Thesis Title

A thesis presented in partial fulfilment of the requirements for the degree of Bachelor of Science

Name

S.B. Degree Candidate in _____ Engineering

Faculty Advisor: _____

Harvard University School of Engineering and Applied Science

Cambridge MA

Date

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Abstract

PLEASE READ THIS PAGE

This is a template for a Harvard engineering thesis.

For errors, corrections or clarifications please contact smeijer11@gmail.com.

No prior knowledge of LaTeX is expected, just take a look around and try to work out how it works! There is lots of documentation in both the source code of this file and the text so I would suggest you look at both while reading!

(You can get to the source code of this abstract by navigating to preamble/abstract.tex [on Overleaf this is in the file explorer on the left of the page or sometimes you can double click on a word in the document on the right to take you to the place]) I would suggest you now go and look in main.tex now to understand how the document is laid out.

Good luck with your work, I hope this is useful to you!

Acknowledgements

This is a good place to acknowledges those who helped you along the way.

Also please note how LaTex has put this on a new page as it is a new chapter. No command (apart from starting a new chapter) was needed to do this.

Also note the lack of number on the title, and contrast this to proceeding chapters, the abstract and acknowledgements should be unnumbered, the proceeding chapters should be numbered.

Chapter 1

How to do Sections and Other Simple Text Formatting

Here you should put a short introduction to your chapter. What is covered? In how much detail? Imagine you were coming back to this in 10 years time and wanted to find that one key equation, this part of the chapter should orient the reader to help find that information.

1.1 Sections

Sections are great for a lower level breakdown of a topic. This first chapter generally introduces the topic of your thesis, so perhaps you have one section for an explanation of the problem you are looking to solve and another for how you are trying to solve it. An extremely sensible thing to do it use the `\label{}` tag for each section, chapter and subsection which allows easy referencing as shown in the code of section 1.1.

1.1.1 Subsections

Subsections are good for dividing up sections and...

Subsubsections

Subsubsections are good for dividing up subsections.

1.2 Lists

So you like lists?

There are a few ways to do this: use the `\begin{itemize}` command, which gives bullet points, each denoted by `\item`.

- Itemize

- lists

- look

- like

- this.

There are other options, if you like numbered lists, use `\begin{enumerate}`, with each item denoted by `\item` again.

1. Enumerate

2. lists

3. look

4. like

5. this.

You can also do fun things like this:

- Wow

– a

   ∗ nested

   · list

and this:

1. Wow

   (a) another

   i. nested

   A. list

(Look in the source code to see how this is done)

1.3 Formatting

Font changes are a bit of a faff in LaTeX. But you shouldn't really be using them in a thesis anyway. It can however be useful to emphasise certain words in **bold** or *italics*. These can be invoked by using the `\textbf{}` and `\textit{}` commands respectively, with your text within the curly braces. Overleaf auto generates these commands using the classic Word shortcuts of cmd+B and cmd+I.

1.4 Tables

Tables are extremely useful for theses. They are great for showing specifications and results to different test environments etc.

I use this template for my tables. Though it is easy to change to suite your own needs/style.

Tables in LaTeX are somehow both extremely complicated and extremely obvious once you have some idea of how to use them. I would recommend reading up on them externally[1],

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[1]`https://www.overleaf.com/learn/latex/Tables`

and fiddling with this example below to see how it works.

Thing 1	Thing 2	Thing 3	Thing 4
TODO	TODO	TODO	TODO
TODO	TODO	TODO	TODO
TODO	TODO	TODO	TODO
TODO	TODO	TODO	TODO
TODO	TODO	TODO	TODO

Table 1.1: Example Table

1.5 Other things

Sometimes it is useful to put in a URL to your text. I have turned off the colouring of URLs in this document as I think it looks more professional, especially when printed. A URL is places in line in text using the `\url{}` command. A URL then looks like this: `www.google.com` and is a clickable hyperlink when viewed on a computer.

It can also be useful to put in a footnote if a thought needs continuing outside of the main body of text. This is done using the `\footnote{}` command, which does this: [2]. Where the text of the footnote is within the curly braces.

---

[2]This is a footnote

Chapter 2

Images

Your thesis will likely contain images, graphs and charts. This chapter explains how to deal with these.

2.1   Single Image

As you can see in the code for this section, images are enclosed within a figure environment.

Figure 2.1: GB W4- rowing behind the Dutch W4- during the 2018 World Championships ©Merijn Soeters

LaTeX will helpfully(?) try to position the figure/table/image where it thinks it fits best into the text. You may disagree with LaTeX, which is fine. To disagree there are many options. I tend to force LaTeX to put the figure where I have put the figure environment in my code as this often allows me better control of the image positioning. This is done using [H] on the same line as the `\begin{figure}` command. There are other places you can force the figure to be placed and these are covered in `https://www.overleaf.com/`
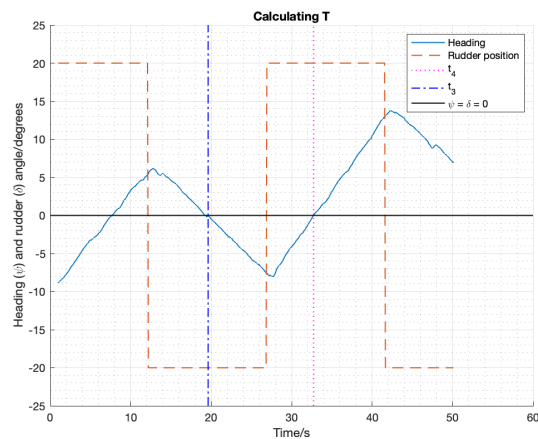
`learn/latex/Positioning_images_and_tables`. Please see the annotated code for this chapter for an example.

2.2   Multiple Images

It is also possible to put multiple images side by side to compare them. Please look at the code for the following images to see how this is done.
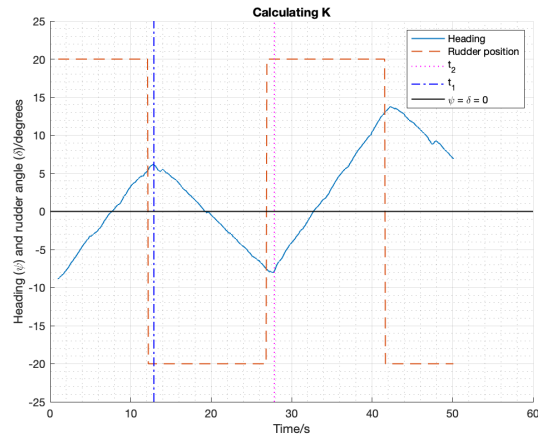
(a) Derivation of K

(b) Derivation of T

Figure 2.2: Results from Kempf maneuver

2.3 Drawing in LaTeX

It is also possible to draw diagrams in LaTeX. Information on this can be found here `https://www.overleaf.com/learn/latex/Picture_environment`. (It is also possible to do many other things using LaTeX as it is a Turing-complete programming language. However, if at any point in time you are tempted to use LaTeX for anything other than typesetting, you should stop whatever you are doing and seek help from HUHS).

2.4 Graphs in LaTeX

It is also possible to draw graphs in LaTeX. These come out looking rather nice, and may be preferable to MATLAB graphs, though the extra hassle may negate any prettiness benefit. See `https://www.overleaf.com/learn/latex/Pgfplots_package` for details.

Chapter 3

What to do About References

References in LaTeX can be slightly cumbersome, but it is not too bad. Further reading can be found here `https://www.overleaf.com/learn/latex/Bibliography_management_with_bibtex`.

3.1 Generating and Importing a Reference File

I would recommend using a reference collating software such as Zotero or any other software that can readily produce a `.bib` file. In Zotero, on a mac, this is done by exporting the collection (right-clicking on your collection of sources or selecting File → Export Collection) and then selecting the format as BibTex.

The `.bib` file should then be imported into overleaf (using the rightmost of the three icons above the sidebar when editing a document) and called something like `references.bib`.

3.2 Citing in Text

To cite in text, simply import your references file, then use the `\cite{}` command. Overleaf will then present you with a searchable directory of all the references in the file, and you will be able to place the desired reference at the desired loaction. If you leave all the settings as

trhey are in this file, you will get in text citations of the style '[1]' and the bibliography will be in IEEETR style.

3.3 BibLatex

I have no experience with BibLatex, but I believe it to be a good option instead of BibTex if you are having trouble. Details can be found here `https://www.overleaf.com/learn/latex/Bibliography_management_in_LaTeX`

Chapter 4

Maths

One. of the main reasons for using LaTeX in the first place for a document is the ease with which maths can be formatted. In this chapter I will provide an overview of how best to lay out maths in LaTeX.

4.1 Maths overview

As with sections and chapters there are varying degrees of importance associated with mathematical information in LaTeX. If you are showing an important equation, it is desirable to use a numbered 'equation' environment which allows referencing of that equation.

If you want go through a proof, you will probably want to use an 'align*' environment to align the equality signs.

For out of line maths not of the same importance as an equation, you will want to use `\[ 'maths goes here'\]` and for in line maths you will want to use `$'maths goes here'$`. With the maths going in between the `[\` and the `$$` respectively.

A few examples are shown below. Please see the source code to see examples of the code for these different maths environments.

Equation (note the number on the right for referencing):

$$lat_{int}(t) = \frac{lat_2 - lat_1}{long_2 - long_1}long_{int}(t) + lat_1 - \frac{lat_2 - lat_1}{long_2 - long_1}long_1 \tag{4.1}$$

Non-equation non-inline maths:

$$\psi_{desired}(t) = \arctan 2\left(\frac{LengthLongitude}{LengthLatitude}\frac{(long_{int}(t) - long_b(t))}{lat_{int}(t) - lat_b(t)}\right).$$

Inline maths: $long_{int}(t) = long_1 = long_2$

Proof or derivation (or just a neat list in this cast) with lined up equality signs:

$$m = \frac{lat_2 - lat_1}{long_2 - long_1}$$

$$g = lat_1 - m \cdot long_1$$

$$a = 1 + m^2$$

$$b = 2(mg - m \cdot lat_b(t) - long_b(t))$$

$$c = long_b(t)^2 + lat_b(t)^2 + g^2 - 2g \cdot lat_b(t) - R^2$$

$$long_{int}(t) = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Here is an example of some more complicated maths:

$$[\boldsymbol{M}_{RB}^b + \boldsymbol{M}_A^b]\dot{\boldsymbol{\nu}} + \boldsymbol{C}^b(\boldsymbol{\nu})\boldsymbol{\nu} + \boldsymbol{D}^b(\boldsymbol{\nu})\boldsymbol{\nu} + \boldsymbol{g}^b(\boldsymbol{\eta}) = \boldsymbol{\tau}^b. \tag{4.2}$$

Other people have written good summaries of how to format maths in LaTeX. I will not repeat one here, I would recommend Overleaf's own documentation as a starting point.

Chapter 5

How to Use Overleaf Well

This chapter briefly covers layout of LaTeX files and file management in Overleaf.

I would recommend doing as I have done in this template, keeping 'main' short, and using longer chapters which are then imported into the main much as functions are called in programming. This reduces clutter and allows you to insert and move chapters easily.

I would also recommend using folders for images, chapters, etc. as this will. greatly clean up. your workspace. A thesis could easily have 100 pages and 50 figures; it is much simpler if these are in smaller chunks, stored in folders.

Appendix A

An example of an appendix

This is what an appendix looks like!

Appendix B

Session Protocol

Zigzag Session Protocol

Samuel Meijer

March 2019

1   Introduction and Motivation

In order to understand how to steer a boat, it is necessary to understand how the boat responds to rudder inputs. The methods used in this protocol to measure the response of the boat are adapted from the methods presented in the work of Abkowitz[1] and Lewis[2].

2   Description

The goal of this session is to perform the zigzag maneuver (also known as *Kempf Overshoot* or "Z" maneuver[3]) to derive a relationship between the rudder angle, δ, and the rate of rotation of the boat, $\dot{\theta}$. This involves steering the boat in a controlled zigzag pattern.

3   Procedure

The maneuver is conducted as follows:
while rowing,

1. the boat is set travelling straight (rudder angle, $\delta = 0$)

2. the rudder is turned to a set angle ($\delta = \delta_1$) for a set period of time, τ (until the change of rate of rotation, $\dot{\theta}$, is equal to zero [$\dot{\theta} = 0$])

3. the rudder it turned to a set angle in the opposite direction ($\delta = -\delta_1$)

Steps 2 and 3 are repeated a number of times the same rudder angles, δ_1 and the same length of time for the rate of rotation to approach zero, τ.

For this session, the rudder position will be controlled **automatically** by a servo running a programmed course. In this case, $\tau = 15s$ and $\delta_1 = -\delta_2 = 20°$.

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[1] Martin A. Abkowitz. *Measurement of Ship Hydrodynamic Coefficients in Maneuvering From Simple Trials During Regular Operations.* M.I.T. Department of Ocean Engineering, Cambridge, November 1984.

[2] Edward V. Lewis. *Principles of naval architecture.* Society of Naval Architects and Marine Engineers, Jersey City, 2nd revision (3rd ed.) 1988.

[3] Ibid.

Appendix C

Software

```
1  #include <Wire.h>

2  #include <Adafruit_Sensor.h>

3  #include <Adafruit_BNO055.h>

4  #include <utility/imumaths.h>

5  #include <Adafruit_GPS.h>

6  #include <SPI.h>

7  #include <SD.h>

8  #include <Servo.h>

9  #include <math.h>

10 #include "Filter.h"

11

12 /* This driver reads raw data from the BNO055, Potentiometer and
       GPS

13

14    Connections for ADALOGGER

15    ===========

16
```

```
17    Potentiometer

18    _____

19    Connect one side to VCC

20    Connect other to common ground

21    Connect Middle to A0

22

23    GPS

24    _____

25    Connect VIN to VCC

26    Connect GROUND to common ground

27    Connect GPS TX to RX1 (D0)

28    Connect GPS RX to TX1 (D1)

29

30 */

31

32 /********************************************/

33 /*BNO055 (orientation) setup, variables and def'n*/

34 /********************************************/

35 // Sample delay

36 const float SAMPLERATE = 10;

37 // Setup for the differentiation variables

38 double psierror = 0;

39 double dt = 0;

40 double dpsierror_dt = 0;

41 double previouspsierror = 0;
```

Bibliography

[1] R. D. Winter, "Designing Ships using Constrained Multi-Objective Efficient Global Optimization," *Unpublished*, 2018.