

# IDEA League

MASTER OF SCIENCE IN APPLIED GEOPHYSICS  
RESEARCH THESIS

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**Test**  
Subtitle

**Fabian Antonio Stamm**

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March 22, 2017



# Test

## Subtitle

MASTER OF SCIENCE THESIS

for the degree of Master of Science in Applied Geophysics at  
Delft University of Technology  
ETH Zürich  
RWTH Aachen University  
by

Fabian Antonio Stamm

March 22, 2017

Department of Geoscience & Engineering	·	Delft University of Technology
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**Delft University of Technology**

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Delft University of Technology, The Netherlands  
ETH Zürich, Switzerland  
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# Abstract

Please pay particular attention to the preparation of your abstract; use this text as a guide. Every master thesis report must be accompanied by an informative abstract of no more than one paragraph (max 300 words). The abstract should be self-contained. No references, figures, tables, or equations are allowed in an abstract. Do not use new terminology in an abstract unless it is defined or is well-known from the literature. The abstract must not simply list the topics covered in the paper but should (1) state the scope and principal objectives of the research, (2) describe the methods used, (3) summarize the results, and (4) state the principal conclusions. Do not refer to the master thesis report itself in the abstract. For example, do not say, "In this thesis we will discuss". Furthermore the abstract must stand alone as a very short version of the master thesis report rather than as a description of the contents. Remember that the abstract will be the first and most widely read portion of the master thesis report. Readers will be influenced by the abstract to the point that they decide to read the master thesis report or not.





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# Acknowledgements

First of all I want to thank all the people who have participated in this project .. Remember, often more people have (in some way) contributed to your final thesis than you would initially think of....

RWTH Aachen University  
March 22, 2017

Fabian Antonio Stamm



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# Table of Contents

<b>Abstract</b>	<b>v</b>
<b>Acknowledgements</b>	<b>vii</b>
<b>Nomenclature</b>	<b>xv</b>
<b>Acronyms</b>	<b>xv</b>
<b>1 Introduction</b>	<b>1</b>
<b>I First Part</b>	<b>3</b>
<b>2 Methods</b>	<b>5</b>
2-1 Bayesian analysis and decision theory . . . . .	5
2-1-1 Bayesian inference . . . . .	5
2-1-2 Estimation . . . . .	6
2-1-3 Expected loss and loss functions . . . . .	6
2-2 Application in structural geological modeling . . . . .	7
2-3 Example section . . . . .	7
2-3-1 The first subsection . . . . .	8
Subsection Short Title . . . . .	8
<b>Bibliography</b>	<b>11</b>
<b>A The back of the thesis</b>	<b>13</b>
A-1 An appendix section . . . . .	13
A-1-1 An appendix subsection with C++ Lisitng . . . . .	13
A-1-2 A MATLAB Listing . . . . .	13
<b>B Yet another appendix</b>	<b>15</b>
B-1 Another test section . . . . .	15



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# List of Figures

2-1	Stability conditions for the vertical stability of saturated and unsaturated air. . .	9
-----	---	---



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# List of Tables

2-1	Good-looking program data deck files. . . . .	9
-----	---	---





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# Acronyms

**RWTH** Aachen University



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# Chapter 1

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## Introduction

Welcome to the standard layout for your IDEA LEAGUE MSc thesis written in L<sup>A</sup>T<sub>E</sub>X. L<sup>A</sup>T<sub>E</sub>X has a variety of advantages over conventional/ standard text editing programs, which you will soon enough discover yourself. L<sup>A</sup>T<sub>E</sub>X almost forms a standard in the Scientific Community, especially due to its effective and straightforward mathematical capabilities. This is Chapter 1. If you want to know more about L<sup>A</sup>T<sub>E</sub>X you better read [Knuth, 1984] or use the extensive help available on the internet. . This 'hidden' index command helps you making an index at the end of your thesis. You can add this flag anywhere you want to make an index hit. You can see here also how to use acronyms, like **DUT!** (**DUT!**). The acronyms are automatically listed in the corresponding section. Also, hyperlinks are created automatically with the developed class file, such that your digital PDF version of your thesis can be read dynamically. Have fun with L<sup>A</sup>T<sub>E</sub>X and your M.Sc. research project and good luck!

The purpose of the introduction is to tell readers why they should want to read what follows the introduction. This chapter should provide sufficient background information to allow readers to understand the context and significance of the problem. This does not mean, however, that authors should use the introduction to rederive established results or to indulge in other needless repetition. The introduction should (1) present the nature and scope of the problem; (2) review the pertinent literature, within reason; (3) state the objectives; (4) describe the method of investigation; and (5) describe the principal results of the investigation.



# **Part I**

## **First Part**



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## Chapter 2

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# Methods

The methods utilized in this work are presented in the following chapter. This includes introductions into Bayesian analysis and decision theory. In particular Bayesian inference, estimation of uncertain values and how loss function can be used in this context. These methods are incorporated in the context of numerical modeling of structural geological settings. This is done by programming in a python environment. Central tools for model construction and conduction of the statistical evaluation are Geomodeler3D, GemPy and PyMC in particular and are also presented in this chapter.

### 2-1 Bayesian analysis and decision theory

Introduction into section: What is decision theory, what is Bayesian analysis? Why use it here? What is a decision here and in relation to geoscientific cases and models?

#### 2-1-1 Bayesian inference

Bayesian inference is most importantly characterized by its preservation of uncertainty, in contrast to standard statistical inference [?]. Probability is seen as a measure of belief for an event to occur. It has been argued by [?] that this Bayesian approach is intuitive and inherent in the natural human perspective. These beliefs can furthermore be assigned to individuals [?]. Thus, different and even contradicting beliefs about the probability of an event might be held by different individuals, based on variations and disparities in the information available to each one individual [?]. The initial belief or guess about an event  $A$  can be denoted as  $P(A)$ . This is used as the so-called prior probability on which Bayesian updating is based. The beliefs about the occurrence of an event are revalued in the presence of additional information, i.e. the observation of new evidence which can be denominated as  $X$ . These observations are included as likelihoods  $P(X|A)$ . This process of updating results in a posterior probability  $P(A|X)$  [?]. It is important to note that the prior is not simply discarded but re-weighted by Bayesian updating. It was also pointed out by [?] that by utilizing an uncertain prior, the

potential for wrongfulness of the initial guess is already included. This means that Bayesian updating is about reducing uncertainty in a belief and reaching a guess that is less wrong [?]. Bayesian updating is defined by and conducted via the following equation, called the Bayes' Theorem:

$$P(A|X) = \frac{P(X|A)P(A)}{P(X)} \propto P(X|A)P(A) \quad (2-1)$$

-Law of Large Numbers!

### 2-1-2 Estimation

The resulting posterior distribution can be used to acquire point estimates for the true state of nature  $\theta$ . Common and simple examples for such estimators are the mode (i.e. the generalized maximum likelihood estimate), the mean and the median of a distribution [?]. The presentation of a point estimate should usually come with a measure for its estimation error. According to [?], the posterior variance is most commonly used as an indication for estimate accuracy. However, it is argued by [?] that by using pure accuracy metrics, while this technique is objective, it ignores the original intention of conducting the statistical inference in cases, in which payoffs of decisions are valued more than their accuracies. A more appropriate approach can be seen in the introduction of loss and the use of loss functions [?].

### 2-1-3 Expected loss and loss functions

Loss is a statistical measure of how bad an estimate is, i.e. how much is lost by making a certain decision. Gains are considered by statisticians as negative losses [?]. The magnitude of an estimate's loss is defined by a loss function, which is a function of the estimate of the parameter and the true value of the parameter [?]:

$$L(\theta, \hat{\theta}) = f(\theta, \hat{\theta}) \quad (2-2)$$

So, "how bad" a current estimate is, depends on the way a loss function weights accuracy errors and returns respective losses. Two standard loss functions are the absolute-error and the squared-error loss function. Both are simple to understand and commonly used [?].

As implied by its name, the absolute-error loss function returns loss as the absolute error, i.e. difference between the estimate and the true parameter [?]:

$$L(\theta, \hat{\theta}) = |\theta - \hat{\theta}| \quad (2-3)$$

Accordingly, losses increasing linearly with the distance to the true value are returned for respective estimates.

Using the squared-error loss function returns losses that increase quadratically with distance of the estimator to the true parameter value [?]:



$$L(\theta, \hat{\theta}) = |\theta - \hat{\theta}|^2 \quad (2-4)$$

This exponential growth of loss also means that large errors are weighted much stronger than small errors. This might come with overvaluation of distant outliers and misrepresentation of magnitudes in distance. Regarding this, the absolute-error loss function can be seen as more robust [?].

- each give mean or median - estimator with accuracy metric? objective and symmetric! aim at high precision.

-shift in perspective. look at outcome instead of estimation precision!

[?] and (LF DESIGN PAPER?) propose that it might be useful to move away from these type of objective loss functions to the design of new loss functions that are specifically customized to an reflect an individual's, i.e. the decision maker's objectives, preferences and outcomes.

The standard loss function defined above are symmetric, but can easily be adapted to be asymmetric, for example by weighting on the negative side stronger than those on the positive side. Preference over estimates larger than the true value is thus incorporated in an uncomplicated way [?]. Much more complicated designs of loss functions are possible, depending on purpose, objective and application [?]. Some case-specific loss functions are designed in the following chapters of this work.

- Cite from paper about the design of loss functions! Subjectivity of customized loss functions!

The presence of uncertainty during decision making implies that the truly incurred loss  $L(\theta, a)$  cannot be known at the time of making the decision [?]. A suitable alternative is to consider a decision's expected loss and to decide on a decision that is optimal in relation to this expected loss [?].

- Averaging of EL over prob. distribution

- Bayesian point estimate

- Law of Large Numbers

- MAP?

- Implementation of risk as done by [?]

## 2-2 Application in structural geological modeling

### 2-3 Example section

This is the section. Referring to equations, figures and tables can easily be done by the commands `\eqnref{}`, `\figref{}` and `\tabref{}`.

$$H(s) = \frac{1}{s+2} \quad (2-5)$$

You see? Refer to equations like this Eq. (2-5), i.e. the name of the label you have given the specific equation, figure or table.

### 2-3-1 The first subsection

Now I demonstrate, numbering equations, using subequations:

$$\nabla \times \mathbf{L} = \frac{\partial \mathbf{G}}{\partial t} \quad (2-6a)$$

$$\nabla \times \mathbf{G} = \frac{\partial \mathbf{L}}{\partial t} + \mathbf{J} \quad (2-6b)$$

$$\mathbf{G} = \sigma \mathbf{J} \quad (2-6c)$$

Or we can make matrices:

$$\mathbf{Q}_{12} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

This can also be done using the `\align{}` command. Equation arrays are also possible:

$$\nabla \times \mathbf{L} = \frac{\partial \mathbf{G}}{\partial t} \quad (2-7)$$

$$\nabla \times \mathbf{G} = \frac{\partial \mathbf{L}}{\partial t} + \mathbf{J} \quad (2-8)$$

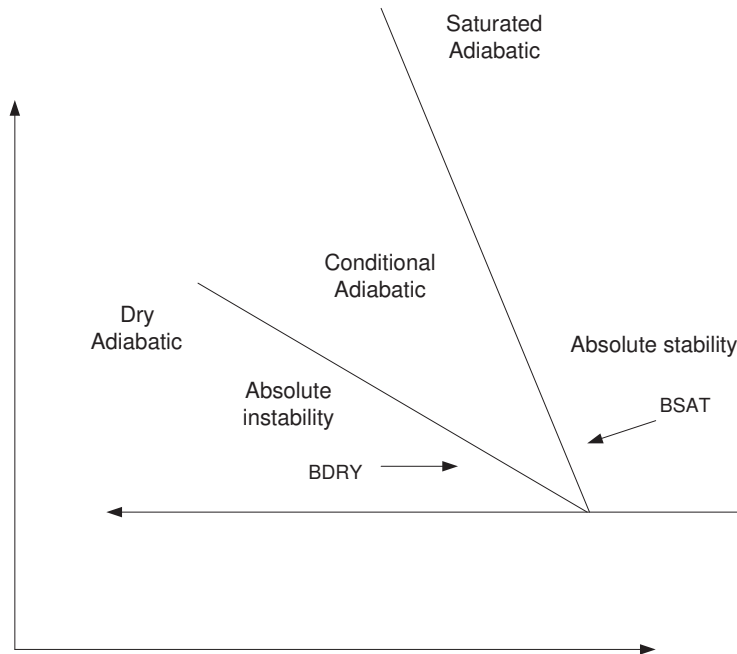
$$\mathbf{G} = \sigma \mathbf{J} \quad (2-9)$$

**The first sub-subsection with a very very very long title, but in the table of contents one can only see the short title in square brackets**

Impressed by the capabilities? If you want to know more about the capabilities of  $\text{\LaTeX}$ , take a look at the "**The Not So Short Introduction to  $\text{\LaTeX}$  2 $\epsilon$** ", which can be found on the internet.

**Next paragraph.** .

And finally I end this example file with a table which will be centered in the middle of the following page



**Figure 2-1:** Stability conditions for the vertical stability of saturated and unsaturated air.

<i>Data files listed in a table</i>	
<b>First part</b>	
Fabracadabra.m	- Saturation computation
Fobracadabra.m	- Pressure computation
Fibricadibri.m	- Permeability computation
<b>Structural rock model</b>	
struct.m	- Rock structural data using symmetric boundary condition
bstruct.m	- Rock structural data using anti-symmetric boundary condition

**Table 2-1:** Good-looking program data deck files.



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# Bibliography

[Knuth, 1984] Knuth, D. E. (1984). *The T<sub>E</sub>Xbook*. Addison-Wesley.



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# Appendix A

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## The back of the thesis

### A-1 An appendix section

#### A-1-1 An appendix subsection with C++ Lisitng

```
// 1
// C++ Listing Test
//
#include <stdio.h>
for(int i=0;i<10;i++)
{
    cout << "Ok\n";
}
```

#### A-1-2 A Matlab Listing

```
%
% Comment
%
n=10;
for i=1:n
    disp('Ok');
end 5
```





---

## Appendix B

---

# Yet another appendix

### **B-1 Another test section**

Ok, all is well.

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# Index

LaTeX, [1](#)

Nicecapabilities, [6](#)  
nomenclature, [5](#)