Study on player momentum based on rank-sum ratio evaluation method

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Abstract. Tennis is a global sport, with Wimbledon being one of the most historic and prestigious international tennis opens. The concept of "momentum" in tennis matches, defined as "strength or force gained by motion or by a series of events," plays a critical role in influencing the course of a match. The Rank-sum ratio evaluation method (RSR) based on the CRITIC weighting method was used to score players' performances at specific moments using the aforementioned seven indicators. Using this model, we evaluated the the billiards championship final, compared players' performances, and effectively explained the fluctuations observed during the final. Meanwhile, Kendall correlation analysis was conducted on the momentum score and success indicators, and the Kendall coefficient was obtained Equal to 0.96. This research is anticipated to contribute to the prediction of scores in sports events

Keywords: Rank-sum ratio evaluation, Player momentum, Kendall coefficient.

1. Introduction

Tennis is a sport celebrated globally[1], with the Wimbledon Championships heralded as one of the most historic and prestigious international tennis events[2]. The concept of "momentum" in tennis matches, defined as the strength or force acquired through motion or a sequence of events, significantly influences the dynamics of the game[3].

The research conducted by Walid Briki and colleagues discovered that psychological momentum is a dynamic phenomenon characterized by non-linearity and historical dependency[4]. Giovanni Angelini and his team introduced a new version of the Elo rating method, designed for predicting outcomes in tennis matches[5]. Nadav Goldschmied and his collaborators analyzed ice hockey and found that winning a fight does not increase the likelihood of winning the game, regardless of the score. Andrew E[6]. Evans and associates explored the connection between psychological momentum and performance within the context of golf competitions[7].

Addressing the issues identified, this paper proposes Rank-sum ratio evaluation method (RSR) based on the CRITI weighting method, incorporating various influential factors within matches. The model offers a visual representation of the direction and fluctuations of matches and predicts the flow of the competition. This research is expected to contribute to the prediction of outcomes in tennis tournaments.

2. Quantitative Performance Evaluation Model for Athletes

2.1. Analysis of Evaluation Index Weightings

CRITIC weighting technique (using the standard importance of inter standard correlation) is used to determine the importance of each evaluation factor[8,9]. In contrast to alternative approaches, CRITIC excels in managing intricate inter-factor relationships, facilitating an in-depth analysis of their mutual impacts, and is apt for multi-factor evaluation scenarios.

2.2. CRITIC Weight Method Steps

For the creation of the correlation matrix, we employed specialized knowledge to allocate scores to the comparative correlations among each duo of evaluation metrics in the professional sphere[10]. As shown in Table 1:

Table 1. Description Table of Evaluation Indicators

Point	0 did not get score	1 p1 get score
Winner streak	0 not won	1(n) Consecutive victories n times
Server	1 server later	1 server later
Break_pt	0 Unforced error on serve	1 server error
Winner	0 No points if the opponent does not go out of bounds	1 Opponent scores out of bounds
Unf_err	0 no unforced error	1 unforced error
Net_pt	0 net.pt	0 net.pt

Within this chart, represent negative signs, in contrast to the rest, which are positive indicators. Notably, within the extensive assessment framework, we've allocated favorable markers to athletes prioritizing service, based on the fact that the likelihood of a tee winning a point is rated much higher. Athletes' performance is greatly influenced by the sequence of serving; therefore, this serving sequence is acknowledged as a key metric for evaluation.

The data from the official source was processed as depicted in the preceding table. The evaluation criteria' scores were populated into the respective spots on the correlation matrix, forming amatrix where 'p' signifies the count of factors under evaluation.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1p} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{np} \end{pmatrix} \tag{1}$$

To construct a matrix, we utilize n instances of data from the initial game's four matches, combined with the scores of seven chosen evaluation criteria.

2.3. Process of CRITIC Weighting Method

(1) Dimensionless Processing In order to eliminate the impact of different dimensions on evaluation results, it is necessary to standardize each indicator and to address them in the absence of dimensions.

(2) Our model utilizes either forward or reverse processing techniques. Utilizing standardization results in all standard deviations equating to the numeral 1. In essence, the uniformity in the standard deviation across all measures leads to indicators of volatility that lack significance. Differential Indicators Representing this as a standard deviation

$$\bar{X_j} = \frac{1}{n}\sum_{i=1}^{n} x_{ij} \tag{2}$$

$$S_j = \sqrt{\frac{\sum_{i=1}^{n}(x_{ij}-\bar{x}_j)^2}{n-1}} \tag{3}$$

Within this context, $X_{i\,j}$ signifies the numerical figure for the jth assessment marker of the ith sample, while S_j denotes the standard deviation for the jth indicator.

Standard deviation is employed to represent the variations in internal values across each indicator. An increased standard deviation signifies a higher degree of numerical fluctuation in the indicator, signifying a greater amount of information and a more robust level of assessment for the indicator. Consequently, a greater emphasis should be placed on this metric.

(3) Indicator Conflict Represented by correlation coefficient.

$$R_j = \sum_{j=1}^{P} (1 - r_{ij}) \tag{4}$$

Ri $_j$ indicate the correlation coefficient between evaluation metrics i and j. Employing correlation coefficients to signify the interrelation among indicators. As the correlation with other indicators intensifies, so does the level of inconsistency between the indicator and others, indicating a greater sharing of information. Consequently, the repetitive nature of the evaluative material diminishes its robustness to a degree. Consequently, there should be a decrease in the emphasis placed on this metric.

(4) Information Density

$$C_j = s_j \sum_{i=1}^{P} (1 - r_{ij}) = S_j \times R_j \tag{5}$$

As the value of C $_j$ increases, the more significant the influence of the j-th evaluation criterion in the whole evaluation system becomes, the higher its importance should be attributed.

(5) Objective Weight

The objective weight W $_j$ for the jth indicator is derived from the following equation:

$$W_j = \frac{C_j}{\sum_{j=1}^{P} C_j} \tag{6}$$

Note: The weights W $_j$ should satisfy

$$\sum_{j=1}^{P} W_j = 1 \tag{7}$$

Upon integrating the processed data into the model for computational purposes, the seven indicators' weights are derived accordingly: winning streak accounts for 25.903%; net points account for 9.115%; unforced errors make up 9.512%; the server contributes 16.078%; serve numbers occupy 16.921%; points represent 12.483%; and winners have a share of 9.988%, as shown in Figure 1.

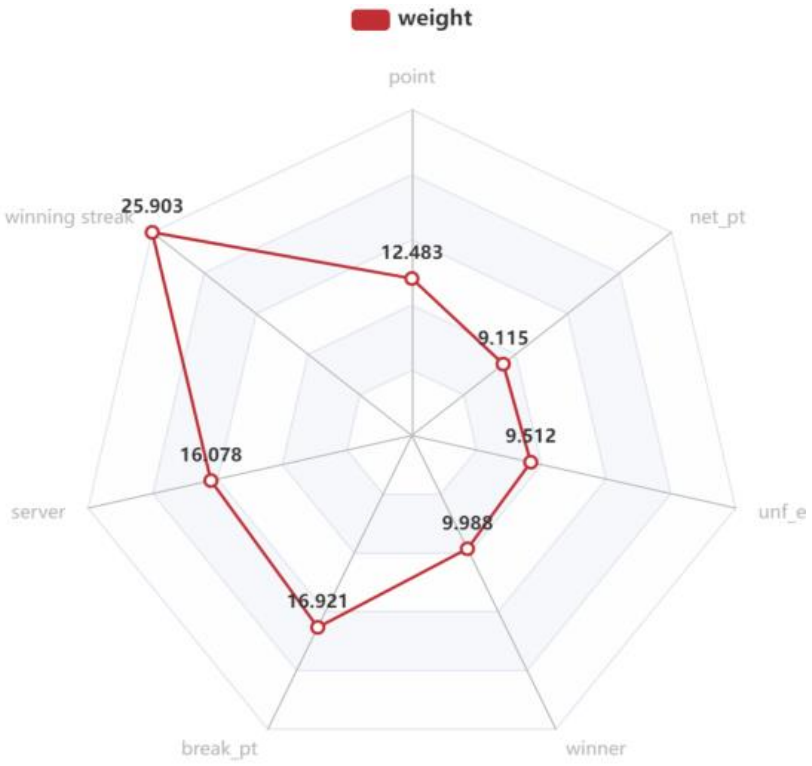


Figure 1. Weighted Index Chart

3. Results

3.1. Quantitative assessment of athletes' game performance based on RSR

The rank sum ratio comprehensive evaluation method was uesd to quantitatively evaluate the athletes' performance from multiple angles and multiple indicators, and get the dimensionless value RSR to judge whether the athletes' performance is good or bad. RSR evaluation model is a multi-factor comprehensive evaluation method based on the idea of information entropy and rank value evaluation. The method is proposed to solve the challenge of weight uncertainty in multi-factor decision-making problems and the flexible trade-off for different factors.

The RSR method combines entropy weighting with rank-value evaluation by introducing information entropy to determine the weight of each factor. Information entropy is used here to measure the uncertainty of each factor, making the evaluation more flexible and adaptable. Rank-value evaluation, on the other hand, reflects the relative position of each factor in the whole by sorting the data and calculating the rank order, which provides a basis for the final comprehensive evaluation.

3.2. Calculate the rank sum ratio (RSR) value

To mirror an athlete's performance at a specific moment, a timeline graph depicting the RSR value is created. Concurrently, based on the RSR value, one can categorize the athlete's performance pros and cons, enabling a quantitative analysis across various athletes, focusing on the same athlete at diverse times and performance levels .

Utilizing the aforementioned model in the initial game between Carlos Alcaraz and Nicolas Jarry, the overall scoring prowess of Carlos Alcaraz throughout the match can be ascertained, as shown in Figure 2 and Table 2.



Figure 2. RSR changes with the course of events

Table 2. RSR changes with the course of events

Point	winning streak	server	break_pt	winner	unf_err	net_pt	RSR
0	0	2	1	0	1	0	0.1551505
1	1	2	0	0	0	0	0.6120582
0	0	2	0	0	1	0	0.3254715
1	1	2	0	1	0	0	0.712594
1	2	2	0	0	1	0	0.7777865
0	0	2	1	0	0	0	0.250895
1	1	2	0	1	0	0	0.712594
0	0	2	1	0	0	0	0.250895
1	1	2	0	0	0	1	0.7038067
1	2	2	0	0	0	0	0.6772506
0	0	1	0	0	0	0	0.269446
1	1	1	0	0	0	0	0.4602881
1	2	1	0	0	0	0	0.5254806
0	0	1	0	0	0	0	0.269446
0	0	1	0	0	0	0	0.269446
1	1	1	1	0	0	0	0.2899671

3.3. Testing of the model

The way an athlete performs in one set influences their subsequent performance, a phenomenon known as an athlete's momentum. The way an athlete performs in every set accumulates his momentum, thereby propelling the game forward. Consequently, the progression of the game will be demonstrated through the athlete's average performance per set, which fluctuates based on the quantity of sets they play.

The mean performance level of an athlete in each set was computed, and a smoothing curve was employed to chart the progression of an athlete's performance over a period.

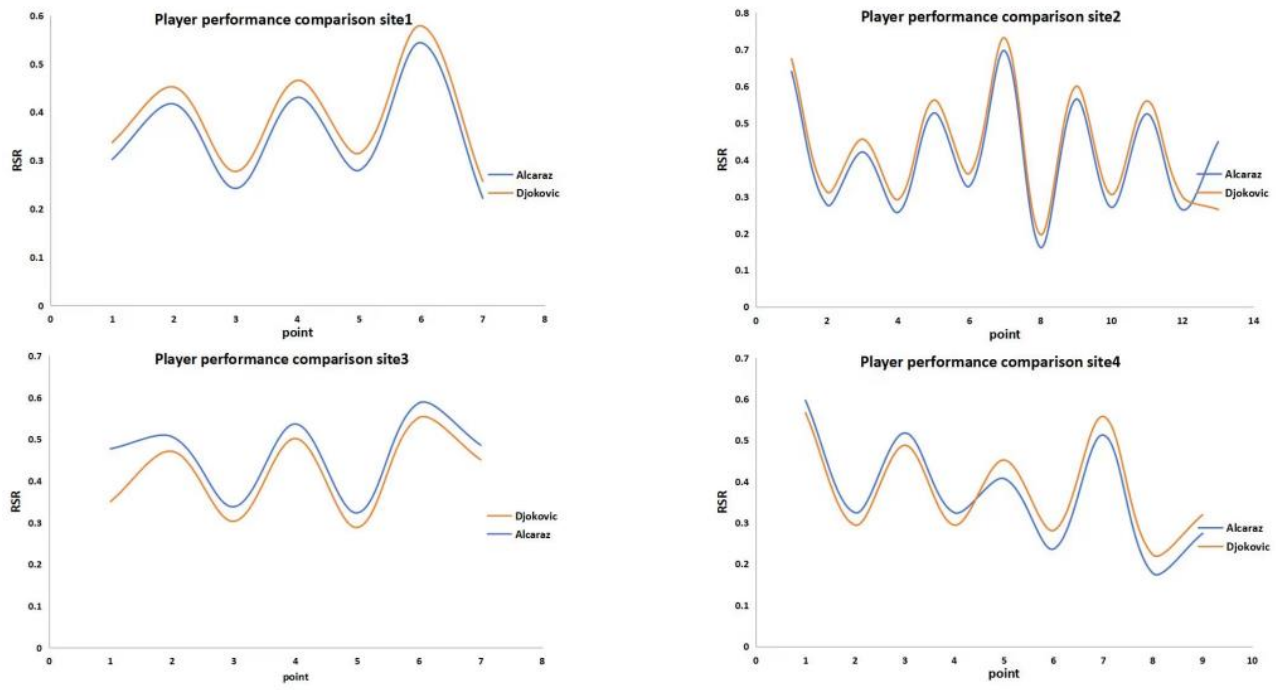


Figure 3. RSR changes with the course of events

From the Figure 3, Carlos Alcaraz's performance is represented by the blue line, while Novak Djokovic's performance is indicated by the orange line. The site1 chart reveals that Djokovic was

likely to clinch the initial set in the match's opening set; at site2, there was little variance in the performance of the two competitors, culminating in Alcaraz's victory; at site3, Alcaraz's momentum was significantly greater, with the graph's outcomes closely mirroring the match's actual results.

3.4. The Chi-Square Test

Expanding upon the data from the initial match mentioned in the first question, a thorough statistical analysis was carried out. After determining the mean momentum for each round, we proceeded to calculate the relative momentum by analyzing the differences. Concurrently, the success rate of the player was documented at this juncture. The detailed outcomes are outlined below in Figure 4.

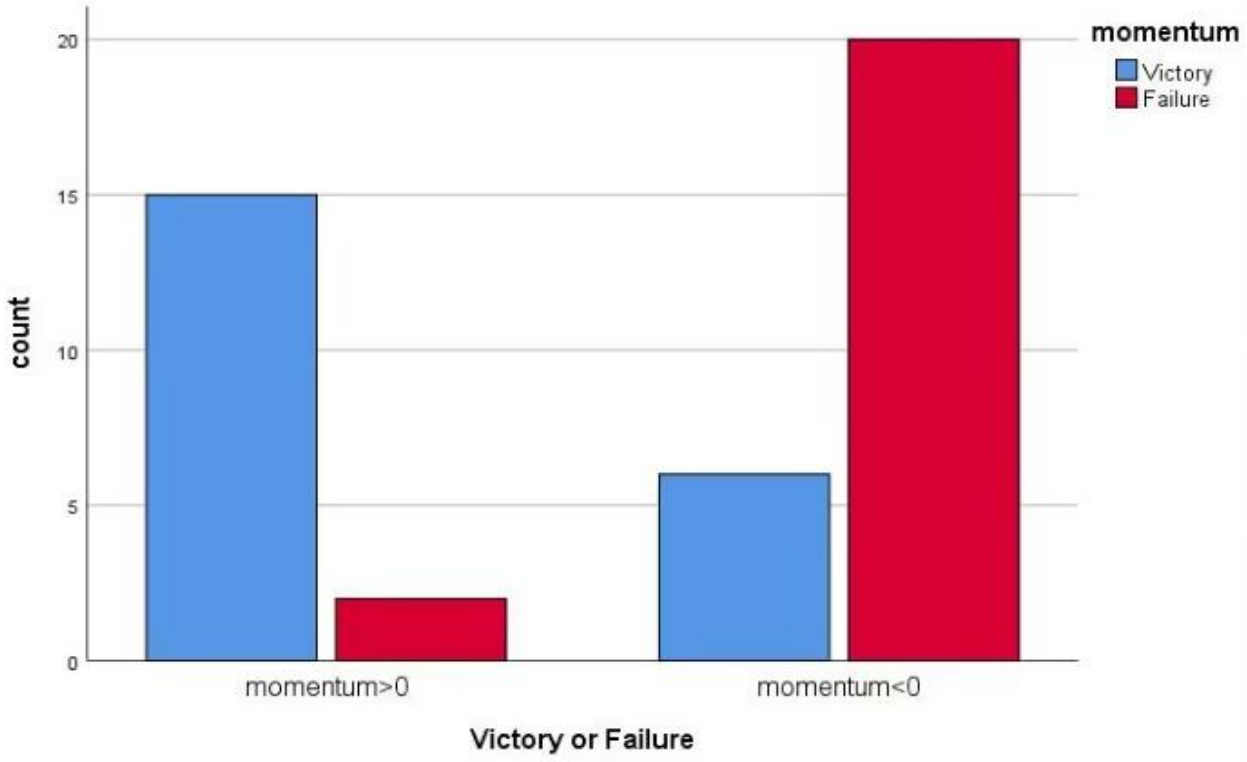


Figure 4. Column chart of winning times statistics

For these data, conducted a chi square test, and the test results are as follows :According to the chi-square test, the Pearson's asymptotic significance of 0.00029<0.05,which shows that "Momentum" is related to success.

Utilizing the initial data set, we determine Player 1's mean momentum in a game and the metrics of success for that particular round. In this context, 1 signifies a round's success, while 0 indicates a failure. The following represents incomplete data: Perform a uniformity analysis on both data groups, resulting in the derivation of Kendall's W coefficient and pertinent data, as shown in Table 3.

Table 3. Kendall's W analysis results

Name	Rank average	Median	Kendall's coefficient	x2	P
Relative RSR	1.01	0.035	0.96	288.12	0.00018
point	1.99	1			

The results of the Kendall coefficient consistency test show that the significance P-value for the overall data is 0.00018, which is significant at the level, leading to the rejection of the null hypothesis. Therefore, the data exhibit consistency. Meanwhile, the model's Kendall's coefficient of concordance is 0.96, indicating that the degree of correlation is almost perfect consistency.

4. Conclusions

The Rank-sum ratio evaluation method (RSR) based on the CRITIC weighting method was used to score players' performances at specific moments using the aforementioned seven indicators. Using this model, evaluated the the billiards championship final, compared players' performances, and effectively explained the fluctuations observed during the final. Simultaneously, we performed a Kendall correlation analysis between momentum' scores and success indicators, obtaining Kendall's coefficient equal to 0.96. This indicates a significant correlation between' momentum' and success. It is anticipated that the findings of this study will contribute to the future analysis of momentum within tennis competitions and enhance the predictive accuracy of match outcomes.

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