

A study on visualization of tennis match performance based on momentum function

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Abstract. This study was conducted to investigate the dynamic characteristics of players' performance in tennis matches, and analyze the match performance by combining the momentum function. First, the important factors affecting momentum were screened out by corrected chi-square test and the momentum function model was established. Second, the dynamic features of players' performance in the game were extracted and analyzed by using the 3-element rule. Finally, taking the match between Carlos Alcaraz and Nicolas Jarry as an example, the weights of the indicators were obtained by MATLAB solution, and the momentum values were charted to further analyze the results of the match. The study provides an important reference and methodology for a deeper understanding of player performance in tennis matches.

Keywords: Momentum functions, tennis matches, performance analysis.

1. Introduction

Player performance in tennis is a complex and dynamic process, which is affected by a variety of factors. In order to deeply understand and analyze this dynamic characteristic, this study combines the momentum function theory with the tennis game as the research object to explore the dynamic change law of player performance[1-2]. First, the important factors affecting players' momentum were screened out through the corrected chi-square test, and a momentum function model was established so as to quantify the degree of influence of each factor on players' performance during the match. Secondly, dynamic feature extraction and analysis of players' performance during the match were carried out by using the 3-element rule, which revealed the differences and trends of players' performance at different moments of the match. Finally, the model was solved and validated using actual match data as an example to further verify the effectiveness and accuracy of the momentum function model in analyzing player performance in tennis matches. This study not only provides new perspectives and methods for the in-depth understanding of players' performance in tennis matches, but also provides reference for the use of momentum function theory to analyze the dynamic characteristics in other sports matches[3-4].

2. Data preprocessing

Through data screening, it is found that there are missing data in speed_mph and Serve_depth. As there is a connection between each round of the competition data, it cannot be simply removed from the missing rows of data, so it is necessary to fill in the missing data. At the same time, considering that the player's status is different at each time point, the average value method cannot be simply used for processing. In view of this, the data filling method based on standard Euclidean distance can be selected[5].

The data filling method based on standard Euclidean distance is mainly calculated and filled based on the following principles:

(1) Distance calculation: For each missing data point, calculate the distance between it and other known data points. In this algorithm, the standard Euclidean distance is used to represent the similarity between data points. The formula for calculating the distance is as follows:

Distance $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$, where x_1 and y_1 represent the coordinates of known data points, and x_2 and y_2 represent the coordinates of missing data points.

(2) Selection of neighboring data: Select the nearest k known data points to the missing data point as the neighboring dataset. k By setting an appropriate k value through cross-validation or other methods, the accuracy of the filling result can be guaranteed.

(3) Data filling: Based on the flow value of the neighboring dataset, the missing data are filled in by using weighted average method. The weighted average method calculates the distance weight between the neighboring data points and the missing data point, and sums up the flow values of the neighboring data points according to the weight to obtain the filled flow value[6-7].

3. Performance analysis based on the momentum function

3.1. A model of tennis player's momentum function based on entropy weighting approach

Let the tennis player's momentum function in the process of the game is Q , the use of corrected chi-square test on the momentum function of the many factors affecting the characteristics of screening, from which six important factors were screened out, the contribution value of the factors to the player's momentum of the game is recorded as the value of the athlete's momentum of the game for the $q_i, i=1,2,\dots,6$, specifically as shown in Figure 1.

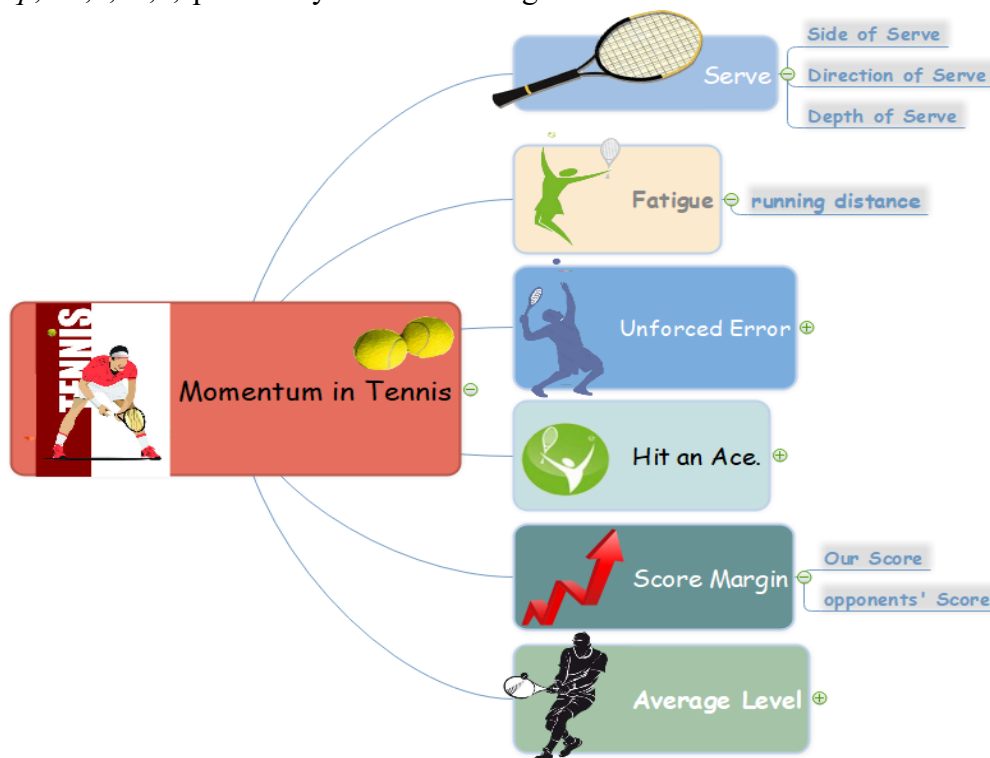


Figure 1 Tennis Match Momentum Factor Analysis Chart

In order to avoid the complex changes in the value of the momentum function caused by the interaction between the factors, it is therefore assumed that there will be no interaction between the factors selected by the corrected chi-square test. In the following, the six factors will be quantified and $q_i, i=1,2,\dots,6$ will be controlled to be in the interval of $[0,1]$ in order to establish the functional expression of the momentum function on the contribution value of these six factors[8].

3.1.1. Serve or not

Since whether a player serves or not in a tennis match will largely affect the match trend of the player's bureau, the contribution value of the player's serve, q_1 , is selected as an important factor

affecting the momentum of a tennis match, and taking into account the two sub-factors of the direction of the serve, d , and the speed of the serve, v , it is not difficult to find out that, when the wider the direction of a player's serve, and the faster the speed of his serve, the more difficult it will be for his opponents to receive the ball, and therefore, it is possible to set up the:

$$q = l_1 \cdot d + l_2 \cdot v, \quad (1)$$

where l_1 and l_2 are the weights of serve direction and serve speed, respectively, which satisfy: $\sum_{i=1}^2 l_i = 1$. Since the probability of the side that serves the ball to win the set is considerably higher than that of the other side, the momentum of the side that serves the ball is higher in comparison to that of the other side, and it can be assumed that the value of the contribution of player X's serve, q_1 , satisfies

$$q_1 = \begin{cases} q, & \text{Player X is the server,} \\ -q, & \text{Player X is not the server.} \end{cases} \quad (2)$$

3.1.2. Fatigue

Since the player's fatigue in the process of the game will greatly affect the player's play, thus directly affecting the game trend, so this question selects the contribution value of the player's fatigue in the process of the game q_2 as an important factor affecting the momentum of the tennis game. Through reviewing the literature, in the tennis game, the player's fatigue in the process of the game has a close relationship with the distance run by the player to catch the ball, the use of MATLAB fitting, specific as shown in Figure 2.

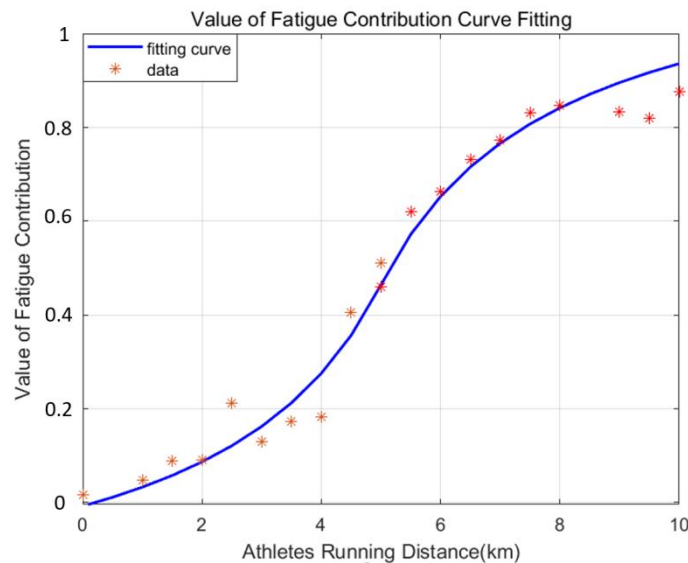


Figure 2 Value of Fatigue Contribution Curve Fitting

Let the total distance run by a tennis player during a match be s , which can be easily obtained by fitting the curve

$$q_2 = s \cdot e^{0.172s} - 2.18s + 0.481. \quad (3)$$

3.1.3. Unforced errors

An unforced error is a player's own initiative error that causes a return to go over the net or out of bounds, and can largely reflect a player's game status for the day. Therefore, in this question, the contribution value of unforced errors q_3 is chosen as an important factor affecting the momentum of a tennis match, and is quantified by whether or not a player has made an unforced error in the last three rounds. And it is taken into consideration that the performance in the later rounds will be affected

due to the player's mindset in the later rounds after the occurrence of unforced errors. Therefore it is defined in the following way: if a player makes an unforced error in round t , by reviewing the literature[9], it is possible to get.

$$q_4(m) = \begin{cases} -1, m = t, \\ -0.5, m = t + 1, \\ -0.2, m = t + 2, \\ 0, \text{else.} \end{cases} \quad (4)$$

3.1.4. Score margin

Since the mutual scores of the two players during the match directly determine the trend of the match, this question selects the contribution value of the difference in the players' scores within the last 5 rounds, q_4 , as an important factor affecting the momentum of a tennis match. Which can be quantified by the difference in the number of rounds won by both players within the last 5 rounds to get

$$q_4 = v_1 - v_2, \quad (5)$$

Where v_1, v_2 represent the number of rounds won by their own player and the opposing player in the first 5 rounds respectively.

3.1.5. Hit an Ace

Ace shots are always invigorating for the server, and will also change the mindset and game level of the server in the later rounds to a certain extent, thus directly affecting the momentum of the match. Therefore, this question selects the contribution value q_5 of hitting Ace ball as an important factor affecting the momentum of tennis game. And define q_5 by whether hitting Ace ball in the last three rounds, as follows: if a player hits Ace ball in the n round, by reviewing the literature^[4] can get

$$q_5(m) = \begin{cases} 1, m = t, \\ 0.7, m = t + 1, \\ 0.3, m = t + 2, \\ 0, \text{else.} \end{cases} \quad (6)$$

3.1.6. Average level

Since the average level of a player can directly lead to the trend of a match, the average contribution of a player, q_6 , is chosen in this question as an important factor that affects the momentum of a tennis match. And quantified by the average of the player's scores in all recent matches, it can be obtained as

$$q_6 = \frac{\sum_{i=1}^N R_i}{N}, \quad (7)$$

where R_i denotes the player's score in game i and N denotes the total number of games the player has played in the recent past. Then a player's momentum Q in a match can be expressed as

$$Q(t) = \sum_{i=1}^6 w_i q_i, \quad (8)$$

where $q_i = \sum_{j=1}^t q_j(i)$, $j = 3, 5$, t represents the number of rounds now.

The following entropy weight method is used to determine the weights corresponding to the contribution values of each factor. With the above data, the decision matrix $D = (d_{ij})_{n \times 6}$ is obtained,

since the data in D are all benefit data. The following can then directly perform the normalization operation on the decision matrix d to obtain the normalized matrix as $R=(r_{ij})_{n \times 6}$, where.

$$r_{ij} = \frac{d_{ij}}{\sum_{i=1}^n d_{ij}}, \quad (9)$$

Where the weights of each of the six functions $w_i, i=1,2,\dots,6$ are obtained as.

$$w_j = \frac{1 - E_j}{\sum_{i=1}^n (1 - E_i)}, \quad j=1,\dots,6. \quad (10)$$

$$r_{ij} = \frac{d_{ij}}{\sum_{i=1}^n d_{ij}}, \quad (11)$$

3.2. The performance Analysis of two players during the match based on 3σ meta-rule

For a given match, the momentum values of the two players in each round can be calculated according to the above model, and after the elimination of abnormal values in the data preprocessing in the preliminary stage, it can be assumed that the remaining data are all normal, and therefore the 3σ meta-rule can be used to filter the points where the momentum of a certain player in the whole match is too big or too small as the zones and the slump. thus, we can get the division of the momentum values reflecting the performance of the players in different moments of the match, which is shown in Figure 3.

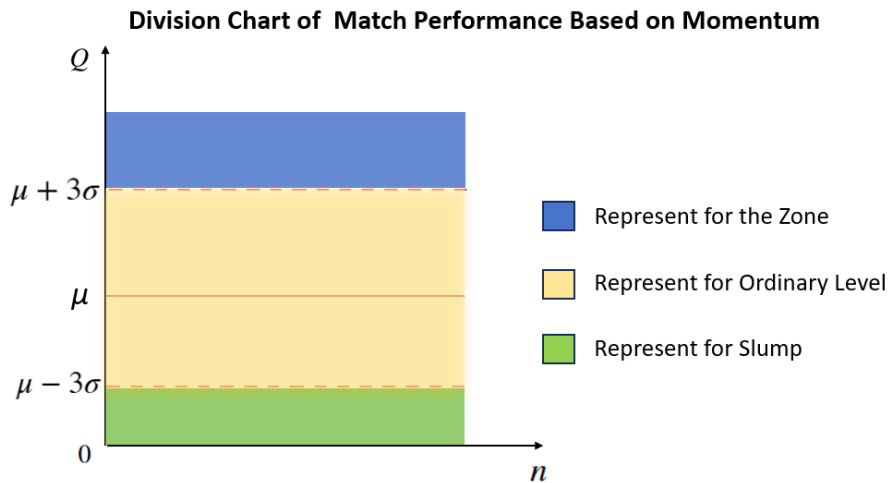


Figure 3 Division Chart of Match Performance Based on Momentum

3.3. Model Solution

Taking the first game of Carlos Alcaraz against Nicolas Jarry as an example, the weights of the indicators obtained by solving through MATLAB are shown in Figure 4.

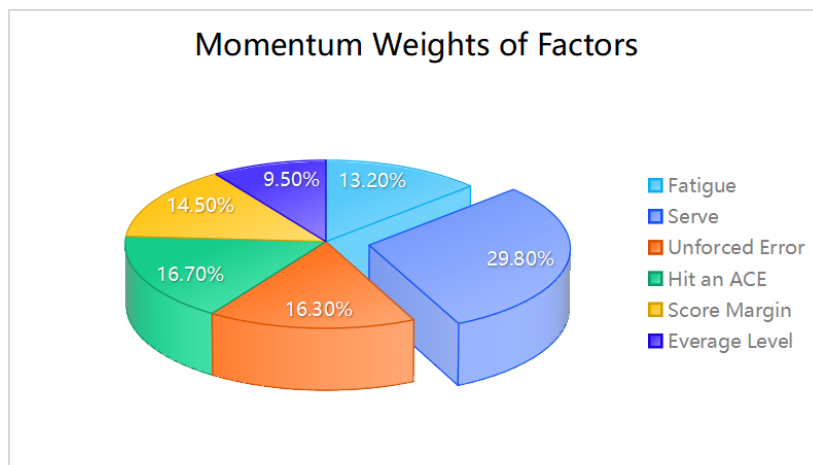


Figure 4 Momentum Weights of Factors

The respective momentum values of the two fighters in each round were obtained, and by using the 3σ rule, an image of the momentum values corresponding to Carlos Alcaraz's performance throughout the match can be obtained as shown in Figure 5.

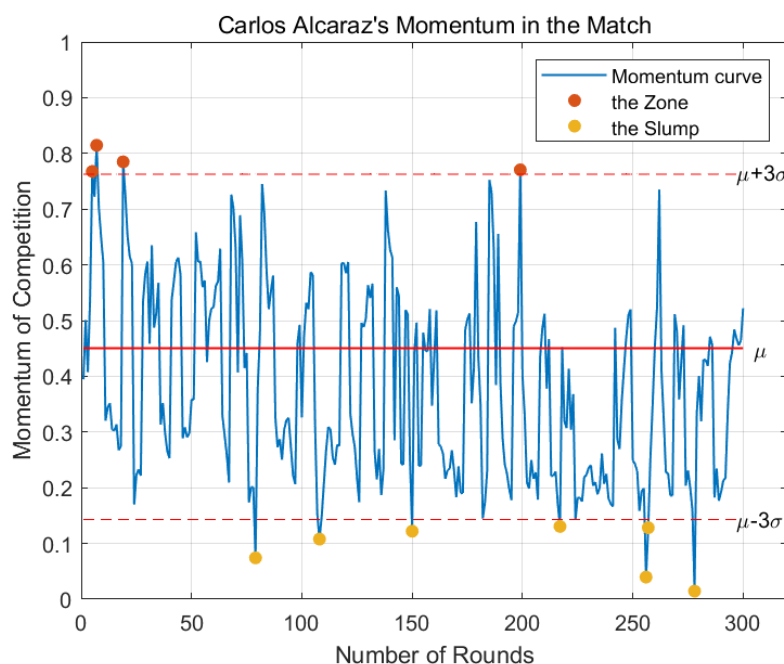


Figure 5 Carlos Alcaraz 's Momentum in the Match

Overall, Carlos Alcaraz's played better in the first set, with very bright performances in the 5th, 7th and 19th rounds and no slumps in the first set, so Carlos Alcaraz's won the first set. However, in the second set the player's overall momentum dropped compared to the previous set, and he lost the second set due to a very poor performance in the 7th, 109th and 150th rounds. Similarly, the momentum value of Nicolas Jarry's performance in the whole match can be obtained as shown in Figure 6.

Similarly, Nicolas Jarry had a very bright performance in the 26th, 27th and 48th rounds of the first set, but the average momentum of the player's game was not as good as Carlos Alcaraz's, and thus he lost the first set. However, the player dominated the field in the 121st, 124th, 125th, 134th, 135th and 147th rounds of the second set, and did not show any sluggishness in the second set, so he managed to win the second set. However, in the next two sets, Carlos Alcaraz won two sets in a row to take the victory as the player was slumping at a high frequency, causing the format of the match to change[10].

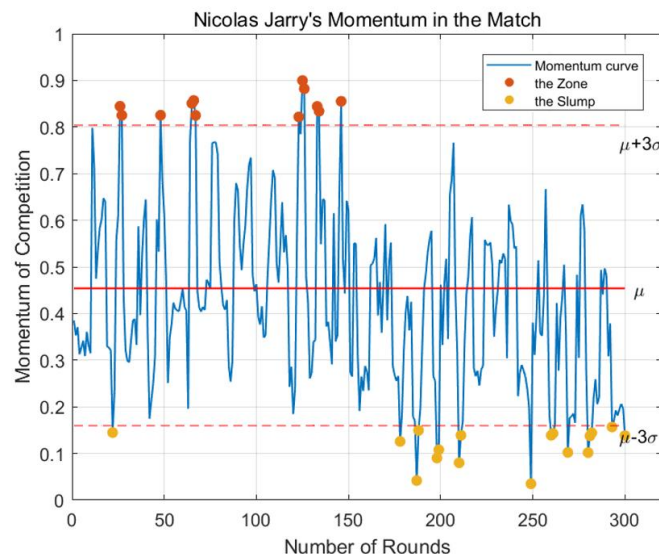


Figure 6 Nicolas Jarry 's Momentum in the Match

4. Conclusions

Based on the momentum function theory, this study launched an in-depth research on the dynamic features of players' performance with tennis matches as the object. Important factors were screened by corrected chi-square test, the momentum function model was established, and the dynamic features of player performance in the match were extracted and analyzed by using the 3-element rule. The results of empirical analysis show that the momentum function model can accurately reflect the changing trends and key moments of players' performance in a match, which provides new perspectives and methods for an in-depth understanding of tennis matches. Meanwhile, this study solved and validated the actual match data to verify the validity and accuracy of the model. Overall, this study has achieved certain research results in the dynamic characterization method, which provides a reference for the use of momentum function theory to analyze the dynamic characteristics in other sports competitions. However, there are still some shortcomings in the study, such as the further optimization and extension of the model, and the inclusion and validation of more game data still need to be further explored. It is believed that with further research and practice, the momentum function theory will play a more important role in the field of sports game analysis, providing a more reliable basis for improving athletes' performance and predicting game results.

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