Settling the Debate: The GOAT of tennis

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1. Introduction

The Open Era of tennis has seen the world's greatest players and some of the most riveting and exceptional performances in big events. Players such as Rod Laver, John McEnroe, Ivan Lendl and Pete Sampras made a name for themselves over the course of their careers but it is arguably the Big 3 - Roger Federer, Rafael Nadal and Novak Djokovic - who have captured the world's attention and have elevated the sport beyond anything seen before. The following machine learning project thus aims to predict which of these men should be considered the GOAT - the greatest of all time. I make use of a random forest model applied to a dataset containing all the matches in the main ATP tour events from 2003, when Federer won his first Grand Slam. However, I first provide descriptive statistics to better understand the nature of the data as well as to gain insight into the Big 3's performance.

2. Descriptive statistics

These descriptive statistics make use of the ATP data from 1968, the start of the Open Era, before focusing on the current period with Nadal, Federer and Djokovic. I have chosen to first look at the top Grand Slam wins over time, choosing the players with top 10 most titles. Number of Grand Slams is the most commonly used metric in the debate of the best player and can thus be used to understand which players in the Open Era gained recognition for their performances. The following graph highlights this, showing the top 10 Grand Slam winners from 1968 to 2022.

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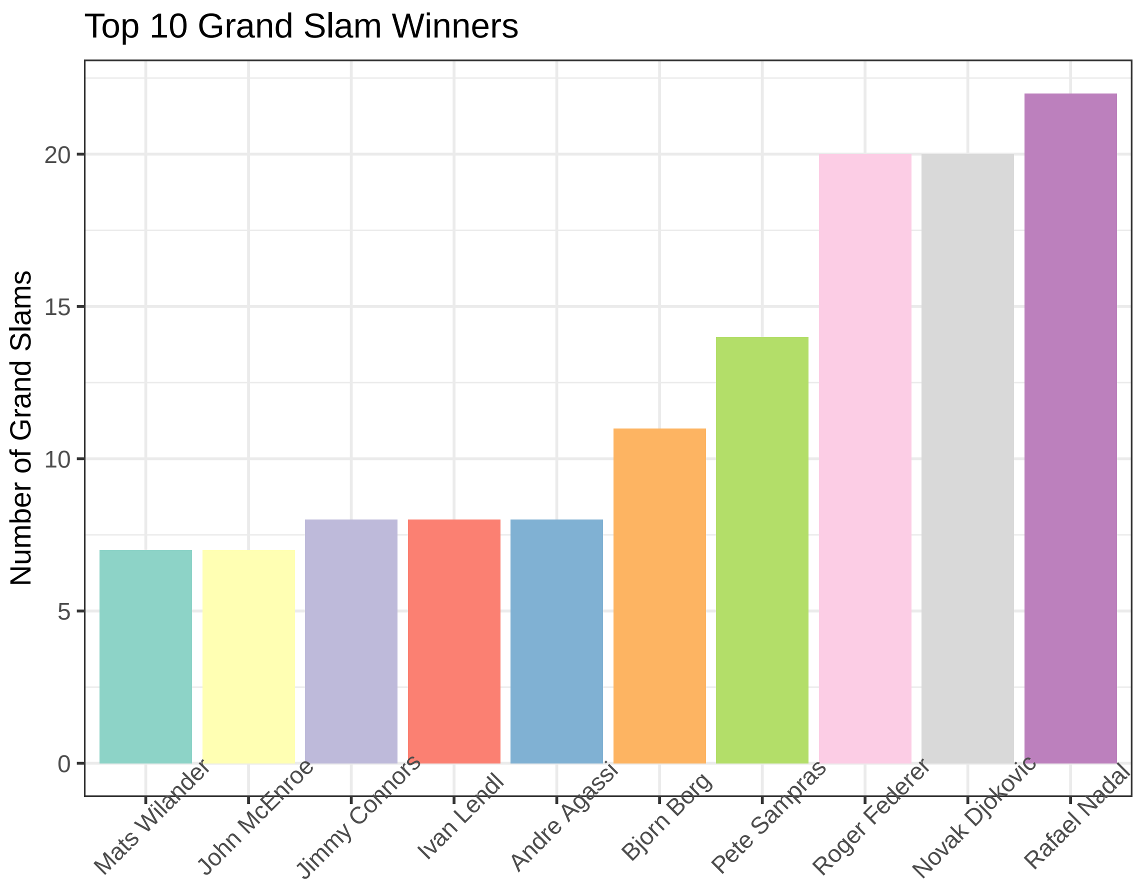


This graph illustrates the dominance of the Big 3 in Grand Slam wins, with Nadal holding the most titles at 22 as of 2022. The other seven players in the graph, who also had illustrious careers, lag quite far behind Nadal, Federer and Djokovic. Pete Sampras, for example, who was still competing when Federer began his career, only has 14 Grand Slams to his name while the other players have even fewer. This shows how the Big 3 have elevated the level of the game and raised the bar for what is considered high-level achievement.

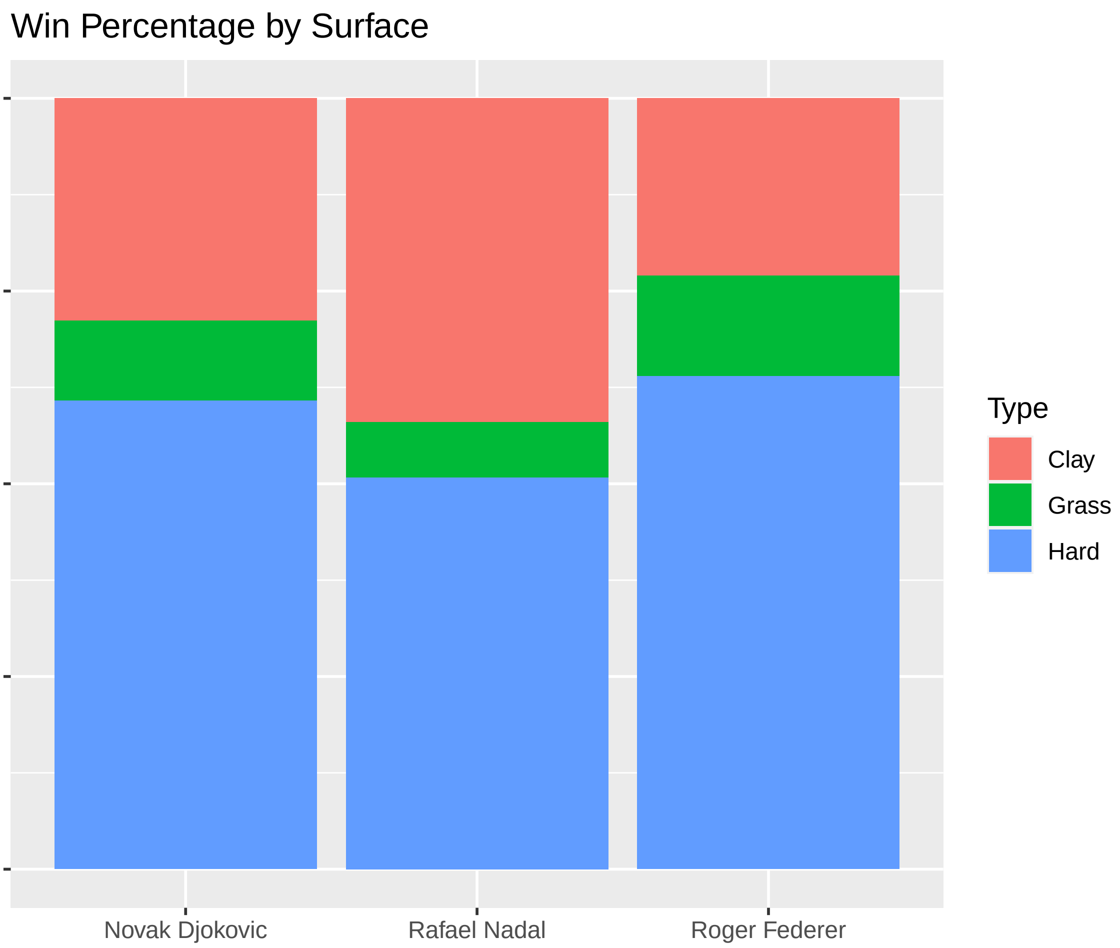
The following table further supports the Big 3's supremacy, showing the winners of each Grand Slam from 2003 to 2019.

	year	Australian Open	Roland Garros	Wimbledon	US Open
1	2003	Andre Agassi	Juan Carlos Ferrero	Roger Federer	Andy Roddick
2	2004	Roger Federer	Gaston Gaudio	Roger Federer	Roger Federer
3	2005	Marat Safin	Rafael Nadal	Roger Federer	Roger Federer
4	2006	Roger Federer	Rafael Nadal	Roger Federer	Roger Federer
5	2007	Roger Federer	Rafael Nadal	Roger Federer	Roger Federer
6	2008	Novak Djokovic	Rafael Nadal	Rafael Nadal	Roger Federer
7	2009	Rafael Nadal	Roger Federer	Roger Federer	Juan Martin del Potro
8	2010	Roger Federer	Rafael Nadal	Rafael Nadal	Rafael Nadal
9	2011	Novak Djokovic	Rafael Nadal	Novak Djokovic	Novak Djokovic
10	2012	Novak Djokovic	Rafael Nadal	Roger Federer	Andy Murray
11	2013	Novak Djokovic	Rafael Nadal	Andy Murray	Rafael Nadal
12	2014	Stan Wawrinka	Rafael Nadal	Novak Djokovic	Marin Cilic
13	2015	Novak Djokovic	Stan Wawrinka	Novak Djokovic	Novak Djokovic
14	2016	Novak Djokovic	Novak Djokovic	Andy Murray	Stan Wawrinka
15	2017	Roger Federer	Rafael Nadal	Roger Federer	Rafael Nadal
16	2018	Roger Federer	Rafael Nadal	Novak Djokovic	Novak Djokovic
17	2019	Novak Djokovic	Rafael Nadal	Novak Djokovic	Rafael Nadal

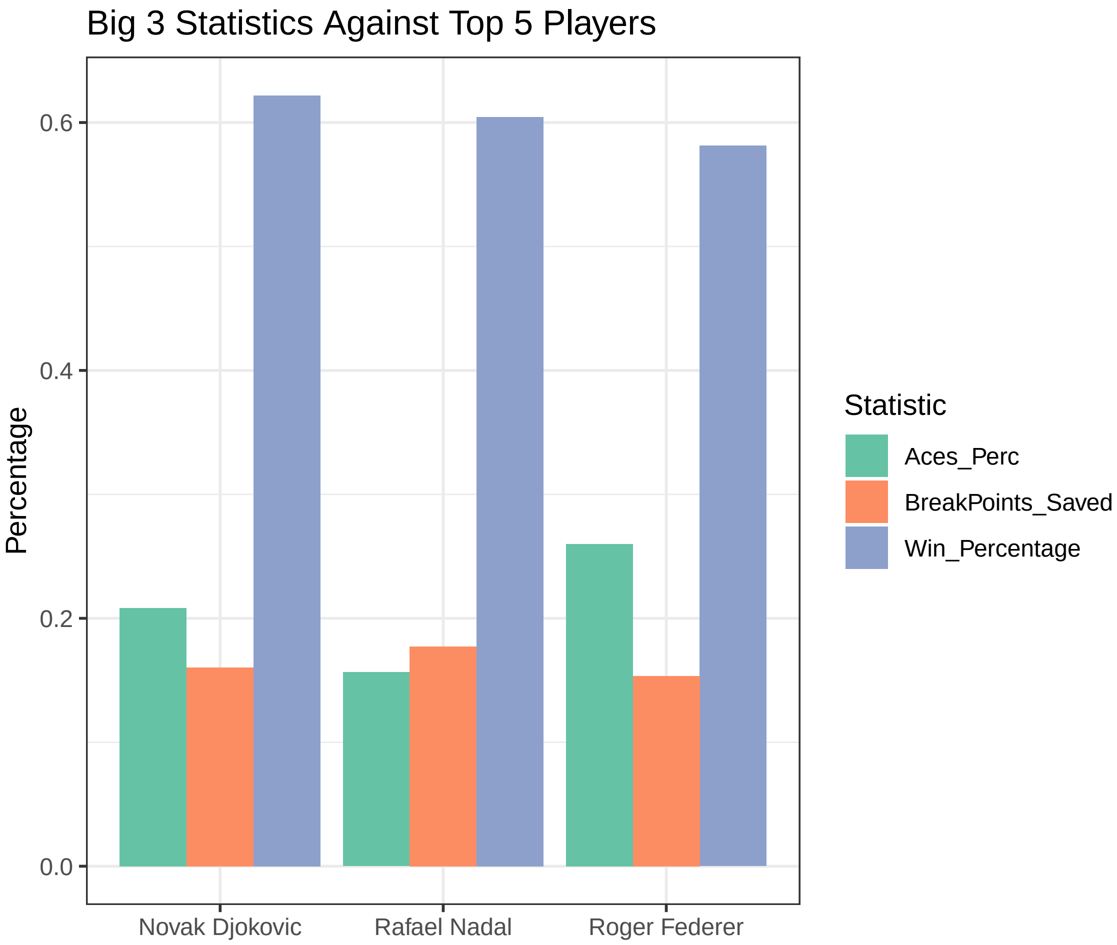
Table 2.1: Grand Slam Winners Since 2003

This is evidence of the extent to which Nadal, Federer and Djokovic have dominated the Grand Slam circuit. Since 2003, when Federer won his first Grand Slam, the Big 3 have won 55 out of the 68 tournaments in this period, with only Andy Murray and Stan Wawrinka winning more than one each of all the other players. There is therefore no doubt that these top 3 players will rival each other as being the greatest of all time.

Beyond showing Grand Slam wins, the data also provides additional information on the statistics of each match played relating to length of the game, serving and break points statistics and the surface of the tournament among others. The following tables and figures illustrate how each of the Big 3's wins are broken down and relate to some of these variables.



These graphs, referencing surfaces by their colour, show each of Nadal, Federer and Djokovic's win percentages on each surface. This indicates that Nadal has a much higher win record on clay than the other two, confirming his status as the King of Clay. All players have the highest win records on hard court, which may partly link to this being the surface with the most number of matches, but Federer and Djokovic have a more even split across surfaces, indicating their versatility.



The grouped chart sheds further light into each of the Big 3's statistics against top 5 players, averaging across matches. Djokovic has the highest win percentage, Nadal the highest breakpoints saved and Federer the highest ace percentage. Federer is known to have a strong serve that is difficult to read so it is understandable that his ace percentage is higher than the others, while Nadal is known to fight back when he is at a disadvantage, hence the high breakpoints saved. However, I would argue that win percentage is the most important statistic to consider because this relates directly to number of wins and titles. This graph shows that Djokovic has the best record against top 5 players in the main ATP events, winning approximately 62 percent of his matches.

	Player	TTaken
1	Rafael Nadal	125.00
2	Roger Federer	109.00
3	Novak Djokovic	121.00

Table 2.2: Average Time Taken

This final table provides an overview of the Big 3's average match times across all games. Roger Federer is shown to take the least amount of time to finish matches, averaging at 109 minutes or approximately 1 hour and 45 minutes. This is quite significantly different from Nadal and Djokovic, suggesting that Federer prefers a shorter game format. This may link to his playing style which involves big serves and net play which generally induces shorter matches due to less rallies.

These graphs and tables provide a sufficient overview of player performance and offers a comparison of the Big 3' 's results and more specifics of their playing style and outcomes. However, to obtain a more definitive answer to the question of the GOAT, I make use of a random forest model which is discussed and interpreted in the next sections.

3. Data and methodology

I have made use of a dataset that includes all the ATP matches from 1968 to 2022, within which is included match and player statistics. I merged these documents and filtered the data frame to include only main tour events i.e. Grand Slams, Masters and Tour Finals. These are the most important events in the tennis circuit and the ones in which the top players participate the most. I further subset the data to include matches from 2003, when Roger Federer won his first Grand Slam at Wimbledon. This allows me to focus on the time period of the Big 3 who are at the centre of the debate surrounding the GOAT. There is also a large amount of missing information in earlier dates, particularly in the 1960s, 70s and 80s, so subsetting to start at 2003 avoids issues related to NA values. Finally, I selected the features I deemed most relevant to my model to arrive at the final data frame. These features included tournament names and surfaces, player characteristics - such as their height and age - and various match statistics linked to time taken, breakpoints faced and saved, aces and first serves in. These features were included for both the winner and the loser of each match. Additional feature engineering involved turning categorical variables, such as surface, into factors to ensure the model accurately processed the data.

Lastly, I had to perform target engineering to establish an outcome variable to use for predictions in the model. I created a random binary variable and assigned the winner and loser of each game to player 1 and player 2 based on the random binary variable. This ensured that the new match winner column had an even split between player 1 winning or losing each match and could be used as the target variable.

3.1. The random forest model

I made use of a random forest model model to process my data and perform predictions. Random forests are extensions or modifications of bagged decision trees and build a series of de-correlated trees to improve predictive performance. They have become a popular out-of-the-box learning algorithm because they enjoy good predictive performance and require minimal hyperparameter tuning (Boehmke & Greenwell, 2019). My model had 19 features with a binary target variable, making it a classification problem. I constructed two random forest models, a baseline model using the default hyperparameters as outlined by Boehmke & Greenwell (2019) and a second model based on the hyperparamater tuning done via a grid search. The predictions from the hypertuned model as well as its accuracy measures are presented and discussed below, including comparisons with the default model.

4. Results and discussion

The following table shows the predictions from my hypertuned model, indicating that Roger Federer is the GOAT based on win percentage. Djokovic and Nadal follow closely behind, while Andy Murray and Gael Monfils have the fourth and fifth highest win percentages, respectively.

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## [1] 0.3038952
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	Player	win_percentage	win_count
1	Roger Federer	0.89	110
2	Novak Djokovic	0.88	108
3	Rafael Nadal	0.86	107
4	Andy Murray	0.84	67
5	Gael Monfils	0.82	45

Table 4.1: The Best of Tennis

The model produces results that make sense. The Big 3 are the top three highest performers, while Andy Murray (who has sometimes been grouped into the Big 4 category) is in fourth place. I was surprised to see Gael Monfils finish in fifth place given that he has never won a major but the data set looks at matches across all main ATP events which could point to why he appears in the top winners.

Although the results make intuitive sense, it is also necessary to test the predictive performance of the model to see how accurate these predictions are based on the data. I compare the accuracy, sensitivity and specificity of the baseline and tuned models to highlight their predictive performance.

	Model	Accuracy	Sensitivity	Specificity
1	Baseline model	0.92	0.93	0.91
2	Tuned model	0.92	0.92	0.91

Table 4.2: Accuracy Across the Baseline and Tuned Models

This table, firstly, shows that both models have high and almost identical results across the accuracy measures. This could be due to the fact that the tuned model has very similar hyperparameters to the default model. The best model, as determined by the grid search, is given below.

	mtry	min.node.size	replace	sample.fraction	rmse	perc_gain
1	4.00	1.00	FALSE	0.63	0.30	2.73

Table 4.3: Grid Search Results

The mtry and node size hyperparameters determined by the grid search are the same as those in the baseline model and both models also have the same number of trees (500). This could account for the similarity in results. The actual values in the table indicate that the model is highly accurate and predicts the data well. The sensitivity shows that the model predicts successes (i.e. player 1 winning) correctly 92 percent of the time and predicts failures (player 1 losing) correctly 90 percent of the time.

An additional evaluation of the model considers errors within the random forest. One metric is the Out-of-Bag (OOB) prediction error which is calculated by evaluating the predictions of each tree on the out-of-bag samples that were not used during training (Boehmke & Greenwell, 2019). The RMSE, which is just the squareroot of the OOB prediction error, is another useful metric to understand the model's errors. The following output shows the errors from the baseline model and the tuned model.

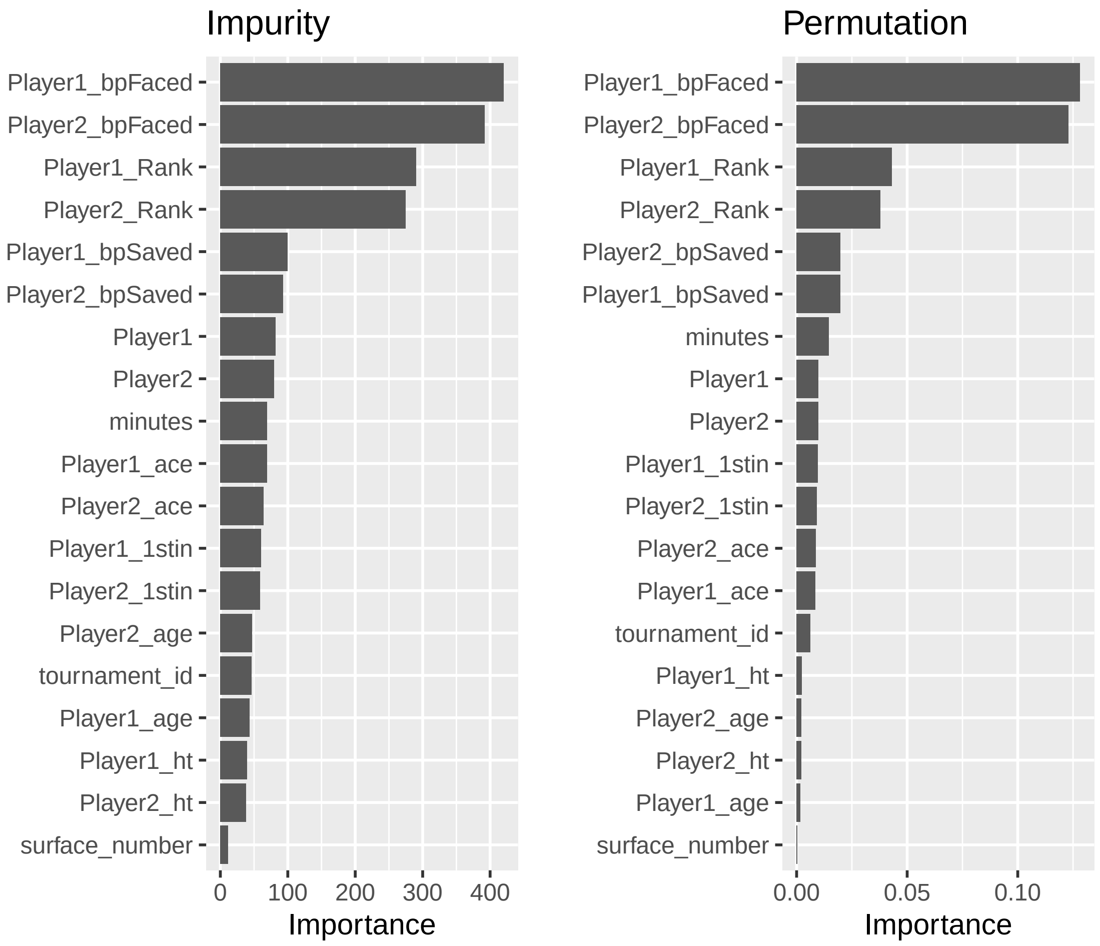
	Model	OOB	RMSE
1	Baseline model	9.24	30.39
2	Tuned model	8.66	29.56

Table 4.4: Errors Across the Baseline and Tuned Models in Percent

These results show that the tuned model performs slightly better than the baseline, with a lower OOB prediction error and RMSE. This indicates that the tuned model is a better predictive model.

4.1. Feature importance

The final element of evaluating the random forest is assessing the feature importance using both the impurity and permutation measures. The impurity-based measure bases feature importance on how much each feature contributes to reducing impurity when making splits in the trees. Permutation-based feature importance, on the other hand, measures how much the accuracy of the model deteriorates when the values of a feature are randomly shuffled. Both are necessary to determine the ranking of each feature's importance in the model.



Impurity

Permutation

Both feature importance graphs indicate that breakpoints faced, rank and breakpoints saved are the most important features in predicting the match winner. This makes sense as, understandably, higher ranked players generally win more matches, while breakpoints are highly important in tennis matches. Players gain advantage by breaking their opponents service games which is normally directly correlated with winning matches. These graphs therefore align with general tennis practice.

5. Conclusion

This machine learning model provided an accurate prediction of who the best tennis players of this generation are. I used a random forest trained on a dataset consisting of all the ATP matches in the main events from 2003 to 2019. Based on this model, I predict Roger Federer to be the greatest of all time. However, there are two caveats to this conclusion. Firstly, the data only runs to 2019 which does not take into account the most recent events in tennis i.e. Novak Djokovic winning his 23rd Grand Slam at the 2023 Roland Garros. Because of this feat, many are hailing him as the GOAT. Additionally, I have only 19 features in my model, relating to player characteristics and match statistics. To say someone is a great player goes beyond these metrics - popularity on and off the court, viewership, prize-money and many other factors also play a contributing role. As a Federer fan, I am very pleased with the results of the model but it is very difficult to settle the debate of the GOAT of tennis. Each of the Big 3 - Nadal, Djokovic and Federer - have achieved exceptional results and will be considered the greatest players of this generation and the greatest players of all time.

Boehmke, B. & Greenwell, B.M. 2019. *Hands-on machine learning with r.* CRC press.