

1. Look carefully at the figures, diagrams and other illustrations in the paper. Pay special attention to graphs. Are the axes properly labeled? Are results shown with error bars, so that conclusions are statistically significant? Common mistakes like these will separate rushed, shoddy work from the truly excellent.
2. Remember to mark relevant unread references for further reading (this is a good way to learn more about the background of the paper).

The second pass should take up to an hour for an experienced reader. After this pass, you should be able to grasp the content of the paper. You should be able to summarize the main thrust of the paper, with supporting evidence, to someone else. This level of detail is appropriate for a paper in which you are interested, but does not lie in your research speciality.

Sometimes you won't understand a paper even at the end of the second pass. This may be because the subject matter is new to you, with unfamiliar terminology and acronyms. Or the authors may use a proof or experimental technique that you don't understand, so that the bulk of the paper is incomprehensible. The paper may be poorly written with unsubstantiated assertions and numerous forward references. Or it could just be that it's late at night and you're tired. You can now choose to: (a) set the paper aside, hoping you don't need to understand the material to be successful in your career, (b) return to the paper later, perhaps after reading background material or (c) persevere and go on to the third pass.

2.3 The third pass

To fully understand a paper, particularly if you are reviewer, requires a third pass. The key to the third pass is to attempt to *virtually re-implement* the paper: that is, making the same assumptions as the authors, re-create the work. By comparing this re-creation with the actual paper, you can easily identify not only a paper's innovations, but also its hidden failings and assumptions.

This pass requires great attention to detail. You should identify and challenge every assumption in every statement. Moreover, you should think about how you yourself would present a particular idea. This comparison of the actual with the virtual lends a sharp insight into the proof and presentation techniques in the paper and you can very likely add this to your repertoire of tools. During this pass, you should also jot down ideas for future work.

This pass can take many hours for beginners and more than an hour or two even for an experienced reader. At the end of this pass, you should be able to reconstruct the entire structure of the paper from memory, as well as be able to identify its strong and weak points. In particular, you should be able to pinpoint implicit assumptions, missing citations to relevant work, and potential issues with experimental or analytical techniques.

3. DOING A LITERATURE SURVEY

Paper reading skills are put to the test in doing a literature survey. This will require you to read tens of papers, perhaps in an unfamiliar field. What papers should you read? Here is how you can use the three-pass approach to help.

First, use an academic search engine such as Google Scholar or CiteSeer and some well-chosen keywords to find three to

five *recent highly-cited* papers in the area. Do one pass on each paper to get a sense of the work, then read their related work sections. You will find a thumbnail summary of the recent work, and perhaps, if you are lucky, a pointer to a recent survey paper. If you can find such a survey, you are done. Read the survey, congratulating yourself on your good luck.

Otherwise, in the second step, find shared citations and repeated author names in the bibliography. These are the key papers and researchers in that area. Download the key papers and set them aside. Then go to the websites of the key researchers and see where they've published recently. That will help you identify the top conferences in that field because the best researchers usually publish in the top conferences.

The third step is to go to the website for these top conferences and look through their recent proceedings. A quick scan will usually identify recent high-quality related work. These papers, along with the ones you set aside earlier, constitute the first version of your survey. Make two passes through these papers. If they all cite a key paper that you did not find earlier, obtain and read it, iterating as necessary.

4. RELATED WORK

If you are reading a paper to do a review, you should also read Timothy Roscoe's paper on "Writing reviews for systems conferences" [3]. If you're planning to write a technical paper, you should refer both to Henning Schulzrinne's comprehensive web site [4] and George Whitesides's excellent overview of the process [5]. Finally, Simon Peyton Jones has a website that covers the entire spectrum of research skills [2].

Iain H. McLean of Psychology, Inc. has put together a downloadable 'review matrix' that simplifies paper reviewing using the three-pass approach for papers in experimental psychology[1], which can probably be used, with minor modifications, for papers in other areas.

5. ACKNOWLEDGMENTS

The first version of this document was drafted by my students: Hossein Falaki, Earl Oliver, and Sumair Ur Rahman. My thanks to them. I also benefited from Christophe Diot's perceptive comments and Nicole Keshav's eagle-eyed copy-editing.

I would like to make this a living document, updating it as I receive comments. Please take a moment to email me any comments or suggestions for improvement. Thanks to encouraging feedback from many correspondents over the years.

6. REFERENCES

- [1] I.H. McLean, "Literature Review Matrix," <http://psychologyinc.blogspot.com/>
- [2] S. Peyton Jones, "Research Skills," <http://research.microsoft.com/en-us/um/people/simonpj/papers/giving-a-talk/giving-a-talk.htm>
- [3] T. Roscoe, "Writing Reviews for Systems Conferences," <http://people.inf.ethz.ch/troscoe/pubs/review-writing.pdf>
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- [5] G.M. Whitesides, "Whitesides' Group: Writing a Paper," http://www.ee.ucr.edu/~rlake/Whitesides_writing_res.paper.pdf