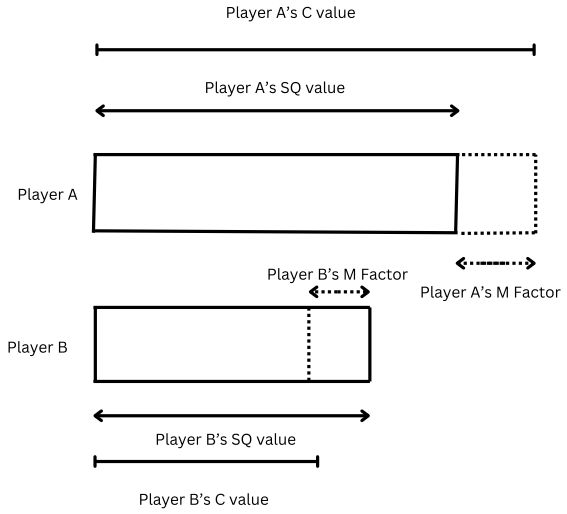
BU Additional Transfer Essay

Prompt A jellyfish is not a fish. Cat burglars don't burgle cats. Rhode Island is not an island. Write an essay about some other misnomer, and either come up with and defend a new name for it or explain why its inaccurate name should be kept.

Tennis players are often said to be "on fire" if they are winning more points on average in the short-term than their opponent. This term is not only misleading, but is damaging in the way that it reduces an extremely valuable metric for tracking tennis player's performance to simply being "on fire." I suggest the replacement term of "performance momentum", which has a calculable value, as opposed to being a simple boolean trait. I also will show a method for calculating this value and demonstrate how it can be used to analyze player performance with quantitative rigor.

For analytical reasons tennis coaches, players, and bettors would love to have a way of tracking a player's amount of time "on fire" and how much it influences the match's outcome. Whether or not the phenomenon of being "on fire" even exists is hotly debated. The argument for being "on fire" is not improved by its proponents attributing its existence to non-quantitative traits like motivation, inspiration, and other emotional components. Whether they are factors or not, they are extremely difficult to track, especially precisely. Because of this, I need to start by giving the momentum a concrete, mathematical definition.

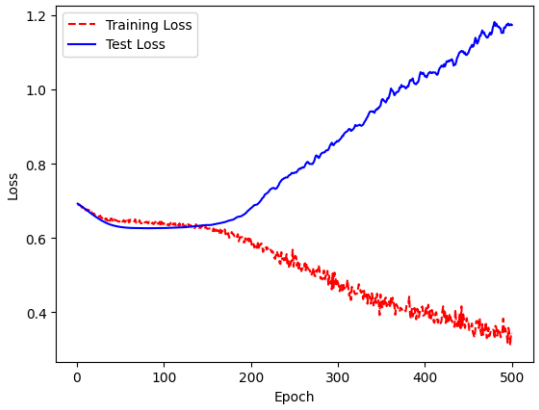
In its purest form, what the momentum should track is a player's current performance compared to their average performance. Specifically, I define a player's momentum as $M = C - SQ$, where M is the momentum, C is a player's current chance of winning a point, and SQ is the player's average chance of winning a point that match. I will call SQ the player's skill quotient, as it was inspired by IQ testing. The figure to the right shows how this definition plays into our analysis. Since we are looking at probability, the sum of Player A's probability to win and Player B's probability to win should always equal one. In other words, If player A has positive momentum, player B has the same amount negative momentum. This points to the superiority of momentum over being "on fire", as it implies that when momentum is zero, the chance of a player winning the next point depends only on their skill. This useful definition reduces the problem of finding momentum to the two easier problems of finding a player's time-dependent odds and their time-independent odds.



A time-hardened method of analyzing a player's skill at any game is an Elo system. Invented by a fellow physicist, the chess Elo system quantifies a player's skill based on their win history. Even more usefully, it can predict the odds of a player winning against an opponent to a very high accuracy. For this reason, I made a similar system for tennis. This has been done before on the match-scale but never on the point-scale like I have done. I created an Elo system in Python which uses principles from a recently published paper by Rémi Coulom (Whole-History Rating: A Bayesian Rating System for Players of Time-Varying Strength). I then trained the system on all 29,684 points played during the 2023 Men's Open Championship at Wimbledon. I also broke this data up such that each player has two different Elo ratings, one for their serving skills, and one for their returning skills. I did this because players are far more likely to win when serving, so I have to break them into categories to offset this effect.

Tracking a player's time-dependent performance odds is considerably more difficult. This added difficulty comes from the sheer multitude of factors that play a role in this calculation. One must consider historical skill differences, like before, but also other factors like point streaks, the way previous points ended,

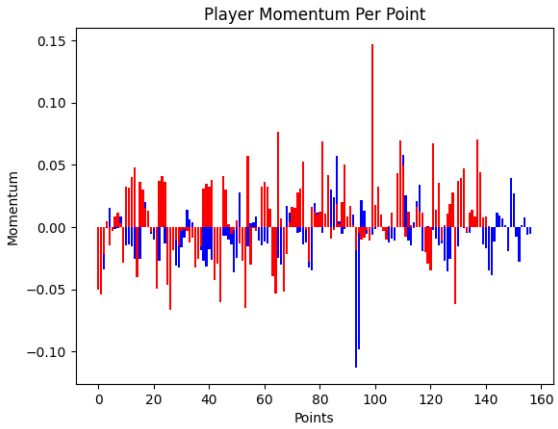
surface types, and more. Again, my primary gripe with the current term of being "on fire" is that it reduces the effect of these countless small factors. A player may feel like they are "on fire", but this feeling is caused by the myriad factors that create their momentum. In this way, being "on fire" can be viewed as a symptom of having a positive momentum and knowing it. Luckily, I have recently been dealing with similar problems of complexity in my neurophysics research, so I had the idea to apply similar a solution.



I created a machine-learning algorithm to track these variables. Specifically, I created a multi-layered long short-term memory (LSTM) deep learning network. This model uses a method called time-dependent back-propagation to take a large number of variables and output the probability of an event occurring over a varying time interval. Basically, it takes into account all the variables we provided, and considers their past values, to determine what the player's odds of winning the point are in that very specific moment. I trained the model on an 80-20 train-test split of every point that we trained the Elo system on 500 times. The figure to the left shows that we had our best version of the system when the blue and red lines met. This was the 131st iteration, which had a Bayesian-adjusted accuracy of around 85%.

Finally, I had both parts and was ready to analyze the momentum in its full glory. The figure to the right shows the result of this. This figure is of the championship match of last year's Wimbledon. The red bars indicate Carlos Alcaraz's momentum, and the blue bars indicate Novac Djokavic's.

It can be clearly seen that player's momentum goes up when they score more points in a row, as expected. It is also worth noting that there are points where the momentum switches so quickly and often that both players appear to have positive momentum at this scale, such as in the point range around 40. This is likely telling us that the momentum is unstable here, with neither player gaining high point-streaks. Maybe most importantly, it is quite clear that the total area of momentum is mostly red, albeit marginally. Looking at this, someone might infer that Alcaraz played better this game, and for this reason, won. They would be correct!



There can, has, and will be more analysis of these results done, but I believe that I have at least sufficiently made the point that momentum, regardless of cause, does play a factor in how tennis is played. I argue therefore that it should also play a factor is how we analyze tennis and discuss it. The tennis community is one of the world's most analytical. With the tennis training and betting markets being billion-dollar markets individually, there is massive incentive to analyzing the game as optimally as possible. It is past time to hang up the vague and unhelpful distinction of being "on fire" and the ideal time to embrace the rigorous and measurable quality of performance momentum.