

Writing Scientific Papers and Software

Sven Hammann, Stefan Dietiker, Jannick Griner
Department of Computer Science, ETH Zurich, Switzerland

Abstract—A critical part of scientific discovery is the communication of research findings to peers or the general public. Mastery of the process of scientific communication improves the visibility and impact of research. While this guide is a necessary tool for learning how to write in a manner suitable for publication at a scientific venue, it is by no means sufficient, on its own, to make its reader an accomplished writer. We also describe the rules for submission in the computational intelligence laboratory. This guide should be a starting point for further development of writing skills.

I. INTRODUCTION

The aim of writing a paper is to infect the mind of your reader with the brilliance of your idea [1]. The hope is that after reading your paper, the audience will be convinced to try out your idea. In other words, it is the medium to transport the idea from your head to your reader's head. In the following section, we show a common structure of scientific papers and briefly outline some tips for writing good papers in Section III.

At that point, it is important that the reader is able to reproduce your work [2], [3], [4]. This is why it is also important that if the work has a computational component, the software associated with producing the results are also made available in a useful form. Several guidelines for making your user's experience with your software as painless as possible is given in Section IV.

Finally, we describe the rules for submission in the computational intelligence laboratory in Section V. This brief guide is by no means sufficient, on its own, to make its reader an accomplished writer. The reader is urged to use the references to further improve his or her writing skills.

II. THE STRUCTURE OF A PAPER

Scientific papers usually begin with the description of the problem, justifying why the problem is interesting. Most importantly, it argues that the problem is still unsolved, or that the current solutions are unsatisfactory. This leads to the main gist of the paper, which is "the idea". The authors then show evidence, using derivations or experiments, that the idea works. Since science does not occur in a vacuum, a proper comparison to the current state of the art is often part of the results. Following these ideas, papers usually have the following structure:

Abstract

Short description of the whole paper, to help the reader decide whether to read it.

Introduction

Describe your problem and state your contributions.

Models and Methods

Describe your idea and how it was implemented to solve the problem. Survey the related work, giving credit where credit is due.

Results

Show evidence to support your claims made in the introduction.

Discussion

Discuss the strengths and weaknesses of your approach, based on the results. Point out the implications of your novel idea on the application concerned.

Summary

Summarize your contributions in light of the new results.

III. TIPS FOR GOOD WRITING

The ideas for good writing have come from [5], [1], [6].

A. Getting Help

One should try to get a draft read by as many friendly people as possible. And remember to treat your test readers with respect. If they are unable to understand something in your paper, then it is highly likely that your reviewers will not understand it either. Therefore, do not be defensive about the criticisms you get, but use it as an opportunity to improve the paper. Before you submit your friends to the pain of reading your draft, please *use a spell checker*.

B. Abstract

The abstract should really be written last, along with the title of the paper. The four points that should be covered [1]:

- 1) State the problem.
- 2) Say why it is an interesting problem.
- 3) Say what your solution achieves.
- 4) Say what follows from your solution.

C. Figures and Tables

Use examples and illustrations to clarify ideas and results. For example, by comparing Figure 1 and Figure 2, we can see the two different situations where Fourier and wavelet basis perform well.



Figure 1. Signal compression and denoising using the Fourier basis.

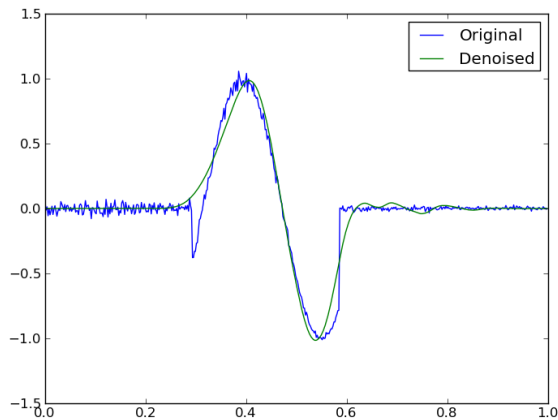


Figure 2. Signal compression and denoising using the Daubechies wavelet basis.

D. Models and Methods

The models and methods section should describe what was done to answer the research question, describe how it was done, justify the experimental design, and explain how the results were analyzed.

The model refers to the underlying mathematical model or structure which you use to describe your problem, or that your solution is based on. The methods on the other hand, are the algorithms used to solve the problem. In some cases, the suggested method directly solves the problem, without having it stated in terms of an underlying model. Generally though it is a better practice to have the model figured out and stated clearly, rather than presenting a method without specifying the model. In this case, the method can be more easily evaluated in the task of fitting the given data to the underlying model.

The methods part of this section, is not a step-by-step, directive, protocol as you might see in your lab manual, but detailed enough such that an interested reader can reproduce your work [6], [3].

The methods section of a research paper provides the information by which a study's validity is judged. Therefore, it requires a clear and precise description of how an experiment was done, and the rationale for why specific experimental procedures were chosen. It is usually helpful to structure the methods section by [7]:

- 1) Layout the model you used to describe the problem or the solution.
- 2) Describing the algorithms used in the study, briefly including details such as hyperparameter values (e.g. thresholds), and preprocessing steps (e.g. normalizing the data to have mean value of zero).
- 3) Explaining how the materials were prepared, for example the images used and their resolution.
- 4) Describing the research protocol, for example which examples were used for estimating the parameters (training) and which were used for computing performance.
- 5) Explaining how measurements were made and what calculations were performed. Do not reproduce the full source code in the paper, but explain the key steps.

E. Results

Organize the results section based on the sequence of table and figures you include. Prepare the tables and figures as soon as all the data are analyzed and arrange them in the sequence that best presents your findings in a logical way. A good strategy is to note, on a draft of each table or figure, the one or two key results you want to address in the text portion of the results. The information from the figures is summarized in Table I.

When reporting computational or measurement results, always report the mean (average value) along with a measure of variability (standard deviation(s) or standard error of the mean).

IV. TIPS FOR GOOD SOFTWARE

There is a lot of literature (for example [8] and [9]) on how to write software. It is not the intention of this section to replace software engineering courses. However, in the interests of reproducible research [2], there are a few guidelines to make your reader happy:

- Have a README file that (at least) describes what your software does, and which commands to run to obtain results. Also mention anything special that needs to be set up, such as toolboxes¹.

¹For those who are particularly interested, other common structures can be found at <http://en.wikipedia.org/wiki/README> and <http://www.gnu.org/software/womb/gnits/>.

Basis	Support	Suitable signals	Unsuitable signals
Fourier wavelet	global local	sine like localized	localized sine like

Table I
CHARACTERISTICS OF FOURIER AND WAVELET BASIS.

- A list of authors and contributors can be included in a file called `AUTHORS`, acknowledging any help that you may have obtained. For small projects, this information is often also included in the `README`.
- Use meaningful filenames, and not `temp1.m`, `temp2.m`. The code should also unzip into a subdirectory.
- Document your code. Each file should at least have a short description about its reason for existence. Non obvious steps in the code should be commented.
- Describe how the results presented in your paper can potentially be reproduced.

V. COMPUTATIONAL INTELLIGENCE LABORATORY REQUIREMENTS

Your semester project is a group effort. It consists of four parts:

- 1) The programming assignments you solve during the semester.
- 2) Developing a novel solution for one of the assignments, e.g. by combining methods from previous programming assignments into a novel solution.
- 3) Comparing your novel solution to previous assignments.
- 4) Writing up your findings in a short scientific paper.

A. Developing a Novel Solution

As your final programming assignment, you develop a novel solution to one of the four application problems. You are free to exploit any idea you have, provided it is not identical to any other group submission or existing Matlab implementation of an algorithm on the internet².

Two examples for developing a novel solution:

- You implemented a collaborative filtering algorithm based on dimension reduction as part of an assignment. Now you apply dimension reduction to inpainting.
- You implemented both a clustering and a sparse coding algorithm for image compression. Now you combine both techniques into a novel compression method.

B. Comparison to Baselines

You compare your novel algorithm to *at least two baseline algorithms*. For the baselines, you can use the implementations you developed as part of the programming assignments.

²http://www.ethz.ch/students/semester/plagiarism_s_en.pdf

C. Write Up

The submission must be in PDF form, using the \LaTeX template corresponding to the IEEE style of publication. Refer to Section V-D for more information about preparing your document. The document should be a maximum of **4 pages**.

D. \LaTeX Primer

\LaTeX is one of the most commonly used document preparation systems for scientific journals and conferences. It is based on the idea that authors should be able to focus on the content of what they are writing without being distracted by its visual presentation. The source of this file can be used as a starting point for how to use the different commands in \LaTeX . We are using an IEEE style for this course.

1) *Installation*: There are various different packages available for processing \LaTeX documents. On Windows, use the MikTeX package (<http://miktex.org/>), and on OSX use MacTeX (<http://www.tug.org/mactex/2009/>). Alternatively, on OSX, you can install the `tetex` package via Fink³ or Macports⁴.

2) *Compiling \LaTeX* : Your directory should contain at least 4 files, in addition to image files. Images should be in `.png`, `.jpg` or `.pdf` format.

- `IEEEtran.cls`
- `IEEEtran.bst`
- `groupXX-submission.tex`
- `groupXX-literature.bib`

Note that you should replace `groupXX` with your chosen group name. Then, from the command line, type:

```
$ pdflatex groupXX-submission
$ bibtex groupXX-literature
$ pdflatex groupXX-submission
$ pdflatex groupXX-submission
```

This should give you a PDF document `groupXX-submission.pdf`.

3) *Equations*: There are three types of equations available: inline equations, for example $y = mx + c$, which appear in the text, unnumbered equations

$$y = mx + c,$$

which are presented on a line on its own, and numbered equations

$$y = mx + c \tag{1}$$

³<http://www.finkproject.org/>

⁴<http://www.macports.org/>

which you can refer to at a later point (Equation (1)).

4) *Tables and Figures*: Tables and figures are “floating” objects, which means that the text can flow around it. Note that `figure*` and `table*` cause the corresponding figure or table to span both columns.

E. Grading

There are two different types of grading criteria applied to your project, with the corresponding weights shown in brackets.

Competitive

The following criteria is scored based on your rank in comparison with the rest of the class.

- time taken for computation (10%)
- average rank for all other criteria relevant to the task, for example reconstruction error and sparsity (20%)

The ranks will then be converted on a linear scale into a grade between 4 and 6.

Non-competitive

The following criteria is scored based on an evaluation by the teaching assistants.

- quality of paper (30%)
- quality of implementation (20%)
- creativity of solution (20%)

F. Submission System

The deadline for submitting your project report is Friday, 22 June 2012. You need to submit:

- PDF of paper.
- Archive (`.tar.gz` or `.zip`) of software. Please do not forget to include author information in the source archive.

Important: Please check the submission instructions on the webpage as it is the most updated instructions.

VI. SUMMARY

The aim of a scientific paper is to convey the idea or discovery of the researcher to the minds of the readers. The associated software package provides the relevant details, which are often only briefly explained in the paper, such that the research can be reproduced. To write good papers, identify your key idea, make your contributions explicit, and use examples and illustrations to describe the problems and solutions.

ACKNOWLEDGEMENTS

The author thanks Christian Sigg for his careful reading and helpful suggestions.

REFERENCES

- [1] S. P. Jones, “How to write a great research paper,” 2008, microsoft Research Cambridge.
- [2] M. Schwab, M. Karrenbach, and J. Claerbout, “Making scientific computations reproducible,” *Computing in Science and Engg.*, vol. 2, no. 6, pp. 61–67, 2000.
- [3] J. B. Buckheit and D. L. Donoho, “Wavelab and reproducible research,” Stanford University, Tech. Rep., 2009.
- [4] R. Gentleman, “Reproducible research: A bioinformatics case study,” *Statistical Applications in Genetics and Molecular Biology*, vol. 4, no. 1, 2005. [Online]. Available: <http://www.bepress.com/sagmb/vol4/iss1/art2>
- [5] Editorial, “Scientific writing 101,” *Nature Structural & Molecular Biology*, vol. 17, p. 139, 2010.
- [6] G. Anderson, “How to write a paper in scientific journal style and format,” 2004, <http://abacus.bates.edu/ganderso/biology/resources/writing/HTWtoc.html>.
- [7] R. H. Kallet, “How to write the methods section of a research paper,” *Respiratory Care*, vol. 49, no. 10, pp. 1229–1232, 2004.
- [8] A. Hunt and D. Thomas, *The Pragmatic Programmer*. Addison Wesley, 1999.
- [9] J. Spolsky, *Joel on Software: And on Diverse & Occasionally Related Matters That Will Prove of Interest etc.: And on Diverse and Occasionally Related Matters ... or Ill-Luck, Work with Them in Some Capacity*. APRESS, 2004.