How to write a passable technical paper

Anindya Chatterjee[1]
Mechanical Engineering
IIT Kharagpur

November 11, 2010

Introduction

In my job I see many students who have not learned to write a technical paper. When they do competent work, I want them to be able to write passable reports. This article is for them.

There are well established principles for citing the relevant work of others; for not copying things without giving credit; for *not stealing*. If a reader feels you have copied anything, a figure, *even a phrase*, from elsewhere without citing its source, then you are guilty of plagiarism in the eyes of that reader. Committing plagiarism is so bad that I cannot do justice to it here. So I merely say: ***never do it***.

On, then, to writing your own honest and original material.

Art requires talent. In contrast, through discipline and persistence alone, you can learn how to differentiate functions and ride bicycles. Similarly, you *can* write a passable technical paper. You just have to realize that your job does not end with research. ***Writing a passable paper involves extra work***.

What is a passable paper?

Your aim is to tell a certain story. The story is rather dry (hardly a murder mystery). If your reader loses interest and stops, you fail. Your story is also complicated. You have manipulated long mathematical expressions and conducted painstaking experiments using fancy equipment. Your readers, being human, will not always re-derive every expression and check every fact. Often, in a first reading, readers will decide whether your story is plausible. If it seems implausible, you fail.

If your reader reads to the end and understands the story on the first attempt, your paper is passable. But some readers begin by skimming, not reading. If a skimmer successfully extracts and believes the main storyline, your paper is also passable. You must serve both reader and skimmer *at the same time.*

To summarize: the reader owes you nothing, has other interests, may read or may skim, and gives you one chance. Can you communicate (a) your main story, (b) the flavor of the details, (c) an impression of reliability, and (d) the reason why your results merit publication? If you manage it, you have written a passable paper.

Your goal

Your goal is this. *Make it easy for a busy reader to read, understand, and believe your story.* The reader gives you a limited amount of attention: work within that budget. Respect her time: keep things simple, short, clear, and linear (I will discuss linearity below). If she thinks you are trying to fool her, then you fail. You must build and protect her faith in your straightness and competence.

Let us begin with some rules (ten of them).

[1] Former address: Mechanical Engineering, IISc, Bangalore. Email: anindya100@gmail.com

1. Avoid suspense (this is not a crime novel). Say right up front what the paper is about. Following Raibert [1], say it in the title, the abstract, and early in the introduction.

2. Linear means, at the minimum, no spaghetti logic ("here in section 7, we have now shown why the prediction made in section 2 about the results in section 5 were, essentially, correct; a full proof follows in section 9"). Linearity is discussed further below.

3. It is too much to expect the reader to be interested in your work *and* your personality. Avoid jokes, extraneous things that showcase your erudition, and other evidence of how interesting you are. Hunt for places where you have unconsciously tried to impress. *Present your work, remove your personality.*

4. Resist the temptation to expound on the greater context. ("Other work on control of various types of systems, using various types of actuators, and based on various control strategies other than ours, can be found in many other papers; see references [22-105]. A review of this general background literature now follows.")

5. Hunt for places where you have been lazy. For example, instead of "as shown earlier, $b = \sqrt{a+2}$" say "by Eq. 5, $b = \sqrt{a+2}$."

   Instead of "As discussed earlier, we have assumed the function satisfies various requirements, which now allow us to write …" say "As stated in section 3.2, we assume $f(x)$ is continuous, differentiable, and square integrable on $[0,1]$. Therefore, we can write …"

   Laziness can enter text through words like "this" or "these". ("Many prior works have examined the main reasons behind the different engine failures in ships. ***These*** have been of different types, and …" Here, "these" could refer to the prior works, the main reasons, the engine failures, or the ships.)

6. Keep the text short. Pretend you are paying cash per word. Let every word earn its presence.

7. Speak plainly. Minimize the use of jargon and abbreviations.

8. Put road signs along the way so that the reader can keep track of the area map, route, present location, direction of movement, and estimated time of arrival.

9. Check for smooth flow between sentences in a paragraph, and between paragraphs in a section. If there are discontinuities, consider connecting lines to maintain the flow.

10. Do not get attached to your prose [1]. If a beautiful paragraph no longer serves the goals of the paper, throw it out. You will find it difficult. Be strong.

As you examine the above list, I trust that you realize we need more than such rules. We need *principles*. I offer 5 principles below. The foremost is to plan in advance.

<u>Plan in advance.</u>

See Ashby's article [2]. Planning helps greatly.

Begin with a tentative title. The title brings discipline to your thinking. Plan the section titles, and make section-wise lists of ideas to include. The list of section titles itself can be posted on a wall where you write. A longer sheet with the planned contents of each section can be kept handy.

Your plan can include appendices. If, say, section 3 has a detailed calculation planned, you might instead outline the calculation and state the main result in section 3; and present the details in an appendix. The consequences can be significant.

I bought a plot of land for 1 million rupees. I built a house on it for 4 million rupees (for details, see appendix). I sold it immediately for 9 million rupees, making a profit of 80% in 6 months.

Compare the above, which I consider linear, with an alternative storyline.

I bought a plot of land for 1 million rupees. I built a house on it over the next 6 months. The house had 2 floors, 4 bedrooms, 3 bathrooms, a large verandah, a tiled roof, a lawn, a two-car garage, and a garden with 3 mango trees. Costs were as follows. Cement: 1.2 million, steel: 0.9 million, other materials: 0.9 million, and labor: 1 million; total: 4 million rupees. After completion, I sold the house almost immediately for 9 million rupees, making a profit of 80% in 6 months.

The first plan presents a linear *financial* story, with peripherals moved out of the main storyline. The second plan is less linear: it might at best be called a *chronologically* linear story of the overall experience. The title of the first version might be *"A case study in profitable house building."* What title might suit the second version? Maybe *"A detailed account of property acquisition, house construction, and subsequent profitable sale."* I prefer the first plan and title. Some might prefer the second. Make a conscious choice.

With your plan in place, write. As you write, you may revise your plan. If so, every section must be reexamined.

To summarize: plan the paper title, plan the section titles and sequence, plan the section contents. Put the plan on a wall where you write.

The next principle involves counting.

<u>Count your ideas.</u>

Each sentence must have one idea. Each paragraph must have one idea. Each section must have one idea. I also suggest the paper must have one idea. In each case, the ``level'' of the idea is different.

Here are some examples.

Smith (1999) has shown that faulty gearboxes can make lots of noise, and Sinha (2000) has shown that elephants are heavy.

The above sentence has two ideas. Not acceptable.

Sinha (1999) has shown that faulty gearboxes can make lots of noise, but Smith (2000) has given an example of a faulty gearbox that was not noisy.

The above sentence does have one idea. The idea is not that gearboxes make noise. Rather, the idea is that people seem to differ on the relationship between gearbox faults and noise. If you think Sinha (1999) is basically correct and want to indicate it, then the following may be better.

Sinha (1999) has shown that faulty gearboxes can make lots of noise, as indeed they generally do, although Smith (2000) has given an example of a faulty gearbox that was not noisy.

Read your draft slowly. What <u>one</u> idea do you want a given sentence to convey? Examine <u>each</u> sentence.

Now consider paragraphs.

In this paper we first derive the equations of motion of a bridge impacted by falling rocks. The mass of a typical rock is M. The rock is modeled as a rigid sphere which drops from a height h. The bridge may fail due to impact-induced stresses, and we use a modified von Mises type of failure criterion to predict if the bridge will fail. The stresses will be calculated using ANSYS.

Clearly, the above paragraph has more than one idea. Consider instead:

Our mechanical model consists of a bridge modeled as a beam, built-in at both ends, impacted by falling rocks modeled as rigid spheres. The beam has length L, mass per unit length $\overline{m}$, and bending modulus EI. The beam starts from rest at the instant of impact. A sphere falls from a height h, and hits the beam at a distance a from the left end. Contact between the beam and sphere is mediated by a spring of stiffness k. The differential equations of motion, given below, are solved using a 4th order Runge-Kutta method in Matlab.

The above paragraph is still unacceptable. It talks about the model as well as the solution method: more than one idea.

Secondly, it is not linear. The differential equations are not presented, yet the solution method is being discussed already.

Finally, when discussing the sequence of details, I might mention the contact stiffness k before the contact location a. Here I assume we are in fact considering the following sequence: take a bridge, take a sphere (contact stiffness k), drop the sphere on the bridge (location a).

Maybe the sequence is different? Choose a point on a bridge, and drop a series of different rocks on that same location? Then I might write this:

Our mechanical model begins with a bridge modeled as a beam. The beam has length L, mass per unit length $\overline{m}$, and bending modulus EI, and is built-in at both ends. A series of rocks, modeled as rigid spheres of mass M, are dropped from a height h on to a location a on the bridge. Contact between the bridge and each sphere is mediated by a spring of stiffness k. [Optional extra line: This completes our mechanical model.]

To summarize the discussion of paragraphs: a paragraph develops a single idea.

Now consider sections. Each section has one idea. The ideas of sections are broader than those of individual paragraphs. Section-level ideas you might consider include a general introduction, motivation for the specific work done, mechanical model and equations of motion (one section or two? you choose), and equations of motion and numerical solution technique.

Finally, the paper itself should have one main idea. Some find this restrictive. ("Why not two ideas?") But I recommend that you identify the one main idea of your paper. If you have two distinct ideas, choose one and call it the main idea and make the second *seem* less important. Think of a bottle of water and a pen, if you like. You might buy these separately; or you might buy a bottle of water and accept a free pen with it; or you might buy a fancy pen and maybe accept a complimentary bottle of water! But only a rare buyer seeks combined deals on water bottles and pens. What holds for marketing holds for writing. Decide what you are selling: a bottle of water, or a pen. If both ideas are equally strong and important, write two papers.

Choosing a title before you begin will help you count the ideas in the paper.

Accordingly, do not consider "*Investigation of wave propagation in long metal bridges, with a new constitutive model for nonlinear viscoelastic vibration dampers*." Instead, emphasize one topic and let the other be less important. Either "*Wave propagation in long metal bridges with nonlinear viscoelastic*

dampers" or "*A new model for nonlinear viscoelastic vibration dampers, with application to wave propagation in bridges*." Better still, consider one called "*Wave propagation in nonlinearly damped metal bridges*," and another called "*A new constitutive model for bridge vibration dampers*."

The choice of a title is important, and can be iterative. Here is an imagined sequence of iterations.

Vibrations of machinery.

Too broad. Are you writing a paper or a textbook?

Vibration reduction of machinery.

Still too broad.

Vibration reduction of machinery using viscoelastic mounts and dampers.

Getting better; but still probably broad enough for a review paper written by someone with 30 years in the field. Not for the beginning researcher I assume you are.

A case study in vibration reduction of machinery using viscoelastic mounts and dampers.

Mysterious! What sort of machinery? Was it a successful, or unsuccessful, attempt to reduce vibrations?

Vibration reduction of a portable diesel generator using viscoelastic mounts and dampers.

Sounds better; more specific, certainly.

Optimization of viscoelastic mounts and dampers for vibration reduction of a portable diesel generator.

Better still, assuming of course that you did do optimization. And finally,

Optimization of viscoelastic mounts and dampers in a portable diesel generator.

With this final version, you realize that "vibration reduction" was superfluous. That is what viscoelastic mounts and dampers are for. I like this last title, and would tentatively accept it at the start of my planning.

Now that we understand how we should write, can we just do it? Sadly, never. That is the next principle.

Expect to revise.

Repeated revision is the secret of *achieving* your goal. You will have to revise your overall plan as you write your sections. You will have to revise your section plan as you write your text. You will have to revise, and revise, and revise your text.

After the above basic principles, we consider linearity.

Practice linearity.

In common usage, linear means straight. By linearity in writing, I mean "no unnecessary changes in direction." Linearity obviously includes "no spaghetti," as mentioned above. But it means more.

Imagine you are a student escorting an important visitor from Building A to a meeting in Building B at your university. You will surely follow a roughly straight path. You will not turn the walk into a tour of the campus! Perhaps a change in direction is unavoidable? Maybe the path is blocked due to construction. As

you begin the detour, you might explain its necessity. Afterwards, you might indicate (maybe indirectly) the point when you hit the straight route again.

So it is in writing. Follow a straight path. If a detour is essential, consider leaving markers for when you leave and when you return to the main storyline. ("Having established that the rock was not unduly heavy, we now return to the collapse of the bridge.")

Linearity implicitly assumes smooth flow (a broken line is not a line). See rule 9.

Appendices can aid linearity: see the house-building example above. When you juggle many sections and subsections, use a table of contents to check for linearity; you may find a repairable flaw. Linearity really helps make a paper more passable.

Let us pause to take stock. We started with a goal: *Make it easy for a busy reader to read, understand, and believe your story.* We have so far addressed reading and understanding. We have yet to discuss *belief*. The following principle, though presented last, affects everything when you write.

Help the reader believe.

Following Senturia [3], say things that are as reliable as possible, for as long as possible.

"Two spheres were dropped on the bridge." This line is highly reliable. You can surely count till two.

"I used the specimen of figure 1 in a 100 ton Instron machine to find the tensile strength." This line is fairly reliable: use of a standard machine for a routine task.

"We used the algorithm of our unpublished papers [3-17] to compute the eigenvalues, and they were all negative within the accuracy of the calculation." This line is unreliable. While it might well be correct, I would not use it. Why take on other papers' burden of disbelief?

"The bridge broke into three pieces, probably because of unmodeled wave reflections." If such speculation is unavoidable, save it till late in the paper and admit clearly that it is speculative.

I am tempted to expound on the greater context (rule 4): style, grammar, punctuation, and why a picture is worth a thousand words. But 10 rules and 5 principles are enough. I will stop here.

I am tempted to wish you luck. But passable writing needs discipline, not luck.

Acknowledgments

I was influenced by Andy Ruina's essay on writing. He revises it periodically, and it is usually somewhere on his web pages at Cornell University. Reviewers of my own papers helped me think about passable papers. I got feedback and encouragement from G. K. Ananthasuresh and D. D. Ganguly.

References

1. Marc Raibert. "Good writing." Available readily on the web. 1985, revised 1995.
2. Mike Ashby. "How to write a paper." 6th edition. Available readily on the web. 2005.
3. Stephen D. Senturia. "How to avoid the reviewer's axe: One editor's view." Guest editorial, *Journal of Micromechanical Systems*, 12(3), 2003, pp. 229.