Poker Project - Team #07

Arielyte Tsen Chung Ming, Devarajan Preethi, James Pang Mun Wai, Lee Yi Wei Joel, Yip Seng Yuen
National University of Singapore
chungming.tsen@u.nus.edu, e0203237@u.nus.edu, jamespang@nus.edu.sg, lywjoel@u.nus.edu, yip@u.nus.edu

1 Introduction

This paper talks about the steps that we took in designing an AI Poker Player agent in Heads Up Limit Texas Hold'em. An agent that is subjected to reinforcement learning must learn to interact with the environment in order to maximize its reward. Reinforcement learning was chosen as a way to get the best possible action based on the current state. Pruning methods such as grouping cards with similar values were used to cut down the size of the search tree.

The problem with Limit Texas Hold'em is that there is no input or output training data sets available for the agent to gather feedback from. Hence, the only way an agent can learn is by trial and error based on feedback from its own actions and experiences. A reward function where actions that led to positive outcomes are rewarded, and actions that led to negative outcomes are punished is created, with the goal of maximizing its reward. The design of a reward function good enough for the agent to master poker is the basis for this project. In a game of poker, the agent does not have a complete model of the environment, nor does it know the states that its actions will lead to. Thus, a Q-learning agent, which compares the expected utilities of the remaining choices without the need to know the outcomes nor the model of the environment, is our agent design of choice as it fits the scenario of a poker game.

2 Pre-Flop Hand Strength

To begin with, we wanted decide how the bot will determine the strength of its hand, just from the pre-flop round. Due to the limited amount of information that we can manipulate during pre-flop round, the strength of a hand at pre-flop is determined by the probability of winning simply based on the prior knowledge of the two private cards currently in hand. In order to estimate this probability and thus the strength of a hand, we simulated 10000 games for each possible combination of starting hand. We then calculate the probability of winning based on the starting hand by dividing the number of wins with the total number of games played, which is 10000 in our case.

The estimated probabilities of winning given the following starting hands is as seen in Figure 1.

At each pre-flop street, the bot will decide its actions based on the starting hand's estimated probabilities of winning,

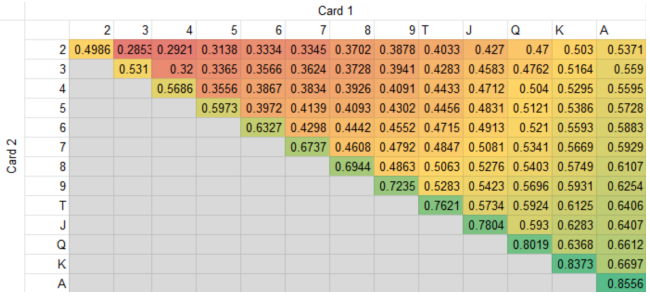

Figure 1: Estimated winning probabilities with starting hands

which are:

$$\left.\begin{array}{l} raise\text{: } Pr(Win) > kcall\text{: } Pr(Win) > j \\ fold\text{: } Pr(Win) \leq j \end{array}\right\} \quad \text{where } 0 < j < k \leq 1$$

3 Post-Flop Rounds

In the subsequent post-flop rounds, reinforcement learning is employed. Specifically, the technique of Q-learning, which was described in the Introduction, was used to train our agent.

In Q-learning, we maintain a table of states and actions as inputs for the agent. Each permutation generates an expected reward. An illustration of it can be seen in Table 2.

State	**Action**		
	fold	*call*	*raise*
1			
2			
3			
...			
S			

Table 1: Q-learning Training

After each training round, the state of each permutation is updated based on the formula

$$Q\left(s',a'\right) = Q\left(s,a\right) + \sum_{0}^{t} \lambda^{t} R_{t}\left(s,a\right)$$

where t is the number of turns between the move and the terminal node, R_t is the reward for round t, and λ is the discount factor.

$$R_t = \begin{cases} +\frac{pot}{2} & \text{if win,} \\ -\frac{pot}{2} & \text{otherwise} \end{cases}$$

$\lambda =$ discount rate for future reward

4 ε-Greedy Algorithm

At every turn, with a probability of ε, a random action is chosen to be performed, otherwise an action with the best expected reward is chosen.

The value of ε will slowly decrease as the agent acquires more training. A relatively large initial value ensures that all possible paths will be explored before the agent settles into a sub-optimal pattern. The *State* and *Action* for the ε-Greedy Algorithm is

$$State = \{HS, HP, S, P, \#OR, \#SR, AF\}$$

$$Actions = \{fold, call, raise\}$$

where

HS is the current Hand Strength of a given player.

HP is the current Hand Potential of a given player.

S is the Street, which is the start of each new round.

P is the Pot, which is the total amount in the player's bet.

#OR is the Opponent-Raise, which is the number of raises by the opponent per street.

#SR is the Self-Raise, which is the number of raises by the AI itself per street

OPS is the Opponent Playing Style, which classifies the opponent's style of play into four categories.

5 Opponent Playing Styles

The opponent player can be classified under four categories of playing styles. Each style describes the frequency of play and how the player bets. The four playing styles are loose/passive, loose/tight, conservative/passive and conservative/tight. They are determined by the Aggressive Factor and Player Tightness, which are calculated as follows:

$$\text{Aggressive Factor, } AF = \frac{\#\ raises}{\#\ calls}$$

$$\text{Player Tightness, } PT = \frac{\#\ folds}{\#\ games}$$

Later, a classification process is conducted to classify the opponent's style of play into four categories:

	AF $\leq$ **1**	**AF** $>$ **1**
PT $\geq$ **0.28**	loose/passive	loose/aggressive
PT $<$ **0.28**	conservative/passive	conservative/aggressive

Table 2: Style of Play Classification

6 Hand Strength

The Hand Strength, HS is the probability of the current hand of a given player winning if the game reaches a showdown. The HS factors in all possible combinations of the opponents' hands, the remaining hidden board cards, and performing a comparison between the agent's hand and the hands in the enumeration to see which is better. The quality of the hand is then measured based on the number of times the hand turns out to be better.

Given n number of opponents, the remaining cards, *Rem* is given by:

$$Rem = [\alpha \backslash \beta]^5$$

where α is the set of all cards in the deck, and β is the set of all hole cards of a particular player. The formula to calculate the rank of each hand, $Rank(h)$ is:

$$Rank(h) = max(\forall x \in [\beta \cup \Omega]^5 : s(x))$$

where Ω is the set of community cards. Having *Rem* and $Rank(h)$, it is now possible to calculate HS through the formulas below:

$$Ahead(h) = \#\{\forall x \in Rem : s(x) > Rank(h)\}$$

$$Tied(h) = \#\{\forall x \in Rem : s(x) = Rank(h)\}$$

$$Behind(h) = \#\{\forall x \in Rem : s(x) < Rank(h)\}$$

$$HS(h) = \left(\frac{Ahead(h) + \frac{Tied(h)}{2}}{Ahead(h) + Tied(h) + Behind(h)} \right)^n$$

Note that the $E[HS]$ may be used at any round of the game. However, it does not address the possibility of the hand improving in future rounds of the game. To resolve this problem, the Hand Potential Formula is applied.

7 Opponent Playing Styles

Hand Potential is an extension of the Hand Strength algorithm, whereby instead of merely considering the available cards in hand and in the community pool, it also considers the as yet unrevealed community cards and possible opponent hands that might improve. In the River street, this algorithm will output the same result as Hand Strength.

Hand Potential can be split into Positive Potential, *PPot* and Negative Potential *NPot*, which are defined as such:

PPot All scenarios where the agent is behind but eventually wins.

NPot All scenarios where the agent is ahead but eventually loses.

The algorithm for Hand Potential is described in detail via pseudo-code in Algorithm 1.

8 Effective Hand Strength

The probability of winning, $Pr(Win)$, can be calculated as:

$$Pr(Win) = HS * (1 - NPot) + (1 - HS) * PPot$$

To calculate effective hand strength, EHS, we set $NPot = 0$ since we want the probability of the hand being the best or improving to become the best. Thus, we eventually get the equation of EHS to be:

$$EHS = HS + (1 - HS) * PPot$$

Algorithm 1 Hand Potential

function HANDPOTENTIAL($agCard$, $commCard$)
  Let $HP[3][3]$ and $HPTotal[3]$ be new arrays
  $agRank \leftarrow Rank(agCard, commCard)$
  for each $opCard$ **do**
    $opRank \leftarrow Rank(opCard, commCard)$
    if $agRank > opRank$ **then**
      $index \leftarrow ahead$
    else if $agRank == opRank$ **then**
      $index \leftarrow tied$
    else
      $index \leftarrow behind$
    end if
    $HPTotal[index]++$
    for each $scenario$ **do**
      $agBest \leftarrow Rank(agCard, scenario)$
      $opBest \leftarrow Rank(opCard, scenario)$
      if $agBest > opBest$ **then**
        $HP[index][ahead]++$
      else if $agBest == opBest$ **then**
        $HP[index][tied]++$
      else
        $HP[index][behind]++$
      end if
    end for
  end for
  $PPot = \frac{HP[behind][ahead] + \frac{HP[behind][tied]}{2} + \frac{HP[tied][ahead]}{2})}{HPTotal[behind] + \frac{HPTotal[tied]}{2}}$
  $NPot = \frac{HP[ahead][behind] + \frac{HP[tied][behind]}{2} + \frac{HP[ahead][tied]}{2}}{HPTotal[ahead] + \frac{HPTotal[tied]}{2}}$
  return $PPot$, $NPot$
end function

8.1 Monte Carlo Effective Hand Strength

The Hand Potential algorithm generates all possible scenarios to come, so its running time is high. To significantly reduce the running time, we randomly sample a fixed number of scenarios (100) will little impact on accuracy.

8.2 Pot Size

The pot sizes are grouped into categories with intervals of

8.3 Word Processing Software

As detailed below, IJCAI has prepared and made available a set of LaTeX macros and a Microsoft Word template for use in formatting your paper. If you are using some other word processing software (such as WordPerfect, etc.), please follow the format instructions given below and ensure that your final paper looks as much like this sample as possible.

Note that I did not edit the word document, and it still contains the original IJCAI formatting instructions. Please ignore those!

9 Style and Format

LaTeX and Word style files that implement these instructions can be retrieved electronically. (See Appendix A for instructions on how to obtain these files.)

9.1 Layout

Print manuscripts two columns to a page, in the manner in which these instructions are printed. The exact dimensions for pages are:

- left and right margins: .75″
- column width: 3.375″
- gap between columns: .25″
- top margin—first page: 1.375″
- top margin—other pages: .75″
- bottom margin: 1.25″
- column height—first page: 6.625″
- column height—other pages: 9″

All measurements assume an 8-1/2″ × 11″ page size. For A4-size paper, use the given top and left margins, column width, height, and gap, and modify the bottom and right margins as necessary.

9.2 Format of Electronic Manuscript

For the production of the electronic manuscript, you must use Adobe's *Portable Document Format* (PDF). A PDF file can be generated, for instance, on Unix systems using `ps2pdf` or on Windows systems using Adobe's Distiller. There is also a website with free software and conversion services: `http://www.ps2pdf.com/`. For reasons of uniformity, use of Adobe's *Times Roman* font is strongly suggested. In LaTeX2e, this is accomplished by putting

```
\usepackage{times}
```

in the preamble.[1]

Additionally, it is of utmost importance to specify the American **letter** format (corresponding to 8-1/2″ × 11″) when formatting the paper. When working with `dvips`, for instance, one should specify `-t letter`.

9.3 Title and Author Information

Center the title on the entire width of the page in a 14-point bold font. The title should be capitalized using Title Case. Below it, center author name(s) in a 12-point bold font. On the following line(s) place the affiliations, each affiliation on its own line using a 12-point regular font. Matching between authors and affiliations can be done using superindices. Additionally, a comma-separated email addresses list using a 12-point regular font is also allowed. Credit to a sponsoring agency can appear on the first page as a footnote.

9.4 Text

The main body of the text immediately follows the abstract. Use 10-point type in a clear, readable font with 1-point leading (10 on 11).

Indent when starting a new paragraph, except after major headings.

9.5 Headings and Sections

When necessary, headings should be used to separate major sections of your paper. (These instructions use many headings to demonstrate their appearance; your paper should have fewer headings.). All headings should be capitalized using Title Case.

Section Headings

Print section headings in 12-point bold type in the style shown in these instructions. Leave a blank space of approximately 10 points above and 4 points below section headings. Number sections with arabic numerals.

Subsection Headings

Print subsection headings in 11-point bold type. Leave a blank space of approximately 8 points above and 3 points below subsection headings. Number subsections with the section number and the subsection number (in arabic numerals) separated by a period.

Subsubsection Headings

Print subsubsection headings in 10-point bold type. Leave a blank space of approximately 6 points above subsubsection headings. Do not number subsubsections.

Special Sections

You may include an unnumbered acknowledgments section, including acknowledgments of help from colleagues.

Any appendices directly follow the text and look like sections, except that they are numbered with capital letters instead of arabic numerals.

The references section is headed "References," printed in the same style as a section heading but without a number. A sample list of references is given at the end of these instructions. Use a consistent format for references, such as that provided by BibTEX. The reference list should not include unpublished work.

9.6 Citations

Citations within the text should include the author's last name and the year of publication, for example [**?**]. Append lowercase letters to the year in cases of ambiguity. Treat multiple authors as in the following examples: [**?**] or [**?**] (for more than two authors) and [**?**] (for two authors). If the author portion of a citation is obvious, omit it, e.g., Nebel [**?**]. Collapse multiple citations as follows: [**?**; **?**].

9.7 Footnotes

Place footnotes at the bottom of the page in a 9-point font. Refer to them with superscript numbers.[2] Separate them from the text by a short line.[3] Avoid footnotes as much as possible; they interrupt the flow of the text.

10 Illustrations

Place all illustrations (figures, drawings, tables, and photographs) throughout the paper at the places where they are first discussed, rather than at the end of the paper. If placed at the bottom or top of a page, illustrations may run across both columns.

Illustrations must be rendered electronically or scanned and placed directly in your document. All illustrations should be in black and white, as color illustrations may cause problems. Line weights should be 1/2-point or thicker. Avoid screens and superimposing type on patterns as these effects may not reproduce well.

Number illustrations sequentially. Use references of the following form: Figure 1, Table 2, etc. Place illustration numbers and captions under illustrations. Leave a margin of 1/4-inch around the area covered by the illustration and caption. Use 9-point type for captions, labels, and other text in illustrations.

Acknowledgments

The preparation of these instructions and the LATEX and BibTEX files that implement them was supported by Schlumberger Palo Alto Research, AT&T Bell Laboratories, and Morgan Kaufmann Publishers. Preparation of the Microsoft Word file was supported by IJCAI. An early version of this document was created by Shirley Jowell and Peter F. Patel-Schneider. It was subsequently modified by Jennifer Ballentine and Thomas Dean, Bernhard Nebel, and Daniel Pagenstecher. These instructions are the same as the ones for IJCAI–05, prepared by Kurt Steinkraus, Massachusetts Institute of Technology, Computer Science and Artificial Intelligence Lab.

[1] You may want also to use the package `latexsym`, which defines all symbols known from the old LATEX version.

[2] This is how your footnotes should appear.

[3] Note the line separating these footnotes from the text.

A LaTeX and Word Style Files

The LaTeX and Word style files are available on the IJCAI–18 website, `http://www.ijcai-18.org/`. These style files implement the formatting instructions in this document.

The LaTeX files are `ijcai18.sty` and `ijcai18.tex`, and the BibTeX files are `named.bst` and `ijcai18.bib`. The LaTeX style file is for version 2e of LaTeX, and the BibTeX style file is for version 0.99c of BibTeX (*not* version 0.98i). The `ijcai18.sty` file is the same as the `ijcai07.sty` file used for IJCAI–07.

The Microsoft Word style file consists of a single file, `ijcai18.doc`. This template is the same as the one used for IJCAI–07.

These Microsoft Word and LaTeX files contain the source of the present document and may serve as a formatting sample.