

Writing a bachelor or master thesis with Thomas Bolander

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Contents

1	Before deciding to write a thesis with me	2
1.1	What to provide when contacting me	2
1.2	Types of projects I supervise	2
1.3	Choosing a topic and project	3
1.4	Group projects	3
2	During the project period	4
2.1	Supervision meetings	4
2.2	Project plan	5
2.3	A master thesis is expected to be a full-time job	6
2.4	A thorough literature study is essential	6
3	Writing the report/thesis	6
3.1	Length	6
3.2	Style of a thesis	7
3.3	Addressing the intended audience	7
3.4	Writing strategy	8
3.5	Formalities, intuition and examples	8
3.6	Defend your claims!	9
3.7	Citations and making your own contributions clear	9
3.8	Feedback on thesis drafts	9
4	Defence	10
4.1	Formalities	10
4.2	Presentation	10
4.3	Examination	10

1 Before deciding to write a thesis with me

1.1 What to provide when contacting me

You should include your **grade sheets**, so that I can see which courses you took and where your strengths and weaknesses might be. Due to my theoretical inclination and my expectation of receiving student theses with high theoretical and mathematical precision, I would normally expect high grades in the theoretically oriented courses. There can of course always be exceptions for various reasons, but it is important that the project you end up doing is well aligned with your expertises and strengths—no matter whether I or someone else end up supervising it.

There is no strict rule that you need to have taken any of my courses to be supervised by me, but it's obviously an advantage if you have done courses related to my research and expertise, so areas such as logic, symbolic AI, search, automated planning, social aspects of AI, cognitive robotics, neurosymbolic AI. For a master thesis with me, it will most often be ideal if you have completed both 02285 and 02287, as they together cover a significant part of the background of my own research.

When you contact me, please also specify what you yourself see as **your main strengths and weaknesses**, and what kind of project you would like to engage in. That can help me to suggest projects that are a good fit. For some students, it's important that the project is implementation-oriented, or at least has implementation as a significant component. Others prefer more theoretically inclined projects not necessarily involving any implementation. There might be many other factors as well, for instance your specific personal interests regarding theories and application areas of AI, or whether you're considering a research career afterwards (pursuing a PhD). These things can matter for choosing the ideal project.

Also make all the relevant details clear, such as **when you would like to commence your thesis** (which semester, possibly also a concrete starting date), how many ECTS you expect it to be and anything else that might be relevant for me to know. Make sure to check the Programme Specifications for rules regarding master theses on your particular master programme, <https://studieinformation.dtu.dk/english>. Here you can for instance find information about the possible number of ECTS of a master thesis and how this affects the overall duration of the master thesis project.

1.2 Types of projects I supervise

For any supervisor you might choose to work with, it makes sense to take a short while to check out the research of this person, to see if you seem to be aligned in terms of interests and style of research. A list of my papers can be found on my web page, <http://www2.compute.dtu.dk/~tobo/>. My web page also has a list of previous bachelor, master and PhD projects, but it is not always up to date. Probably the ideal way to get an idea about what kind of projects

I supervise, and what I expect from my students, is to look through some of my recently supervised projects. Go to DTU Findit, <http://findit.dtu.dk>, choose “Thesis” under Type, write “supervisor:Bolander” in the search field and sort by most recent.

I do both theoretical and practical projects, but I’m definitely leaning towards the theoretical side, or at least projects that include theory. It means that most of my papers develop new theory, usually involving mathematical definitions, theorems and proofs. I don’t mind supervising projects that have a more practical focus and implement existing theories or algorithms, but my theoretical incline means that I find mathematical precision very important. If you prefer something less formal and mathematical, you might want to consider whether I’m the right supervisor, as there might be a mismatch between your interests and my expectations. All this of course doesn’t imply that I’m not interested in projects that are directed towards practical applications.

The closer a project is to my own research, the more time I can dedicate to it, since then it might not only count as fulfilling my duties as a supervisor, but can also contribute to fulfilling my duties as a researcher. Projects that can potentially lead to publications are particularly attractive in this respect, though it’s naturally quite rare that a bachelor or master thesis leads to results that are publishable in respectable venues (but it happens). If you might potentially consider to eventually do a PhD, you should definitely try to do a project that has some research flavour and can in the best case lead to a publication (either within the project period itself or afterwards). If I’m a co-author, I’ll be happy to assist. If I’m not a co-author, I will of course still be happy to give feedback and general advice, but will not be able to dedicate as much time to it.

1.3 Choosing a topic and project

You don’t need to have a specific idea for a topic or project when you contact me, but it is of course fine if you have. However, as I get many requests to be a supervisor, I will generally turn down supervision of projects that are not relying on my specific expertises. For instance, a project that *only* involves deep learning and no symbolic AI and no robotics could be better supervised by someone else who is specifically an expert on deep learning. If you’re uncertain about my specific research expertise, have a look at my papers as also suggested above. As I’m very interested in neuro-symbolic AI, I can of course supervise projects that *also* involve deep learning (say), but it just makes more sense for me when it’s deep learning combined with symbolic techniques.

It’s also completely fine for you to approach me without any specific topic or project in mind, and then I can try to suggest some potential projects based on my current research.

1.4 Group projects

I generally encourage students to work in groups of 2 or even 3 whenever possible. This will give you more resources to do an interesting project, and you

will have the advantage of being able to support each other, since you probably don't have exactly the same strengths and weaknesses, and hence don't get stuck on exactly the same things. However, I'm also OK with supervising single students, as long as you're aware of the expected independence (see more under Section 2.1 below).

2 During the project period

2.1 Supervision meetings

Meeting frequency I rarely have weekly meetings with students. I tend to be busy and supervise many students, and if I had weekly meetings with everybody, I would have very little time left for research. Meetings with me are usually on demand. This means that when you have something interesting to show me or you get stuck and need help to progress further, you can write me by email and set up a meeting.

Independence I generally expect a relatively high degree of independence from my students. I'm of course fully aware that more independence can be expected from a PhD student than a master student, and more from a master student than a bachelor student, but I still see all types of projects as a chance of learning to work more independently and get some experience with independent research. The best projects are usually the ones where the students take ownership and try to work on their own ideas and find their own way. It might still be a project where I have come up with the overall idea, for instance based on my current research, but it's best if you can take the project in your own direction and make it your own. This said, there might of course be cases where it is not so easy for you to take ownership and work independently, and then I will of course try to help.

Weekly status reports (optional) Sometimes it can be a bit hard to ensure progress in a project when not having regular meetings with a supervisor. If you feel that might potentially be true for you, I propose that you every Friday send me an email with a short status report on what you have done during the week and what you plan to do next week. This is actually more a tool for you to ensure progress than it is for me to keep track of you, but in my experience it can still work quite well (I've done this myself as a student and assistant professor).

Preparation for meetings Make sure to prepare for your supervision meetings. It is very good to start out with you showing your progress since last we met. The most professional thing is to do a small slideshow presentation, but that might of course be irrelevant or overkill in some cases. A crucial point about the supervision meetings is for you to get feedback on your progress, but also on your doubts, problems or questions. Make sure to spend some time

reflecting on your doubts, problems and questions before the meeting, so that you can present them clearly and precisely (and so that you know that they are not things you can easily solve yourself). This will make it easier for me to help you, and it will make the meeting more efficient (given how many things I'm engaged in, I need to focus on making meetings efficient).

2.2 Project plan

DTU now requires that all master students submit a project plan within the first month. There are no specific requirements except “outlining the objects of the thesis” and “taking into account the overarching learning objectives listed under ‘The content and the learning objectives of the thesis’.” (see the Programme Specifications for your master programme for details). In general, it plays the following roles:

1. **Alignment of expectations between you and your supervisor.** Hence, it should clarify what you plan to do in your project, what goals you plan to achieve, and how you plan to achieve them. Here it is quite important that you explain your plan in sufficient details to make it clear that the project is feasible. It's not enough to say that you want to, say, apply technique X to problem Y if it is not at all clear how to do that, or if it is not clear whether that is even possible (within the limits of a master thesis).
2. **A tool for you to keep track of progress.** If you make a fairly detailed plan, e.g. using a Gantt chart, you can also use this during the project period to detect whether you're on track or not. If not, you should probably adjust the plan. Such a plan can be good to create an overview of what has to be done, and avoid unnecessary stress towards the end of the project from not having a clear idea of what is left to do.
3. **Clarify goals vs success criteria.** Your goals can in principle be arbitrary ambitious, but your success criteria can't. So while your goal might be to prove $P \neq NP$ or develop AGI, then since that might not be feasible, you need to have some more realistic success criteria that you *know* you can achieve. In many cases it would mean that you first do something “easy” like implement something that exists or describe or compare existing theories. This should then be sufficient to count as a successful thesis (you can of course discuss this with your supervisor before handing in the project plan). You can then in addition have more ambitious goals that are what you'd really like to achieve in the project, but where success might not be guaranteed, e.g. develop a new method for X.

As there are no specific rules or conditions, it is a bit up to you to decide on the specific format of the project plan. But try to think about the above points when you write it.

2.3 A master thesis is expected to be a full-time job

As stated by DTU officially, writing a master thesis is supposed to be a full-time job. I strongly recommend to not work on the side while doing your master thesis. If you have student work for a company, consider asking them to be on leave while writing the thesis. And if this is not possible, then maybe at least for the last 2 months of the thesis period. It is your last chance to grow academically during your studies, and writing a good master thesis is very time consuming. It should also be in the interest of your company that you develop academically and deliver a good thesis, I think. You might of course be forced to work for financial or other reasons, but then at least try to keep it minimal. At the very least, your master thesis should take precedence. Another reason to do full-time work on the thesis is that it is well-known that the greatest ideas come from doing deep work, and deep work usually involves focusing deeply on just one thing for an extended period of time. That said, life always put various demands and constraints on us, which is of course understandable and acceptable. But at least try your best to make the “boundary conditions” for the project period as good as possible.

2.4 A thorough literature study is essential

The ideal master thesis presents novel ideas and results. To make sure that what you do is novel and doesn’t already exist, it’s important to do a thorough literature study in the beginning of the project period—and maybe keep an eye out throughout the project period as the project develops and it becomes increasingly clear what to search for and how.

A good place to start is to do a number of searches in Google Scholar using relevant combinations of keywords. Sometimes getting the right keywords can also be difficult, but try your best. If you find a paper that seems central, but maybe not very recent, use Google Scholar to search for papers that cite it, since then it’s likely that the newer papers on the same topic will have cited it.

One can also try to explain the overall topic and ideas to a large language model (LLM) and see what it suggests.

It can be a good idea to specifically look for surveys papers or slides from tutorials, as these would be sources that try to give an overview of what already exists on a topic (so consider to include “survey” or “tutorial” in your search terms in the search engine). If you are planning to implement a system, also try to look for existing implementations that might be related to what you want to do.

3 Writing the report/thesis

3.1 Length

A bachelor or master thesis should rarely be more than 50 pages long. I would by default aim for 30 pages for a bachelor thesis and 50 pages for a master

thesis. If it's joint work between several students, it can be a bit longer, but usually not more than 60 pages, and definitely never more than 70. Quality is rarely about length. A concise, precise and well-structured report is usually way better than a long and verbose one. You can consider research papers for inspiration. These are usually relatively short, since journals and in particular conferences have quite strict page limits. A 6 page paper in a top AI journal could still easily be the result of a full year of research, so it's a lot of ideas compressed into very little space. Bachelor and master theses are not supposed to be *that* compressed, they are supposed to be accessible to a wider audience, but still, conciseness is a huge value in research. Try to be as mathematically precise as possible, that also often means using less space.

In comparison to research papers, a bachelor or master thesis would usually spend much more space on describing the background, i.e., the ideas and theories that your work relies on. In a research paper on e.g. automated planning or reinforcement learning, one probably expects the reader to be in the same area and the paper would be very brief in introducing the required notions and definitions. In a bachelor or master thesis, the intended audience is assumed to be wider, meaning that you should spend more space on carefully introducing the notions, definitions and theories that your work builds on (see also Section 3.3).

3.2 Style of a thesis

A thesis is supposed to tell a nice and coherent story about your project. It's not a software documentation report or similar where the coherence and quality of writing might be less important. You should take the reader by the hand and guide her through your project, from the initial ideas and research questions to the final outcomes and ideas for future work. It's important that the thesis has a natural flow, where each chapter and section leads naturally to the next one.

3.3 Addressing the intended audience

It's very important to reflect on your intended audience. The reader is normally expected to be one at a similar level as yourself when you started working on the thesis. But in some cases, the expected level of the reader could be higher, e.g. if the thesis is supposed to become a research paper, then it might be directed towards the experts in the field. In any case, make sure to clarify in the thesis who the expected reader is, and try to always be aware of this expected reader when you write it.

Writing for the intended audience Writing for an intended audience means trying to put yourself into the shoes of the intended reader whenever reading through your drafts. For each single sentence you wrote, ask yourself: Is this sentence sufficiently clear and precise for the intended reader, and will it be understandable by the intended reader at this point in the thesis?

Avoid repetitions You should expect that the thesis will be read in its entirety from the beginning to the end (perhaps except for the appendix). This means that you should avoid unnecessary repetitions. If something was defined or explained in Chapter 1, don't define or explain it again in Chapter 3. You can of course refer back to Chapter 1 to help the reader, e.g. write "(cf. the definition of X in Chapter 1)".

3.4 Writing strategy

It's usually a bad idea to start writing the thesis at the very end. Try to get into the habit of at least writing fairly detailed notes throughout the project period that can then later be turned into parts of the thesis. You can for instance start up a latex document already initially that will eventually become your thesis, but where you in the beginning only try to write structured notes about your ideas and thoughts and findings. If you for instance start out with a literature study, you would here put down notes about each paper in something that can later become a background chapter of the thesis.

Iterate! Often a thesis can become significantly better by going through several iterations. So don't worry too much about the first version you write, it might lead a lot of open ends. Just make sure to add todo notes to yourself of what is missing or unclear and has to be fixed later (e.g. add these notes in another color or use the `todonotes` package in latex). A comment could e.g. be "TODO: I'm here using the notion of a policy. Make sure this notion has been defined before this point." No matter how careful and thorough you are, it's unrealistic that you can write a perfect thesis in one iteration, so it's best to rely on iterating in any case. Every new read will also reveal new things that can be improved.

3.5 Formalities, intuition and examples

It's important that all your concepts and ideas are clearly and precisely formulated, but also that you provide the underlying intuition behind each introduced concept. This usually means that you should (mathematically) define each introduced concept, and that you should also exemplify it. If you're e.g. using graphs, you should first define them (in a definition environment in latex), and then later you can exemplify the concept by saying "Consider for instance the graph $G = (V, E)$ given by..." (in an example environment unless the example is very short). Figures are also usually important to support intuition. If you talk about state spaces, provide a figure showing a concrete example of a state space, and if you talk about solution paths in such state spaces, highlight a path as an example. If you struggle with defining a concept in a sufficiently mathematically precise way, examples can also help to show what the intention is, even if the definition has some weaknesses or flaws.

Define before using Always make sure to define concepts before using them. So never start talking about graphs before having defined them—unless you assume the notion of a graph to be already known by the intended reader, but then you should still either remind the reader what it is or cite a source that defines it (e.g. a suitable textbook). If you use abbreviations or acronyms, like DAG or MCTS, then also make sure to define them at their first occurrence. For instance: A *directed acyclic graph* (*DAG*) is defined as...

Running examples It is often nice to work with a running example. You might start out with a simple version of it, and then build on top of it as you introduce more and more concepts allowing you to analyse the example more deeply. You should normally come up with your own example(s) rather than copying from the existing literature. This is in particular important for theses that don't include any original research, as it's then important that you show that you can present your own version of the existing research and still contribute creatively to it.

3.6 Defend your claims!

All claims made in the thesis have to be supported/defended. If you e.g. say “in recent years, AI has come to focus more on X”, then you need to either explain your evidence for this claim or cite a source stating it (an existing publication).

3.7 Citations and making your own contributions clear

It's very important that the thesis makes it clear which parts explain existing work and which parts are your own contributions (if any). For existing work, make sure to use citations. So if you for instance introduce a particular existing algorithm, make sure to tell the reader where it comes from, e.g. “The algorithm X was introduced in [Y, 2020]” (use bibtex or similar to manage your references). Similarly for definitions, for claims, etc. (cf. Section 3.6). The main point is that the reader should always be able to see the sources of your information, when you present existing work, and also be able to understand when something is your own contribution, like: “Below, we generalise algorithm X into algorithm X' in order for it to handle problems of type Z. Algorithm X' is one of the main novel contributions of this thesis.” In some cases, you might want to use an existing definition or concept but change it slightly to fit your needs. This also has to be made explicit, e.g. “Below, we define the concept of X. This concept was originally introduced by Y [2020], but we here rephrase it slightly to fit our context, more precisely, we ...”.

3.8 Feedback on thesis drafts

Unless otherwise agreed, you should send me a draft version of the thesis exactly halfway through the project period (so start out computing the exact date). I will then give you feedback on this in terms of style and content. You will

obviously not have a full thesis at this point, maybe you will mainly have the background stuff, and not so much of the (potentially) novel stuff of the thesis. However, it can still be very helpful in terms of aligning expectations between you and me. I can for instance let you know if I feel that your writing is not sufficiently mathematically precise, if you don't have enough examples or figures, if there's not enough intuition, or whatever it might be. But of course you should still from the outside try your best to follow all the advice given in this document.

I normally only offer to read one draft of the thesis, and never a final one. It makes sense to not give feedback on a final or near-final draft, as there needs to be chapters where I can tell the external examiner that it's exclusively your own work. However, I can of course still give feedback on specific parts you might be in doubt about, e.g. specific paragraphs, definitions or examples.

4 Defence

4.1 Formalities

A bachelor or master thesis defence starts with a presentation by you, with slides. This can be at most 30 minutes long, possibly including a demo (if you implemented something that would be relevant to demonstrate). Sometimes bachelor presentations are a bit shorter, 20 minutes. The following examination will then be 15-30 minutes long, followed by up to 15 minutes for grading.

4.2 Presentation

The most natural place to start is to say something general about the project, its purpose and scope. Then afterwards you can dig into some of the more technical stuff, but you probably can't cover everything, so pick the stuff that you think is most novel, original and/or you are most proud of. And if you had some thoughts or progress after handing in, you can also include that. It's also often relevant to shortly describe the process of the project: where you started, what happened during the project period, any possible change of direction during the project. If you've found errors in the report, mention these in the presentation rather than waiting for us to ask questions about them in the examination.

It's advisable to practice the presentation before the defence. You can either record it and see it yourself afterwards to learn from it, or you can try to see if some of your fellow students would be willing to attend your rehearsal and give feedback.

4.3 Examination

Make sure you can defend anything written in your reports and can clarify all the theory you build on. You should reread your thesis as part of the preparation for the defence. When you do so, try to put yourself in the shoes of an examiner. Are all your statements clear and precise? If not, how would you make them

clearer? Can you explain every formula and concept introduced in the thesis and can you defend any claim you made?

Questions asked can be everything from very detailed questions like “what does α mean in formula (5) on page 37?” to very general questions like “what is the scientific or societal value of your contribution?”. You can also prepare a bit for the latter type of questions by trying to think about your master thesis in a broader context and which value it has, from a scientific, societal or industrial or whatever perspectives are relevant.

Make sure to have the thesis report ready on your computer, if you get questions about specific details in the report.