Meta-paper: General Style Guide for Scientific Writing

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Abstract

Usually, a meta-paper brings guidelines to help writing a scientific text for a given conference or over a specific research subject. This one is a more general style guide, and illustrates the process of elegantly writing a paper in order to efficiently present research results to the scientific community. Although this guide is targeted at students inexperienced in scientific writing, any researcher can use it as a reference when writing papers or other type of scientific work such as dissertations, thesis and tech reports.

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1 Introduction

The introduction of a paper (or any other scientific text) must give a very clear idea of everything that is contained in the rest of it. This section is the **first** thing most of the readers will read and the **only one** for some of them. So, one must do the best to convince these readers that the presented ideas/results are good enough to be worth carrying on reading. Ideally, every paper introduction should present the following information (one or two paragraphs each) in this exact order:

1. Context - present the specific research area or subject, starting with a very shallow/generic sentence and finishing the paragraph being more specific;
2. Problem - in a paper, we are almost always proposing new methods or results to solve a specific problem, so one has to clearly present what is the problem discussed in this work;
3. Current Solutions - even if there is a specific section to this (related work), one must always write at least one paragraph telling how this problem has been dealt with in previous research, finishing it by saying what is fundamentally wrong with these current solutions. These two paragraphs (problem and incomplete solutions) are the motivation that justify the paper;
4. General Idea - what is the scientific contribution of this work? One must take special care in writing a (maybe two) very clear paragraph to explain the general idea of the proposed new method/results. Sometimes it is good to put a list of contributions that show how unique this research is;
5. Paper Organization - finally, it is mandatory to explain what are the contents of the remaining sections. There is no summary in a paper, so this is the only place where the reader can find clues about what is the rest of the paper all about.

As an example, for this meta-paper the mandatory items of a proper introduction should be something like this:

- Context - scientific research presentation and writing, specifically papers;
- Problem - how to organize/write a good one;
- Current Solutions - books about scientific methodology, they are all too long;
- General Idea - a meta-paper that provides for writing guidelines is a good complementary material in this subject;
- Paper Organization - given bellow...

The rest of this meta-paper is organized as follows: section 2 discusses how one should write a good related work section, while section 3 explains general ideas about how to present a work in written format. Section 4 discusses what are the intrinsics of presenting scientific results in a paper, and section 5 talks about the correct way to perform experiments and analyze their results. Finally, section 6 gives an example conclusion.

2 Related work

Citations are of fundamental importance in scientific writing. As will be better explained in section 4, it is one of the methods for **backing up strong affirmatives** one put in a paper. Usual places where citations should be used include the introduction and also the first development section (after this one). However, it is the related work section where they play their major role. Every paper must have such section, which aims to present an analysis of what has been accomplished so far on the particular research subject in order to show that the new proposed contributions are still relevant. The hidden goal of this section is to show **conference referees** that, before developing the proposed new methods/techniques, a proper literature review was done by the writers.

It is not very difficult to organize such section and the only concern in this matter is about deciding if some form of sub-sections are necessary, based on the **categorization** of this related work. In any case, this section should always start with a paragraph that explains classification criteria and then go on to the sub-sections (or first previous work review). The **reviews** should be organized in paragraphs, and the order in which the previous works should be presented may be chronological, or based on a top-down approach. in this case, one starts by citing more general/abstract works and goes on to the more specific/closely-related ones.

Each paragraph must summarize a work (or a group of very similar ones) by using the following pattern:

- Present the analyzed paper by using a sentence that gives a brief view of its main proposition. Usually, the citation is included in this sentence;
- Give more details about the approach and results presented;
- Last and more important, compare the work presented in this paper with the new proposition/results. Try to show that the new one is relevant/better/complementary, but without criticizing too much since the cited author (if alive) is possibly a candidate reviewer for the paper.

In the next section, we give a general explanation on writing techniques that also apply to this section.

3 Fundamental concepts on instructional writing

Writing is a laborious task and a constant work in progress, but *it's not rocket surgery* [1] and, with some practice, one can learn to be quite good at it. The fundamental key is to focus on the presentation language, thinking of it as a tool for communication. Yes, it seems quite redundant to say so, but most writers put too much attention on the technical subject, while instead, the writing process itself should be more important. Remember that the ultimate goal is to present a new method/technique in an easy to grasp package. Those who actually researched the subject obviously have a clear image of what their work is all about, but what is the best way to present it to

[1] Popular idiom to say something is very complicated. Etymologically a blend of *rocket* science and brain *surgery*, recognized as very difficult subjects [Krug 2000]

an audience that, even being scientists themselves, does not know so much about the proposed concepts/problems/ideas?

3.1 Repetition-based layers

The key to effectively present a dense subject is repetition, which is intrinsic to the structure of technical writing. One can remember that a paper is organized into sections, which are (possibly) split into sub-sections, being themselves composed of paragraphs. Repetition will be the basis of all these elementary structures (including the paper itself), which should all be semantically split into three parts:

- First, tell what you are going to say;
- Second, say it in a more deeply/detailed fashion;
- Last, but not least, remember what you have just said.

3.1.1 Paper and sections

In the paper, this repetition pattern appears as the introduction-development-conclusion mantra everybody is aware of, but the point we are trying to express is that the contents of all these parts are fundamentally the same, only being presented in a different package. What this means is that the introduction should make clear everything one will learn from that particular paper; the development sections explain it in more detail; and the goal of the conclusion is to remember the important contributions, in essence what one just learned from that piece of writing.

For sections and subsections, this rule means that everyone of them must start with a very light paragraph that gives a general idea of what will be presented there. The next paragraphs and sub-sections better develop the ideas/concepts. Finally, it is recommended to avoid leaving important things to the last one, which is more appropriate to contain a fresh memory of what was learnt from the section.

Finally, most scientists are also familiar with the bottom-up and top-down approaches to problem solving, which are very important when the issues grow large. It is possible to associate these approaches with the way a paper should be organized: first top-down and then bottom-up the contents of the presentation. This means that one should first try to expose the general context/issues/concepts (top) and getting deeper as the text progresses (down). And from that on (bottom), it is possible to build new concepts and find consequences or results (up).

3.1.2 Paragraphs

The other major guideline is about paragraph writing (apart from literate), which should be composed of very small sentences. The smaller a sentence is, easier it will be to understand, specially if based on difficult concepts. There are several ways to structure a paragraph, but a common pattern if to use three sentences.

Example paragraph structure - consequences of a just explained concept/assumption:

- Sentence one - present the general concept;
- Sentence two - give more details about the assumption or idea;
- Sentence three - explain the immediate consequences that one should learn from what was just said.

An example paragraph to explain neurons as the components of artificial neuronal networks:

"Neuronal networks are composed of neurons, which are computational units that give an output based on a array of inputs values and associated weights. The neuron is a data classification unit, whose output is the result of applying a non-linear function, such as the step or sigmoid ones, over the weighted sum of the inputs. By modifying the weights of a neuron, one can "teach" it to give different outputs, and this is the basic mechanism used to make it recognize patterns."

Notice that the first sentence introduces the concept of a neuron by only saying that they take an input, have associated weights, compute an output and that they are the components of a artificial networks. The second sentence explains in more detail how this output is calculated, while the last one illustrates a consequence: that the weights are the mechanism to teach a neuron.

4 Scientific writing details

The guidelines presented in the previous section are very useful to create comprehensive texts, but what are the requirements to consider such text as scientific? In this section, we aim to answer this question by showing that the difference relies on the care that is dedicated to writing **strong affirmative sentences**. We also provide a brief explanation of the most common paper types and how to organize one. The reader is also encouraged to read relevant literature on this subject [Strunk et al. 2000; Hirsch 2003; Robert F. Dugan and Polanski 2006; Desjardins 1994] in order to avoid memorizing and repeating the writing patterns proposed in this meta-paper.

4.1 What can I say in a paper?

This can be difficult to grasp for some, but one must be very careful with all **affirmative sentences** in a paper. The core goal of the scientific method is the search of truth, and the mantra of its necessary skeptical view is to doubt everything unless some proof or evidence, based on repeatable experiments, is given [Sagan 1996]. The consequence of this method is that there are **only three** scientifically valid ways to back up such **strong affirmatives** [2]:

1. Citation - if taken from a accredited source (well referenced papers or books), one must point to it when affirming something;
2. Mathematical proof - given well referenced assumptions, one can build a mathematical proofs to base his affirmations on;
3. Statistical evidence - one example is not enough to prove anything, so one has to provide results of experiments that show strong evidence of his conclusions. These experiments need special care in order to isolate variables and actually test what is relevant to back up these conclusions. In Section 5 we give a more in-depth look on how to design and perform experiments under the light of science.

Notice that all three approaches are valid within the scientific method because, if wrong, they are somehow **repeatable/verifiable** by peers. Anyone who feels there is something odd about a paper is welcome to try to show it is actually wrong (using the scientific method as well, of course). However, things are a bit more simple to the "inquisitor", since a mere counter-example is enough (given the same assumptions of the paper) to proof something is wrong, specially when a mathematical approach was used.

4.2 Example paper organizations

In this section we will give an overview on how to properly organize the sections of three types of papers which, not coincidentally, rely on the aforementioned back up methods: those strongly based on mathematical proofs, those based on experiment results; and surveys. Each research problem/solution induces one of these paper types and follows a brief explanation and example of their contents and organization.

4.2.1 Paper based on mathematical proof

This kind of paper usually describes a new mathematical approach to solve a known problem or to proof that it is actually impossible to solve it, given some assumptions. Although difficult to achieve, such results tend to become seminal works on the subject area when

[2] By strong affirmatives we mean any sentence related to the subject of the paper, such as assumptions, explanations and specially any type of inferred consequence or conclusion. Structure-related sentences, such as section/figure references or any explanation of the paper organization, are not included in this rule and can be written with less care

correct. Given the mathematical background, there is no need to include an experiments/results section and bellow is a proposed structure for such paper:

1. Introduction;
2. Related work;
3. Background concepts/lemas;
4. Explanation of the method/impossibility result;
5. Proof of the hipotesys;
6. Discussion on the consequences;
7. Conclusion.

4.2.2 Work with experimental results

Experimental research is one of the more important building blocks of the scientific method. Every hipotesys that cannot be backed up by mathematical proof is a candidate for such method. Common examples include: results that depend on real world testing such as drugs research, software engineering techniques, optimization methods, among others. In summary, every time one has to **collect data** to find evidence for the hypothesis, even if this data comes from simulated environments, one is dealing with **experiment-based research**. Follows a sample organization to present results for this type of research:

1. Introduction;
2. Related work;
3. Background concepts;
4. Explanation of the proposed ideas;
5. Description of the experiments;
6. Results and analysis;
7. Conclusion.

Although fundamental to science, this is also the method that is more prone to flaws, because it is very difficult to perform and correctly analyze such experiments. Section 5 is dedicated to clarify this craft.

4.2.3 Survey

A survey is an **extensive review** over relevant previous research on a specific subject, and is more a technical report than a proper paper because it does not contain any new contribution besides the classification/organization/analysis of previous works. Even being a very specific type of scientific literature, it is subject to the same rules as the others, since it is main goal is to summarize scientific work, so it is important to follow the same guidelines. However, the organization is different since it is more like a oversized section on related work. Surveys are also subject to peer reviews/publication and, when relevant and well done, often targeted at journals, given their usual (big) size. Example organization:

1. Introduction/overview of the subject;
2. Categorization criteria for the reviewed work;
3. Category 1. There may be sub-sections, if also sub-categorized;
4. Category 2;
5. Category N;
6. Conclusion.

5 Achieving results

This section aims to clarify some misconceptions about scientific experimentation and also brings some guidelines on how to create presentation charts that are clear to understand. This is a vast subject and the reader is encouraged to search for more detailed sources of information as well.

5.1 Experimentation guidelines

TODO

5.2 Results presentation and chart guidelines

TODO

6 Conclusion

As already mentioned in section 3, the conclusion must summarize the contribution of the work to the specific research domain. Another important component of this closing section is the presentation of the future work that is expected to be done on the subject by the writers. For instance, bellow we give a sample conclusion for this meta-paper:

"In this meta-paper we..."

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To Nietzche, from whom I learnt how to find the guts to write this text.

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