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# Thinking Poker Through Game Theory: Does Aggression Pay off in Heads Up Texas Holdem Poker

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## Abstract

The game of Poker is a complex game to analyze, as there are many possibilities that can change through the course of the game. In a game of Heads Up Texas Holdem an individual player may opt for an aggressive playstyle, one by which the player bets with higher risk and uses more bluffs in order to win the game. Another approach is to be passive and carefully analyze the current values of cards in order to create a strategy that will limit losses and increase winnings strategically. The purpose of this paper is to analyze data provided by an AI which would play against a human player that chooses either an aggressive playstyle and a passive one. By simulating multiple games, we will ultimately understand which playstyle in a 2 player Heads Up Texas Holdem game yields the best results.

## 1 Introduction

Poker is a very complex game to analyze. There are about 2.6 million unique 5 card hands in a game of Poker with a 52 card deck, 3 of which appear on the table provided by the dealer, and 2 cards that remain on each player's hand throughout a round of Poker. The outcome of a Poker game can change drastically whenever a new card is dealt to the table by the dealer. A player who has the highest hand rank once the 4th card has been shown to everyone on the table can immediately lose the game if the 5th card makes the hand of another player stronger. Taking this into account, there are no clear winners until entire round is played. However, a player can influence the flow of the game by altering their playstyle.

There exist 2 prominent styles of play in the game of Poker: aggressive and passive. An aggressive player will take higher risks during his game. This type of player tends to bet coins even if he has a losing hand in order to throw off his opponents into thinking that he actually has a better hand than the one dealt to him. He is not afraid to raise or call high bets in order to assert his presence in the table. On the other hand, a passive player will attempt to play safely at all costs, folding his hand if he knows a bad hand has been dealt to him and only raising a bet if he feels extremely confident about his hand.

By analyzing a player's play style, we can determine if an aggressive playstyle can be used in order to win more games. This is what we intend to focus on in this publication.

### 1.1 Related Work

Analyzing an optimal strategy for a Poker game has been researched before by a study of a two-person zero-sum game Poker model used by Borel and von Neumann.

Boyle's Poker model works as follows. A player bets one dollar into the pot, Player I draws a hand  $X$  with a uniform distribution on  $[0,1]$  and Player II draws a hand  $Y$  with the same uniform distribution. Then, the first player can either fold or raise. If Player I folds, he loses the pot and Player II acquires the dollar and the game ends. If Player I raises, he adds an additional dollar to the pot. Player II responds by either calling or folding. If Player II folds the outcome will be similar to when Player I folds. If Player II calls Player I's bet, Player II adds an additional dollar to the pot and both players reveal their hands in a "showdown". The player with the highest hand wins the pot, and  $X \neq Y$ , with a net gain of two dollars.

Von Neumann's model is similar to Borel's with the difference being that Player I has the option to either check or raise instead of folding or raising. This means that Player I can stay in the game without raising the bet. If Player I checks, both players show their hands in the showdown, and the Player with the highest hand wins.

Borel's model yields equilibrium bluffing, indicating that a player will occasionally bet even if they have a weaker hand and the other player will sometimes fold based on the bet even if he had a stronger hand.

Von Neumann's model yields even more bluffing on the part of the player because they have nothing more to lose than their initial forced bet.

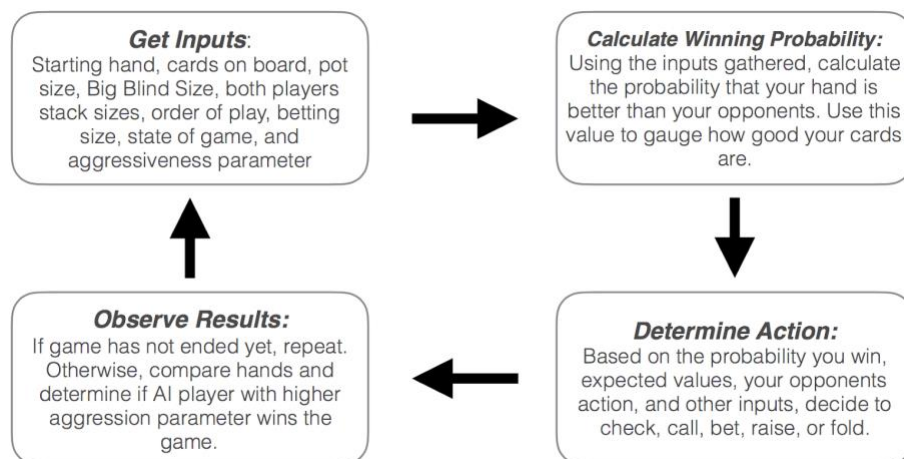
In this sense we see that Borel's model tends to lean more towards a passive style of play while Von Neumann's leans more towards an aggressive play style. However, these versions of Poker are simplified and do not scale well into a full Texas Holdem game.

## 1.2 Our Contribution

As we have seen by the previous 2 models mentioned before, an analysis for a full Heads Up Texas Holdem Poker Game has not been thoroughly investigated. The purpose of our project is to analyze the outcome of a Texas Holdem game with 100 round based on an individual's' playstyle. This will provide us with a better understanding to determine whether an aggressive playstyle dominates a passive one most of the time, or if being aggressive does not have much influence in the flow of the game

## 2 Constructing an AI

We take advantage of a computer's ability to make large amounts of fast calculations and its ability to randomize when designing our AI poker player. In addition, we watched videos on how poker professionals play Heads up poker to get inspiration for our AI design. Below is a brief summary of the flow of our poker AI's decision making process:



To calculate the probability of winning, I compare my hand against every possible hand the

opponent might hold. I count the number of hands I beat, and therefore can calculate the probability of winning as the number of hands we beat divided by total number of hands. For example, during preflop, I compare my hand with all remaining 50 choose 2 possible combinations (52 total cards - the two cards I hold myself). The higher your winning probability is, the better quality cards you have. Therefore you will be more likely to bet or call.

At each stage of the game (preflop, postflop, turn, and river), the AI reads the board and determines its winning probability. Based on this probability, we define mechanisms on how the AI should play. For example, we say if winning probability  $> 75\%$ , bet half the pot, or if winning probability  $< 20\%$  and opponent bets you, then fold. However, if the AI simply bets every time it gets good hands and folds bad hands, the opponent can quickly catch on to the AI's betting habits and strategize against it. Therefore, we also sprinkle some random elements throughout our AI to make it less predictable. Below are some strategies implemented in our AI player:

- Bluffing:

Often times you will find yourself with a bad hand and the only way to win might be to bluff your opponent. If your opponent also holds a weak hand, and sees a bet from you, your opponent may be reluctant to call and just give up. When the AI poker player sees its chance to win is too low, it will bluff with probability correlated to its aggressiveness parameter.

- Betting for value:

Value betting occurs when you may think your opponent has a decent and (pair or Ace high etc), but you have a better hand (two pair or pair etc). You can evaluate how much your opponent is willing to call to see the showdown, and make that bet to get extra value from the opponent.

- Shoving

Going all in is a very aggressive poker play, and oftentimes your opponent will put you on a strong hand. When the poker A.I has 10 Big Blinds or less left, it will increase the range of hands it is willing to shove. When the AI has 4 Big Blinds or less left, it will go all in on even a wider range of cards.

We define our aggressiveness parameter to be a number between  $[0, 1]$ . Throughout our code, we incorporate this parameter so that the higher it is, the more likely the player will bluff, make bets, and call the opponent.

### 3 Experiment

To explore how aggressiveness factors into heads up poker play, we play AIs with different aggressiveness parameters and observe which type of player wins more often. In order to do so, we implement a simulation program to simulate the poker game letting two AI players play against each other.

The simulation can be considered as a finite state machine with 7 states: player initialization, game initialization, preflop, flop, turn, river and showdown. Before the game initialization state, the program will create two instances of players with initial stack sizes of 500 chips and also a board with a shuffled card deck. In the game initialization state, the program first checks if both players have remaining chips, or else the game is over. Then, two cards will be dealt to each player and five cards to the board (We chose to let all five cards so the observer can see how the AI player plays, the AI program itself only reads the cards that it is allowed to). Afterwards, big blind and small blind bets are placed and the game goes to the preflop stage.

In preflop, flop, turn and river stages, the AI program reads the inputs and returns a list of two numbers. The first is which action to take out of a total of four actions (Call, Fold, Check, Raise), and the second number is the bet size if there is one. If at any point the AI makes an illegal move (we defined mechanisms to catch illegal moves) the game simulation program will consider such moves as "fold", which means the AI "gives up" the game, as a punishment

for illegal moves. If one of the players chooses to fold, the chips in the pot will be given to his opponent, and the game will go back to the game initialization state and repeat. If none of both players have folded by the end of the river round, the game will go to showdown.

During showdown, the simulation program determines which player has the better hand and the winner receives all the chips in the pot. Then, the game state will jump back to the game initialization stage and repeat. This is played until one player has no remaining chips.

Our simulation program also allows you to enter specific hands and boards and see how our AI program will play in these situations.

## 4 Analysis

To determine if aggression pays off in heads up poker, we play two AI players with different aggressiveness parameters  $\alpha$  against each other, and record how they do over 50 games. Below are the winning probabilities from player one's perspective for playing against different  $\alpha$ 's against each other.

P1_ $\alpha$ \ P2_ $\alpha$	0.3	0.4	0.7	0.8
0.3	\	43.7%	28.6%	22.1%
0.4	56.3%	\	36.4%	33.7%
0.7	71.4%	63.6%	\	46.7%
0.8	77.9%	66.3%	53.3%	\

## 5 Conclusion

From our simulations, we can observe a positive correlation between a player's aggressiveness and his winning percentage. In addition, we see that the more aggressive you are relative to your opponent, the more likely you are to win. However, our AI poker player is far from perfect, so we cannot just assume that this is how professional players will play as well. In real life, if you consistently play the same aggressive style, your opponent might be able to get a good read on how you play, and respond accordingly. However, our project sheds light on the fact that if two players have similar poker playing abilities (ability to read opponent, make good calls/folds etc.), then the more aggressive you play, the higher your payoff will be in Heads Up Texas Poker.

## 6 References

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