Research Article

Design and Research of Dynamic Evolution System in Football Tactics Under Computational Intelligence

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With the rapid development of computer vision, it has been widely used in football. Aiming at the problems of incomplete collection of information, poor operability of system, and bad practical application in the field of football match, an analysis system of football tactics is designed in this paper. Combining the requirements of functions and performance, the analysis system is divided into management of basic information, collection of tactical information, detection of passing pattern, inquiry of tactical information, and visual display, which puts forward the method of the detection of passing pattern based on model. Through the intelligent design, the visual display of the information of athlete, team, competition, tactics, and passing pattern is realized under computational intelligence, which has certain practical value in application.

1. Introduction

Football is the most popular competitive sport in the world, which attracts hundreds of millions of spectators and has high commercial value. It is not only colorful in technology but also unpredictable in tactics that its flexibility and variability attract countless audiences to be fascinated, and it also stimulates the enthusiasm of research by scholars. Strategies are a significant component that influences the presentation of football players, and whether it is applied properly is the decisive factor that affects the result of football matches [1]. Consequently, to work on the strategic level in football, it is important to set up a logical strategic examination framework to help mentors to settle on logical choices by concentrating on the strategic principles in football.

With the rapid development of computer vision, computer vision technology has been widely used in football. Examples include video assistant referee (VAR) and goal line technology. In recent years, computer intelligent algorithm has been widely used in the tactical decision-making research of competitive football. Machine learning algorithms are used to make judgements about events and situations during matches and perform qualitative or quantitative analysis of the attributes of the event, such as rating the quality of threatening shots or passes. In addition, Artificial Neural Networks (ANN) are often used in the research of football tactics, which can analyze tactics according to position data. By running a simulation to see how Artificial Intelligence (AI) teams behave in certain situations, AI teams are created by “ghosting” the features of ordinary and top teams. Deep imitation learning is used here by AI teams to compare the actions of their players to the league average or the top teams in the league.

Thanks to these devices and technologies, people can easily collect a large number of fine-grained data in football matches, such as the behavior and spatial position of players at every moment, so as to master the tactical skills and rules of football players. In addition, with the help of computer technology, collecting and processing complex data of football matches to complete football tactical analysis has become the current focus, which has high academic value and broad prospects of application. At present, some scholars have studied the analysis system of football tactics,
put forward the information collection scheme consistent with the football match, and established the model of corresponding data [2]. The video information is integrated into the tactical information, and at the same time, simple data is input by mouse and keyboard to analyze more complicated information intelligently, which breaks away from the traditional manual statistical mode to the maximum extent [3]. However, the systems are only limited to the collection of football tactical information, which is lack of detection on football tactical tracking. Based on this, the design of analysis system of football tactics in this paper can extract useful information from football matches more conveniently and make the collected data more complete, which is of practical significance to the development of China’s football industry.

2. Requirements Analysis of Football Tactical Analysis System

2.1. Analysis Functional Requirements. Football tactical analysis system is a subsystem of the research project of the State Sports General Administration. Its purpose is to realize the collection and tracking of football tactics information of players, so as to master the tactics skills and rules of football players and guide the daily training of players and the on-the-spot decisions of coaches.

The football tactical analysis system is an interactive system, which includes the detection module of backend passing pattern and the frontend visual analysis module, which concretely realizes the following basic functions.

2.1.1. Management of Basic Information. Management of basic information is the basic function of football tactics analysis system, which mainly manages information of players, teams, and competitions by adding, modifying, deleting, and inquiring.

2.1.2. Collection of Tactical Information. Collection of tactical information mainly includes the collection of the information of athlete’s position and event. Among them, location information is collected by sensors, and event data is marked manually.

2.1.3. Detection of Passing Pattern. Passing pattern detection is the core function of football tactical analysis system, which provides the basis for tactical analysis. According to the players’ passing strategies, their tendency is analyzed by focusing on the grasp of the scale of football passing and the judgement of their patterns and strategies.

2.1.4. Inquiry of Tactical Information. By inputting related keywords such as specific competitions, specific teams, and specific athletes, the tactical information of athletes can be searched and queried, and the categories of tactics and relevant information can also be inquired.

2.1.5. Visual Display. The visual display of football tactical analysis system mainly displays basic information management, collection of tactical information, detection of passing pattern, and inquiry of tactical information.

2.2. Analysis of Performance Requirement. In addition to meeting the functional requirements above, the system also needs to meet the performance requirements.

2.2.1. Applicability. Combined with the characteristics of the football field, the football tactical analysis system adopts the interface in mainstream design style, so that the operation of the interface is professional, simple, and smooth, which conforms to the operation habits of football practitioners [4]. In this paper, Action Script3.0 is adopted, and the interface of football tactics analysis system is designed by using programmable and visual operation mode. The function controls and football and player controls in the system can be redesigned and can be redeveloped by dragging and setting attribute, which will improve the applicability and expansibility of the system.

2.2.2. Maintainability and High Scalability. As the antagonistic sport of football is constantly developing, and the tactics and rules of football are constantly progressing [5], it is necessary that the football tactics analysis system designed in this paper has strong maintainability and high expansibility to ensure that football practitioners can continue to use the system through the expansion and maintenance of it when the demand for the system is expanded.

2.2.3. Stability. Football tactical analysis is not only used in normal teaching and training, but also used in on-the-spot matches. It is necessary to ensure the stability of the function when designing the function of football tactics analysis system [6]. If tactical analysis and rehearsal fail due to unstable functions, the consequences will be unimaginable.

2.2.4. Sensitivity. For the football tactics analysis system designed in this paper is mainly used for the analysis and rehearsal of football tactics, football practitioners need to explain and speak tactics [7] by controlling the football and players’ controls, which requires the football tactics analysis system to be highly sensitive in the processing of control movement, and quickly respond to the user’s actions, to make the tactics be explained smoothly.

3. Design of Football Tactics Analysis System

Combining the analysis of functional requirements and performance requirements of the football tactical analysis system, the overall framework and core functions of the system are designed.
3.1. Requirements of System Architecture. The architecture requirements of the football tactics analysis system designed in this paper are as follows:

1. The football tactics analysis system is designed with three-tier architecture, and the programming language is Action Script 3.0 [8].

2. The system runs in C/S mode.

3. Data storage of football tactics analysis system uses XML to process and interact with data [9].

4. The system adopts modular design [10], which enhances the expansibility of the system, reduces the coupling degree between the functional modules of the system, and provides convenience for the upgrade of the system.

5. The system is built with knowledge base [11], SQL SERVER 2005 is used to build the database for the data needed for retrieval, and XML documents are built for the information described by tactics and rules.

3.2. Design of Core Function. Through the demand analysis of football tactical analysis system, its core functions can be divided into management of basic information, collection of tactical information, detection of passing pattern, inquiry of tactical information, visual display, and others. The functional structure of the system is shown in Figure 1.

The basic information module is the preparation part of data, including athlete information, competition information, etc. Passing pattern detection is the core function of football tactical analysis system. Tactical information collection, tactical information query, and visual display are the key modules of football tactical analysis system, which realize the collection logic and analysis and statistics logic, respectively.

3.2.1. Basic Information Management. The executives of essential data is comprised of three sections, specifically competitor data, group data, and contest data. Each sort of data is recorded by a different information base table in the data set. Athlete information, team information, and competition information are stored relatively independently, and the association among them is established in the database with the AthleteIn-Match table [12]. In the system, every kind of basic information can be added and modified.

Basic information is the important related information of tactical acquisition and the subject of information analysis, so it is very important to record basic information correctly. In the football tactics analysis system, the correctness of basic information will be checked, such as whether necessary information is added and whether the
team information and player information corresponding to the game are correct which will be further checked before data collection. For example, in a football match, each team is required to have 11 players. Before data collection, the system will automatically detect the number of players of the two teams in the match. When the basic information is incorrect, a prompt will be given correctly, and the data acquisition module will not be open.

3.2.2. Collection of Tactical Information. Module of collection of tactical information is the main logic module of football tactical analysis system. The module of game integrates the function of video playback, which can be played back in a single frame, fast forward, fast rewind, and select the playback speed [13]. It can be collected after opening the corresponding game video.

Collection tactical information mainly includes the data of position and event of players.

At present, scholars mainly use image gray information to segment images in video sequences [14]. However, the information of the image’s original color is ignored when recognizing the football trajectory, so the results often have problems with large error and slow recognition speed. Compared with traditional tracking of pedestrian, athletes often move quickly with unpredictable directions, such as sudden stop, deceptive feint, and collision with players, which increases the difficulty of tracking. Therefore, the selection of acceleration sensor is adopted to collect data of players’ position. Kalman filter model [15] is introduced to filter the data collected by sensors; the model [16] can be expressed by formula (1):

$$x_m = \phi_m x_m + \delta_m,$$

where $x_m$ matrix represents system state, $\phi_m$ represents a matrix of system state transition, and $\delta_m$ indicates system noise. The data of motion trajectory is input into the Kalman filter model, and the new state data collected are sequentially input into the update equation to obtain the dynamic data of football motion trajectory with the elimination of noise. Then, the estimated value is updated, the noise variance and forward prediction are calculated according to the measured value, while the estimated value is returned to the Kalman filter model again, and the cycle is also repeated. Finally, the filtering is stopped until the motion of the soccer curve ball stops and all the values of updated input are 0.

Event data refers to a series of events that happen on the court [17], such as passing, shooting, and scoring. Event data is marked manually. Users browse the game video on an interactive interface and mark events by clicking and recording. A user needs about 90 minutes to complete the event collection of a game.

In the football tactical analysis system, a storage object and related processing method of technical information and tactical information in attack sequence are provided to realize the encapsulation of storage and management of tactical information [18], in which the storage objects of technical information and tactical information are sat Recs and tactics Rec, respectively. In the process of collecting, every technical action is abstracted as the process of catching and delivering the football. The process corresponds to a technical record, which records the team in ball control, players in ball control, positions of starting and ending site, technical action types, video clips, and other information. The algorithm only needs to operate in the memory to realize the function of recovery, without frequently reading and writing, which improves the system effectively. The logic flow of acquisition is shown in Figure 2.

3.2.3. Detection of Passing Pattern. In the football tactical analysis system, detection of passing pattern is the core function where scholars mainly adopt the network-based method [19] and the sequence-based method [20]. The organization based technique totals players’ passing records to get a coordinated graph [21], in which the hubs address players and the lines address recurrence of passing between players. Arrangement based strategy respects a progression of successive passes in a group assault as a grouping, while in view of the examination of example mining in arrangement information, the discovery of passing examples is like the model of text. The occurrence of players observed in the passing sequence is the result of implementing the passing strategy (which cannot be directly observed in the data) [22]. This is very similar to the idea of topic modeling; that is, the occurrence of word observed in natural text sequences is determined by the potential subjects [23].

On the basis of previous results, the detection of passing patterns based on topic model is proposed [24].

According to the passing strategy, players have a tendency to pass the ball. For example, when adopting the long pass strategy, the defender tends to pass the ball directly to the striker and attack. In this attack mode, the striker and defender will appear in the passing sequence at the same time with high frequency, while that is relatively rare in the midfield. Therefore, different strategies will lead to different cooccurrence modes of players, where patterns can make a more in-depth analysis of passing strategies. Therefore, subject modeling is used to detect the passing pattern, as shown in Figure 3.

First, establish a dictionary of players. For each stage, the continuous passing is transformed into a player sequence (A). Then, the model of word bag is used to transform the sequence of players into the one-heat vector pattern (B), where a number of football stages constitute the text library in the model. The text library is defined where $n$ represents the total number of football stages and $m$ represents the total number of players (C). Nonnegative matrix factorization (NMF) is used to extract subject model [25]. Compared with other algorithms, NMF has the advantage that it can easily support acceleration of parallelization.

Nonnegative Matrix Factorization (NMF) was proposed by Lee et al. [26], which first proposed block processing of data, providing a new idea for large-scale data processing. The principle of the algorithm is to express the original nonnegative matrix as the product of two small nonnegative matrices, improving the efficiency of data processing. Nonnegative matrix decomposition algorithm is introduced
into data processing according to the principle that physiological human perception as a whole is composed of local perception (pure additive) and constitutes global data by accumulating all parts of data [27]. Different from other feature extractions, NMF algorithm ensures that all data are nonnegative during processing. It has the advantages of interpretability, physical meaning, simple calculation, and small storage space, so it is widely used in pattern recognition, computer vision, biomedical, and other fields. Now, it has been applied to face recognition, image restoration, blind source separation, gene detection, and other directions [28]. NMF directly uses the relationship between data for matrix factorization, resulting in incomplete data mining. For data without labels, the essential high-dimensional features and sparse performance of the data are ignored, resulting in information waste and complex calculation. The NMF algorithm is used directly for the built-in label information, causing the label information to be ignored.

In order to describe the process of detection conveniently, this section will first describe the traditional NMF algorithm, which can be expressed as formula (2):

$$\min_{W,H} \|X - WH\|_F, \quad \text{s.t. } W > 0, H > 0,$$

where $W \in \mathbb{R}^{m \times k}, H \in \mathbb{R}^{k \times n}, \| \cdot \|_F$ represents the distance of L2, and $k$ represents the number of subjects. The subjects are represented by columns in the $W$ matrix. Each subject is about the distribution of players (D), and then the distribution of players is transformed into a passing pattern by extracting keywords, that is, a group of players who frequently pass each other. Next, judge which passing mode the passing in each stage belongs to, which can be accomplished by $H$ matrix. Each column in the $H$ matrix, namely, $c_i$, represents the weight of each football stage in each passing mode. According to the common allocation of subjects, the passing mode with the highest weight is allocated to the football stage [29]. Through this method, a group of passing patterns and the labels of each football stage can be successfully detected.

The implementation scheme of NMF algorithm is as follows:

1. All football stages in the match are divided into two categories, namely, the stage of defensive counter-attack and the stage of positional attack. Counter-attack defense represents a direct way of playing in which a team plays an attack with a small number of passes. Positional play means that the team makes a series of passes to control the ball and complete the attack. The two forms of attack are so different that experts often discuss them separately when conducting tactical analyses.

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**Figure 2: Flowchart of collection of tactical information.**
3.2.4. Tactical Information Inquiry. The football tactical analysis system provides the query function of flexible combination of multiple conditions. In the query module, users can query the technical and tactical information of specific competitions, specific teams, and specific athletes, respectively, and also query the categories of tactics, so that the system has the ability to analyze information from multiple angles. The query can be modified. When the technical information is modified, the system will automatically update the corresponding tactical information to keep it correct and consistent. The module integrates functions of video preview, cutting, and merging and then selects one or more records from the queried tactical information to preview their corresponding video clips. These clips can also be cut and merged into a video file, which is conducive to the preservation and extraction of effective information.

In addition, the system also has an important function of analysis; that is, the data can be counted by Excel and then be exported. According to the data commonly used in football, the system designs several templates of Excel data. Users only need to select the templates, and the system will statistically analyze the data in the background and then return the tables filled with corresponding data to the users, which makes the statistical data more comprehensive and correct.

3.2.5. Visual Display. Visualization has been widely used in analysis of football matches. Analysis of football tactics involves many kinds of data and models such as background, players, tactics, passing, and so on; in order to visually display football tactics, the system supports visual display, which mainly realizes visual display of basic information, tactical information, and passing patterns, which provides an effective tool for analysis of football tactics.

4. Visualization of Football Tactics Analysis System

Combined with the design of football tactical analysis system, the core functions of the system are displayed visually.

4.1. Visualization of Basic Information Management. Basic management is the basic function of football tactics analysis system, which mainly realizes the basic settings of the information of players, team, and competition. After determining the competition plan, it can be given priority to rapid formation. There are two teams in a football match; each team consists of 11 players. The players of each team can be divided into four roles: Goalkeeper, defender, midfielder, and striker, which indicates the relative positions of players on the court. Players’ roles can be subdivided according to their responsibilities, tactical needs, or players’ characteristics, such as left midfielder, attacking midfielder, and shadow striker. The formation of football tactical analysis system describes the position of players on the field, as shown in Figure 4.

4.2. Visualization of Collection of Tactical Information. Collection of tactical information is mainly realized by moving the controls of football and players, and at the same time, it records the trajectory of football and players in real time by drawing lines. Interface of tactical acquisition is shown in Figure 5. Firstly, the system determines whether the color selected by the user is red or blue. In the process of implementation, a status sign is set to TRUE when the user selects red; then the line follows the player’s movement and draws a red line.
4.3. Visualization of Detection of Passing Pattern. There are two types of information features in passing pattern detection, namely, the player’s identity and the player’s spatial position, as shown in Figure 6.

Figure 6 shows the passing pattern and its characteristics. Each node in (b) represents 11 players, and each small court on the right represents a passing pattern. The passing mode at the bottom represents the stage of defensive counterattack, while other passing modes represent the stage of positional attack. The heat map (B2) on the small court is used to indicate the position of players when passing the ball. By extracting the starting position and ending position of each passing trajectory, and expressing this spatial information through heat map, the diagram shows the statistical information of passing patterns. C2 shows the defensive effect of the defender, which is expressed by the coverage area of the defender that the higher the height, the worse the defensive effect.

The visual display of passing pattern is shown in Figure 7. In this visualization, each column consists of a series of icons, which represents the multidimensional information of passing in a stage. There are different technologies for visualizing multidimensional information, among which parallel coordinates and reduced-dimension projection are typical examples. According to the reference, the information of the first passer and the last catcher is considered as the most representative in a series of passing in the stage. Therefore, the information of both of them is used to
characterize the passing in a stage. For each stage, icons are used to show three types of information, namely, formation (A), player identity (B), and spatial position (C). The end event of the stage is placed at the bottom of the column (D). The density of the triangle in the middle of the column represents the number of passing in the stage.

The football tactical analysis system helps users to identify the similarities and differences of passing in different stages more quickly by displaying visualization of icon of multiple stages side by side. At the same time, cause-and-effect simulations can be done using dimensional and tabular views. Take Causality Explorer as an example to realize the simulation of football game, as shown in Figure 8. In the dimensional view, each histogram represents the data distribution of a variable in the data. The height of the column codes the proportion of each value to complete the interactive process of simulation deduction.

In particular, Flash software development tools are used to describe and demonstrate the interactive patterns and movement paths required in the football tactical rehearsal system. By using multitouch technology, the design and
rehearsal of football tactics with fingers are realized, and the process of tactical rehearsal is recorded and played back.

4.4. Visualization of Query of Tactical Information. Tactical information can be queried by the input of keywords. Take an athlete as an example; the visual display of his position is shown in Figure 9.

In order to save or print it permanently, it is necessary to export this tactical map from the system and store it in jpg format. Firstly, use Bitmap Data class to create an object containing the picture data obtained from the component, encode it into JPEG or PNG format by using the method provided by mx.graphics.codec package, and then save it locally by using the File and FileStream provided by AIRAPI.

5. Analysis of Systematic Effectiveness

5.1. Evaluation Methods. The data used in the system evaluation was a football tournament organized by CONMEBOL, which was the final match between Argentina and Brazil. In order to verify the effectiveness of the system, in the case study, the senior coach (E) with the Asian Football Confederation coaching certificate was invited to analyze the match between Argentina and Brazil, who already know the outcome of the game (i.e., the score, winner, and type of goal) before analyzing it. But this is the first time they have analyzed the game from a passing point of view. Before the case study, we demonstrated the use of the system to the experts. After the case study, we interviewed experts to gather their feedback and suggestions.
5.2. Evaluation Results. As there are many football tactics, this paper only tests the system with the counterattack strategy. The result is shown in Figure 10.

In this case, $E$ was invited to analyze the match between Argentina and Brazil. $E$ is very interested in passing on counterattack. At the beginning of the analysis, $E$ hovered over the pass pattern representing the defensive counter to see which players were deeply involved in the defensive counter. According to the bar chart of the players, $E$ found three important players in the counterattack defense,
namely, the two forward 9 and 11 players and a midfield 6 player (Figure A). According to the identities of the players, $E$ judged that most of the defensive counterattacks were initiated and completed by these three players. $E$ then look at the thermal map of the defensive counterattack to learn the specific spatial position information. $E$ stands for counterattack, usually when the team recovers the ball by closing down and moves the ball forward quickly to launch an attack. In the thermal map, $E$ found a highlighted area in the middle half of the circle (Figure B). $E$ says this means most of the counterattacks are likely to come from the back.

$E$ then turns to the mode stream to see when the team has used the counterattack and the result. The bar chart of defensive effectiveness, shown in Figure D, shows that Argentina most of the time attacked when the opposition was defending poorly. $E$ says it is a reasonable counterattack strategy. Through the time distribution of the stages, it is further found that the occasions of Argentina’s defensive counterattack are random. But towards the end of the second half (Figure C), Argentina’s attacking pattern changed and they began to play consistently on the counterattack. According to the end of the period, $E$ found that the switch allowed Argentina to take a one-goal lead (Figure C) and to continue to counter defensively at the end of the game after gaining the advantage. $E$ said Argentina reduced possession to avoid mistakes in the final stages to maintain their lead. $E$ then turns to the mode flow at the detail level to see the details of the counterattack defense.

Based on the observations, $E$ focuses on Argentina’s counterattack in the final period. According to the formation icon, $E$ finds that the position of the first passer in the formation gradually moves forward in the three reciprocal phases (Figure E). This meant that Argentina had more players involved in defensive pressing, leading to a shift in tackling positions. The defensive counterattack for the scoring opportunity was initiated by the number four on the right and ended by the number six being robbed out of bounds. In order to have a deeper understanding of how the counterattack creates goal chances, $E$ then jumps to the phase view to see the detailed process of the counterattack. $E$ found the counterattack created a corner for Argentina. Argentina then took advantage of the corner to score. Therefore, $E$ believes that the counterattack played an important role in Argentina’s victory. In this case, the expert found and studied the phenomenon of Argentina changing its passing strategy and using defensive counterattack through the model graph, which was consistent with the prediction results.

6. Conclusion

Football is a complex event of team sports. The traditional collection of skills and tactics is generally received by coaches, and then the participation of teams or players in the game are counted manually. Manual collection of information not only is cumbersome and inefficient, but also causes incomplete data and high rate of error, which will adversely affect the analysis of follow-up game. Through the investigation of football tactics, the design of football tactics analysis system is put forward in order to extract useful information from football matches more conveniently. In the design of the system, the emphasis is on the analysis of data collection and passing mode, while the method of collecting position data and event data of players is also put forward. The model of subject is used to detect the passing pattern. Through the design, the visualization of management of basic information, collection of tactical information, detection of passing pattern, query of tactical information, and other functions is realized, which has important practical significance and value.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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