Teaching machines how to win at Blackjack

Thinkful Capstone Project

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Popularity of Blackjack

- Blackjack was first referenced in 1601 in Spanish novels.
- It is one of the most popular casino games today.
- The first scientific paper on blackjack strategy was published in 1956.
- A search on Amazon today shows 3,000 books on blackjack!

Optimal Play

- The casino's "House Edge" is 2-4% given optimal play
- But what is optimal play?
- Let's see if we can train a machine to learn to play optimally

Rules of Blackjack

- The rules of blackjack are simple.
  - The player is dealt 2 cards
  - The dealer is also dealt 2 cards, with one face up
  - The player takes their turn first
  - The player may hit (take another card) as many times as they'd like
  - If the player's total goes over 21, they lose
  - An Ace is worth either 1 or 11
  - Face cards are worth 10
  - Once the player completes their turn, the dealer takes their turn
  - The dealer must hit on any total less than 17 and must stay on any total 17 or greater
  - If the player's total is greater than the dealer's, the player wins

Other rules

- Blackjack: If the player is dealt a blackjack, (any combination of a 10 and an Ace) the payout is 1.5 to 1 and the player is paid immediately.
- Doubling Down: The player may "double down" at any time, where they double their bet and hit exactly once.
- Splitting: If the player is dealt two of the same card, (ie. Two 8s or two Kings), the player may split their hand into 2 hands (and placing a new matching bet on the second hand). They then play each hand independently.

Optimal Strategy

- Deciding when to hit, stay, double, or split is outlined in basic cheat sheets such as this one found on Wikipedia

- There are 3 factors (features) driving each decision:
  1) Dealer's face up card
  2) Player's total
  3) Soft Hand (Yes/No): Hand is soft if it contains an Ace. Meaning it can be converted from 11 to 1 if necessary

The Goal: See if a machine can learn to play by optimal rules such as these without programming it.

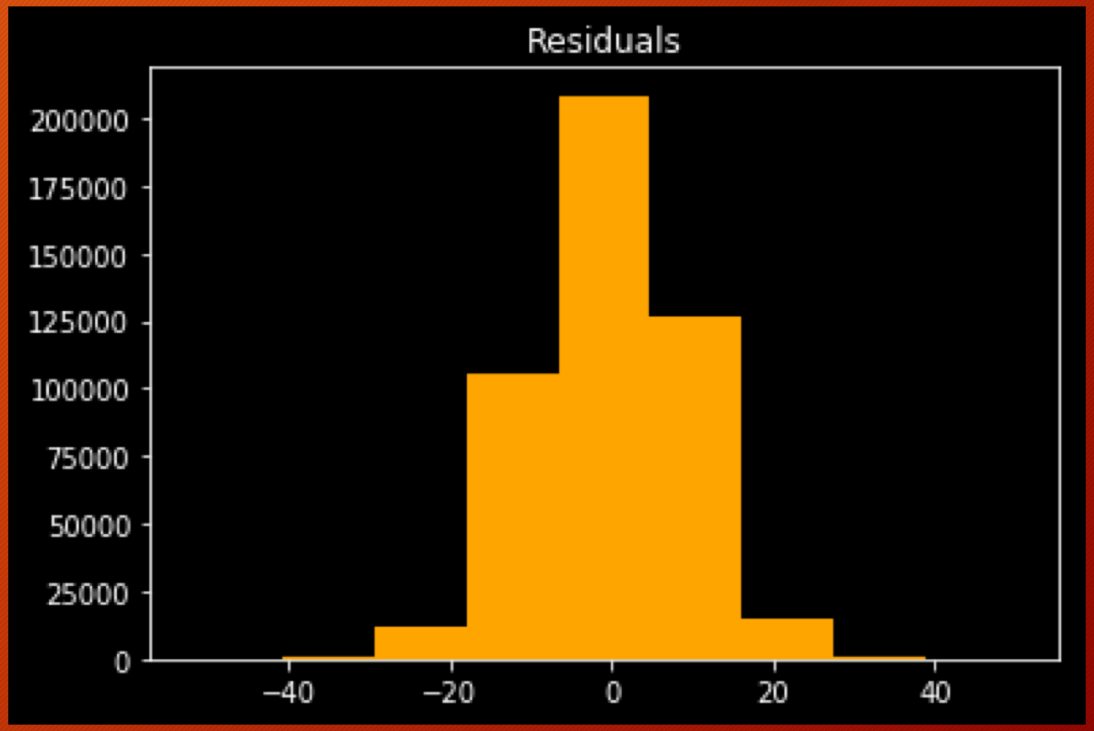
Player hand	Dealer's face-up card									
	2	3	4	5	6	7	8	9	10	A
Hard totals (excluding pairs)										
17–20	S	S	S	S	S	S	S	S	S	S
16	S	S	S	S	S	H	H	SU	SU	SU
15	S	S	S	S	S	H	H	H	SU	H
13–14	S	S	S	S	S	H	H	H	H	H
12	H	H	S	S	S	H	H	H	H	H
11	Dh	Dh	Dh	Dh	Dh	Dh	Dh	Dh	Dh	Dh
10	Dh	Dh	Dh	Dh	Dh	Dh	Dh	Dh	H	H
9	H	Dh	Dh	Dh	Dh	H	H	H	H	H
5–8	H	H	H	H	H	H	H	H	H	H
Soft totals										
	2	3	4	5	6	7	8	9	10	A
A,9	S	S	S	S	S	S	S	S	S	S
A,8	S	S	S	S	Ds	S	S	S	S	S
A,7	Ds	Ds	Ds	Ds	Ds	S	S	H	H	H
A,6	H	Dh	Dh	Dh	Dh	H	H	H	H	H
A,4–A,5	H	H	Dh	Dh	Dh	H	H	H	H	H
A,2–A,3	H	H	H	Dh	Dh	H	H	H	H	H
Pairs										
	2	3	4	5	6	7	8	9	10	A
A,A	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
10,10	S	S	S	S	S	S	S	S	S	S
9,9	SP	SP	SP	SP	SP	S	SP	SP	S	S
8,8	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
7,7	SP	SP	SP	SP	SP	SP	H	H	H	H
6,6	SP	SP	SP	SP	SP	H	H	H	H	H
5,5	Dh	Dh	Dh	Dh	Dh	Dh	Dh	Dh	H	H
4,4	H	H	H	SP	SP	H	H	H	H	H
2,2–3,3	SP	SP	SP	SP	SP	SP	H	H	H	H

Training via Simulation + Supervised Learning Setting up the Model:

- Via simulation, shuffle six 52-card decks together (into a ”shoe)
- Create labeled training data by randomly simulating 6 million hands
- Each player’s decision is made randomly and falls within the game rules (i.e. You cannot split a hand that is not a pair)
- The six decks are reshuffled whenever the shoe’s count falls below 25%
- Each time a decision is randomly made, 4 features are recorded to the training data along with the labeled outcome.
- **4 Features (X)**: Dealer Face Up Card, Player’s Total, Action Taken (Hit/Stay/Double/Split), Soft Hand (Y/N)
- **Outcome (Y)**: player’s winnings on their $10 bet.
- Random Forest Regression was used to create a model that predicts how much a $10 bet will return given the scenario and how the simulation played the hand.

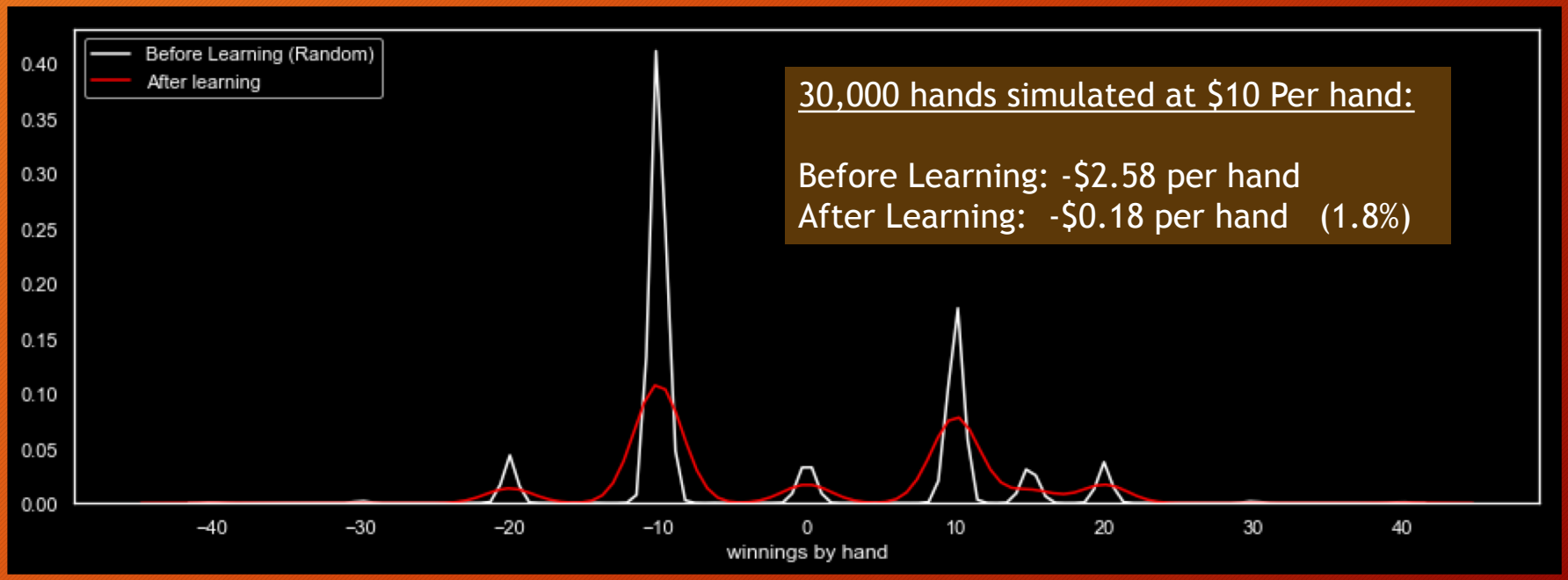
Training Results

- Regression model predicted winnings in continuous numbers ranging from $-10 to $10
- The actual results were either -$20, -$10, $0, $10, $20
- Plotting the residuals appears normal centered around 0



Results After Learning

1. Reran simulation where model recommends best action based on its learning.



Machine Learning vs Published Strategies

- The model's learnings are similar to published strategies with some exceptions.
- Model was more aggressive doubling down on soft hands.
- Model avoided busting at all costs! It does not hit on anything over 12 unless the dealer has an Ace showing.
- Model does not like splitting anything other than Aces.

		Dealer's face-up card									
Player hand		2	3	4	5	6	7	8	9	10	A
Hard Totals	17–20	S	S	S	S	S	S	S	S	S	S
	16	S	S	S	S	S	H	H	H	H	H
	15	S	S	S	S	S	H	H	H	H	H
	14	S	S	S	S	S	H	H	H	H	H
	13	S	S	S	S	S	H	H	H	H	H
	12	H	H	S	S	S	H	H	H	H	H
	11	D	D	D	D	D	D	D	D	D	D
	10	D	D	D	D	D	D	D	D	H	H
	9	H	D	D	D	D	H	H	H	H	H
	2-8	H	H	H	H	H	H	H	H	H	H
Soft Totals	A,9	S	S	S	S	S	S	S	S	S	S
	A,8	S	S	S	S	D	S	S	S	S	S
	A,7	D	D	D	D	D	S	S	H	H	H
	A,6	H	D	D	D	D	H	H	H	H	H
	A,4–A,5	H	H	D	D	D	H	H	H	H	H
	A3	H	H	H	D	D	H	H	H	H	H
	A,2	H	H	H	D	D	H	H	H	H	H
	A,A	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
Pairs	10,10	S	S	S	S	S	S	S	S	S	S
	9,9	SP	SP	SP	SP	SP	S	SP	SP	S	S
	8,8	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
	7,7	SP	SP	SP	SP	SP	SP	H	H	H	H
	6,6	SP	SP	SP	SP	SP	H	H	H	H	H
	5,5	D	D	D	D	D	D	D	D	H	H
	4,4	H	H	H	SP	SP	H	H	H	H	H
	2,2–3,3	SP	SP	SP	SP	SP	SP	H	H	H	H
		Model is less aggressive									
		Model is more aggressive									

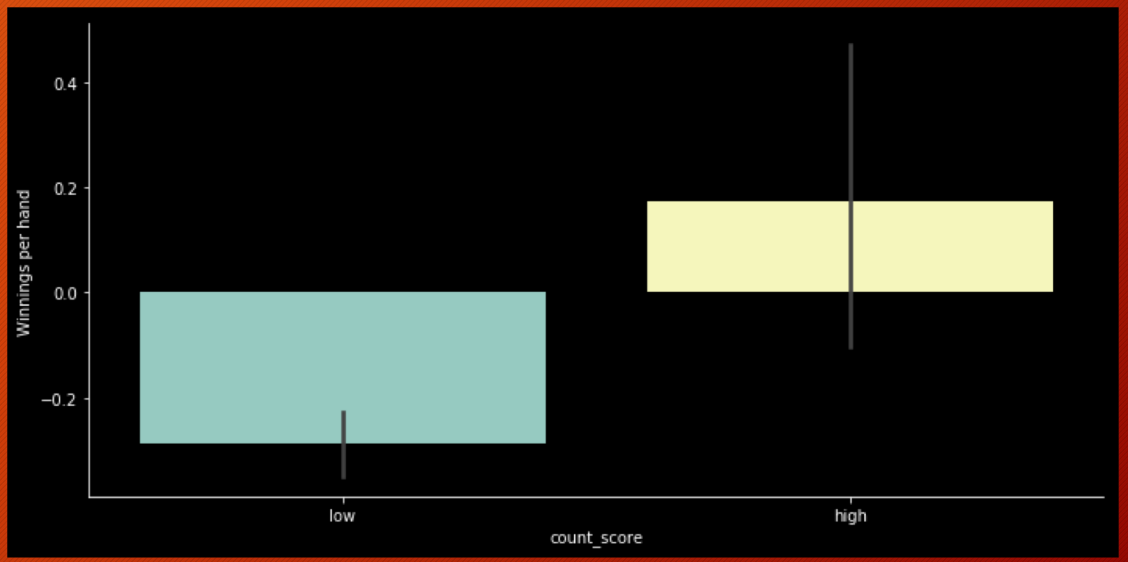
How about Counting Cards?

- Card Counting is believed to increase odds.
- If casinos suspect you are counting they may kick you out.
- I tracked card count in the simulation to test theory.

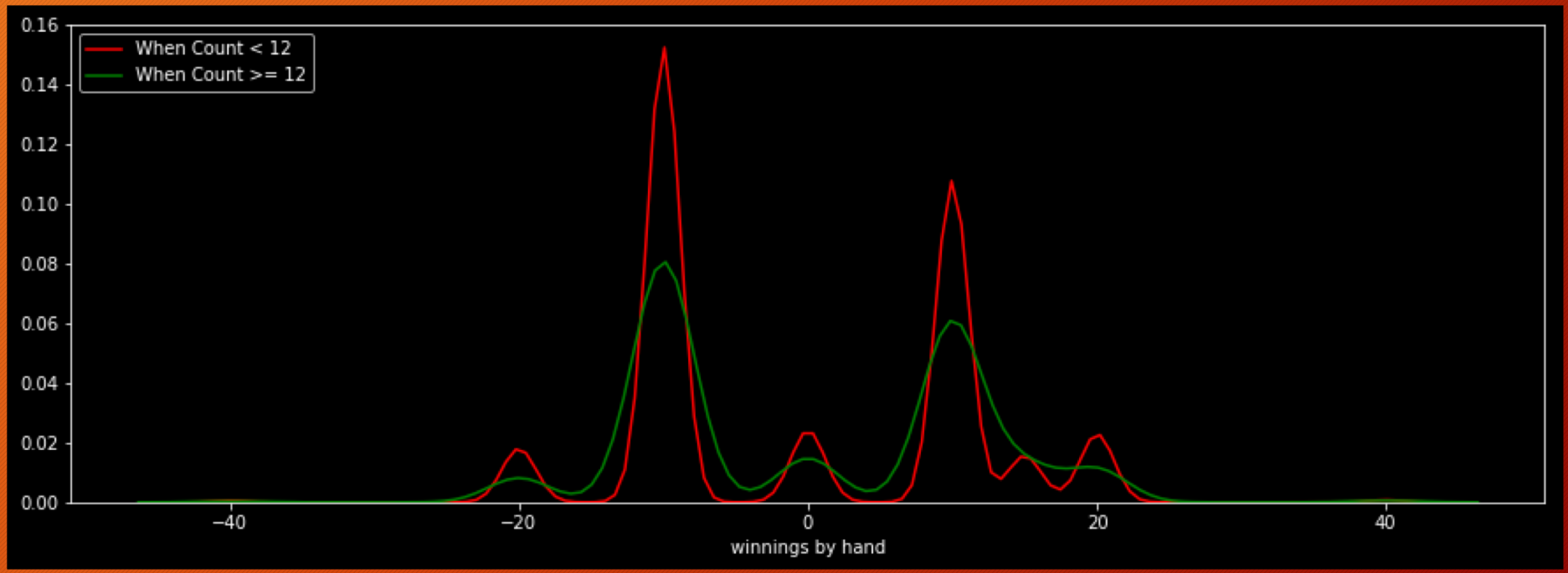
- How card counting works:
  - Keep a running mental count of revealed high cards and lows cards
  - 2,3,4,5,6 adds 1 to count
  - 10,J,Q,K,A subtracts 1 from count
  - When count exceeds 12ish, you should raise your bet.
  - A high count suggests there are more high cards in the deck and odds of winning go up.

Card Counting Simulation Results

- The simulation proved that counting can work.
- On a simulation of 150k hands playing optimally.
- When count exceeded 12, the average winnings increased 270%
- Winnings Increased to +.17 cents per $10 bet compared to a loss of .29 cents.



Winning distribution: high count vs low count



Is the impact of card count significant? (t-test)

- When comparing the 2 samples in a t-test.
- We conclude that card count does have an impact on winnings.
- P-Value is .001
- Meaning, with nearly 100% confidence, we can reject null hypothesis that states card count has no impact on winnings.

	count_score	low	high
winnings	count	143088.000000	6912.000000
	mean	-0.287760	0.174334
	std	11.860344	11.730372
	min	-40.000000	-40.000000
	25%	-10.000000	-10.000000
	50%	0.000000	0.000000
	75%	10.000000	10.000000
	max	40.000000	40.000000

The Challenges with Card Counting

- Rare Occurrence: The count reaches high levels very rarely – only 2-4% of the time.
- Suspicious: To take advantage of high counts, player must increase bet significantly. (Casinos may notice this)
- Casinos Shuffle Often: To avoid skewed card counts, some casinos shuffle the shoe more often than others.
- You can still lose! A high count doesn't guarantee winning. It reduces the house's 2-3% edge.

Simulation with Card Counting Off

Simulations are 6 hour sessions (360 hands)
Bet $10 every hand

Simulation 1
Total Winnings: **$80**

Avg. winnings per hand: $.22

Simulation 2
Total Winnings: **-$70**

Avg. winnings per hand: -$.19

Simulation 3
Total Winnings: **-$160**

Avg. winnings per hand: -$.44

Simulation 4
Total Winnings: **-$245**

Avg. winnings per hand: -$.68

Simulation 5
Total Winnings: **-$190**

Avg. winnings per hand: -$.52

Simulation with Card Counting On

Simulations are 6 hour sessions (360 hands)
Raised bet from $10 to $50 when count reaches +12

Simulation 1
Total Winnings: -$120

Hands with high count: 0
Average winnings high: N/A

Avg. winnings all other: -$.33

Simulation 2
Total Winnings: $260

Hands with high count: 6
Average winnings high: $63

Avg. winnings all other: $.73

Simulation 3
Total Winnings: -$80

Hands with high count: 9
Average winnings high: -$5.55

Avg. winnings all other: -$.08

Simulation 4
Total Winnings: -$175

Hands with high count: 26
Average winnings high: $3.85

Avg. winnings all other: -$.82

Simulation 5
Total Winnings: $370

Hands with high count: 10
Average winnings high: $27.50

Avg. winnings all other: .$27

Conclusion

- Machine Learning is effective at learning optimal play for games such as blackjack.
- If actual data is not available, synthetic data may be generated to train the model.
- Use Cases for a blackjack learning model:
  - **Casinos**: Enables casinos to create fun variations of blackjack with altered rules and test predicted outcomes.
  - **Book Authors**: Allows authors of strategy guides to quickly adapt their models to any rule variations.