YuShan2021 Team Description Paper for RoboCup2021

Zekai Cheng[1], Feng Zhang[1], Bolun Guang[1] and Liting Wang[1]

[1] Department of Computer Science, AnHui University of Technology, MaAnShan, P.R.China

YuShan2d@gmail.com

1 Introduction

YuShan Soccer 2D Simulation Team was established in 2009, affiliated with AnHui University of Technology in China. Having participated in RoboCup six times since 2012, YuShan team ranked 4th in the RoboCup2019 in Sydney, Australia and won three consecutive championships in RoboCup China Open Tournaments from 2016 to 2018. In recent years, YuShan team has used data mining technology to analyze the characteristics of the team, and on this basis, proposed a digital twin framework. In the formation, player movement, passing analysis, shooting strategy, offensive and defensive judgment as well as other aspects have achieved some results. The development of YuShan 2020 is depended on YuShan base, and YuShan base is based on the reconstruction project of agent-2d3.1.0 [1], mainly including attack module and defense module.

2 Three layer architecture based on digital twin framework

In 2019, YuShan team proposed a framework namely simulation 2D digital twin. Based on this framework, the team built portraits for each team, and YuShan 2020 was further optimized. As shown in Figure 1, the digital twin framework is divided into three parts: the physical layer, the information layer and the digital twin layer. The main function of the physical layer is to generate and manage the binary. The information

layer mainly processes and analyzes the log files. The digital twin layer establishes the team portrait, and feeds back the differences between the portraits to the physical layer to find a new research and development direction [2]. Based on the idea of digital twin framework, YuShan analyzes the gap between the team and the strong team in shooting, passing, formation and physical strength, so as to adjust the tactical strategy of the team in time, improves the performance of the team's attack and defense as well as the stability of passing and receiving the ball.

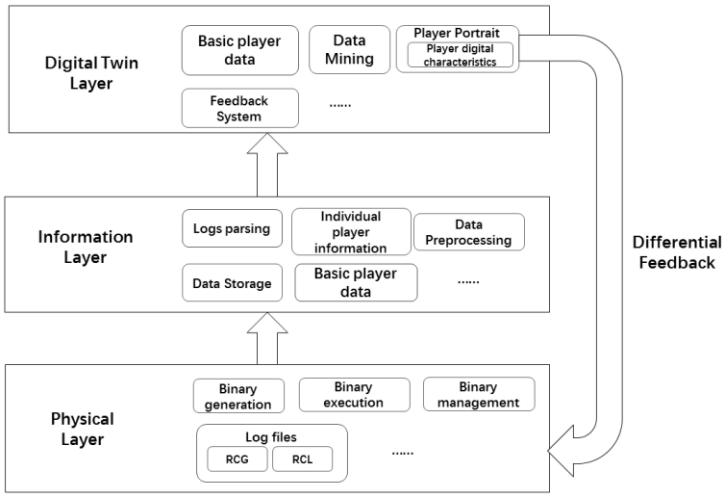


Figure 1. Three-layer architecture of the YuShan2020 digital twin framework

3 Using HFO to build the team's overall portraits

Generally speaking, the basis of judging the strength of a team is the score. Different teams have differences in attack and defense. How YuShan comprehensively analyzes the internal factors of the team's strength is the key to the team's research and development. YuShan2020 uses HFO [3] (half field offense) open-source tools to collect team information and build a comprehensive and overall digital portrait for the team. HFO is a local attack and defense drill platform limited to half court, which provides a standardized tool to evaluate the team's attack and defense performance. According to this characteristic of HFO, YuShan obtains the attack performance and defense performance metrics of the team.

HFO can set any attack and defense mode, YuShan adopts 6vs8 mode, that is, the attacker considers the forward and midfield players, and the defender considers the

defender and midfield players. Each round of test is set to 10000 cycles. YuShan utilizes TR, TG, DC, BOB, GR and other indicators to analyze the overall performance differences between teams. The above indicators can be obtained by using the python script provided by HFO, and the indicators are shown in Table 1.

Table 1. Definition and description of each indicator

Symbol	Unit	Meaning
TR	times（t）	The total number of rounds
TG	times（t）	The total number of goals
DC	times（t）	The number of defenders captures
BOB	times（t）	The number of balls out of bounds
GR	percentage（%）	Goal rate (the ratio of total goals to rounds)

HFO test adopts A-{B_1，B_2，… ，B_n} (a team and n Bi teams are tested respectively, referred to as A-NB) mode. The main purpose is to analyze the performance differences of different teams, such as offensive performance, defensive performance, combined with these differences, to further measure the overall performance of the team. YuShan selected base (agent2d), Helios 2013 [4], MT2019, YuShan2019, YuShan2013, YuShan2011 and other teams' binaries to test 75 rounds of matches in HFO environment in turn, and integrated and saved the original test data to CSV file. Table 2 selects some fragments of the original data.

Table 2. Partial fragments of the original data

Teams	TR	TG	DC	BOB	GR
……					
YuShan2019-Base	163	36	99	28	22.1
YuShan2019-Base	171	50	81	40	29.2
YuShan2019-Base	172	40	95	37	23.3
Helios2013-Base	102	34	40	28	33.3
Helios2013-Base	93	31	37	25	33.3
Helios2013-Base	89	31	35	23	34.8
……					

The component matrix, also known as the factor load matrix, is the coefficient of the factor expression of each original variable. The component matrix shows the influence degree of the extracted common factor (principal component) on the original variable. When extracting common factors, factor analysis not only pays attention to whether the variables are related, but considers the strength of the correlation, which makes the

extracted common factors not only play a role of dimension reduction, but can be well explained. YuShan uses the principal component extraction method of factor analysis to transform the original data into the form of component matrix, so that the common factor can be interpreted with the original variable with large load, so as to better explain the impact of each metric on the attack and defense performance.

It can be seen from the composition matrix in Table 3 that the first common factor is mainly interpreted by TG and GR, and the second common factor is mainly interpreted by DC and BOB. Therefore, YuShan takes the TG and GR of the first common factor as the indicators to measure the offensive performance of the team, and the DC and BOB of the second common factor as the indicators to measure the defensive performance of the team.

Table 3. The composition matrix after conversion of the original data

Performance indicator	Component 1	Component 2
TR	-0.049	0.296
TG	**0.902**	0.310
DC	0.003	**0.848**
BOB	-0.754	**0.558**
GR	**0.897**	0.278

Based on the results of component matrix analysis in Table 3, YuShan analyzes the performance differences of each team from two aspects of attack and defense, so as to establish the overall portrait of the team. Through the visualization of the integrated data, the team's attack performance chart and defense performance chart are obtained. The attack and defense performance are described by radar chart. The performance difference of the team is reflected by the encircling area and extending distance of the corresponding curve of different indexes/metrics on the radar chart.

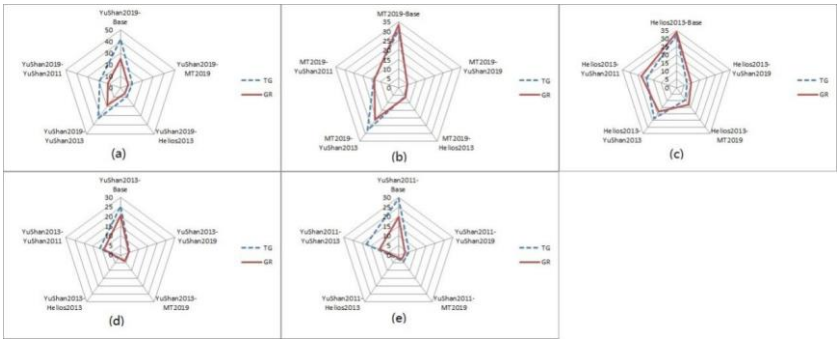


Figure 2. Team offensive performance diagram

From Figure 2, it is easy to know the difference of attack portraits of each team:

1. Take the test of base in Figure 2 (a) - (c) as an example: combined with Figure 2 (a), it can be seen that the TG curve of YuShan2019 extends far, indicating that YuShan2019 has strong attack, but the gap between GR curve and TG curve is large, indicating that YuShan2019's attack is not stable. Combined with Figure 2 (b) ~ (c), it can be seen that MT2019 is highly offensive, and the GR curve extends beyond TG, indicating that MT2019 is relatively stable in attack. Helios 2013 has a relatively balanced attack strength and stability.
2. Combined with the surrounding area and extension distance of TG and GR curves in Figure 2, the relative relationship between the team's attack strength and stability is expressed by '≻', and the relative relationship between the team's attack strength is: Helios2013 ≻ YuShan2019 ≻ MT2019 ≻ YuShan2011 ≻ YuShan2013. The relative relationship of attack stability is: Helios2013 ≻ MT2019 ≻ YuShan2019 ≻ YuShan2011 ≻ YuShan2013.

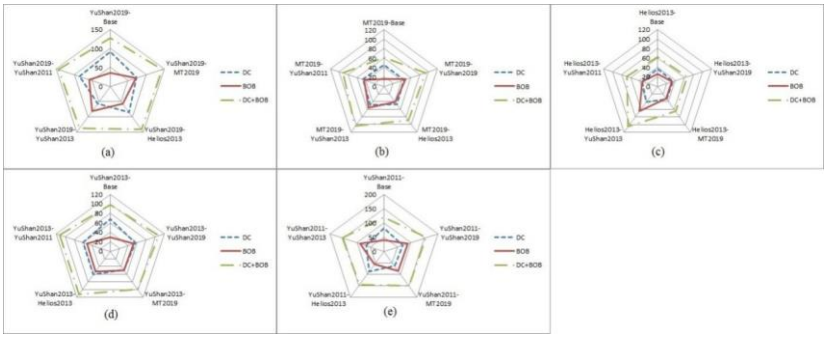


Figure 3. Team defensive performance diagram

From Figure 3, it is easy to know the differences of defense portraits of each team:

1. Take Figure 3 (d) as an example: the DC + BOB curve extension distance of YuShan2019 is greater than MT2019, less than Helios2013 and YuShan2011, indicating that YuShan2019 defenders' oppression is higher than MT2019, lower than helios2013 and YuShan2011.
2. Combined with DC, BOB, DC + BOB curve surrounding area and extension distance in Figure 3, the relative relationship of team compression degree is expressed with '≻ ': Helios2013 ≻ YuShan2013 ≻ YuShan2011 ≻ YuShan2019 ≻ MT2019.
3. Combined with the extended distance of TG curve in Figure 2, YuShan introduces OG (offensive goal number) index to measure the defensive strength of the team.

The lower the OG, the higher the defensive strength of the team. Using '≻' to express the relative relationship of the defensive strength of the team: Helios2013 ≻ YuShan2019 ≻ MT2019 ≻ YuShan2013 ≻ YuShan2011.

YuShan further summarizes the performance of each team and uses ☆ to indicate the relative strength relationship between each team's performance. The overall portrait of the team is obtained from the combination of offensive performance and defensive performance, as shown in Table 4.

Table 4. The comparison of the overall team portrait

Teams	Offensive intensity	Offensive stability	Defensive pressure	Defensive intensity
YuShan2019	☆☆☆☆☆	☆☆☆	☆☆	☆☆☆☆
MT2019	☆☆☆☆	☆☆☆☆	☆	☆☆☆
Helios2013	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆
YuShan2013	☆	☆	☆☆☆☆	☆☆
YuShan2011	☆☆	☆☆	☆☆☆	☆

Combined with the differences between the team's overall portraits, it can be concluded that a strong team (such as Helios) generally improves its overall stability performance to the maximum extent under the premise of ensuring the attack and defense intensity. Therefore, YuShan takes the offensive and defensive performance of the team as the focus of research and development. Through the analysis of the key areas of the team's attack, the team's attack portrait is constructed, and the similarities and differences in the attack and defense strategies of different teams are obtained.

4 Analysis on the key areas of team attack

In 2019, Helios extracted kick data by processing log files, and analyzed the similarity of kick data of different teams to find the commonness between teams[5]. There are some similarities and differences between different teams in offense and defense. In the game, the key to the victory of the enemy is the offense and defense, if the other team can defense the key areas of offensive will reduce the team's points. YuShan used to watch a lot of video to find weak defensive areas and key offensive areas, which took time and effort. It would be more scientific and reasonable to use data mining technology to analyze the weak defensive area and the key offensive area according to the characteristics of each team. Based on this, YuShan conducted in-depth research on the problem of targeted defense in key areas of attack for

different teams.

In the research process of the team's attacking key areas, we are divided into the following steps:

Step1: Through the analysis of the log file, draw the players' attack path diagram and the players' passing relation diagram.

Step2: The distribution of the position of the ball in the attacking path is analyzed to divide the court.

Step3: The adaptive density clustering algorithm is used to locate the balls in different areas to obtain the key areas of the team's offense.

Step4: The defensive strategy is obtained by comparing the key player's passing sequence to the key area of the offense.

YuShan first parsed the log files from the game, extracting information from the RCG and RCL files about where the ball was when our players issued the kick command. If successive kicks are given by our players, we call the sequence of kicks a chain of action. If the chain starts in our half and ends below the other team's penalty area (the ball position coordinates X>36.0), we call this chain an offensive chain. YuShan links the position coordinates of the balls in the chain of all offensive moves in a game to get a team's chain of offensive moves. As shown in figure 4.1(a), the offensive movement chain diagram of a team on the left side.

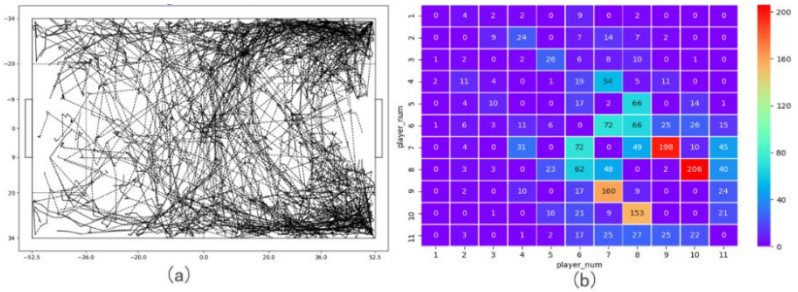


Figure 4.1 the team's offensive movement chain and passing heat diagram

It can be seen from figure 4.1(a) that the team's movement chain crosses more in the side area of the other team's half, indicating that the team's attacking strategy is mainly to go down the other side's side and have an obvious cross in front of the penalty area. In all chains of movement, if the last kicker is different from the next, we consider it a pass. All passing movements were taken out to form the player passing frequency shown in figure 4.1(b). From the passing frequency between players of this team, it can be seen that players 7 and 9, 8 and 10 have the highest passing frequency, so players 7,

8, 9 and 10 should be focused on players in the game.

4.1 Course Area Division

The traditional way of partitioning is through figure 6.2(a), but the partitioning is fixed. By analyzing the movement chain of the team in the game, it can be known that the team's offensive path has different focuses, that is, the position of the ball is not evenly distributed in the whole court, and there is a big gap between different areas. In light of this fact YuShan used a dynamic zonal algorithm to calculate the team's key areas on offense.

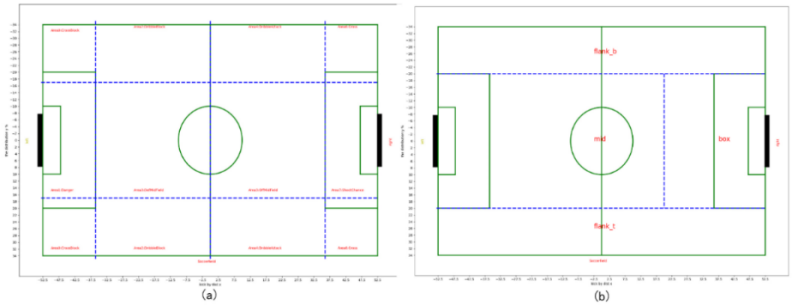


Figure 4.2 course division diagram

The position coordinates of the ball are collected from the offensive movement chain, and the position coordinates are projected on the X-axis and Y-axis respectively. For example, the position of the ball collected in the offensive action chain is two-dimensional coordinates :(x_1,y_1),(x_2,y_2)... (x_n,y_n), projected onto the X-axis, becomes a series of one-dimensional vectors consisting of points on the X-axis :$(x_1,x_2...$ $x_n)$, The projection operation on the Y axis turns into a series of one-dimensional vectors Y composed of points on the Y axis :$(y_1,y_2... y_n)$. The gaussian kernel function was used to fit the data distribution on vector X and vector Y, and the trough with the greatest difference in data change rate on the left and right sides of the image was selected as the dividing point. Figure 4.3(a) and figure 4.3(b) are the results of fitting the data on vector X and vector Y, respectively. According to this figure, we divided the field into areas, as shown in figure 4.2(b):

(1) In the Y direction, it is bounded by -20 and 20 into (-34,-20), (-20,20) and (20,34);

(2) In the X direction, it is bounded by 20 into (-52.5,20) and (20,52.5).

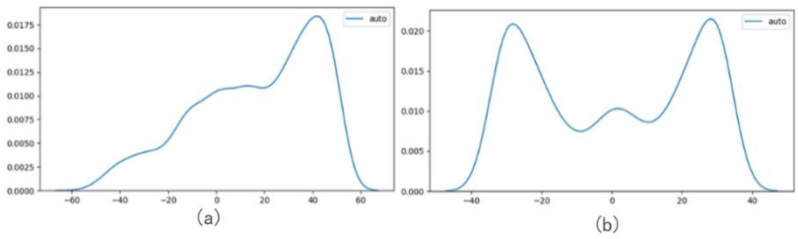


Figure 4.3 data distribution diagram of X axis and Y axis

4.2 Analysis of key areas of Offensive

After using the dynamic field division method, we divided the field into four parts and used the adaptive DBSCAN algorithm to cluster the team's offensive key areas for each part. Since the density clustering (DBSCAN) algorithm [8] is insensitive to outliers of data and can cluster any shape that conforms to the actual clustering, YuShan adopted the DBSCAN algorithm with adaptive parameters to cluster the location points in different regions. DBSCAN algorithm for adaptive parameters is to generate candidate cluster radius (Eps) and cluster point (MinPts) parameters by using the distribution characteristics of the data set, automatically find the stable interval of cluster number change of clustering results, and take Eps and MinPts with the minimum density threshold in the region as the optimal parameters [6]. Using the algorithm, YuShan found that the number of points in each zone was very large, as the number of matches tested was more than 10, in particular, the middle and side can reach more than 10,000 points. Because this algorithm needs to calculate the distance between every two points to form the distance matrix, the size of the distance matrix formed is very large and the time complexity is very high. To solve this problem, YuShan adopted the method of systematic sampling to sample areas with too much data, effectively reducing the time complexity while keeping the data distribution as constant as possible. Figure 4.4 shows that the field is divided into four regions of flank_t, flank_b, mid and box through data distribution. Triangles, triangles, circles and squares are used to represent the clustering points in each region, and the clustering results are obtained according to DBSCAN algorithm of adaptive parameters.

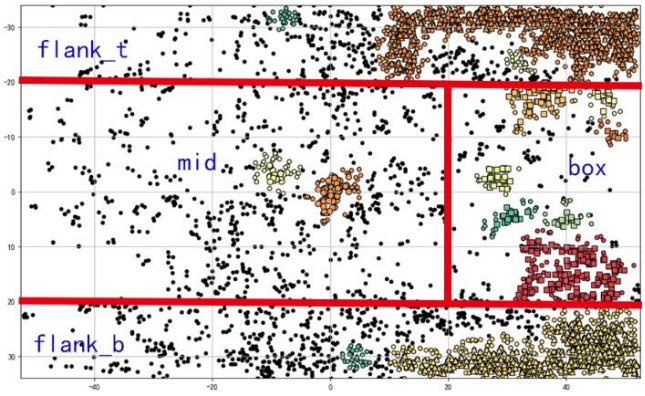


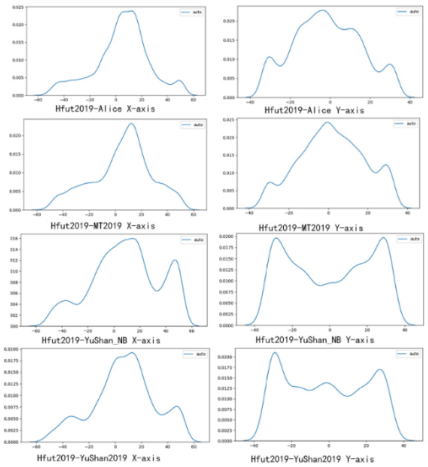
Figure 4.4 DBSCAN clustering result graph of sub-region adaptive parameter

4.3 Defensive strategy analysis

In the physical layer, YuShan selected the Hfut2019(national competition) team as the benchmark and tested them in Alice, MT2019, YuShan_NB and YuShan2019 respectively. 10 matches were played between each team and RCG and RCL data generated for every 10 matches were kept separately. Extract the offensive action chain of each game, and store the attack action chain of every ten games in the same file, and divide each action chain by newline.

In the digital twin layer, the ball's position coordinates are extracted for each action chain, and the gaussian kernel function is used to fit the ball's position points on the offensive action chain. The fitting results are shown in figure 4.5. It can be seen from the data distribution map that the data distribution of Hfut2019 is very similar to that of Alice and MT2019, and that of Hfut2019 is very similar to that of YuShan_NB and YuShan2019. The data distribution regions of different test teams and the calculation results of adaptive Eps and Minpts in different regions are shown in table 4.6.

Table 4.6 adaptive Eps and Minpts values



A-B	Area(x, y)	Eps	MinPts
Hfut2019-Alice	mid(x<30, |y|<20)	3.4	19.18
	box(x>30, |y|<20)	5.1	39
	flank_t(y<-20)	2.15	26.03
	flank_b(y>20)	2.79	27.35
Hfut2019-MT2019	mid(x<20, |y|<20)	3.07	30.59
	box(x>20, |y|<20)	2.33	18.85
	flank_t(y<-20)	3.2	25.28
	flank_b(y>20)	2.43	21.36
Hfut2019-YuShan_NB	mid(x<30, |y|<10)	2.94	28.97
	box(x>30, |y|<10)	2.5	18.89
	flank_t(y<-10)	4.38	34.56
	flank_b(y>10)	2.72	15.14
Hfut2019-YuShan2019	mid(x<30, |y|<20)	4.14	36.97
	box(x>30, |y|<20)	3.59	10.08
	flank_t(y<-20)	1.74	18.28
	flank_b(y>20)	3.28	27.91

Figure 4.5 data distribution of different teams

YuShan divided each pair of test teams' pitches according to their data distribution and conducted an adaptive DBSCAN cluster within each zone to obtain their attack critical areas. According to the heat map of passing, the key players (players who pass more than 70 passes to each other are regarded as key players) are taken out. The passing sequence pairs are shown in figure 4.7. It can be seen from the clustering results and the key player passing sequence pairs that Hfut2019 plays very similar to Alice and MT2019, and YuShan can get its offensive characteristics:

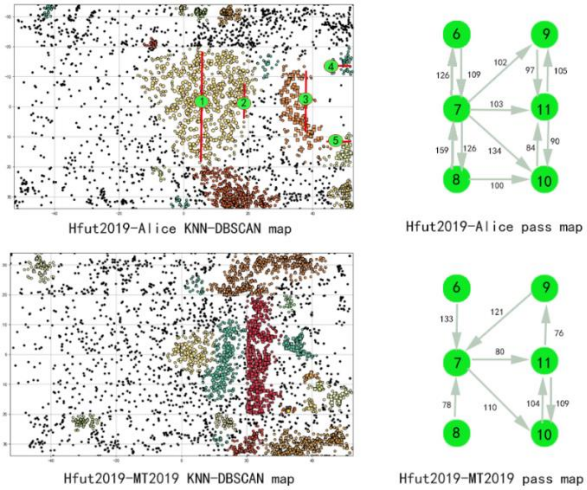


Figure 4.7 adaptive DBSCAN and pass-order pair figure (1)

(1) Player 7 passes the ball to the forward and dribble from the middle to the

penalty area.

(2) Player 7 is the key player in attack, the hub connecting the midfield and the front field.

(3) In the offensive, the three forward 9, 10, 11 cooperate very closely.

According to their attack portrait, Alice and MT2019 can properly adjust the player base to carry out three-tier defense against this team, as shown in figure 6.7 in "hfut2019-alice KNN-DBSCAN map":

(1) Retract the striker to the "1" area of the picture and defend in midfield.

(2) Place part of the midfield player in the "2" area and watch the opponent's player 7.

(3) Near the penalty area, put the remaining midfielders and some defenders in the 4 and 5 zones to block passes, and the rest in the 3 zone to stop shots.

Hfut2019 is similar to YuShan_NB and YuShan2019, and we can get its offensive characteristics according to figure 4.8.

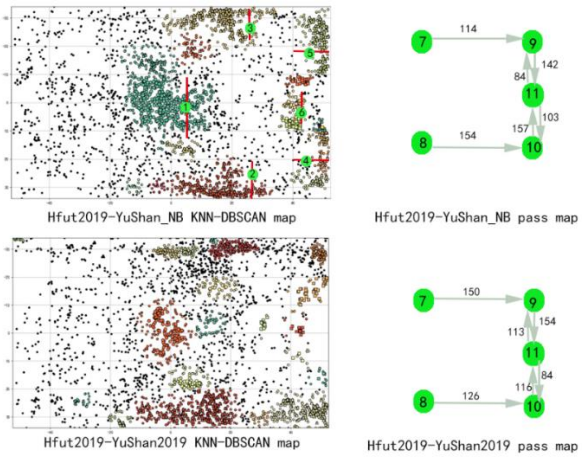


Figure 4.8 adaptive DBSCAN and pass-order pair figure (2)

(1) From the side 7, 8 will pass the ball to the forward 9, 10, along the side to the penalty area for dribbling.

(2) In the offensive between 9, 10, 11 relatively close cooperation.

According to its offensive portrait, we can properly adjust the players' base points for a three-tier defense, as shown in figure 6.8 "hfut2019-yushan2019 KNN-DBSCAN map":

(1) We may withdraw the striker to the "1" zone as appropriate and engage in

midfield defence.

(2) Our midfield can place some players in the 2 and 3 areas to prevent them from dribbling to the penalty area.

(3) Near the penalty area, put the remaining midfielders and some defenders in the 4 and 5 zones to block passes, and the rest in the 6 zone to stop shots.

4.4 Simulation experiment and results

In the feedback layer, we selected hfut2019-yushan_nb as the analysis object (Hfut2019 is referred to as team H and YuShan_NB is referred to as team Y), modified the YuShan_NB code, and carried out simulation experiment verification. According to the above analysis of the defensive strategy made the following three plans:

A: 6 players on team Y watches 11 players on team H. Team Y's 8 players ran between 7 players and 9 players, limiting team H's 7 players pass to 9 players. Team Y 7 players ran between team H 8 players and 10 players, limiting the pass from team H 8 players to 10 players.

B: on the side, team Y's no. 4 and no. 5 players execute the movement logic according to the maximum strength, prevent team H's no. 9 and no. 10 from going down the side, and modify the base point of team Y's no. 4 and no. 5 side to make it as close to the ball as possible.

C: based on plan B and A, team Y's no. 2 and no. 3 watch team H's players in the penalty area.

Let Hfut2019 play 10 matches respectively in the modified teams (hereinafter referred to as team A, team B and team C according to the revised plans of A, B and C), and record the number of goals, losses and times on the field in every 10 matches.

Table 4.9 Hfut2019 test data table with different teams

Teams	goals	losses	avg
Y	0	48	0
A	0	33	0
B	1	23	0
C	1	20	1

It can be seen from the table that after the improvement, team A, team B and team C lost A lot less than team Y. The number of lost balls extracted from the table is compared with YuShan_NB on the bar chart, as shown in figure 4.10.

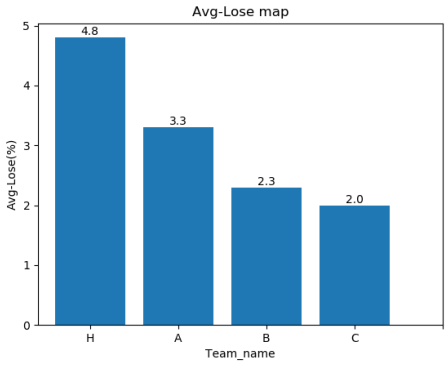


Figure 4.10 average team loss rate

As can be seen from figure 4.10, the improved A, B and C versions have greatly improved the defense of YuShan_NB team compared with the unchanged version. This paper illustrates the effectiveness of the three schemes A, B and C designed, and also verifies the correctness of the extraction of the team's attack key areas.

5 Summary and Prospect

Based on the simulation 2D digital twin framework, YuShan2020 initially uses HFO open-source tools to build an overall portrait of the team, and on this basis, it makes an in-depth analysis of the different teams attacking key areas. Finally, it analyzes the differences between the portraits, guides the research and development direction of the underlying code, and effectively improves the overall performance of the team. YuShan will further build a more comprehensive team portrait, and at the same time consider combining human football game [7] with simulation 2D game, mining the common mode of the two. I would like to express my sincere thanks to hidehisa Akiyama and others for promoting the 2D alliance over the years.

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