
Shortest Path Algorithms: Taxonomy and Advance in Research

my summary

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1 Introduction

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1.1 Overview

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1.2 Restatement of the Problem

Second Problem “momentum’s role in the match” means the level of momentum affects the future scores of the match. The coach may subscribe to the idea that each point is an independent event and governed by probability. In this view, consecutive success and momentum changes (swings) are seen as more random than influenced by previous events. To judge this autocorrelation and to use our model, we

- perform autocorrelation test on momentum, and perform correlation test between current momentum and future scores.

1.3 Our Work

- develop a model to

2 Notations and assumptions

2.1 Notations

To access a certain field in a point, we simply use the field name stated in the given dictionary as index, i.e. for a point *point*, we use $point_{ace}$ to denote the binary variable that shows whether *player* hits an ace ball in the point.

2.2 Assumptions

To simplify the problem, we made the following assumptions:

- **Assumption 1:** The `px_unf_err` column of the data only counts those unforced errors that occurred when the player was hitting in baseline.
Justification: Usually when a player is at net, the point will end in a few strikes, and there’s little probability that the player will hit an unforced error within that few strikes. What’s more, the `px_net_point` and `px_net_point_won` columns of the data can predominantly reflect the player’s ability at net, therefore reducing the impact of counting the unforced errors while at net.
- **Assumption 2:** The current performance on a certain aspect of a player can be reflected by the player’s 3 latest shots of that aspect.
E.g. P_{ace} can be reflected by the proportion of aces in the 3 latest **serves** of the player, P_{win} can

Symbols	Description
$player$	the current player we are considering (e.g. while calculating momentum)
$point_i$	the i^{th} point of the match, a vector consists of fields stated in the given dictionary
cur	the current index of the point, i.e. the match is currently at the cur^{th} point
H_i	denotes the set $\{point_{cur}, point_{cur-1}, \dots, point_{cur-i+1}\}$
S_i	the set of latest i points where $player$ serves
R_i	the set of latest i points where $player$ returns
P_{ace}	current probability of hitting an ace by $player$
P_{df}	current probability of double-faulting by $player$
P_{1st}	current first serve goal rate by $player$
P_{fw}	current probability of $player$ winning a served point within 3 rallies
rd	current return depth of $player$
P_{win}	current probability of hitting a winner by $player$
P_{net}	current net win rate of $player$
$dist$	$player$'s running distance on the point
P_{unf}	current probability of hitting an unforced error by $player$
$scored$	whether $player$ scored the current point
$diff$	the score difference for $player$ in the current game (by number of points)
M	the current momentum of $player$ after a point

be reflected by the proportion of winners in the 3 latest **shots** of the player, rd can be reflected by the return depth of the 3 latest **returns** of the player, etc.

Justification: The current performance of a player consists of the average performance and the status of the player at the moment, which can be comprehensively reflected in the player's performance on recent shots. For convenience, we specified that the 3 latest shots can reflect the player's current performance.

3 Momentum Evaluation Model

To determine which player is performing better at a specific time, we create an indicator "Momentum" to give a quantitative and overall evaluation.

Definition 3.1. *Niche width is the range of resources that a species can use.*

Niche width is an indicator [1]

3.1 Model Overview

3.2 Data Processing and Normalization

In order to quantify the factors used in our model, based on our assumptions, we calculate them using the following formulae:

$$P_{ace} = \frac{\sum_{p \in S_3} P_{ace}}{3} \quad (1)$$

$$P_{df} = -\frac{\sum_{p \in S_3} P_{double_fault}}{3} \quad (2)$$

$$P_{1st} = \frac{\sum_{p \in S_3} [p_{serve_no} = 1]}{3} \quad (3)$$

$$P_{fw} = \frac{\sum_{p \in S_3} [p_{rally_count} \leq 3][p_{point_victor} = player]}{3} \quad (4)$$

$$rd = \frac{\sum_{p \in R_3} \begin{cases} 0, & p_{return_depth} = ND \\ 1, & p_{return_depth} = D \\ -1, & p_{return_depth} = NA \end{cases}}{3} \quad (5)$$

$$P_{win} = \frac{\sum_{p \in H_3} P_{winner}}{3} \quad (6)$$

$$P_{net} = \frac{\sum_{p \in H_3} P_{net_pt_won}}{\sum_{p \in H_3} P_{net_pt}} \quad (7)$$

$$dist = \begin{cases} 0, & point_{cur,distance_run} < 5 \\ -1, & point_{cur,distance_run} > 45 \\ \frac{5 - point_{cur,distance_run}}{40}, & otherwise \end{cases} \quad (8)$$

$$P_{unf} = -\frac{\sum_{p \in H_3} P_{unf_err}}{3} \quad (9)$$

$$scored = [point_{cur,point_victor} = player] \quad (10)$$

$$diff = \frac{\sum_{p \in point} [p_{set_no} = point_{cur,set_no}][p_{game_no} = point_{cur,game_no}](2[p_{point_victor} = player] - 1)}{\min\{3, \sum_{p \in point} [p_{set_no} = point_{cur,set_no}][p_{game_no} = point_{cur,game_no}]\}} \quad (11)$$

In order to normalize the data processed, we convert the original data to limit them in $[-1, 1]$. For those factors that negatively influence the momentum, such as P_{df} , we made sure it's in $[-1, 0]$. For those factors that positively influence the momentum, such as P_{win} , we made sure it's in $[0, 1]$. For those factors that influence the momentum in both ways, such as $diff$, we made sure it's in $[-1, 1]$.

3.3 Visualization and Analysis

In figure 1, when the red line is above the blue line, it means that the player is performing better than the opponent.

In figure 2, we minus the opponent's momentum from the player's momentum to get the difference. And the difference indicates how much better the player is performing than the opponent.

3.4 momentum autocorrelation and correlation with runs of success

To answer the coach's doubt, we need to perform autocorrelation test on momentum, and perform correlation test between current momentum and future scores in this section.

If the momentum has a high autocorrelation, it means that the momentum at this moment has a high impact on future performance. And if the correlation between momentum and future scores is high, it means that the player with higher momentum has a higher chance to win the next multiple round.

momentum autocorrelation

To check if sequence of momentum is self-related, we calculate the Pearson correlation between momentum and that with a time lag.

Algorithm 1 Calculate autocorrelation function

```

for  $i = 1$  to 31 do
     $time\_series \leftarrow momentum(i^{th} match\_index : i + 1^{th} match\_index - 1)$ 
     $max\_lag \leftarrow \lfloor length(time\_series)/2 \rfloor$   $\triangleright$  Consider lags up to half of the length of the time series
     $autocorrelation \leftarrow zeros(1, max\_lag)$ 
    for  $shift = 1$  to  $max\_lag$  do
         $correlation \leftarrow corrcoef(time\_series(1 : end - shift), time\_series(shift + 1 : end))$ 
         $autocorrelation(shift) \leftarrow correlation(1, 2)$ 
    end for
     $\triangleright$  Further processing or visualization can be performed here
end for

```

Here we display the autocorrelation of momentum of the first player in first three games. There are similar results for the second player and for the momentum difference.

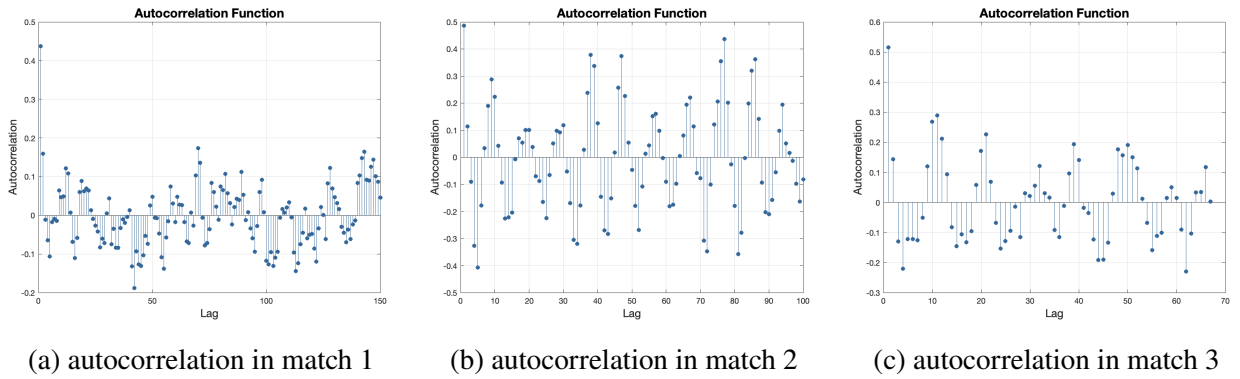


Figure 1: Momentum autocorrelation

The $corrcoef$ of lag 1 in match one is 0.4546, match two 0.5149, match three 0.5342. It can be seen that the autocorrelation of lag one is high, which means that the momentum at this moment has a strong relationship with the momentum in the next round. And the autocorrelation decreases to random as the lag increases.

correlation with runs of success

To give a quantitative evaluation of “future scores”, we count points gain in future multiple rounds, and derive the difference by minus that of the opponent. For example, if the player gains 3 points in the next 5 rounds, and the opponent gains 2 points, the difference is 1. The difference indicates how much better the player is performing than the opponent.

In intuition, the player with higher momentum should have a higher chance to win the next round. And momentum at this moment should have less impact on the future rounds as time extends. The correlation between momentum and future scores verifies our intuition.

We calculate points gain difference in future one to five rounds at each time of all matches. Here we display five points gain difference and momentum difference in first three games.

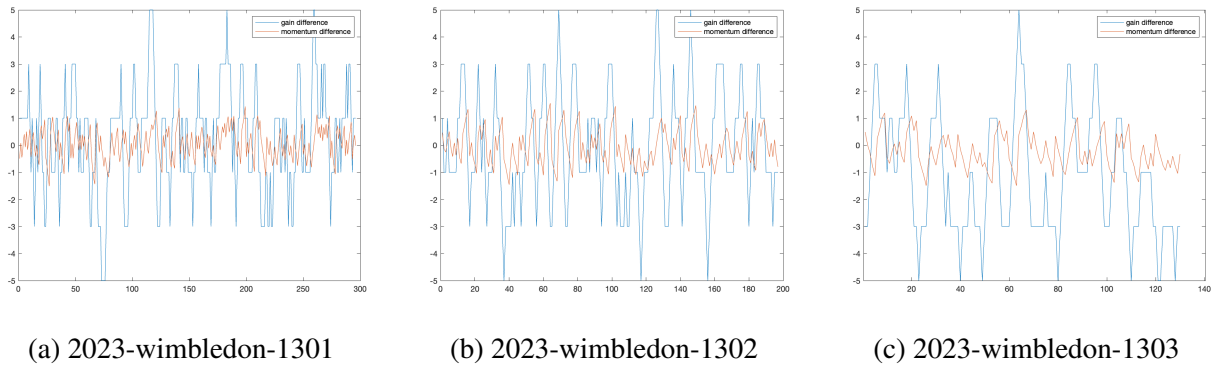


Figure 2: Gain Difference and Momentum in First Three Games

And we derive the correlation between gain difference from one to five rounds and momentum difference of all matches. Here we display the three of them.

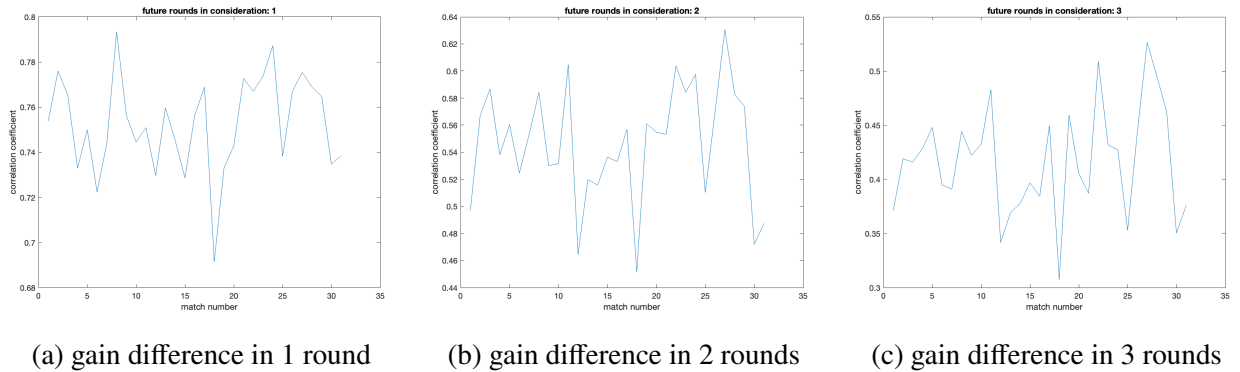


Figure 3: Correlation Between Gain Difference and Momentum Difference

Here we display the max and min correlation in different rounds. (hint. the max and min correlation means maximum and minimum of all matches.)

As we can see from the table, the correlation between momentum and future scores is bigger than 0.5 considering the next 1 round, it implies that momentum has a substantial impact on the next round. And the correlation decreases as the rounds extend, which verifies our intuition, that the momentum at this moment has less impact on the future rounds as time extends.

rounds	1	2	3	4	5
max	0.7934	0.6307	0.5264	0.4678	0.3910
min	0.6914	0.4516	0.3074	0.1824	0.0627

Table 1: max and min Correlation of all matches in different rounds

Now, we have finished problem 2.

4 Robustness Analysis

5 Strength and Weaknesses

5.1 Strengths

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5.2 Weaknesses

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References

[1] Alice Axford, Bob Birkin, Charlie Copper, and Danny Dannford. Demonstration of bibliography items. *Journal of T_EXperts*, 36(7):114–120, Mar 2013.

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A 1

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B report on Use of AI

1.

OpenAI ChatGPT (Feb 2,2024 version,ChatGPT3.5)

Query1: *“swings in play and runs of success by one player are random” can this sentence to be interpreted as swings in play and runs of success by one player are independent?*

Output: *Yes, the sentence ”swings in play and runs of success by one player are random” can be interpreted as suggesting that swings in play and runs of success by one player are independent of each other. In statistical terms, independence means that the occurrence or outcome of one event does not influence the occurrence or outcome of another.*

In the context of tennis, this would imply that the fluctuations in the dynamics of the match (swings in play) and a player’s success streaks (runs of success) are not connected or dependent on each other. Each event is considered random and not influenced by the occurrence of the other.