How to Read an Engineering Research Paper[1]

Reading research papers effectively is challenging. These papers are written in a very condensed style because of page limitations and the intended audience, which is assumed to already know the area well. Moreover, the reasons for writing the paper may be different than the reasons the paper has been assigned, meaning you have to work harder to find the content that you are interested in. Finally, your time is very limited, so you may not have time to read every word of the paper or read it several times to extract all the nuances. For all these reasons, reading a research paper can require a special approach.

To develop an effective reading style for research papers, it can help to know two things: what you should get out of the paper, and where that information is located in the paper. First, I'll describe how a typical research paper is put together.

Despite a paper's condensed form, it is likely repetitive. The introduction will state not only the motivations behind the work, but also outline the solution. Often this may be all the expert requires from the paper. The body of the paper states the authors' solution to the problem in detail, and should also describe a detailed evaluation of the solution in terms of arguments or an experiment. Finally, the paper will conclude with a recap, including a discussion of the primary contributions. A paper will also discuss related work to some degree. Because of the repetition in these papers at different levels of detail and from different perspectives, it may be desirable, to read the paper ``out of order'' or to skip certain sections. More on this below.

The questions you want to have answered by reading a paper are the following:

1. **What are the motivations for this work?** For a research paper, there is an expectation that a problem has been solved that no one else has published in the literature. This problem intrinsically has two parts. The first is often unstated, what I call the **people problem**. The people problem is the benefits that are desired in the world at large; for example some issue of quality of life, such as saved time or increased safety. The second part is the **technical problem**, which is: *why doesn't the people problem have a trivial solution?* There is also an implication that previous solutions to the problem are inadequate. *What are the previous solutions and why are they inadequate?* Finally, the motivation and statement of the problem are distilled into a **research question**, the question that the paper sets out to answer. This might be more focused than the problem stated at the outset. Oftentimes, one or more of these elements are not explicitly stated, making your job more difficult.
2. **What is the proposed *solution*?** This is also called the **hypothesis** or **idea**. This is the proposed answer to the research question. There should also be an answer to the question *why is it believed that this solution will work, and be better than previous*

[1] Adapted from the document prepared by William G. Griswold, CSE, UC San Diego

solutions? There should also be a discussion about *how the solution is achieved (designed and implemented)* or is at least achievable.

3. **What is the work's *evaluation* of the proposed solution?** An idea alone is usually not adequate for publication of a research paper. This is the concrete engagement of the research question. What argument, implementation, and/or experiment makes the case for the value of the ideas? What benefits or problems are identified?
4. **What is your analysis of the identified problem, idea and evaluation?** Is this a good idea? What flaws do you perceive in the work? What are the most interesting points made? What are the most controversial ideas or points made? For work that has practical implications, you also want to ask: *Is this really going to work, who would want it, what it will take to give it to them, and when might it become a reality?*
5. **What are the *contributions*?** The contributions in a paper may be many and varied. Beyond the insights on the research question, a few additional possibilities include: ideas, software, experimental techniques, or an area survey.
6. **What are *future directions* for this research?** Not only what future directions do the authors identify, but what ideas did you come up with while reading the paper? Sometimes these may be identified as shortcomings or other critiques in the current work.
7. **What questions are you left with?** What questions would you like to raise in an open discussion of the work? What do you find confusing or difficult to understand? By taking the time to list several, you will be forced to think more deeply about the work.
8. **What is your take-away message from this paper?** Sum up the main implication of the paper from your perspective. This is useful for very quick review and refreshing your memory. It also forces you to try to identify the essence of the work.

As you read or skim a paper, you should actively attempt to answer the above questions. Presumably, the introduction should provide motivation. The introduction and conclusion may discuss the solutions and evaluation at a high level. Future work is likely in the concluding part of the paper. The details of the solution and the evaluation should be in the body of the paper. You may find it productive to try to answer each question in turn, writing your answer down. I recommend that you keep a notebook on all the papers you read, or mark-up the papers themselves. You could use my standard two-page form that you can fill out for each paper. In practice, you are not done reading a paper until you can answer all the questions.

Also, you should be aware of the context of the paper in relation to the other papers in the class. Often a paper will represent a generalization, new direction, or contradiction to earlier papers.

Taking time to write down *questions* you have about the paper will often surface thoughts that were not initially articulated. Perhaps the paper was vague on key issues, or ignored issues that you think are important. If you come to class with such questions, you are prepared to counter or preempt my own questions.

Reading a book is somewhat different. Although you want to answer the above questions for a book, it may not do the book justice given the amount of detail in each chapter. You may want to

fill out the above questions on a chapter-by-chapter basis, and then produce a summary form for the entire book when you have finished reading it. However, each chapter will have a particular slant that may make certain questions irrelevant. Also, a book is often not oriented towards explaining the solution to a research problem. However, engineering books are invariably oriented towards problem solving of one kind or another.

Advice on note taking. Although I have provided a form that can be filled out, I also advocate annotating the paper directly. The paper is a rich canvas on which to layer your thoughts. Here is how I suggest approaching the reading and mark-up process:

- Highlight important comments as you go. Using a highlighter, as opposed to underlining, can really help key sentences "pop out" at you when you return to review the paper later.
- Mark the important paragraphs of the paper according to motivation/problem, idea/solution, their evaluation, and contributions.
- On the front of the paper, write down the take-away message.
- On the front of the paper, or near the end, write down your key questions. Other questions may be written in the margins as you read.
- Try to answer the questions for yourself, as best you can. Use Google or other sources as appropriate.

Until you have been able to complete the above process, it is likely that you have not yet thought critically enough about the paper. A second pass over the paper is sometimes required to have it all come together for you. To help you further structure your reading and note-taking activities, you might want to follow this rubric, using it as a kind of checklist.