategy.

10. Conclusion

After establishing the passing network of a team, we use **assignment** and clustering to get team configuration and formation respectivel. Based on the team configuration, we can know who likes to cooperate with others, who often cooperate with others and other relevant information. Through the analysis of social network, this paper explores the changes of average passing times and clustering coefficient with time in the dimension of LAN, and then describes the overall performance and outstanding performance of the team from the long-term and short-term time dimensions; in the dimension of personal network, the information of Betweenness Centrality and Configuration Degree can be obtained, and then the importance of a player in the network and his tactical tendenciescan be measured.

We select 11 indicators to measure the performance of teamwork, and then entropy weight method is applied to integrate the indexes into the Teamwork model from 6 aspects.Then we regroup these indicators into Comprehensive Structural Performance (CSP), Comprehensive Configurational Performance (CCP), and Comprehensive Dynamic Performance (CDP), applying entropy weight method again to capture different aspects of the teamwork.

After applying our model, we find that the more team configurations, the more likely to win. And Huskies has a weak backcourt since opponents take possessions many times and shoot. Aiming at these findings we propose some advice. Based on the analysis and findings of Huskies performance, We put forward the following suggestions: strengthen the team cooperation, improve the ability to grasp the score, improve the left rear and enhance the quality of long pass as much as possible.

Based on the previous analysis, we found that in order to build a more favorable team, we need to consider from the four perspectives of effective cooperation, team foundation, direction control and reasonable division of labor.And three aspects of Leadership style, Team atmosphere and External environment should also be considered in building a general model of team performance.

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Appendices

Appendix A Statistics of passing times

	head pass		high pass		smart pass		cross		simple pass		launch		hand pass		total_pass	
Match_ID	Huskies	Opponent	Huskies	Opponent	Huskies	Opponent	Huskies	Opponent	Huskies	Opponent	Huskies	Opponent	Huskies	Opponent	Huskies	Opponent
1	13	14	15	18	2	3	5	5	329	149	1	5	4	3	369	197
2	10	14	14	9	0	5	1	7	150	374	4	3	1	4	180	416
3	4	12	13	11	0	5	0	3	294	430	6	5	7	5	324	471
4	17	22	16	19	3	5	10	10	296	281	6	1	6	7	354	345
5	16	14	8	12	2	4	2	3	342	338	8	1	4	1	382	373
6	14	17	22	19	7	4	6	3	267	246	1	1	1	4	318	294
7	28	16	10	14	0	0	12	3	326	140	5	5	3	1	384	179
8	11	12	14	13	1	1	1	5	261	231	1	12	6	3	295	277
9	11	27	8	17	1	2	4	7	139	437	2	7	3	4	168	501
10	13	16	18	16	2	1	7	5	313	168	5	7	1	1	359	214
11	11	22	12	13	3	4	2	4	145	255	9	14	1	5	183	317
12	6	16	6	14	1	8	3	3	114	377	2	7	0	1	132	426
13	18	12	15	14	0	7	1	3	119	463	11	2	3	3	167	504
14	11	14	24	14	1	2	5	3	297	310	8	2	1	2	347	347
15	20	12	12	9	6	0	2	0	215	200	12	1	4	2	271	224
16	6	25	5	25	1	4	0	8	62	535	4	3	2	5	80	605
17	18	19	9	17	0	1	2	5	267	305	6	13	2	2	304	362
18	18	13	14	10	1	0	0	0	275	275	3	3	1	1	312	302
19	18	13	12	13	0	2	5	2	192	461	17	1	4	6	248	498
20	13	16	24	13	1	2	1	8	179	184	2	3	10	4	230	230
21	19	14	19	1	3	0	3	5	300	177	17	2	5	5	366	204
22	11	13	10	11	1	7	5	4	205	438	2	1	5	2	239	476
23	11	19	28	14	5	8	1	6	185	418	2	4	4	4	236	473
24	23	16	14	10	1	1	2	2	272	140	4	15	4	2	320	186
25	27	11	22	11	2	0	4	4	179	242	7	0	8	5	249	273
26	9	12	21	7	3	5	5	2	241	391	5	2	3	4	287	423
27	11	14	22	10	2	6	4	5	241	182	2	2	1	1	283	220
28	22	14	22	9	1	2	6	5	180	228	5	1	2	1	238	260
29	24	20	9	13	1	4	7	5	168	202	11	6	0	5	220	255
30	20	12	14	4	3	1	4	3	265	147	6	1	0	4	312	172
31	17	15	10	10	5	2	6	0	282	180	4	8	5	0	329	215
32	4	19	13	17	2	5	0	8	87	825	2	0	1	3	109	877
33	11	23	12	15	0	5	3	3	177	387	4	10	0	3	207	446
34	15	17	26	8	2	1	4	4	274	258	11	1	4	4	336	293
35	14	22	19	21	1	5	2	2	301	182	1	4	9	4	347	240
36	25	12	24	12	4	0	1	0	232	267	10	2	6	5	302	298
37	14	11	14	15	0	3	3	1	255	210	3	5	4	1	293	246
38	19	11	16	12	5	2	1	5	229	319	3	3	2	3	275	355

Appendix B Matlab code: calculating adjacency matrix

```
clear;
d1 = xlsread('d1.xls');
id1 = d1(:,3);
id2 = d1(:,4);
[l,~] = size(id1);
n = max(id2);
m = zeros(n,n);
for i = 1:l
   m(id1(i),id2(i)) = m(id1(i),id2(i)) + 1;
end
xlswrite('d1_dis.xlsx',m,'sheet1','B2');
```

Appendix C Calculating clustering coefficient

```
d1 = xlsread('d1.xls');
[m,~] = size(d1);
[h,~] = size(d2);
be1 = d1(:,3);
de1 = d1(:,4);
t1 = d1(:,6);
ts = 47;
tx = 49;

m1 = max(be2);
lj1 = zeros(m1,m1);
lj3 = zeros(m2,m2);
```

```
dt = zeros(ts,1);
dt2 = dt;
dtx = zeros(tx,1);
dtx2 = dtx;


n=1;
ms = 222;
hs = 97;
rg1 = zeros(ts,1);
for i = 1:ms
    if(t1(i)<60+(n-1)*60)
        lj1(be1(i),de1(i)) = lj1(be1(i),de1(i)) + 1;
    else
        sm1 = sy(lj1);
        rg1(n) = qv(sm1);
        lj1 = zeros(m1,m1);
        n = n + 1;
    end
end
n = 1;
lj2 = zeros(m1,m1);
rg2 = zeros(tx,1);
for i=ms+1:m
    if(t1(i)<60+(n-1)*60)
       lj2(be1(i),de1(i)) = lj2(be1(i),de1(i)) + 1;
    else
        sm2 = sy(lj2);
        rg2(n) = qv(sm2);
        lj2 = zeros(m1,m1);
        n = n + 1;
    end
end


function rg = qv(ma)
[m,~] = size(ma);
rv = zeros(m,1);
mb = ma;
nv = sum(mb,2);
dv = qd(mb);
dv = 2.*dv;
for i = 1:m
    if(nv(i)>0&(dv(i)>1))
      rv(i) = nv(i)./(dv(i)*(dv(i)-1)./2);
    end
end
rg = sum(rv);
rv(rv>0) = 1;
if sum(rv)>0
    rg = rg./sum(rv);
```

```
else
   rg = 0;
end
end

function d = qd(ma)
ma(ma>0) = 1;
d = sum(ma,2);
end
```

Appendix D Entropy weight method

```
function [newdat,p,e,w,score] = EWM(data,type)
  [m,n] = size(data);
  newdat = zeros(m,n);%Data standardization processing
  if(type==1)
    mean_dat = zeros(1,n);
    min_dat = zeros(1,n);
    max_dat = zeros(1,n);
    for j = 1:n
        mean_dat(j) = mean(data(:,j));
        min_dat(j) = min(data(:,j));
        max_dat(j) = max(data(:,j));
    end
    range_dat = max_dat - min_dat;
    for j = 1:n
        for i = 1:m
            newdat(i,j) = (data(i,j)-min_dat(j))/range_dat(j);
        end
    end

  else if(type==2)
       mean_dat = zeros(1,n);
       std_dat = zeros(1,n);
       for j = 1:n
         mean_dat(j) = mean(data(:,j));
         std_dat(j) = std(data(:,j));
       end
       for j = 1:n
          for i = 1:m
              newdat(i,j) = (data(i,j)-mean_dat(j))./std_dat(j);
          end
       end
       add = ceil(abs(min(newdat)));
       newdat = newdat + add;
      end
  end

  p = zeros(m,n);
  w_sum = zeros(1,n);
  for j = 1:n
      w_sum(j) = sum(newdat(:,j));
```

```
        for i = 1:m
          p(i,j) = newdat(i,j)./w_sum(j);
        end
    end

    p(p==0) = 0.0001;

    k = 1 ./ log(m);
    e = zeros(1,n);
    p_ln = p .* log(p);
    p_ln_col = sum(p_ln);
    for j = 1:n
       e(j) = -k .* p_ln_col(j);
    end
    d = 1 - e;

    w = zeros(1,n);
    for j = 1:n
        w(j) = d(j)./sum(d);
    end

    score = zeros(m,1);
    for i = 1:m
        score(i) = sum(data(i,:) .* w);
    end

end
```