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Master of Science

An effective Pest Monitoring System for outdoor farms

Dissertação para obtenção do Grau de Mestre em
Engenharia Informática

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Presidente: Name of the committee chairperson
Arguentes: Name of a rapporteur
 Name of another rapporteur
Vogais: Another member of the committee
 Yet another member of the committee



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An effective Pest Monitoring System for outdoor farms

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ABSTRACT

The dissertation must contain two versions of the abstract, one in the same language as the main text, another in a different language. The package assumes that the two languages under consideration are always Portuguese and English.

The package will sort the abstracts in the appropriate order. This means that the first abstract will be in the same language as the main text, followed by the abstract in the other language, and then followed by the main text. For example, if the dissertation is written in Portuguese, first will come the summary in Portuguese and then in English, followed by the main text in Portuguese. If the dissertation is written in English, first will come the summary in English and then in Portuguese, followed by the main text in English.

The abstract should not exceed one page and should answer the following questions:

- What's the problem?
- Why is it interesting?
- What's the solution?
- What follows from the solution?

Keywords: Keywords (in English) ...

RESUMO

Independentemente da língua em que está escrita a dissertação, é necessário um resumo na língua do texto principal e um resumo noutra língua. Assume-se que as duas línguas em questão serão sempre o Português e o Inglês.

O *template* colocará automaticamente em primeiro lugar o resumo na língua do texto principal e depois o resumo na outra língua. Por exemplo, se a dissertação está escrita em Português, primeiro aparecerá o resumo em Português, depois em Inglês, seguido do texto principal em Português. Se a dissertação está escrita em Inglês, primeiro aparecerá o resumo em Inglês, depois em Português, seguido do texto principal em Inglês.

O resumo não deve exceder uma página e deve responder às seguintes questões:

- Qual é o problema?
- Porque é que ele é interessante?
- Qual é a solução?
- O que resulta (implicações) da solução?

E agora vamos fazer um teste com uma quebra de linha no hífen a ver se a \LaTeX duplica o hífen na linha seguinte...

zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz comentar-
-lhe zzz zzzz zzz zzzz

Sim! Funciona! :)

Palavras-chave: Palavras-chave (em Português) ...

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GLOSSARY

aliquam	tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris..
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..
cras viverra	metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat..
donec nonummy	pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo..
integer sapien	est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus..
lorem ipsum	dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris..
maecenas lacinia	nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem..
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..
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 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..
nam dui	ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo..
name 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..
nulla malesuada	porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis..
sed lacinia	nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus..

ACRONYMS

aaa	acornym aaa.
aab	acornym aab.
aba	acornym aba.
abbrev	abbreviation of a longer text.
AEU	adipiscing elit ut.
AFM	aenean faucibus morbi.
AMD	a magna donec.
ANP	ac nunc praesent.
ATG	amet tortor gravida.
AVF	adipiscing vitae felis.
bbb	acornym bbb.
CAS	curabitur auctor semper.
CDG	curabitur dictum gravida.
CEA	congue eu accumsan.
CIV	consectetuer id vulputate.
DIA	duis eget orci.
DNM	dolor nulla malesuada.
DNMC	duis nibh mi congue.
DRN	dignissim rutrum nam.
EII	est iaculis in.
ENE	et netus et.
EPA	eu pulvinar at.
ESQ	eleifend sagittis quis.
ESV	eget sem vel.
ETS	eu tellus sit.

ACRONYMS

FUP fringilla ultrices phasellus.

LID lorem ipsum dolor.

LNE libero nonummy eget.

LUB leo ultrices bibendum.

LVU lectus vestibulum urna.

MAC mollis ac nulla.

MFA malesuada fames ac.

MNA mauris nam arcu.

MTS morbi tristique senectus.

NDV nulla donec varius.

NPH neque pellentesque habitant.

OER orci eget risus.

PA Precision Agriculture.

PEV purus elit vestibulum.

PIS placerat integer sapien.

PQV pretium quis viverra.

SAO sit amet orci.

SNE sem nulla et.

STC sit amet consectetur.

TEM turpis egestas mauris.

ULC ut leo cras.

UPA ut placerat ac.

VAE vehicula augue eu.

VMR viverra metus rhoncus.

xpto and extension of a xpto xpto xpto xpto xpto xpto xpto xpto xpto xpto
xpto xpto xpto xpto xpto xpto xpto xpto.

INTRODUCTION

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1.1 Motivation and context

Throughout the history of mankind, plant pests and diseases have been numerous times responsible for large losses in society. From starvation, extinction of natural resources, negative impact on national/international resources or even deaths in a population.

Nowadays, pests and diseases do not present such threats but still constitute a relevant problem since they result in substantial losses to farmers by reducing the value of their products: yield loss.

To reduce loss, there are two main approaches when handling plant pests and diseases.

1. Prevention
2. Treatment

Prevention is based on prediction models, field records or general management tactics that are applied before the plants are actually infected. Treatment, on the other hand, is all about deploying active substances to fight the already present disease. Prevention is obviously the preferable option when handling pest control since it represents no yield loss and no chemicals are used.

This dissertation proposes a full pest monitoring system for outdoor farming fields. Several emerging pests will be studied, but more than a system to fight specific pests (or pests in specific cultures), a framework for the study and modelling of any pest will be developed. Ranging from data collection to a visual monitoring system, the system

will be able to visually empower producers and farmers to make better decisions when protecting their assets from pests and diseases. A couple of research questions waiting to be answered are "Can we detect a geographic pattern in a pest's behaviour?" or "Can the data collection process of pest occurrences be automated?". Pest and disease study is, obviously, a continuous field of study since human interaction keep disturbing nature's balance, which eventually leads to new mutations, migrations, species.

During the development of this dissertation, the project Fitoagro will be used as a case study of the methodology developed in this work. Fitoagro, as an Operational Group, consists of several partners with a common interest in a specific, practical innovation project: Pest Monitoring for the Apple and Pear Cultures in West Portugal. The people involved in the Operational Group come from a diverse combination of practical and scientific backgrounds (farmers, scientists, agri-business and others). Below are listed the main partners of the Fitoagro project.

COTHN Centro Operativo e Tecnológico Hortofrutícola Nacional

FCT/UNL Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa

ISA Instituto Superior de Agronomia

ESAS Escola Superior Agrária de Santarém

ESACB Escola Superior Agrária de Castelo Branco

Other entities such as agricultural cooperatives will also directly contribute as associates of the COTHN national entity, mainly in the data-collection process and the study of the biological species present in their very own farming fields. These above listed organizations work together on concrete and practical solutions to the following emerging pests (harmful ectoparasites):

1. *Stemphylium vesicarium*
2. *Aphanostigma pyri*
3. *Pseudococcus viburni* / *Planococcus ficus*
4. *Dasineura pyri*

Like above said, more relevant pests may be relevant to the study. To successfully study a species, a big amount of data is needed. That being said, if this farming season brings new pest species with a decent number of samples, they will be considered to the study.

1.2 Problem

1.2.1 A little bit of History

The first agricultural revolution came along during the advent of increased mechanization, from 1900 to 1930. Each farmer produced enough food to feed about 26 people during this time. The 1990s prompted the Green Revolution with new methods of genetic modification, which led to each farmer feeding about 155 people. It is expected that by 2050, the global population will reach about 9.6 billion, and food production must effectively double from current levels in order to feed every mouth. With new technological advancements in the agricultural revolution of precision farming, each farmer is expected be able to feed 265 people on the same acreage.

Digital agriculture is widely recognized as the third great revolution of modern agriculture. The introduction and implementation of mechanization (1900 to 1930) and genetic modification (1990 to 2005) are referred to as Ag 1.0 and Ag 2.0 respectively. Both revolutions drove efficiency, yield and profitability to levels previously unattainable, and are now conventional in developed countries across the world.

While Ag 1.0 and Ag 2.0 definitely drove significant changes in agriculture, Ag 3.0 will be the most transformative and disruptive, not only on the farm, but across the entire agriculture and food value chain.

1.2.2 The ever going study of Pest

A Pest is any plant or animal detrimental to humans or human concerns including crops, livestock, and forestry. In its broadest sense, a pest is a competitor of humanity. Pests are usually categorized by taxon. Different taxonomies are usually studied by different branches of Biology.

The term "plant pest" has a specific definition in terms of the *International Plant Protection Convention* and phytosanitary measures worldwide. A pest is any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products. Plants may be considered pests themselves if an invasive species. These "plant pests" are often focus of study in Biology but, as the *Theory of Evolution* clearly states, evolution is the change in the heritable characteristics of biological populations over successive generations.

Plant pests keep developing resistances against active substances used in the fields (pesticides). Pest species evolve pesticide resistance via natural selection: the most resistant specimens survive and pass their genetic traits to their offspring. Although the evolution of pesticide resistance is usually discussed as a result of pesticide use, it is important to keep in mind that pest populations can also adapt to non-chemical methods of control.

Speciation (repeated formation of new species) leads to a hierarchical structure of the same species that developed specific traits for each culture it threatens.

These pest life cycles are also changing, arguably with temperate. So their first seasonal appearance is gradually evolving over time.

All the above-mentioned factors contribute to the idea that pest control is still a problem, and Nature makes sure of that. In fact, it is a growing problem since yield loss accounted for pests has been growing year by year.

1.3 Objectives

1.3.1 Precision Agriculture

Precision Agriculture(PA) , Satellite Farming or Site-specific crop management (SSCM) is a key-component of the third wave of modern agricultural revolutions (Ag 3.0). In it's essence, it is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. Its main goal is to provide a decision support system for a whole farm management in order to optimize returns on inputs and, most importantly, preserving resources.

Precision Agriculture offers the potential to fundamentally change agriculture's decision-making process. The use of large machinery and hired labour has caused many farmers to think of large fields as a basic management unit. Even though farmers know from experience that yields are higher in some parts of the field than in others, conventional farming management practices have focused on applying inputs in a uniform manner throughout the field extent. Information Technologies empower these farmers to obtain detailed information at a crop level, enabling them to efficiently manage their farm at these finer scales.

The basic principle of precision farming is an exact positional controlling of fertilisation, growth levels, pest presence, risk estimate or any other relevant key-performance indicator with the accuracy of a few meters. The whole process requires a big amount of data to be collected which enables the control of the management process. The better the data collection method, the more resolution data will have, which allows for better conclusions to be taken.

Precision farming is usually divided into the following steps:

Data Collection Inter field systems collect data with a field-level of resolution. Increasing the number of sources provides a smaller scale analysis. Geolocating data sources enables the farmer to read a map of his property (henceforth called soil map) with the most important crop variables.

Variables The data collected can measure different things. Usually, climatic conditions (hail, drought, rain, etc.), soils (texture, depth, nitrogen levels), cropping practices (no-till farming), weeds and disease. Permanent indicators as weather stations, provide information about the main environmental constants. Point indicators allow them to track a crop's status, i.e., to see whether diseases are developing, if

the crop is suffering from water stress, nitrogen stress, or lodging, whether it has been damaged by ice and so on. This information may come from weather stations and other sensors (soil electrical resistivity, detection with the naked eye, satellite imagery, etc.). Soil resistivity measurements combined with soil analysis make it possible to measure moisture content. Soil resistivity is also a relatively simple and cheap measurement.

Strategies Once with soil maps, Strategies can be either predictive (Predictive Approach), where based on history and static features of the field, the farmer takes decisions. The Control Approach, on the other hand, collects data regularly during the crop cycle to provide a better temporal resolution. Decisions may be based on decision-support models and/or the farmer.

Implementing practices If some decisions are to be trusted to an algorithm, Variable Rate Technology can help to administer variable rates of pesticides(biological or chemical), nutrients, water, etc. through Variable Rate Application (VRA). Map Based and Sensor Based VRA present two very different paths.

These simple four steps present a methodology for the continuous management of the farming field. [IMAGE THIS]

The objective is to combine the methodology from Precision Agriculture with the Pest Control, more precisely study the available options for Data Collection from different sources (several variables), regarding cost, efficiency, resolution, limitations while focusing on the needs of the Pest study.

1.4 Major Contributions

1.4.1 Combining Multispectral Satellite imagery and Weather Stations

Satellite information is becoming freely available and their functionality is constantly evolving to provide richer information from the earth surface. At this moment, free satellite data has low resolution, a reduced number of features and some exporting/data access limitations. The paid satellite services, on the other hand, generated rich multispectral imagery available via stream (very high temporal resolution) and with an accuracy of less than a meter. The big, and probably one of the few, disadvantage of Satellite is meteorologic conditions. Clouds will break the line-of-sight between the satellite and the crops, resulting in temporal gaps within, supposedly continuous data sources.

Weather Stations, even though they require an initial investment by the farmer, provide continuous streams of data with no holes. They could also provide better readings of meteorologic conditions such as temperature, humidity etc.

The mixing of both methods may help farmers who want to use the upcoming mentioned framework without relying on having their own weather stations. The system

developed for the FitoAgro study case may train its model from weather stations and compare with the readings of the Satellite imagery.

1.4.2 State of the Art as a Review of Recent Efforts

The State of the Art presents a good contribution itself. By organising and categorising different techniques by area, culture and pest taxonomy it is expected to achieve a detailed analysis of the recent trends in pest control: their pros and cons, cost, resolution, limitations, efficiency and maintenance.

1.4.3 A framework for pest study

The study of a Pest needs specific data depending on the pest being analyzed. Solutions for proper tracking the species mentioned on 1.1 will be developed for the FitoAgro project. This means that the framework will be used directly by 5000 farmers spread across 30 agricultural organizations (COTHN associates) and, hopefully, many more can use the same framework independent of the crop culture or geographic location. The case study will be on specific cultures and location but the framework should be ready to scale out this "Pest Study" to a global level if needed. This pest control monitoring is not available to all farmers due to the cost of registering all the data. Since some pest species require specific equipment to be read/analyzed, some design thinking techniques will be used to ease out the data collection process into, hopefully, an effortless process for the farmer.

1.4.4 Mapping the field digitally

A big component of the framework described above is the end-user analysis of the data being processed by the system. Visualization is of the utmost importance when analysing the data, so, in order to communicate the geolocated data that is to be collected, we will develop a specific soil map visualization that tackles all the necessities of the Pest Control domain. The focus will be on minimizing the complexity of the work so that, the farmer intuitively understands his farm at a glance. In a broad sense, Design and Usability meet big data.

1.5 Document Structure

1. Introduction

- a) Motivation and Context
- b) Problem
- c) Objectives
- d) Major Contributions

e) Document Structure

2. Detailed Problem - Details of the problem briefly described in the Introduction.
3. State of the Art - Previous works in this domain and their solutions. Organize by sections, keywords, results and exclusion criteria.
4. Approach - What is going to be implemented, why and how.
5. The framework - Explaining the methodology, beneficts and limitations.
6. Development Planning - General planning of the development of the FitoAgro solution according to the framework developed.
7. Design and Implementation - Specific design choices and implementation details.
8. Testing and fixes - A/B Testing process description of the proposed framework *in situ*.
9. Conclusions - General conclusions, final remarks and future work.

THESISDIRECTNL USER'S MANUAL

2.1 Introduction

These instructions are outdated! Please see also the “template.tex” file!

This chapter describes how to use the \LaTeX *novathesis* template (and the “novathesis.cls” class file).

Let's start with some simple suggestions:

1. No! You don't have to use this template to write your thesis. You don't even have to use \LaTeX . However, writing a thesis is serious stuff, and which tool you shall use to write it is not a decision to make lighthearted.
2. \LaTeX is hard enough by itself. This template aims at making your life easier, but not easy. If you choose to use this template to write your thesis, you are very welcome. However, don't expect me to provide you help with \LaTeX . Look for help with your friends (you have some friends, don't you?), or search the web, or try even to read some book(s) on \LaTeX . In the end you will certainly find the experience rewarding.
3. So, don't forget, when you come to the point of “*How do I do this with \LaTeX ?*” look for help! Google is your best friend.
4. If you believe the difficulty is related with the *novathesis* template itself (and not with \LaTeX), please **do not** send me an email asking for help. Please look for help in the *novathesis* Google Group (URL) and the *novathesis* Facebook group (URL). If you can't find help there from previous posts/messages, then post your own question. Hopefully someone will answer you.

Now, let's go to a major issue for Windows users. Characters have to be encoded in files as numbers, and that is how character encodings were born. ASCII and EBCDIC standards are long lost in the past. The world now uses UTF-8. Well, not all the world... Windows is still stick in its *codepages*, and "latin1" is what windows uses as the codepage for Western Europe. This messes up with the template. Please be sure you use an editor with UTF-8 support. *Go to the preferences/options/... of your text editor and set up its default file encoding as UTF-8.*

2.2 Folder Structure

The *novathesis* template is organized into files and folders. At the main level it includes the following files and folders:

<code>novathesis.cls</code>	<i>file</i>	The main class file. It will include additional files from <code>novathesis-files</code> folder.
<code>template.tex</code>	<i>file</i>	The main user file. Use this file as the main file for your thesis.
<code>bibliography.bib</code>	<i>file</i>	An example of a bibliography file. You may have has many as you want.
<code>template.pdf</code>	<i>file</i>	A possible result of applying pdfL ^A T _E X to the <code>template.tex</code> file. The template supports multiple types of documents (e.g., MSc dissertation, PhD thesis, ...) and multiple Schools (e.g., FCT-NOVA, FCSH-NOVA, IST-UL, FC-UL, ...) and each will produce different results.
Chapters	<i>folder</i>	Examples of thesis chapters. Replace them with your own chapters.
Examples	<i>folder</i>	Some more examples of the use of the template for different document types and Schools.
Scripts	<i>folder</i>	Some (possibly useful) scripts for Unix-based systems (Linux, Mac OSx). If you are a windows user, ignore this folder (you may safely delete it if you want).
<code>novathesis-files</code>	<i>folder</i>	Additional files for the <code>novathesis.cls</code> file. Unless you know what you are doing, avoid messing up with the files and folders inside this folder (except for deleting the unused Schools, see below).

The `novathesis-files` folder contains additional files and folders that complement the main `novathesis.cls` file. These are:

README.txt	file	A file that should be read! :)
fix-babel.clo	file	Simple fixes to the babel package.
lang-text.clo	file	Translations of important strings used in the template. Currently fully supported are Portuguese and English, but French is on the way. If you add translations for your own language, please be so kind and send them to me. Thank you!
options.clo	file	Processing of novathesis.cls options. <i>Don't mess with this!</i>
packages.clo	file	Additional packages to be loaded into the novathesis template. <i>You should not mess with this!</i>
spine.clo	file	This file is loaded only if the option spine=true, and includes the typesetting of the book spine.
ChapStyles	folder	Contains a lot of files, one for each chapter style. If you really know what you are doing, you may add your own chapter style here.
FontStyles	folder	Contains a few files, one for each set of fonts (main text font, chapter font, section font, subsection font, etc). If you really know what you are doing, you may add your own set here.
Schools	folder	Configuration files for each school. This folder is organized into subfolders, one for each university. <i>You may safely delete all the subfolders except the one for your University.</i> Then open the subfolder of your University and <i>you may safely delete all the subfolders except the one for your School/Faculty.</i>

As stated above, the Schools folder contains per-university folders and per-school (faculty) subfolders. Currently these are the available folders:

ul / ist	folder	The folder for the <i>Instituto Superior Técnico</i> of the <i>University of Lisbon</i> .
nova / fcsh	folder	The folder for the <i>Faculty of Human and Social Sciences</i> of the <i>NOVA University of Lisbon</i> .
nova / fct	folder	The folder for the <i>Faculty of Sciences and Technology</i> of the <i>NOVA University of Lisbon</i> .
nova / novaims	folder	The folder for the <i>Information and Management School</i> of the <i>NOVA University of Lisbon</i> .

2.3 novathesis.cls Class Options

The novathesis class can be customized with the options listed below.

docdegree=OPT	phd(*), phdplan, phdprop, msc, mscplan, bsc
<i>The type of the document: PhD Thesis (default), PhD Plan, PhD Proposal, MSc Disseration, MSc Plan, BSc Report</i>	

school=OPT nova/fct(*), nova/fcsh, nova/ims, ul/ist, ul/fc

The name of the school. This option changes the typesetting of the cover and some School specific formatting, like margins, fonts, paragraph spacing and indentation, etc. . .

lang=OPT en(*), pt

The main language for the document. Currently only Portuguese and English are supported. Other languages are expected to be support in forthcoming versions.

fontstyle=OPT bookman, charter, fourier, kpfonts(*), mathpazo1, mathpazo2, newcent

The font set to be used in the document. Please note that a font set include definitions for the main text, headings, maths, etc.

chapstyle=OPT bianchi, bluebox, brotherton, dash, default, elegant(*), ell, ger, hansen, ist, jenor, lyhne, madsen, pedersen, veelo, vz14, vz34, vz43

The chapter style, i.e., the look of the chapter beginning.

converlang=OPT en, pt(*)

The language to be used when typesetting the cover page.

otherlistsat=OPT front(*), back

Where to put the other lists besides the table of contents. The default is (front) before the main text. But some scientific areas prefer them at the end of the document (back), just before the Appendixes.

aftercover=OPT true, false(*)

Include or don't include the contents of the "aftercover" file. The default is for this file to be ignored (if it exists).

linkscolor=OPT darkblue(*), black

The color for all the hyperlinks in the PDF file. The "media=paper" option (see below) will override this option to "black"

spine=OPT true, false(*)

Generate the book spine and the last page in the PDF.

biblatex=OPT OPT={list of options for biblatex}

Customize biblatex, the bibliography management system used in this class. Probably you will want to change the value of the biblatex "style" option. For other customizations of biblatex check its manual.

memoir=OPT OPT={list of options for memoir}

Customize the base class memoir. The memoir manual should be the first document to be consulted when looking for "how can I do this?" You may want to change the base font size from 11pt to a smaller (10pt) or larger (12pt) size. Also, remember to change the "draft" to final when your document is finished.

media=OPT screen(*), paper

Behavior to be customized in the school options/configuration. Expected definitions for screen are: left and right margins are equal and use colored links. Expected definitions for paper are: left and right margins are different and use black links.

2.4 Additional considerations about the class options

In this section we will provide some additional considerations about some of the customizations available as class options.

2.4.1 The main language

The choice of the main language with the option “`lang=OPT`” affects:

- **The order of the summaries.** First is printed the abstract in the main language and then in the foreign language. This means that if your main language for the document is English, you will see first the “abstract” (in English) and then the “resumo” (in Portuguese). If you switch the main language for the document for Portuguese, it will also automatically switch the order of the summaries to “resumo” and then “abstract”.
- **The names for document sectioning.** E.g., “Chapter” vs. “Capítulo”, “Table of Contents” vs. “Índice”, “Figure” vs. “Figura”, etc.
- **The type of documents in the bibliography.** E.g., “Technical Report” vs. “Relatório Técnico”, “PhD Thesis” vs. “Tese de Doutoramento”, etc.

No matter which language you chose, you will always have the appropriate hyphenation rules according to the language at that point. You always get Portuguese hyphenation rules in the “Resumo”, English hyphenation rules in the “Abstract”, and then the main language hyphenation rules for the rest of the document.

2.4.2 Class of Text

You must choose the class of text for the document. The available options are:

1. **bsc** — BSc graduation report.
2. ***mscplan** — Preparation of MSc dissertation. This is a preliminary report graduate students at DI-FCT-NOVA must prepare to conclude the first semester of the two-semester MSc work. The files specified by `\dedicatoryfile` and `\acknowledgmentsfile` are ignored, even if present, for this class of document.
3. **msc** — MSc dissertation.

4. **phdprop** — Proposal for a PhD work. The files specified by `\dedicatoryfile` and `\acknowledgmentsfile` are ignored, even if present, for this class of document.
5. **prepphd** — Preparation of a PhD thesis. This is a preliminary report PhD students at DI-FCT-NOVA must prepare before the end of the third semester of PhD work. The files specified by `\dedicatoryfile` and `\acknowledgmentsfile` are ignored, even if present, for this class of document.
6. **phd** — PhD dissertation.

2.4.3 Printing

You must choose how your document will be printed. The available options are:

1. **oneside** — Single side page printing.
2. ***twoside** — Double sided page printing.

2.4.4 Font Size

You must select the encoding for your text. The available options are:

1. **11pt** — Eleven (11) points font size.
2. ***12pt** — Twelve (12) points font size. You should really stick to 12pt...

2.4.5 Text Encoding

You must choose the font size for your document. The available options are:

1. **latin1** — Use Latin-1 ([ISO 8859-1](#)) encoding. Most probably you should use this option if you use Windows;
2. **utf8** — Use [UTF8](#) encoding. Most probably you should use this option if you are not using Windows.

2.4.6 Examples

Let's have a look at a couple of examples:

- Preparation of PhD thesis, in portuguese, with 11pt size and to be printed single sided (I wonder why one would do this!)
`\documentclass[prepphd,pt,11pt,oneside,latin1]{thesisdifct-nova}`
- MSc dissertation, in english, with 12pt size and to be printed double sided
`\documentclass[msc,en,12pt,twoside,utf8]{thesisdifct-nova}`

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 Exmaple glossary and acronyms

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 \(xpto\)](#) and reused [xpto](#). Let's also use a few other acronyms such as [acornym aaa \(aaa\)](#), [acornym aab \(aab\)](#), [acornym aba \(aba\)](#), [acornym bbb \(bbb\)](#) and [xpto](#).

Lets add the term “[computer](#)” to the glossary!

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

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.

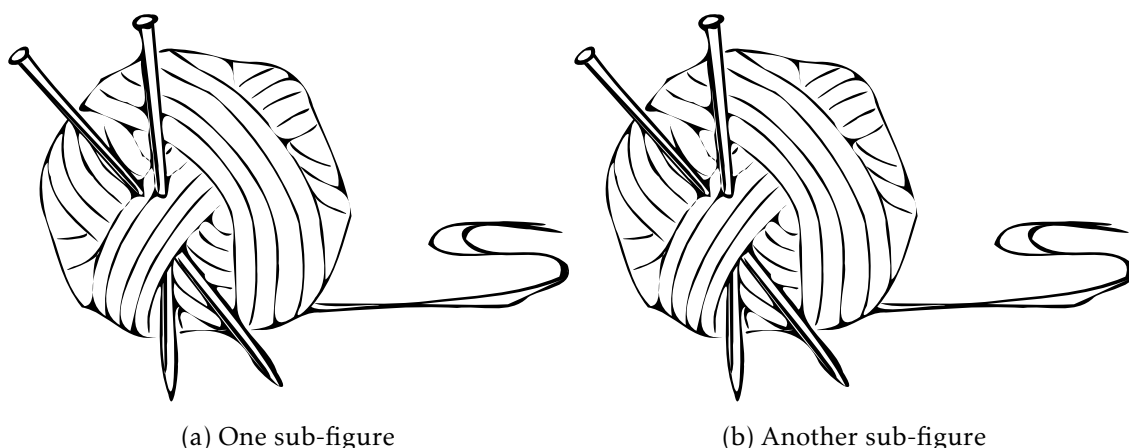


Figure 31: A figure with two sub-figures!

And this is a small text that references the Figure 31 and its Subfigures 31a and 31b.

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 \LaTeX

3.7.1 Generating PDFs with `pdflatex`

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 `pdf \LaTeX` , 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 \LaTeX . 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 or 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 Creating Source Files Compatible with both `latex` and `pdflatex`

Do not include the extension of the file in the `\includegraphics` command. E.g., use `\includegraphics{sonwman}` and not `\includegraphics{sonwman.eps}`.

If you use the first form, `latex` or `pdflatex` will add an appropriate file extension.

This means that, if you plan to use only `pdflatex`, you need only to keep (preferably) a PDF version of all the images. If you plan to use also `latex`, then you also need an EPS version of each image.

To be included in the sections above

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{Artho04}). Caso queira fazer múltiplas citações [6–8], 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.

Footnotes¹ will be numbered and shown in the bottom of the page.

A Tabela 31 ilustra alguns conceitos importantes associados à construção de tabelas:

- i) Não usar linhas verticais;
- ii) A legenda deve ficar por cima da tabela;
- iii) Usar as macros `\toprule`, `\midrule` e `\bottomrule` para fazer a linha horizontal superior, interiores e inferior, respectivamente.

Table 31: Test results summary.

Test	Anomalies	Warnings	Correct	Categories	Missed
[3] Connection	2	2	1	C	1
[1] Coordinates’03	1	4	1	2B, 1C	0
[1] Local Variable	1	2	1	A	0
[1] NASA	1	1	1	—	0
[2] Coordinates’04	1	4	1	3C	0
[2] Buffer	0	7	0	2A, 1B, 2C, 2D	0
[2] Double-Check	0	2	0	1A, 1B	0
[4] StringBuffer	1	0	0	—	1
[9] Account	1	1	1	—	0
[9] Jigsaw	1	2	1	C	0
[9] Over-reporting	0	2	0	1A, 1C	0
[9] Under-reporting	1	1	1	—	0
[5] Allocate Vector	1	2	1	C	0
Knight Moves	1	3	1	2B	0
Total	12	33	10	5A, 6B, 10C, 2D	2

As figuras a inserir no documento deverão ser de qualidade, preferencialmente em formato vectorial (PDF vectorial) e não em *bitmap* (PNG, JPG, etc). As imagens *bitmap* (Figura 32) não escalam bem e têm reflexos negativos na qualidade do seu documento. Pelo contrário, as imagens *vectoriais* Figura 33 escalam muito tanto quanto o necessário sem degradar a qualidade da imagem.

Só deve usar *screenshots* se não tive mesmo nenhuma alternativa. Em vez de gerar um *screenshot*, tente usar uma impressora virtual PDF e imprimir para um ficheiro PDF.

¹This is a simple footnote.

Regra geral obterá um PDF vetorial. Mesmo que o seu PDF contenha imagens, elas terão sempre qualidade maior ou igual à que obteria com um *screenshot*.

Para agregar várias figuras numa única... Poderá assim referenciar o conjunto 34, a primeira delas 34a ou a segunda 34b.

Para incluir listagens de código no seu documento, deverá incluir o pacote *listings* e depois usar o ambiente *lstlisting*, como exemplificado na Listagem 3.1.

Listing 3.1: Hello World

```
1  /**
2   * The HelloWorldApp class implements an application that
3   * simply prints "Hello World!" to standard output.
4   */
5  class HelloWorldApp {%
6      public static void main(String[] args) {%
7          System.out.println("Hello_World!"); // Display the string.
8      }
9  }
```

3.8 Equações

O LaTeX é uma ferramenta poderosa para escrever em estilo matemático. Permite inserir fórmulas no meio do texto como por exemplo esta: $ax^2 + bx + c = 0$. Também permite que as fórmulas sejam destacadas numa linha separada e centradas na página

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

ou numeradas

$$aaa \tag{3.1}$$

que depois pode ser referida no texto como sendo a equação 3.1

$$aa$$

$$a \tag{3.2}$$

$$b \tag{3.3}$$

$$c \tag{3.4}$$

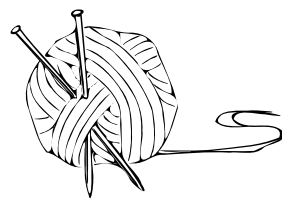
$$\tag{3.5}$$



Figure 32: Imagem em formato *bitmap* (JPG)



Figure 33: Imagem em formato PDF vectorial



a Novelo de lã



b Tempestade com neve

Figure 34: Exemplo de utilização de *subbottom*

BIBLIOGRAPHY

- [1] C. Artho, K. Havelund, and A. Biere. *High-Level Data Races*. 2003. URL: citeseer.ist.psu.edu/artho03highlevel.html.
- [2] C. Artho, K. Havelund, and A. Biere. “Using Block-Local Atomicity to Detect Stale-Value Concurrency Errors.” In: *ATVA*. Ed. by F. Wang. Vol. 3299. Lecture Notes in Computer Science. Springer, 2004, pp. 150–164. ISBN: 3-540-23610-4.
- [3] N. E. Beckman, K. Bierhoff, and J. Aldrich. “Verifying Correct Usage of Atomic Blocks and Typestate.” In: *SIGPLAN Not.* 43.10 (2008), pp. 227–244. ISSN: 0362-1340. DOI: <http://doi.acm.org/10.1145/1449955.1449783>.
- [4] C. Flanagan and S. N. Freund. “Atomizer: a dynamic atomicity checker for multi-threaded programs.” In: *POPL ’04: Proceedings of the 31st ACM SIGPLAN-SIGACT symposium on Principles of programming languages*. Venice, Italy: ACM, 2004, pp. 256–267. ISBN: 1-58113-729-X. DOI: <http://doi.acm.org/10.1145/964001.964023>.
- [5] *IBM’s Concurrency Testing Repository*.
- [6] J. E. B. Moss. *Nested transactions: an approach to reliable distributed computing*. Cambridge, MA, USA: Massachusetts Institute of Technology, 1985. ISBN: 0-262-13200-1.
- [7] N. Shavit and D. Touitou. “Software transactional memory.” In: *PODC ’95: Proceedings of the fourteenth annual ACM symposium on Principles of distributed computing*. Ottawa, Ontario, Canada: ACM, 1995, pp. 204–213. ISBN: 0-89791-710-3. DOI: <http://doi.acm.org/10.1145/224964.224987>.
- [8] A. Silberschatz, H. F. Korth, and S. Sudarshan. *Database System Concepts*. Fifth. McGraw-Hill, 2006. ISBN: 007-124476-X.
- [9] C. von Praun and T. R. Gross. “Static Detection of Atomicity Violations in Object-Oriented Programs.” In: *Journal of Object Technology*. 2003, p. 2004.

