



DEPARTMENT OF  
COMPUTER SCIENCE

JOÃO RICARDO BOGALHO BRILHA

BSc in Computer Science and Engineering

## MICROBABEL

A MULTI-PROTOCOL APPROACH FOR RESILIENT  
AND DECENTRALIZED IOT NETWORKS

MASTER IN COMPUTER SCIENCE AND ENGINEERING  
SPECIALIZATION IN DISTRIBUTED AND PARALLEL SYSTEMS

NOVA University Lisbon

*Draft: December 29, 2025*



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# ABSTRACT

Regardless of the language in which the dissertation is written, usually there are at least two abstracts: one abstract in the same language as the main text, and another abstract in some other language.

The abstracts' order varies with the school. If your school has specific regulations concerning the abstracts' order, the NOVAthesis L<sup>A</sup>T<sub>E</sub>X (`novathesis`) (L<sup>A</sup>T<sub>E</sub>X) template will respect them. Otherwise, the default rule in the `novathesis` template is to have in first place the abstract in *the same language as main text*, and then the abstract in *the other language*. For example, if the dissertation is written in Portuguese, the abstracts' order will be first Portuguese and then English, followed by the main text in Portuguese. If the dissertation is written in English, the abstracts' order will be first English and then Portuguese, followed by the main text in English. However, this order can be customized by adding one of the following to the file `5_packages.tex`.

```
\ntsetup{abstractorder={<LANG_1>,...,<LANG_N>}}  
\ntsetup{abstractorder={<MAIN_LANG>={<LANG_1>,...,<LANG_N>}}}
```

For example, for a main document written in German with abstracts written in German, English and Italian (by this order) use:

```
\ntsetup{abstractorder={de={de,en,it}}}
```

Concerning its contents, the abstracts should not exceed one page and may answer the following questions (it is essential to adapt to the usual practices of your scientific area):

1. What is the problem?
2. Why is this problem interesting/challenging?
3. What is the proposed approach/solution/contribution?
4. What results (implications/consequences) from the solution?

**Keywords:** One keyword · Another keyword · Yet another keyword · One keyword more  
· The last keyword

## RESUMO

Independentemente da língua em que a dissertação está escrita, geralmente esta contém pelo menos dois resumos: um resumo na mesma língua do texto principal e outro resumo numa outra língua.

A ordem dos resumos varia de acordo com a escola. Se a sua escola tiver regulamentos específicos sobre a ordem dos resumos, o template (L<sup>A</sup>T<sub>E</sub>X) *novathesis* irá respeitá-los. Caso contrário, a regra padrão no template *novathesis* é ter em primeiro lugar o resumo *no mesmo idioma do texto principal* e depois o resumo *no outro idioma*. Por exemplo, se a dissertação for escrita em português, a ordem dos resumos será primeiro o português e depois o inglês, seguido do texto principal em português. Se a dissertação for escrita em inglês, a ordem dos resumos será primeiro em inglês e depois em português, seguida do texto principal em inglês. No entanto, esse pedido pode ser personalizado adicionando um dos seguintes ao arquivo `5_packages.tex`.

```
\abstractorder(<MAIN_LANG>):={<LANG_1>,...,<LANG_N>}
```

Por exemplo, para um documento escrito em Alemão com resumos em Alemão, Inglês e Italiano (por esta ordem), pode usar-se:

```
\ntsetup{abstractorder={de={de,en,it}}}
```

Relativamente ao seu conteúdo, os resumos não devem ultrapassar uma página e frequentemente tentam responder às seguintes questões (é imprescindível a adaptação às práticas habituais da sua área científica):

1. Qual é o problema?
2. Porque é que é um problema interessante/desafiante?
3. Qual é a proposta de abordagem/solução?
4. Quais são as consequências/resultados da solução proposta?

**Palavras-chave:** Primeira palavra-chave · Outra palavra-chave · Mais uma palavra-chave · A última palavra-chave

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## GLOSSARY

This document is incomplete. The external file associated with the glossary ‘main’ (which should be called `template.gls`) hasn’t been created.

Check the contents of the file `template.glo`. If it’s empty, that means you haven’t indexed any of your entries in this glossary (using commands like `\gls` or `\glsadd`) so this list can’t be generated. If the file isn’t empty, the document build process hasn’t been completed.

You may need to rerun  $\text{\LaTeX}$ . If you already have, it may be that  $\text{\TeX}$ ’s shell escape doesn’t allow you to run `makeindex`. Check the transcript file `template.log`. If the shell escape is disabled, try one of the following:

- Run the external (Lua) application:  
`makeglossaries-lite "template"`
- Run the external (Perl) application:  
`makeglossaries "template"`

Then rerun  $\text{\LaTeX}$  on this document.

This message will be removed once the problem has been fixed.

## ACRONYMS

This document is incomplete. The external file associated with the glossary ‘acronym’ (which should be called `template.acr`) hasn’t been created.

Check the contents of the file `template.acn`. If it’s empty, that means you haven’t indexed any of your entries in this glossary (using commands like `\gls` or `\glsadd`) so this list can’t be generated. If the file isn’t empty, the document build process hasn’t been completed.

You may need to rerun  $\text{\LaTeX}$ . If you already have, it may be that  $\text{\TeX}$ ’s shell escape doesn’t allow you to run `makeindex`. Check the transcript file `template.log`. If the shell escape is disabled, try one of the following:

- Run the external (Lua) application:  
`makeglossaries-lite "template"`
- Run the external (Perl) application:  
`makeglossaries "template"`

Then rerun  $\text{\LaTeX}$  on this document.

This message will be removed once the problem has been fixed.

## SYMBOLS

This document is incomplete. The external file associated with the glossary ‘symbols’ (which should be called `template.sls`) hasn’t been created.

Check the contents of the file `template.sls`. If it’s empty, that means you haven’t indexed any of your entries in this glossary (using commands like `\gls` or `\glsadd`) so this list can’t be generated. If the file isn’t empty, the document build process hasn’t been completed.

You may need to rerun  $\text{\LaTeX}$ . If you already have, it may be that  $\text{\TeX}$ ’s shell escape doesn’t allow you to run `makeindex`. Check the transcript file `template.log`. If the shell escape is disabled, try one of the following:

- Run the external (Lua) application:  
`makeglossaries-lite "template"`
- Run the external (Perl) application:  
`makeglossaries "template"`

Then rerun  $\text{\LaTeX}$  on this document.

This message will be removed once the problem has been fixed.

# INTRODUCTION

The proliferation of Internet of Things (IoT) devices has changed how we monitor and interact with physical spaces – from smart homes to industrial facilities – with the global IoT market reaching 18.5 billion connected devices in 2024, and projected to reach 39 billion by 2030[25]. Industry analysts estimate that IoT technologies could unlock between \$5.5 and \$12.6 trillion in economic value by 2030 [20].

However, current IoT systems remain fundamentally dependent on continuous Internet connectivity and centralized cloud infrastructures[30, 14]. The dominant architectural pattern across the industry involves edge devices collecting data and transmitting it to remote cloud servers for processing, storage, and other control logic. This approach delivers scalability and ease of management but creates a fundamental dependency on network availability.

This centralized model introduces several concerns beyond just connectivity: operational costs for cloud services create economic dependencies on third-party providers and often lead to vendor lock-in, data sovereignty issues arise when sensitive information must travel to and reside on external infrastructure, and system resilience becomes fundamentally tied to the availability of these remote services.

While cloud platforms can benefit IoT deployments through additional computational resources and storage capacity, systems that *depend* on constant cloud connectivity sacrifice local autonomy and introduce single points of failure. This cloud-centric model has enabled rapid IoT adoption, but introduces critical vulnerabilities across scenarios where continuous connectivity cannot be guaranteed.

Recent infrastructure failures illustrate the fragility of cloud-dependent architectures: the AWS US-EAST-1 outage in October 2025[27] disrupted services from banking to smart homes worldwide, demonstrating how a DNS configuration error in a *single region* can cascade into global disruptions[26].

Attempts have been made to address these challenges through incremental improvements, such as shifting focus to edge computing in order to reduce latency[14, 30, 22], redundant cloud regions for availability[19, 18], and hybrid architectures that combine local and remote processing.[1, 7, 16]

However, these solutions remain fundamentally tied to the assumption of eventual connectivity, and often increase system complexity without eliminating the core dependency. This leads to shortcomings in key areas that demand more fundamental architectural reconsideration:

### **Limited suitability for hazardous environments**

Remote or dangerous locations (industrial sites, disaster-prone areas) require systems that can operate reliably without constant human intervention or stable network infrastructure;

### **Lack of autonomous operation**

Device deployment and operation en masse can be brittle, with little tolerance for individual node failures in the IoT infrastructure, which is naturally susceptible to network failures and intermittent connectivity;

### **Privacy and data sovereignty concerns**

Cloud platforms and other third-parties are oftentimes an unavoidable middle layer between end devices and end users, raising questions about data processing and control.

fazer distinção  
maior entre iot  
e domotics?

While these challenges affect both IoT and domotics systems alike – from industrial monitoring to residential automation – they become particularly acute in disaster response and emergency scenarios, where additional difficulties arise: communication infrastructure failing precisely when needed most, rapid deployment with little configuration becoming essential, and autonomous operation transitioning desirable to indispensable.

These limitations are accentuated in disaster response and awareness scenarios, where real-time data collection and dissemination are crucial. During earthquakes, floods, and other emergencies, traditional communication infrastructure often fails first, yet the need for sensor data (structural integrity, air quality, evacuation routes) and bidirectional communication (threats alerts, user feedback) becomes critical.

A pragmatic issue in the context of smart homes is that without cloud connectivity, users cannot interact with their appliances, such that during a Wi-Fi outage smart lights become uncontrollable despite all hardware being physically present. While merely inconvenient domestically, this architectural dependency has critical implications in other contexts and **MicroBabel** addresses such scenarios across scales: from residential systems requiring local control, to building monitoring infrastructures that must operate during emergencies, to disaster response networks where autonomous operation becomes essential when traditional infrastructure fails.

While cloud platforms like Amazon Alexa, Google Home, and Microsoft Azure IoT Hub offer convenience for data processing and remote device control, their inherent dependence on continuous Internet connectivity introduces some critical limitations:

increased latency from round-trip communication to distant servers[22, 21], reduced availability during network disruptions or cloud outages[29, 18], and poor fault-tolerance when infrastructure fails[2].

These characteristics make cloud-centric architectures fundamentally unsuitable for scenarios that require or prioritize local operation, autonomous behavior, or guaranteed responsiveness during emergencies.

The Babel Ecosystem [12] addresses these limitations by enabling devices to operate autonomously without cloud infrastructure, while still supporting cloud integration when connectivity is available and desired.

In this document we introduce **MicroBabel**, a lightweight framework targeting embedded platforms (ESP32, Raspberry Pi Pico) aimed at developing resilient, multi-protocol and decentralized IoT systems that can operate autonomously during infrastructure failures. **MicroBabel** integrates with the broader Babel Ecosystem, which runs hardware with greater resources such as full Raspberry Pi boards or computers, enabling a tiered architecture where resource-constrained edge devices can seamlessly interoperate with computational nodes for data aggregation, processing, and coordination.

## Research Topics

We focus on three main research questions:

### **How can these systems maintain communication when traditional infrastructure fails?**

Traditional IoT deployments rely heavily on Wi-Fi access points, cellular towers, or other centralized infrastructure that often becomes unavailable during disasters, or is altogether unreliable in remote locations. **MicroBabel** addresses this by leveraging a multi-protocol communication approach, supporting a diverse protocol stack (Bluetooth Low Energy (BLE), LoRa, ESP-NOW, ZigBee, infrared) that can operate independently of infrastructure.

By enabling adaptive protocol selection and peer-to-peer mesh formation, devices can establish alternative communication paths when primary channels fail.

### **How can device heterogeneity be leveraged to create and orchestrate these networks?**

IoT deployments naturally comprise devices with varying capabilities, from resource-constrained sensors, to gateway nodes with greater processing power and storage. Rather than treating this heterogeneity as a limitation, **MicroBabel** exploits it through capability-aware protocols that allow devices to negotiate roles dynamically via discovery.

Resource-rich nodes can serve as data aggregation and processing points, or bridges between a remote deployment and traditional network infrastructure (if desired), while simpler devices focus on sensing and actuation, creating a resilient multi-tier architecture.

### **How can we achieve (near-)zero-configuration deployment, suitable for emergency scenarios and hazardous location monitoring where manual setup is impractical or**

**even impossible?** Emergency response and hazardous environment monitoring demand systems that can be deployed rapidly without extensive configuration. **MicroBabel** provides automatic peer discovery across multiple channels, self-organizing network formation, and decentralized coordination mechanisms that eliminate the need for pre-configured master nodes or manual network planning.

Devices autonomously establish connectivity with each other, negotiate protocols, and begin operation upon being activated, enabling deployment by non-technical personnel or in hard-to-reach locations.

### Contributions

We plan to make the following contributions:

- A decentralized architecture supporting multiple communication channels (BLE, LoRa, ZigBee, ESP-NOW, IR) with adaptive protocol switching based on Quality of Service (QoS) requirements, resource availability and device capabilities;
- A resource-efficient programming framework for embedded platforms that enables autonomous operation without central coordination, providing abstractions for multi-protocol communication, peer discovery, and opportunistic data forwarding;
- A proof-of-concept implementation demonstrating infrastructure- independent operation and automatic disaster-mode failover in a real-world deployment.

fico na dúvida se devia reword this para não "prometer too much"?



# NOVATHESIS TEMPLATE *USER'S MANUAL*

This manual is outdated and must be revised!

## 2.1 Introduction

This Chapter describes how to use the NOVAtHesis L<sup>A</sup>T<sub>E</sub>X (`novathesis`) template. It is assumed that you have a working of L<sup>A</sup>T<sub>E</sub>X, either local (in your own computer) or remote (in Overleaf), and that you were able to generate a PDF for the default configuration of the template: a PhD thesis for NOVA School of Science and Technology (FCT).

## 2.2 Quick Start

### 2.2.1 With a Local L<sup>A</sup>T<sub>E</sub>X Installation

Follow these steps to get started with a local L<sup>A</sup>T<sub>E</sub>X installation:

1. Download L<sup>A</sup>T<sub>E</sub>X. There are two major L<sup>A</sup>T<sub>E</sub>X distributions — [MikT<sub>E</sub>X](#) and [T<sub>E</sub>XLive](#) — that share lots of similarity, and L<sup>A</sup>T<sub>E</sub>X documents are portable between them. This means that, for most users, both systems are equally usable.

**T<sub>E</sub>X-Live** is maintained by (La)T<sub>E</sub>X developers and is certainly the best distribution you may install in your computer: However, the default distribution will take more than 5 GB on your hard disk. . . so, if you are not short on disk space, install T<sub>E</sub>XLive!

**MikT<sub>E</sub>X** will, by default, install only a minimal set of packages. The extra/additional packages will be installed on the fly. Installing packages on the fly is useful if disk space is limited, but has its own caveats in the longer term. Definitely choose MikT<sub>E</sub>X if you're short on disk space.

Which one to download? There are [pros and cons for both distributions](#) so it is essentially a question of where does your heart fall first! Mine falls to T<sub>E</sub>XLive, but yours can fall elsewhere! :D

2. Install  $\text{\LaTeX}$ . Installation of  $\text{\LaTeX}$  is as hard as installing any other software. Just do your best and you will certainly succeed.
3. Update your  $\text{\LaTeX}$  installation using the *TeXLiveUtility* program of the MikTeX console.
4. Download the `novathesis` template by either:

- Cloning the [GitHub repository](#) with

```
git clone --depth=1 https://github.com/joaomlourengo/novathesis.git
```

or

- Downloading the [latest version from the GitHub repository](#) as a Zip file.

5. Download additional School specific files if applicable:

**Universidade do Minho (UMINHO)** download the required *NewsGotT* font files from <https://github.com/joaomlourengo/novathesis-extras/raw/main/Fonts/NewsGotT.zip>

then unzip the file and copy the 3 font files

`"n015002t.ttf", "n015003t.ttf", and "n015006t.ttf"`

to the folder

`"NOVAthesisFiles/FontStyles/Fonts"`.

**Escola Superior de Enfermagem do Porto (ESEP)** download the required *Calibri* font files from <https://github.com/joaomlourengo/novathesis-extras/raw/main/Fonts/Calibri.zip>

then unzip the file and copy the 4 font files

`"Calibri.ttf", "Calibrib.ttf", "Calibrii.ttf", and "Calibriz.ttf"`

to the folder

`NOVAthesisFiles/FontStyles/Fonts`.

6. Compile the document with you favorite LaTeX processor (pdfLaTeX, XeLaTeX or LuaLaTeX).

- The main file is named `"template.tex"`, but you are free to rename it as you please.
- Either load the main file in your favorite [LaTeX text editor](#) and press the appropriate (*magic*) button to generate a PDF file, or open a terminal and compile it with `"latexmk -pdf template"`. If you use a  $\text{\LaTeX}$  text editor, please notice that the `novathesis` template uses `"biber"` and not `"bibtex"` to process the bibliography, which means that most probably you have to open

the *Editor Preferences* and somewhere (depending on the Editor you are using) change “bibtex” to “biber”.

- Notice that, due to the external font sets used, pdfL<sup>A</sup>T<sub>E</sub>X will not work for both UMINHO and ESEP, and you have to use either X<sub>Y</sub>L<sup>A</sup>T<sub>E</sub>X (“latexmk -pdfxe template”) or LuaL<sup>A</sup>T<sub>E</sub>X (“latexmk -pdflua template”).

7. Edit the files in the “Config” folder. See [Table 2.2](#).

8. Recompile de document.

9. And you’re done with a beautifully formatted thesis/dissertation! :D

### 2.2.2 With a Remote Cloud-based Service





Follow these steps to get started with a remote L<sup>A</sup>T<sub>E</sub>X installation:

- Download the [latest version from the GitHub repository as a Zip file](#).
- Login to your favorite LaTeX cloud service. I recommend [Overleaf](#) but there are alternatives. These instructions apply to Overleaf and you’ll have to adapt for other providers.
- In the menu select New project → Upload project.
- Select “template.tex” as the main file.
- Follow from Step 5 above in Section 2.2.1 ([With a Local L<sup>A</sup>T<sub>E</sub>X Installation](#)).

## 2.3 Folder and Files

The novathesis template is organized into many files and folders. At the main level it includes the following files and folders listed in [Table 2.1](#).

Table 2.1: The folders and files (top level).

Name	Type	Access	Contents
template.tex			The main template file. You need to <i>compile</i> this file with one of pdfL <sup>A</sup> T <sub>E</sub> X, X <sub>Y</sub> L <sup>A</sup> T <sub>E</sub> X, or LuaL <sup>A</sup> T <sub>E</sub> X to obtain the PDF file (“template.pdf”). I recommend the usage of the “latexmk” command or, if you use a UN*X-like OS, you may use “make” (and the ggiven “Makefile”).
Config			Configuration files. Please customize your template by changing the files in this folder!

































Chapters			Examples of document contents, including Chapters, Appendices, Annexes, Abstracts, Glossaries, Lists of Symbols, etc. Replace them with your own.
Bibliography			Where all your bibliography files should be located. You may have has many bibliography files as you want.
template.pdf			A possible result of applying pdfL <sup>A</sup> T <sub>E</sub> X to the “template.tex” file. The look and feel of the document will depend on the parametrization/configuration (e.g., School) of this template.
novathesis.cls			The main class file.
NOVAthesisFiles			Additional files for the <b>novathesis</b> template. This is where all the juice is so, unless you are a T <sub>E</sub> Xmagician, don't mess up with the files and folders inside this folder.

Table 2.2: The configuration files (Config folder).

Name	Type	Access	Contents
0_memoir.tex			Options specific for the memoir class. <i>Don't touch this file unless you know what you are doing!</i>
1_novathesis.tex			The main configuration file for the template, e.g., select the document type, the school, the used languages, etc.
2_biblatex.tex			Select how your citations and bibliographic references will be printed. The default is numbers inside square brackets, e.g. [17], but you can change it to other formats, such as author-year, e.g., Lourenço (2021).
3_cover.tex			Configure cover contents (e.g., author's name, thesis/dissertation title, author, advisers, committee, etc)
4_files.tex			Select which files shall be included in the document as chapters, appendices, annexes, etc. . .
5_packages.tex			User's customization, such as loading additional packages and declare user defined commands.

6_list_of.tex			Configure the lists to be printed (table of contents, list of figures, list of tables, list of listings, etc). <i>Don't touch this file unless you know what you are doing!</i>
9_nova_fct.tex			Configurations specific to NOVA FCT. <i>Otherwise ignored.</i>
9_ulisboa_fmv.tex			Configurations specific to ULISBOA FMV. <i>Otherwise ignored.</i>
9_ulisboa_ist.tex			Configurations specific to ULISBOA IST. <i>Otherwise ignored.</i>
9_uminho.tex			Configurations specific to UMINHO (all schools). <i>Otherwise ignored.</i>

---

## 2.4 Customizing the *novathesis* template

The *novathesis* template can be customized by editing the files in the Config folder.

### 2.4.1 Options in 1\_novathesis.tex

#### 2.4.1.1 Most Relevant Options (1\_novathesis.tex)

---

<b>doctype=OPT</b> <i>phd, phdprop, phdplan, msc, mscplan, bsc, plain</i>	<b>The type of the document.</b> phd → PhD thesis ( <i>⇐ default</i> ). phdprop → PhD thesis proposal (for FCT-NOVA). phdplan → PhD thesis plan. msc → MSc thesis. mscplan → MSc thesis plan. bsc → BSc report. plain → Other report.
--	--

---

**school=OPT**

*nova/fct, nova/fcsh, nova/ims,  
nova/ims/mcsig, nova/ims/mgt,  
nova/ensp, nova/itqb/green,  
nova/itqb/gray, ulisboa/ist, ulisboa/fcul,  
ulisboa/fmv, uminho/eaad, uminho/ec,  
uminho/ed, uminho/eeg, uminho/eeng,  
uminho/elach, uminho/emed,  
uminho/epsi, uminho/ese, uminho/i3bs,  
uminho/ics, uminho/ie, iscteiu/eta,  
ips/ests, ipl/isel, ipl/isel/meb, ulht/deisi,  
ulht/mge, other/esep*

**Selection of the university and of the school (and degree variant).**

⇒ *Default: school=nova/fct*

This option changes the typesetting of the document to some specific School formatting and layout, like covers, margins, fonts, paragraph spacing and indentation, etc.

**docstatus=OPT**

*draft, provisional, final*

**The current status of the document.**

working → Working version (⇐ *default*).  
provisional → Version for submission.  
final → Final version.

**lang=OPT**

*en, pt, de, es, fr, gr, it*

**The main language for the document.**

en → English (⇐ *default*).  
pt → Portuguese.  
de → German.  
es → Spanish.  
fr → French.  
gr → Greek.  
it → Italian.

**media=OPT**

*screen, paper*

**The target media for the PDF.**

screen → No empty/white pages (⇐ *default*).  
paper → Empty/white pages are added when necessary.

**print/webography=OPT**

*User defined title*

**Generate a separate bibliography for @online references.**

⇒ *Default: print/webography=undefined*

If undefined, the @online references are listed in the main bibliography. If defined, the @online references will be printed in a separate bibliography titled as given in the option.

**color/links=OPT**

*Color name*

**The color for the hyperlinks (URLs, cross references, citations).**

⇒ *Default: color/links=DarkBlue*

The valid color names as listed in “xcolor” manual, the “svgname” color set.

<b>color/gls=OPT</b> <i>Color name</i>	<b>The color for the glossary managed hyperlinks (glossary, symbols, etc).</b> $\Rightarrow$ <i>Default: color/gls=Black</i> The valid color names as listed in “xcolor” manual, the “svgname” color set.
<b>print/index=OPT</b> <i>true,</i> <i>false</i> ( $\Leftarrow$ default)	<b>Print the (words) index at the end of the document.</b> Print the index (in Portuguese <i>Índice Remissivo</i> ).

#### 2.4.1.2 Less Relevant Options (1\_novathesis.tex)

<b>abstractorder=OPT</b> $L_0 = \{L_1, L_2, \dots, L_n\}$	<b>Forces the abstracts languages and order for documents in language <math>L_0</math>.</b> $\Rightarrow$ <i>Default: abstractorder={en={en,pt}} for english</i> $\Rightarrow$ <i>Default: abstractorder={L={L,en}} for lang L</i> $L_i$ is a two-letters language code from the set of valid language codes, following ISO 3166-1 (alfa-2).
<b>lang/extra=OPT</b> $\{L_1, L_2, \dots, L_n\}$	<b>List of additional languages are used in the document besides the main language and those used in the abstracts (above).</b> $\Rightarrow$ <i>Default: lang/extra={}</i> $L_i$ is a two-letters language code from the set of valid language codes, following ISO 3166-1 (alfa-2).
<b>gnumberlist=OPT</b> <i>true,</i> ( $\Leftarrow$ default) <i>false</i>	<b>Shall the glossary entries list the page numbers where those entries are used? (Like a reverse index!)</b>
<b>numberallpages=OPT</b> <i>true,</i> <i>false</i> ( $\Leftarrow$ default)	<b>Shall all the pages (except cover) be numbered?</b>
<b>tocintoc=OPT</b> <i>true,</i> <i>false</i> ( $\Leftarrow$ default)	<b>Shall table of contents be listed in the table of contents?</b>
<b>tocintoc=OPT</b> <i>true,</i> <i>false</i> ( $\Leftarrow$ default)	<b>Shall a second cover page be forced?</b> If the contents for the second page are not defined, the second cover will be a replica of the first cover.

<b>print/committee=OPT</b> <i>true,</i> <i>false</i>	<b>Shall the evaluation committee be printed?</b> ⇒ <i>Default: print/committee=true if docstatus=final</i> ⇒ <i>Default: print/committee=false otherwise</i>
<b>print/frontmatter=OPT</b> <i>true, (⇐ default)</i> <i>false</i>	<b>Shall the front matter be printed?</b> Set to false to generate a PDF with only the cover and the book chapters.
<b>print/statement=OPT</b> <i>true,</i> <i>false (⇐ default)</i>	<b>Shall the honor/originality statement be printed?</b>
<b>print/copyright=OPT</b> <i>true, (⇐ default)</i> <i>false</i>	<b>Shall the copyright message be printed?</b>
<b>print/timestamp=OPT</b> <i>true,</i> <i>false</i>	<b>Shall a timestamp (with the PDF generation date/time) be printed in the cover?</b> ⇒ <i>Default: print/timestamp=true if docstatus=working</i> ⇒ <i>Default: print/timestamp=false otherwise</i>
<b>style/url=OPT</b> <i>default, (⇐ default)</i> <i>same</i>	<b>Use the same (main) font in URLs?</b>
<b>style/font=OPT</b> <i>arial, bookman, calibri, erewhon,</i> <i>kieranhealy, kpfonts, libertine, newpx,</i> <i>newsgott, scholax</i>	<b>Which font set to use in the document?</b> arial → Use 'arial' font. Requires Xe <sup>L</sup> A <sub>T</sub> E <sub>X</sub> or Lua <sup>L</sup> A <sub>T</sub> E <sub>X</sub> . bookman → Use 'bookman' font. calibri → Use 'calibri' font. Requires Xe <sup>L</sup> A <sub>T</sub> E <sub>X</sub> or Lua <sup>L</sup> A <sub>T</sub> E <sub>X</sub> . erewhon → Use 'erewhon' font. kieranhealy → Use 'kieranhealy' font. kpfonts → Use 'palatino' font. libertine → Use 'libertine' font. newpx → Use 'palatino' font. (⇐ <i>default</i> ) newsgott → Use 'newsgott' font. Requires Xe <sup>L</sup> A <sub>T</sub> E <sub>X</sub> or Lua <sup>L</sup> A <sub>T</sub> E <sub>X</sub> . scholax → Use 'scholax' font.

---



**style/chapter=OPT**

See list on the side!

**Which chapter style to use in the document?**

Besides the standard [memoir chapter styles](#) (default, section, article, reparticle, hangnum, companion, demo, bianchi, bringhurst, brotherton, chappell, culver, dash, demodemoell, ger, lyhne, madsen, pedersen, southall, thatcher, veelo, verville, crosshead, dowding, komalike, ntglke, tandh, wilsondob), the customized list of chapter styles below is also available.

bar → Use ‘bar’ chapter style. ( $\Leftarrow$  *default*)

bar-compact → Use ‘bar-compact’ chapter style.

bluebox → Use ‘bluebox’ chapter style.

compact → Use ‘compact’ chapter style.

elegant → Use ‘elegant’ chapter style.

fmv → Use ‘fmv’ chapter style.

hansen → Use ‘hansen’ chapter style.

ist → Use ‘ist’ chapter style.

ist2 → Use ‘ist2’ chapter style.

pedersen → Use ‘pedersen’ chapter style.

**lang/cover=OPT***en, pt, de, es, fr, gr, it***The main language for the cover.** $\Rightarrow$  *Default: The same as the main language.***lang/copyright=OPT***en, pt, de, es, fr, gr, it***The main language for the copyright message.** $\Rightarrow$  *Default: The same as the main language.***spine/layout=OPT***no, full, trim***Print the “book spine” at the end of the document?** $\Rightarrow$  *Default: ‘trim’ if docstatus=final* $\Rightarrow$  *Default: ‘no’ otherwise*

no → do not print the book spine.

full → print the book spine in a full page.

trim → print and trim the page to the width of the book spine.

**spine/width=OPT** $\text{\LaTeX}$  dimension**Force the width of the “book spine”.** $\Rightarrow$  *Default: The “natural width”.*

The default width for the book spine will be the width of the number of pages of the document if printed in standard paper ( $80\text{g}/\text{m}^2$ ).

**debug=OPT***cover, spine***Activate debug mode for cover and/or book spine.** $\Rightarrow$  *Default: debug={}*

## 2.5 How to Write Using L<sup>A</sup>T<sub>E</sub>X

Please have a look at Chapter 3, where you may find many examples of L<sup>A</sup>T<sub>E</sub>X constructs, such as Sectioning, inserting Figures and Tables, writing Equations, Theorems and algorithms, exhibit code listings, etc.

## 2.6 Example glossary, acronyms, and symbols

This is the first occurrence of an abbreviation: abbreviation of a longer text (abbrev). And now the second occurrence of the same abbreviation: abbrev. And a new acronym with capital letter: And extension of a xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto (xpto) and reused xpto. Let's also use a few other acronyms such as acronym aaa (aaa), acronym aab (aab), acronym aba (aba), acronym bbb (bbb) and xpto. In geometry, the area enclosed by a circle of radius  $r$  is  $\pi r^2$ . Here the Greek letter  $\pi$  is equal to the ratio of the circumference of any circle to its diameter. Lets add "computer" to the glossary! Be carefull with mathematical symbols in acronyms, please see the definition of  $\mu$ .

# A SHORT L<sup>A</sup>T<sub>E</sub>X TUTORIAL WITH EXAMPLES

This Chapter aims at exemplifying how to do common stuff with L<sup>A</sup>T<sub>E</sub>X. We also show some stuff which is not that common! ;)

Please, use these examples as a starting point, but you should always consider using the *Big Oracle* (aka, [Google](#), your best friend) to search for additional information or alternative ways for achieving similar results.

## 3.1 Document Structure

## 3.2 Dealing with Bibliography

Citing something online [6, 10, 13].

## 3.3 Inserting Tables

## 3.4 Importing Images

## 3.5 Floats, Figures and Captions

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

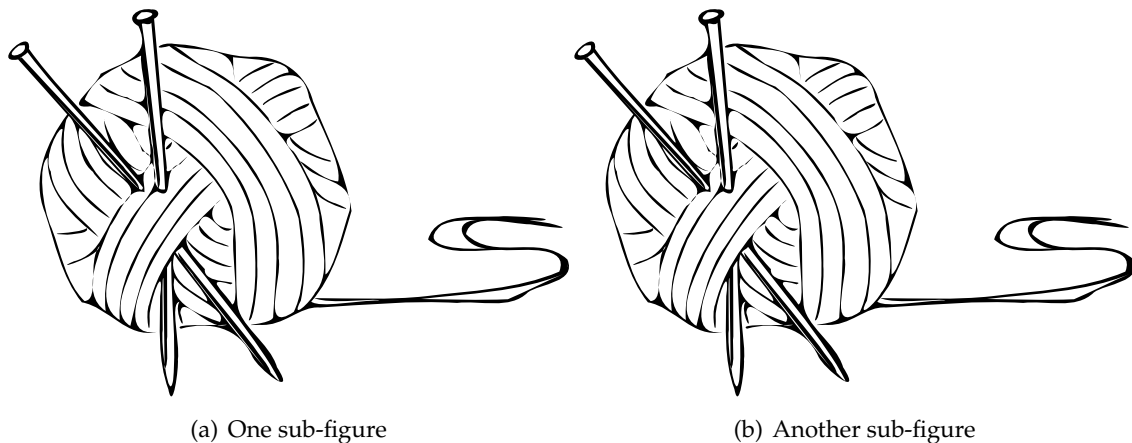


Figure 3.1: A figure with two sub-figures!

And this is a small text that references the Figure 3.1 and its Subfigures 3.1(a) and 3.1(b).

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan

eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

## 3.6 Text Formatting

## 3.7 Generating PDFs from L<sup>A</sup>T<sub>E</sub>X

### 3.7.1 Generating PDFs with pdf<sub>l</sub>atex

You may create PDF files either by using `latex` to generate a DVI file, and then use one of the many DVI-2-PDF converters, such as `dvipdfm`.

Alternatively, you may use `pdflatex`, which will immediately generate a PDF with no intermediate DVI or PS files. In some systems, such as Apple, PDF is already the default format for L<sup>A</sup>T<sub>E</sub>X. I strongly recommend you to use this approach, unless you have a very good argument to go for `latex + dvipdfm`.

A typical pass for a document with figures, cross-references and a bibliography would be:

```
$ pdflatex template
$ bibtex template
$ pdflatex template
$ pdflatex template
```

You will notice that there is a new PDF file in the working directory called `template.pdf`. Simple :)

Please note that, to be sure all table of contents, cross-references and bibliographic citations are up-to-date, you must run `latex` once, then `bibtex`, and then `latex` twice.

### 3.7.2 Dealing with Images

You may process the same source files with both `latex` or `pdflatex`. But, if your text include images, you must be careful. `latex` and `pdflatex` accept images in different (exclusive) formats. For `latex` you may use EPS ou PS figures. For `pdflatex` you may use JPG, PNG or PDF figures. I strongly recommend you to use PDF figures in vectorial format (do not use bitmap images unless you have no other choice).

### 3.7.3 Dealing with Citations

Para fazer citações, deverá usar-se a chave da referência no ficheiro BibTeX. Se for uma única referência [4], usar um “~” para ligar o `\cite{...}` à palavra que o precede (...referência~\cite{Artho04}). Caso queira fazer múltiplas citações [23, 24, 9], deverá agrupá-las dentro de um único `\cite{...}`.

Note que o ficheiro de bibliografia pode ter tantas entradas quantas quiser. Apenas aquelas cuja chave seja referenciada no texto é que serão incluídas na listagem de bibliografia.

### 3.7.4 Footnotes

Footnotes<sup>1</sup> will be numbered and shown in the bottom of the page.

### 3.7.5 Tables

The Table 3.1 illustrates some important concepts associated with table construction:

- i) Do not use vertical lines;
- ii) The caption should be above the table;
- iii) Use the macros `\toprule`, `\midrule` and `\bottomrule` to make the top, inner and bottom horizontal lines, respectively.

Table 3.1: Test results summary.

Test	Anomalies	Warnings	Correct	Categories	Missed
Connection [5]	2	2	1	C	1
Coordinates’03 [3]	1	4	1	2B, 1C	0
Local Variable [3]	1	2	1	A	0
NASA [3]	1	1	1	—	0
Coordinates’04 [4]	1	4	1	3C	0
Buffer [4]	0	7	0	2A, 1B, 2C, 2D	0
Double-Check [4]	0	2	0	1A, 1B	0
StringBuffer [11]	1	0	0	—	1
Account [28]	1	1	1	—	0

---

<sup>1</sup>This is a simple footnote.

Jigsaw [28]	1	2	1	C	0
Over-reporting [28]	0	2	0	1A, 1C	0
Under-reporting [28]	1	1	1	—	0
Allocate Vector [15]	1	2	1	C	0
Knight Moves [5]	1	3	1	2B	0
Total	12	33	10	5A, 6B, 10C, 2D	2

### 3.7.6 Figures

The images inserted in the document must be of good quality, preferably in vector format (vector PDF) and not in *bitmap* (PNG, JPG, etc.). *bitmap* images (Figure 3.2) do not scale well and have negative effects on the quality of your document. On the other hand, *vector* images Figure 3.3 scale as much as necessary without degrading the quality of the image.

You should only use *screenshots* for your plots, charts, etc, if you absolutely have no other alternative. Instead of generating a *screenshot*, try using a virtual PDF printer and printing to a PDF file. As a general rule, you will get a vector PDF. Even if your PDF contains images, they will always be of higher or equal quality than what you would get with a *screenshot*.

To combine several figures into a single one... You can then reference the set as Figure 3.4 or the sub-figures separately as 3.4() and 3.4(a).

## 3.8 Equations

LaTeX is a powerful tool for writing in a mathematical style. It allows you to insert formulas into the text, such as this:  $ax^2 + bx + c = 0$ . It also allows formulas to be highlighted on a separate line and centered on the page.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

or numbered

$$e = mc^2 \tag{3.1}$$

which can latter be referenced as equation 3.1

## 3.9 Test for listings

Testing the package “listings”...

Listing 3.1: cap

```
1 if(a==b)
2   puts("YESS!")
```

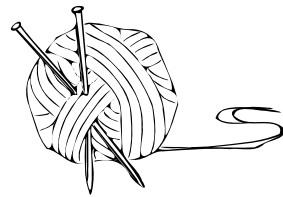


Figure 3.2: Bitmap image (JPG/PNG)





Figure 3.3: Vectorial image (PDF)



(a) Novelo de lã



(b) Tempestade com neve

Figure 3.4: Exemplo de utilização de *subbottom*

### 3.10 Test for algorithms

Uncomment the algorithms source below and add the following to file “5\_packages.tex”

```
\usepackage{algorithm2e}
\RestyleAlgo{ruled}
```

and uncomment

```
\ntaddlistof{listofalgorithms}
```

in file “8\_list\_og.tex”.

## ADDING SUPPORT TO A NEW SCHOOL (WORK IN PROGRESS)

My advice to customize the `novathesis` template to another School/University/Department/Degree is to browse the existing supported degrees to find one that is *close enough*, and depart from there!

The multitude of layouts supported by the `novathesis` template is based in a three-tier naming scheme, separated by slashes: University / School / Department-or-Degree. This three-tier naming scheme is also reflected in a three-tier directory (folder) structure in: `<project_root>a/NOVAthesiFiles/Schools/....` For example:

```
...
|
+-- nova
|   +-- Images
|   +-- fct
|   |   \-- Images
|   +-- ims
|   |   \-- Images
|   ...
|
\-- uminho
    +-- Images
    +-- ea
    |   \-- Images
    +-- ec
    |   \-- Images
    ...
```

The directory `uminho` contains the customization for all Schools of Universidade do Minho. This university is an example of the case where the regulations are defined at

University level and all the schools apply the same thesis layout and organization. So, the all the customization is done in the file `uminho/uminho-defaults.ldf`, except the definition of the name and logo of each individual school.

As another example, the directory `nova` contains the customization for all Schools from NOVA University Lisbon. This university grants a lot of freedom in the definition of the thesis layouts. In some cases, they are defined at the School level (e.g., NOVA FCT), while in some other cases they are defined separately for each degree (e.g., NOVA IMS).

1. Try all the already supported schools and check which one is closer to your needs;
  - a) Edit `Config/1_novathesis.tex` and near line 28 uncomment the line with key `\ntsetup{school=<SOMETHING>};`
  - b) For each school supported (see the comment), replace `<SOMETHING>` with the school name, e.g., make it `\ntsetup{school=ulisboa/fmv}`
  - c) Recompile and check the document. Particularly, check the cover layout, the front-page (second cover) layout, the front-matter contents, the bibliography style;
  - d) Repeat for the next school, until you find one close enough.
- 2.

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## NOVATHESIS COVERS SHOWCASE

This Appendix shows examples of covers for some of the supported Schools. When the Schools have very similar covers (e.g., all the schools from Universidade do Minho), just one cover is shown. If the covers for MSc dissertations and PhD thesis are considerable different (e.g., for FCT-NOVA and UMinho), then both are shown.

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## APPENDIX 2 LOREM IPSUM

This is a test with citing something [\[8\]](#) in the appendix.



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## ANNEX 1 LOREM IPSUM

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