

Computer diagnostics for the analysis of table tennis matches *

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Abstract. With the development of computer science and technology, the analysis of techniques and tactics of ball games is developing in three dimensions. First, the visualization technology is being employed in game analysis. Secondly, modern scientific computations are increasingly used in the diagnostic analysis. Thirdly, with more and more researches conducted in game analysis, people are beginning to be aware of the many factors which are likely to influence the performance of the players in ball games.

Keywords: computer diagnostics, analysis, table tennis

1. Introduction

With the development of computer science and technology, the analysis of techniques and tactics of ball games is developing in three dimensions. First, the visualization technology is being employed in game analysis. The application of computer multimedia technology, especially the application of video analysis system in the analysis of the characteristics of techniques and tactics (SIMI Scout, Dartfish, *utilius@VS*), has improved the understanding of the coaches and players about the technical and tactical characteristics of the opponents. (Zhang & Li, 2004; Zhao & Zhang, 2005; Zhang, 2006; Dai & Zhang 2008).

Secondly, modern scientific computations are increasingly used in the diagnostic analysis of ball games, such as the diagnostics through mathematic simulations of ball games (Lames, 1989, 1994, 1997; Zhang & Hohmann, 2004, 2006), the diagnostic models for techniques and tactics based on Artificial Neural Networks (Perl, 2002; Wang & Zhang, 2005, 2007; Xiao, Wu and Zhang, 2008), and the game analysis based on data mining technology (Schoeman, 2006; Osama, 2006, Gao & Zhao, 2006; Zhao, Yu and Zhang, 2008; Meng, Ling and Zhang, 2008; Wu, Li and Dai, 2008).

Thirdly, with more and more researches conducted in game analysis, people are beginning to be aware of the many factors which are likely to influence the performance of the players in ball games. Besides the techniques and tactics, the psychology, physical conditioning and game environments may also have certain influences on the game results. Hence the systemic integration research is beginning to be applied to game analysis, evaluations and prediction, a case in point is the analysis of table tennis matches with system dynamics or decision support system (Yu, Zhang, Ling and Meng, 2008). This paper serves as an introduction to the research findings of Professor Yu and her research team in table tennis program.

2. Analysis of technique and tactic indexes in table tennis matches

2.1 The attributes of techniques and tactics indexes fall into two types, the first type can be observed from games and described by data, including the technique, position, direction, effectiveness of the stroke. The second type of attributes can also exert influences on the characteristics of the players' techniques and tactics. These attributes include the rotation, rhythm, arc, velocity and force of the stroke, but they can only be obtained by rigid tests conducted in the lab (Table 1).

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Tab. 1: Attributes of techniques and tactics

Types of Attributes	Indexes of Techniques and tactics
First type	technique, position, direction, effect of the stroke, and game action,
Second type	rotation, speed, rhythm, arc and force of the stroke

2.2. The score system of table tennis is composed of points, games and matches. Therefore scores are closely influenced by the techniques and tactics employed in the competition. For example, different techniques and tactics are used in the beginning, middle and end of a game. So, in the analysis of techniques and tactics in table tennis competition, it is necessary to relate to scores for them to be truly reflecting the level of players and improving the reliability of the diagnostics and analysis of techniques and tactics.

2.3. Time sequencing is a main characteristic of table tennis. In table tennis matches, for example, each rally begins with one side' serving and the other side' receiving, and finishes when one or the other side scores. Time sequencing also characterizes table tennis tactics, for example, the tactics of attacking after serving, receiving and attacking, rally etc. Data mining is thus applicable to the analysis of table tennis tactics.

2.4. In a table tennis match, winning corresponds with losing, that is, when one scores, the other loses. Then converse reasoning can be made in tactics data. If one side scores by serving, it means the other side misplays in receiving; if one side misplays at the third stroke, then the other side scores by receiving, which makes it very convenient to collect data in the match.

2.5. According to the requirements of table tennis match analysis, the indexes for computer diagnosis and analysis of the table tennis are shown in table 2.

Tab. 2: Computer data collection indexes of the techniques and tactics in a table tennis match

Observation items	Technique and tactic indexes
Stroke technique	service, topspin, flip, fast attack, smash, chop, chopping shot, block, cut, push, short ball, get the lob
Stroke position	forehand, backhand, pivot, backhand turn
Stroke direction	short forehand, half-long forehand, long forehand, short backhand, half-long backhand, long backhand, short in the middle zone, half-long in the middle zone, long in the middle zone
Game action	serve, receive, neutral, offense, defense, control
Stroke effect	very good, good, general, bad, very bad
Result	point, rally, fault

3. Multimedia-based analysis of table tennis games

3.1. Multimedia-based analysis of techniques and tactics of table tennis games

The analysis of techniques and tactics of the table tennis began in 1960s, and reached its prime in 1990s. Wu and Zhang etc (1989 , 1990 , 2000) have long been using "three-phased-evaluation method" to analyze the competitive states and tactics level of elite player in their preparation for the Olympic Games and world Championships, which has proved quite effective. Li and Su (1998) propose a more detailed "ten-index evaluation method" of statistical analysis. By using mathematic simulation diagnostic method, Zhang and Hohmann (2004) carry out a systematic analysis of the techniques and tactics of world elite male players. The major forms of the above mentioned researches are illustrated in statistics, texts, data and graphs.

With the development of computer technology, multimedia analysis of techniques and tactics is characterized in the following aspects:

(1) The video data includes a much larger amount of information than words and statistical data. For example, as the most important technical and tactical index, the score or fault rate of serving and attacking only reflects the general circumstances of the player's serves and attacks in this game, but fails to reveal when the player scores, how he does and what techniques he uses in the game. Fortunately, the treated video data can cover all the key information about serves and attacks.

(2) The tactical information represented by video data, animations, graphs and words is vivid and clear.

It can help coaches and players observe, analyze and recollect the technical data.

(3) The interaction of technical and tactical multimedia analysis makes it possible for free controlling and intervening of the game information, and it helps direct more of the coaches and players' attention to the game information. It could also maintain the game information for longer time. What's more, by way of this interactivity, the coaches and players are likely to get more information on techniques and tactics and acquire a better understanding.

3.2. The basic methods of multimedia analysis of table tennis techniques and tactics

Multimedia Analysis can be divided into two kinds: technique analysis and tactic analysis. The former generally uses sequent pictures and slow play of the video for analysis, while the latter uses more of the combination of statistics, animations and videos.

The core elements of the multimedia analysis of techniques and tactics of table tennis singles are of five main parts: analysis of service, receiving, the third stroke, the fourth stroke and rally. The analyses are similar in doubles and singles. Since four players serve, receive and strike alternatively, technical and tactical analysis of doubles is also 4 sequenced: player A1 serves, player A2 strikes the 3rd bat; A2 receives, and A1 strikes the fourth bat; A2 serves, and A1 strikes the third bat; A1 receives, and A2 strikes the fourth bat.

Because attacking players and chopping players play in quite different styles, the contents for the second part of multimedia technical and tactical analysis are also different. The analysis mainly includes the service, receive, offensive of the attacking players and attacking, forehand and backhand chopping and defense techniques of the chopping players and so on (figure 1).

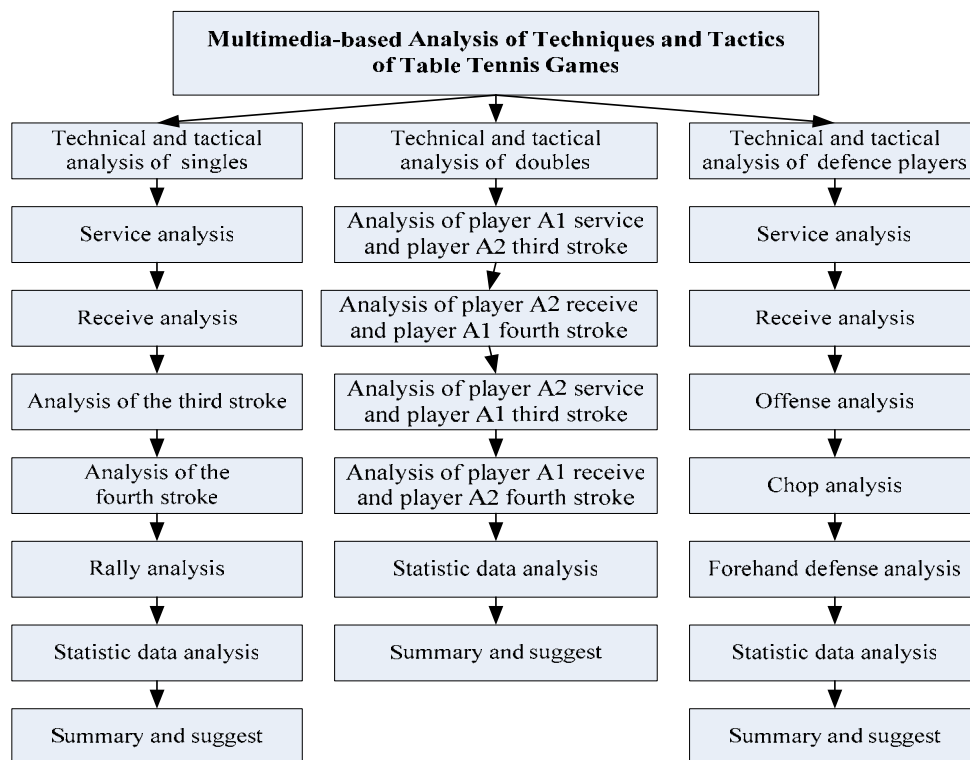


Fig.1: Technical and tactical analysis of Chinese table tennis team in preparation for the Olympics Games and World Championship

3.3. Instructions to multimedia-based analysis of techniques and tactics in table tennis matches

(1) Games with close scores are preferred for analysis, because players sometimes may exceed or play too much below themselves. Therefore if the two sides are too mismatched, the competition would not be able to reveal the true picture of their techniques and tactics, sometimes it may even be misleading.

(2) A combination of quantitative and qualitative analysis is necessary. In the analysis of table tennis games, too much data may baffle the coaches and players, because they are likely to miss the major points faced with so much information. Therefore, the key to the improvement of multimedia analysis is to

generalize the characteristics of the opponents' techniques and tactics with quantitative analysis, carry out high quality quantitative analysis and integrate with video recordings and the games.

(3) Left-handed and right-handed players should be treated differently. For example, LI Jia-wei (Singapore) plays quite different techniques and tactics when playing against different types of players. Therefore, if permitted, different analyses should be made on the matches not only with left-handed opponents but also with right-handed opponents.

4. Analysis and diagnosis of techniques and tactics based on data mining

Data Mining results from long time database technology research and development. Initially all kinds of commercial data were stored in the computer database, later people could easily inquire about and have access to the data base, finally the data base becomes instantly accessible. Database helps bring the data mining technology into an advanced stage. It can not only help people inquire about the historical data query and traverse, but also help identify the underlying relationships among data, thereby help generate useful information.

Yu, Zhang, Ling and Meng, etc (2007) developed an Interactive Multimedia System of data gathering and Intelligent Analysis of table tennis techniques and tactics. After a large number of technical and tactical data of world elite table tennis players is collected, the algorithms of association rules and the clusterings in Data Mining is applied and the following technique and tactic attributes are mined: stroke direction and stroke position according to the serve and receive round, and the research findings have been directly applied to Chinese table tennis team in their preparation for the 49th World Championships in 2008.

4.1. Analysis of the association characteristics of techniques and tactics in table tennis matches

According to the characteristics of table tennis competition and the requirements of technique and tactic analysis, the association characteristic analysis mainly seeks the following relationships: (1) The association characteristics between the directions of the first three strokes and the scoring/losing in the serve round; (2) The association characteristics between the positions of the first three strokes and the scoring/losing in the serve round; (3) The association characteristics between the techniques of the first three strokes and the scoring/losing in the serve round; (4) The association characteristics between the directions of the first three strokes and the scoring/losing in the receiving round; (5) The association characteristics between the positions of the first three strokes and the scoring/losing in the receiving round; (6) The association characteristics between the techniques of the first three strokes and the scoring/losing in the receiving round.

The following is the analysis of the German player Boll's techniques and tactics. He is a left-handed player, and in January 2008 he ranks the fifth of the world (next only to Chinese players). Seven matches were Boll VS Wang Hao (2005 Japan Open), Boll VS Wang Li-qin (2006 Guangzhou, China Open), Boll VS Wang Hao (2006 Hunan, China), Boll VS Ma Lin (2007 Kuwait Open), Boll VS Wang Hao (2007 World Cup), Boll VS Ma Lin (2007 Pro Tour Finals), Boll VS Wang Li-qin (2007 Finals, Hunan)

4.1.1. Association characteristics between Boll's serving/receiving directions and his scoring

Table 3 shows that if Boll serves the ball in short forehand zone, then his winning support is 23.49 percent, the confidence reaches the highest: 60.26 percent; if Boll serves the balls in short middle zone, then his winning support is 44.88 percent, the confidence is 55.70 percent.

Tab. 3: The relationship between BOLL's serving directions and his scoring

Serial number	Serve direction	Sup (%)	Conf (%)
1	Short middle zone	44.88	55.70
2	Short forehand zone	23.49	60.26
3	Short backhand zone	9.93	48.48
4	half-long middle zone	5.72	52.63

Table 4 shows the relationship between Boll's receiving direction and the scores. When the opponent serves to Boll's short middle zone, Boll strikes to the opponent's long backhand zone, the support rate is 8.33 percent, the confidence is 53.57 percent. But if Boll strikes to the opponent's long forehand zone, the support is the same, but the confidence is only 46.43 percent (sup=8.33%). Besides, if Boll strikes to the opponent's half-long middle zone, although the support rate is 5.06 percent, the confidence is more than 50.00 percent.

Tab. 4: The relationship between Boll's receiving directions and his scoring

Serial number	Receiving placement	Sup (%)	Conf (%)
1	Receiving in short middle zone →opponent's long backhand zone	8.33	53.57
2	Receiving in short middle zone →opponent's long forehand zone	8.33	46.43
3	Receiving in short middle zone →opponent's half-long backhand zone	7.44	36.00
4	Receiving in short middle zone →opponent's short forehand zone	6.85	39.13
5	Receiving in short middle zone →opponent's half-long middle zone	5.06	52.94

4.1.2. Association characteristics between the directions of the first two strokes of Boll and his opponent and Boll's scoring

Table 5 shows that when Boll serves to the other side's short middle zone and the opponent receives to Boll's short forehand zone, then the scoring support is 5.72 percent, and the confidence is 68.42 percent.

Tab. 5: The relationship between the directions of Boll's serving/the opponent's receiving and Boll's scoring

Serial number	Direction of serving and opponent's receiving	Sup (%)	Conf (%)
1	Serving to opponent's short middle zone→opponent receiving to short middle zone	8.43	35.71
2	Serving to opponent's short middle zone→opponent receiving to long middle zone	8.13	51.85
3	Serving to opponent's short middle zone→opponent receiving to long backhand zone	6.63	59.09
4	Serving to opponent's short middle zone→opponent receiving to short forehand zone	5.72	68.42
5	Serving to opponent's short middle zone →opponent receiving to long middle zone	5.72	57.89

When Boll “serves to the other side's short middle zone→the opponent hits to Boll's backhand back zone” and “serves to the other side's short middle zone→opponent hits to Boll's middle backhand zone”. The support of scores are 6.63% and 5.72%, and the relatively high level of confidence are 57.89 percent and 59.09 percent.

Tab. 6: The relationship between the directions of Boll's receiving/the opponent's third stroke and Boll's scoring

Serial number	Receiving direction and opponent's third stroke direction	Sup (%)	Conf (%)
1	Receiving from short middle zone to opponent's long forehand zone→opponent striking to long backhand zone	4.46	53.33
2	Receiving from short middle zone to opponent's long backhand zone→opponent striking to long backhand zone	4.46	46.67
3	Receiving from short middle zone to opponent's half-long backhand zone→opponent striking to long backhand zone	3.27	18.18

Table 6 shows the relationship of scores and directions between Boll's receiving and the opponent's third stroke. When Boll receives from short middle zone to the opponent's half-long backhand zone→the opponent strikes to long backhand zone. Although the support of scoring is only 3.27 percent, yet the level of confidence is also very low, only 18.18%, which is Boll's poorest link.

4.1.3. Association characteristics between three stroke directions of Boll/his opponent and Boll's scoring

Research shows that when Boll serves to short middle zone or short forehand zone, if the opponent strikes to Boll's long backhand zone, and Boll strikes the third stroke to opponent's long forehand zone, then his winning rate is higher. Though the supports are not high: 2.41 percent and 3.31 percent respectively, their corresponding confidences are 81.82 percent and 75.00 percent, as shown in Table 7:

Tab. 7: The relationship between first three stroke directions of Boll/ the opponent and Boll's scoring

Serial number	Directions of the first three strokes	Sup (%)	Conf (%)
1	Serving to the other side's short middle zone→opponent receiving to long backhand zone→striking to the opponent's long forehand zone	3.31	81.82
2	Serving to the other side's short middle zone→opponent receiving to half-long middle zone→striking to opponent's long backhand zone	2.71	44.44
3	Serving to the other side's short forehand zone→opponent receiving to long backhand zone→striking to opponent's long forehand zone	2.41	75.00

In addition, in the round of receiving, when Boll “receives from short middle zone to the other side's long forehand zone→the opponent strikes to long backhand zone→Boll strikes to the other side's long forehand zone”, then his winning support is 2.38 percent, and the confidence is 87.50 percent.

4.1.4. Association characteristics between first four stroke positions of Boll / his opponent's and Boll's scoring

The relationship between first four stroke positions of Boll/ his opponent and Boll's scoring is shown in Table 8. After Boll serves, the opponent receives at forehand position→Boll strikes at forehand position →his opponent strikes at backhand position, then Boll's winning support is 12.35 percent, and the confidence is 58.54 percent. One more thing noteworthy is that after Boll serves, the opponent receives at forehand position→Boll strikes at pivot position→the opponent strikes at forehand position, then his winning support is 4.22 percent, and the confidence is 71.43 percent.

4.2. Analysis of the time sequence patterns of technique and tactics in table tennis matches

The basic idea of data mining of technical and tactical sequence pattern in table tennis matches lies in that the technical and tactical database will be converted to the database the players' striking sequence. Then the search algorithm of large item sets will be used to calculate large item sets, which will be set as a first-scale sequence. Then all the large-scaled sequences are searched in turn and the subsequences are deleted from the big bands sequence, and finally the sequential pattern comes.

Tab. 8: The relationship between first four stroke positions of Boll / his opponent and Boll's scoring

Serial number	Positions of the first four strokes	Sup (%)	Conf (%)
1	Boll serving→opponent receiving at forehand→Boll striking at forehand→opponent striking at backhand	12.35	58.54
2	Boll serving→opponent receiving at forehand→Boll striking at forehand →opponent striking at forehand	9.34	58.06
3	Boll serving→opponent receiving at backhand→Boll striking at forehand→opponent striking at backhand	4.52	66.67
4	Boll serving→opponent receiving at forehand→Boll striking at forehand→opponent striking at forehand	4.52	66.67
5	Boll serving→opponent receiving at forehand→Boll striking at pivot→opponent striking at backhand	4.22	71.43

The rules for table tennis singles are: the first player serves legally, then the other player strikes legitimately, followed by alternative legal strikes between the two. Table tennis competition rules allow us to automatically obtain a set of chronological sequences of techniques and tactics. For example, player A serves to player B's backhand zone→player B strikes backhand loop to player A's forehand zone→player A strikes forehand loop to players B's forehand zone→player B strikes forehand loop and misses, from which the following technical sequence is obtained:

{A serving, B backhand loop in backhand zone, A forehand loop in forehand zone, B forehand loop in forehand zone}

All the players' technical and tactical winning sequences in the game can be collected according to the above rules, then the sequence patterns can be found through data mining algorithms. The following are examples of time sequence analyses of the techniques and tactics of Zhang Yi-ning (China) and Li Jia-wei (Singapore) in seven matches, Zhang and Li are all right-handed players, and ranked the second and the eighth of the world in January 2008 respectively.

4.2.1. Analysis of Zhang's main technical and tactical scoring sequences

Table 9 shows the mining results of Zhang's technical and tactical winning sequence patterns (taking the minimum threshold of $\text{sup} = 0.1$). Zhang's main technical and tactical scoring sequences are: (1) the sequence of "serving→backhand loop in the third stroke " has the highest scoring rate, up to 25 percent, followed by (2) the sequence of "serving→pivot loop in the third stroke ", with the scoring rate of 15 percent, and (3) the sequence of "serving→backhand loop in the third stroke→pivot loop in the fifth stroke " ranks the third, with a winning rate of 10 percent.

Tab. 9: Zhang's main technical and tactical scoring sequences

Technical and tactical sequences	Proportion
Serving→backhand loop in the third stroke	25%
Serving→pivot loop in the third stroke	15%
Serving→backhand loop in the third stroke→pivot loop in the fifth stroke	10%

4.2.2. Analysis of Li's main technical and tactical scoring sequences

LI's main technical and tactical scoring sequences are similar to Zhang: (1) the sequence of "serving→backhand loop in the third stroke " has the highest scoring rate, 23 percent, followed by the sequence of (2) "serving→forehand fast attacking in the third stroke ", with a scoring rate of 18%, and the sequence of (3)"serving→backhand loop in the third stroke→forehand fast attacking in the fifth stroke " ranks the third, with a scoring rate of 15 percent.

Tab. 10: Li's main technical and tactical scoring sequences

Technical and tactical sequence	Proportion
Serving→backhand loop in the third stroke	23%
Serving→forehand fast attacking in the third stroke	18%
Serving→backhand loop in the third stroke→forehand fast attacking in the fifth stroke	15%

5. The diagnosis and analysis of the techniques and tactics of table tennis based on Artificial Neural Network

The character of neural networks can be captured in the following words: "compared with the traditional ways of predicting, decision-making, planning, scheduling, it does not need to re-engineer any other mathematic model and only needs to establish a model according to input and output data, with the network statistical information stored in the huge weighted matrix. This unique self-organizing, self-learning, super fault-tolerating and information distribution storage capacity is promising in resolving the complex and uncertain nonlinear human movement systems. "

Another characteristic is that it can retain the mapping relationship between technical indexes and the performance of past games. When the player's technical and tactical level changes, as long as the latest data are introduced on the existing basis and re-training the neural network model, the neural network's connection weights can be obtained reflecting the player's current technical level, which lead to the revised technical diagnosis model. The model can reflect the function between the player's latest technique indexes and game results, and it still has memories of past matches.

The choice of neural network structure is a very important task. A good choice may reduce the network training times, increase the network study precision; otherwise, it may cause the failure of network study. The establishment of three-layer BP (back propagation) network model's structure mainly involves the following parameters: input layer, output layer, hidden layer, transferring function, training function, etc. The key to establishing neural model is the determination of the number of input layer's neurons, the number of hidden layers, the number of hidden layer's neurons, the selection of transferring function as well as of training function.

Zhang Hui, Wang Yong-mei, Xiao Yi and Wu Yin, et al (2005; 2007) took table tennis matches as an example, and established a technical and tactical diagnostic model of table tennis matches by resorting to the powerful self-study function of the artificial neural networks, and based on this, made a preliminary analysis of the techniques and tactics of the outstanding table tennis players in the world today..

5.1. The analytic model of excellent woman players' techniques and tactics in table tennis games

10 technical and tactical indexes (i.e. 10 nerve cells in inputs) are selected by Wang and Zhang (2005) from 40 international table tennis games, in which Chinese elite players like Zhang Yi-ning, Wang Nan, Guo Yue, Niu Jian-feng, Guo Yan took part. These indexes are: (1) the scoring rate of serving; (2) the using rate of serving and attacking; (3) the scoring rate of serving and attacking; (4) the fault rate of the third stroke; (5) the using rate of receiving and attacking; (6) the using rate of the fourth attacking; (7) the scoring rate of the fourth attacking; (8) the fault rate of the fourth stroke; (9) the scoring rate of rally; (10) the fault rate of rally.

Suppose the number of output layer is 1, and the output data is the winning probability of table tennis match. The number of the hidden layer is taken to be 30. The transferring function among neurons is taken to be alignment S function $\text{purelin}(n)$, and the Levenberg-Marquardt training function is used to construct the model, whose structure is shown in figure 3.

Establish the analysis model for outstanding female players' techniques and tactics built on 30 games, and take 10 games to verify the validity of the model. The result shows the absolute value of the 10 games' biggest tolerance is 0.0446, the smallest is 0.0039, the average is 0.0231, and the accuracy of the model is 97.69 percent.

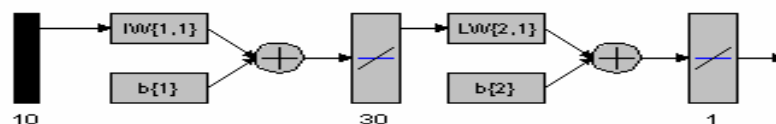


Fig. 3: Structure of neural network model for the analysis of the techniques and tactics of elite woman table tennis players

5.2. Examples of technical and tactical analyses based on artificial neural network

To Wang Nan and Zhang Yi-ning, the 9th index (score rate of rally) and the 10th index (fault rate of rally) have more important influence over the winning of the game than other techniques and tactics. And improving the ability of rallying is more significant to Wang than to Zhang as shown in figure 7

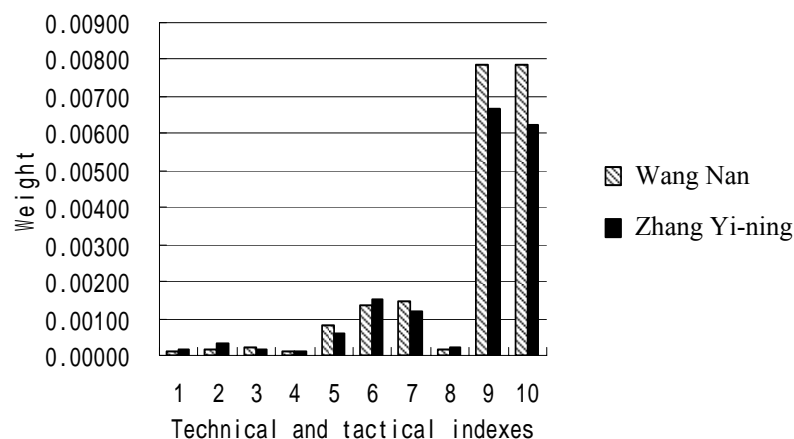


Fig. 4: The technical and tactical weights of Wang Nan and Zhang Yi-ning

Figure 4 also indicates that the 6th index (the using rate of the fourth attacking) and the 7th index (the scoring rate of the fourth attacking) have a 2nd high position, which shows that the fourth stroke joint technique after receive is becoming increasingly important on high-level female table tennis matches in modern times.

6. Theoretical research on technical and tactical evaluation and prediction based on system dynamics

System Dynamics (SD) is an interdisciplinary and integrated subject which understands and solves system problems. It is also a subject that analyzes feedback system. It emphasizes a systematic, holistic, interrelated and developing vision to address problems, which secures a unique advantage in solving non-

linear, high-level and complex time-varied systems. In recent years, it has been further applied to the social, economic, ecological, military confrontation and other fields. Yu and Mao (2008), based on a profound analysis of causal relationship of technical and tactical strength in table tennis competition, introduced the system dynamic theory and established a tentative assessment and prediction model for technical and tactical strength of table tennis player.

6.1. Analysis of the causal relationship of table tennis technical and tactical strength

A number of factors affect the technical and tactical strength in table tennis competition, and these factors jointly contribute to the winning of the games. The contributing factors can be grouped into five major categories: factors of technology, tactics, physical conditioning, psychology and environment. Among these, technical and tactical factors are major ones in winning, and bodily function factors are security factors of high-intensity training and the using of skills and tactics, and psychological factors are the key to winning games. In addition, coaches, spectators and environmental factors also have direct impact on the results of games.

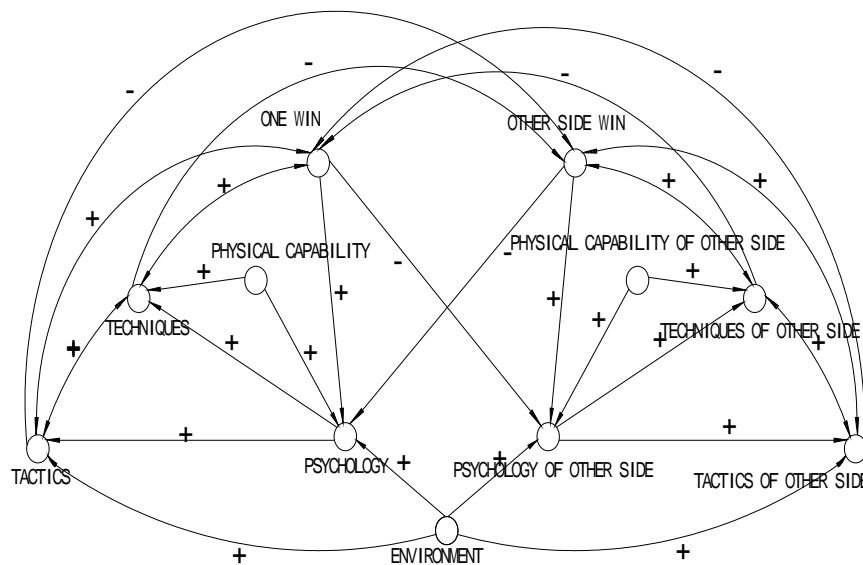


Fig. 5: The causal loop diagram of the major factors of table tennis technical and tactical strength

The causal relationship among the major factors of table tennis technical and tactical strength shows that the interaction among the techniques, tactics, physical conditioning, psychological level of the player and environment of the competition has a combined effect on the results of games. If the techniques and tactics, physical conditioning, and psychological level of the player impose on one side positive feedback and the other negative, then in case one side wins, psychological pressure is likely to be imposed on the other side and hence influences his next competition. Similarly, the winning player will be more confident of his techniques and tactics because of the victory, which in turn, will provide positive feedback on his psychology and tactics in the following game. Among these winning factors also exist feedback relations. For example, bodily functions provide positive feedback on the psychology and techniques and tactics, and environmental factors provide positive feedback on the winning of the game.

6.2. The system dynamic model for the evaluation and prediction of the technical and tactical strength of table tennis

Figure 6 is the simplified version of system dynamic model of the evaluation and prediction of the technical and tactical strength. Each factor affecting technical and tactical strength is further composed of various interactive parameters, which in turn have their own system dynamic models.

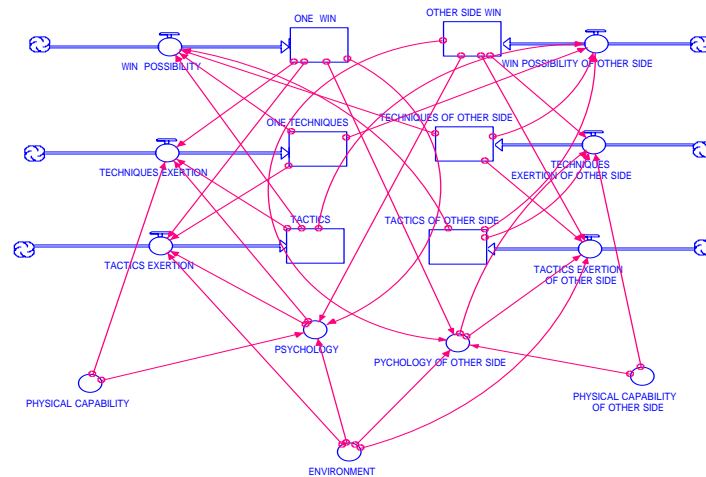


Fig. 6: The simplified version of system dynamic model for the assessment and prediction of technical and tactical strength in table tennis matches

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