

Writing a literature review for MSc students

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These notes are based on several emails and discussions I was having with master students that I supervise through their literature review (which is a separate project done before the MSc Thesis). I noticed that many students struggled with the same problems, and that there is some confusion on what the objective is of a literature review, and how to approach writing one. Hopefully, the compiled tips down in this document will make it easier for others to successfully complete their literature review.

The objective of writing the literature study

In the literature review you do not present any new experiments by yourself. As a consequence, you will not suggest or design any new methods until, maybe, the future work section after your conclusions.

However, the review does have a scientific contribution! You create insight by putting a lot of existing published pieces together, and drawing interesting non-trivial conclusions from this overview (e.g. 'there are currently no real-time methods that are sufficiently accurate for application X', 'most methods assume rgb, but rgb+depth is relatively unexplored'). In the conclusion, you identify open problems, possible solutions, or unexplored directions from the reviewed papers, so your conclusions are supported by other people's observations and experiments. For instance, you can conclude that the assumptions of method do or do not hold for a new application domain, that no-one has explored a certain direction yet which appears feasible, or what exactly the requirements are for some future solution.

In the future works section it is good to give an overview of the problem and proposed method for the MSc thesis. This choice should be supported by the conclusions of the literature review.

Here are some important consequences from this insight:

- You cannot solve any new problems in the lit. review, since that would require testing hypothesis or comparing methods. You will do that in the master thesis later! For now, you need to reflect what others have done with respect to your literature review's Research Questions (RQs).
- Therefore, the RQs of the lit. review are different from the RQs of the following MSC Thesis! The literature Research Question seeks to understand what is known about the problem area, and what are still interesting directions to explore (e.g. 'What existing benchmarks exist for instance segmentation in IV?', 'How is temporal information used in existing methods?', etc.).
- The whole is more than the sum of its parts. The goal of the lit. review is to organize many pieces of info, put them together in an easy to follow manner, and draw insights from the overview. You create new knowledge from existing science!
- Your review is not a lab journal in which you chronologically list what you did. It should (eventually) be a consistent self-contained story where you guide the reader to build an argument to support your conclusion. Starting at the introduction, each chapter logically follows and contributes to that goal.

- The discussion/conclusion of the review is not just a summary of what you looked at: it's not an abstract. It is where you reflect back on the RQs from the introduction, answer them with what you have found out, or identify them as open problems.

Research Questions of the literature review and the thesis

- It is important to realize that when you write a paper, thesis, or literature report, you need to present a clear and logically structured text for the reader. The reader does not have your familiarity with the problem, nor with the direction that you want to go. So, each part should motivate the presence of the next part!
- Like any story, the review has three parts: a beginning (where you pose research questions), a middle (where you explore the research question) and an end (where you answer the question using the exploration).
- Note that a MSc Thesis would come after the literature review, so its beginning should follow from the literature review's conclusions! In other words, the thesis' Research Questions should logically follow from the future research directions identified by your review. In an ideal work, you are doing the literature review to first identify problems, boundary conditions, and actual Research Questions that you will explore in the thesis. In practice, you could actually be working 'backwards' from a rough research idea of a thesis to finding related work which validates that idea; just be ready to adapt the idea if the existing work seems to point to other approaches, or shows that your original idea has already been tested).
- To decide how much you need to explain in your review, It can help to picture yourself as a potential reader, but not your "current you", but the "old you" from before you started the literature review research. If the old you did not know the terminology, problems, methods of the papers that you discuss, then explain these in more detail.
- Sometimes less is more. A very good literature review is not a long list and description of papers, it is a document where the information is condensed to the most relevant differences, pros and cons of each method, or type of methods, proposed in the past. The reader should quickly understand the state of the art of the field from reading the literature review. For details s/he will read the referred papers.
- Published survey papers are a good example.

Research Questions for a literature review can be answered by digging through published material. For example:

- a) "What are the main approaches to object tracking in intelligent vehicles, has their performance been explored in fog, and what are the open challenges (if any)?"
- b) "What are existing Advanced Driver Assistance Systems in production, and what are the real-time performance requirements for on-vehicle sensors?"
- c) "What are the baseline methods and open problems in 3D object detection from LiDAR measurements, and what are the main methods for evaluation?"

Research Questions for a following thesis may result from conclusions in the review. These questions can be answered by doing experiments (maybe with to compare some new approach that you suggest to baselines). For example:

- a) "Can uncertainty bounds of object detections from multiple sensors be integrated in a JPDA filter to improve tracking robustness in changing weather conditions? How much does tracking quality improve?"

- b) "Which neural network architecture provides the best performance at 20 Hz on an embedded platform for depth estimation?"
- c) "How can we learn to estimate the 3D bounding box of vehicles from sparse point clouds from annotated disparity maps"

Structure of literature review

Once the review is complete, it should have a beginning, middle and end. Try to flesh out this structure early on in a rough form, so you can iteratively improve it through an integrated whole. Typically, the content of these parts is:

- a) Introduction: setup of the problem, background info.
 - Here you introduce the reader to the problem domain:
 - Why care about the problem?
 - Why is it a hard problem (without too much details, just the intuition or an example would suffice)?
 - You formulate the scope of the review for the reader by formulating the review's Research Questions that address the problem of interest.
 - Put here literally several questions that the review seeks to answers. Questions are not statements, so make sure that you put a question mark at the end of each sentence!
 - From the problem domain and research question, it should logically follow which areas of research ('topics') are relevant to investigate in the remainder of the literature review to answer the research questions. Introduce these shortly in the introduction, so you can explore them in depth in the next chapters.
 - A set of metrics, or features, that will be used to compare the different approaches should be stated in the introduction.
- b) Exploration of the topics (multiple chapters typically)
 - Which topics are relevant for the problem should be clear from the introduction
 - Each chapter presents a topic with a short introduction about the research area, but quickly starts splitting out in subsections (e.g. different types of 'pre-processing', 'design choices', 'methods', 'benchmarks', 'use cases', 'evaluation metrics' etc.)
 - The objective is that the chapter presents sufficient detail to understand the relation between the papers in the sections, what their contributions are, what general problems they are addressing. There should be sufficient detail for you to draw relevant conclusions to answer the research questions from the introduction.
 - You can think of this as a tree structure, as each subsection could have finer subsections/subparagraphs. However, not every branch in this tree needs to be worked out in the same detail! For instance, not all methods may be applicable or interesting to your problem, so not much detail is needed apart from shortly naming them and explaining why they are less interesting here. Think of the topics as in a Venn diagram, your problem probably lies at the intersection of different fields. Show high-level where you are in each field, but work out the depth only in the relevant part (the "centre of the Venn diagram").
 - A summary table where you compare the various methods will help clarifying the differences between them.
 - You may have sub-conclusions in each section.
- c) Conclusion
 - Here you loop back the research questions from the intro, and answer as much as possible using the insights from the previous sections.

- You also draw overarching conclusions from what you have found, and identify directions for future research and new research questions. If you cannot really give answer your questions with what you found, this may suggest future research. If the literature does answer the questions, you should have a good idea of the most promising follow-up questions.
- Ideally, the research question for the subsequent MSc Thesis is formulated here (though this is not necessary, the lit. review is a standalone project), together with the proposed approach (supported by the conclusion of the literature review) !

The process of writing the literature review

Writing a paper, thesis, or review is an iterative process.

- Initially you would just get a grasp of the scope and all possible ways to look at the problem. Therefore, form an initial high-level research question to direct this initial search ("What are the relevant research fields for problem x? Under what conditions can it be solved already? Which existing methods could be suited, and what are open challenges?"). Here you identify all the "circles" in the "Venn diagram", all the angles that could be taken on the problem, and see where they overlap.
- Then, you start to focus on the most relevant topics, possibly adjusting the RQs, and create a rough structure of the thesis. As you search for and read relevant papers, start sorting them in your structure and describe them with keywords and short sentences. You do not read everything into detail yet, maybe only some key papers that help you understand the others. For other papers, only read their abstract and quickly scan them to place them in your overview.
- When you have several papers in a section, make your sentences more descriptive to describe their relations, contributions, differences. Here you may need more papers in more detail (now you know which ones). You'll also find out if you need more references or background to properly explain certain terms, methods, assumptions.
- Over time, the sentences, paragraphs, and sections will get more detailed as your understanding, scope and story consolidates.
- During this process, you will probably go back and forth between reading papers and also finetuning the introduction, research question, and conclusions. Sub-section may turn out to be sufficiently large to warrant a separate section, while other topics may turn out to be less relevant than initially anticipated. Don't be afraid to re-order and re-structure, especially if you have not written large sentences and full paragraphs yet.
- The initial research questions may have been too broad, or too specific, or turn out to be irrelevant. Remember that you research the literature in order to answer the RQs! The sooner you get the research questions clear, the better you can select the correct topics to read and discuss. Similarly, if you notice that the work you are trying to discuss does not relate to your RQs, ask yourself what questions you are actually interested in answering. Refine and update the RQs in the introduction if needed. One way or another, the topics that you present must follow logically from the RQ in your final report.
- Note that some papers may be cited in multiple topics (e.g. both in 'methods' and in 'applications'). Maybe you describe the paper in more detail in only one section where it makes a bit contribution (e.g. 'methods') and only cite it the other ('Different methods have been applied to this application, such as X (see [p1,p2,p3]) and Y [p4,p5], ...")

How to search for relevant papers, and how to read them

Quickly scanning papers is an important skill that you will develop. It will become easier as you understand the problems and approaches better and better.

Even so, note that you do not need to understand all papers to the same detail! Some papers may only be interesting for a dataset that everybody uses, or because the conclusions come from a related field and are relevant (even though you do not understand the details of its equations). Other papers are directly related to what you want to figure out, so spent more time on fleshing them out.

Look for:

- relevant recent work (last few years) in major journals and conferences: these show the cutting edge and open problems
- relevant older work with many citations: these are the trusted baselines, benchmarks, and foundations on which others have build
- surveys and reviews on whole topics help your reader (and you!) a lot to get an overview. Also useful to refer your reader to areas you do not want to delve into any further (e.g. a survey on alternative sensors that are out of scope for your review)
- look at other work from others or research groups that did your most interesting papers
- once you start writing more details on the key concepts in each section/topic, you'll find that you will might clarify some terminology, baseline methods, benchmarks, etc., which will give you more references to include and explore.
- If you find a very relevant paper, you can check the papers that are cited it later on.

You can find many relevant papers in:

- Related work sections of the most relevant papers you already found
- Use google scholar to search for keywords (sometimes slightly different keywords yield very different results!)
- Use google scholar to find more recent papers that cited relevant papers you found (use 'cited by' below a search result)
- Some papers have videos as supplementary material, especially with computer vision, so sometimes searching on youtube is a quick way to see some novel results with little effort :-)
- For yourself, if you are not familiar with the basics of an area, you could also find useful 'for dummies' sources (tutorials, courses, books video lectures, wikipedia) that help you get an understanding of this area. For important mathematical concepts or introductions to unknown research areas, the links on wikipedia could be good starting points too.