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# Reinforcement Learning: Solving Two Player Games

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## Abstract

1        In this paper, we explore the application of reinforcement learning (RL) tech-  
2        niques to address the strategic decision-making challenges inherent in two-player  
3        games. As competitive environments provide a rich testbed for intelligent agents,  
4        we leverage RL algorithms to train agents capable of learning optimal strategies  
5        through interaction.

6        Our study focuses on the development of RL-based agents for playing classic  
7        two-player games, such as chess, Go, and tic-tac-toe. We employ deep reinforce-  
8        ment learning methodologies to enable agents to learn from experience, adapt  
9        to opponents, and refine their strategies over time. The use of neural networks  
10       allows our agents to generalize across different game states and learn complex  
11       patterns, contributing to their ability to make strategic decisions. We present ex-  
12       perimental results demonstrating the effectiveness of our approach in achieving  
13       competitive performance against skilled human players and benchmark algorithms.  
14       Additionally, we investigate the transferability of learned strategies across different  
15       games, highlighting the potential for RL-based agents to acquire strategic insights  
16       applicable to a broad spectrum of two-player adversarial scenarios.

17       Our findings contribute to the growing body of research on reinforcement learning  
18       in strategic settings, showcasing the adaptability and effectiveness of RL techniques  
19       in the context of two-player games. We discuss implications for the broader field of  
20       artificial intelligence and the potential for RL to enhance decision-making processes  
21       in adversarial environments.

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23    NeurIPS requires electronic submissions. The electronic submission site is

24                    <https://cmt3.research.microsoft.com/NeurIPS2020/>

25    Please read the instructions below carefully and follow them faithfully.

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27    Papers to be submitted to NeurIPS 2020 must be prepared according to the instructions presented  
28    here. Papers may only be up to eight pages long, including figures. Additional pages *containing only*  
29    *a section on the broader impact, acknowledgments and/or cited references* are allowed. Papers that  
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31    the conference.

32 The margins in 2020 are the same as those in 2007, which allow for  $\sim 15\%$  more words in the paper  
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34 Authors are required to use the NeurIPS  $\text{\LaTeX}$  style files obtainable at the NeurIPS website as  
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36 style files may be grounds for rejection.

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38 The style files for NeurIPS and other conference information are available on the World Wide Web at

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41 quirements your NeurIPS paper must satisfy.

42 The only supported style file for NeurIPS 2020 is `neurips_2020.sty`, rewritten for  $\text{\LaTeX} 2_{\epsilon}$ .  
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56 replace the author, title, abstract, and text of the paper with your own.

57 The formatting instructions contained in these style files are summarized in Sections 2, 3, and 4  
58 below.

## 59 2 General formatting instructions

60 The text must be confined within a rectangle 5.5 inches (33 picas) wide and 9 inches (54 picas) long.  
61 The left margin is 1.5 inch (9 picas). Use 10 point type with a vertical spacing (leading) of 11 points.  
62 Times New Roman is the preferred typeface throughout, and will be selected for you by default.  
63 Paragraphs are separated by  $\frac{1}{2}$  line space (5.5 points), with no indentation.

64 The paper title should be 17 point, initial caps/lower case, bold, centered between two horizontal  
65 rules. The top rule should be 4 points thick and the bottom rule should be 1 point thick. Allow  $\frac{1}{4}$  inch  
66 space above and below the title to rules. All pages should start at 1 inch (6 picas) from the top of the  
67 page.

68 For the final version, authors’ names are set in boldface, and each name is centered above the  
69 corresponding address. The lead author’s name is to be listed first (left-most), and the co-authors’  
70 names (if different address) are set to follow. If there is only one co-author, list both author and  
71 co-author side by side.

72 Please pay special attention to the instructions in Section 4 regarding figures, tables, acknowledgments,  
73 and references.

## 74 **3 Headings: first level**

75 All headings should be lower case (except for first word and proper nouns), flush left, and bold.

76 First-level headings should be in 12-point type.

### 77 **3.1 Headings: second level**

78 Second-level headings should be in 10-point type.

#### 79 **3.1.1 Headings: third level**

80 Third-level headings should be in 10-point type.

81 **Paragraphs** There is also a `\paragraph` command available, which sets the heading in bold, flush  
82 left, and inline with the text, with the heading followed by 1 em of space.

## 83 **4 Citations, figures, tables, references**

84 These instructions apply to everyone.

### 85 **4.1 Citations within the text**

86 The `natbib` package will be loaded for you by default. Citations may be author/year or numeric, as  
87 long as you maintain internal consistency. As to the format of the references themselves, any style is  
88 acceptable as long as it is used consistently.

89 The documentation for `natbib` may be found at

90 `http://mirrors.ctan.org/macros/latex/contrib/natbib/natnotes.pdf`

91 Of note is the command `\citet`, which produces citations appropriate for use in inline text. For  
92 example,

93 `\citet{hasselmo}` investigated\dotso

94 produces

95 Hasselmo, et al. (1995) investigated...

96 If you wish to load the `natbib` package with options, you may add the following before loading the  
97 `neurips_2020` package:

98 `\PassOptionsToPackage{options}{natbib}`

99 If `natbib` clashes with another package you load, you can add the optional argument `nonatbib`  
100 when loading the style file:

101 `\usepackage[nonatbib]{neurips_2020}`

102 As submission is double blind, refer to your own published work in the third person. That is, use “In  
103 the previous work of Jones et al. [4],” not “In our previous work [4].” If you cite your other papers  
104 that are not widely available (e.g., a journal paper under review), use anonymous author names in the  
105 citation, e.g., an author of the form “A. Anonymous.”



Figure 1: Sample figure caption.

Table 1: Sample table title

Part		
Name	Description	Size ( $\mu\text{m}$ )
Dendrite	Input terminal	$\sim 100$
Axon	Output terminal	$\sim 10$
Soma	Cell body	up to $10^6$

## 4.2 Footnotes

Footnotes should be used sparingly. If you do require a footnote, indicate footnotes with a number<sup>1</sup> in the text. Place the footnotes at the bottom of the page on which they appear. Precede the footnote with a horizontal rule of 2 inches (12 picas).

Note that footnotes are properly typeset *after* punctuation marks.<sup>2</sup>

## 4.3 Figures

All artwork must be neat, clean, and legible. Lines should be dark enough for purposes of reproduction. The figure number and caption always appear after the figure. Place one line space before the figure caption and one line space after the figure. The figure caption should be lower case (except for first word and proper nouns); figures are numbered consecutively.

You may use color figures. However, it is best for the figure captions and the paper body to be legible if the paper is printed in either black/white or in color.

## 4.4 Tables

All tables must be centered, neat, clean and legible. The table number and title always appear before the table. See Table 1.

Place one line space before the table title, one line space after the table title, and one line space after the table. The table title must be lower case (except for first word and proper nouns); tables are numbered consecutively.

Note that publication-quality tables *do not contain vertical rules*. We strongly suggest the use of the `booktabs` package, which allows for typesetting high-quality, professional tables:

<https://www.ctan.org/pkg/booktabs>

This package was used to typeset Table 1.

<sup>1</sup>Sample of the first footnote.

<sup>2</sup>As in this example.

## 5 Final instructions

Do not change any aspects of the formatting parameters in the style files. In particular, do not modify the width or length of the rectangle the text should fit into, and do not change font sizes (except perhaps in the **References** section; see below). Please note that pages should be numbered.

## 6 Preparing PDF files

Please prepare submission files with paper size “US Letter,” and not, for example, “A4.”

Fonts were the main cause of problems in the past years. Your PDF file must only contain Type 1 or Embedded TrueType fonts. Here are a few instructions to achieve this.

- You should directly generate PDF files using `pdflatex`.
- You can check which fonts a PDF file uses. In Acrobat Reader, select the menu Files>Document Properties>Fonts and select Show All Fonts. You can also use the program `pdf fonts` which comes with `xpdf` and is available out-of-the-box on most Linux machines.
- The IEEE has recommendations for generating PDF files whose fonts are also acceptable for NeurIPS. Please see <http://www.emfield.org/icuwb2010/downloads/IEEE-PDF-SpecV32.pdf>
- `xfig` “patterned” shapes are implemented with bitmap fonts. Use “solid” shapes instead.
- The `\bbold` package almost always uses bitmap fonts. You should use the equivalent AMS Fonts:

```
\usepackage{amsfonts}
```

followed by, e.g., `\mathbb{R}`, `\mathbb{N}`, or `\mathbb{C}` for  $\mathbb{R}$ ,  $\mathbb{N}$  or  $\mathbb{C}$ . You can also use the following workaround for reals, natural and complex:

```
\newcommand{\RR}{\mathbb{R}} %real numbers
\newcommand{\Nat}{\mathbb{N}} %natural numbers
\newcommand{\CC}{\mathbb{C}} %complex numbers
```

Note that `amsfonts` is automatically loaded by the `amssymb` package.

If your file contains type 3 fonts or non embedded TrueType fonts, we will ask you to fix it.

### 6.1 Margins in L<sup>A</sup>T<sub>E</sub>X

Most of the margin problems come from figures positioned by hand using `\special` or other commands. We suggest using the command `\includegraphics` from the `graphicx` package. Always specify the figure width as a multiple of the line width as in the example below:

```
\usepackage[pdftex]{graphicx} ...
\includegraphics[width=0.8\linewidth]{myfile.pdf}
```

See Section 4.4 in the `graphics` bundle documentation (<http://mirrors.ctan.org/macros/latex/required/graphics/grfguide.pdf>)

A number of width problems arise when L<sup>A</sup>T<sub>E</sub>X cannot properly hyphenate a line. Please give LaTeX hyphenation hints using the `\-` command when necessary.

### Broader Impact

Authors are required to include a statement of the broader impact of their work, including its ethical aspects and future societal consequences. Authors should discuss both positive and negative outcomes,

167 if any. For instance, authors should discuss a) who may benefit from this research, b) who may be  
168 put at disadvantage from this research, c) what are the consequences of failure of the system, and d)  
169 whether the task/method leverages biases in the data. If authors believe this is not applicable to them,  
170 authors can simply state this.

171 Use unnumbered first level headings for this section, which should go at the end of the paper. **Note**  
172 **that this section does not count towards the eight pages of content that are allowed.**

## 173 **References**

174 References follow the acknowledgments. Use unnumbered first-level heading for the references. Any  
175 choice of citation style is acceptable as long as you are consistent. It is permissible to reduce the font  
176 size to small (9 point) when listing the references. **Note that the Reference section does not count**  
177 **towards the eight pages of content that are allowed.**

178 [1] Alexander, J.A. & Mozer, M.C. (1995) Template-based algorithms for connectionist rule extraction. In  
179 G. Tesauro, D.S. Touretzky and T.K. Leen (eds.), *Advances in Neural Information Processing Systems 7*, pp.  
180 609–616. Cambridge, MA: MIT Press.

181 [2] Bower, J.M. & Beeman, D. (1995) *The Book of GENESIS: Exploring Realistic Neural Models with the*  
182 *GENeral NEural Simulation System*. New York: TELOS/Springer-Verlag.

183 [3] Hasselmo, M.E., Schnell, E. & Barkai, E. (1995) Dynamics of learning and recall at excitatory recurrent  
184 synapses and cholinergic modulation in rat hippocampal region CA3. *Journal of Neuroscience* **15**(7):5249-5262.