Preface

Reading research papers in mathematical disciplines takes training. A student's natural tendency is to read a paper from beginning to end in a depth-first manner. Every time they get stuck at a concept, they branch down another path, and then another, to the point where even getting through an abstract for a paper can take days and is exhausting.

Needless to say, this is not the best way to read technical material of any kind, mathematical or otherwise.

I have spent many hours explaining to my students how they should be reading papers, and if you're reading this and you have students of your own, you've probably done the same. While I don't claim to have the perfect method for reading any given paper, I've learnt over the years how to quickly skim a paper, flying over it and scanning the terrain as it were. I've learnt when to make a deep dive all the way to ground level, and when to resurface. And above all, I've learnt to distinguish the different reasons for reading technical material in the first place, and that each mode requires a different treatment.

I've looked all over the web for good material to give to students to learn how to read papers in (theoretical) computer science. I've found a few short articles here and there: S. Keshav's note on reading systems papers, Michael Mitzenmacher's helpful document, a page by Jason Eisner, and the many blog posts by Terry Tao, to name a few. There are also a number of good short articles on reading mathematics that I've drawn some inspiration from.

But none of these capture the essence of what I try to achieve in my reading and what I want my students to be able to do. It's a kind of Thurstonian ideal of understanding: where the proof falls away and what you're left with is a deep conceptual appreciation of how the parts of a proof (or a theorem, or a set of definitions) fit together, and what they really *mean*.

Moreover, if one is to *teach* the art of reading, it is important not just to describe the goal, but to find a way to get there: with exercises, little practices, and muscle-strengthening activities. This is after all the difference between teaching and showing.

That is my motivation for this collection of notes. It is my attempt to demystify and systematize a set of tools for reading papers. It will not be complete, and it will likely not resemble how you read papers. But hopefully it provides one way of getting to the promised land.

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Narrowing the scope

There is no one-size-fits-all strategy for learning how to read technical material. Indeed, even within computer science, one would read a paper in operating systems very differently to one in algorithms, or one in machine learning or even one in programming languages.

I make no claim to generality in these notes. I will limit myself to what I know: papers in algorithms (and theoretical computer science in general), with some side excursions to areas like data mining and machine learning that combine mathematical treatment with some empirical validation. I cover these other areas mainly because many of my students work on the border between theory and practice, as do I, and there's often a "intimidation by mathematics" effect that I hope can be mitigated by being better able to understand the mathematical elements of such papers.

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On Reading "with purpose"

But what is "reading with purpose" anyway ? We read for many reasons. We might read a paper to learn about a problem, or review it for a conference or journal. We might be looking for a particular lemma, or a proof technique. We might be using it as a reference for related work. And we don't just read papers. We read lecture notes, surveys, monographs, textbooks, short abstracts, and proposals. ==Each of these different media, and purposes, require a slightly different reading strategy. And I've found that even this realization is both surprising and important for students.==

And thus the title. The idea in this seminar is to be aware of the different reasons ("*telos*") a paper is written and read, and adjust one's interpretation of the work and strategies accordingly.

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On Reading And Writing

If you're reading these notes in an attempt to learn how to read papers better, be warned that as a side effect you might start *writing* better as well! Indeed, reading and writing are really two sides of the same communication coin. One of the most basic precepts in writing is: "know your audience". Once you have a good understanding of how to read a paper, and thus understand the reader (the "audience") well, your writing will inevitably improve as you seek to provide that which the reader wants.

On Persuasion

<div style="text-align: right">*1*</div>

For the purpose of exposition, I'll refer to any document that we read as a "paper" with the understanding that this includes research papers, surveys, theses, books, blog posts, lecture notes, and so on.

We typically think of a paper as a delivery vehicle for information. It has a list of theorems and proofs, and the goal of reading is to learn all the theorems and all the proofs.

But a paper does a lot more than that. It tells a story, often with the explicit goal of trying to *persuade* us of the relevance or significance of a concept or set of results. Given that most research papers in our field are submitted for review to conferences and journals, persuasion becomes possibly the most important factor in how a paper is written, and therefore becomes a factor in how it is read.

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§1.1   Why Should I Care?

When an author is trying to persuade the reader of the value of their argument, they're answering the question "Why should I care?" This is a useful way to think about all forms of communication, written or oral. And when you're reading a paper, even if it seems wholly neutral on the surface, there's always an undercurrent of persuasion (especially in a well-written paper).

Persuasion is not manipulation. The author-reader relationship is not adversarial. Rather, as a reader, you should think of persuasion as the author's attempt to construct a narrative of the work, emphasizing what they think is important along the way.

Think of a our guide taking you through a famous monument, highlighting what they think are the interesting aspects of the structure. The tour guide is not trying to "fool" you into believing the monument is interesting. Rather, they're making a judgment about what is the best single path through it from your perspective.

Similarly, an author is describing a body of work and their contributions and chooses a particular narrative to guide the reader, with the intent of impressing upon you the value and central ideas of the work. A different author might have made different choices and indeed you as a reader might have a different interpretation of the work. The key is therefore to make explicit the author's path through the work, evaluate it on its merits, and then (if appropriate) figure out if there are also other paths that are equally meaningful.

Types of Papers

There are many different kinds of technical documents one might come across in the course of doing research. These include

- Review/survey articles

- Conference/Journal papers

- Dissertations

- Textbooks

- Lecture notes

- Tutorials

- Explanatory notes/"pearls".

- Articles on the web (wikipedia, for example)

- Software documentation (rarer)

We read these for many different reasons. For example[1]

Type of material	Purpose
Review article	General sense of an area; a focus on the material rather than the researchers
Ph.D Thesis	More detailed explanations and self-contained
Lecture notes	Targeted at students; simple explanations.

Recognizing the kind of document you're reading and why is important. A conference paper is not the best way to understand background material, or even get a detailed explanation. But it might be the best way to quickly get a sense of the related work, or provide the seeds of a longer literature search.

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[1]This table comes from student feedback in the class.

Figure 1.1: The interaction triangle

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§1.2   Rhetoric

Rhetoric is often defined (and used) as the study of persuasion. We think of a politician's "lofty rhetoric" as a way to convince a pliant audience of their message. But rhetoric is really the study of the mechanisms of persuasion, and of communication more generally. And some of the basic concepts in rhetoric date back to Aristotle and are useful even today as a way to break down and categorize a text into its persuasive elements.

While the basic tools of rhetoric do not capture all the ways in which we read mathematical material (or technical material in general), they provide a useful foundation for talking about them. So let's dive into the key notions.

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§1.3   The Triangle

The way to understand communication is via a triangle of interacting entities. One obvious corner of this triangle is the author. And another obvious corner is the subject material. The third corner of this triangle is the audience. To understand the different components of communication, it is important to study how these three entities interact.
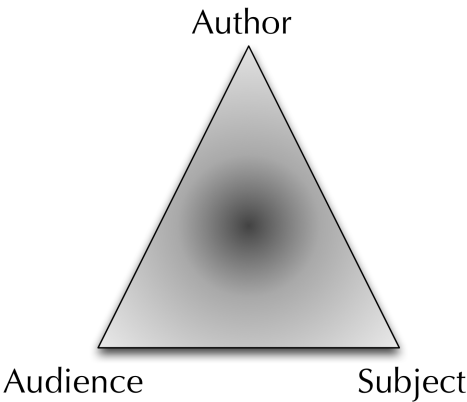
Author

Audience   Subject

Figure 1.2: The Triangle of Interaction

Badly written research papers tend to forget that the audience exists be-

yond the reviewer, and tend to be mostly an interaction between the author and subject. A campaign speech typically tends to be a performance piece between author and audience, and any sightings of subject matter are rare and furtive.

Associated with this triangle are different modes of persuasion, based on which corner of the triangle is the dominant mode.

Ethos

Ethos refers originally to persuasion via the author's credibility: a form of "You should believe what I say because it's me who says it". More generally, persuasion in a research paper that comes from *ethos* relates to how the author establishes credibility for their claims. One might think that the theorems and proofs by themselves should provide validation of the claims, but since proofs are never sketched out in sufficient detail in conference submissions, there are other more subtle mechanisms by which the author might signal "Trust me".

One of the most basic forms of persuasion is via **credentialling**. The author is at famous University XYZ and therefore their statements should be given higher credibility. More insidiously, there is much evidence for the phenomenon that researchers might get undue credit for work depending on their seniority / eminence or their gender: the former is known as the Matthew effect and the latter as the Matilda effect. Indeed, one strong argument in favor of double blind reviewing is to eliminate the persuasive power of identity.

Another indirect and common form of author-oriented persuasion is publication venue credentialling: "this paper appeared in prestigious venue X and therefore is worthy of consideration". Again, the paper is persuading you of its quality indirectly (without reference to the text itself). This is also a common phenomenon in research communities, with "top conferences", "high impact-factor journals" and so on. A related form of this persuasion is via citations, either for the paper or for the author.

Scott Aaronson has a post titled "Ten Signs A Claimed Mathematical Breakthrough Is Wrong"[2]. Items #1 and #7 are two more ways of (not) establishing author credibility. Item #7 says "the paper does not build on or refer to prior work". Citing a large body of work is a signal that the author is aware of and is claiming membership in a community of researchers working on a topic, and not doing so is often grounds for suspecting the authors don't fully appreciate the topic[3].

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[2] http://www.scottaaronson.com/blog/?p=304
[3] This is particularly common in conference reviews.

Item #1 says "the paper is not written in [La]TeX". While on the surface this seems awfully churlish (what's so great about LATEXafter all?), it is again a signal that the author does not conform to standard community norms.

A third way in which authors signal community membership and therefore credibility is by the use of jargon. For example, if I read a paper that refers to a graph S with k nodes and ℓ edges, I might be a little puzzled since I'd expect a graph to be usually defined as G, having n vertices and m edges. But more seriously, if the author insists on referring to edges as "pair representatives", I might find other claims in their paper a little harder to follow and trust.

Unfortunately, the converse of this causes most of the problems we see with bad writing. Namely, the excessive use of jargon to make a paper look "serious" and part of the group. While jargon is an efficient way to communicate terms in common parlance in a community X, it is also a big neon sign saying "See ! I know how to speak X", and it's easy to conclude that the more use of jargon, the more the sense of belonging.

Yet another to (not) establish credibility: proof-reading. A paper that is rife with typos, grammatical errors and other presentation issues is one that comes across as hasty, careless, and maybe not as serious as one that does not have these problems. This is why most researchers learn quickly to run spell-checks, do a number of proof-reading passes, and so on. The point is not that a badly written paper is automatically inferior; rather, it's that a well-written paper sends a signal about author competence that has a subtle effect on our perception of the work. See also the first three bullets of a blog post on "how to get your papers accepted" by Matt Welsh[4].

Logos

Logos refers to the content of the text itself. In other words, persuasion via *logos* is persuasion by reason, by using arguments in the text. This is how we expect research papers to persuade us: by reasoned arguments laid out in the paper.

Most research papers come with a hefty dose of persuasion by reason, as well they should. Theorems and lemmas have proofs. Implementations are backed up by thorough and hopefully well-designed experiments with statistical backing. Even proofs are often supported by intuitive explanations, special cases and examples. In fact, there is very little specifically to point out here: if a research paper doesn't have content, it really has nothing at all.

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[4]http://matt-welsh.blogspot.com/2009/12/how-to-get-your-papers-accepted.html.

Pathos

To complete the triangle, *pathos* focuses attention on the audience, and in particular the emotions of the audience. Persuasion via *pathos* attempts to convince the audience by playing on their emotions. While one might expect a research paper to avoid such persuasion techniques, they are all too common. After all, even if I establish that I have authority and that all my theorems are correct, how do I convince you that something is even worth studying ?

A simple way to convince an audience to have a positive emotional reaction is by conveying a sense of complexity and depth. This can be done by brute mathematical intimidation: the use of words like "trivial" or "obvious" or the infamous "it can easily be seen that...". The statements might very well be trivial or obvious or easily seen. But explicitly making these claims puts pressure on the reader to see it the same way or else feel a little inadequate[5]. Other methods include ways of signalling the richness of the topic being studied either by dropping names of famous people working on the topic selectively, or even by use of the phrase "well-studied" or "extensively studied".

Exercise 1.1. Take any paper from the most recent incarnation of your favorite conference. Limiting yourself to the title, abstract and introduction, find two examples of the use of *ethos*, *logos* and *pathos* in order to persuade the reader of the quality of the work.

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Perspective

The triangle described here is really a simplex. That is to say, one should not expect any rhetorical device to be exactly one of the above categories. Further, it is not my intention to present this as a game between adversaries ("find the rhetorical devices and remove them!"). Rather, this is merely an example of what might be called "close reading": being aware of conscious (and unconscious!) markers in the text that signal author intent: how *they* want to persuade you, and therefore how *they* think the work has value.

When we talk about reading papers for reviewing, this will become more important. It will then be necessary to understand the author's position and judge that, rather than interposing what we think the author should be writing about. But that's a story for later.

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[5] With a confident reader, this can often backfire on the authors, especially if said statements are not that trivial or obvious or easy to see.