



DEPARTMENT OF
COMPUTER SCIENCE

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BSc in Computer Science and Engineering

DEVELOPMENT OF AN AUTOMATED TOOL FOR DNA SANGER ALIGNMENTS BASED ON AI

**INNACURACY DETECTION ON DNA SANGER SEQUENCED DATA USING
MACHINE AND DEEP LEARNING**

MASTER IN COMPUTER SCIENCE AND ENGINEERING

NOVA University Lisbon

Draft: January 11, 2025

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ABSTRACT

Sanger sequencing, while a cornerstone of DNA analysis, frequently yields alignment results that require labor-intensive manual verification to identify anomalies and inaccuracies. This process is not only time-consuming but also susceptible to human error, posing significant challenges for laboratories managing high-throughput sequencing data. Addressing this issue is critical for improving efficiency and reliability in genomic workflows.

This thesis introduces an AI-driven tool designed to automate the verification of DNA sequence alignment results produced by the ABI3730xl sequencer. By utilizing machine learning models trained on real-world data from 96-well plates, the tool identifies anomalies, detects sequence homologies, and determines the acceptability of results with a high degree of precision. To facilitate broader adoption, the tool is accessible via an online platform, enabling remote usage by laboratories worldwide.

The proposed solution significantly enhances laboratory workflows by streamlining the verification process and reducing reliance on manual oversight. This not only minimizes errors but also accelerates data processing, paving the way for advancements in precision genomics and biotechnology. The tool's ability to identify inaccurately labeled wells further underscores its practical value in supporting high-throughput DNA analysis.

By addressing key limitations in current practices, this work demonstrates the transformative potential of integrating artificial intelligence into genomic research, contributing to a future of more efficient and accurate DNA sequencing.

Keywords: Sanger Sequencing, Artificial Intelligence, DNA verification, Machine Learning, Genomic Workflows

RESUMO

A sequenciação Sanger, apesar de ser uma pedra angular na análise de DNA, frequentemente produz resultados de alinhamento que requerem verificação manual intensiva para identificar anomalias e imprecisões. Este processo não é apenas moroso, mas também suscetível a erros humanos, apresentando desafios significativos para laboratórios que gerem dados de sequenciação de alto desempenho. Abordar este problema é crucial para melhorar a eficiência e a confiabilidade nos fluxos de trabalho genômicos.

Esta tese apresenta uma ferramenta baseada em inteligência artificial (IA) concebida para automatizar a verificação dos resultados de alinhamento de sequências de DNA produzidos pelo sequenciador ABI3730xl. Utilizando modelos de aprendizagem automática treinados com dados reais de placas de 96 poços, a ferramenta identifica anomalias, detecta homologies de sequências e determina a aceitabilidade dos resultados com um elevado grau de precisão. Para facilitar a adoção ampla, a ferramenta é acessível através de uma plataforma online, permitindo a utilização remota por laboratórios em todo o mundo.

A solução proposta melhora significativamente os fluxos de trabalho laboratoriais ao simplificar o processo de verificação e reduzir a dependência da supervisão manual. Isto não apenas minimiza erros, mas também acelera o processamento de dados, abrindo caminho para avanços na genômica de precisão e na biotecnologia. A capacidade da ferramenta de identificar poços rotulados de forma incorreta destaca ainda mais o seu valor prático no suporte à análise de DNA de alto desempenho.

Ao abordar limitações-chave nas práticas atuais, este trabalho demonstra o potencial transformador de integrar inteligência artificial à investigação genômica, contribuindo para um futuro de sequenciação de DNA mais eficiente e preciso.

Palavras-chave: Sequenciação Sanger, Inteligência Artificial, Verificação de DNA, Aprendizagem Automática, Fluxos de trabalho genômicos

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GLOSSARY

computer An electronic device which is capable of receiving information (data) in a particular form and of performing a sequence of operations in accordance with a predetermined but variable set of procedural instructions (program) to produce a result in the form of information or signals. This is a test that adds a citation [2] to the glossary! (*p. 13*)

ACRONYMS

| | |
|-------------------|--|
| aaa | acronym aaa (<i>p. 13</i>) |
| aab | acronym aab (<i>p. 13</i>) |
| aba | acronym aba (<i>p. 13</i>) |
| abbrev | abbreviation of a longer text (<i>p. 13</i>) |
| bbb | acronym bbb (<i>p. 13</i>) |
| novathesis | NOVAthesis L ^A T _E X (<i>pp. 1, 5–8</i>) |
| xpto | and extension of a xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto (<i>p. 13</i>) |

SYMBOLS

μ Mu (*p.* [14](#))

π the numerical value of pi (*p.* [13](#))

r the radius of a circle (*p.* [13](#))

INTRODUCTION



This is the NOVAthesis \LaTeX (nova`thesis`) \LaTeX template Version 7.2.5 from Template!date2024-11-03.

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1.1 Motivation

The ever-growing demand for efficient and accurate DNA sequencing solutions has highlighted the limitations of traditional methods, particularly in high-throughput environments. Sanger sequencing remains a widely used technique due to its reliability and precision. However, the manual verification of alignment results introduces bottlenecks that hinder the scalability and efficiency of laboratories, especially those handling extensive genomic datasets.

This bottleneck is not merely an operational issue but a scientific challenge. As genomic research expands its applications in fields like medicine, agriculture, and biotechnology, the need for automated tools capable of minimizing errors and optimizing workflows becomes increasingly evident. By integrating artificial intelligence (AI) into these processes, laboratories can achieve new levels of efficiency and accuracy, ultimately advancing the frontiers of genomic research.

1.2 Context

Sanger sequencing, developed in the 1970s, revolutionized genetic research and remains a gold standard for DNA analysis. The ABI3730xl sequencer is one of the most prominent

instruments used for this purpose, providing high-quality sequence alignments. However, the process is not immune to errors, particularly in labeling and detecting sequence anomalies within 96-well plates.

In recent years, artificial intelligence has emerged as a powerful tool for tackling complex problems across various domains, including genomics. Machine learning models, trained on extensive datasets, can identify patterns and anomalies with a precision that surpasses human capabilities. Applying these advancements to the verification phase of Sanger sequencing presents an opportunity to overcome existing limitations and enhance the reliability of DNA sequencing results.

1.3 Objectives

The primary goal of this thesis is to develop a tool that automates the verification of alignment results obtained from Sanger sequencing. The specific objectives include:

- Designing an AI algorithm capable of detecting anomalies and homologous sequences in alignment data.
- Training the algorithm using real-world datasets from ABI3730xl sequencers 96-well plates.
- Designing an AI algorithm capable of detecting anomalies and homologous sequences in alignment data.
- Training the algorithm using real-world datasets from ABI3730xl sequencers 96-well plates.
- Validating the tools performance against traditional manual verification methods.
- Deploying the tool via an online platform to ensure accessibility for laboratories worldwide.

1.4 Structure

This document is organized as follows:

- Introduction: Provides the motivation, context, objectives, and structure of the thesis.
- State of the Art:
- Related Work: Reviews existing literature and technologies in Sanger sequencing and AI applications in genomics.

- Methodology: Details the design and implementation of the proposed AI driven tool, including data collection, model training, and deployment.
- Planning: Presents the planning of the proposed work, composed by desired checkpoints and finish dates.

STATE OF THE ART

2.1 State of the Art

Sanger sequencing remains a cornerstone of genomic studies due to its high accuracy and reliability. However, the manual analysis of chromatograms and sequence data has traditionally been labor-intensive and prone to human error. Recent advancements have introduced automated tools and methodologies to streamline this process, with artificial intelligence (AI) playing a transformative role in enhancing efficiency and accuracy.

2.1.1 Automated Sequence Alignment

Tools like DNASTAR's SeqMan Ultra and Geneious have become benchmarks in sequence alignment, offering robust algorithms capable of assembling sequences into contigs and generating consensus sequences. These tools integrate features such as ClustalO, MUSCLE, MAFFT, and LASTZ algorithms to support precise alignment and visualization [dnastar, geneious].

2.1.2 AI in DNA Sequence Analysis

Machine learning (ML) and AI have emerged as powerful technologies in genomic data analysis. ML algorithms are utilized for alignment, classification, clustering, and pattern mining, significantly improving the efficiency of DNA sequence analysis. AI techniques also enhance sequencing accuracy, particularly in detecting genetic variations and anomalies [frontiers, pmc_ml].

2.1.3 Automated Pipelines for Sanger Sequencing

Automated pipelines such as the Automated Sanger Analysis Pipeline (ASAP) and SangeR have revolutionized the processing of Sanger sequencing data. These tools facilitate rapid data analysis with minimal user intervention, allowing for high-throughput and reproducible results [pmc_asap, bioinformaticsadvances].

2.1.4 Online Accessibility of Sequencing Tools

The proliferation of online tools has democratized access to sequencing analysis. Tools like Champuru 2 provide web-based platforms for analyzing mixed Sanger chromatograms, making advanced functionalities accessible to a broader audience [[champuru2](#)].

2.1.5 Automation in DNA Sequencing Laboratories

Automation in modern DNA sequencing laboratories has increased sample throughput, enhanced reproducibility, and reduced human error. These advancements enable precise sample tracking and high-throughput sequencing, meeting the demands of large-scale genomic studies [[base4](#)].

2.2 Quick Start

ee

2.2.1 With a Local L^AT_EX Installation

1. Download L^AT_EX. There are two major L^AT_EX distributions — [MikT_EX](#) and [T_EXLive](#) — that share lots of similarity, and L^AT_EX documents are portable between them. This means that, for most users, both systems are equally usable.

T_EX-Live is maintained by (La)T_EX 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_EXLive!

MikT_EX 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_EX 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_EXLive, but yours can fall elsewhere! :D

2. Install L^AT_EX. Installation of L^AT_EX is as hard as installing any other software. Just do your best and you will certainly succeed.
3. Update your L^AT_EX installation using the *T_EXLiveUtility* program of the MikT_EX console.
4. Download the NOVAthesis L^AT_EX ([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 \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, pdf \LaTeX will not work for both **UMINHO** and **ESEP**, and you have to use either X \LaTeX (`"latexmk -pdfxe template"`) or Lua \LaTeX (`"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^AT_EX 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^AT_EX 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 ^A T _E X, X _Y L ^A T _E X, or LuaL ^A T _E 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 given "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 ^A T _E 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 <code>novathesis</code> template. This is where all the juice is so, unless you are a \TeX magician, 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 <code>memoir</code> 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. [11], 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). *Otherwise ignored.*

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)

| | |
|---|--|
| doctype=OPT <i>phd, phdprop, phdplan, msc, mscplan, bsc, plain</i> | The type of the document. phd → PhD thesis (\Leftarrow <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 <i>nova/fct, nova/fcsh, nova/ims, nova/ims/mcsig, nova/ims/mgt, nova/ensp, nova/itqb/green, nova/itqb/gray, ulisboa/ist, ulisboa/fc, ulisboa/fmr, uminho/eaad, uminho/ec, uminho/ed, uminho/eeg, uminho/eeng, uminho/elach, uminho/emed, uminho/epsi, uminho/ese, uminho/i3bs, uminho/ics, uminho/ie, iscteiul/eta, ips/ests, ipl/isel, ipl/isel/meb, ullht/deisi, ullht/mge, other/esep</i> | Selection of the university and of the school (and degree variant). \Rightarrow <i>Default: school=nova/fct</i> 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 <i>draft, provisional, final</i> | The current status of the document. working → Working version (\Leftarrow <i>default</i>). provisional → Version for submission. final → Final version. |

| | |
|--|---|
| lang=OPT <i>en, pt, de, es, fr, gr, it</i> | The main language for the document. en → English (\Leftarrow <i>default</i>). pt → Portuguese. de → German. es → Spanish. fr → French. gr → Greek. it → Italian. |
| media=OPT <i>screen, paper</i> | The target media for the PDF. screen → No empty/white pages (\Leftarrow <i>default</i>). paper → Empty/white pages are added when necessary. |
| print/webography=OPT <i>User defined title</i> | Generate a separate bibliography for @online references. \Rightarrow <i>Default: print/webography=undefined</i> If undefined, the @online references are list 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 <i>Color name</i> | The color for the hyperlinks (URLs, cross references, citations). \Rightarrow <i>Default: color/links=DarkBlue</i> The valid color names as listed in “xcolor” manual, the “svgname” color set. |
| color/gls=OPT <i>Color name</i> | The color for the glossary managed hyperlinks (glossary, symbols, etc). \Rightarrow <i>Default: color/gls=Black</i> The valid color names as listed in “xcolor” manual, the “svgname” color set. |
| print/index=OPT <i>true,</i> <i>false (\Leftarrow default)</i> | Print the (words) index at the end of the document. Print the index (in Portuguese <i>Índice Remissivo</i>). |

2.4.1.2 Less Relevant Options (1_novathesis.tex)

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

print/copyright=OPT*true*, (\Leftarrow default)*false***Shall the copyright message be printed?**

print/timestamp=OPT*true*,*false***Shall a timestamp (with the PDF generation date/time) be printed in the cover?** \Rightarrow Default: *print/timestamp=true* if *docstatus=working* \Rightarrow Default: *print/timestamp=false* otherwise

style/url=OPT*default*, (\Leftarrow default)*same***Use the same (main) font in URLs?**

style/font=OPT*arial*, *bookman*, *calibri*, *erewhon*,*kieranhealy*, *kpfonts*, *libertine*, *newpx*,*newsgott*, *scholax***Which font set to use in the document?***arial* \rightarrow Use ‘arial’ font. Requires Xe \LaTeX or Lua \LaTeX .*bookman* \rightarrow Use ‘bookman’ font.*calibri* \rightarrow Use ‘calibri’ font. Requires Xe \LaTeX or Lua \LaTeX .*erewhon* \rightarrow Use ‘erewhon’ font.*kieranhealy* \rightarrow Use ‘kieranhealy’ font.*kpfonts* \rightarrow Use ‘palatino’ font.*libertine* \rightarrow Use ‘libertine’ font.*newpx* \rightarrow Use ‘palatino’ font. (\Leftarrow default)*newsgott* \rightarrow Use ‘newsgott’ font. Requires Xe \LaTeX or Lua \LaTeX .*scholax* \rightarrow 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 \rightarrow Use ‘bar’ chapter style. (\Leftarrow default)*bar-compact* \rightarrow Use ‘bar-compact’ chapter style.*bluebox* \rightarrow Use ‘bluebox’ chapter style.*compact* \rightarrow Use ‘compact’ chapter style.*elegant* \rightarrow Use ‘elegant’ chapter style.*fmv* \rightarrow Use ‘fmv’ chapter style.*hansen* \rightarrow Use ‘hansen’ chapter style.*ist* \rightarrow Use ‘ist’ chapter style.*ist2* \rightarrow Use ‘ist2’ chapter style.*pedersen* \rightarrow Use ‘pedersen’ chapter style.

| | |
|---|--|
| lang/cover=OPT <i>en, pt, de, es, fr, gr, it</i> | The main language for the cover. ⇒ <i>Default: The same as the main language.</i> |
| lang/copyright=OPT <i>en, pt, de, es, fr, gr, it</i> | The main language for the copyright message. ⇒ <i>Default: The same as the main language.</i> |
| spine/layout=OPT <i>no, full, trim</i> | Print the “book spine” at the end of the document? ⇒ <i>Default: ‘trim’ if docstatus=final</i> ⇒ <i>Default: ‘no’ otherwise</i> 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 L ^A T _E X dimension | Force the width of the “book spine”. ⇒ <i>Default: The “natural width”.</i> The default width for the book spine will be the width of the number of pages of the document if printed in standard paper (80g/m ²). |
| debug=OPT <i>cover, spine</i> | Activate debug mode for cover and/or book spine. ⇒ <i>Default: debug={}</i> |

2.5 How to Write Using L^AT_EX

Please have a look at Chapter 3, where you may find many examples of L^AT_EX 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 (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 πr^2 . Here the Greek letter π 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 μ .

A SHORT L^AT_EX TUTORIAL WITH EXAMPLES

This Chapter aims at exemplifying how to do common stuff with L^AT_EX. 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 [[4](#), [7](#), [9](#)].

3.3 Inserting Tables

3.4 Importing Images

3.5 Floats, Figures and Captions

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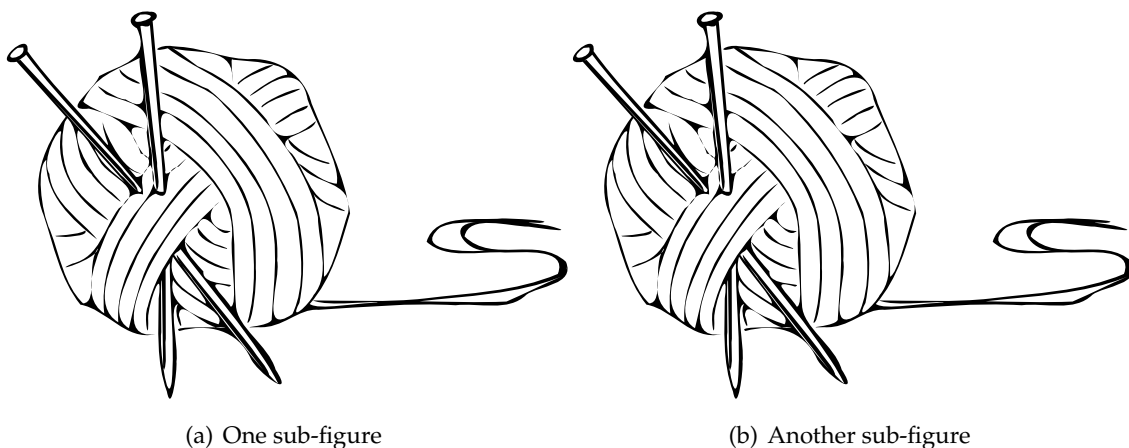


Figure 3.1: A figure with two sub-figures!

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

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3.6 Text Formatting

3.7 Generating PDFs from L^AT_EX

3.7.1 Generating PDFs with pdf_latex

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^AT_EX. 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 [2], usar um “~” para ligar o `\cite{...}` à palavra que o precede (...referência~`\cite{Art`. Caso queira fazer múltiplas citações [12, 13, 6], 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

Footnotes¹ 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 [3] | 2 | 2 | 1 | C | 1 |
| Coordinates’03 [1] | 1 | 4 | 1 | 2B, 1C | 0 |
| Local Variable [1] | 1 | 2 | 1 | A | 0 |
| NASA [1] | 1 | 1 | 1 | — | 0 |
| Coordinates’04 [2] | 1 | 4 | 1 | 3C | 0 |
| Buffer [2] | 0 | 7 | 0 | 2A, 1B, 2C, 2D | 0 |
| Double-Check [2] | 0 | 2 | 0 | 1A, 1B | 0 |
| StringBuffer [8] | 1 | 0 | 0 | — | 1 |
| Account [14] | 1 | 1 | 1 | — | 0 |

¹This is a simple footnote.

| | | | | | |
|----------------------|----|----|----|-----------------|---|
| Jigsaw [14] | 1 | 2 | 1 | C | 0 |
| Over-reporting [14] | 0 | 2 | 0 | 1A, 1C | 0 |
| Under-reporting [14] | 1 | 1 | 1 | — | 0 |
| Allocate Vector [10] | 1 | 2 | 1 | C | 0 |
| Knight Moves [3] | 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 3.7.6 and 3.7.6.

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 numbererd

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

which can latter be referenced as equation 3.1

3.9 Test for algorithms

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

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

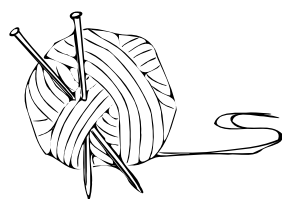
and uncomment



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*

```
\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.

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.

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APPENDIX 2 LOREM IPSUM

This is a test with citing something [\[5\]](#) in the appendix.

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ANNEX 1 LOREM IPSUM

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