

Walk To Run: Teaching An Intelligent Agent To Play QWOP

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Abstract

We have decided to recreate the game QWOP and create an AI that can sufficiently play the game. In QWOP, a player attempts to control a track runner's thighs and legs using Q and W and calves using O and P to make them run without falling over. Our goal is to create an AI that can play this game and improve at it to eventually be able to travel 100m. We intend to use a combination of approaches that includes a genetic algorithm, a neural network, and reinforcement learning to train the AI to improve its gameplay. Our plan is to develop the AI using milestones such as crawling, standing, walking, etc. We intend to further expand this plan with more specific algorithms, milestones, etc.

The core issue that this program intends to solve is creating a biomechanical model of locomotion. This issue is bioinspired because most land-borne animals must learn to balance and walk on their own. This problem is explored in many fields including engineering, medicine, and robotics. Our goal is to successfully develop a program that can learn to maneuver the character without falling over.

Our approach to the problem is to develop a neural network and use a genetic algorithm and reinforcement learning with it.

The neural network will be given a set of inputs, which involves the positions of all the limbs in the environment. The goal is to create a deep enough neural network with enough layers, so we can train it using a large dataset of inputs and supervised learning.

To optimize the weights of the neural network we will use a genetic algorithm. The approach that we will use is population-based. In such an approach, we generate multiple agents with various neural networks, which have randomly assigned weights for the first time, and as they evolve the weights will change based on the successful performances of the neural networks.

Finally, to further improve the agent's performance we will use reinforcement learning. For this portion of the development, we will develop a utility function that would indicate how well the agent performs to make further updates to the neural network's weights based on the rewards received by the agent during gameplay. The simplest version

of the utility function that we have in mind is to give rewards if the figure moves forward and penalize it for falling or moving backward. We will potentially use a replay buffer to store the outputs of the utility function (agent's experiences) for further improvements in the stability of the learning process.

We believe that we will be successful because we have planned out a system of a neural network and genetic algorithm/reinforcement learning to help accomplish our goal. Our neural network has been coded to fully perceive the character's body and movements relative to the environment. This will allow us to determine if the character is balancing, and measure its movement. We already have a functional draft of a neural network that can be used and upon which we can expand. We believe that Our [genetic algorithm/reinforcement learning] approach will allow our program to learn the best approach to balancing and walking. Due to the genetic algorithm, we would be able to assign starting weights that would have some meaning due to trial and error. Due to reinforcement learning the weights and the actions would be polished (further improved). We believe that such a combination will give us better results compared to the ones that would be given if we were only to use one of the mentioned above algorithms.

—ignore—

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- Your `.tex` file must compile in PDF \LaTeX — (you may not include `.ps` or `.eps` figure files.)
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- Modifications to the style file, whether directly or via commands in your document may not ever be made, most especially when made in an effort to avoid extra page charges or make your paper fit in a specific number of pages.
- No type 3 fonts may be used (even in illustrations).
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- You may not alter the line spacing of text.
- Your title must follow Title Case capitalization rules (not sentence case).
- Your `.tex` file must include completed metadata to pass-through to the PDF (see PDFINFO below).
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- Your source must compile on our system, which includes only standard L^AT_EX 2020 TeXLive support files.
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Your L^AT_EX source will be reviewed and recompiled on our system (if it does not compile, your paper will be returned to you). **Do not submit your source in multiple text files.** Your single L^AT_EX source file must include all your text, your bibliography (formatted using aaai21.bst), and any custom macros.

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Do not send supporting files that are not actually used in the paper. We don't want you to send us any files not needed for compiling your paper, including, for example, this instructions file, unused graphics files, style files, additional material sent for the purpose of the paper review, and so forth.

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In the L^AT_EX source for your paper, you **must** place the following lines as shown in the example in this subsection. This command set-up is for three authors. Add or subtract author and address lines as necessary, and uncomment the portions that apply to you. In most instances, this is all you need to do to format your paper in the Times font. The helvet package will cause Helvetica to be used for sans serif. These files are part of the PSNFSS2e package, which is freely available from many Internet sites (and is often part of a standard installation).

Leave the setcounter for section number depth commented out and set at 0 unless you want to add section numbers to your paper. If you do add section numbers, you must uncomment this line and change the number to 1 (for section numbers), or 2 (for section and subsection numbers).

The style file will not work properly with numbering of sub-subsections, so do not use a number higher than 2.

The Following Must Appear in Your Preamble

```
\def\year{2021}\relax
% File: formatting-instruction.tex
\documentclass[letterpaper]{article}
% DO NOT CHANGE THIS
\usepackage{aaai21} % DO NOT CHANGE THIS
\usepackage{times} % DO NOT CHANGE THIS
\usepackage{helvet} % DO NOT CHANGE THIS
\usepackage{courier} % DO NOT CHANGE THIS
\usepackage[hyphens]{url} % DO NOT CHANGE THIS
\usepackage{graphicx} % DO NOT CHANGE THIS
\urlstyle{rm} % DO NOT CHANGE THIS
\def\UrlFont{\rm} % DO NOT CHANGE THIS
\usepackage{graphicx} % DO NOT CHANGE THIS
\usepackage{natbib}
% DO NOT CHANGE THIS OR ADD OPTIONS
\usepackage{caption}
% DO NOT CHANGE THIS OR ADD OPTIONS
\frenchspacing % DO NOT CHANGE THIS
\setlength{\pdfpagewidth}{8.5in} % DO NOT CHANGE THIS
\setlength{\pdfpageheight}{11in} % DO NOT CHANGE THIS
%
% PDF Info Is REQUIRED.
% For /Author, add all authors within the parentheses,
% separated by commas. No accents or commands.
% For /Title, add Title in Mixed Case.
% No accents or commands. Retain the parentheses.
\pdfinfo{
/Title (AAAI Press Formatting Instructions for Authors
Using LaTeX -- A Guide)
/Author (AAAI Press Staff, Pater Patel Schneider,
Sunil Issar, J. Scott Penberthy, George Ferguson,
Hans Guesgen, Francisco Cruz, Marc Pujol-Gonzalez)
/TemplateVersion (2021.1)
}
```

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After the preamble above, you should prepare your paper as follows:

```
%
\begin{document}
\maketitle
\begin{abstract}
%...
\end{abstract}
```

You should then continue with the body of your paper. Your paper must conclude with the references, which should be inserted as follows:

```
% References and End of Paper
% These lines must be placed at the end of your paper
\bibliography{Bibliography-File}
\end{document}
```

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```
\begin{document}\\
\maketitle\\
...\\
\bibliography{Bibliography-File}\\
\end{document}\\
```

Commands and Packages That May Not Be Used

There are a number of packages, commands, scripts, and macros that are incompatible with aaai21.sty. The common ones are listed in tables 1 and 2. Generally, if a command, package, script, or macro alters floats, margins, fonts, sizing, linespacing, or the presentation of the references and citations, it is unacceptable. Note that negative vskip and vspace may not be used except in certain rare occurrences, and may never be used around tables, figures, captions, sections, subsections, subsections, or references.

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<code>\abovecaption</code>	<code>\abovedisplay</code>	<code>\addevensidemargin</code>	<code>\addsidemargin</code>
<code>\addtolength</code>	<code>\baselinestretch</code>	<code>\belowcaption</code>	<code>\belowdisplay</code>
<code>\break</code>	<code>\clearpage</code>	<code>\clip</code>	<code>\columnsep</code>
<code>\float</code>	<code>\input</code>	<code>\input</code>	<code>\linespread</code>
<code>\newpage</code>	<code>\pagebreak</code>	<code>\renewcommand</code>	<code>\setlength</code>
<code>\text height</code>	<code>\tiny</code>	<code>\top margin</code>	<code>\trim</code>
<code>\vskip{-</code>	<code>\vspace{-</code>		

Table 1: Commands that must not be used

<code>authblk</code>	<code>babel</code>	<code>cjk</code>	<code>dvips</code>
<code>epsf</code>	<code>epsfig</code>	<code>euler</code>	<code>float</code>
<code>fullpage</code>	<code>geometry</code>	<code>graphics</code>	<code>hyperref</code>
<code>layout</code>	<code>linespread</code>	<code>lmodern</code>	<code>maltepaper</code>
<code>navigator</code>	<code>pdfcomment</code>	<code>pgfplots</code>	<code>psfig</code>
<code>pstricks</code>	<code>tlenc</code>	<code>titlesec</code>	<code>tocbind</code>
<code>ulem</code>			

Table 2: LaTeX style packages that must not be used.

If you are unsure if your paper contains type 3 fonts, view the PDF in Acrobat Reader. The Properties/Fonts window will display the font name, font type, and encoding properties of all the fonts in the document. If you are unsure if your graphics contain type 3 fonts (and they are PostScript or encapsulated PostScript documents), create PDF versions of them, and consult the properties window in Acrobat Reader.

The default size for your type must be ten-point with twelve-point leading (line spacing). Start all pages (except the first) directly under the top margin. (See the next section for instructions on formatting the title page.) Indent ten points when beginning a new paragraph, unless the paragraph begins directly below a heading or subheading.

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```
\author{
    Author 1, ..., Author n \\
}
\affiliations {
    Address line \\
    ... \\
    Address line
}
```

For authors from different institutions, use `\rm x` to match authors and affiliations.

```
\author{
    AuthorOne,\textsuperscript{\rm 1}
    AuthorTwo,\textsuperscript{\rm 2}
    AuthorThree,\textsuperscript{\rm 3}
    AuthorFour,\textsuperscript{\rm 4}
    AuthorFive \textsuperscript{\rm 5}\\
}
\affiliations {
    \textsuperscript{\rm 1}AffiliationOne, \\
    \textsuperscript{\rm 2}AffiliationTwo, \\
    \textsuperscript{\rm 3}AffiliationThree, \\
    \textsuperscript{\rm 4}AffiliationFour, \\
    \textsuperscript{\rm 5}AffiliationFive \\
    \{email, email\}@affiliation.com,
    email@affiliation.com,
    email@affiliation.com,
    email@affiliation.com
}
```

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```
\title{Very Important Results in AI}\thanks{This work is supported by everybody.}}
```

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Citations within the text should include the author's last name and year, for example (Newell 1980). Append lower-case letters to the year in cases of ambiguity. Multiple authors should be treated as follows: (Feigenbaum and Englemore 1988) or (Ford, Hayes, and Glymour 1992). In the case of four or more authors, list only the first author, followed by et al. (Ford et al. 1997).

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Long quotations and extracts should be indented ten points from the left and right margins.

This is an example of an extract or quotation. Note the indent on both sides. Quotation marks are not necessary if you offset the text in a block like this, and properly identify and cite the quotation in the text.

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When necessary, headings should be used to separate major sections of your paper. Remember, you are writing a short paper, not a lengthy book! An overabundance of headings will tend to make your paper look more like an outline than a paper. The `aaai21.sty` package will create headings for you. Do not alter their size nor their spacing above or below.

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Appendices. Any appendices follow the acknowledgments, if included, or after the main body of text if no acknowledgments appear.

References. The references section should be labeled "References" and should appear at the very end of the paper (don't end the paper with references, and then put a figure by itself on the last page). A sample list of references is given later on in these instructions. Please use a consistent format for references. Poorly prepared or sloppy references reflect badly on the quality of your paper and your research. Please prepare complete and accurate citations.

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Figures, drawings, tables, and photographs should be placed throughout the paper on the page (or the subsequent page) where they are first discussed. Do not group them together at the end of the paper. If placed at the top of the paper, illustrations may run across both columns. Figures must






if there are no  showing, add the sum to their turn total. At each decision point, a player may continue to roll or stop. If they decide to stop, they add their turn total to their total score and then it becomes the opponent's turn. Otherwise, they roll dice again  continue adding to their turn total. If a single  turn  and the turn ended (no points gained); if a  then the players

Figure 1: Using the trim and clip commands produces fragile layers that can result in disasters (like this one from an actual paper) when the color space is corrected or the PDF combined with others for the final proceedings. Crop your figures properly in a graphics program – not in LaTeX

not invade the top, bottom, or side margin areas. Figures must be inserted using the `\usepackage{graphicx}`. Number figures sequentially, for example, figure 1, and so on. Do not use minipage to group figures.

If you normally create your figures using pgfplots, please create the figures first, and then import them as pdfs with proper bounding boxes, as the bounding and trim boxes created by pgfplots are fragile and not valid.

When you include your figures, you must crop them **outside** of L^AT_EX. The command `\includegraphics*[clip=true, viewport 0 0 10 10]...` might result in a PDF that looks great, but the image is **not really cropped**. The full image can reappear (and obscure whatever it is overlapping) when page numbers are applied or color space is standardized. Figures 1, and 2 display some unwanted results that often occur.

If your paper includes illustrations that are not compatible with PDF_TE_X (such as .eps or .ps documents), you will need to convert them. The `epstopdf` package will usually work for eps files. You will need to convert your ps files to PDF however.

Figure Captions. The illustration number and caption must appear *under* the illustration. Labels, and other text with the actual illustration must be at least nine-point type. However, the font and size of figure captions must be 10 point roman. Do not make them smaller, bold, or italic. (Individual words may be italicized if the context requires differentiation.)

Tables

Tables should be presented in 10 point roman type. If necessary, they may be altered to 9 point type. You may not use any commands that further reduce point size below nine points. Tables that do not fit in a single column must be placed across double columns. If your table won't fit within the margins even when spanning both columns, you must split it. Do not use minipage to group tables.

Table Captions. The number and caption for your table must appear *under* (not above) the table. Additionally, the font and size of table captions must be 10 point roman and must be placed beneath the figure. Do not make them smaller, bold, or italic. (Individual words may be italicized if the context requires differentiation.)

Low-Resolution Bitmaps. You may not use low-resolution (such as 72 dpi) screen-dumps and GIF files—these files contain so few pixels that they are always blurry, and illegible when printed. If they are color, they will become an indecipherable mess when converted to black and white. This is always the case with gif files, which should never be used. The resolution of screen dumps can be increased by reducing the print size of the original file while retaining the same number of pixels. You can also enlarge files by manipulating them in software such as PhotoShop. Your figures should be 300 dpi when incorporated into your document.

L^AT_EX Overflow. L^AT_EX users please beware: L^AT_EX will sometimes put portions of the figure or table or an equation in the margin. If this happens, you need to make the figure or table span both columns. If absolutely necessary, you may reduce the figure, or reformat the equation, or reconfigure the table. **Check your log file!** You must fix any overflow into the margin (that means no overfull boxes in L^AT_EX). **Nothing is permitted to intrude into the margin or gutter.**

Using Color. Use of color is restricted to figures only. It must be WACG 2.0 compliant. (That is, the contrast ratio must be greater than 4.5:1 no matter the font size.) It must be CMYK, NOT RGB. It may never be used for any portion of the text of your paper. The archival version of your paper will be printed in black and white and grayscale. The web version must be readable by persons with disabilities. Consequently, because conversion to grayscale can cause undesirable effects (red changes to black, yellow can disappear, and so forth), we strongly suggest you avoid placing color figures in your document. If you do include color figures, you must (1) use the CMYK (not RGB) colorspace and (2) be mindful of readers who may happen to have trouble distinguishing colors. Your paper must be decipherable without using color for distinction.

Drawings. We suggest you use computer drawing software (such as Adobe Illustrator or, (if unavoidable), the drawing tools in Microsoft Word) to create your illustrations. Do not use Microsoft Publisher. These illustrations will look best if all line widths are uniform (half- to two-point in size), and you do not create labels over shaded areas. Shading should be 133 lines per inch if possible. Use Times Roman or Helvetica for all figure call-outs. **Do not use hairline width lines** — be sure that the stroke width of all lines is at least .5 pt. Zero point lines will print on a laser printer, but will completely disappear on the high-resolution devices used by our printers.

Photographs and Images. Photographs and other images should be in grayscale (color photographs will not reproduce well; for example, red tones will reproduce as black, yellow may turn to white, and so forth) and set to a minimum of 300 dpi. Do not prescreen images.

Resizing Graphics. Resize your graphics **before** you include them with L^AT_EX. You may **not** use trim or clip options as part of your `\includegraphics` command. Resize the

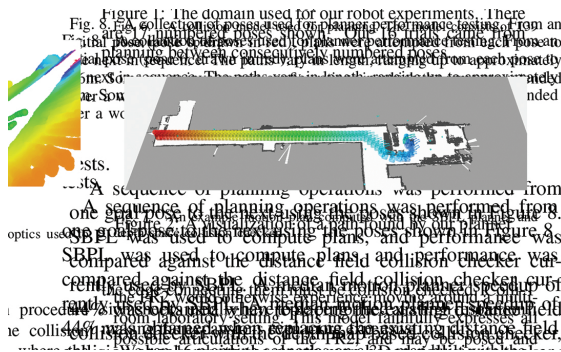


Figure 1: The domain used for our robot experiments. There are 100 obstacles in the domain, and the robot's path is shown in light blue. The distance field is shown in the background, with a color gradient from red (near obstacles) to blue (far from obstacles). The path is a sequence of planning operations, and the distance field is used to compute the path. The path is a sequence of planning operations, and the distance field is used to compute the path.

Figure 2: Adjusting the bounding box instead of actually removing the unwanted data resulted multiple layers in this paper. It also needlessly increased the PDF size. In this case, the size of the unwanted layer doubled the paper's size, and produced the following surprising results in final production. Crop your figures properly in a graphics program. Don't just alter the bounding box.

media box of your PDF using a graphics program instead.

Fonts in Your Illustrations. You must embed all fonts in your graphics before including them in your LaTeX document.

References

The AAAI style includes a set of definitions for use in formatting references with BibTeX. These definitions make the bibliography style fairly close to the one specified below. To use these definitions, you also need the BibTeX style file "aaai21.bst," available in the AAAI Author Kit on the AAAI web site. Then, at the end of your paper but before `\enddocument`, you need to put the following lines:

```
\bibliography{bibfile1,bibfile2,...}
```

Please note that the `aaai21.sty` class already sets the `bibliographystyle` for you, so you do not have to place any `\bibliographystyle` command in the document yourselves. The `aaai21.sty` file is incompatible with the `hyperref` and `navigator` packages. If you use either, your references will be garbled and your paper will be returned to you.

References may be the same size as surrounding text. However, in this section (only), you may reduce the size to `\small` if your paper exceeds the allowable number of pages. Making it any smaller than 9 point with 10 point linespacing, however, is not allowed. A more precise and exact method of reducing the size of your references minimally is by means of the following command:

```
\fontsize{9.8pt}{10.8pt} \selectfont
```

You must reduce the size equally for both font size and line spacing, and may not reduce the size beyond `{9.0pt}{10.0pt}`.

The list of files in the `\bibliography` command should be the names of your BibTeX source files (that is, the `.bib` files referenced in your paper).

The following commands are available for your use in citing references:

`\cite`: Cites the given reference(s) with a full citation. This appears as "(Author Year)" for one reference, or

"(Author Year; Author Year)" for multiple references.

`\shortcite`: Cites the given reference(s) with just the year. This appears as "(Year)" for one reference, or "(Year; Year)" for multiple references.

`\citeauthor`: Cites the given reference(s) with just the author name(s) and no parentheses.

`\citeyear`: Cites the given reference(s) with just the date(s) and no parentheses.

Formatted bibliographies should look like the following examples.

Book with Multiple Authors

Engelmore, R., and Morgan, A. eds. 1986. *Blackboard Systems*. Reading, Mass.: Addison-Wesley.

Journal Article

Robinson, A. L. 1980a. New Ways to Make Microcircuits Smaller. *Science* 208: 1019–1026.

Magazine Article

Hasling, D. W.; Clancey, W. J.; and Rennels, G. R. 1983. Strategic Explanations in Consultation. *The International Journal of Man-Machine Studies* 20(1): 3–19.

Proceedings Paper Published by a Society

Clancey, W. J. 1983. Communication, Simulation, and Intelligent Agents: Implications of Personal Intelligent Machines for Medical Education. In *Proceedings of the Eighth International Joint Conference on Artificial Intelligence*, 556–560. Menlo Park, Calif.: International Joint Conferences on Artificial Intelligence, Inc.

Proceedings Paper Published by a Press or Publisher

Clancey, W. J. 1984. Classification Problem Solving. In *Proceedings of the Fourth National Conference on Artificial Intelligence*, 49–54. Menlo Park, Calif.: AAAI Press.

University Technical Report

Rice, J. 1986. Polygon: A System for Parallel Problem Solving, Technical Report, KSL-86-19, Dept. of Computer Science, Stanford Univ.

Dissertation or Thesis

Clancey, W. J. 1979. Transfer of Rule-Based Expertise

through a Tutorial Dialogue. Ph.D. diss., Dept. of Computer Science, Stanford Univ., Stanford, Calif.

Forthcoming Publication

Clancey, W. J. 2021. The Engineering of Qualitative Models. Forthcoming.

For the most up to date version of the AAAI reference style, please consult the *AI Magazine* Author Guidelines at <https://aaai.org/ojs/index.php/aimagazine/about/submissions#authorGuidelines>

Proofreading Your PDF

Please check all the pages of your PDF file. The most commonly forgotten element is the acknowledgements — especially the correct grant number. Authors also commonly forget to add the metadata to the source, use the wrong reference style file, or don't follow the capitalization rules or comma placement for their author-title information properly. A final common problem is text (especially equations) that runs into the margin. You will need to fix these common errors before submitting your file.

Improperly Formatted Files

In the past, AAAI has corrected improperly formatted files submitted by the authors. Unfortunately, this has become an increasingly burdensome expense that we can no longer absorb). Consequently, if your file is improperly formatted, it will be returned to you for correction.

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If you use L^AT_EX 209 your paper will be returned to you unpublished. Convert your paper to L^AT_EX 2_ε.

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Instructions on paper submittal will be provided to you in your acceptance letter.

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If you have any questions about the preparation or submission of your paper as instructed in this document, please contact AAAI Press at the address given below. If you have technical questions about implementation of the aaai style file, please contact an expert at your site. We do not provide technical support for L^AT_EX or any other software package. To avoid problems, please keep your paper simple, and do not incorporate complicated macros and style files.

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Additional Resources

L^AT_EX is a difficult program to master. If you've used that software, and this document didn't help or some items were not explained clearly, we recommend you read Michael Shell's excellent document (testflow doc.txt V1.0a 2002/08/13) about obtaining correct PS/PDF output on L^AT_EX systems. (It was written for another purpose, but it has general application as well). It is available at www.ctan.org in the tex-archive.

Acknowledgments

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The preparation of the L^AT_EX and BibT_EX files that implement these instructions was supported by Schlumberger Palo Alto Research, AT&T Bell Laboratories, Morgan Kaufmann Publishers, The Live Oak Press, LLC, and AAAI Press. Bibliography style changes were added by Sunil Issar. \pubnote was added by J. Scott Penberthy. George Ferguson added support for printing the AAAI copyright slug. Additional changes to aaai21.sty and aaai21.bst have been made by Francisco Cruz, Marc Pujol-Gonzalez, and Mico Loretan.

Thank you for reading these instructions carefully. We look forward to receiving your electronic files!