An Analysis of the Game of Blackjack

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Purpose:

The goal of this project was to explore the game of blackjack by programming a complete and playable version of the game in python. This game in particular was chosen because it is one that deeply involves probability and logical thought. If a player has a good grasp on these concepts, blackjack can be one of the most profitable games in a casino. Through my project I learned a lot about the intricate rules of the game and how the concepts we learned this semester can be applied to analyze these rules.

Introduction:

In any typical casino the game of blackjack will have a standard set of rules. To begin a hand, bets are placed and the player and the dealer are each dealt two cards with the dealer's first card dealt face down. The value of a player's hand is determined by the sum of the cards where face cards are worth 10 and an ace is treated as either a 1 or an 11. Before the dealer reveals their hidden card the player is asked if they would like to hit or stand. If the player stands they indicate that they are done playing on their hand. The player may hit as many times as they would like where hitting means that the player is dealt another card. If the value of the player's hand is over 21 they bust and lose their bet. If the value of a player's hand is exactly 21 this is a blackjack and the bet is typically paid back at a higher rate of either 3:2 or 6:5. If the player's hand is below 21 the dealer reveals their hidden card. If the value of the dealer's hand is less than 17 the dealer will continue to hit until their hand either busts or is greater than or equal to 17. Assuming the dealer does not bust, the hand with a higher value wins. If the hands are the same value this is a push and the player's bet is returned. On top of these rules there are many other rules that a casino may choose to include in the game. Doubling down is an option that the player has on the first turn of their hand. If the player chooses to double down they will double their initial wager and be dealt only one more card. Surrender is another option that the player must make on the first turn of their hand. If a player chooses to surrender they forfeit their hand and immediately receive back half of their initial wager. Splitting is an option that players have when both of their cards are the same value. When a player splits they must double their initial wager as the two cards are split into two new hands each dealt a card. The two new hands are played separately and win or lose their wagers independently. On top of this some casinos may allow players to double down or surrender a hand after splitting. Another rule commonly found is that dealers must hit on a soft 17. A soft hand is one that contains an ace counted as an 11. For example, say a player has a soft 15 with a 4 and an ace and decides to hit. If the player receives an 8 they do not bust as the ace is then counted as a 1 and the hand is valued instead as a hard 13. A final rule is that of insurance. If after dealing the dealer is showing an ace the player is allowed to place an insurance bet that is half of their initial wager. If the dealer has a blackjack the insurance bet covers the money lost on the players initial bet. Otherwise the insurance bet is lost.

Program:

The program included alongside this paper is an .ipynb file that can be run in browser through either Google Colab or Jupyter Notebook. The program contains around 900 lines of code that run a complete game of blackjack. Before playing the user has the option to either enable or disable doubling down, surrendering, splitting, doubling down after splitting, surrendering after splitting, dealer hitting on soft 17, and insurance. In addition, players can change the blackjack payout and the number of decks used. By default all rules are enabled, blackjack payout is 3:2, and 6 decks are used. It is important to note that casinos will often use between 4 and 8 decks for a game of blackjack. This decision became standard to improve the casino's edge and discourage card counting, two concepts discussed later in the paper. All hands played in the program follow a constant shuffling machine or CSM shuffling pattern where the deck is reshuffled after every hand. CSM is another card counting prevention method discussed later. When the game starts the user enters in the money they would like to start with and their first wager. Following this, hands are played until the user either runs out of money or prompts the program to stop. Once stopped the program will display the users net earnings. Two sample runs of the program can be seen in the figure below.

```
WOULD YOU YOU LIKE TO CONFIGURE RULES? (0/1) 0

ENTER AMOUNT OF MONEY: 100

##############################################

MONEY: $100.00
ENTER WAGER: 50

DEALER CARDS:    [ ? ] [ 5 ]
YOUR CARDS:      [ 8 ] [ K ]

TOTAL:  18
1:HIT
2:STAY
3:DOUBLE ($50.00)
4:SURRENDER
2

DEALER CARDS:    [ 2 ] [ 5 ] [ 9 ] [ A ]
YOUR CARDS:      [ 8 ] [ K ]
DEALER TOTAL:     17
YOUR TOTAL:       18

WINNER! (DEALER LOW)

0:STOP
1:PLAY AGAIN
0

NET: +$50.00
```

```
WOULD YOU YOU LIKE TO CONFIGURE RULES? (0/1) 0

ENTER AMOUNT OF MONEY: 100

##############################################

MONEY: $100.00
ENTER WAGER: 50

DEALER CARDS:    [ ? ] [ 8 ]
YOUR CARDS:      [ K ] [ 9 ]

TOTAL:  19
1:HIT
2:STAY
3:DOUBLE ($50.00)
4:SURRENDER
2

DEALER CARDS:    [ 6 ] [ 8 ] [ 7 ]
YOUR CARDS:      [ K ] [ 9 ]
DEALER TOTAL:     21
YOUR TOTAL:       19

LOSER! (DEALER HIGH)

0:STOP
1:PLAY AGAIN
0

NET: -$50.00
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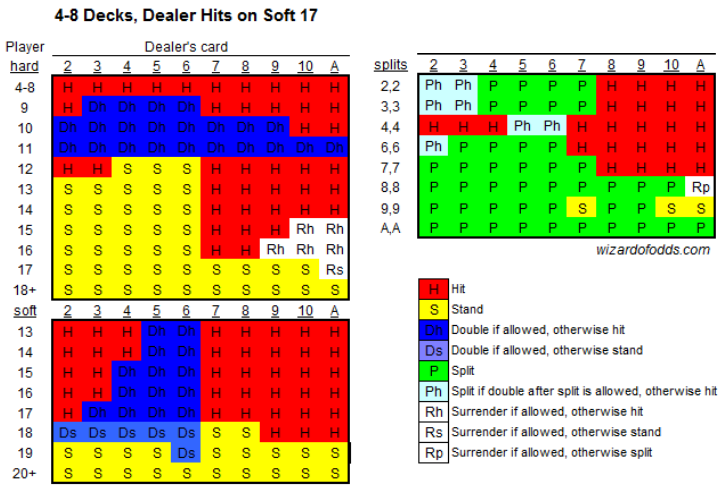
Strategy:

When thinking about the probability behind blackjack it is important to understand the concept of a casino's edge. The casino's edge is expressed as the percentage of money that the casino will take over time if a wager is continuously bet. For example the casino's edge with the default rules of the program attached is approximately 0.4% assuming perfect play. This edge is largely affected by the rules in play, number of decks used, and blackjack payout rate. To minimize the edge of the casinos, blackjack players have developed tables that detail a perfect blackjack strategy under certain sets of rules. An example of one of these perfect strategy tables can be found in the figure below. To better understand the game of blackjack it is important to understand how these tables are built using the laws of probability. When we think about a deck of cards in blackjack we find that 16 out of 52 cards have a value of 10. With a newly shuffled deck the probability of dealing a 10 is approximately 30.77% compared to 7.69% for any other card. For this reason many players make their decision for a hand under the assumption that the next card dealt will likely be a 10. To explore this phenomenon let's look at the strategy table for the situation where the player has 16 while the dealer shows an ace. In this situation the dealer has a high probability to hit 21, an unbeatable hand, with no immediate possibility to bust. The player on the other hand will bust on any card over 5, a 61.53% chance. With this in mind you can see how it would be in the players best interest to surrender. By retaining half of their initial wager the player has effectively cut the casino's edge on this particular hand in half. For another example let's look at any situation where the player has an 11. In these situations the strategy table always recommends that the player double down. With an 11 the player has no immediate possibility to bust and a high probability to hit 21. By doubling down the player is effectively doubling their edge against the casino on a particular hand. With these examples you can see how the addition of rules such as surrendering and doubling down can increase the players odds. Overall understanding this strategy is crucial to deciding what kind of blackjack table to play at and how to walk away from that table winning money.



Analysis:

To analyze the effectiveness of my code and the strategy detailed above I personally played 100 hands of blackjack on the program attached. The initial amount of money played with was $100 and each hand was played with a wager of $1. The process took a little over an hour and I exited the game with $85 for a net -$15. The tables in the figure below show the amount of wins, losses, pushes, and surrenders for the 100 hands. It is important to note the sum of these outcomes is greater than 100. This is due to the fact that some of the hands were splits and produced multiple wins and losses. The table also displays the amount of splits, double downs, double down wins and losses, double downs after splitting, surrenders after splitting, insurance offers, amount of wins that were blackjacks, and amount of the blackjacks that were natural blackjacks. A natural blackjack being a blackjack dealt to the player before the hand begins. It is important to note that even though number of insurance offers is displayed that insurance was never taken during the game as it is a bet that favors the house. The results of this experiment gives us some interesting data. Considering that the house edge is meant to be 0.4% a net loss of $15 seems very high. This indicates that I had an overall unlucky game. Another interesting piece of data is that I only split 3 times out of 100 hands. Without considering the more complex strategy table above, a common blackjack strategy is to never split 10's. Following this, using 6 decks and excluding 10's gives the player an approximately 7% chance to have the option to split on any given hand. By far the most interesting aspect of the game was the fact that I had three natural blackjacks in a row. The odds of receiving a natural blackjack are approximately 4.75%. Given that each draw was independent, the odds of three happening in a row are roughly 1 in 10,000.

WINS	LOSSES	PUSH	SURRENDER
38	53	5	7

BJ	NBJ
5	4

SPLIT	DOUBLE DOWN	INSURANCE
3	15	10

DD	SUR	DDW	DDL
1	0	6	9

Discussion:

For this discussion I will elaborate on the strategy of card counting and how it can give the player an edge over the casino. It is important to note that while card counting is completely legal it is frowned upon by casinos and will often result in a player being ejected or banned entirely. The basic strategy of card counting is as follows. 2s through 6s are counted as a 1, 7s through 9s are counted as a 0, and 10s through aces are counted as a -1. As the player plays their hands at a table they will keep a running count for every card that they see, including those of other players. A count of a high number indicates to the player that there is a higher concentration of 10s and aces left in the deck. As discussed previously the presence of 10s in the deck plays a large role in the strategy of the game. Knowing the concentration of 10s remaining may change the betting strategy or decision that a card counter takes. For example, say that the count is +5 halfway through a single deck of cards. This means that there are 5 more 10s or aces in the second half of the deck than there were in the first. This could bring the probability of drawing a 10 up to 50%. Knowing this, a player for example may decide it is worth it to buy insurance when the dealer is showing an ace. If the dealer draws a 10 then the player breaks even on their bet. The player may also decide to bet more on their hand as there is a higher likelihood of being dealt a natural blackjack. Another example would be if the count is low such as -5. Let's say that in this case the player has 12 and the dealer is showing a 6. Typically the dealer has very high odds of busting when showing a 6. If the dealer's hidden card is a 10 then they have 16 and must hit. If the count is low then the odds of this happening naturally lower. If a card counter knows this they may choose to take advantage of it and hit the 12 instead of standing which is suggested by the perfect strategy. As you can see counting cards gives players the opportunity for an advantage over a casino and as such casinos have adopted many measures to combat it. One measure taken is increasing the amount of decks played with and shuffling them into a shoe. When more decks are in play, the significance of the count is diminished. To get the true count of multiple decks you must divide the running count by the number of decks left in the shoe. In this case the count only becomes statistically significant late in the shoe. Furthermore casinos often reshuffle the shoe before this can occur. A method that eliminates the possibility to count cards entirely is the constant shuffling machine or CSM. These machines reshuffle all cards in multiple decks after every hand, effectively resetting the count. This shuffling style is the one used in the program attached. Finally many dealers are knowledgeable of card counting strategies and will inform the casino if they suspect a player of counting cards. Overall counting cards is an increasingly difficult practice to get away.

Conclusion:

Overall blackjack is a game with an extremely complex strategy behind it and the understanding of these strategies incorporates many aspects of what we have learned this semester from logic to probability and combinatorics. Through this project I have learned a lot about the game and more importantly the math that makes it so interesting. If you have the chance I hope you will play a few hands on the program and explore the strategy yourself.