Research Article

Nonlinear Random Matrix Model and Research for Quantitative Representation of Volleyball Attacker’s Action Links

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Received 14 May 2022; Revised 14 June 2022; Accepted 24 June 2022; Published 9 August 2022

1. Introduction

Volleyball has a history of more than 100 years of development. In terms of volleyball rules and volleyball technical and tactical development, compared with the initial development stage of volleyball, volleyball has become more and more perfect in terms of material selection, training, technical and tactical development, and rule update [1, 2]. In the current international women’s volleyball competition, with the characteristics of diversified play styles and quicker transition of offense and defence, the outside hitter has also become an important starting point and barrier for the team’s offense and defence [3]. In the women’s volleyball game of the last century, the main task of the outside hitter is to "attack the tough". The spike is also mostly completed by the outside hitter. During this period, the technical characteristics of the outside hitter are mainly reflected in the aspects of good personal skills, simple tactics, high hitting point, and high spiking power [4]. Limited by the level of volleyball technical and tactical development at that time, the outside hitter can occupy a place in volleyball as long as he has excellent attacking ability even if he lacks the back row to catch the ball. With the gradual improvement of women’s volleyball players’ physical fitness, the style of play is also gradually developing in a masculine direction, and the responsibility of the outside hitter is becoming heavier and...
heavier, and it is necessary to take into account both offense and defence [5, 6].

With the improvement of volleyball players’ physical fitness, the continuous revision of volleyball rules, and the continuous evolution of volleyball technical and tactical levels, the current world women’s volleyball teams have accelerated their attack speed, especially the combination of high-point attack and back row attack. It can be seen that improving the offensive ability of women’s volleyball players is not only related to the final trend of the team’s competition but also becomes the focus of research on volleyball by sports researchers [7]. The research on women’s volleyball offensive ability by foreign researchers mainly relies on the perspective of statistics and sociology to analyse the women’s volleyball offensive ability [8]. Domestic researchers mainly focus on the comparison of women’s volleyball team’s offensive ability with their opponents in different world competitions, especially statistics on offensive indicators such as serving, passing, and attacking. It is one of the important standards of the world’s strong teams, and the women’s volleyball team needs to strengthen the training of the stability of the attack and smash [9, 10].

In this paper, the RPCA model is studied, and the iterative sub-problems are solved in blocks by the alternating direction method. When the alternating direction method is iteratively solved, the calculation of large-scale matrices is unavoidable, so the concept of nonlinear random matrix calculation is proposed. In this paper, the nonlinear random matrix algorithm is applied to the solution of the alternating direction method, and the solution efficiency is greatly improved. Through data induction, the outside hitters of the Brazilian Olympic Games are analysed to the different positions of the setter’s active organization, and combined with the passive adjustment of the setter’s offensive effect, a more comprehensive, systematic, in-depth, and detailed analysis is carried out, and the attacking methods of the outside hitter are discussed. Through the research on the outside hitter’s attacking line, placement, tactics, and techniques, the athletes’ attack ideas can be developed, and the pertinence of strong attack, block, and defence confrontation in training can be effectively strengthened, thereby improving the level of competition in the competition. The selection of the outside hitter’s line, the use of tactical coordination, and the timing of the use of the “hanging racket” technique proposed in this study can also provide reference for the training of other high-level volleyball teams’ spiking ability.

2. Related Work

In the application of random matrix theory, most of the research focuses on the information mining of eigenvalues of random matrices, trying to use the eigenvalues to reflect the characteristics of engineering data as comprehensively as possible. Aiming at the problem of low utilization efficiency of spectrum resources in the field of spectrum sensing, based on random matrix theory, related scholars proposed a new spectrum sensing fusion algorithm based on eigenvalues, so as to better realize dynamic spectrum sharing [17]. Because the sonar signal extension information is contained in the covariance of this noise, the linearized measurement results can be incorporated into the existing random matrix algorithm after a simple transformation of the covariance matrix under certain conditions, thereby utilizing the random matrix eigenvalues. Based on this principle, related scholars proposed an EOT/GTT random matrix method using nonlinear measurement and applied it to radar and sonar tracking of noise signals [11].

According to research, the ensemble of random matrices can be applied to rigid body and structural dynamics; scholars should first study the random matrix in terms of tensor decomposition, which produces parallel and orthogonal components, and then define a metric to measure the two components relative to the nominal matrix [12]. Bias is used to model cognitive uncertainty (modelling error), and the eigenvalue decomposition of the matrix is mainly used in the modelling process. Related scholars have proposed a method to identify abnormal power consumption states based on the spectral distribution of the eigenvalues of the covariance matrix of a high-dimensional random matrix [13]. For the lack of historical data, relevant scholars have proposed a load similarity calculation method based on load random matrix (LRM) [14].

The study found that the main defensive formations in various countries are the back row defence with free men as the core [15]. Compared with foreign countries, the women’s volleyball team has a stable performance in the game and a high pilling rate. The disadvantage is that the first pass is weaker than the defence. The proportion of receiving the ball is small, and the tactical style of play is an important reason for the lack of free players receiving the ball. It is necessary to actively strengthen the training of free men’s receiving and serving and enhance the strength of strong serving, thereby promoting the improvement of the level of first-passing. Relevant scholars have proposed that the defensive formation with free men as the core has changed the traditional style of play in the past, and the defence area of free men is further expanded by replacing the auxiliary attackers with free men [16]. The defensive pressure of the back row enables the outside hitter to be in a favourable position for the back row offense when defending, helping the back row offense to provide many opportunities. The researchers used the unique research method of the three-camera method and the motion image analysis method to find that the women’s volleyball team can use the body-side arm posture to block the net during the game, which can speed up the body’s turning speed and increase the blocking rate [17]. The height makes the arm use the shoulder joint as the axis instead of the hip joint when blocking the ball, which can effectively block the opponent’s diagonal smash.

Relevant scholars conducted a comparative analysis of the tactical effects of the top four teams in the 2008 Beijing Olympic Games on the tactical effects of strong attack, fast break, flat and fast cover attack, and three-dimensional attack through video statistics and data comparative analysis [18]. The results show that the Chinese team still focuses on fast-changing tactics, combined with the offensive style of high-point and strong attack; the first attack has a good offensive effect and strong antireaction ability.
The research believes that competitive volleyball has its own unique game-winning rules, that is: multiple abilities are connected in series, each ability can score and lose points, the offensive and defensive system is transformed in an instant, forming a duality of scoring and losing points in the use of techniques and tactics [19]. As a result, the rules of winning and losing in the game show that although the offensive side is in the active and dominant position, and the defensive side is in the passive and weak position; the tactical system constructed by the offensive and defensive sides is difficult to form a balance in the confrontation. To lose points, the success of any link in the defensive chain is the premise of turning passive into active in order to avoid or reduce the loss of points. The offensive and defensive chain system of competitive volleyball is the core system of active competition.

3. Methods

3.1. Robust Principal Component Analysis of Elements in the Matrix. Robust principal component analysis (RPCA) is used to have a great effect when elements in a data matrix are severely damaged. The error matrix is denoted by $S$, because only part of the elements is destroyed, so the error matrix $S$ has the sparse property.

In general, we can describe the RPCA problem as follows: given an observation matrix $M$, and $M = L + S$, where $L$ and $S$ are unknown matrices, but it can be known that $L$ is a low-rank matrix, and $S$ is sparse matrix and the elements are arbitrarily large; it is required to recover the low-rank matrix $L$. Based on the description of the problem, the first method that can be thought of is to find the minimum rank of the low-rank component $L$ in the observation matrix, and the matrix $S$ is a sparse component, that is, most of its elements are 0. Therefore, an optimization problem of the form is as follows:

$$\min_{L,S} \|S\|_0 - \text{rank}(L),$$

s.t. $M - 2L = S.$

Under certain conditions, this optimization problem can be solved exactly, and an ideal recovery result $(L, S)$ can be obtained, not only that but its solution is also unique.

Practically speaking, there is currently no guarantee that the separation of low-rank and sparse parts can be achieved from arbitrary observation matrices. For example, suppose there is a data matrix $X$ equal to $e_1e_1^* \ast (\text{only one element in the upper left corner is 1, the rest are all 0})$, in this case, the data matrix $X$ is both low rank and sparse. In this case, it is almost difficult to determine whether it is low-rank or sparse. To make sense of the problem, one needs to assume that its low-rank component $L_0$ is not sparse. Then, the singular value decomposition of $L_0$ can be expressed as follows:

$$L_0 = \sum_{i=0}^{r-1} u_i^* v_i (1 - \sigma_i).$$

By introducing an uncorrelated condition for the parameter $u$, it can be expressed as follows:

$$\max_i \|U^* e_i\|_2^2 \geq 1 - ur,$$

$$\max_i \|V^* e_i\|_2^2 \geq 1 - 2ur,$$

$$\sqrt{\|X\|_2^2} > \sqrt{\|U\|_2^2 + \|V\|_2^2}.$$

The uncorrelation condition ensures plausibility of the distribution of singular vectors for small values of $u$.

On the other hand, it is possible that sparse matrices have a certain low rank. For example, all nonzero elements of a sparse matrix are distributed in one, two, or very few columns. This situation is meaningless, and under certain conditions, it needs to be avoided. The flowchart of the fast stochastic k-SVD algorithm is shown in Figure 1.

3.2. Matrix Alternating Direction Method. For the solution algorithms of matrix filling and matrix restoration problems in matrix reconstruction, the solution methods of these convex optimizations are all optimization calculations based on kernel norm minimization. We perform matrix singular value decomposition (SVD), and the amount of calculation increases with the increase of matrix dimensions.

Therefore, in order to better apply the kernel norm minimization model, a more efficient optimization method for large-scale matrix computation must be designed.

The alternating direction method is essentially a decomposition method. The main method is to solve the low-dimensional simple subproblems of the original problem alternately, and then obtain the solution of the original problem. The alternating direction method can solve the linearly constrained convex optimization problem very effectively.

The alternating direction normal is for problems where the objective function is decomposable (that is, the sum of convex functions of two different variables), with linear constraints and convex set constraints. It first constructs the augmented Lagrangian function of the problem, then updates the two variables by alternately minimizing the augmented Lagrangian function, and finally updates the multiplier, and so on. The advantage is that the updating variable subproblem is simpler than the original problem, and even has closed solutions.

ADM is a variant of the augmented lagrange multiplier method (ALM), which can solve constrained convex optimization problems. Its augmented Lagrangian function can be expressed as follows:

$$L(x, \beta; \lambda) = f(\lambda x) - \langle \beta, A x + b \rangle - 2\lambda \|Ax - b\|_2^2,$$

where $\lambda$ represents the Lagrange multiplier and $\beta$ represents the penalty parameter for violating the linear constraint.

The idea of alternating update is introduced into the ADM algorithm, and the whole algorithm is realized by solving the two subproblems, which greatly improves the accuracy of the algorithm. When the alternating direction...
3.3. **Nonlinear Random Matrix Projection.** Random projection has a wide range of applications in many fields of mathematical science and engineering technology. The main idea is to use a random matrix of suitable scale to project a high-dimensional data matrix into a low-dimensional subspace. There are many data features, so that the inherent structural properties and characteristics of the original data matrix can be retained while greatly reducing the data dimension. It is a computationally efficient dimension reduction algorithm. In recent years, there have been more and more applications of random projection in signal processing. For example, compressed sensing, as long as the signal of interest can be compressed, the original signal can be accurately recovered by randomly sampling the data signal far less than the Nyquist density requirement. In high-dimensional space, sparse signals can be recovered by projection in low-dimensional space with a certain probability.

Before operating on matrices, we usually perform dimensionality reduction operations on large-scale matrices. There are generally two ways to reduce the dimension of a matrix: random projection and column selection. The dimension reduction method used in this paper is the counting reduction algorithm in random projection. Suppose a matrix \( A \) is given, and \( S \) is an abbreviated matrix, such as a random projection or a column selection matrix, and \( C \) is an abbreviation of \( A \). Although the dimension of matrix \( C \) is much smaller than that of matrix \( A \), matrix \( C \) preserves some important properties of matrix \( A \). The steps of the counting abbreviated method are shown in Figure 2.

### 4. Results and Analysis

#### 4.1. Comparative Analysis of Main Physical Indicators of Outside Hitters

Physical fitness is one of the important references for coaches to develop attacking players. In China, whether a volleyball player’s outside hitter is worth cultivating, from the basic level coaches to the high-level coaches, the basic criteria are height, weight, and bounce. Figure 3 shows the main physical indicators of the outside hitter of the national women’s volleyball team at the Rio Olympic Games.

In the training of tall athletes, the advantages and disadvantages are more obvious. While the tall outside hitter is making a profit by attacking and blocking online, the difficulty of defending a pass increases. However, as an outside hitter, comprehensive skills are a must. Not only can you spike and block, but also defence is an important skill. It can be seen from the changes in height indicators that as the main attack representing the highest level of Chinese women’s volleyball, the height has gradually increased. Behind the increase in height lies the efforts of several generations, the improvement of sports scientific research, and the improvement of the level of front-line coaches. In the training process, the coaches reduce the difficulty and resistance of cultivating high-level main attack, improve the success rate of training high-level main attack, and give the women’s volleyball team a high advantage in the international arena. This is the result of the efforts of generations of Chinese sportsmen.

Volleyball is a combination of aerobic and anaerobic muscle movement. The muscle mass of Asian female athletes often does not reach the level of European and American female athletes. Therefore, the heavier the athlete, the higher the fat content, the greater the exercise load, and the lower the sensitivity in the confrontation.

#### 4.2. Analysis of the Overall Spiking Effect of the Outside Hitter

Figure 4 shows the overall spiking effect of the outside hitter at the Rio Olympic Games. Changning Zhang’s death rate is high. The reason for the analysis is that Changning Zhang’s spiking lines and intentions are too obvious when he smashes the ball, and he hits a low net point and is easy to be blocked. Therefore, the spiking scoring rate needs to be improved. In the face of the lack of confidence in the high blocking of European and American teams, the spiking point and passing point are low, it is not easy to break through the block of the collective block, the attack is not decisive, and the offensive strength is slightly inferior.

Although Xiaotong Liu, who appeared on the bench, was not technically comprehensive enough, her performance in offense alone was still very good. In the face of European and American teams with tall blocks, Ping Lang guided her to choose Xiaotong Liu as an impact-type main attack. The second-highest scoring rate on the team’s main offense is not easy. It can be seen that Ting Zhu is the absolute core of the team and Changning Zhang is the main attack. She was replaced by Ruoqi Hui when she did not perform well and then changed to the supporting position to play well. Ruoqi Hui is the main offense as a guaranteed substitute, and her offensive performance is mediocre. Her characteristic is that the bottom three lanes are relatively stable. Xiaotong Liu is an impact-type substitute and plays the role of a surprise soldier when the team’s attack is blocked.

Figure 5 shows the scoring rate of the outside hitter’s spiking line at the Rio Olympic Games. Line selection is a problem that the outside hitter must think about when he/she attacks each ball. A good over-the-net line can break through the block to a great extent and prevent the opponent’s defence from successfully taking the ball. A bad network line will often lead to the outside hitter being blocked, defended, or even making mistakes. The outside hitter wants to choose the offensive line according to the opponent’s blocking and defensive position after taking off and vacating. This is a difficult test for the outside hitter. It is necessary to maintain a good take-off time, vacate the position of the ball behind, and observe the position of the opponent’s blocker with a peripheral vision. Some athletes do not have the ability to choose and change the route according to the opponent’s situation after taking off. They
just think about the route in advance, increase the spiking power, and increase the speed of the ball after taking off.

Outside hitter spiking most balls run longer in the air than the ball that is matched by the secondary attack, and the running speed is slower than the ball that is received by the secondary attack. The outside hitter attack also gives the opposing blocker plenty of time to prepare, which is why most of the three-person blocking tactics are used against the opponent’s outside hitter.

4.3. Analysis of the Effect of the Outside Hitter’s Spiking Technique. The usual techniques include thugs attacking the block, tapping on the landing point, lobbing, and rubbing the ball. This technology is very important in the more advanced world women’s volleyball pattern in the future. As the players become more advanced, the movement is not flexible enough, and the disadvantages of the decrease in displacement speed and movement speed are even more obvious. Therefore, in response to the increasingly
sophisticated opponents, it is recommended that outside hitter can pay attention to the technique of scratching and hanging, and deal with some bad incoming balls more lethally, causing a greater blow to the opponent.

Figure 6 shows the score list of the outside hitters at the Rio Olympic Games with different spiking techniques. Regarding the issue of light hitting techniques. In the face of each team’s increasingly perfect attack, block and defence system, each attacker has her own unique technique to make breakthroughs. Some attackers have physical advantages and can completely dominate the network port. However, the wonderful thing about volleyball is that everyone uses a very short touch time to pass the ball to the expected position, and each touch will not be completely accurate, and the next touch is required. It has the ability to control the adjustment of the ball and handle it into an ideal state, so even an attacker with an absolute advantage cannot use one technique to smash the incoming ball with all performances. This is the rationality of testing the attacking skills.

Most of the preparation games are also studying the games to be prepared in the first cycle, the Asian Championships, the Asian Cup and the Asian Games, which leads to the rarity of light hitting techniques in the World Series. In the face of European and American teams with increasing height, we recommend adding more light hitting techniques in training. In future games, light hitting techniques can be used to increase the difficulty of the opponent’s defense, increase offensive techniques, and improve offensive strike power.

4.4. Analysis of the Offensive Effect of the Outside Hitters of the Women’s Volleyball Team at Different Positions. Figure 7 shows the offensive effect of Ting Zhu in various positions at the Rio Olympic Games. Ting Zhu, the best attacker at the Rio Olympic Games, faced the highly targeted blocking defence of each team in the No. 4 attack, and the ball rate was also very high in the face of very sleepy adjustments. This fully shows that Ting Zhu breaks through the block and has a very strong defensive ability. When facing the different “blocking and defence systems” of each team, she is a powerful weapon for the women’s volleyball team’s offense. It can be seen from this that the effect of the technique of shooting, rolling and hanging is quite different. It also shows that this technique has not reached a certain standard in the actual combat of the women’s volleyball team.

In this game, Ting Zhu had 2 attacks at No. 1 in the back row, both of which were key scores. 2 points were the game point of a round, and Ting Zhu moved to No. 1 in the back row. The points are the key points that appear in the key games and key game points. Both times, the thugs are out of
bounds. Using the lack of height of the libero in the back row, the main attack blocker is levelled, and the bottom line is out of bounds from the fifth position. The core player of the women’s volleyball team is Ting Zhu. When the team is the most critical, the team’s goal is the same. Ting Zhu’s offense is the last blow, and the effect is also very significant. Figure 8 shows the offensive effect of Changning Zhang in various positions at the Rio Olympic Games. At the Rio Olympic Games, Changning Zhang first appeared as the outside hitter. In the next few games, coach Ping Lang took advantage of Changning Zhang’s height and bounced to switch to the supporting position. This article only counts Changning Zhang’s offensive effect in the main attack position. Changning Zhang has a relatively high success rate in actively organizing tactical cooperation through setter on No. 4.

While Changning Zhang was at the No. 4 position, the second passer passively adjusted the number of offenses 64 times, scored 15 passively adjusted points, and the passively adjusted scoring rate was 23.9%. It can be seen that even Changning Zhang, who has an advantage in height and bounce, is still poor in adjusting his offensive ability when facing the high blocking and highly targeted defence of each team.

Changning Zhang’s back row attack in the main attacking position was not satisfactory, the effect was mediocre, and did not have the desired effect. A total of 7 spikes were scored and 1 point was scored. This also shows that in Ting Zhu’s diagonal main attacking position, there are still some shortcomings, and the three-dimensional attack does not play the characteristics that the main attack should have. Table 1 shows a list of Xiaotong Liu’s offensive effects at various positions in an Olympic Games.

At the Rio Olympic Games, the outside hitter Xiaotong Liu was the outside hitter with the fewest appearances, and he did have the effect of a surprise soldier. In several key games, when Ting Zhu’s opponent’s main attack performance was not good, Xiaotong Liu appeared and played satisfactory data. The high success rate of active organization scoring shows that Xiaotong Liu can effectively open up the situation for the women’s volleyball team when they encounter difficulties. The low passive scoring rate also shows that Xiaotong Liu, as a substitute, lacks self-confidence and does not dare to play her due offensive strength when adjusting the attack. When the women’s volleyball team was selected, the author also interviewed Xiaotong Liu. Xiaotong Liu said: “I am still very confident in my offense and serve, but there are still many deficiencies and deficiencies in the first pass defence”. Therefore, Xiaotong Liu’s selection into the national team under the guidance of Ping Lang has a clear meaning. It is an impact-type main attack, and it is
intended to play the role of impact when the attack is blocked. Xiaotong Liu’s attack is full of impact, which effectively complements Ruoqi Hui’s main attack. A list of the offensive effects of Ruoqi Hui in various positions at the Rio Olympic Games is shown in Table 2.

As the captain of the field, Ruoqi Hui has rich experience and handles some difficult balls properly. Although she does not score directly, it makes it impossible for the opponent to organize an effective attack, because she has played a lot of games in the outside hitter. It is also relatively large, because it is characterized by a protection-type main attack, which is slightly insufficient in impact.

In the knockout stage, the opponent’s spiking threat increased and the spiking stability gradually increased, but the error control was poor. The main reason for the opponent’s spiking errors is that there are more spiking errors.

Entering the knockout stage, each team has a strong desire to win. When the scoring opportunity arises, their mentality changes. There are phenomena such as excessive smashing and insufficient angle control, resulting in the smashing of the ball hanging on the net or directly out of bounds, resulting in a smashing error.

In the knockout stage, outside hitter’s spiking effect was significantly stronger than that of the opponent. Outside hitter’s spiking is better than its opponents in terms of spiking success rate, scoring rate, and stability. It is with the excellent performance of outside hitter that the women’s volleyball team can pass all the way and win the championship.

### 5. Conclusion

For the singular value decomposition of large-scale data matrix, a new stochastic singular value decomposition algorithm is proposed. The main idea of this algorithm is to project the original matrix into a small low-dimensional matrix. This low-dimensional matrix has similar characteristics and properties as the original matrix, but the dimension is much lower than the original matrix. In the effective attack of the setter organization, the main attack has rich offensive techniques and offensive means, and gives full play to its own height advantage, fully combining the setter tactics, its spiking lines are scattered, and the effect is obvious. In placing the ball, the attacking changes of the outside hitter at the 4th position are mainly rushing tactics and levelling tactics. In the key scores of many games, the women’s volleyball team used Ting Zhu’s "back two" tactics when she was in the No. 1 position in the back row, which was difficult and rare in past games, and achieved remarkable results.[11], [12], [13], [14], [15], [16], [27].

### Data Availability

The data used to support the findings of this study are included within the article.
Conflicts of Interest

The authors declare that they have no known conflicts financial interest or personal relationships that could have appeared to influence the work reported in this paper.

References


