

MSc thesis in Geomatics for the Built Environment

# The optimal Delaunay triangulation of cheesy songs

Céline Dion

2016





# THE OPTIMAL DELAUNAY TRIANGULATION OF CHEESY SONGS

A thesis submitted to the Delft University of Technology in partial fulfillment  
of the requirements for the degree of

Master of Science in Geomatics for the Built Environment

by

Céline Dion

May 2015

Céline Dion: *The optimal Delaunay triangulation of cheesy songs* (2015)  
© This work is licensed under a Creative Commons Attribution 4.0 International License. To view a copy of this license, visit  
<http://creativecommons.org/licenses/by/4.0/>.

ISBN 999-99-9999-999-9

The work in this thesis was made in the:



3D geoinformation group  
Department of Urbanism  
Faculty of Architecture & the Built Environment  
Delft University of Technology

Supervisors: Prof.dr. Jan Smit  
Dr. Gerard Joling  
ir. Gordon Heuckeroth  
Co-reader: Dr. Pietje de Piet

## ABSTRACT

*[Should fit on one page.]*

Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail. Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail. Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail.



## ACKNOWLEDGEMENTS

Thanks to everyone, especially to my supervisors and my mum. And obviously to the ones who made that great template.

Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail.

Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail.

Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail.

...





# CONTENTS

1	INTRODUCTION	1
1.1	How to get started with L <sup>A</sup> T <sub>E</sub> X? . . . . .	1
1.2	Cross-references . . . . .	1
1.3	Figures . . . . .	2
1.3.1	Shorter section name for the TOC . . . . .	2
1.4	How to add references? . . . . .	3
1.5	Footnotes . . . . .	3
1.6	Equations . . . . .	3
1.7	Tables . . . . .	3
1.8	Plots . . . . .	4
1.9	Pseudo-code . . . . .	4
1.10	Acronyms . . . . .	6
1.11	Miscellaneous . . . . .	6
2	RELATED WORK; TITLE WHICH CAN SPAN MULTIPLE LINES	7
A	SOME UML DIAGRAMS	11



## LIST OF FIGURES

Figure 1.1	One nice figure . . . . .	2
Figure 1.2	Shortened title for the list of figures . . . . .	2
Figure 1.3	Three PDF figures. . . . .	3
Figure 1.4	A super plot . . . . .	4
Figure 1.5	Some GML for a <code>gml:Solid</code> . . . . .	5
Figure A.1	The UML diagram of CityGML . . . . .	12



## LIST OF TABLES

Table 1.1	Details concerning the datasets used for the experiments. . . . .	4
-----------	---	---



# LIST OF ALGORITHMS

1.1	WALK . . . . .	5
-----	----------------	---





## ACRONYMS

DT	Delaunay triangulation.....	6
GIS	geographical information system.....	6
TIN	triangular irregular network.....	6



# 1 | INTRODUCTION

This is a complete template for the MSc Geomatics thesis. It contains all the parts that are required and is structured in such a way that most/all supervisors expect. Observe that the MSc Geomatics at TU Delft has no formal requirements, how the document looks like (fonts, margins, headers, etc) is entirely up to you. We basically took the template `arsclassica` (by Lorenzo Pantieri), which is an adaption of the original `classicthesis` package from André Miede, added the front/back matters (cover page, copyright, abstract, etc.), and gave examples for the insertion of figures, tables and algorithms.

*It is not an official template and it is not mandatory to use it.*

But we hope it will encourage everyone to use  $\text{\LaTeX}$  for writing their thesis, and we also hope that it will *discourage* some from using Word.

If you run into mistakes/problems/issues, please report them on the GitHub page, and if you fix an error, then please submit a pull request.

<https://github.com/tudelft3d/MScGeomaticsThesisTemplate>.

## 1.1 HOW TO GET STARTED WITH $\text{\LaTeX}$ ?

Basically everything you need to know—from installation to details—is there: <http://en.wikibooks.org/wiki/LaTeX>

To compile this template, you need a full installation of either:

- **MiKTeX** (Windows);
- **MacTeX** (MacOS).
- **TeXLive** (Linux);

We suggest the following editors:

- **TeXnicCenter** (Windows);
- **TeXShop** (MacOS), which is bundled with MacTeX;

but any text editor will do.

## 1.2 CROSS-REFERENCES

The command `autoref` can be used for chapters, sections, subsections, figures, tables, etc.

**Chapter 1** is what you are currently reading, and its name is **INTRODUCTION**. **Section 1.9** is about pseudo-code, and **Section 1.3.1** is about something else. The next chapter (**RELATED WORK; TITLE WHICH CAN SPAN MULTIPLE LINES**), is on page 7.

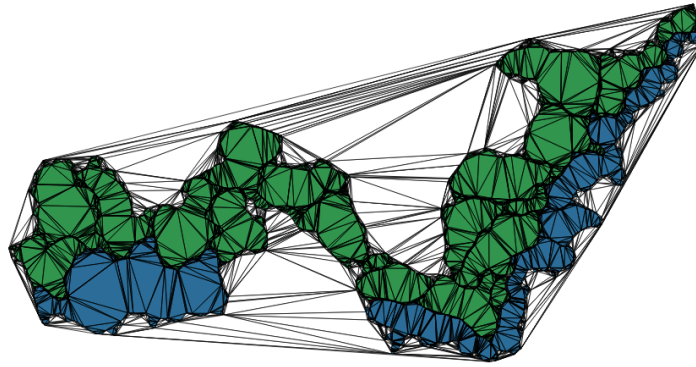


Figure 1.1: One nice figure

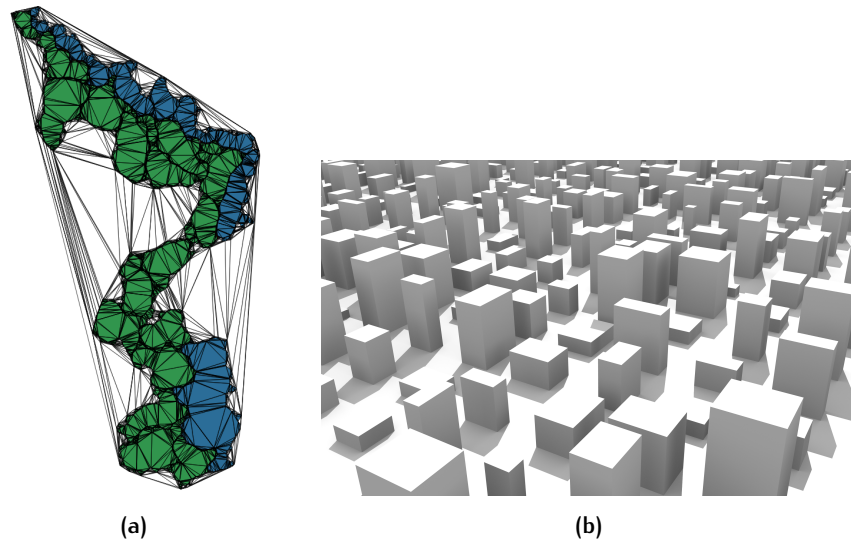


Figure 1.2: Two figures side-by-side. (a) A triangulation of 2 polygons. (b) Something not related at all.

### 1.3 FIGURES

Figure 1.1 is a simple figure. Notice that all figures in your thesis should be referenced to in the main text. The same applies to tables and algorithms.

It is recommended *not* to force-place your figures (e.g. with commands such as: `\newpage` or by forcing a figure to be at the top of a page).  $\LaTeX$  usually places the figures automatically rather well. Only if at the end of your thesis you have small problem then can you solve them.

As shown in Figure 1.2, it is possible to have two figures (or more) side by side. You can also refer to a subfigure: see Figure 1.2b.

#### 1.3.1 Figures in PDF are possible and even encouraged!

If you use Adobe Illustrator or Ipe you can make your figures vectorial and save them in PDF.

You include a PDF the same way as you do for a PNG, see Figure 1.3,

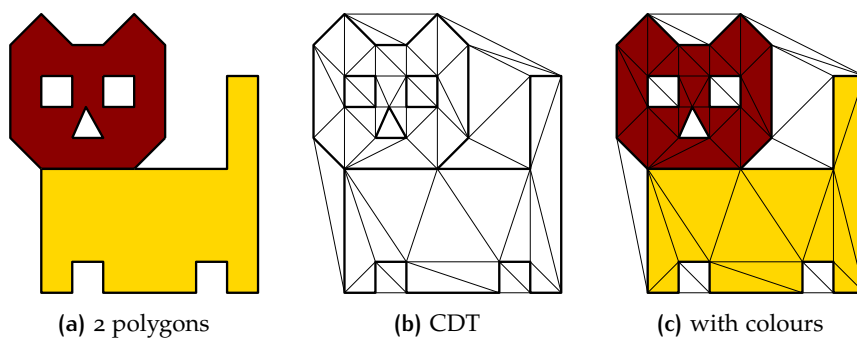


Figure 1.3: Three PDF figures.

## 1.4 HOW TO ADD REFERENCES?

References are best handled using Bib $\TeX$ . See the `myreferences.bib` file. A good cross-platform reference manager is [JabRef](#).

[Descartes \[1637\]](#) wrote this and that [[Voronoi, 1908](#); [Delaunay, 1934](#)]. Instead of citing the whole paper [[Delaunay, 1934](#)], it is also possible to cite only the authors (e.g. [Delaunay](#)).

## 1.5 FOOTNOTES

Footnotes are a good way to write text that is not essential for the understanding of the text<sup>1</sup>.

## 1.6 EQUATIONS

Equations and variables can be put inline in the text, but also numbered.

Let  $S$  be a set of points in  $\mathbb{R}^d$ . The Voronoi cell of a point  $p \in S$ , defined  $\mathcal{V}_p$ , is the set of points  $x \in \mathbb{R}^d$  that are closer to  $p$  than to any other point in  $S$ ; that is:

$$\mathcal{V}_p = \{x \in \mathbb{R}^d \mid \|x - p\| \leq \|x - q\|, \forall q \in S\}. \quad (1.1)$$

The union of the Voronoi cells of all generating points  $p \in S$  form the Voronoi diagram of  $S$ , defined  $\text{VD}(S)$ .

## 1.7 TABLES

The package `booktabs` permits you to make nicer tables than the basic ones in  $\LaTeX$ . See for instance [Table 1.1](#).

---

<sup>1</sup> but please do not overuse them

	3D model		input	
	solids	faces	vertices	constraints
<b>campus</b>	370	4 298	5 970	3 976
<b>kvz</b>	637	6 549	8 951	13 571
<b>engelen</b>	1 629	15 870	23 732	15 868

Table 1.1: Details concerning the datasets used for the experiments.

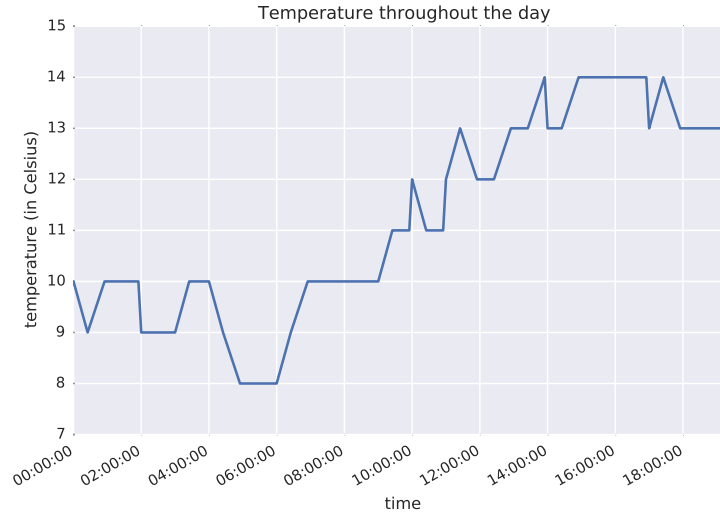


Figure 1.4: A super plot

## 1.8 PLOTS

The best way is to use `matplotlib`, or its more beautiful version (`seaborn`). With these, you can use Python to generate nice PDF plots, such as that in Figure 1.4.

In the folder `./plots/`, there is an example of a CSV file of the temperature of Delft, taken somewhere. From this CSV, the plot is generated with the script `createplot.py`.

## 1.9 PSEUDO-CODE

Please avoid putting code (Python, C++, Fortran) in your thesis. Small excerpt are probably fine (for some cases), but do not put all the code in an appendix. Instead, put your code somewhere online (e.g. GitHub) and put *pseudo-code* in your thesis. The package `algorithm2e` is pretty handy, see for instance the Algorithm 1.1. All your algorithms will be automatically added to the list of algorithms at the beginning of the thesis. Observe that you can put labels on certain lines (with `\label{}`) and then reference to them: on line 4 of the Algorithm 1.1 this is happening.

If you want to put some code (or XML for instance), use the package `listings`, e.g. you can wrap it in a Figure so that it does not span over multiple pages.

**Algorithm 1.1:** WALK ( $\mathcal{T}$ ,  $\tau$ ,  $p$ )

**Input:** A Delaunay tetrahedralization  $\mathcal{T}$ , a starting tetrahedron  $\tau$ ,  
and a query point  $p$

**Output:**  $\tau_r$ : the tetrahedron in  $\mathcal{T}$  containing  $p$

```

1 while  $\tau_r$  not found do
2   for  $i \leftarrow 0$  to 3 do
3      $\sigma_i \leftarrow$  get face opposite vertex  $i$  in  $\tau$ ;
4     if  $\text{Orient}(\sigma_i, p) < 0$  then
5        $\tau \leftarrow$  get neighbouring tetrahedron of  $\tau$  incident to  $\sigma_i$ ;
6       break;
7   if  $i = 3$  then
8     // all the faces of  $\tau$  have been tested
9     return  $\tau_r = \tau$ 

```

```

<gml:Solid>
  <gml:exterior>
    <gml:CompositeSurface>
      <gml:surfaceMember>
        <gml:Polygon>
          <gml:exterior>
            <gml:LinearRing>
              <gml:pos>0.000000 0.000000 1.000000</gml:pos>
              <gml:pos>1.000000 0.000000 1.000000</gml:pos>
              <gml:pos>1.000000 1.000000 1.000000</gml:pos>
              <gml:pos>0.000000 1.000000 1.000000</gml:pos>
              <gml:pos>0.000000 0.000000 1.000000</gml:pos>
            </gml:LinearRing>
          </gml:exterior>
          <gml:interior>
            ...
          </gml:surfaceMember>
        </gml:CompositeSurface>
      </gml:interior>
    </gml:Solid>

```

Figure 1.5: Some GML for a gml:Solid.

### 1.10 ACRONYMS

If you want to have a list of acronyms you use in your thesis, use the `acronym` package. The first time you speak about geographical information system ([GIS](#)), it will be spelled out. Further use, [GIS](#), you'll get the acronym plus a hyperlink to the list in the preamble of the thesis.

Add yours to `front/acronyms.tex`. Notice that only these used are printed, e.g. Delaunay triangulation ([DT](#)) and triangular irregular network ([TIN](#)).

### 1.11 MISCELLANEOUS

In the file `mysettings.tex`, there are some handy shortcuts. This is the way to properly write these abbreviations, i.e. so that the spacing is correct.

You should use one - for an hyphen between words ('multi-dimensional'), two -- for a range between numbers ('1990–1995'), and three --- for a punctuation in a sentence ('I like—unlike my father—to build multi-dimensional models').



## 2

## RELATED WORK; TITLE WHICH CAN SPAN MULTIPLE LINES

Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail. Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail. Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail.

Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail. Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail. Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail. Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail.

Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail. Bacon ipsum dolour sit amet porchetta beef turkey, bacon turducken boudin hamburger venison ball tip. Brisket pork loin bresaola short loin ground round leberkas pastrami tongue jerky cow turducken beef ribs. Pork ribeye landjaeger prosciutto pig venison tenderloin. Swine beef ribs kielbasa, porchetta tenderloin salami venison pork belly tail.

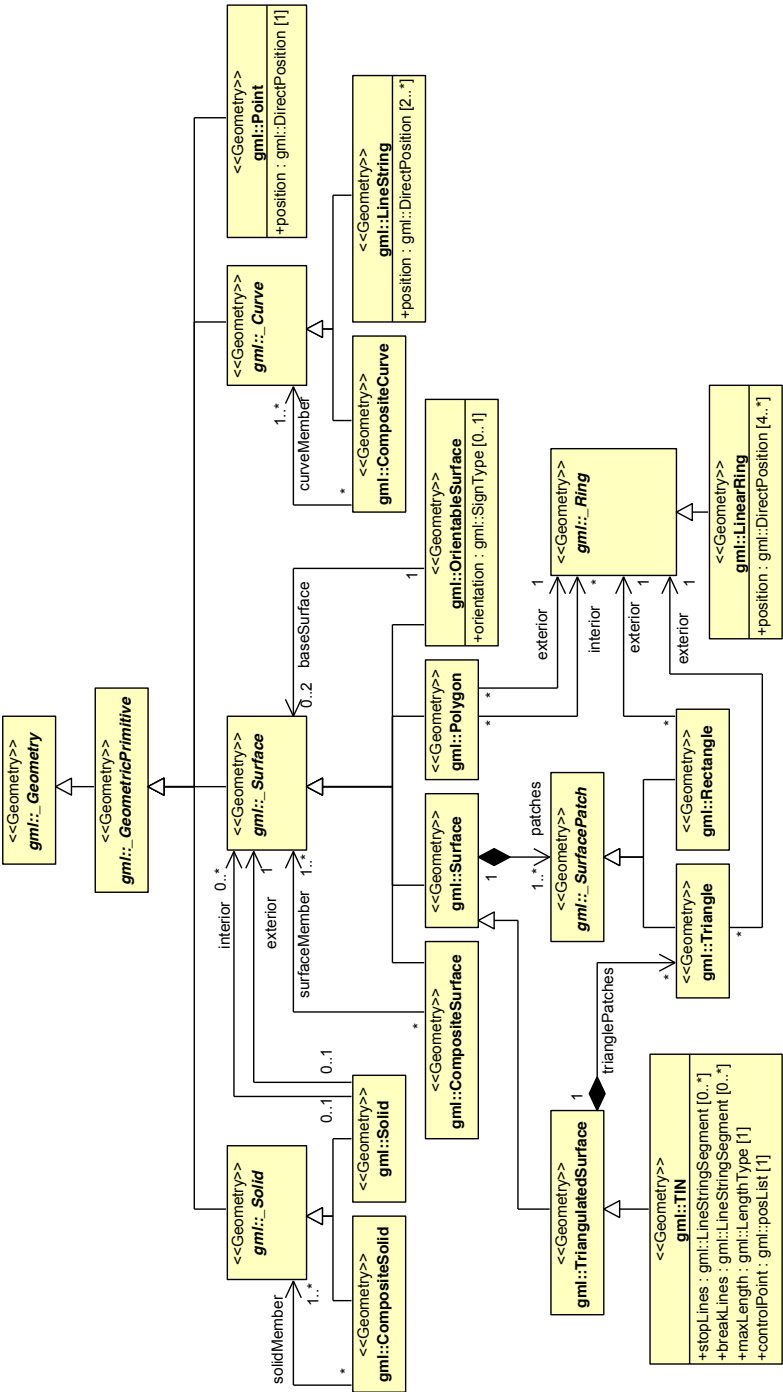


## BIBLIOGRAPHY

- Delaunay, B. N. (1934). Sur la sphère vide. *Izvestia Akademia Nauk SSSR, Otdelenie Matematicheskii i Estestvennyka Nauk*, 7:793–800.
- Descartes, R. (1637). *Discours de la méthode*. Jan Maire, Leyde.
- Voronoi, G. M. (1908). Nouvelles applications des paramètres continus à la théorie des formes quadratiques. *Journal für die Reine und Angewandte Mathematik*, 134:198–287.



# A | SOME UML DIAGRAMS



**Figure A.1:** The UML diagram of CityGML

## COLOPHON

This document was typeset using  $\text{\LaTeX}$ . The document layout was generated using the `arsclassica` package by Lorenzo Pantieri, which is an adaption of the original `classicthesis` package from André Miede.





