Basic Blackjack Strategy Simulation

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Abstract

The problem asks to use simulation to determine which blackjack strategy is the best. I tested 5 strategies using 50,000 iterations of 100 hands of blackjack. The results are clear: the house always wins. However, you can significantly minimize your losses by playing an optimal strategy. This strategy is well-known and published by playing card companies and includes basic hit strategy based on your point total and the dealer's up card, doubling down, and splitting when appropriate. Blackjack may not make you a lot of money as a casual player, but you can enjoy yourself at a lower price if you know how to play.

Background and Description of Problem

Casinos are in the business of making money. Sure, they pay out large sums to certain individuals, but all games are rigged against the player. You have to be lucky to win any money against a system that is designed to take it from you.

Table games at the casino are a lot of luck. In the long run, if you play enough hands, you will lose money. Some short-term gains can be made by starting and stopping at the right time. Another thing that can help is playing with good strategy. Your losses can be significantly cut by knowing the right time to hit and stand while playing blackjack. Many people play blackjack with proper strategy for the enjoyment of the game, knowing that they are likely to lose money.

Bicycle Cards has rules and strategy for many card games on their site. Their Blackjack page contains the basic rules and optimal strategy. I separated the strategy into different parts to evaluate the effectiveness of each. The strategy components are as follows:

- Basic Strategy, or hitting and staying at the appropriate times
- Doubling Down
- Splitting

Basic Strategy depends on your cards plus the dealer's up card, and optimizes your winning chance by setting targets for your card total. Since tens through kings are worth 10, it is the most probable single card in the deck. These targets often revolve around how many hits the dealer will take. The idea is to beat the dealer without going bust (total over 21), or letting the dealer hit and hopefully go bust. For example, if a dealer's up card is a 6, the most likely down card is a card with value 10, so their total would be 16. The dealer has to hit if their total is 16 or less and stand if their total is 17 or more, so the dealer would hit in this situation. Again, the most probable card is a 10-valued card, so the dealer may go bust after the hit.

Doubling Down means that you double your bet because you believe you will win the hand. This is common on hands worth 9, 10, or 11 points since the most probable hit card is valued at 10. You are in great position to win the hand if your total is 19-21. When you double down, you take one hit then must stand. Since you have a higher chance of winning in these scenarios, it makes sense to double your bet.

Splitting is when you have identical up cards and place a second bet to play both cards in separate hands. You have a better chance of winning if you split certain cards, so it is advantageous to do so.

In the main findings, I will go through each strategy tested for effectiveness and expected payout. I will then conclude with the optimal strategy.

Main Findings

For the purpose of this simulation, I chose each card randomly from 2 to ace. In most casinos, blackjack is played with 6 full decks without replacement. The last 20% or so of cards are not played to discourage card counting (Bicycle Cards). Strategy may change depending on the number of high cards that have already been played, but for the purpose of this simulation, we will keep everything consistent to purely evaluate strategy.

Additionally, some casinos will allow the player to split multiple times, but we will assume for the purpose of this simulation that the casino has a one-split-per-hand rule (QFIT).

My process was to first code each player strategy and test 2,000,000 times for a baseline. The dealer strategy remains the same since they must play by the house rules. After that, I conducted 50,000 trials of a sample visit to a blackjack table (100 hands). I will present the confidence interval of the player's profit. For each hand, I assumed a $1 bet from the player. Betting strategy may differ based on what cards the player thinks are left in the deck, but that is out of scope for this simulation.

Briefly going through the general code structure:

1. Initialize variables for each of the cards in a list and assign the cards' point values in another list
2. Subtract the player's bet from the profit variable
3. "Deal" two cards to each the player and the dealer using the random package. These are pseudo random integers. Specify which dealer card is up since the player's strategy depends on that card
4. Check if either player or dealer has a natural blackjack (ace plus a ten card). If so, the hand is over. In the code, we can proceed with the hit strategy for simplicity, but in the end, the payouts are calculated with natural blackjacks in mind first
5. Implement player strategy and calculate final hand total
    a. Note that aces can be flexed to be worth 1 point instead of 11. Strategy always assumes that aces are worth 11 to start, but if the value of the hand goes over 21, that ace will be flexed to be worth only 1 point
6. Implement dealer strategy and calculate final hand total
7. Calculate payoffs
    a. If the player has a natural blackjack and the dealer does not, the player wins 1.5 times their bet plus retains their bet
    b. If the dealer has a natural blackjack and the player does not, the dealer wins
    c. If the player goes bust (over 21), the dealer wins

d. If the dealer goes bust and the player does not, the player wins
e. Otherwise, the highest point total wins the hand

As stated in the abstract, the house always wins in the long run. We will evaluate these strategies for which will lose the least amount of money, or, what is the cheapest way to play blackjack?

To run the code for yourself, simply open the .ipynb file and run each cell. If you do not have a program that can do this (e.g. the Anaconda Python Distribution/Jupyter Notebooks), you can open the .html code and copy the code into wherever you normally run Python code.

Dealer Strategy

In this strategy, I replicated the dealer strategy for the player exactly. That strategy is:

- Always hit if your card total is less than or equal to 16
- Always stay if your card total is greater than or equal to 17

The dealer has a distinct advantage over the player because the player acts first. If the player busts (which happens often), the dealer takes the player's bet no matter what. Since this is known to be a bad strategy given the dealer's advantages, it is a good control.

This is by far the worst strategy I tested. The player ends up losing about $120,000 in the 2 million hands played. Player win rate is only 41%, and if the player goes through 100 hands, we are 95% confident that the player will lose between $5.86 and $6.03.

Basic Strategy

Basic strategy is slightly complicated for a new player, but dramatically cuts losses. This strategy is standard across most blackjack players, but I used Bicycle Cards to confirm all strategy points. Here is a rundown of the strategy:

- If your hand is soft (contains an ace), aim for a total of 18+
- If the dealer's up card is a 7 through an ace, aim for 17+
- Dealer up 4-6, 12+
- Dealer up 2-3, 13+

These figures optimize your chance of winning based on the dealer's likelihood to bust, or the value that the dealer is likely to have to stop hitting after reaching.

In my code, I checked the player's total and the dealer's up card and hit accordingly. If the player busts, I check to see if any aces can be flexed down to a value of 1. Note that any aces that the players receive in a hit can also be flexed to 1.

Implementing just this strategy cuts players' losses by over half. In the simulation of 2 million hands, the player only lost about $59k. Player win rate increases to 43%, and we are 95% confident that the player will lose between $2.72 and $2.89 when playing 100 hands.

Basic Strategy + Doubling Down

The idea of doubling down is that you increase your bet because you have a higher chance of winning based on your hand total and the dealer's up card. Again, from Bicycle Cards, here is the strategy:

- If your hand total is 11, always double down
- If your hand total is 10, double down unless the dealer shows a 10 or an ace
- If your hand total is 9, double down only if the dealer shows a 2-6 card

In my code, I checked these rules and applied an additional bet if the hand qualified. I also set a Boolean indicator for each hand to calculate appropriate payouts in the final payout section.

This strategy again dramatically cuts the player's total losses. Compared to just playing with basic strategy, the player lost 45% less money (about $32.5k over 2 million hands). Player win rate does not increase since this is just a betting strategy change, but the 95% confidence interval of losses over 100 hands decreases to ($1.80,$1.60).

Basic Strategy + Splitting

When you get a certain pair, it is sometimes advantageous to split that pair and play two hands. This is because, given a great first card, you are more likely to beat the dealer. An example is if you get a pair of aces (often referred to as snake eyes), you are more likely to hit a natural blackjack with your next card. Given the first card is worth 11, you have a 4/13 chance of pulling a 10-value card for a natural blackjack.

Here are Bicycle's rules for splitting:

- Aces or 8s: always split
- 2s, 3s, or 7s: split unless the dealer shows an 8 through ace
- 6s: split if dealer shows a 2 through 6

In my code, I checked if a hand qualified for splitting. If it did, I calculated the dealer's hit strategy first. This does not happen in real blackjack, but for the purpose of the simulation it makes it easier. The player's strategy in the simulation does not depend on what the dealer's final total is, but only on the dealer's up card.

After the dealer's strategy is implemented, I run a loop of the basic strategy twice and calculate payout each time. The player's first card is given as the cards that are being split. The second card is randomly generated, and strategy continues as normal.

This strategy when combined with Basic Strategy gives similar results to the Basic Strategy + Doubling Down. In the run of 2 million hands, there was slight improvement as the player only lost $28k. Note that more hands are played since some are now split. The player splits about 45,000 times to bring the total hands to about 2,045,000, and the win rate for the player is about 44%. This improves over Basic + Doubling Down because the player is more likely to win in the situations that qualify for a split. The 95% confidence interval for player losses also slightly improves from the strategy before, now with the player losing between $1.40 and $1.58.

Basic Strategy + Splitting + Doubling Down

Since both splitting and doubling down were improvements to the basic strategy, it is expected that combining all three will give the best possible result.

In the code, I started with the split strategy, then replaced basic strategy with basic strategy + doubling down.

As expected, player losses are minimized with this strategy. Now, in 2,000,000 trials (with 2,044,560 hands being played due to splitting), the player only loses $7.5k and wins 44% of the time. (Note that this win percentage is approximately equal to the splitting strategy winning percentage. Like discussed in the double down strategy section, doubling down does not increase your chance of winning, but rather increases your chance of winning more due to smart betting.)

When combining all three strategies, we are 95% confident that the player will lose between $0.20 and $0.39 over 100 hands of $1 bets.

Conclusions

Although the dealer will always win in the long run, a gambler can minimize losses by implementing optimal strategy. Player losses decrease by about 94% with the optimal strategy as compared to a bad strategy (playing by dealer strategy alone). Our charts in the appendix show that there are many instances when players end up ahead after 100 hands, but the mean payout is always less than 0 in the long run. In the optimal strategy, the house edge has a mean of 0.3%. The house will capture more with less savvy players, however. Blackjack players must assess the risk and decide if the entertainment value of the game is at least as much as the expected value of their losses.

For future studies, I am interested in diving deeper into my assumptions from this simulation. What changes when you play with only 6 decks? Can you implement a better betting strategy based on the number of high-value cards that have shown? This is the basis of card counting, and can get you kicked out of many casinos.

Appendix

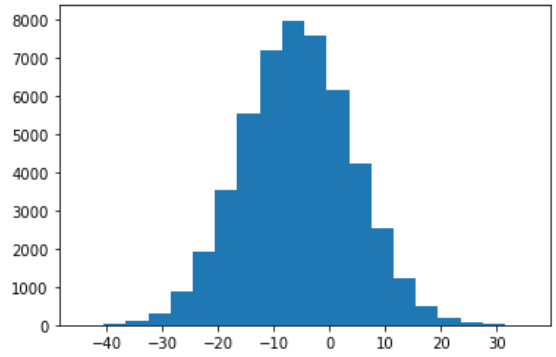
See zip file included with this report for code and output. The code is well-documented and explains each step of what was done to implement the various strategies.

Strategy Results and Statistics

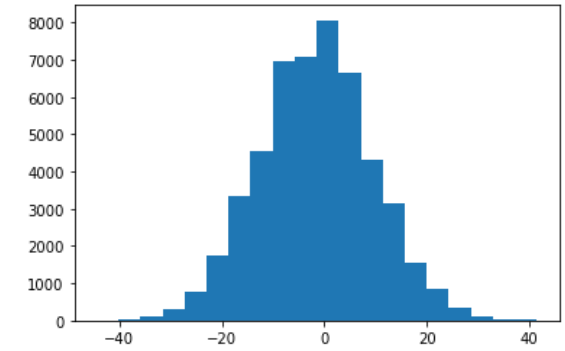
STRATEGY	95% CONF LOW	95% CONF HIGH	MEAN LOSS (100 HANDS)	% CHANGE FROM DEALER STRATEGY
DEALER	5.86	6.03	5.95	0%
BASIC	2.72	2.89	2.81	-53%
BASIC + DOUBLE	1.60	1.80	1.70	-71%
BASIC + SPLIT	1.40	1.58	1.49	-75%
BASIC + DOUBLE + SPLIT	0.20	0.39	0.30	-95%

Histogram of Payouts by Strategy

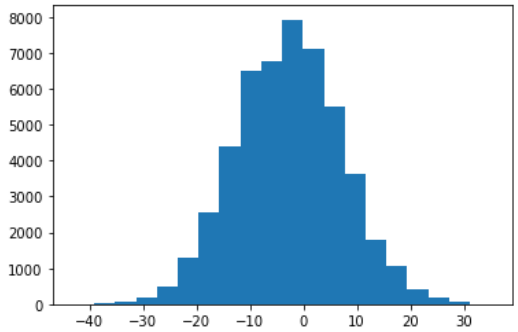
Dealer Strategy



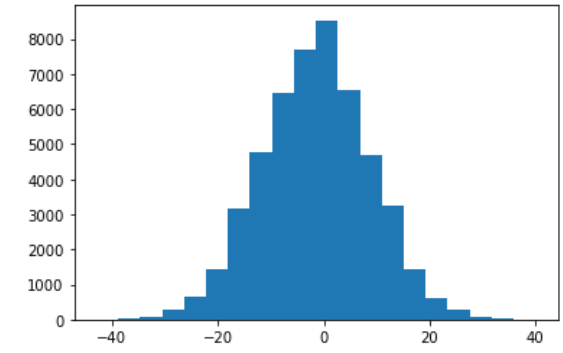
Basic Strategy + Double Downs



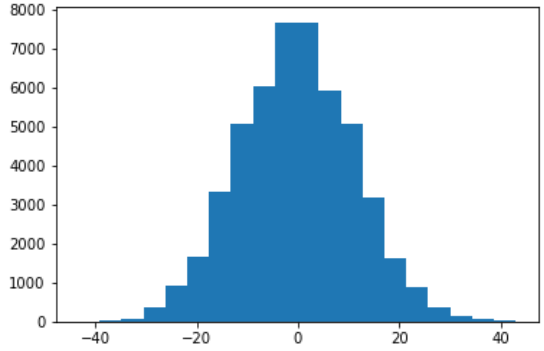
Basic Strategy



Basic Strategy + Splits



Basic Strategy + Splits + Double Downs



Literature Cited

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