[[1]](#footnote-1)

Building Poker Bot with Reinforcement Learning (December 2020)

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*Impact Statement* — The impact statement should not exceeed 150 words. This section offers an example that is expanded to have only and just 150 words to demonstrate the point. Here is an example on how to write an appropriate impact statement: Chatbots are a popular technology in online interaction. They reduce the load on human support teams and offer continuous 24-7 support to customers. However, recent usability research has demonstrated that 30% of customers are unhappy with current chatbots due to their poor conversational capabilities and inability to emotionally engage customers. The natural language algorithms we introduce in this paper overcame these limitations. With a significant increase in user satisfaction to 92% after adopting our algorithms, the technology is ready to support users in a wide variety of applications including government front shops, automatic tellers, and the gaming industry. It could offer an alternative way of interaction for some physically disable users.

*Index Terms*—poker, reinforcement learning

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# INTRODUCTION

T

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# Literature review

Poker and Reinforcement learning solutions

Literature Review is needed for the analysis of past studies or scholarly articles to be familiar with research questions or topics. Hence, this section summarizes and synthesizes arguments and ideas from scholarly sources without adding new contributions. In turn, this part is organized around arguments or ideas, not sources.

If you wish, you may write in the first person singular or plural and use the active voice (“I observed that ...” or “We observed that ...” instead of “It was observed that ...”). Remember to check spelling. If your native language is not English, please get a native English-speaking colleague to carefully proofread your paper.

# Methodology

Algorithm and environments

We used RLCard card environments [1] that are designed for reinforcement learning research. It is an easy-to-use toolkit that provides Limit Hold’em and Leduc Hold’em environment. The latter is a simplified version of Limit Texas Hold’em and it was constructed to have a more tractable game [2].

Both types have the same actions: *check, call*, *raise* and *fold*. During *checking* the action passes to the next player without betting. In the case of someone bets, this action is not possible anymore. *Calling* means matching a bet or a raise. If the player chooses to *raise*, he/she increases the size of an existing bet in the round. *Folding* is discarding one’s hand.

The payoff is identical as well in both environments. It is based on the big blinds per hand. The player gets the positive or negative R reward if he/she wins or loses R times the amount of the big blind, respectively.

Limit Hold’em is played with 52 cards. Each player has 2 hole cards and there are 5 community cards with 3 phases, called the *flop*, the *turn* and the *river*. The players have 4 *raise* actions per round each with 4 betting rounds in total. The state representation in this game is a vector of length 72. The first part contains the known cards, namely the hole cards and the already known community cards. The first 13 represents the cards from the Ace of Spade to the King of Spade, followed by the Heart, the Diamond and the Club similarly. The rest of the vector is the number of *raise* actions in each round.

Leduc Hold’em is limited to 6 cards, which are two pairs of King, Queen and Jack. This game is played by 2 players with 2 rounds, where there are 2 *raise* actions in the first one and 4 in the second one. The game is fixed with two-bet and 14 chips maximum.

We implemented a DQN agent in PyTorch. For this, we used the TensorFlow code from RLCard [3] as a base and created a more powerful, more manageable, and easy to use code in PyTorch. This implementation is an advanced Q-learning agent in two aspects. First, it uses a replay buffer to store past experiences and we can sample training data from it periodically. Second, to make the training more stable, another Q-network is used as a target network in order to backpropagate through it and train the policy Q-network. These features were first described in [4].

Furthermore, as an extra component, we added the opportunity of a more aggressive playing strategy. In case of the given action has the maximum q-value, the agent chooses the *raise* action as a replacement for it if *raising* is a valid action. Hence, the 3 possible extra settings are to encourage the agent to *raise* instead of *calling*, *checking* and *folding*. We investigate its impact on the performance of the agent.

# Results and Discussion

Hyperparameter optimalization, compare results

In Leduc Hold'em environment, the best mean result comes from the model with 3 layers of 128 neurons each, batch size of 64, 0.99 gamma, 0.1 learning rate, replay memory with size 2000.

I. Table

Best performance in Leduc Hold'em

|  |  |  |
| --- | --- | --- |
| strategy | mean reward | reward variance |
| 0 | 0.960 | 0.265 |
| 1 | 1.261 | 0.352 |
| 2 | 0.682 | 0.285 |
| 3 | 0.723 | 0.202 |

In Limit Hold'em environment the best parameter setting is: the best is 2 layers with 128 neurons, 64 batch size, 0.99 gamma, 0.001 learning rate, replay memory size 2000

--> network architecture and learning rate is different

II. Table

Performance in Limit Hold'em

|  |  |  |
| --- | --- | --- |
| strategy | mean reward | reward variance |
| 0 | 2.057 | 0.258 |
| 1 | 2.870 | 0.465 |
| 2 | 1.806 | 0.433 |
| 3 | 1.713 | 0.276 |

Discussion is a section of a research paper where scientists review the information in the introduction part, evaluate gained results, or compare it with past studies. In particular, students and scholars interpret gained data or findings in appropriate depth. For example, if results differ from expectations at the beginning, scientists should explain why that may have happened. However, if results agree with rationales, scientists should describe theories that the evidence is supported.

# Conclusions

What findings did we make.

Conclusion includes final claims of a research paper based on findings. Basically, this section covers final thoughts and the summary of the whole work. Moreover, this section may be used instead of limitations and recommendations that would be too small by themselves. In this case, scientists do not need to use headings for recommendations and limitations.



Fig. 1. Magnetization as a function of applied field. Note that “Fig.” is abbreviated. There is a period after the figure number, followed by two spaces. It is good practice to explain the significance of the figure in the caption.

TABLE I

Units for Magnetic Properties

|  |  |  |
| --- | --- | --- |
| Symbol | Quantity | Conversion from Gaussian and  CGS EMU to SI a |
| Φ | magnetic flux | 1 Mx → 10−8 Wb = 10−8 V·s |
| *B* | magnetic flux density,  magnetic induction | 1 G → 10−4 T = 10−4 Wb/m2 |
| *H* | magnetic field strength | 1 Oe → 103/(4π) A/m |
| *m* | magnetic moment | 1 erg/G = 1 emu  → 10−3 A·m2 = 10−3 J/T |
| *M* | magnetization | 1 erg/(G·cm3) = 1 emu/cm3  → 103 A/m |
| 4π*M* | magnetization | 1 G → 103/(4π) A/m |
| σ | specific magnetization | 1 erg/(G·g) = 1 emu/g → 1 A·m2/kg |
| *j* | magnetic dipole  moment | 1 erg/G = 1 emu  → 4π × 10−10 Wb·m |
| *J* | magnetic polarization | 1 erg/(G·cm3) = 1 emu/cm3  → 4π × 10−4 T |
| χ*,* κ | susceptibility | 1 → 4π |
| χρ | mass susceptibility | 1 cm3/g → 4π × 10−3 m3/kg |
| μ | permeability | 1 → 4π × 10−7 H/m  = 4π × 10−7 Wb/(A·m) |
| μr | relative permeability | μ → μr |
| *w, W* | energy density | 1 erg/cm3 → 10−1 J/m3 |
| *N, D* | demagnetizing factor | 1 → 1/(4π) |

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

aGaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

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### *Color/Grayscale figures*

### Figures that are meant to appear in color, or shades of black/gray. Such figures may include photographs, illustrations, multicolor graphs, and flowcharts.

### *Line Art figures*

### Figures that are composed of only black lines and shapes. These figures should have no shades or half-tones of gray, only black and white.

### *Author photos*

### Head and shoulders shots of authors that appear at the end of our papers.

### *Tables* Data charts which are typically black and white, but sometimes include color.

## Multipart figures

Figures compiled of more than one sub-figure presented side-by-side, or stacked. If a multipart figure is made up of multiple figure types (one part is lineart, and another is grayscale or color) the figure should meet the stricter guidelines.

## File Formats For Graphics

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## Sizing of Graphics

Most charts, graphs, and tables are one column wide (3.5 inches / 88 millimeters / 21 picas) or page wide (7.16 inches / 181 millimeters / 43 picas). The maximum depth a graphic can be is 8.5 inches (216 millimeters / 54 picas). When choosing the depth of a graphic, please allow space for a caption. Figures can be sized between column and page widths if the author chooses, however it is recommended that figures are not sized less than column width unless when necessary.

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The term color space refers to the entire sum of colors that can be represented within the said medium. For our purposes, the three main color spaces are Grayscale, RGB (red/green/blue) and CMYK (cyan/magenta/yellow/black). RGB is generally used with on-screen graphics, whereas CMYK is used for printing purposes.

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## Using Labels Within Figures

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Figure axis labels are often a source of confusion. Use words rather than symbols. As an example, write the quantity “Magnetization,” or “Magnetization *M*,” not just “*M*.” Put units in parentheses. Do not label axes only with units. As in Fig. 1, for example, write “Magnetization (A/m)” or “Magnetization (Am−1),” not just “A/m.” Do not label axes with a ratio of quantities and units. For example, write “Temperature (K),” not “Temperature/K.”

Multipliers can be especially confusing. Write “Magnetization (kA/m)” or “Magnetization (103 A/m).” Do not write “Magnetization (A/m) × 1000” because the reader would not know whether the top axis label in Fig. 1 meant 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8 to 10 point type.

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References

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2. Finnegan Southey, Michael P. Bowling, Bryce Larson, Carmelo Piccione, Neil Burch, Darse Billings and Chris Rayner, “Bayes' Bluff: Opponent Modelling in Poker,” 2012, [Online]. Available: arXiv:1207.1411
3. DATA Lab at Texas A&M University (2020) RLCard [Source code]. <https://github.com/datamllab/rlcard>
4. V. Mnih, K. Kavukcuoglu, D. Silver, “Human-level control through deep reinforcement learning,” *Nature* 518, 529–533, Feb. 2015.
5. W.-K. Chen, *Linear Networks and Systems.* Belmont, CA, USA: Wadsworth, 1993, pp. 123–135.

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2. E. P. Wigner, “Theory of traveling-wave optical laser,”   
   *Phys. Rev*.,   
   vol. 134, pp. A635–A646, Dec. 1965.
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2. J. H. Davis and J. R. Cogdell, “Calibration program for the 16-foot antenna,” Elect. Eng. Res. Lab., Univ. Texas, Austin, TX, USA, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

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1. G. O. Young, “Synthetic structure of industrial plastics,” in Plastics, vol. 3, Polymers of Hexadromicon, J. Peters, Ed., 2nd ed. New York, NY, USA: McGraw-Hill, 1964, pp. 15-64. [Online]. Available: http://www.bookref.com.
2. *The Founders’ Constitution*, Philip B. Kurland and Ralph Lerner, eds., Chicago, IL, USA: Univ. Chicago Press, 1987. [Online]. Available: http://press-pubs.uchicago.edu/founders/
3. The Terahertz Wave eBook. ZOmega Terahertz Corp., 2014. [Online]. Available: http://dl.z-thz.com/eBook/zomega\_ebook\_pdf\_1206\_sr.pdf. Accessed on: May 19, 2014.
4. Philip B. Kurland and Ralph Lerner, eds., *The Founders’ Constitution.* Chicago, IL, USA: Univ. of Chicago Press, 1987, Accessed on: Feb. 28, 2010, [Online] Available: http://press-pubs.uchicago.edu/founders/

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*Examples:*

1. J. S. Turner, “New directions in communications,” *IEEE J. Sel. Areas Commun*., vol. 13, no. 1, pp. 11-23, Jan. 1995.
2. W. P. Risk, G. S. Kino, and H. J. Shaw, “Fiber-optic frequency shifter using a surface acoustic wave incident at an oblique angle,” *Opt. Lett.*, vol. 11, no. 2, pp. 115–117, Feb. 1986.
3. P. Kopyt *et al., “*Electric properties of graphene-based conductive layers from DC up to terahertz range,” *IEEE THz Sci. Technol.,* to be published. DOI: 10.1109/TTHZ.2016.2544142.

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2. Teralyzer. Lytera UG, Kirchhain, Germany [Online]. Available: http://www.lytera.de/Terahertz\_THz\_Spectroscopy.php?id=home, Accessed on: Jun. 5, 2014

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c) J. K. Author, “Title of paper,” to be published.

*Examples:*

1. A. Harrison, private communication, May 1995.
2. B. Smith, “An approach to graphs of linear forms,” unpublished.
3. A. Brahms, “Representation error for real numbers in binary computer arithmetic,” IEEE Computer Group Repository, Paper R-67-85.

*Basic formats for standards:*

a) *Title of Standard*, Standard number, date.

b) *Title of Standard*, Standard number, Corporate author, location, date.

*Examples:*

1. IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.
2. Letter Symbols for Quantities, ANSI Standard Y10.5-1968.

*Article number in reference examples:*

1. R. Fardel, M. Nagel, F. Nuesch, T. Lippert, and A. Wokaun, “Fabrication of organic light emitting diode pixels by laser-assisted forward transfer,” *Appl. Phys. Lett.*, vol. 91, no. 6, Aug. 2007, Art. no. 061103.
2. J. Zhang and N. Tansu, “Optical gain and laser characteristics of InGaN quantum wells on ternary InGaN substrates,” *IEEE Photon. J.*, vol. 5, no. 2, Apr. 2013, Art. no. 2600111

*Example when using et al.:*

1. S. Azodolmolky *et al.*, Experimental demonstration of an impairment aware network planning and operation tool for transparent/translucent optical networks,” *J. Lightw. Technol.*, vol. 29, no. 4, pp. 439–448, Sep. 2011.

**First A. Author** (M’76–SM’81–F’87) and all authors may include biographies. Biographies are often not included in conference-related papers. This author became a Member (M) of IEEE in 1976, a Senior Member (SM) in 1981, and a Fellow (F) in 1987. The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author’s educational background is listed. The degrees should be listed with type of degree in what field, which institution, city, state, and country, and year the degree was earned. The author’s major field of study should be lower-cased.

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1. [↑](#footnote-ref-1)