

# Blackjack Monte Carlo Simulation

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## Background

Blackjack is a well-known and popular gambling game. The objective is simple: beat the dealer by getting a hand value as close to 21 as possible without exceeding it. Despite its simplicity, the game involves decision-making under uncertainty, making it an interesting subject for strategy optimization.

In this study, we are interested in understanding how different player strategies impact the win rate. By simulating multiple games using Monte Carlo methods, we explore various strategies that players can adopt to maximize their chances of winning.

## Methods

We tested several player strategies using Monte Carlo simulations of 100,000 Blackjack games per strategy. The strategies included:

**Continuous Strategy:** The player stops drawing cards once their hand reaches a predefined threshold (ranging from 12 to 20).

**Card Count Strategy:** The player's decision to stop drawing cards is based on the total number of cards held.

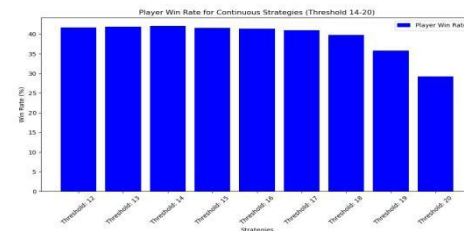
**Small Card Strategy:** The player becomes more aggressive if a significant number of small cards (2-6) have already appeared in the deck.

Each strategy was evaluated against a dealer who follows a fixed strategy of standing at 17 or higher.

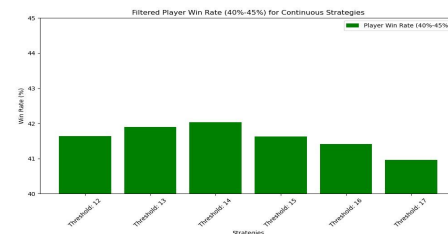
## Result

### Continuous Strategy Performance

We first evaluated the continuous strategies by setting the player's threshold for stopping at values between 12 and 20. The bar chart below shows the win rates for each threshold:



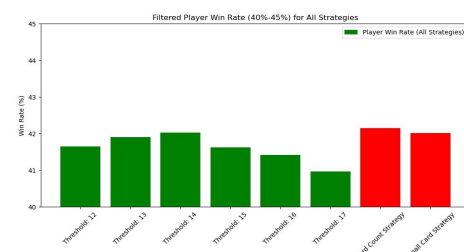
From the chart, we created a filtered chart to compare the most effective strategies:



This filter highlights that the best-performing continuous strategies are those where the player stops at thresholds 12, 13, 14, or 15.

### Comparison with Card Count and Small Card Strategies

We then set the card count and small card strategies with thresholds 12, 13, 14, or 15 as a reference. And compared the top continuous strategies with the card count and small card strategies.



We can see from the chart that these two new strategies are just as effective as the best-performing continuous strategies, with the card count strategy even achieving a slightly higher win rate.

To better highlight their strengths and weaknesses, and to explore just how unfair this game is for the player, I output the specific win rates, tie rates, and loss rates for each strategy.

Strategy	Player Win Rate (%)	Dealer Win Rate (%)	Tie Rate (%)
Threshold: 12	41.38	52.86	6.57
Threshold: 13	41.83	51.86	7.11
Threshold: 14	41.76	50.17	8.08
Threshold: 15	41.85	49.43	8.72
Threshold: 16	41.65	48.99	9.36
Threshold: 17	40.72	48.97	10.31
Threshold: 18	39.74	51.31	8.94
Threshold: 19	36.20	56.54	7.26
Threshold: 20	29.22	65.08	5.70
Card Count Strategy	42.36	49.70	7.94
Small Card Strategy	42.04	50.05	7.90

From the chart, we can see that the two new strategies, Card Count Strategy and Small Card Strategy, have win rates of 42.36% and 42.04%, respectively, both higher than the highest win rate of the continuous strategy (Threshold 13 at 41.83%). The Card Count Strategy has the highest win rate overall. However, regardless of the strategy used, the player's win rate is consistently lower than the dealer's, which highlights that gambling is inherently difficult to win against the house.

## Conclusion and Future Outlook

Through this project, we verified that the Card Count Strategy performs better than the other strategies, offering a higher win rate for the player. Moving forward, we can refine and further complicate this strategy by taking more specific factors into account, aiming to discover methods that yield even higher win rates. This opens up avenues for deeper exploration into optimizing player advantage in Blackjack.