

Efficiently Retrieving Images that We Perceived as Similar

Hui-Ju Katherine Chiang¹, Shih-Han Wang²

¹Graduate Institute of Electronics Engineering, National Taiwan University, Taipei 10617, Taiwan

²Graduate Institute of Networking and Multimedia, National Taiwan University, Taipei 10617, Taiwan
{d01943033, r02944022}@ntu.edu.tw

Abstract

Despite growing interest in using sparse coding based methods for image classification and retrieval, progress in this direction has been limited by the high computational cost for generating each image's sparse representation. To overcome this problem, we leverage sparsity-based dictionary learning and hash-based feature selection to build a novel unsupervised way to efficiently pick out a query image's most important high-level features that can determine to which group we would visually perceived as similar. The preliminary results based on L1 feature map show the method's efficiency and high accuracy from the visual cognitive perspective. Finally, we consider a more general problem of how to make the pre-learned dictionary to adaptively refine the features contained according to past queries.

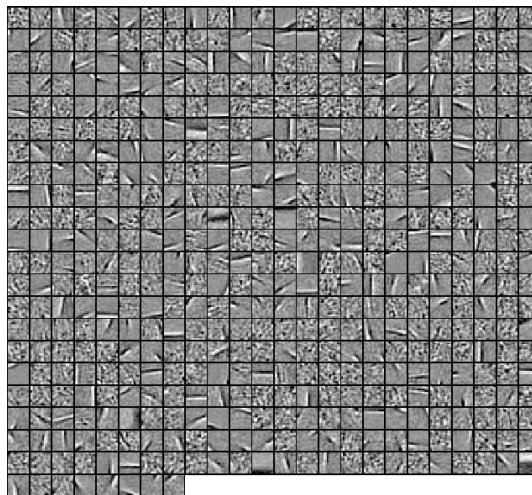
Motivation and Introduction

Similar image retrieval has become an important problem with many real-world applications in artificial intelligence field. To be able to process the growing amount of data, more efficient and reliable algorithms are needed. Until now, there is still a lack of an effective guideline to decide similarity for a computer, though the problem posts no difficulty to human beings. This motivated us to incorporate the biology-inspired sparse coding and hashing techniques for more intuitive, real time retrieval results. There are many researches studying about how to make image retrieval effective. Conventionally, there are three steps in large-scale content-based image retrieval when given a set of indexed images and a query image. The first is feature extraction. Many complex approaches are developed to find effective image representation to encode a variety of images. Secondly, dimension reduction is important to speed up the retrieval process. Finally, effective metric is needed to compute the similarity between features. Compared to the traditional framework we propose a different solution without the part of feature extraction to solve this problem by the plausible model of visual cortex sparse coding.

Sparse representation based on an *overcomplete* basis (Olshausen and Field 1996), inspired by mammalian striate cortex mechanism from neural science community has been

widely applied in many computer science fields, such as data compression, speech recognition and image denoising, etc. (Sivaram 2010), (Wright et al. 2009). One important property of sparse coding is that it can extract from data higher-level features that are actually more cognitively effective than hand-picked ones by simulating partial activity of neurons. According to promising neural science theory and the high performance of algorithms developed within decades, we assume that sparse coding which simulates mammalian visual cortex activities is a very efficient approach to find the latent features compared to traditional unsupervised learning such as PCA. We also assume that neuron simulation-based approach for image representation is better than other widely used computer vision features including SIFT (Lowe 1999), GIST (Oliva et al. 2001), HOG (Dalal et al. 2005) and etc. because we have our visual system as promising evidence to support.

Some people have images search problem with the representation of sparse codes proposed by (Ge et al. 2013). However, finding sparse codes has high computational costs on doing effective real time search. We propose a novel approach to solve this problem by using overcomplete basis in dictionary rather than computing sparse codes and we will show that our approach is effective in natural image.



Preprocessing-Unsupervised dictionary learning

Sparse-based dictionary learning has proven been effective in natural images which are mostly scene image. Given input unlabeled scene images, the effective sparse coding proposed by (Lee et al. 2007) captures succinct feature with higher meanings and generate a dictionary with overcomplete bases which are effective to represent the image in data set given the corresponding sparse code. The basic descriptions such as edges and line segments are efficiently encoded into atoms of dictionary so we will pre-trained the dictionary as our dimension reduction projection bases. (dictionary)

System framework

Given a query natural image, we firstly decorrelate the image to equalize the variance which is also employed in preprocessing for dictionary due to potential factual and corrupted and this also roughly simulate spatial-frequency response characteristic of retinal ganglion cells proposed by (Olshausen 1997) in our cognitive system. We then uniformly select several image patches to extract a certain pattern of the image. We feed all extracted vectors into our auto-learned feature selection algorithms to encode the data. Finally, we use L2 distance as default metric to compute similarity score. The system diagram is shown in Figure 2.

Auto-learned feature selection algorithms

Since our retrieval framework encode the image pattern of natural images into sparsity-based dictionary, we are motivated to select effective feature, especially those have high response to patches of natural images. Inspired by localitive sensitive hashing proposed by (Andoni et al. 2008), where high dimensional data can be projected to lower dimensional space with similarity preserving promise, we propose our novel algorithm to find out the atom of feature pattern in the dictionary to perform our hash-based dimensional reduction.

Firstly, we project our patches vector onto the atom of dictionary to get the highest values of the result for each vector of patches and have another zero array with the same size. We call those atoms strong responsive to the corresponding patches vector. Then, we set the value of each patches vector at corresponding atom of dictionary to be one.

Secondly, we subtract the strong responsive atom from the corresponding patches vector in order to select second strong responsive atom with respect to the corresponding patches vector.

Iteratively, we will rank out the top n strong responsive atoms as our output for each patch vector. By this way, we can encode the raw data directly by the ranking of the response of corresponding atom based on sparsity based dictionary and we will show that the result has some effects consistent with our visual system.

Experimental results

- show the recall and precision for some image
- show the result images

Conclusion

Rather than traditional human-turned feature extraction our cognitive system based on sparse coding successfully combine proposed novel auto-learned feature selection algorithm with sparsity-based dictionary to retrieve natural images with high performance. The sparsity-based dictionary which capture basic elements consisting a natural image is a well learned structure to encode images. Although it needs more powerful algorithm and research in large-scale image retrieval or other big data, this is the promising direction of relative application.

How to work with big data?

When the world is filled with big data, effective approach is needed to deal with such a challenge. Large-scale image with effective and reliable performance is one of examples. Recently, we are attempting to address an open question if there is new approach based our framework to handle this old but not well-solved problem. Our work lies in how we design the connection between visual neuron encoding simulation and image retrieval problem and how we investigate an effective large-sale image retrieval new candidate.

References

- Ge, Tiezheng, Qifa Ke, and Jian Sun. "Sparse-Coded Features for Image Retrieval." (2013).
- Wright, John, et al. "Sparse representation for computer vision and pattern recognition." *Proceedings of the IEEE* 98.6 (2010): 1031-1044.
- Sivaram, Garimella SVS, et al. "Sparse coding for speech recognition." *Acoustics Speech and Signal Processing (ICASSP)*, 2010 IEEE International Conference on. IEEE, 2010.
- Olshausen, Bruno A., and David J. Field. "Sparse coding with an overcomplete basis set: A strategy employed by V1?." *Vision research* 37.23 (1997): 3311-3325.
- Lee, Honglak, et al. "Efficient sparse coding algorithms." *Advances in neural information processing systems* 19 (2007): 801.
- Lowe, David G. "Object recognition from local scale-invariant features." *Computer vision, 1999. The proceedings of the seventh IEEE international conference on*. Vol. 2. Ieee, 1999.
- Oliva, Aude, and Antonio Torralba. "Modeling the shape of the scene: A holistic representation of the spatial envelope." *International journal of computer vision* 42.3 (2001): 145-175.
- Dalal, Navneet, and Bill Triggs. "Histograms of oriented gradients for human detection." *Computer Vision and Pattern Recognition, 2005. CVPR 2005. IEEE Computer Society Conference on*. Vol. 1. IEEE, 2005.
- CACM survey of LSH (2008): "Near-Optimal Hashing Algorithms for Approximate Nearest Neighbor in High Dimensions" (by Alexandr Andoni and Piotr Indyk). *Communications of the ACM*, vol. 51, no. 1, 2008, pp. 117-122. directly from CACM

key sentence

Critical question or point we had better contain or answer:

- **software systems: emulate actual neurophysiological mechanisms and algorithms that support human cognition**
- **what are the emerging machine learning technologies that address the big data challenges implied by cognitive computing applications?**
- **How can cognitive computing techniques improve human computation, and what demands do the latter put on the former?**
- **Sparsity-based techniques and process unstructured data**
Our point:
- **sparse coding**
- **images patches rather than human-turned feature extraction**
- **unsupervised dictionary learning**
- **hashing rather than sparse code computing**
- **large-scale data search (future work and our vision)**
- **effective similarity preservation by auto-learned feature selection algorithm**

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. 1983b. 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. 1979b. 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. 1986a. The Engineering of Qualitative Models. Forthcoming.

Formatting Requirements in Brief

We need source and PDF files that can be used in a variety of ways and can be output on a variety of devices. AAAI imposes some requirements on your source and PDF files that must be followed. Most of these requirements are based on our efforts to standardize conference manuscript properties and layout. These requirements are as follows, and all papers submitted to AAAI for publication must comply:

- Your .tex file must compile in PDF \LaTeX — **no .ps or .eps figure files.**
- All fonts must be embedded in the PDF file — **this includes your figures.**
- Modifications to the style sheet (or your document) in an effort to avoid extra page charges are NOT allowed.
- No type 3 fonts may be used (even in illustrations).
- Your title must follow US capitalization rules.
- \LaTeX documents must use the Times or Nimbus font package (do not use Computer Modern for the text of your paper).
- No \LaTeX 209 documents may be used or submitted.
- Fonts that require non-English language support (CID and Identity-H) must be converted to outlines or removed from the document (even if they are in a graphics file embedded in the document).
- Two-column format in AAAI style is required for all papers.
- The paper size for final submission must be US letter. No exceptions.
- The source file must exactly match the PDF.
- The document margins must be as specified in the formatting instructions.
- The number of pages and the file size must be as specified for your event.
- No document may be password protected.
- Neither the PDFs nor the source may contain any embedded links or bookmarks.
- Your source and PDF must not have any page numbers, footers, or headers.
- Your PDF must be compatible with Acrobat 5 or higher.
- Your \LaTeX source file (excluding references) must consist of a **single** file (use of the “input” command is not allowed).
- Your graphics must be sized appropriately outside of \LaTeX (do not use the “clip” command) .

If you do not follow the above requirements, it is likely that we will be unable to publish your paper.

What Files to Submit

You must submit the following items to ensure that your paper is published:

- A fully-compliant PDF file.

- Your L^AT_EX source file submitted as a **single** .tex file (do not use the “input” command to include sections of your paper — every section must be in the single source file). The only exception is the bibliography, which you may include separately. Your source must compile on our system, which includes the standard L^AT_EX support files.
- All your graphics files.
- The L^AT_EX-generated files (e.g. .aux and .bib file, etc.) for your compiled source.
- All the nonstandard style files (ones not commonly found in standard L^AT_EX installations) used in your document (including, for example, old algorithm style files). If in doubt, include it.

Your L^AT_EX source will be reviewed and recompiled on our system (if it does not compile, you may incur late fees). **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 aaai.bst), and any custom macros. Accompanying this source file, you must also supply any nonstandard (or older) referenced style files and all your referenced graphics files.

Your files should work without any supporting files (other than the program itself) on any computer with a standard L^AT_EX distribution. Place your PDF and source files in a single tar, zipped, gzipped, stuffed, or compressed archive. Name your source file with your last (family) name.

Do not send 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, and so forth. A shell script (created by an AAAI member — it might not work without modification on your system) that might help you create the L^AT_EX source package is included in the Author Kit.

Using L^AT_EX to Format Your Paper

The latest version of the AAAI style file is available on AAAI’s website. Download this file and place it in a file named “aaai.sty” in the T_EX search path. Placing it in the same directory as the paper should also work. You must download the latest version of the complete author kit so that you will have the latest instruction set.

Document Preamble

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, and the courier package will cause Courier to be used for the typewriter font. 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 subsections, so do not use a number higher than 2.

```
\documentclass[letterpaper]article
% Required Packages
\usepackage{aaai}
\usepackage{times}
\usepackage{helvet}
\usepackage{courier}
\setlength{\pdfpagewidth}{8.5in}
\setlength{\pdfpageheight}{11in}
%%
% PDFINFO for PDFLATEX
% Uncomment and complete the following for metadata
% (your paper must compile with PDFLATEX)
\pdfinfo{
/Title (Input Your Paper Title Here)
/Author (John Doe, Jane Doe)
/Keywords (Input your paper’s keywords in this optional
area)
}
%%
% Section Numbers
% Uncomment if you want to use section numbers
% and change the 0 to a 1 or 2
% \setcounter{secnumdepth}{0}
%%
% Title, Author, and Address Information
\title{Title}
\author{Author 1 \and Author 2\
Address line\
Address line\
\And
Author 3\
Address line\
Address line}
%%
% Body of Paper Begins
\begin{document}
\maketitle
...
%%
% References and End of Paper
\bibliography{Bibliography-File}
\bibliographystyle{aaai}
\end{document}
```

Inserting Document Metadata with L^AT_EX

PDF files contain document summary information that enables us to create an Acrobat index (pdx) file, and also allows search engines to locate and present your paper more accurately. **Document Metadata for Author and Title are REQUIRED.**

If your paper includes illustrations that are not compatible with PDFL^AT_EX (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.

Important: Do not include *any* L^AT_EX code or nonascii characters (including accented characters) in the metadata. The data in the metadata must be completely plain ascii. It may not include slashes, accents, linebreaks, unicode, or any L^AT_EX commands. Type the title exactly as it appears on the paper (minus all formatting). Input the author names in the order in which they appear on the paper (minus all accents), separating each author by a comma. You may also include keywords in the Keywords field.

Preparing Your Paper

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

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

Incompatible Packages

The following packages are incompatible with aaai.sty and/or aaai.bst and must not be used (this list is not exhaustive — there are others as well):

- hyperref
- natbib
- geometry
- titlesec
- layout
- caption
- titlesec
- T1 fontenc package (install the CM super fonts package instead)

Illegal Commands

The following commands may not be used in your paper:

- \input
- \vspace (when used before or after a section or subsection)
- \addtolength
- \columnsep
- \top margin (or text height or addsidemargin or even side margin)

Paper Size, Margins, and Column Width

Papers must be formatted to print in two-column format on 8.5 x 11 inch US letter-sized paper. The margins must be exactly as follows:

- Top margin: .75 inches
- Left margin: .75 inches

- Right margin: .75 inches
- Bottom margin: 1.25 inches

The default paper size in most installations of L^AT_EX is A4. However, because we require that your electronic paper be formatted in US letter size, you will need to alter the default for this paper to US letter size. Assuming you are using the 2e version of L^AT_EX, you can do this by including the [letterpaper] option at the beginning of your file: \documentclass[letterpaper]article.

This command is usually sufficient to change the format. Sometimes, however, it may not work. Use PDFL^AT_EX and include \setlength{\pdfpagewidth}{8.5in} \setlength{\pdfpageheight}{11in} in your preamble.

Do not use the Geometry package to alter the page size. Use of this style file alters aaai.sty and will result in your paper being rejected.

Column Width and Margins. To ensure maximum readability, your paper must include two columns. Each column should be 3.3 inches wide (slightly more than 3.25 inches), with a .375 inch (.952 cm) gutter of white space between the two columns. The aaai.sty file will automatically create these columns for you.

Overlength Papers

If your paper is too long, turn on \frenchspacing, which will reduce the space after periods. Next, shrink the size of your graphics. Use \centering instead of \begin{center} in your figure environment. If these two methods don't work, you may minimally use the following. For floats (tables and figures), you may minimally reduce \floatsep, \textfloatsep, \abovecaptionskip, and \belowcaptionskip. For mathematical environments, you may minimally reduce \abovedisplayskip, \belowdisplayskip, and \arraycolsep. You may also alter the size of your bibliography by inserting \fontsize{9.5pt}{10.5pt} \selectfont right before the bibliography.

Commands that alter page layout are forbidden. These include \columnsep, \topmargin, \topskip, \textheight, \textwidth, \oddsidemargin, and \evensidemargin (this list is not exhaustive). If you alter page layout, you will be required to pay the page fee *plus* a reformatting fee. Other commands that are questionable and may cause your paper to be rejected include \parindent, and \parskip. Commands that alter the space between sections are also questionable. The title sec package is not allowed. Regardless of the above, if your paper is obviously “squeezed” it is not going to be accepted. Before using every trick you know to make your paper a certain length, try reducing the size of your graphics or cutting text instead or (if allowed) paying the extra page charge. It will be cheaper in the long run.

Figures

Your paper must compile in PDFL^AT_EX. Consequently, all your figures must be .jpg, .png, or .pdf. You may not use the .gif (the resolution is too low), .ps, or .eps file format for your figures.

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 when page numbers are applied or color space is standardized.

Type Font and Size

Your paper must be formatted in Times Roman or Nimbus. We will not accept papers formatted using Computer Modern or Palatino or some other font as the text or heading typeface. Sans serif, when used, should be Courier. Use Symbol or Lucida or Computer Modern for *mathematics only*.

Do not use type 3 fonts for any portion of your paper, including graphics. Type 3 bitmapped fonts are designed for fixed resolution printers. Most print at 300 dpi even if the printer resolution is 1200 dpi or higher. They also often cause high resolution imagesetter devices and our PDF indexing software to crash. Consequently, AAI will not accept electronic files containing obsolete type 3 fonts. Files containing those fonts (even in graphics) will be rejected.

Fortunately, there are effective workarounds that will prevent your file from embedding type 3 bitmapped fonts. The easiest workaround is to use the required times, helvet, and courier packages with L^AT_EX 2_ε. (Note that papers formatted in this way will still use Computer Modern for the mathematics. To make the math look good, you'll either have to use Symbol or Lucida, or you will need to install type 1 Computer Modern fonts — for more on these fonts, see the section “Obtaining Type 1 Computer Modern.”)

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 should 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.

Obtaining Type 1 Computer Modern for L^AT_EX. If you use Computer Modern for the mathematics in your paper (you cannot use it for the text) you may need to download type 1 Computer fonts. They are available without charge from the American Mathematical Society: <http://www.ams.org/tex/type1-fonts.html>.

Title and Authors

Your title must appear in mixed case (nouns, pronouns, and verbs are capitalized) near the top of the first page, centered over both columns in sixteen-point bold type (twenty-four point leading). This style is called “mixed case.” Author’s names should appear below the title of the paper, centered in twelve-point type (with fifteen point leading), along with affiliation(s) and complete address(es) (including electronic mail address if available) in nine-point roman type (the twelve point leading). (If the title is long, or you have

many authors, you may reduce the specified point sizes by up to two points.) You should begin the two-column format when you come to the abstract.

Formatting Author Information Author information can be set in a number of different styles, depending on the number of authors and the number of affiliations you need to display. For several authors from the same institution, use `\and`:

```
\author{Author 1 \and ... \and Author n}
Address line \ \ ... \ \ Address line}
```

If the names do not fit well on one line use:

```
\author{Author 1} \ \
{\bf Author 2} \ \ ... \ \ {\bf Author n} \ \
Address line \ \ ... \ \ Address line}
```

For authors from different institutions, use `\And`:

```
\author{Author 1 \ \ Address line \ \ ... \ \ Address line
\And ... \And Author n}
Address line \ \ ... \ \ Address line}
```

To start a separate “row” of authors, use `\AND`:

```
\author{Author 1 \ \ Address line \ \ ... \ \ Address line} \ \
\AND
Author 2 \ \ Address line \ \ ... \ \ Address line \ \
\And
Author 3 \ \ Address line \ \ ... \ \ Address line \ \
}
```

If the title and author information does not fit in the area allocated, place `\setlength\titlebox{height}` after the `\documentclass` line where `{height}` is something like 2.5in.

L^AT_EX Copyright Notice

The copyright notice automatically appears if you use `aaai.sty`. If you are creating a technical report, it is not necessary to include this notice. You may disable the copyright line using the `\nocopyrightcommand`. To change the entire text of the copyright slug, use: `\copyrighttext{text}`. Either of these must appear before `\maketitle`. Please be advised, however, that *if you disable or change the copyright line and transfer of copyright is required, your paper will not be published*.

Credits

Any credits to a sponsoring agency should appear in the acknowledgments section, unless the agency requires different placement. If it is necessary to include this information on the front page, use `\thanks` in either the `\author` or `\title` commands. For example:

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

Multiple `\thanks` commands can be given. Each will result in a separate footnote indication in the author or title with the corresponding text at the bottom of the first column of the document. Note that the `\thanks` command is fragile. You will need to use `\protect`.

Please do not include `\pubnote` commands in your document.

Abstract

The abstract must be placed at the beginning of the first column, indented ten points from the left and right margins. The title Abstract should appear in ten-point bold type, centered above the body of the abstract. The abstract should be set in nine-point type with ten-point leading. This concise, one-paragraph summary should describe the general thesis and conclusion of your paper. A reader should be able to learn the purpose of the paper and the reason for its importance from the abstract. The abstract should be no more than two hundred words in length. (Authors who are submitting short one- or two-page extended extracts should provide a short abstract of only a sentence or so.) **Do not include references in your abstract!**

Page Numbers

Do not **ever** print any page numbers on your paper.

Text

The main body of the paper must be formatted in ten-point with twelve-point leading (line spacing).

Citations

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).

Extracts

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.

Footnotes

Avoid footnotes as much as possible; they interrupt the reading of the text. When essential, they should be consecutively numbered throughout with superscript Arabic numbers. Footnotes should appear at the bottom of the page, separated from the text by a blank line space and a thin, half-point rule.

Headings and Sections

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.

First-level heads should be twelve-point Times Roman bold type, mixed case (initial capitals followed by lower case on all words except articles, conjunctions, and prepositions, which should appear entirely in lower case), with

fifteen-point leading, centered, with one blank line preceding them and three additional points of leading following them. Second-level headings should be eleven-point Times Roman bold type, mixed case, with thirteen-point leading, flush left, with one blank line preceding them and three additional points of leading following them. Do not skip a line between paragraphs. Third-level headings should be run in with the text, ten-point Times Roman bold type, mixed case, with twelve-point leading, flush left, with six points of additional space preceding them and no additional points of leading following them.

Section Numbers The use of section numbers in AAAI Press papers is optional. To use section numbers in L^AT_EX, uncomment the setcounter line in your document preamble and change the 0 to a 1 or 2. Section numbers should not be used in short poster papers.

Section Headings. Sections should be arranged and headed as follows:

Acknowledgments. The acknowledgments section, if included, appears after the main body of text and is headed "Acknowledgments." This section includes acknowledgments of help from associates and colleagues, credits to sponsoring agencies, financial support, and permission to publish. Please acknowledge other contributors, grant support, and so forth, in this section. Do not put acknowledgments in a footnote on the first page. If your grant agency requires acknowledgment of the grant on page 1, limit the footnote to the required statement, and put the remaining acknowledgments at the back. Please try to limit acknowledgments to no more than three sentences.

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.

Illustrations and Figures

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

The illustration number and caption should appear under the illustration. Labels, and other text in illustrations must be at least nine-point type.

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 a minimum of 266 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 scale the figure or table down, or reformat the equation. Check your log file! You must fix any overflow into the margin (that means no overfull boxes in L^AT_EX). If you don't, the overflow text will simply be eliminated. **Nothing is permitted to intrude into the margins.**

Using Color. Your paper will be printed in black and white and grayscale. 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. Of course, any reference to color will be indecipherable to your reader.

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 266 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 `\includgraphics` command. Resize the 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 L^AT_EX document.

References

The `aaai.sty` file 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 “`aaai.bst`,” available in the author kit on the AAAI web site. Then, at the end of your paper but before `\enddocument`, you need to put the following lines:

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

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.

Warning: The `aaai.sty` file is incompatible with the `hyperref` and `natbib` packages. If you use either, your references will be garbled.

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. 1983b. 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. Poligon: A System for Parallel Problem Solving, Technical Report, KSL-86-19, Dept. of Computer Science, Stanford Univ.

Dissertation or Thesis

Clancey, W. J. 1979b. Transfer of Rule-Based Expertise through a Tutorial Dialogue. Ph.D. diss., Dept. of Computer Science, Stanford Univ., Stanford, Calif.

Producing Reliable PDF Documents with L^AT_EX

Generally speaking, PDF files are platform independent and accessible to everyone. When creating a paper for a proceedings or publication in which many PDF documents must be merged and then printed on high-resolution PostScript RIPs, several requirements must be met that are not normally of concern. Thus to ensure that your paper will look like it does when printed on your own machine, you must take several precautions:

- Use type 1 fonts (not type 3 fonts)
- Use only standard Times, Nimbus, and CMR font packages (not fonts like F3 or fonts with tildes in the names or fonts—other than Computer Modern—that are created for specific point sizes, like Times~19) or fonts with strange combinations of numbers and letters
- Embed all fonts when producing the PDF
- Do not use the [T1]fontenc package (install the CM super fonts package instead)

Creating Output Using PDFL^AT_EX Is Required

By using the PDFL^AT_EX program instead of straight L^AT_EX or T_EX, you will probably avoid the type 3 font problem altogether (unless you use a package that calls for metafont). PDFL^AT_EX enables you to create a PDF document directly from L^AT_EX source. The one requirement of this software is that all your graphics and images must be available in a format that PDFL^AT_EX understands (normally PDF).

PDFL^AT_EX's default is to create documents with type 1 fonts. If you find that it is not doing so in your case, it is likely that one or more fonts are missing from your system or are not in a path that is known to PDFL^AT_EX.

dvipdf Script Scripts such as dvipdf which ostensibly bypass the Postscript intermediary should not be used since they generally do not instruct dvips to use the config.pdf file.

dvipdfm Do not use this dvi-PDF conversion package if your document contains graphics (and we recommend you avoid it even if your document does not contain graphics).

Ghostscript

L^AT_EX users should not use GhostScript to create their PDFs.

Graphics

If you are still finding type 3 fonts in your PDF file, look at your graphics! L^AT_EX users should check all their imported graphics files as well for font problems.

Proofreading Your PDF

Please check all the pages of your PDF file. Is the page size A4? Are there any type 3, Identity-H, or CID fonts? Are all the fonts embedded? Are there any areas where equations

or figures run into the margins? Did you include all your figures? Did you follow mixed case capitalization rules for your title? Did you include a copyright notice? Do any of the pages scroll slowly (because the graphics draw slowly on the page)? Are URLs underlined and in color? 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 may not be possible to include your paper in the publication. If time allows, however, you will be notified via e-mail (with a copy to the program chair) of the problems with your file and given the option of correcting the file yourself (and paying a late fee) or asking that AAAI have the file corrected for you, for an additional fee. If you opt to correct the file yourself, please note that we cannot provide you with any additional advice beyond that given in your packet. Files that are not corrected after a second attempt will be withdrawn.

L^AT_EX 209 Warning

If you use L^AT_EX 209 we will not be able to publish your paper. Convert your paper to L^AT_EX 2_ε.

Naming Your Electronic File

We request that you name your L^AT_EX source file with your last name (family name) so that it can easily be differentiated from other submissions. If you name your files with the name of the event or “aaai” or “paper” or “camera-ready” or some other generic or indecipherable name, you bear all risks of loss — it is extremely likely that your file may be overwritten.

Submitting Your Electronic Files to AAAI

Submitting your files to AAAI is a two-step process. It is explained fully in the author registration and submission instructions. Please consult this document for details on how to submit your paper.

Inquiries

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.

AAAI Press
2275 East Bayshore Road, Suite 160
Palo Alto, California 94303
Telephone: (650) 328-3123
E-mail: See the submission instructions for your particular conference or event.

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

AAAI is especially grateful to Peter Patel Schneider for his work in implementing the `aaai.sty` file, liberally using the ideas of other style hackers, including Barbara Beeton. We also acknowledge with thanks the work of George Ferguson for his guide to using the style and BibT_EX files — which has been incorporated into this document — and Hans Guesgen, who provided several timely modifications, as well as the many others who have, from time to time, sent in suggestions on improvements to the AAAI style.

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 `aaai.sty` and `aaai.bst` have been made by the AAAI staff.

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