
Pulsar Classification using Deep Neural Networks

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Abstract

Pulsars are rapidly rotating, highly magnetized, neutron stars and white dwarfs that emit focused electromagnetic radiation in a beam. The beam is only visible to us when it is directly facing Earth and is the reason for their pulsed nature. This paper approaches classification of pulsars and non-pulsars with the intent of learning more about TensorFlow. The classification method used is Deep Neural Networks and an acceptable level of accuracy was obtained.

1 Introduction

We were tasked with picking a dataset and training a deep learning network. First thing to do was to pick a dataset. Being an open-ended assignment there was uncertainty as to what particular dataset to explore. Initial looks involved different image classification datasets such as CIFAR-10, Caltech 101, and NORB. Down the road there is no desire to work with image data classification, work with files and datasets of continuous and discrete data are preferred. After thorough search of the available datasets it was decided pulsar classification best suited this paper.

The last decision before pressing on to data format was to pick the correct deep learning framework for the job. There were several options but TensorFlow seemed like a good choice. Keras and PyTorch are other tools that utilize TensorFlow but were not used because those are often considered a "front end" for TensorFlow, which was not part of the goals of the assignment.

2 Method

2.1 Data Format

After determining the dataset and the framework to be utilized it is necessary to figure out how to read data from the dataset. A modular approach was taken with this project. Users will be able to select a comma-separated values (CSV) file to load in. By specifying a class to contain the CSV data it is possible to run multiple datasets while making only minor modifications to the code. The format is also much easier to read as a result of the class format.

Rather than code up a custom method of moving CSV data into a format usable by the deep learning framework it was determined to "stand on the shoulders of giants". Pandas was used to bring CSV data into usable form. After pulling the data into a single structure it was necessary to split the data into training and testing data. Again, rather than code that from scratch it was determined best practice to utilize existing tools.

For that endeavour scikit-learn was used, specifically the *train_test_split()* method. As is standard for classification problems the data was segmented into 80% training and 20% testing data. It was then necessary to place the *class* label into a data structure for later. For both the train and test data, associated labels are passed, along with the data, as tuples. The pseudocode for this section can be found under Algorithm 1.

Algorithm 1 *input_fn()*

```
data ← CSV
test, train ← train_test_split(data)
test_label ← test.pop(class)
train_label ← train.pop(class)
return (train, train_label), (test, test_label)
```

3 Retrieval of style files

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

<http://www.nips.cc/>

The file `nips_2017.pdf` contains these instructions and illustrates the various formatting requirements your NIPS paper must satisfy.

The only supported style file for NIPS 2017 is `nips_2017.sty`, rewritten for $\text{\LaTeX 2}_{\epsilon}$. **Previous style files for \LaTeX 2.09 , Microsoft Word, and RTF are no longer supported!**

The new \LaTeX style file contains two optional arguments: `final`, which creates a camera-ready copy, and `nonatbib`, which will not load the `natbib` package for you in case of package clash.

At submission time, please omit the `final` option. This will anonymize your submission and add line numbers to aid review. Please do *not* refer to these line numbers in your paper as they will be removed during generation of camera-ready copies.

The file `nips_2017.tex` may be used as a “shell” for writing your paper. All you have to do is replace the author, title, abstract, and text of the paper with your own.

The formatting instructions contained in these style files are summarized in Sections 4, 5, and 6 below.

4 General formatting instructions

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

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

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

Please pay special attention to the instructions in Section 6 regarding figures, tables, acknowledgments, and references.

5 Headings: first level

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

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

5.1 Headings: second level

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

71 **5.1.1 Headings: third level**

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

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

75 **6 Citations, figures, tables, references**

76 These instructions apply to everyone.

77 **6.1 Citations within the text**

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

81 The documentation for `natbib` may be found at

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

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

85 `\citet{hasselmo}` investigated\dots

86 produces

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

88 If you wish to load the `natbib` package with options, you may add the following before loading the
89 `nips_2017` package:

90 `\PassOptionsToPackage{options}{natbib}`

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

93 `\usepackage[nonatbib]{nips_2017}`

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

98 **6.2 Footnotes**

99 Footnotes should be used sparingly. If you do require a footnote, indicate footnotes with a number¹
100 in the text. Place the footnotes at the bottom of the page on which they appear. Precede the footnote
101 with a horizontal rule of 2 inches (12 picas).

102 Note that footnotes are properly typeset *after* punctuation marks.²

103 **6.3 Figures**

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

¹Sample of the first footnote.

²As in this example.

Table 1: Sample table title

Part		
Name	Description	Size (μm)
Dendrite	Input terminal	~ 100
Axon	Output terminal	~ 10
Soma	Cell body	up to 10^6

108 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.



Figure 1: Sample figure caption.

109

110 6.4 Tables

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

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

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

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

119 This package was used to typeset Table 1.

120 7 Final instructions

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

124 8 Preparing PDF files

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

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

- 128 • You should directly generate PDF files using `pdflatex`.
- 129 • You can check which fonts a PDF files uses. In Acrobat Reader, select the menu
130 Files>Document Properties>Fonts and select Show All Fonts. You can also use the program
131 `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 NIPS. 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.

8.1 Margins in L^AT_EX

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^AT_EX cannot properly hyphenate a line. Please give LaTeX hyphenation hints using the `\-` command when necessary.

Acknowledgments

Use unnumbered third level headings for the acknowledgments. All acknowledgments go at the end of the paper. Do not include acknowledgments in the anonymized submission, only in the final paper.

References

References follow the acknowledgments. Use unnumbered first-level heading for the references. Any choice of citation style is acceptable as long as you are consistent. It is permissible to reduce the font size to `small` (9 point) when listing the references. **Remember that you can go over 8 pages as long as the subsequent ones contain only cited references.**

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

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

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