The style files

Tony Roberts' *Style Files* were published in 12 installments in *Gazette* issues 33(1)–35(3). They have been combined into one document here for easy access. This document can be downloaded from
http://www.austms.org.au/Publ/Gazette/TheStyleFiles.pdf

1. Prefer active writing to passive

Tony Roberts*

I propose this note as the first of a series to encourage better writing skills among mathematicians. Why? Because many technical articles I read as an editor are boringly turgid. We and our students must do better. We must do better not only to communicate with each other, but with employers and the wider community.

> If you ... have strong communications skills and leadership potential, can write reports ... you are the type of employee we are looking to recruit.
>
> Australian Bureau of Statistics

But, you say, 'I have tried to read Roberts' research articles before and made no sense of them'. Unfortunately true — I seek to pass on the wisdom of others rather than my considerably poorer practise.

Each note, and I plan eight at the moment, will address one aspect of English usage. Each aspect may be only a small point in itself. But improving many little aspects will empower you to write with much better effect.

Use the active voice

Active writing is more direct and vigorous than passive writing. For example, [1, Section 11]

> *Passive:* My first visit to Boston will always be remembered by me.
> *Active:* I shall always remember my first visit to Boston.

The latter version is more direct, bold and concise. Active writing adds life and movement, whereas consistently passive writing weakens communication [2, Section 4.4]. Prefer to write 'X did Y' to 'Y was done by X'. Three examples demonstrate such revision:

> *Passive:* The answer was provided to sixteen decimal places by Gaussian elimination.
> *Active:* Gaussian elimination gave the answer to sixteen decimal places.
>
> *Passive:* Gene expression in 40 tumour and 22 normal colon tissue samples was analyzed with an Affymetric oligonucleotide array.
> *Active:* An Affymetric oligonucleotide array analysed gene expression in 40 tumour and 22 normal colon tissue samples.
>
> *Passive:* An investigation focusing on higher blockage effects was carried out by Sahin and Owens (2004).
> *Active:* Sahin and Owens (2004) focused on higher blockage effects.

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Observe in these examples that, to eliminate the passive 'was verb', I recommend you attribute action to methods, equipment or people. As well as revising to avoid most 'was verb' constructs, similarly revise to avoid most 'is verb' constructs. I give two examples: the first reaffirms how reordering the sentence and attributing the action promotes active writing.

Passive: The error for the Atkinson problem is plotted in Figure 5.
Active: Figure 5 plots the error for the Atkinson problem.

Passive: The explicit Euler method is dominant in the extant literature of computational finance.
Active: The explicit Euler method dominates computational finance.

Why is passive writing so popular?

Perhaps it self-perpetuates: our students copy not only our good habits, but also our bad. But passive writing must also be easier. Perhaps passive writing is perpetuated by the natural habit to put first in the sentence the first thing that comes to mind. Revise your writing to put methods or people first when reasonable. Students often cling blindly to what they perceive as correctness — a formula consisting (almost invariably) of third-person, passive voice, cliches and far too many quotations from secondary sources (Susan Thomas, *The Australian*, 14 July 2004).

Observe in the examples that the active voice makes for forcible writing. Tame descriptions and expositions become lively and emphatic in the active voice. Consequently, you must have the courage to be direct and assertive, rather than insipidly passive.

However, do not entirely discard the passive voice. Instead, employ it when necessary to invoke appropriate emphasis. For example, a passive sentence may be necessary to bring a key phrase to the start of the sentence in order to set the scene for the sentence.

Summary

Avoid passive phrases such as most 'was' or 'is' verbs. How? Attribute action to people or methods.

2. Clarify this

This second note in a series to encourage better writing advises us all to use the pronoun 'this' unambiguously. Too often 'this' is open to misinterpretation. Such misinterpretation hinders effective communication.

As with much of the advice I will describe, this clarification is a small gain. But good writing is composed of making many such small improvements.

> Tone is important, and tone consists entirely of making these tiny, tiny choices. If you make enough of them wrong ... then you won't get your maximum readership. The reader who has to read the stu will go on reading it, but with less attention, less commitment than you want. Van Leunen

The word 'this' is frequently ambiguous

The word 'this' refers to something just mentioned; but what? You know, but the reader probably will not. Ensure that your use of 'this' is absolutely clear and unambiguous. Often simply insert an appropriate noun after the 'this' [2, Section 4.7].

The following examples illustrate the problem and a remedy. All alternatives in the parentheses are potentially possible.

Ambiguous: In 6 out of 15 contests, the shadower appeared stationary to the other insect. This makes the insects hard to spot.
Clearer: This (contest — shadowing) makes the insects hard to spot.

Ambiguous: The disadvantage of this approach is that there may not be enough data at each time point. We overcome this by using a smoothed covariance or correlation matrix.
Clearer: We overcome this (disadvantage — lack of data) by using a smoothed covariance or correlation matrix.

Ambiguous: A correction factor can be applied and this brings the M-functional very close to the quantiles of the original distribution.
Clearer: A correction factor can be applied and this (correction — application) brings the M-functional very close to the quantiles of the original distribution.

> The pronoun 'this' is the most dangerous of all ... because it is potentially the most ambiguous. It might or might not refer to the thing last denoted by a noun. It might refer to the whole of the last page or even to the whole of the next page. The cure, very often, is to replace the pronoun by lucid repetition of a noun or noun phrase. McIntyre (2005)

Other pronouns frequently require clarification

such as 'these', 'those', 'it', 'its', 'they' and 'their'. The following example illustrates the clarification.

Ambiguous: We introduce and explore an approximate regression quantiles method. It is based on a new interpretation of M-functionals.
Clearer: We introduce and explore an approximate regression quantiles method. The (introduction — exploration — method) is based on a new interpretation of M-functionals.

Ambiguous: Various state-of-the-art spatial and temporal discretisation methods employed to solve Maxwell equations on multi-dimensional structured grid networks are investigated and the dispersive and dissipative errors inherent in those examined.

Clearer: Various state-of-the-art spatial and temporal discretisation methods employed to solve Maxwell equations on multi-dimensional structured grid networks are investigated and the dispersive and dissipative errors inherent in those (methods — grids — equations) examined.

Summary

How many times have you read a Reviewer's comments and wondered how the Reviewer could possibly have misunderstood you that way? I suspect a lot of times. I know I despair of Reviewers many times. Yet often the Reviewer has misunderstood you because you have allowed him/her to misunderstand. Work with Reviewers to eliminate such misunderstandings. Clarify your pronouns, especially 'this'.

> One should not aim at being possible to understand, but at being impossible to misunderstand. Quintillion

3. Inform with titles, abstracts and introductions

Many years ago, Ernie Tuck told me that when he has a research article to read he first reads the Introduction and the Conclusion. Why? Because Ernie wants to discover quickly whether to invest time to read the entire article.

But I ask you: why should Ernie have to find and read the conclusion? Answer: he reads the conclusion to find out important information. But surely such important information should be at the start of the article, in the abstract and introduction, where information is easy to find. Scientists should be able to decide whether to read an article in detail by reading the start of the article. Consequently, write to convey quality information in the abstract and introduction. Include some results.

> Quite aside from format and style, mathematical writing is supposed to say something. Put another way: the number of ideas divided by the number of pages is supposed to be positive. Kelley

Attract with your title. The title is your first chance to lose a reader; thus make the title interesting. Start with a keyword. Put in a verb and make the title a statement. Be specific.

For example, the vague 'Stochastic inertial manifolds' should be the definite statement 'Stochastic inertial manifolds exist and attract' which informs us what aspect is being proved.

The abstract is not a table of contents. Instead, say what you deliver in the article, give the essential qualities of the research and its results. Use less than 50 words for each of the following questions:

- What was done?
- Why do it?
- What were the results?
- What do the results mean in theory and/or practice?
- What is the reader's benefit?
- How can readers use this information for themselves?

The abstract is probably all most readers read — the abstract is often the only freely available information. The abstract must be a complete though necessarily sketchy description in itself.

A wide range of people in your discipline may read your abstract if you have made the title interesting. Keep the level of jargon low, perhaps to that appropriate to Honours degree students.

The introduction must show your story is worth reading. The introduction is likely to be all that interested readers read; again it must be complete in itself. Use a level of jargon appropriate to say postgraduate students. Place your work in the context of other research. Summarise your main results, albeit in a suitably simplified form.

> ... the introduction is the most important part of your paper, because few of your readers will ever read beyond it. And there's not much hope that any of them will if you don't grab their attention from the start. So it's a mystery why so many papers begin with twaddle ... Jonathan Shewchuk

Face it: only the dedicated diehards are going to want to wade through the details of the rest of the paper. Give key results and connections in your introduction. Address the same questions as those given above for the abstract, but address in more detail and give copious citations to the work of others and copious forward references to later sections where you give the full gory details.

Avoid what Shewchuk[1] calls 'an oozing cyst like this moribund specimen:

> This paper is organized as follows. In Section 2, we describe ... In Section 3, we describe ... In Section 4, we prove ... '

Instead, throughout the introduction embed forward references to the later sections. Such forward references must be placed in the description of what was done, your results and their meaning.

Summary

People spend time on what they perceive will benefit them. Structure your document so that even those who read only a little can take away something of value

[1] http://www.cs.cmu.edu/~jrs/sins.html

— that way they are more likely to take note of what you say and come back for more. Help Ernie and me by filling the title, abstract and introduction with understandable and useful information.

4. Explicitly avoid false conditionals

An infestation of termites is weakening mathematical writing. We all too often resort to wishy-washy conditionals such as 'can be' or 'wish to' hidden within the body of sentences. Just as termites weaken a building, these conditionals erode writing by turning what should be definite statements into weak conditionals. Get rid of them. If in your analysis or computational experiments you do something, then say so definitely; if not, say that; be explicit.

> There's almost no more beautiful sight than a simple declarative sentence.
>
> Zinsser

Eliminate indefiniteness

The following five examples show how you may make statements more explicit. Eliminating 'can be' is the most common improvement.

Weak: This paper shows how a similar increase in accuracy can be obtained, with a little more effort.
Definite: This paper shows how to obtain, with a little more effort, a similar increase in accuracy.

Weak: A correction factor can be applied and this brings the corrected M-functional very close to the quantiles.
Definite: Applying a correction factor brings the corrected M functional very close to the quantiles.

The following example eliminates two unnecessary qualifiers in making one definite statement.

Weak: The method can be applied to variety of problems in such areas as antiplane strain in elastostatics.
Definite: We apply the method to antiplane strain in elastostatics.

Being definite and explicit extends to acknowledgements: if you would like to thank someone, then do so.

Weak: I would like to thank ...
Definite: I thank ...

Avoid over conditioning

Sometimes writers overload a sentence or phrase with multiple conditionals. One genuine conditional is enough.

Weak: 'where occasionally requests for function values may not be met'
Definite: either 'where requests for function values may not be met' or 'where occasionally requests for function values are not met'

> Lucid writing and speaking are highly explicit. The need for explicitness is more important than is commonly recognised by novice communicators, and its neglect far more expensive. McIntyre [3]

Higham [2, Section 4.17], also advises against the false 'If'. That is, the use of 'if' when we are not actually making a conditional statement.

False: If we look at the inlet velocity profile, it returns $U = 0.285U_0$.
Definite: The inlet velocity profile has $U = 0.285U_0$.

False: If we define the norm $\|\vec{p}\| = \sum_i p_i^2)^{1/2}$, we would like to establish sufficient conditions to ensure boundedness.
Definite: Defining the norm $\|\vec{p}\| = \sum_i p_i^2)^{1/2}$, we proceed to establish sufficient conditions to ensure boundedness.

Remember

After drafting an article, search through your source for 'can be' and delete almost all of them. Similarly omit other weakening conditionals like the other examples above.

Make definite assertions. Avoid tame, colourless, hesitating, non-committal language.

5. Favour the present tense

> I recommend the rule 'if in doubt, use the present tense'.
> Higham [2, Section 4.29]

The present tense works well for scientific writing. The eternal truths we present in an article should all be in the present tense: instead of 'experiments have shown that', prefer 'experiments show that'. The present tense helps make more active writing.

Write derivations in the present tense: not the past tense of 'where we have assumed $R = \{k_1, \ldots, k_r\}$' but instead 'where we assume $R = \{k_1, \ldots, k_r\}$'; nor the future tense of 'As we will scale later the Hamiltonian with the inverse temperature', but instead 'As we scale the Hamiltonian with the inverse temperature, Section 4'. Generally avoid 'will': prefer 'The potential in Example 2 is central' to 'The potential in Example 2 will be central'.

> In summarizing the action of a drama, the writer should always use the present tense. In summarizing a poem, story, or novel, he should preferably use the present. Strunk [1, Section 17]

However, report actions undertaken in computational experiments using the past tense. For example, 'All simulations used a fine lattice of size $N = 512$'. Similarly, instead of 'we solve the linear equations (4.9)–(4.12) with $\Delta t = 0.0063$ and 8192 FFT points', prefer 'we solved the linear equations ...'.

Refer to previous work in an earlier article using either the past tense or the present tense. Choose depending upon whether your main emphasis is the historical development (use the past tense) or whether your emphasis is the eternal truths in the work (use the present tense). In this fragment the emphasis is on the result, 'theoretical studies [10, 11] have shown that', so prefer the present tense of 'theoretical studies [10, 11] show that'. However, the past tense suitably fits the historical aspect in 'Nolasco and Dahlen [15] and Guevara *et al.* [16] demonstrated that'.

Use future tense to refer to future work — that is, work forecast to be in a different article. Such discussion usually only occurs in the conclusion.

> Other than in conclusions, future tense is rarely used in science writing.
>
> Zobel [4, p. 40]

Summary

This quote says it all.

> Facts are true: use the present tense to denote unchanging truths. When telling what the authors or other researchers did, use the past tense. For what is being done in the paper, use the past tense for referring back ("in Section 5 it was shown that ..."). For referring ahead, use ... the present tense if the writer is thinking of how the paper is set out ("in Section 7 it is shown that ...").[1]
>
> Garrett [5]

6. Omit redundant words

> 'Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all his sentences short, or that he avoid all detail and treat his subjects only in outline, but that every word tell.'
>
> Strunk [1, Section 13]

Redundancy occurs in so many forms that a smooth discourse is almost impossible to write. In a rather piecemeal fashion, let us look at just some ways to tighten your writing. Why? So that each word you write serves a definite useful purpose in communicating concepts, actions and results.

[1] But remember to write actively, not passively. In particular, avoid 'it was/is'. I recommend the two parenthetical examples in this quote be 'Section 5 showed that ...' and 'Section 7 shows that ...'.

Two words that proliferate like weeds in academic writing are ‘have’ and ‘has’. They occur unnecessarily in many ‘have/has *verbed*’ combinations. For example, not ‘we have observed’ but simply ‘we observed’, and not ‘his colleagues have compared’ but simply ‘his colleagues compared’. As in the later examples, such padding seems to have crept in to scientific writing without notice. Omit such padding. After you have drafted an article, do a global search for ‘have/has’ and ask yourself whether each occurrence is necessary.

Remember that I do not advocate that shorter is better. Good writing experts just recommend that every word tell. Consequently, do not be tempted to use abbreviations and contractions [2, Sections 4.2 and 4.13] as they tend to make sentences stilted. For example, the most common abbreviations are probably ‘e.g.’ and ‘i.e.’, but many authorities contend that ‘for example’ and ‘that is’ make for smoother flowing sentences. Certainly avoid TLAs, three-letter acronyms, unless you invoke the acronym many times.

Instead I advocate that we simplify long-winded ways of writing. See how the following two examples cut out unnecessary waffle.

Long winded: We initially reproduce ..., and very good agreement is confirmed.
Concise: We reproduced accurately ...

Long winded: The computed inviscid and viscid solutions were presented, and were shown to compare very well with ...
Concise: The computed inviscid and viscid solutions compare very well with ...

You may think: easy, I do not write like that. Yet almost all the examples I use in these articles come from infelicities encountered in editing research articles (my apologies to those who recognise their sentence fragments). Ask a colleague to read your draft articles with a mandate to improve long winded exposition.

> In especial the expression ‘the fact that’ should be revised out of every sentence in which it occurs. [1, Section 13]

Other words to almost always omit are ‘actually’, ‘very’, ‘really’, ‘currently’, ‘in fact’, ‘thing’, ‘without doubt’ [2, Section 4.21]. Such words typically pad sentences to no advantage. Also cull ‘given by’, ‘expressed by’, and ‘the following equation’. These usually occur as a prelude to an equation. Omit them. For example, and also culling a useless ‘in this paper’,

Long winded: In this paper, let us consider the fractional-order transfer function given by the following expression $G_n(s) = \cdots$
Concise: Now consider the fractional order transfer function $G_n(s) = \cdots$

Writing cysts such as ‘It is noted here that blah’ should be mercilessly excised to ‘Note: blah’ or even just ‘blah’. Search for passive sentences beginning ‘It is’ and rewrite actively.

Active writing aids conciseness. The following example shows the simplification in writing actively:

Passive: The two different representations of the manifold are clearly displayed in Figure 2
Active: Figure 2 displays the two different representations of the manifold

> As positive statement is more concise than negative, and the active voice more concise than the passive [1, Section 13]

Summary. Describing science accurately is a difficult task: it is so easy to be misunderstood. We need to write from many different angles to cater for a wide variety of readers. Make each view of your discourse as concise as possible so that your reader's attention is not exhausted. Expunge useless padding.

7. Appearance affects communication; but not necessarily as you like

Many people are trained to produce documents that look appealing. For example, many favour the supposedly clean appearance of a sans serif font such as the mainstream Arial. However, research by Australian Colin Wheildon [6] showed that a miserable 12% of readers comprehended a text in a sans serif font; in comparison, 67% of readers comprehended the same text when it was typeset in a serif font (as is the bulk of this document). Not only does a supposedly pretty or clean appearance not equate to effective communication, it is far different.

Decide now whether you are more interested in your own subjective opinion of the look of your document, or whether you are more interested in how to format your document so that *others can most easily comprehend your writing.*

If the former, then stop reading now. I write here only for those who wish to learn to effectively communicate.

Short solution

Wheildon's [6] research shows we should use serif fonts such as Computer Modern or Times. Is there a simple solution to implement for your documents a style that is effective in communication? Silly question: of course there is. The short answer is to *use LaTeX and accept all the defaults of LaTeX.*

Knuth and Lamport consulted many professional printers to find out what they did and why. Knuth and Lamport then encoded into LaTeX the wisdom of centuries of experience in printing. I know many have difficulty accepting this: nonetheless, accept that LaTeX knows best.

Slightly better solution

Priestly [7] comments that page layout, especially for instructional documents, should best be in two columns with the right column for the main text and the left column for headings, major points and prompts. Fortunately, Hubert Partl and Axel Kielhorn implement such a two-column layout for us in their LaTeX classes refart.cls and refrep.cls for articles and reports respectively[1].

Apart from font and a left column for headings, what other aspects help readers comprehend our documents? I summarise here some of the aspects reported by Priestly [7] and based upon research into effective communication. I emphasise again, you should prefer such a style not because it might or might not look pretty, but because research demonstrates the style is most effective for comprehension.

Line width

On average, each line should have 10 to 12 words, or equivalently, be roughly 60 characters wide. Human eyes do not scan well wider lines[2]. But we want to save trees by having as much text per sheet of paper as possible. I offer two solutions: either typeset in two columns utilising the whole page; or typeset as a document on A5 paper[3] and print two A5 pages per sheet of A4 paper.

Text colour

As Priestly [7] puts it: use any colour so long as it is black. For example, although eight out of ten people consider blue text more attractive than black text, give them a couple of pages to read and their comprehension tells a different story: in one test 70% of readers of black text showed good comprehension, whereas barely 10% of readers showed good comprehension of the same text when it was coloured blue. Colour attracts the eye and can be good for headings, but colour is woeful for comprehending text.

Emphasise discreetly

Modern computer publication allows us almost infinite variety in style. Many writers adopt variety with enthusiasm, but at the unseen cost of confusing their readers. Here are some rules of thumb.

- Use bold only for navigation: bold text is much less readable. In one test, 70% of readers comprehended a text in ordinary font, but only 30% of readers comprehended the text in bold. Bold font attracts the eye and thus in headings and definitions usefully helps a reader to navigate around a document. Bold is not useful for comprehending sentences.

[1] Download refman.dtx from any ctan site and install.
[2] This is why LaTeX in 10-point font has more characters per line than LaTeX in the larger 12-point font.
[3] Use the a5paper option in the geometry package.

- Never use all capitals: we recognise words partly by the shape of their outline, and all capitals destroys that shape; use lower case.
- Similarly avoid underlining, reverse type, and outline type.
- Italic font also degrades the word image and thus interferes with reading. Use italics when you emphasise, but use it sparingly.
- Placement is your most effective tool for emphasis. Ensure that: your most important sentences are at the start or end of each paragraph; your most important paragraphs are at the start and end of each section.

Summary

Learn to love the default style of LaTeX: it is close to being the best that research shows is effective for written communication.

8. Write what you mean

> The only proper attitude is to look upon a successful interpretation, a correct understanding, as a triumph against the odds. We must cease to regard a misinterpretation as a mere unlucky accident. We must treat it as the normal and probable event. Richards [8]

Surely communication cannot be quite as difficult as Richards suggests. Yet consider this simple sentence which a few years ago appeared in the Review section of the *New Scientist* magazine: 'Mostly, I read the books I review on trains'. We know what the writer means: when he gets a book to review, he generally chooses to read them while travelling on a train, probably while commuting. But imagine a reader who does not share the same context as you, I and the writer; such a reader could easily and justifiably interpret the sentence quite differently. The sentence could mean that when the writer gets to review a book about trains, then the writer mostly chooses to read them. If such a simple little sentence can be subject to such different interpretations, then, yes, communication is difficult.

In this simple sentence, the problem lies in the chosen word order. Reorder the words:

Poor: Mostly, I read the books I review on trains.
Good: Mostly, I read on trains the books that I review.

This reordering is much harder to misinterpret. Carefully reordering words in a sentence will greatly clarify meaning. When revising, read each sentence you write and ask whether you could reorder the words to ensure that the sentence reads what you mean to write [2, Section 4.32].

Higham [2, Section 4.32] gives an example, with a misplaced 'only', where reordering strengthens a sentence and removes ambiguity.

Poor: The limit point is only a stationary point when the regularity conditions are satisfied.

Good: The limit point is a stationary point only when the regularity conditions are satisfied.

Strunk similarly advises us to keep related words together.

> The position of the words in a sentence is the principal means of showing their relationship. The writer must therefore, so far as possible, bring together the words, and groups of words, that are related in thought, and keep apart those which are not so related. Strunk [1, Section 16]

Strunk gives the following example.

Poor: Cast iron, when treated in a Bessemer converter, is changed into steel.
Good: By treatment in a Bessemer converter, cast iron is changed into steel.

Summary

Much confusion arises when words which relate to the same thing are separated by a significant chunk of the sentence. Consider word and phrase order carefully for each sentence.

Postscript

Since writing the previous article on typesetting documents for effective comprehension, I became aware that Colin Wheildon [9] recently published an updated report on his research. Those intrigued by typesetting for communication should read the details Colin describes in this recent book.

9. Use the most informative synonym

Convey the maximum information by using the most precise synonym possible. Avoid unnecessary imprecision.

For example, to write the 'level' of some quantity is vague. Better to write the 'concentration', or the 'frequency', or whatever. The term 'concentration' is more specific than 'level' and so contains more information. Similarly, in an example from human studies, prefer to write 'patient' or 'gymnast' instead of the vague 'subject'. Use synonyms that have more information.

Most terms we use have variants over a wide range of abstraction. Higham [2, Section 4.29] gives these examples:

- graph — function — rational function — polynomial — quadratic — scalar;
- result — theorem — relation — inequality — bound;
- statistic — error — relative error;
- optimum — minimum — global minimum;
- random — normally distributed — normal $(0, 1)$.

These lists place the most abstract, general words to the left, and the most concrete, specific words to the right. Prefer the word that is as far to the right as possible as it conveys the most information.

Similarly aim for precision when you choose non-scientific words. Fortunately, the many invaders of England in the past few thousand years left a legacy of a language rich in synonyms: English is one of the most synonym-rich languages. When choosing a synonym, prefer a short, concrete word (often Anglo-Saxon in origin) in preference to a long, abstract word (often of French or Latin origin). Enjoy using uncommon words when connotations associated with the word are just right for you. Then the fewest words will convey the maximum information through their connotations.

Precisely specify forward and backward links. Often authors write 'the above method', 'mentioned above' or 'later we see'. Such links internal to the document are vague and imprecise. You, the writer, are referring to something preceding (but not actually above) or following. Such loose references are convenient for writers, but not for readers. You know exactly what and where, but your readers may have to search. Instead be specific.

Make internal links precise using names or numbering. For examples, the above imprecise links might be more informatively written: 'the quasi-Newton method', or 'mentioned in the Introduction', or 'Section 4 shows'.

> the ill and unfit choice of words wonderfully obstructs the understanding
>
> Francis Bacon, circa 1600

10. Establish a self-similar structure

Previous articles mainly addressed issues of words and sentences: prefer the present tense; clarify 'this'; write actively; be explicit; and so on. Now let us move on to consider how to combine sentences into a document. I propose that structures from the paragraph to the whole document are similar.

Make the paragraph the unit of composition

Strunk beautifully describes the nature of a paragraph.

> Ordinarily, however, a subject requires subdivision into topics, each of which should be made the subject of a paragraph. The object of treating each topic in a paragraph by itself is, of course, to aid the reader. The beginning of each paragraph is a signal to him that a new step in the development of the subject has been reached. Strunk [1, Section 9]

But how do we decide what is a 'topic'? What do we form into one paragraph? We are stymied until we understand what a 'topic' means to us. I suggest you consider a 'topic' to be something about which you can write a summary statement; perhaps a result that some algebra can establish, or perhaps something that might be

labelled a mini-theorem or mini-lemma. Then such a summary statement serves as either the first or ending sentence of the paragraph. As Strunk recommends in the following quote, surround the argument of the body of a paragraph by summary statements or consequences.

> 1. the topic sentence comes at or near the beginning;
> 2. the succeeding sentences explain or establish or develop the statement made in the topic sentence; and
> 3. the final sentence either emphasizes the thought of the topic sentence or states some important consequence. Strunk [1, Section 10]

Example. The following paragraph, extracted from a module teaching writing, starts with a summary statement (italicised here) on the vital importance of technical communication, and ends with a statement (also italicised here) on the consequence that we grade their work explicitly on communication. The middle of the paragraph explains more details.

> *Developing technical communication is essential preparation for the workplace and advanced study.* In this module we help you to structure, prepare and deliver small documents of technical material. Study this module in parallel with the first few modules in preparation for your first assignment. In your assignments you will demonstrate your skills in technical writing for specific tasks. *Your assignment reports will not only be graded on mathematical content, but also on the style and manner of the technical and English expression.*

Self-similarity helps guide readers

Recognise shades of the well-known 'rule of three' in the above quote from Strunk [1, Section 10]: (1) tell them what you will tell them; (2) tell them; (3) tell them what you have told them. I prefer Strunk's expression. But pause just a moment: the 'rule of three' refers to the whole document, whereas Strunk refers to just one paragraph. The large-scale 'rule of three' and the paragraph scale recommended by Strunk are essentially the same. I recommend that you apply the same principle at *all* levels in a document.

> The principle that the start and end of a paper are more important generally applies at the smaller scale. In a long paragraph it is often worth explaining (in advance) what you're doing and why you're doing it. The hierarchy of purposes extends down to paragraphs; after each paragraph, ask yourself if you've achieved your immediate purpose. This principle applies even to sentences; if, for example, you are recapitulating, beginning the sentence with a phrase like "In short..." will prepare the reader. Garrett [5]

Garrett identifies that readers find the start and end of each component to be the most important. Readers typically pay most attention to the Introduction and Conclusion: reiterate important information there, together with a 'map' of the article. The start and finish of a section or subsection are the most important: reiterate and 'map' the section or subsection. The start and finish of a paragraph

are similarly for summary and mapping. Surely documents must be self-similar with appropriate summary explanation at all levels.

11. Write to read breadth first, not depth first

> Technical writing is *not* like writing a detective novel: in your introduction, as well as describing the background, tell your reader upfront in plain language your conclusions.

We discuss how to structure the information over a technical document. The fallacy to dispense with is that humans relate to a logical progression: this is false. A progressive logical development, putting in place 'brick by brick' your arguments, to a triumphant finale is wasted on most readers. Instead, recognise that readers have varying levels of interest and technical knowledge, thus we should present information in a sequence of increasing technical difficulty. Humans are more likely to keep reading when they feel they are learning something useful, thus present useful information early. To effectively communicate you must write to be read 'breadth first', not read 'depth first'.

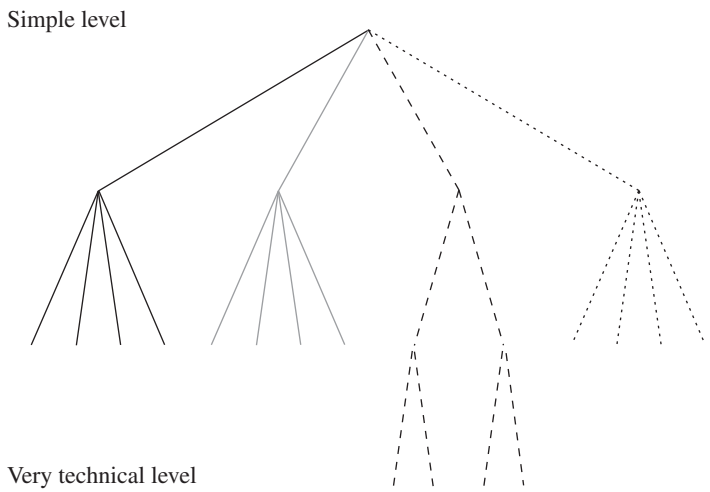

Figure 1. Simplistic schematic diagram of the tree of knowledge in your document. Each major topic you want to discuss is represented by a differently formatted branch, for example: black may be the background; grey, the development of an algorithm; dashed, the performance analysis; and dotted, some examples. The statements you may make will be at different levels of technicality using different amounts of jargon: put the simple easily understood statements higher in the tree; and the very technical statements redolent with jargon deep in the tree.

Consider the knowledge you wish to communicate in the schematic tree structure of Figure 1: technical statements are deep down in the tree; simple statements you may make are higher in the tree. Place a sort of ordering on the tree by having prerequisite knowledge to the left. This is a simplistic model of the knowledge

you wish to write about, but I believe adequate in many cases. Now, many people write in a depth first fashion: they set themselves the task to write about 'blah', so they write everything about 'blah'; then move on to the next topic and write everything about that; and so on for all topics in the document. Figure 1 represents each topic by a different styled branch. What does this style of writing mean for the reader? The reader:

- is rapidly enmeshed in deep technicalities about 'blah' as they are swiftly led deep into some very technical level material;
- has little idea where the discourse is going;
- gets nothing out of the document because of the difficulty discerning the main points among the multitude of details; and
- quits.

Instead, write breadth first. Write your information so it is read in the order of level of technicality as shown in Figure 2. First, in the title and abstract, a reader sees an overview of the entire document in plain language and including the results. Second, in the Introduction, overview the entire document again, but at a little more technical level. Third, the body of the document records the gory details. Conventionally we also place a conclusion at the end — such a conclusion is out of place in this structure, but nonetheless readers do like a recapitulation (recall that humans are not logical). And lastly, as indicated in Figure 2, appendices include any deviously technical material.

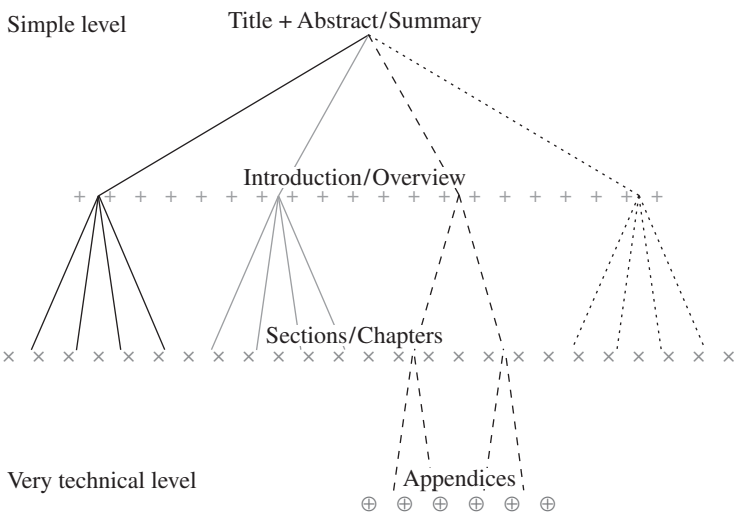

Figure 2. Allocate various parts of a document to the 'tree of knowledge' of your document so that the simplest set of statements overviewing your material is read first.

Urging you to 'write breadth first' is a misnomer; instead write so the document is *read* breadth first. Usually you will write the detailed technical parts, then winnow out of these the lower-level, jargon-free, introductory and conclusion statements to form the overview in the Introduction. Similarly the title and abstract are extracted as the plainest statements about the setting, your achievements, and how

a reader can use the results. Thus at any stage the reader will have an overview of what you are doing and why — readers will be empowered to place increasingly technical material upon the framework you have already constructed for them. This is the structure to keep readers interested in pursuing your efforts.

12. Teach explicit skills with feedback

I write having just come back from the gym: my biceps are tired from hammer curls, my lats from pull downs, my hamstrings from Smith machine lunges. In building strong bodies we *know* to exercise individual muscles. Sound programs of weight training build broad strength that then power us to play sport and live life. Why then do so many of us fail our students by simplistic 'teaching' of writing skills?

We mathematicians frequently pretend to 'teach' writing by the simple expedient of requiring an essay or two from the students. Such an essay may occur in a project course or a professional issues course. Yet requiring such an essay is not teaching; at best it evaluates the student's current writing skill, but often the marks for the writing are small, and the criteria vague. As John Hattie [10] reminds us, learning requires teachers to set appropriate and specific goals, and to give lots of feedback. In analogy with building strong bodies, I argue we need to improve our students mathematical writing with specific writing exercises and feedback focussed to build specific skills.

To further the analogy with body building, once a range of mathematical writing skills are built, we then ask the students to demonstrate these skills in a grand finale of an essay and/or report. Only then will we close the gap between our students' writing and employers' expectations.

> ... a significant gap exists between how ... students perceive and engage in academic writing and how they are expected to communicate, in oral and written modes, in professional situations and contexts.
>
> ... their skills set fails to meet many employers' expectations.
> Susan Thomas, 'Words are failing our graduates', *The Australian*, 14 July 2004

Teach for learning

Writing skills can be so complex we need to keep what we teach simple. After all, we need not aim to develop subtle nuances in writing such as rhyme and rhythm. Instead, surely it is enough to aim for simple, direct and open scientific writing. But nonetheless we want writing that interests the reader, holds their attention, and communicates ideas. Almost all students will improve their writing enormously with a range of simple writing tips.

This series, *The Style Files*, recommends important writing tips: prefer active writing to passive; clarify this; inform with titles and abstracts; avoid false conditionals; favour the present tense; omit redundancy; write what you mean; use informative synonyms; appearance affects communication; and write to read breadth first. In

addition, there are rules of grammar and punctuation to learn when writing with mathematics. All these tips can be learnt with accessible, short examples similar to those presented in this series. Journal and proceedings abstracts then provide a rich source of material for consequent summative assessment.

Also consider psychology. We all find it hard to dissect and critique our own writing. Surely then students need to learn and practice critical writing skills on other people's writing, on writing they do not 'own' and so are psychologically freer. My students happily critique the abstracts I give them from the CTAC and EMAC proceedings. After learning skills in the writing of others, students appear more able to evaluate and improve their own writing.

> Students have plenty of teaching on technical material. They need a break on something that connects them with what they will do when we let them out. Franklin [11]

Strategy

As Leigh Wood comments in last year's *Gazette* [12], we can teach such professional skills in either a stand-alone course, or as modules in others courses. I favour the latter to ensure most students meet the challenge of writing with mathematics as a professional. The brain learns quicker than the body builds muscle, but time and repetition are necessary to build strength in both body and brain for later life.

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