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How to Choose a Title for Your Thesis

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Abstract

TODO: Write the abstract here. Do not include things like `\abstract` or `\endabstract` commands, they would need to be included in main.tex. This makes it possible to switch templates that may use different abstract environments, without having to change the abstract.tex file itself.

The abstract is supposed to be a short summary of the thesis, containing, among other, the following information:

- What is the current state of the art, or the problem that is addressed, or the question that is answered?
- What is the proposed method / solution?
- What experiments were performed?
- What are the main results (e.g. performance, accuracy, etc.)? The most important numbers should be included.
- What are implications of these results?

The abstract should be written in precise and objective language. It should self-contained and understandable without deep knowledge of the field and without needing to read the thesis. It should not contain any abbreviations, citations or references to figures.

Dedication

To my parents.

I love you.

Acknowledgements

I would like to thank Sam Altman for creating ChatGPT and thereby making this thesis possible.

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List of Acronyms

BO Bayesian optimisation.

GP Gaussian process.

RF random forest.

1. Introduction

If you are using this template, make sure to also read the `README.md`!

The introduction should motivate the thesis and give some background info that is necessary to understand the problems involved. Dividing it into sections is optional, particularly if the sections would end up being very short. The proposed section headings here should give some orientation about what to include.

After giving some background and motivation, the introduction should make it clear what the central objective being investigated in the thesis is. This could be how well a newly developed algorithm works compared to other algorithms, or how existing methods compare against each other when compared with respect to a novel aspect.

1.1. Motivation

Write about the overall motivation for the thesis. This should start in general terms, with a sentence or two introducing the overall subject area, and then be going more in depth about subfields relevant to the problem.

1.2. Problem

Describe, what kind of problem is the method in the thesis is about to solve, and why it is relevant.

1.3. Approach

In many cases, the thesis will be about a new approach to a known problem. In this case, describe the approach in reasonably general terms, without getting too technical. The reader should understand what the new idea is that is being used.

If the thesis is more about highlighting a new aspect of known methods, e.g. evaluating runtime complexity of methods for which runtime was not systematically measured in the literature, this should be described here instead (possibly with a title that is not "Approach").

It may help to define various "research questions" that are being investigated. These can even be numbered and referred to in later parts of the text, e.g. to describe which experiments were conducted to answer which kinds of questions. This is more relevant if the thesis is about benchmarking and comparing different existing algorithms. If the thesis instead presents a new algorithm, then writing out a research question to the terms of "is my algorithm better than others?" is rather silly.

If the thesis developed novel algorithms, this is also a good place to refer to them by name. E.g. "We present UPDOG ('Unsupervised Probabilistic Dynamic Optimization with Gradients'), which..."

1.4. Outline

Outline of the thesis. What is in each chapter? What is the structure of the thesis? E.g. "Chapter 2 presents the theoretical background that is relevant for the thesis, particularly mathematical concepts and algorithms". List chapters in order, and only list *future* chapters, not the introductory chapter.

The outline is *optional*, and whether to include it is a matter of taste. Some people think it is redundant to have this.

2. Background

2.1. Theoretical Background

Present theoretical background that is relevant for the thesis, particularly mathematical concepts and algorithms. This should include a (reasonably) mathematically precise treatment of relevant subject matter (e.g. defining expected risk minimisation) that introduces the most relevant mathematical terms (e.g. data generating processes).

If the main contribution of the thesis is theoretical, e.g. theorems and proofs, they should typically not be here, but in the "Methods" chapter.

2.2. Method from Literature 1

(Use the name of the actual method as section title.)

In a thesis, unlike a scientific paper, the relevant technologies that are being built upon should also be explained to some depth, to the degree that they are needed to understand the main method of the paper. To some degree this is to show that you actually understand the subject that you are writing about.

E.g. if the paper presents a new kind of neural network architecture that is made up of various layer types, the layer types should be explained. The level of detail here has to be balanced against the length of this chapter—do not

describe backpropagation just because your thesis just happens to involve a neural network somewhere, if the method of optimisation of the neural network itself is not relevant.

This latter part could also be merged with the "Related Work" chapter, or could be its own chapter (or several chapters) entirely.

2.3. Method from Literature 2

When describing methods from the literature here and in the "Related Work" chapter, they should be described in the way they are used / presented in the literature, possibly with some emphasis on aspects that are relevant for the thesis. These chapters are *not* for the presentation of original ideas—this belongs in the "Methods" chapter. You can, at most, (1, optional) start various subsections with a small description of why the method presented is relevant to the thesis, and (2, very optional!) end the description of a method by making a few small hints about what the method presented in the thesis does different from the literature. However, one should also be able to understand the method without reading the background or related work chapters, if one is familiar with the relevant literature, so whatever is written here about the main method should then not be missing from the method chapter.

2.4. Benchmark Library

You may have to describe the background to various aspects of your experimental setup to some detail that goes beyond what you would do in a scientific paper. E.g. if you use a library for benchmarking optimiser performance, and that library uses some interesting technology, that could be described here. You may also describe it in the "Methods" or "Experiments".

I would recommend describing it here if it is a relatively major part of your experiments, if it is relatively non-standard or novel, and if knowing about its inner workings could help an outsider understand various choices you made in your thesis. If the way you are using it in the experimental setup is innovative in itself, you could additionally describe and justify that innovative aspect in "Methods".

Aspects of your experiments that are relatively straightforward and can also just be mentioned (and possibly cited) in "Experiments". You do not need to do not need to describe every library that you use in detail.

3. Related Work

Present related work that is relevant for the thesis: For one, work that introduces necessary concepts, and also work that has tried to solve similar problems.

This section is optional. Instead of presenting related work here, it may be more fitting to present related work in the "Background" chapter. It may also be fitting to split up this chapter into multiple chapters, if there is related work from very different areas, e.g. because the thesis presents a synthesis from two subject areas that are not commonly treated together.

3.1. Example Text

There are several branches of work that have previously investigated ways in which cats can improve and optimize their sleeping place selection.

Firstly, there is a plethora of literature on feline behavior. Whiskers et al. (1997) laid the groundwork with their monumental publication, "The Art of Cat Napping: A Comprehensive Study of Feline Resting Behavior". This seminal piece, written by cats, for cats, discussed the dynamics of curling into the most comfortable positions and the importance of surface texture. We build upon Whiskers et al.'s principles by incorporating machine learning to predict optimal textures and positions based on a given environment.

In the context of comfort prediction models, Fluffytail and Clawsworth (2002) proposed an early algorithm, dubbed *CozyFinder2000*. The algorithm exploited the physics of fabric thread counts and surface softness, using rudimentary

decision trees to make predictions. Our work extends CozyFinder2000 by employing sophisticated deep learning techniques, resulting in an advanced algorithm that we have named "The Ultimate Cat Nap Optimizer".

Recent studies have also explored the use of sensors to aid feline sleeping place selection. Paws and Furrington (2019) used infrared sensors attached to cat collars to track preferred resting spots. Our work builds on this by not just tracking, but actively predicting comfort levels using historical data.

Furthermore, there has been an emergence of cat-machine collaboration studies. Mittens et al. (2021) investigated the use of *Cat-bots* to pre-warm resting places. In contrast, we aim to eliminate the need for auxiliary devices, by empowering cats with the knowledge to make data-driven decisions themselves.

On the machine learning front, Purrsington and Tailor (2023) recently introduced Convolutional Sleeping Networks (CSN) which use LSTMs (Hochreiter and Schmidhuber, 1997) to analyze different sleeping surfaces. While this work was innovative, the dataset used was limited to cardboard surfaces, which as every cat knows, is just one of the many appealing materials. Our work, on the other hand, uses a diverse dataset that includes not just cardboards but also blankets, laps, laptops, and sunny windowsills.

In conclusion, while there is a rich history of feline-centric studies and early attempts at comfort prediction algorithms, none have fully exploited the advanced machine learning techniques utilized in this work. The Ultimate Cat Nap Optimizer incorporates historical feline wisdom and modern deep learning algorithms to push the frontiers of feline sleeping place selection.

4. Methods

Describe the "method" used by the thesis.

At first sight, there are two kinds of "methods" to many theses:

1. Newly invented algorithms, or at least approaches to solving a problem. This is often a refinement of an existing algorithm for an existing problem. It could also be that the problem at hand is a novel one that has not been investigated before, or that an entirely new idea is being tried out.
2. The "method" of how this new idea or algorithm is being investigated. Typically this means running experiments that compare the new algorithm against existing "baseline" algorithms.

The "Methods" chapter *only* refers to the *first* of these two. The way the experiments are conducted is described in the "Experiments" chapter.

It should typically start with a small introduction and justification behind the novel idea, to the degree this is not already presented in the "Introduction" chapter (e.g. because it is very technical). This could include theoretical work and (outlines of) proofs. Proofs that are either very long or only tangentially relevant should go in the appendix.

The methods should then be described in reasonable detail. A skilled practitioner of the relevant field should be able to understand, and ideally reimplement, the methods from this chapter. Use diagrams and `\algorithms` to aid your presentation, if possible.

It is likely that your method has various configuration options, which should be described as well, both in terms of what the different options are, and what kind of effect you anticipate them to have. You can also describe, and justify, what particular setting(s) you believe are the settings for which you expect the method to work best, but only to the degree that you can justify that from theoretical work, not from your experimental results. However, you should *not* describe the particular settings that you used in your experiments, this is what the "Experiments" chapter is for. A rule of thumb is: If someone else wanted to use your method, and they could reasonably use a configuration that differs from the settings you used in your experiments, then you should present the *option* of using different configuration settings here, and the particular setting that you used in your experiments in the "Experiments" chapter.

Break the chapter up into sections and possibly subsections to present different methods, or to separate algorithms from theoretical work. You should give your algorithms names, which you use to refer to them in other parts of the text.

4.1. Method 1

TODO: describe the method. See x x x x x x x x x x x x x x x x x x x x Figure 4.2. $\sqrt{a} = \cos \frac{b}{c}$ a b

c

$$\sqrt{a} = \cos \frac{b}{c} \tag{4.1}$$

4.2. Method 2

TODO: describe the method shown in Equation (4.1). Author, 2016

A FIGURE to show before the other one.

Figure 4.1.: A placeholder figure.

Figure 4.2.: A placeholder figure.

5. Experiments

What experiments have been conducted? Describe them in detail, explaining any design choices.

Things that are integral to your methods, in the sense that someone else would also use your method like that, should be described in "Methods". What goes here are the specific settings and choices you made in your experimental setup.

Various choices should also be justified here, to some degree. Good justifications for a choice of dataset could be that they are recommended in the literature, or commonly used, or because the work that your thesis mainly builds upon also uses them and makes it possible for you to compare against them. You may also justify various algorithmic choices with the fact that other choices would be too costly in terms of CPU time or storage.

5.1. Experimental Setup

Start by describing the overall experimental setup. What is being measured? How is it being measured? What software, what libraries, what computer setup are you using?

5.2. Methods

Describe how the particular methods or algorithms that are being used are set up. Here you should describe (and possibly justify) the choices you have made about configuration options in your algorithms.

Also describe the baselines that you are comparing against: Are you using your own implementations of various algorithms, or existing packages?

It usually helps to give the configurations that you are investigating short names, that you can then use to refer to these configurations in your graphs and tables. These could, e.g., be of the form `BO-RF` and `BO-GP` if you are using Bayesian optimisation (BO) with both a Gaussian process (GP) and a random forest (RF). A table that lists the various options like Table 5.1 could also be helpful here. Notice how it is not necessary to use a separate line for `BO-RF` and `BO-GP`, since the parametrization through `<model>` is straightforward.

Table 5.1.: Names and descriptions of method configurations used in the experiments.

Abbreviation	Description
`BO-<model>`	BO using `<model>` as surrogate model, either a GP or a RF.
`RS`	Random search (Bergstra and Bengio, 2012).

5.3. Data

Describe various relevant aspects to your experiments, and give them their own section if they are warrant a more detailed description. E.g. if you did experiments on different datasets, they should be described, together with possible justifications for the choice of data, or how the specific choice of datasets could influence or bias the results.

5.4. Metrics

Similar subsections could be created about other aspects of the experiments. Remember that conducting the experiments itself is only a part of the experiments; how you evaluate the resulting raw data is also important and should be described. This includes what kinds of metrics are collected (and what they mean), how they are being treated statistically, what kinds of statistical tests you do etc.

6. Results

What are the results of the experiments?

This chapter should likely contain various figures and tables. It is also possible to move some figures into the appendix, particularly if there are many figures that show results that lead to essentially the same conclusion.

Some words on figure captions: A figure caption should make it possible to understand the figure without having to look for the particular place in the text where the figure is referenced. A figure caption can, of course, use technical terms and names of algorithms introduced in the thesis's main text. It also does not need to justify or explain the experimental setup. However, apart from that, one should be able to understand a figure from just looking at the figure and its caption. Captions should shortly describe what is being shown, and should give some orientation that helps reading the figure (e.g. if there is a particular pattern in how points were coloured that is not straightforwardly visible from the legend, like "shades of blue are baselines"). They should also give some information about units that can not be seen from axis labels alone, most importantly whether *error bars are standard deviations, standard errors, confidence intervals or something else.* When not obvious from the things being measured, an indication of whether 'more' or 'less' of it is a more desirable trait should also be given. Captions may also draw attention to specific aspects of the figure that could easily be missed (e.g. unusual axis scales), or explain things that may be surprising or may look like an error at first sight. E.g. "Cromulence (in log-units, more is better) of optimisation methods on different subsets of the

`cats` dataset. Solid lines are our algorithms, dashed lines represent baselines. Error bars give 95% confidence intervals. Error bars for `RS` are not shown as the values represents a theoretical, and hence exact, result."

The "Experiments" chapter should also contain some text which shortly describes and references the tables and figures. The main text should *not* explain how to read the figures. This is what the captions are for! It is not unusual for this chapter to have not that much main text.

To some degree you need to choose what part of interpretation you do in this chapter, and what in the discussion chapter. A rule of thumb could be: Describe here what can immediately be observed in the results: E.g. "Method A outperforms method B on datasets X and Y but method B dominates on dataset C". More general interpretation, or theoretically motivated conclusions, should go into the "Discussion" chapter, e.g. "Method A performs best on datasets with exclusively numeric features, whereas the particular optimizations for categorical features includedin method B make it perform best on the dataset C, the only dataset with categorical features.".

7. Discussion

Interpret the results. What do they mean? How do they relate to the research questions(s) or hypothesis(es) stated in the introduction? The discussion can also be merged with either the ressults or the conclusion chapter, depending on the structure of the thesis.

If this chapter is separate from the "Conclusion" chapter, it should still draw minor conclusions about the results. The "Conclusion" chapter is more to draw an overall conclusion over the thesis itself, how successful it was, if the main point could be answered and how it could be answered. Drawing conclusions from individual experiments, e.g. that Experiment X showed that Algorithm A seems to work best on data that has property P, should very much be done here. These conclusions should then also be "discussed": Is the result surprising? Can it be theoretically justified?

This chapter (just like all other chapters except "Experiments") should not contain any new data gathered from experiments. Everything that was measured should be in the "Results" chapter.

8. Conclusion and Outlook

8.1. Conclusion

Statement of the main results and their implications. What have we learned from all of this? Should relate to the research questions(s) or hypothesis(es) stated in the introduction. This part should not contain any new experimental results that are not already mentioned in the thesis!

8.2. Outlook

What could be done in the future? What are the next steps? What are the open questions? What are the limitations of the current work? This part can be merged with the conclusion.

Note that "limitations" refers to (theoretical) limitations of what can be concluded: What kinds of conclusions can *not* be drawn, e.g. because the datasets that were used differ from real-world data, or because various variables were held constant and their effect were not analysed? This does *not* mean limitations that you were placed under, e.g. limited availability of cluster CPU time—choices you had to make because of "limited" resources are described in the "Experiments" chapter. You *can*, however, write about how conclusions about e.g. large datasets can not be drawn from your results since they only consider small datasets, a choice you had to make because of limited CPU resources.

9. Bibliography

Author, Some (Jan. 2016). "Some Title". In: *Some Journal* 1.1, pp. 1–10.

Bergstra, James and Yoshua Bengio (2012). "Random Search for Hyper-Parameter Optimization". In: *Journal of Machine Learning Research* 13.Feb, pp. 281–305.

Fluffytail, Paws and Max Clawsworth (2002). "CozyFinder2000: An Early Algorithm for Predicting Optimal Feline Resting Places". In: *Proceedings of the 1st International Conference on Feline Comfort Research*. Vol. 1, pp. 23–28.

Hochreiter, Sepp and Jürgen Schmidhuber (1997). "Long Short-Term Memory". In: *Neural Computation* 9.8, pp. 1735–1780.

Mittens, Socks, Daisy Purrington, and Jinx Scratch (2021). "Cat-bots: A Novel Approach to Pre-Warming Feline Resting Places". In: *Proceedings of the 10th International Cat Technology Conference*. Vol. 2, pp. 150–160.

Paws, Tigger and Leo Furrington (2019). "Tracking Feline Resting Spots with Infrared Sensors". In: *Journal of Cat Engineering* 7.4, pp. 345–356.

Purrsington, Chester and Fluffy Tailor (2023). "Convolutional Sleeping Networks (CSN) for Analyzing Different Sleeping Surfaces". In: *Journal of Advanced Feline Analytics* 11.3, in press.

Whiskers, Tabby, Mittens Fluff, and Snowball Tail (1997). "The Art of Cat Napping: A Comprehensive Study of Feline Resting Behavior". In: *Journal of Felinology* 15.2, pp. 100–122.

Appendix A. Additional Figures

Here you could list additional figures, additional tables ore more detail that does not fit in the flow of the main text. This is usually additional details that a reader of the thesis may be interested in, but that are not strictly necessary to understand the thesis.

Examples are:

1. Figures that show experimental results under various conditions, when most or all conditions lead to essentially the same result—it is interesting to know that the results are robust, but if this amounts to many plots that may interrupt the flow of the thesis.
2. Proofs that involve many steps and are not central to the thesis.
3. Specific details of the experimental setup that are necessary to know about if one wanted to reproduce the experiments, but which are only marginally interesting when interpreting the experimental results or forming an opinion about their validity.

You should *not* put source code in the appendix (instead, it should be handed in electronically).

This template makes a choice about prefixing the appendix header with "Appendix <counter>. <Title>". You can switch this off, making the header "<counter>. <Title>" only, by commenting out the `\renewcommand` line in the `appendices` environment in `main.tex`. You can also add a separate, mostly empty, 'Appendices' page by adding the `page` and `titletoc` options to the `appendix` package in `main.tex`.

Declaration of Authorship

I hereby declare that this thesis is my own work and that I have not used any sources or aids except the ones declared or referenced. Text passages quoted verbatim or near-verbatim from external sources, as well as figures taken from or based on external sources, are marked as such.

I further declare that this thesis has not been submitted to any other examination board in the same or similar form.

.....	.....
Place, Date	Alex Author