Group 1: Predicting the Outcomes of Tennis Tournaments

A Monte Carlo Approach

Olivia Beck, Emma Lewis, Ryan Volkert

December 12, 2019

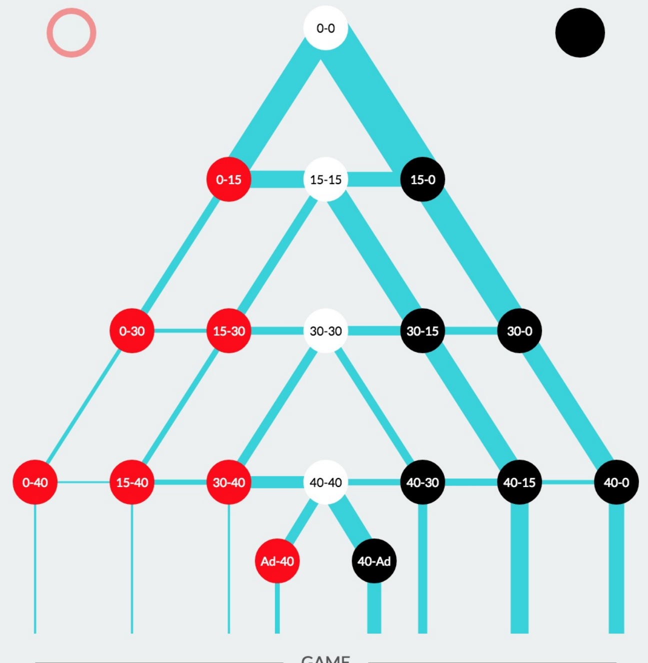
Project

- Based on a paper by Paul K. Newton and Joseph B. Keller called *Probability of Winning at Tennis 1. Theory and Data*
- Paper discussed how the probability of winning a game, a set, and a match in tennis are computed based on each player's probability of winning a point on a serve
- Based on other papers the conclusion was made to treat serves in tennis as independent identically distributed (iid) random variables
- It is noted that points in tennis are not iid for most purposes. This is not a bad assumption as the divergence from iid is small
- Both two out of three and three out of five set matches were considered allowing for 13-point tiebreaker in each set if needed

The Rules of Tennis

- Point: Smallest unit of measurement (Love-15-30-40-game)
- Game: A game is one when a player reaches 4 points with at least a 2 point advantage
- Set: A set is won by the player who wins 6 games first
- Advantage Set: If a game score of 6-6 is reached and advantage set rules are used, a player can only win a set with a 2 game lead
- Matches: Best of 3 sets (for women) or 5 sets (for men)
- Tie-break game: If a game score of 6-6 is reached and tie-break set rules are used. In a tie-break game, a player/team must reach 7 points with a two point advantage to win

The Rules of Tennis



Values

Things we need to know:

- Empirical probability of winning a rally on serve
- Empirical probability of winning a game on serve

Values

Things we need to know:

- Empirical probability of winning a rally on serve
- Empirical probability of winning a game on serve

Things we need to calculate:

- Theoretical probability of winning a game on serve
- Theoretical probability of winning a set
- Theoretical probability of winning the tie-breaker
- Theoretical probability of winning a match

Theoretical Probabilities: Rally and Game

$$\text{P(A Winning a Rally} \mid \text{A Served)} = p_A^R = \frac{\text{Points Won On Serve}}{\text{Points Served}}$$

Theoretical Probabilities: Rally and Game

$$\text{P(A Winning a Rally} \mid \text{A Served)} = p_A^R = \frac{\text{Points Won On Serve}}{\text{Points Served}}$$

$$\text{P(A Winning a Game} \mid \text{A Served)}$$
$$= p_A^G = (p_A^R)^4[1 + 4q_A^R + 10(q_A^R)^2] + 20(p_A^R q_A^R)^3 (p_A^R)^2 [1 - 2p_A^R q_A^R]^{-1}$$

- Where Probability A loses a rally given A served:

$$q_A^R = 1 - \frac{\text{Points Won On Serve}}{\text{Points Served}}$$

Theoretical Probabilities: Set

$$\text{P(A Winnning a Set} \mid \text{A Served)}$$

$$= p_A^S = \sum_{j=0}^{4} p_A^S(6,j) + p_A^S(7,5) + p_A^S(6,6)p_A^T$$

Theoretical Probabilities: Set

$$\text{P(A Winnning a Set} \mid \text{A Served)}$$

$$= p_A^S = \sum_{j=0}^{4} p_A^S(6,j) + p_A^S(7,5) + p_A^S(6,6)p_A^T$$

Where, $p_A^S(i,j)$ is defined recursively as:

$p_A^S(0,0) = 1$, $p_A^S(i,j) = 0$ if $i < 0$ or $j < 0$.

- if i+j -1 is even: $p_A^S(i,j) = p_A^S(i-1,j)p_A^G + p_A^S(i,j-1)q_A^G$
  - omit i-1 term if j=6 and i<6
  - omit j-1 term if i=6 and j<6
- if i+j -1 is odd: $p_A^S(i,j) = p_A^S(i-1,j)q_B^G + p_A^S(i,j-1)p_B^G$
  - omit i-1 term if j=6 and i<6
  - omit j-1 term if i=6 and j<6

Theoretical Probabilities: Tie Breaker

$$\text{P(A Winning the Tie Breaker} \mid \text{A Served Initially)}$$

$$= p_A^T = \sum_{j=0}^{5} p_A^T(7,j) + p_A^T(6,6)p_A^R q_B^R[1 - p_A^R p_B^R - q_A^R q_B^R]^{-1}$$

Theoretical Probabilities: Tie Breaker

$$\text{P(A Winning the Tie Breaker} \mid \text{A Served Initially)}$$
$$= p_A^T = \sum_{j=0}^{5} p_A^T(7,j) + p_A^T(6,6) p_A^R q_B^R [1 - p_A^R p_B^R - q_A^R q_B^R]^{-1}$$

Where, $p_A^T(i,j)$ is defined recursively as:

$p_A^T(0,0) = 1$, $p_A^T(i,j) = 0$ if i<0 or j<0.

- if $i + j - 1 \mod 4 \equiv 0$ or 3:
  $p_A^S(i,j) = p_A^T(i-1,j) p_A^R + p_A^T(i,j-1) q_A^R$
  - omit i-1 term if j=7 and i<7
  - omit j-1 term if i=7 and j<7
- if $i + j - 1 \mod 4 \equiv 1$ or 2:
  $p_A^T(i,j) = p_A^T(i-1,j) q_B^R + p_A^T(i,j-1) p_B^R$
  - omit i-1 term if j=7 and i<7

Theoretical Probabilities: Match

Women's (Best of 3):

$$\text{P(A Winning the Match} \mid \text{A Served First)}$$

$$= p_A^M = (p_A^S)^2 + 2(p_A^S)^2 p_B^S$$

Theoretical Probabilities: Match

Women's (Best of 3):

$$P(\text{A Winning the Match} \mid \text{A Served First})$$

$$= p_A^M = (p_A^S)^2 + 2(p_A^S)^2 p_B^S$$

Men's (Best of 5):

$$P(\text{A Winning the Match} \mid \text{A Served First})$$

$$= p_A^M = (p_A^S)^3 + 3(p_A^S)^3 p_B^S + 6(p_A^S)^3 (p_B^S)^2$$

Where:

- $p_A^S =$ Probabilty A wins a set given A served
- $p_B^S =$ Probabilty B wins a set given B served

Data

Data used in paper:

- Men and Women semifinalists in the 2002 U.S Open tournament
- Men and Women semifinalists in the 2002 Wimbledon tournament

Data

Data used in paper:

- Men and Women semifinalists in the 2002 U.S Open tournament
- Men and Women semifinalists in the 2002 Wimbledon tournament

Data used in our simulation:

- Men and Women semifinalists in the 2019 Wimbledon tournament

Results of Game

Table 1: Data for the Womens Semifinalists in the 2002 U.S. Open Tournament

	P(Win a Rally)	Empirical P(Win a Game)	Paper P(Win a Game)	Our P(Win a Game)
S. Williams	0.69	0.71	0.89	0.89
V. Williams	0.63	0.80	0.79	0.79
L. Davenport	0.65	0.85	0.83	0.83
A. Mauresmo	0.63	0.77	0.79	0.79

Results of Game

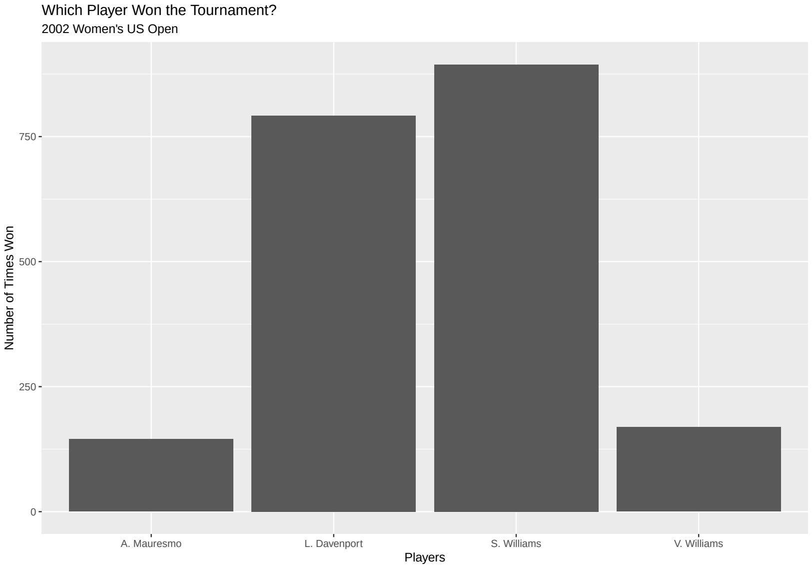
Table 1: Data for the Womens Semifinalists in the 2002 U.S. Open Tournament

	P(Win a Rally)	Empirical P(Win a Game)	Paper P(Win a Game)	Our P(Win a Game)
S. Williams	0.69	0.71	0.89	0.89
V. Williams	0.63	0.80	0.79	0.79
L. Davenport	0.65	0.85	0.83	0.83
A. Mauresmo	0.63	0.77	0.79	0.79

Table 2: Data for the Mens Semifinalists in the 2002 U.S. Open Tournament

	P(Win a Rally)	Empirical P(Win a Game)	Paper P(Win a Game)	Our P(Win a Game)
P. Sampras	0.73	0.95	0.93	0.93
A. Agassi	0.66	0.87	0.85	0.85
L. Hewitt	0.67	0.85	0.86	0.86
S. Schalken	0.68	0.90	0.88	0.88

2002 U.S Open: Women

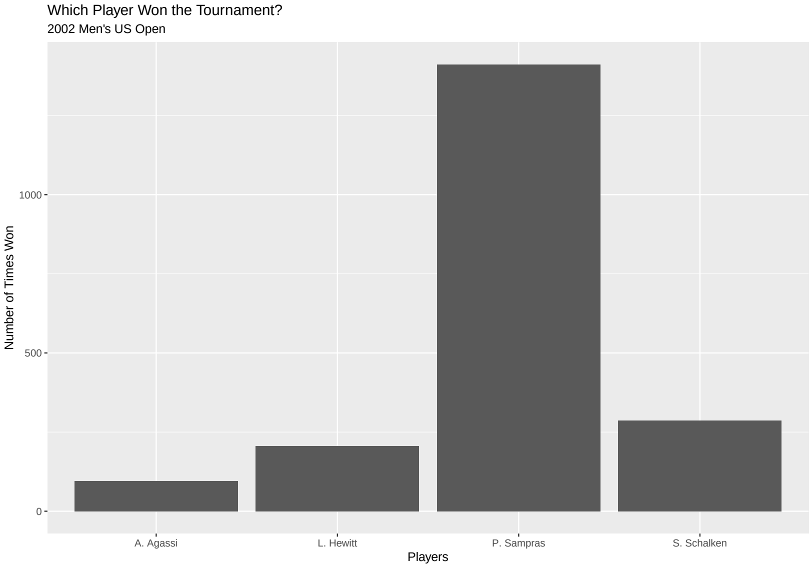


2002 U.S Open: Women

Semifinals				
1	**Serena Williams**	**6**	**7**	
4	Lindsay Davenport	3	5	
10	Amélie Mauresmo	3	**7**	4
2	**Venus Williams**	**6**	5	**6**

Final				
1	**Serena Williams**	**6**	**6**	
2	Venus Williams	4	3	

2002 U.S Open: Men



2002 U.S Open: Men

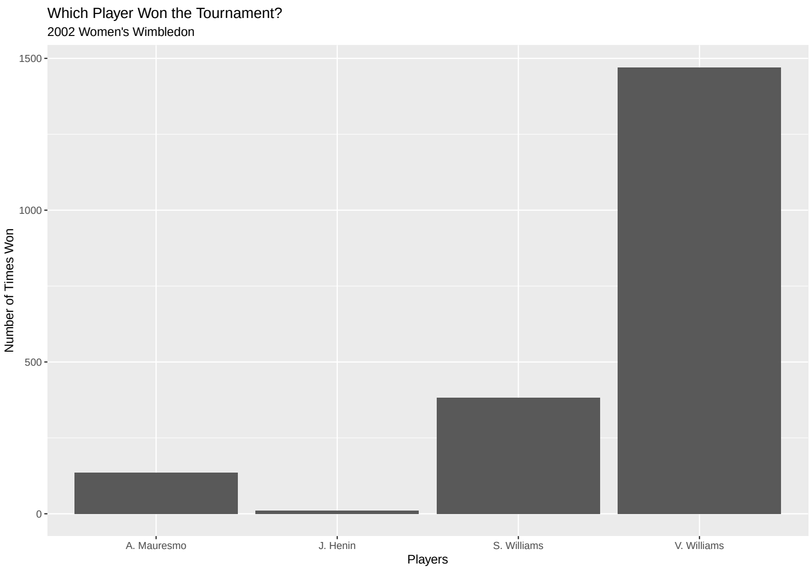
Semifinals

1	Lleyton Hewitt	4	6^{5}	**7^{7}**	2	
6	**Andre Agassi**	**6**	**7^{7}**	6^{1}	**6**	
17	**Pete Sampras**	**7^{8}**	**7^{7}**	**6**		
24	Sjeng Schalken	6^{6}	6^{4}	2		

Finals

6	Andre Agassi	3	4	**7**	4	
17	**Pete Sampras**	**6**	**6**	5	**6**	

2002 Wimbledon: Women



2002 Wimbledon: Women

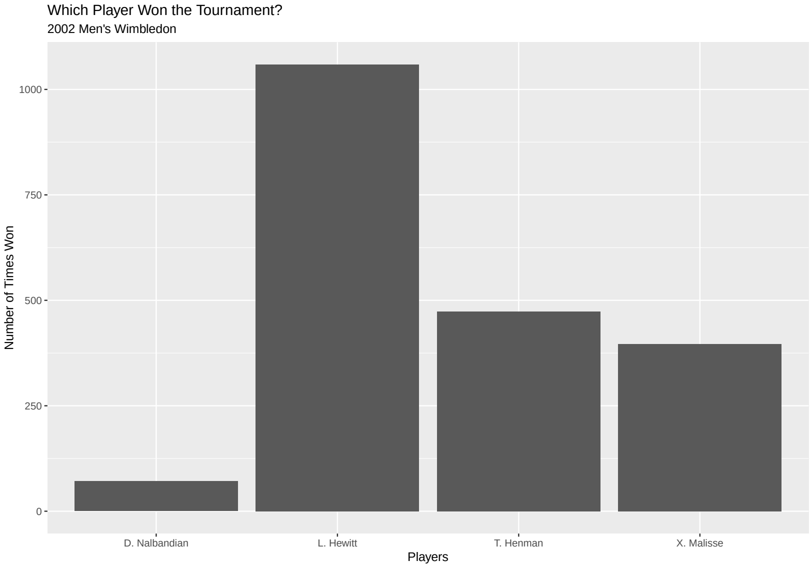
Semifinals

Seed	Player	Set 1	Set 2	Set 3
1	**Venus Williams**	**6**	**6**	
6	Justine Henin	3	2	
9	Amélie Mauresmo	2	1	
2	**Serena Williams**	**6**	**6**	

Final

Seed	Player	Set 1	Set 2	Set 3
1	Venus Williams	6^4	3	
2	**Serena Williams**	$\mathbf{7^7}$	**6**	

2002 Wimbledon: Men



2002 Wimbledon: Men

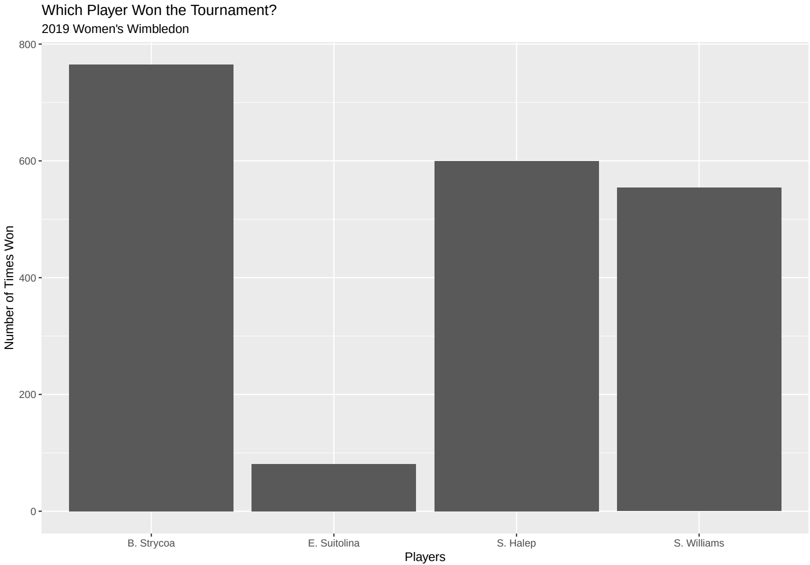
Semifinals

Seed	Player	Set 1	Set 2	Set 3	Set 4	Set 5
1	**Lleyton Hewitt**	**7**	**6**	**7**		
4	Tim Henman	5	1	5		
27	Xavier Malisse	6^{2}	4	**6**	**6**	2
28	**David Nalbandian**	$\mathbf{7^{7}}$	**6**	1	2	**6**

Final

Seed	Player	Set 1	Set 2	Set 3	Set 4	Set 5
1	**Lleyton Hewitt**	**6**	**6**	**6**		
28	David Nalbandian	1	3	2		

2019 Wimbledon: Women



2019 Wimbledon: Women

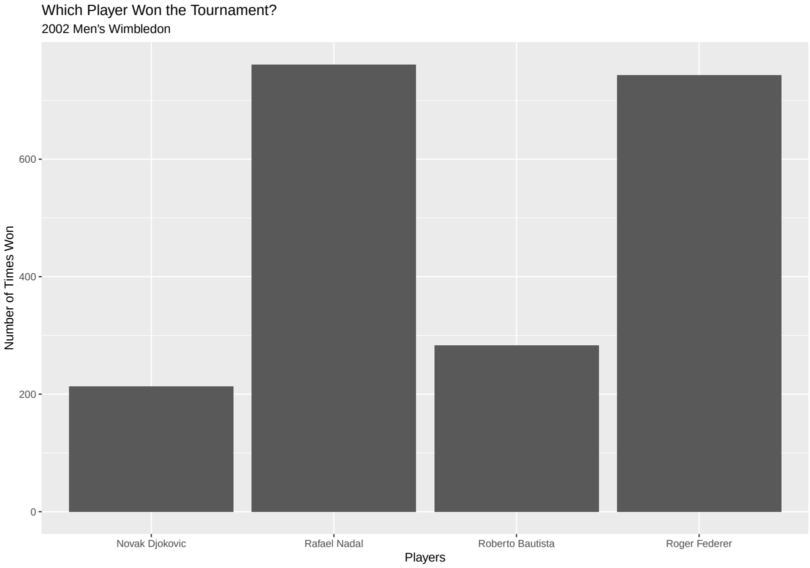
Semifinals

Seed	Player	Set 1	Set 2	Set 3
11	**Serena Williams**	**6**	**6**	
	Barbora Strýcová	1	2	
8	Elina Svitolina	1	3	
7	**Simona Halep**	**6**	**6**	

Final

Seed	Player	Set 1	Set 2	Set 3
11	Serena Williams	2	2	
7	**Simona Halep**	**6**	**6**	

2019 Wimbledon: Men



2019 Wimbledon: Men

Semifinals

Seed	Player	Set 1	Set 2	Set 3	Set 4	Set 5
1	**Novak Djokovic**	**6**	4	**6**	**6**	
23	Roberto Bautista Agut	2	**6**	3	2	
3	Rafael Nadal	6^{3}	**6**	3	4	
2	**Roger Federer**	**7^{7}**	1	**6**	**6**	

Final

Seed	Player	Set 1	Set 2	Set 3	Set 4	Set 5
1	**Novak Djokovic**	**7^{7}**	1	**7^{7}**	4	**13^{7}**
2	Roger Federer	6^{5}	**6**	6^{4}	**6**	12^{3}