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How to write a Master thesis

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There are several ways to write a good report, so this document should only be seen as one possible example/recommendation.

1. Essay

The essay is a short version of the final thesis and is typically about 10 pages long. It might naturally be reused for the intro chapter and for parts of the background chapter of the final master report. All aspects of the master project should be discussed in the essay including intro to the problem / application, relevant methods and technologies, what has been done before and a last part (1-2 pages) with your own ideas on how to address the given master project.

An important feature of the essay is that the supervisor(s) see that the student has a correct understanding of the problem and the techniques to work with in the master project. Therefore, it is natural that there will be a revision or two based on feedback from the supervisor(s). The deadline for submitting the essay is no later than June 1 in the second semester of the master program, so it is beneficial to get started with the essay already at the start of the second semester.

Another motivation behind the essay is too early in the master study gain experience in writing. Often writing a "long" master thesis is a demanding process to get started with. So, it is desirable to continue writing on the thesis throughout the master study to reduce the effort needed in the end. If one makes it a habit to write a few lines summarising relevant articles one comes across (which one is likely to refer to in the final report), it saves work later for re-reading the article again or wondering about what was the most important in an article when the report is to be completed. This is because we would normally put a little bit more effort into understanding what we are reading when we are going to document it in the computer than only keeping in it our own head.

2. Structure of the Report

A Master´s thesis can, in many ways, be seen as an extension of a regular scientific article (from a journal or conference). The same sections would have to be included but extended and with more details. It can be beneficial to prepare a skeleton of the report quite early (with the section titles below as a starting point). Keywords could be included for details to be filled in later.

This is beneficial for reducing the possible writing barrier, which otherwise can quickly becomes large if one starts at page one to write a complete report in one go. Use *present tense* as much as possible throughout the report (e.g. “the system consists of…” rather than “the system consisted of…”).

Summary / Abstract
The report should always start with a brief *summary* of the entire master project. It describes the main methods and results and the main conclusion. Don´t wait until the end to write it, since it is the first text to be read about the project and important that it is easy to understand.

Table of Contents / Table of Contents (TOC)
This is automatically generated by the text editor program. It is common that the introductory pages are numbered with Roman numerals while starting on page 1 of Chapter 1 (Introduction).

Foreword / Preface
This is the place for "informal chat" like how the master thesis task has progressed and acknowledgement to those who one feels for thanking. One can also include what kind of software that has been used in the master thesis work. Some choose to have the foreword before the TOC.

1. Introduction
This should include a relatively brief overview of themes addressed in the master thesis and finally an overview of what the various chapters of the report contain. You can also include fundamental requirements and goals for the system to be designed. It is also relevant to summarise the most important contributions of the work here to make it stand out better than only “hiding” it in the last part of the thesis.

Including 2-3 *research questions* is common to make the reader better understand what the thesis is about. These are often formulated when the thesis is almost finished rather than at the beginning of the work. They should be followed up in the *Experiments and Results* chapter by a discussion of to what extent and in what ways the work has answered them.

2. Background
Here is a list and description of previously undertaken research that is relevant for the project. Details are included to the extent that they are important to understand for what comes later in the thesis. Presentation of the work of others should as far as possible be organised by and/or classified by similarities (technology, methods, applications, etc.). Thus, it is good to highlight the similarities / differences between works in the text, so the reader as far as possible can get an idea of the overall picture of past work (rather than listing and describing them independently).

The level of detail must be adapted to the need for the knowledge when one reads about your own work later in the report. For a reader, it will only be frustrating to read and understand a lot of background that it is not relevant for what follows later in the report. For example, if you are going to learn to drive a car, you do not need detailed knowledge of the structure and function of the car's engine.

The purpose of this section is twofold. Firstly, it provides the examiner with an understanding of the theory if he/she does not already know it. Secondly, and equally important, this part shall demonstrate to the examiner that you have understood the theory correctly. This is important to get the confidence that the subsequent proposed methods and experiments are conducted in accordance with existing theory.

It is fine in the master report to include figures from others' work if one includes a reference in the figure caption. However, one should not use literal transcription (copy–and–paste) of others work (books, articles, web ...) but rather express it with your own words (preferably easier to follow than the original text). Comments on weaknesses of others' work could be included here, but you should normally not bring in own theories and suggestions in this section. This is because it is very important that own work is clearly separated (normally in a separate chapter) from the work of others.

3. My new methods (use a title that is descriptive, for instance "Robot Brain Implementation"
In this part, it is important to have a thorough description to describe both *what* is implemented and *why* it represents progress in research. Many are often too modest here and fail to clearly express the novelty in their work and in what way it can represent progress beyond state of the art research.

In principle, it should be possible for the reader of the thesis to copy your implementation and get the same results in experiments based on the report. All descriptions should also be "top down" with a focus on the “big picture”. It means first presenting the design at top level by a block diagram so that the reader easily gets an idea of the main structure of the designed system/method. Then, the details are presented in an appropriate order. This is very easy to forget when you are deep into the material to be presented! This applies to the whole report. Further, each chapter can preferably start with a few sentences about what the chapter is about.

If the master project is about inventing a vehicle that you call a "car", then you have to start by explaining that the car has four wheels controlled by a steering wheel and driven forward by a motor. The explaining text should preferably be accompanied by an illustration showing how it looks and is assembled. After

the initial overview, you can gradually get into details, including the behaviour of the engine, gear system, etc.

Be sure to be consistent with the concepts. If you have defined a unit in the system to be called "something", so stay with that name when you refer to it later in the report. Anything else confuses the reader and makes it difficult to keep the overview. "A picture expresses more than 1000 words", and this certainly applies to a scientific text too. The one doing research should try to abstract away details that are not necessary to understand the structure of a design (lower level details can be put in an appendix). The reader should e.g. not need to understand the code in the program you have written, but only the principles behind what is implemented. Code may nonetheless be appropriate as an attachment in an appendix to show the extent of the work and be beneficial to students who follow afterwards and want to continue the work. Results–including measurements–should not be included in this chapter but follow in the next.

4. Experiments and Results
Start this section with a table or list of the different runs that have been made. Be sure to refer to exactly what architectures etc. being used for each if multiple options from the previous chapter are applied. Here, cross-referencing back to sections in the "My new methods" chapter could be important to make the reader know the link between methods and experiments. There must also be a discussion of the results. It is beneficial if the experiments build on each other so that experiences gained from the first lead to improvements in the one following. Finish the chapter with a discussion of how well the implementation (based on results from experiments) meets the original requirements / goals of the system / research questions in the intro chapter and possibly also discuss if the results represent an improvement compared to earlier work.

5. Further work / Future work (can also come after the conclusion)
This part contains the ideas that have emerged in the last phase and which one have not had time to implement and/or test (that could potentially lead to further improvement).

6. Conclusions
This chapter summarises methods, results and main conclusions. It resembles the summary at the beginning of the report, but the conclusion is usually a bit longer and more thorough. Normally, no new information is included in the conclusion, but only contains an extract of what has been described earlier in the report.

Appendix
Here follows whatever was too detailed to be included in the report itself. Circuit design files, program code, etc (should be limited in number of pages). The examiner does not normally read this, but rather flip through and take a quick look. A zipped file with programs etc can be submitted together with the report to DUO and also be sent to the supervisor. In that case, the report could preferably contain an overview of the content in the appendix and attachment**.**

References
This is a list of the articles / books one has referred to in the report. It is desirable that each is as complete as possible with minimum: author (s), title of article / book, the title and number of the journal or name (and abbreviation) of the conference and year for all types of publications. Look at the reference lists of articles you have for examples. Reference to web pages is OK if there are no articles to refer to. It is in that case beneficial to include the date when the page was read. The appearance of the references in the text is either only numbers [3] or the first author(s) in one form or another like [NOR04], (Normann, 2005). The first variant is most common in articles, while in reports all variants occur. If more than two authors, use "<first author last name> et al.". References containing authors is more understandable and requires fewer lookups in the reference list when reading. The reference list should come last in the report, so it is easy to find for lookup when reading the report.

3. Various things to consider regarding the report

3.1 Unambiguous concept definition

When something (for example an expression) is defined / explained in the report, the explanation should not be repeated later in the report. If it is far back to the first explanation, it is beneficial to have a reference to the paragraphs (or equation) in which it was defined. One can possibly later in the report add more details about an expression but then it is particularly important to refer to the earlier introduction of it (otherwise the reader will easily get confused and wonder if the same topic has been explained earlier). Chapters and subsections must have numbers assigned to them for effective reference (eg. see section 3.2). Make it easy to find a referred topic by referring to sections of max ½-1 page long. Thus, one should not make each numbered section longer than that.

It is also necessary to use consistent wording throughout the report. For example, do not use computer, laptop, PC, .. interchangeably but choose one of them. All acronyms (eg. FPGA) must be written out completely at their first use and also explained unless they can be assumed to be well known. Don't use acronyms in the title of the master project,

3.2 Readability

Fig/table referencing: Figures and tables must also have numbers and be referred to in the text (for example, Figure 8 shows the architecture ...). The text shall also be pointing out what is interesting in figure / table. If one fails to do so, the reader will easily just skip the figure / table.

Fig/table font-size: Figures and tables are a part of the report, and text in them should match the text size of the main text of the report. Thus, any text in a figure should not be smaller than the figure caption text.

Cross referencing means that you refer to some section following later (forward referencing) or earlier (backwards referencing) in the thesis. Forward referencing is commonly used e.g. in the background section if a number of different techniques are introduced but just one is applied later in own work or if you mention a concept that later is more commonly described. Backwards referencing can be relevant in the experiment section to refer back to in what section the various methods tested have been described.

Avoid personal style. For the text of the report to have a scientific form, it is necessary to limit the use of personal words (I / my). Too much use of personal words will draw the attention from the work to the person who writes the text. A rule of thumb can be not to use I more than what one can count on one hand (5) throughout the whole thesis (only when important to state that you talk about your own work and challenges etc). *We* should be avoided completely unless you have performed some implementation or experiments together with one or more other person. Similarly, *you* should not appear in the text at all since it is very risky to make assumptions about the reader.

Sections in the report. The section hierarchy and numbering bring structure to the report. It is important that the hierarchy helps the reader getting a logical overview. E.g. if you are both presenting some supervised and unsupervised learning algorithms, they should be put in separate sections rather than in a single section with mixed ordering of the algorithms. At the same time, when the number of subsections exceeds about five, it starts to get hard to follow (e.g. 3.1 – 3.5). Thus, consider introducing another level to avoid that (e.g. 3.1.1, 3.1.2,…- 3.3).

Avoid unusual words. Limit the use of obscure English words (especially if you write in English). This can reduce the understanding and result in a negative effect if the text is not otherwise crystal clear and completely without typos. One wonders then whether the words have been included only to impress, without perhaps the author understanding them.

Comma rules: An independent clause (Norwegian: hovedsetning) that comes in front of a dependent clause (Norwegian: bisetning) does not normally result in commas in English while it is common in Norwegian. **If a dependent clause precedes an independent clause, you should use a comma also in**

both English and Norwegian (like in this sentence). This is important to avoid the reader losing track of reading the text and as such, the rule I regard as most important to apply in written text. Example of comma rules here: http://www.grammarbook.com/punctuation/commas.asp

Emphasising. In some sentences, one (or a few) words is essential for understanding. Then, you can help the reader by highlighting (using Italic formatting) just this word. E.g. "The system is designed to *control* the vessel."

There should be space before parenthesis text (...) and references [3].

3.3 Norwegian or English? (only relevant to Norwegian students)

The advantage of the Norwegian language is that it often is easier to write (for Norwegians), while it may also require some effort to find Norwegian words for English terminology (or just deciding on the selection between English or Norwegian terminology). Also note that in English it is common to divide words into two, which in Norwegian is written as one word (e.g. application areas are *anvendelsesområder* in Norwegian).

English makes it easier to use the text directly in international publications. Publications are a strength for the master project and also increases the chances for PhD scholarship (doctorate). The ROBIN-group has an arrangement for co-financing students who present an article at a conference.

3.4 Proofreading

If the text contains clearly visible typos and grammatical errors, it lowers the impression of both the report and the work described. Unfortunately, LaTeX editors normally don´t provide much help on this so you should use additional tools. Word is able to check both single words and grammar of sentences to some extent. However, among the best tools available seems to be Grammarly where the free version is OK. It will also detect if you use some words too often. It works on Word file, so convert the pdf file to Word format first: https://smallpdf.com/nb/pdf-to-word

3.5 Word or Latex?

It is largely Word or LaTeX being used today to write theses. Both have their advantages and drawbacks. LaTeX has a high threshold for first-time users. However, if one has learned to use it, Latex is mostly better than Word. This is especially true regarding automatic numbering / placement of paragraphs, figures, tables, references and more. In a long document as a master report, this is beneficial. Word, on the other hand, is easier to use and has better spelling / grammar check than emacs or similar normally used for Latex. If using Latex, it may be beneficial to check the text in Word to remove typos and grammar errors (tex-files can be opened and saved in Word). Recently many writing in LaTeX use Overleaf.

3.6 Take Backup!

Today, power outage does not represent the greatest danger of losing data, but that one makes a major change in the report with cut-and-paste, which later turns out that one regrets but fails to undo. Copying files between the hard drive and the network is also risky, if one works on files in both locations. It's easy to quickly click "yes" to something that later turns out not to be such a good idea. Therefore, it is important to backup files regularly (or use the file utility that CVS, GitHub etc), so that one has something to return to when the mouse clicks have been too quick.

3.7 What comments would one want from the reader/supervisor?

A document with many typos and bad language makes the reader spending time commenting on them rather than to provide comments on the technical content. Therefore, it is beneficial that even the first versions have reasonably good language and have been checked with a spell-checking tool such as Grammarly (checks both spelling and grammar).

It must be emphasised that a text washed for typos is most important as the report grows in number of pages. You may also guide the supervisor by saying what sections are still premature. In the initial phase of the master project, some pages of written material are often essential for supervision to be effective.

Then, it is often better to deliver a draft than nothing at all. It is important to send or share a draft with your supervisor in Word or pdf format rather than sharing access to a cloud document like Overleaf. At least I (Jim) depend on commenting on a static document that I can later go back to and see what comments I have provided and how the initial text looked like (to see what has been improved). It is not possible for a supervisor to continuously comment on a draft so you must decide when and what parts of a draft the supervisor should read. **Please include your name and draft date in both the file name and on the first page of the draft.**

Every time you send an updated draft to your supervisor, add a short summary in the e-mail of what is new and to what extent you regard each chapter being all from premature to finished. You can, in addition, indicate which parts you are most interested in comments on. Further, for effective supervision, and if you are given hand-written comments from the supervisor, it would be helpful if you return these to the supervisor before he/she does another round of review of a revised report draft. Then, it is easier for the supervisor to remember what was read and corrected earlier and also check parts that had major weaknesses earlier.

In addition to the supervisor, it is valuable to let others read through a nearly completed report draft. This may, for example, be another master student who has the basis to understand the content but does not have as much prior knowledge that you and your supervisor normally have. Thus, this would be a good way of evaluating whether the report is understandable / clear to someone reading it with "fresh" eyes (such as the examiner eventually are going to do).

4. Reach the target

Doing a master project is comparable to embark on the sea. There are usually a number of directions to head for and many places to be fishing. At the beginning of the trip, we can easily be perplexed about which way is best without daring to make a choice. As we come out on the open sea, there are even more directions than in the fjord where we started. This applies to several aspects of the master project: the amount of literature study, the scope of methods to be developed and tested, the number of different experiments, and report writing. The effort put on each of these should match each other. It does not help with a boat full of fish (experiments) if one does not come back to land again (getting the experiments well described in the report). Concentrate on where you feel you get "fish" and "return home" before it gets dark and difficult to get back to the dock.

5. Search for literature

An important part of the report is referring to the work of others and describe how this is different from your own work presented later in the report. Recent research results are mostly in articles from conferences and journals. More general / older background can be found in books. While we previously often had to order paper copies of articles, the vast majority are now available on the web in full-text version. Books are also now increasingly available in electronic form.

In referencing, the principle is that one should always refer to the first occurrence. Thus, if a principle is described in an article, and later described in many other articles / books, one should refer only to the first publication which described the principle.

Internet offers a wide variety of ways to find articles:

Library search

The IFI library (http://www.ub.uio.no/fag/informatikk-matematikk/informatikk) enables searches across multiple types of databases. Earlier one had to select a specific database to search in order to get access to electronic versions of articles. Google has now become an even easier choice, where relevant keywords are entered and matches from publishers and private web pages show up (e.g. including hits in databases as IEEE and Springer). If one then sits on the University network (including laptop

connected with WiFi, alternatively remotely but through Remote Desktop) you get a full version of the articles from publishers which the library at the University of Oslo has an agreement with (IEEE and Springer are included).

It can still be worth searching for books (incl. electronic version) through the library web interface. For books, Oria now seems to be preferred at UiO (here one can also order books that are available in other libraries). See link above.

Web search
Many researchers have personal web pages where they have a publication list with full version of articles available. Therefore, when you have found an article that you think is interesting, try to find the web page (once again with Google) of one of the authors (starting with the first author) and see if also other relevant articles have been published. One should in the master report preferably refer to the articles rather than web pages for projects.

Another way to obtain information / people / articles is to search on the keywords that are relevant (as mentioned under library search).

Follow reference lists
All articles have a shorter or longer reference list of others and own previous work. This is an important source to obtain interesting articles, and would be a good way to see that we have found the most important publications in a given research field.

Conference search
Conferences are organised within limited areas. The searches suggested above and publication channels for articles previously found will often be a good indication of important conferences for your work. Thus, it is advisable to browse through the proceedings of these conferences to see what they have contained. Then, we can come across articles that we otherwise would not have found because the keywords used for searching are not in them.

All conferences normally have the program present on the web, but it is often better to find proceedings at publisher´s web pages (IEEE, Springer etc.), since there are full version of articles available. However, in some cases, conference programs could be good since they also include the name of sessions, that can make the browsing for relevant articles quicker.