

1 Background

Blackjack, also known as 21, is one of the most popular casino card games worldwide. The origins of Blackjack can be traced back to 18th-century France, where it was called “Vingt-et-Un” (21). The game was brought to the United States in the early 20th century, which later evolved into the modern version we play today. The goal of the game is to beat the dealer by getting a hand value as close to 21 as possible. When a game starts, each player will have two cards and can choose to either hit, take additional cards, or stand, keep their current hand, to improve their chances of winning. Ever since invented, this game has never failed to impress both casual and serious players. Countless sparking extensive research has been conducted on its optimal strategies and simulations.

2 Evolution of Blackjack Simulations

The study of Blackjack through simulation has a long and fascinating history, spanning back to the early days of computing. Baldwin et al. published a significant work in 1956, using computer simulations to create the first optimum Blackjack strategy. This fundamental work revealed the power of computer simulations in understanding complex card games, laying the groundwork for future research in the field. Baldwin and his colleagues' research influenced later studies and is now considered a cornerstone in Blackjack literature (Baldwin et al. 1956).

In recent years, new publications and guides have provided understandable insights into the statistics and practical applications of Blackjack simulations. For instance, the Towards Data Science platform offers comprehensive articles that delve into the mathematical aspects of Blackjack, including probabilities, house edge, and strategy optimization. These resources are invaluable for both novices and experienced programmers, as they provide practical examples using R programming (Towards Data Science, 2020).

3 Possibilities

- **Card Values:**

- Number cards (2-10) = face value
- Face cards (J, Q, K) = 10 points
- Aces = 1 or 11 points

- **Gameplay:**

- Each player and the dealer are dealt two cards.
- Players can:
 - * Hit: Take another card

- * Stand: End turn
 - * Double Down: Double bet, one more card
 - * Split: Split pairs
 - * Surrender: Forfeit half bet, if allowed
- **Dealer Rules:** Must hit until 17 or higher, stand on 17+.
 - **Outcomes:**
 - **Blackjack:** Ace + 10-point card (pays 3:2)
 - **Bust:** Exceeding 21 (automatic loss)
 - **Win:** Player hand closer to 21 than dealer's without busting
 - **Loss:** Dealer hand closer to 21 without busting, or player busts
 - **Push:** Tie
 - **Probabilities:**
 - Single Deck: Easier to track cards
 - Multiple Decks: Harder to count, higher house edge
 - **Strategies:** Basic strategy minimizes house edge. Card counting tracks advantageous cards (effective in single deck, often prohibited).

ADVANCED BLACKJACK STRATEGY TABLE										
Dealer's First Card										
Your Hand	2	3	4	5	6	7	8	9	10	A
18+	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND
17	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND
16	STAND	STAND	STAND	STAND	STAND	HIT	HIT	HIT	HIT	HIT
15	STAND	STAND	STAND	STAND	STAND	HIT	HIT	HIT	HIT	HIT
14	STAND	STAND	STAND	STAND	STAND	HIT	HIT	HIT	HIT	HIT
13	STAND	STAND	STAND	STAND	STAND	HIT	HIT	HIT	HIT	HIT
12	HIT	HIT	STAND	STAND	STAND	HIT	HIT	HIT	HIT	HIT
11	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	HIT	HIT
10	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	HIT	HIT
9	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	HIT	HIT	HIT	HIT	HIT
8	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
7	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
6	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
5	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
Soft 20	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND
Soft 19	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND
Soft 18	STAND	STAND	STAND	STAND	STAND	STAND	STAND	HIT	HIT	STAND
Soft 17	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
Soft 16	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
Soft 15	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
Soft 14	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
Soft 13	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
Pair A	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT
Pair 10	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND	STAND
Pair 9	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	STAND	SPLIT	SPLIT	STAND	STAND
Pair 8	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	HIT	HIT
Pair 7	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	HIT	HIT	STAND	HIT
Pair 6	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	HIT	HIT	HIT	HIT	HIT
Pair 5	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	DOUBLE	HIT	HIT
Pair 4	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
Pair 3	HIT	HIT	SPLIT	SPLIT	SPLIT	SPLIT	HIT	HIT	HIT	HIT
Pair 2	HIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	HIT	HIT	HIT	HIT

Figure 1: Probabilities of Blackjack Outcomes Based on Hand Values

4 How to Blackjack Simulations

Here are some steps we will follow based on our understanding of Blackjack to do simulations.

- **Define the Card Deck:**
 - Create a function to generate a standard deck of 52 cards.
 - Each card can be represented by its value and suit.
- **Shuffle the Deck:**
 - Implement a function to shuffle the deck using the `random.shuffle` method.
- **Deal Initial Cards:**
 - Create a function to deal two cards to both the player and the dealer.
 - Remove dealt cards from the deck.
- **Calculate Hand Value:**
 - Implement a function to calculate the value of a hand.
 - Handle Aces as either 1 or 11, depending on which is more favorable.
- **Player's Turn:**
 - Create a loop that allows the player to choose to “hit” or “stand”.
 - If the player hits, deal another card and update the hand value.
 - If the player stands, end the loop.
- **Dealer's Turn:**
 - Implement the dealer's behavior according to standard rules (e.g., hit until the hand value is 17 or higher).
 - Deal cards to the dealer and update the hand value accordingly.
- **Determine the Outcome:**
 - Compare the player's and dealer's hand values to determine the winner.
 - Implement logic for win, lose, or push (tie).
- **Simulate Multiple Rounds:**
 - Create a loop to simulate multiple rounds of the game.
 - Track outcomes and gather statistics (e.g., win rate, average hand values).
- **Visualize Results:**
 - Use `matplotlib` to create graphs and visualize the results of the simulations.
 - Plot win rates, distribution of hand values, and other relevant statistics.
- **Optimize and Refine:**
 - Implement strategies and refine the simulation.
 - Test different numbers of decks and analyze their impact on outcomes and house edge.

5 Usage of Blackjack Simulations

Simulating Blackjack is both an intellectual activity and a useful tool for learning and enhancing gameplay skills. Large datasets of simulated games may be analyzed to uncover patterns and methods that optimize success. These simulations are suitable for teaching probability, decision-making, and strategic thinking in educational contexts. A review paper in the journal *Educational Technology Society* discusses the importance of simulations in education, demonstrating how they may improve learning and comprehension via practical application (Educational Technology and Society, 2016).

Furthermore, applying game theory to Blackjack yields useful insights into strategic decision-making. Zimran, Klis, Fuster, and Rivelli investigate different strategies and their efficacy, providing a theoretical foundation for understanding the game. This document emphasizes the importance of strategic thinking and its impact on gameplay outcomes (Zimran et al., 2016).

References

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