A study of Poker bots and the existent models behaviour

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1 Abstract

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3.1 Overview

Poker is the world's most popular card game and one of the most popular sports in the world. According to some sources, more than 100 million people in the world enjoy playing poker on a regular basis [1]. It combines strategic challenges with psychological elements. With poker, you don't play just your cards - you also need to analyse and react to your opponents. Of course, having a computational environment makes this difficult, as it is still computationally impossible to assess live tells and behaviour. Because of this, poker AI robots need to have an extremely strong mathematical background and build strategies on top of that in order to become successful while playing the game.

The most played variant of poker is Texas Hold'em [2]. Texas Hold'em is one of the most "board" games of poker. In Texas Hold'em, each player receives 2 hole cards, which are considered personal. Then, 5 cards are drawn on the table. These cards are called the "community cards". The player with the best 5-card combination chosen from within the hole cards and the board cards wins the money in that round. Also, players are allowed to bet while the board is being drawn. There are 4 rounds of bets in total, with each round giving the opportunity to all the players to bet, in turn. In this way, players with a weaker hand are being given the chance to win a hand, by betting their opponents out of the game. The full rules of Texas Hold'em can be found here: https://en.wikipedia.org/wiki/Texas_hold_'em [3].

There is a general controversy around the game of Texas Hold'em which is present for most of the other poker games, too: Is poker a game of luck or skill? Many people believe that, since the cards are distributed randomly at the start of each hand, poker has luck as its main feature. Even Phil Helmuth, a well-known profesional poker player and 11-times WSOP(World Series of Poker) Bracelet winner, once said "If it weren't for luck, I'd win every time." [4]. So, there certainly is reason to believe that luck is the main feature of poker, but is it true? First of all, there is no doubt in the fact that luck is part of the game. On the other hand, there are many experienced players, including Phil Helmuth himself, that have won tournaments on several occasions. So, if poker would have been a pure luck game, this wouldn't happen, as new "lucky" winners would emerge almost every tournament. Secondly, the structure of the game enables skilled individuals to emerge as winners, by making better, more profitable plays than an average player. This might include bluffing an opponent, getting value out of a better hand or folding when having a weaker holding. Therefore, skill is an absolute must in order to play a game of poker efficiently. Most of the good players use their skill to get in a advantageous situation, such as a 70%-30% favourite. From there on, it's all about luck, but on a long run, the players who are able to get themselves in more such spots are the ones who win. In conclusion, poker is a game of skill in the first place, with luck only making it more appealing because of the uncertainty that it is unveiled in.

Poker games are traditionally played by 2-9 individuals sitting at a table and betting either chips or money. As technology evolved, so did the opportunity of playing poker. Nowadays, 1 in 4 dollars are gambled online [5], with poker being one of the most successful casino-related businesses, summing up to a grand total of $33 billion dollar market [6]. After poker games have started to move online, poker-playing bots started emerging in the field. Many researchers have since tried different approaches in order to solve the computationally difficult game of Texas Hold'em. In the following part of the "Background and context" section I will present the most honourable of those, continuing with presenting my own view of how the game-solving algorithms should be configured like in the next sections.

3.2 A generic view on poker bots

There are multiple ways of constructing poker bots. One can think of a mathematical approach, while others can try machine learning and AI techniques in order to solve the game of poker. Either way, since Poker is a game of improbability, even newest technologies seem to be far away from being able to virtually win all the time. Moreover, because no-limit Hold'em is a game where a vast number of parameters has to be taken into account, poker bot specialists have trouble even in finding methods of being more successful than an average professional player, mostly because of the fact that a human player can also take information out of emotions and physical tells during a Poker game.

3.2.1 Borel and von Neumann Poker Models

The most low-level Poker model is the Borel Poker model, explained in a detailed way by Émile Borel in his book "Applications de la théorie des probabilités aux Jeux de Hasard" [7]. A very similar model was proposed by John von Neumann in his book "Theory of Games and Economic Behavior" [8]. The two forms of poker represent a starting point for analysing poker as a game of improbabilities. The Poker chapter in the "Fun and Games, A text on game theory" book, by Binmore [9] presents the knowledge of game theory applied on these simple forms of Poker. In these simplistic variants of Poker, the two players each receive a random "card", drawn from a uniform distribution on [0,1]. Each of the players knows their own card, but cannot find out what the opponent's card is. Before the cards are dealt, both of them have to post a unit of value, so that if one of them folds instantaneously, the other one has something to win. Therefore, for each decision someone makes, there is a payoff that needs to be taken into account. After that, the first player has to make a decision, having known his cards: fold/check or bet (add b units of value to the pot). The second player can call or fold afterwards, if the first player hansn't folded. If no player has folded, then the player with the biggest card value wins the pot. The only difference between the two models is that in Borel's model, the first player can only fold or raise, while in von Neumann's he can only check or raise. While this game might sound simplistic for poker players, it contains a strategic and mathematical background that can help deal with other variants of poker, too. Borel has solved [1] this game by using a strategy called "la Relance" [10], also described in his book. This method consists of creating a betting tree for the described game, in a similar way betting trees are being constructed for any game theory problem.

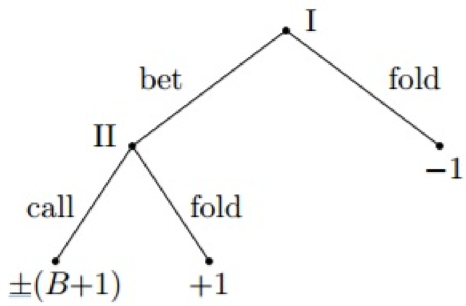

Figure 1: Borel's La Relance betting tree

In the betting tree for "la Relance" [Figure 1], the value indicated at the leafs of the tree represent the winnings from Player I's perspective. The ± sign represents the uncertainty regarding the win/loss of the respective hand which will be determined by the card values of the two players. In the analysis, Borel found out that there is a unique optimal strategy for Player II. His strategy has to be on the form of some number c, c $\in$ [0,1]. He concluded that the unique optimal stragegy for Player II is[11]:

- Call if [2]Y > c
- Fold if Y < c

, where c = B/(B+2). On the other hand, Player I's strategy is not unique and can be though of at different levels, since he has, on top of calculating Nash equilibrium, the opportunity to also bluff in some situations. Even so, Borel found all of them. The common feature of all possible Player I's strategies is his betting threshold. More precisely, he should bet if [3]X > c2. Also, in order for an strategy to be optimal, Player I has to bet with a 1-c proportion for all the hands on which X<c, and fold a c proportion of those. As a conclusion, Borel outlined the value for his "la Relance" poker model as:

$$V(B) = -\frac{B^2}{(B+2)^2} \tag{1}$$

Because this value is negative, we can conclude that this game advantages Player II. Realising this, von Neumann created a model which gives Player I more advantage. Therefore, if he elects not to bet, he still stands chances of winning, when X > Y. As a result, von Neumann's betting tree looks is presented in Figure 2. This modification helps modeling the bluffing concept in more detail, because if Player I elects to bluff with an average hand and looses, will loose B+1, while if he chooses not to bluff, his expected winnings are 0 (± 1).

[1]Solving a (Poker) game means discovering a strategy that is optimal for every possible holding for a player.
[2]Y is the value distributed from [0,1] for Player II
[3]X is the value distributed from [0,1] for Player II

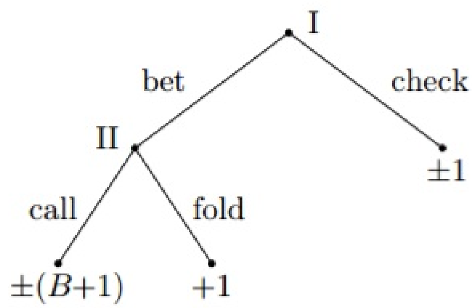

Figure 2: von Neumann's betting tree

The strategy for Player I changes in this situation. As a result, Player I only has one (unique) strategy now, which is in terms of a and b, two values from [0,1], with a<b. The reason for having 2 thresholds instead of one is because even though Player I was only 2 possible ways of playing the hand, a bet decision might come out of a pure value extraction attempt, or a bluff attempt. Therefore, Player I should bet if X>b(for value) or X<a(bluff) and check otherwise. On the other hand, Player II only has one threshold, namely c. He should call if Y>c and fold otherwise. It turns out the following equation holds, as visible in the von Neumann's optimal play decision figure (Figure 3).

$$0 < a < c < b < 1 \tag{2}$$

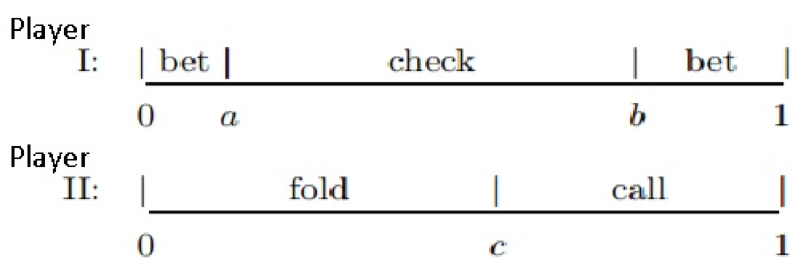

Figure 3: von Neumann's optimal play visualisation

Von Neumann concluded that the expected value for his poker model is:

$$V(B) = \frac{B}{(B+1)(B+4)} \tag{3}$$

The fact that von Neumann's model advantages first player in comparison to Borel's can be seen from the formula. V(B) is a positive term, so the previous statement stands. Also, for completeness, von Neumann computed the values of a, b and c from within the optimal play formulas. These are:

$$
\begin{aligned}
a &= \frac{B}{(B+1)(B+4)} \\
b &= \frac{B^2+4B+2}{(B+1)(B+4)} \\
c &= \frac{B(B+3)}{(B+1)(B+4)}
\end{aligned}
\tag{4}
$$

4 Design and Implementation

5 Evaluation and Results

6 Conclusions

References

[1] https://www.pokerstrategy.com/poker-the-game/

[2] https://www.cardschat.com/top-10-poker-games.php

[3] https://en.wikipedia.org/wiki/Texas_hold_'em

[4] http://realmoney.durrrrchallenge.com/skill-luck-paradox/

[5] http://www.indian.senate.gov/sites/default/files/upload/files/old_hearings/GrantEveTestimony111711pageid=9698.pdf

[6] http://www.uspokersite.net/online-poker-real-money/

[7] Félix Édouard Justin Émile Borel - "Applications de la théorie des probabilités aux Jeux de Hasard" (1938)

[8] John von Neumann and Morgenstern - "Theory of Games and Economic Behavior" (1944)

[9] K.Binmore - "Fun and Games, A text on game theory" (1992)

[10] http://www.chrissnijders.com/eth/Ferguson.pdf

[11] http://www.cs.cmu.edu/afs/cs/academic/class/15859-f01/www/notes/mat.pdf