Analyzing Machine Learning Strategies for Blackjack

Carlos F. Trevino, Thibault Tonnel

Department of Electrical and Computer Engineering, The University of Texas at Austin
2501 Speedway, Austin, TX 78712
carlos.trevino359@utexas.edu, ttonnel@utexas.edu

***Abstract*— This analysis explores the impact of two significant algorithms, Monte Carlo Reinforcement Learning and Genetic Algorithms, on Blackjack. It provides insights into how these advanced technologies are revolutionizing gaming strategies, hinting at the future possibilities in this domain.**

***Keywords*— Machine Learning, Artificial Intelligence, Monte Carlo Reinforcement Learning, Genetic Algorithms, Game Theory**

I. Introduction

The integration of artificial intelligence (AI) and machine learning (ML) into strategic games has revolutionized the field, offering new methods of analysis and decision-making. In the context of casino gaming, particularly in blackjack, these technological advancements have had a significant impact. The application of AI and ML in strategy games goes beyond entertainment, encompassing the development of strategies that are both sophisticated and effective. Blackjack, a game known for its strategic depth, serves as a prime example of how AI and ML are influencing gaming strategies. This report delves into two notable algorithms: Monte Carlo reinforcement learning and genetic algorithms, and their transformative role in blackjack, offering a glimpse into the future of gaming strategies powered by advanced technologies.

A. Understanding Blackjack

Blackjack is a card game played against a dealer. At the start of a round, both player and dealer are dealt 2 cards. The player can only see one of the dealer's cards. The goal of the game is to get the value of your cards as close to 21 as possible, without crossing 21. The value of each card is listed below.

- Jack/Queen/King → 10
- 2 through 10 → Same value as the card
- Ace → 1 or 11 (Player's choice). Note that ace is called useful when It can be counted as 11 without going bust.

If the player has less than 21, they can choose to "hit" and receive a random card from the deck. They can also choose to "stand" and keep the cards they have. Moreover, the player may also choose to "split" if they have a pair of duplicate cards which divides the two cards into separate hands, or "double down" which doubles the player's initial bet after the first two cards, with a commitment to standing after receiving one more card. If the player exceeds 21, they go "bust" and automatically lose the round. If the player has exactly 21, they automatically win. Otherwise, the player wins if they are closer to 21 than the dealer.[1]

B. Basic Strategy

Basic strategy is a set of optimal decisions to maximize your chances of winning in blackjack. It's based on the player's hand and the dealer's

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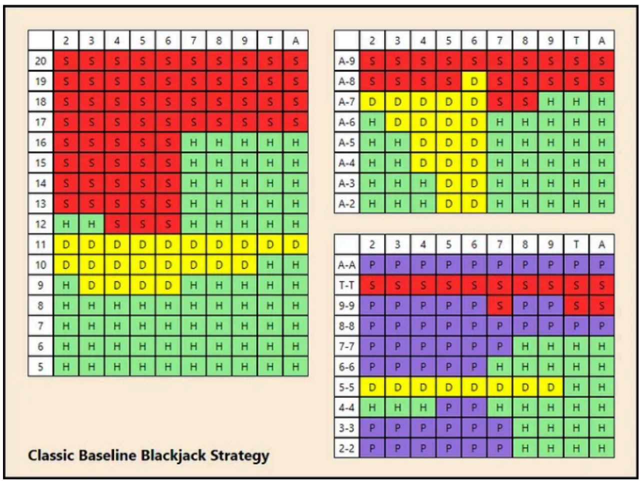
[1] https://towardsdatascience.com/the-statistics-of-blackjack-e3b5fc29e67d

upcard. The strategy guides players on whether to hit, stand, double down, or split. Basic strategy is best known for providing the most optimal decisions for players while providing consistency and maximizing winnings, making it a valuable tool for blackjack players seeking to enhance their odds. It's not foolproof, but it provides a solid foundation for making informed decisions.



	2	3	4	5	6	7	8	9	T	A
20	S	S	S	S	S	S	S	S	S	S
19	S	S	S	S	S	S	S	S	S	S
18	S	S	S	S	S	S	S	S	S	S
17	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
8	H	H	H	H	H	H	H	H	H	H
7	H	H	H	H	H	H	H	H	H	H
6	H	H	H	H	H	H	H	H	H	H
5	H	H	H	H	H	H	H	H	H	H

	2	3	4	5	6	7	8	9	T	A
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-5	H	H	D	D	D	H	H	H	H	H
A-4	H	H	D	D	D	H	H	H	H	H
A-3	H	H	H	D	D	H	H	H	H	H
A-2	H	H	H	D	D	H	H	H	H	H

	2	3	4	5	6	7	8	9	T	A
A-A	P	P	P	P	P	P	P	P	P	P
T-T	S	S	S	S	S	S	S	S	S	S
9-9	P	P	P	P	P	S	P	P	S	S
8-8	P	P	P	P	P	P	P	P	P	P
7-7	P	P	P	P	P	P	H	H	H	H
6-6	P	P	P	P	P	H	H	H	H	H
5-5	D	D	D	D	D	D	D	D	H	H
4-4	H	H	H	P	P	H	H	H	H	H
3-3	P	P	P	P	P	P	H	H	H	H
2-2	P	P	P	P	P	P	H	H	H	H

Classic Baseline Blackjack Strategy

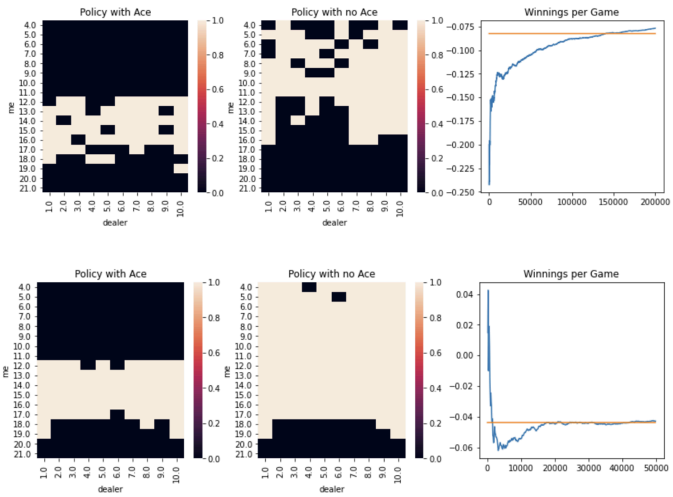
Optimal Strategy for Blackjack

II. Machine Learning Strategies in Blackjack

A. Strategy #1: Monte Carlo Reinforcement Learning (MCRL)

The Monte Carlo algorithm, renowned for its applicability in stochastic methods, finds a significant place in Blackjack, a game rife with uncertainty and diverse decision points. The essence of this algorithm lies in its model-free prediction and control approach. It estimates the value of each action in blackjack without relying on a predefined model of the game's dynamics. This approach employs random sampling from the game's historical data, allowing for a sophisticated strategy in a dynamic environment like blackjack. Its capacity to explore a multitude of potential actions and outcomes positions it as an ideal candidate for games with numerous variables.

The setup of Monte Carlo reinforcement learning in blackjack involves defining agents, the environment, states, and actions. Players act as agents, making decisions within the blackjack environment, which includes the dealer and card draws. States represent the player's hand and the dealer's card, while actions include decisions like staying or hitting. The learning process comprises policy, reward signal, and value function components, focusing on strategy and expected rewards. In the Monte Carlo approach to blackjack, the "environment" refers to all aspects outside the player's control, including the dealer and the cards dealt. The "states" the player navigates are specific scenarios comprising their hand and the dealer's up-card. On-policy methods involve a singular strategy for both learning and playing, while off-policy methods employ distinct strategies for the learning phase and the actual gameplay. These methods are crucial for understanding how players can adapt and optimize their decision-making process in the game.



The results above reveal that on-policy methods with arbitrary initial actions and optimistic initial values yield the best outcomes. The exploration rate significantly affects performance and convergence time. Off-policy methods, varying in initial actions and weighting techniques, also show distinct results. These methods are assessed over tens of thousands of games to determine effectiveness in maximizing winnings and optimizing blackjack strategies. It is noted that "arbitrary initial actions and optimistic initial values" were most effective, and different rates of exploration, or epsilon, significantly altered "average winnings and the time to convergence"[2]. Off-policy methods are differentiated by the use of separate learning and playing policies, which may require more resources but can yield quick convergence.

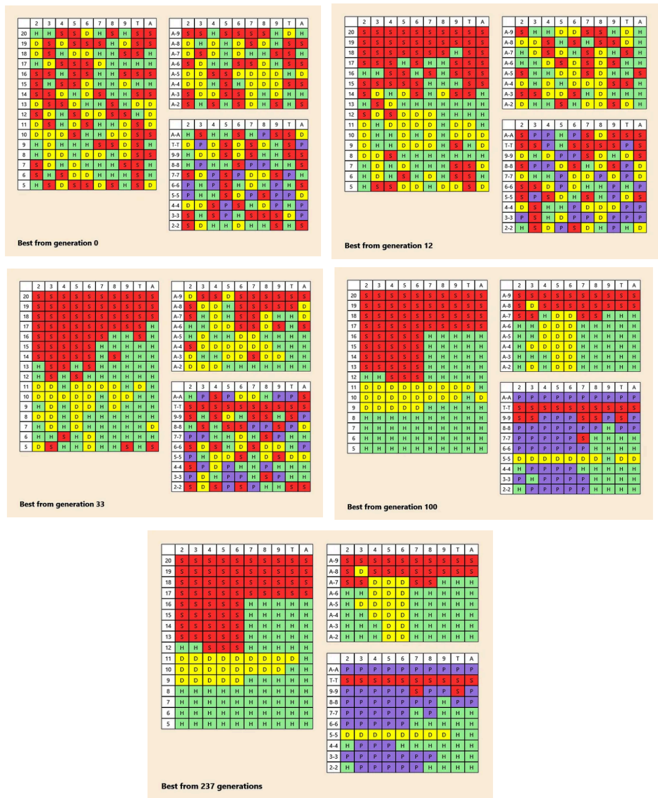
B. Strategy #2: Genetic Algorithms (GAs)

Similarly transformative in the realm of blackjack strategy is the genetic algorithm (GA). Drawing inspiration from evolutionary biology, GAs are able to apply principles like natural selection, mutation, and crossover to refine and enhance blackjack strategies. This algorithm is particularly remarkable for its simulation of strategy evolution over multiple generations, treating potential strategies like individuals in a population to evolve more effective strategies. By testing and refining strategies through numerous game simulations, it epitomizes a dynamic approach to strategy development.

The practical implementation of the genetic algorithm in blackjack goes as follows: the algorithm begins with a diverse set of experimental strategies. These strategies are then tested in simulated games, with the most successful ones (in terms of win rate, risk management, etc.) being selected. Crossover and mutation then occurs with the genetic algorithm selecting and combining individual elements from successful strategies (like risk thresholds, decision points) to create new ones, introducing random variations for diversity. Lastly, the algorithm repeats this process over many iterations (iterative optimization), progressively refining the strategies to maximize success rates under given game conditions.

[2] https://mprego.github.io/Blackjack_MC/

In “Winning Blackjack Using Machine Learning[3],” results from applying a genetic algorithm to the game of blackjack are explored. The evolutionary properties of the genetic algorithm can be analyzed in the following results, constantly optimizing strategies over time until a near-optimal solution is reached after 237 generations (and evaluating around 178,000 strategies:



After countless simulations, the genetic algorithm eventually reaches a final strategy which is nearly identical to the optimal blackjack strategy. For reference, playing a game of blackjack using the optimal strategy for 500,000 hands at $5 per hand would result in a total loss of $176,040, while the genetic algorithm strategy would net a loss of $176,538 under the same conditions, only a $498

[3] https://towardsdatascience.com/winning-blackjack-using-machine-learning-681d924f197c

difference from the optimal strategy according to the article.

After an analysis of the results within “Winning Blackjack Using Machine Learning,” we concluded that despite its theoretical power, genetic algorithms require significant computational resources and time for simulation and evolution, making real-time application challenging. Aside from its costliness, the genetic algorithm proved to excel in environments where other traditional strategies may falter, such as with unusual rule sets or betting structures. Overall, use of the genetic algorithm is best categorized for players or analysts who are deep into strategic exploration and who have the resources to simulate and evolve strategies over time.

III. Comparative Analysis

These two methodologies and the optimal blackjack strategy reveal distinct strengths and weaknesses in the context of blackjack. Ultimately, the conventional, non-ML optimal strategy proves to be superior over these ML strategies, reducing the house edge as much as possible while being easy to learn and access. On the other hand, the ML-based algorithms we explored consider other factors that the conventional strategy does not consider, such as the number of decks being played, as well as what cards are left in the deck, using those numbers to make better guesses. With this knowledge, the Monte Carlo algorithm excels in environments with high uncertainty and a multitude of possible outcomes, offering a comprehensive analysis of potential game scenarios. However, its pros come at the cost of requiring extensive computational resources, proving to be best in environments with complex or changing rules. In the landscape of blackjack strategies, the genetic algorithm stands out for its long-term strategy optimization, effectively adapting to evolving gameplay conditions. This highlights the varied capabilities and benefits of each algorithm, showcasing how they each contribute distinctly to the art of strategizing in blackjack.

IV. Conclusion

The application of AI and ML algorithms like Monte Carlo and genetic algorithms in blackjack signifies a notable advancement in gaming strategies. These technologies not only enhance the gaming experience but also provide deep insights into strategic thinking in complex scenarios. The potential of these algorithms extends beyond gaming, promising advancements in various fields of strategic decision-making and prediction. Future research could explore the combination of these algorithms to create even more sophisticated AI strategies, potentially revolutionizing not just blackjack but a myriad of strategic games and applications. This ongoing evolution in AI and ML heralds a new era in gaming strategies, where technology and human ingenuity converge to explore uncharted territories of strategic gameplay.

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