

THIRD YEAR PROJECT REPORT

3YP Title Here

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UNIVERSITY OF OXFORD

Abstract

Faculty Name
Department of Engineering Science

Third Year Project

3YP Title Here

by Kitty Fung, Edward Gunn, Terence Tan, Di Wan

The Project Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Contents

List of Figures

List of Tables

Chapter 1

Project Definition

1.1 Introduction

The process of writing music often begins with an idea for a melody which is followed by the development of chords to accompany it. The matching of chords to a melody is a skill which usually requires years of training in musical techniques such as harmonisation. There is a large market of amateur musicians who lack the necessary training for this task but would otherwise enjoy the experience of developing music. In this report we will detail the design of **INSERT NAME HERE**, a system which facilitates the generation of an appropriately matched set of chords to a given monophonic melody. Users are able to record a melody using their microphone and regenerate the chord sequence until they feel they have found one suitable for the intended feel of their song. Songs and generated chord accompaniments can be played back to the user, saved to a library of songs and shared using our songwriting community feature.

The problem of converting a recorded melody to a set of chords can be decomposed into a set of simpler sub-problems, these being: The conversion of the recorded melody into a form which numerically represents its features. The generation of a set of chords from this numerical representation. The latter of these two problems can be solved in many ways many of which require a detailed knowledge of music to find patterns in melodies to match to chords. **WHY IS THIS A PROBLEM FOR US** A method which requires little knowledge of music is the use of a machine learning model to extract these patterns from data of known chord melody pairings from professionally composed music. The curation and processing of an appropriate dataset requires significant effort and care in itself. This leads to a natural division of labour across the project into the categories of: User Interface and general product design - detailed in ?? by Di Wan; Curation and preparation of a dataset in an appropriate format - detailed in ?? by Terence Tan; The design of an appropriate machine learning model - detailed in ?? by Edward Gunn; The conversion of recorded melody to the same format as expressed in the dataset - detailed in ?? by Kitty Fung.

1.1.1 Musical terminology

Throughout this report we will use a variety of musical terminology which will be defined here. A piece of music is composed of a sequence of adjacent **measures**, periods of time in which notes and chords can be played. We will generally take a **measure** to mean a bar in the music, however it is not restricted to this. We restrict **chord** to refer to a triad of notes, the justification for this is explained in **reference to explanation**. The use of **melody** refers to a monophonic melody in which only one note is played at a time, excluding accompanying chords, unless otherwise stated.

1.1.2 Subsection 2

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1.2 Project management

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1.3 Tech strat

1.4 Risk

1.5 Finance

1.6 Ethics

Data privacy: Data ethics framework: <https://www.gov.uk/government/publications/data-ethics-framework> From a developer's POV, we should: (i) Treat our users' data as we would for our own (ii) Collect only necessary data for the app to run (iii) Make sure our app does harm in any way (i.e. won't include sensitive topics/ as the app carries on, there will not be a chance for our users to online abuse others) (iv) Be transparent with our user community -> have to delineate a privacy policy and makes sure users read and agree to everything before they use our app probably keep the policy at a place that's easy for everyone to access Took a look at random online sites' privacy and here's a summary of what needs to be included: (a) Who we are – company licence and registration reference number, we have to register on <https://ico.org.uk/> to collect data from the public (b) Delineate the details and purpose of data collected i.e. we will collect - audio data(including metadata) to feed in our model to improve accuracy - networks and connections (for our interactive community feature) - usage (contents users view/ engage with, functions/features used, duration) - device information (device attributes like signal strength, battery levels/ OS versions) - cookie data, when users comment/ interact on our app, we would want to save their usage preference (we would have both first- and third-party cookies since we will be placing advertisements in our app for standard users) ("We use cookies to help personalise and improve content and services, provide a safer experience and

to show you useful and relevant ads on and off”) - Data retention/ account deletion (we should store data until it is not necessary to collect/ users deactivate account) (c) Access rights of different members of the team (d) Third parties that will have access to the data collected (e) Rights that users have over their data (users should have the right to request a copy of data provided/ request the organisation to delete the data/ object to the organisation’s data processing) (f) Notification of changes to privacy policy and ask users to review/ accept the revised policy (if needed) (g) Security standards (SSL/ encryption standards) (h) Contact information

1.7 Responsible Innovation

Not only does research bring novelty and value to society, it may also bring forward ethical dilemmas, social transformations and adverse consequences to society - considers the role that new products, processes or business models have in society - responsible approach towards innovation involves creating change that has positive impacts on society and the environment

Components of RRI: (i) Anticipation: visioning consequences of the research and innovation. It is to ensure that the consequences of undertaking the research are considered and reflected in the research design. Although in this project we are not creating physical innovation/ technology, we are building a platform that allows users to interact and communicate with each other. (ii) Reflection: researchers should always reflect on the research question they are investigating, the type of data collected, the method used to analyse the data and the implications of the findings. They should also judge if the research is required. An organisation can force reflection through organisational process/ structures like a project advisory board/ review quality assurance steps. Reflection allows researchers to review the project from a macroscopic point of view. (iii) Ethics: researchers should uphold integrity and prevent misconduct/ negligence. They should be responsible for both the undergoing research and behaviour. (iv) Gender Equality: Since male engineers still dominate the industry, it is easy to be biased in a project design, i.e. models built suit male users better. (v) Open Access: Making research/ project publicly available to everyone so the whole society can be benefitted by reducing wasteful duplication, increasing transparency reproducibility of results. (vi) Governance: Organisations should establish practices that foster RRI, i.e. • Having transparent and reflective internal procedures • Promoting participatory governance • Fostering stakeholder engagement exercises • Encouraging future-oriented governance • Valuing responsiveness (vii) Public Engagement: Researchers should fix the motivation and suitable audience before any public engagement, i.e. improving musical literacy

1.8 Sustainability

As technology advances, energy consumed by computers and digital personal devices is taking up a larger portion in worldwide energy consumption. There are about 8,918,157,500 active mobile devices consuming about 2 kWh/year energy (<https://www.digitalinformation.org/global-energy-consumption-of-information-technologies-infographic.html>) While a lot of effort has been put into reducing the energy consumption from the hardware perspective, it is also prime to look at the software implementation of a program. Other than writing energy-efficient codes (i.e. optimised searching and sorting algorithms), the programming language chosen can make a substantial difference too.

From paper: <https://greenlab.di.uminho.pt/wp-content/uploads/2017/10/sleFinal.pdf>
When it comes to resources required for running a program, we can categorise into energy, time and memory size. The research shows there is no strong correlation between the 3 components. Since our application has no requirements on the computational time and memory size, we can solely focus on the energy consumption between different languages. Even though the energy needed to run different algorithms varies for different language, it is certain that compiled language requires less energy compared to virtual machine and interpreted languages thus it would make sense to use C/ Rust/ C++ to code.

Also, since we plan to employ a cloud network architecture and host most of the operation on cloud, that would add an enormous carbon footprint to our project too.

Carbon3IT estimates datacentres, including colocation facilities, account for at least 12% of UK electricity consumption, or 41.11TWh a year; Cisco has previously forecast global cloud IP traffic to exceed 14.1 zettabytes (ZB) by the end of 2020; IDC's Seagate sponsored Data Age 2025 report projects overall data growth of 30

Other than looking for ways to reduce energy consumption, we can also take the initiative by offsetting carbon footprints. We can fund an equivalent carbon dioxide saving elsewhere, I.e. planting trees, solar/ wind power projects.

1.9 Legality

Chapter 2

Product Design

2.1 Main Section 1

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2.1.1 Subsection 1

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2.2 Main Section 2

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Chapter 3

Data

3.1 Main Section 1

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Chapter 4

Model

4.1 Main Section 1

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4.1.1 Subsection 1

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4.1.2 Subsection 2

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Chapter 5

Audio Processing

Before we feed the audio clip to our machine learning model, it is crucial to get rid of the noise as to achieve higher accuracy.

5.1 Noise Filter

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5.1.1 Possible Models

A. Low-pass filter Transform time-signal to frequency-signal using fourier transform
Cutoff frequency selection: depending on the gender and age Window function: (most simple) rectangular function/ hamming/ hanning window

B. Wavelet transform Wavelet transform creates a representation of the signal in both time and frequency domain so localized information of the signal can be efficiently accessed. Fourier transform (FT) has limitations: For windowed FT, if the feature is larger or shorter than the window, it cannot be captured completely. Time resolution for high frequencies is the same for low frequencies. As frequency increases, rate of change of the signal increases, and high frequency signals contain more information in a window than that of low frequency, thus we need a higher time resolution for that. Usually for stationary signals, we use traditional fourier transform, but for non-stationary ones, we can use wavelet transform, in particular continuous wavelet transform (CWT) which gives better time-scale information compared to short-time fourier transform (STFT).

Wavelet transform analyses a signal into different frequencies at different resolution (multiresolution analysis).

Advantages of DWT: The wavelet expansion allows a more accurate local description and separation of signal characteristics. A Fourier coefficient represents a component that lasts for all time and, therefore, temporary events must be described by a phase characteristic that allows cancellation or reinforcement over large time periods. A wavelet expansion coefficient represents a component that is itself local and is easier to interpret. The wavelet expansion may allow a separation of components of a signal whose Fourier description overlap in both time and frequency. Wavelets are adjustable and adaptable. Because there is not just one wavelet, they can be designed to fit individual applications. They are ideal for adaptive systems that adjust themselves to suit the signal. Disadvantages of DWT: Sensitive to shifting

Poor directionality Lack of phase information Hard to choose an appropriate mother wavelet and number of decomposition levels

C. PCA Computes eigenvalue, eigenvector pair. Then select the dominant values as principal component (since they explain most of the variance in the signal) and ignore the smaller eigenvalue and eigenvectors. The method helps reducing dimensionality but does not eliminate noise. It is also sensitive to relative scaling of other variables

D. Spectral reduction Define our noisy audio $y(n) = x(n) + d(n)$, for $0 \leq n \leq N-1$, where $x(n)$ is our original signal (signal we wish to recover), $d(n)$ is the noise, n is the time index, N is the number of samples. Assuming $d(n)$ and $x(n)$ have no correlation, $Y(\omega) =$ Used by audacity <https://github.com/timsainb/noisereduce> Did a really good job, able to filter white noise, but not sudden background noise (I accidentally used an audio with a sharp squeal in the beginning and it didn't get filtered, which makes sense if we think about spectral subtraction, it is impossible to subtract an unexpected frequency) Will use spectral reduction in our project!!!

5.1.2 Assumptions

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5.1.3 Implementation

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5.2 Pitch Detection Algorithm

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5.2.1 Possible Models

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5.2.2 Assumptions

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5.2.3 Implementation

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Chapter 6

Chapter Title Here

6.1 Welcome and Thank You

Welcome to this L^AT_EX Thesis Template, a beautiful and easy to use template for writing a thesis using the L^AT_EX typesetting system.

If you are writing a thesis (or will be in the future) and its subject is technical or mathematical (though it doesn't have to be), then creating it in L^AT_EX is highly recommended as a way to make sure you can just get down to the essential writing without having to worry over formatting or wasting time arguing with your word processor.

L^AT_EX is easily able to professionally typeset documents that run to hundreds or thousands of pages long. With simple mark-up commands, it automatically sets out the table of contents, margins, page headers and footers and keeps the formatting consistent and beautiful. One of its main strengths is the way it can easily typeset mathematics, even *heavy* mathematics. Even if those equations are the most horribly twisted and most difficult mathematical problems that can only be solved on a super-computer, you can at least count on L^AT_EX to make them look stunning.

6.2 Learning L^AT_EX

L^AT_EX is not a WYSIWYG (What You See is What You Get) program, unlike word processors such as Microsoft Word or Apple's Pages. Instead, a document written for L^AT_EX is actually a simple, plain text file that contains *no formatting*. You tell L^AT_EX how you want the formatting in the finished document by writing in simple commands amongst the text, for example, if I want to use *italic text for emphasis*, I write the `\emph{text}` command and put the text I want in italics in between the curly braces. This means that L^AT_EX is a "mark-up" language, very much like HTML.

6.2.1 A (not so short) Introduction to L^AT_EX

If you are new to L^AT_EX, there is a very good eBook – freely available online as a PDF file – called, "The Not So Short Introduction to L^AT_EX". The book's title is typically shortened to just *lshort*. You can download the latest version (as it is occasionally updated) from here: <http://www.ctan.org/tex-archive/info/lshort/english/lshort.pdf>

It is also available in several other languages. Find yours from the list on this page: <http://www.ctan.org/tex-archive/info/lshort/>

It is recommended to take a little time out to learn how to use L^AT_EX by creating several, small 'test' documents, or having a close look at several templates on:

<http://www.LaTeXTemplates.com>

Making the effort now means you're not stuck learning the system when what you *really* need to be doing is writing your thesis.

6.2.2 A Short Math Guide for L^AT_EX

If you are writing a technical or mathematical thesis, then you may want to read the document by the AMS (American Mathematical Society) called, "A Short Math Guide for L^AT_EX". It can be found online here: <http://www.ams.org/tex/amslatex.html> under the "Additional Documentation" section towards the bottom of the page.

6.2.3 Common L^AT_EX Math Symbols

There are a multitude of mathematical symbols available for L^AT_EX and it would take a great effort to learn the commands for them all. The most common ones you are likely to use are shown on this page: <http://www.sunilpatel.co.uk/latex-type/latex-math-symbols/>

You can use this page as a reference or crib sheet, the symbols are rendered as large, high quality images so you can quickly find the L^AT_EX command for the symbol you need.

6.2.4 L^AT_EX on a Mac

The L^AT_EX distribution is available for many systems including Windows, Linux and Mac OS X. The package for OS X is called MacTeX and it contains all the applications you need – bundled together and pre-customized – for a fully working L^AT_EX environment and work flow.

MacTeX includes a custom dedicated L^AT_EX editor called TeXShop for writing your '.tex' files and BibDesk: a program to manage your references and create your bibliography section just as easily as managing songs and creating playlists in iTunes.

6.3 Getting Started with this Template

If you are familiar with L^AT_EX, then you should explore the directory structure of the template and then proceed to place your own information into the *THESIS INFORMATION* block of the `main.tex` file. You can then modify the rest of this file to your unique specifications based on your degree/university. Section ?? on page ?? will help you do this. Make sure you also read section ?? about thesis conventions to get the most out of this template.

If you are new to L^AT_EX it is recommended that you carry on reading through the rest of the information in this document.

Before you begin using this template you should ensure that its style complies with the thesis style guidelines imposed by your institution. In most cases this template style and layout will be suitable. If it is not, it may only require a small change to bring the template in line with your institution's recommendations. These modifications will need to be done on the `MastersDoctoralThesis.cls` file.

6.3.1 About this Template

This L^AT_EX Thesis Template is originally based and created around a L^AT_EX style file created by Steve R. Gunn from the University of Southampton (UK), department

of Electronics and Computer Science. You can find his original thesis style file at his site, here: <http://www.ecs.soton.ac.uk/~srg/softwaretools/document/templates/>

Steve's `ecsthesis.cls` was then taken by Sunil Patel who modified it by creating a skeleton framework and folder structure to place the thesis files in. The resulting template can be found on Sunil's site here: <http://www.sunilpatel.co.uk/thesis-template>

Sunil's template was made available through <http://www.LaTeXTemplates.com> where it was modified many times based on user requests and questions. Version 2.0 and onwards of this template represents a major modification to Sunil's template and is, in fact, hardly recognisable. The work to make version 2.0 possible was carried out by **Vel** and Johannes Böttcher.

6.4 What this Template Includes

6.4.1 Folders

This template comes as a single zip file that expands out to several files and folders. The folder names are mostly self-explanatory:

Appendices – this is the folder where you put the appendices. Each appendix should go into its own separate `.tex` file. An example and template are included in the directory.

Chapters – this is the folder where you put the thesis chapters. A thesis usually has about six chapters, though there is no hard rule on this. Each chapter should go in its own separate `.tex` file and they can be split as:

- Chapter 1: Introduction to the thesis topic
- Chapter 2: Background information and theory
- Chapter 3: (Laboratory) experimental setup
- Chapter 4: Details of experiment 1
- Chapter 5: Details of experiment 2
- Chapter 6: Discussion of the experimental results
- Chapter 7: Conclusion and future directions

This chapter layout is specialised for the experimental sciences, your discipline may be different.

Figures – this folder contains all figures for the thesis. These are the final images that will go into the thesis document.

6.4.2 Files

Included are also several files, most of them are plain text and you can see their contents in a text editor. After initial compilation, you will see that more auxiliary files are created by \LaTeX or BibTeX and which you don't need to delete or worry about:

example.bib – this is an important file that contains all the bibliographic information and references that you will be citing in the thesis for use with BibTeX. You can write it manually, but there are reference manager programs available that will create and manage it for you. Bibliographies in \LaTeX are a large subject and you

may need to read about BibTeX before starting with this. Many modern reference managers will allow you to export your references in BibTeX format which greatly eases the amount of work you have to do.

MastersDoctoralThesis.cls – this is an important file. It is the class file that tells L^AT_EX how to format the thesis.

main.pdf – this is your beautifully typeset thesis (in the PDF file format) created by L^AT_EX. It is supplied in the PDF with the template and after you compile the template you should get an identical version.

main.tex – this is an important file. This is the file that you tell L^AT_EX to compile to produce your thesis as a PDF file. It contains the framework and constructs that tell L^AT_EX how to layout the thesis. It is heavily commented so you can read exactly what each line of code does and why it is there. After you put your own information into the *THESIS INFORMATION* block – you have now started your thesis!

Files that are *not* included, but are created by L^AT_EX as auxiliary files include:

main.aux – this is an auxiliary file generated by L^AT_EX, if it is deleted L^AT_EX simply regenerates it when you run the `main .tex` file.

main.bbl – this is an auxiliary file generated by BibTeX, if it is deleted, BibTeX simply regenerates it when you run the `main.aux` file. Whereas the `.bib` file contains all the references you have, this `.bbl` file contains the references you have actually cited in the thesis and is used to build the bibliography section of the thesis.

main.blg – this is an auxiliary file generated by BibTeX, if it is deleted BibTeX simply regenerates it when you run the `main .aux` file.

main.lof – this is an auxiliary file generated by L^AT_EX, if it is deleted L^AT_EX simply regenerates it when you run the `main .tex` file. It tells L^AT_EX how to build the *List of Figures* section.

main.log – this is an auxiliary file generated by L^AT_EX, if it is deleted L^AT_EX simply regenerates it when you run the `main .tex` file. It contains messages from L^AT_EX, if you receive errors and warnings from L^AT_EX, they will be in this `.log` file.

main.lot – this is an auxiliary file generated by L^AT_EX, if it is deleted L^AT_EX simply regenerates it when you run the `main .tex` file. It tells L^AT_EX how to build the *List of Tables* section.

main.out – this is an auxiliary file generated by L^AT_EX, if it is deleted L^AT_EX simply regenerates it when you run the `main .tex` file.

So from this long list, only the files with the `.bib`, `.cls` and `.tex` extensions are the most important ones. The other auxiliary files can be ignored or deleted as L^AT_EX and BibTeX will regenerate them.

6.5 Filling in Your Information in the `main.tex` File

You will need to personalise the thesis template and make it your own by filling in your own information. This is done by editing the `main.tex` file in a text editor or your favourite LaTeX environment.

Open the file and scroll down to the third large block titled *THESIS INFORMATION* where you can see the entries for *University Name*, *Department Name*, etc . . .

Fill out the information about yourself, your group and institution. You can also insert web links, if you do, make sure you use the full URL, including the `http://` for this. If you don't want these to be linked, simply remove the `\href{url}{name}` and only leave the name.

When you have done this, save the file and recompile `main.tex`. All the information you filled in should now be in the PDF, complete with web links. You can now begin your thesis proper!

6.6 The `main.tex` File Explained

The `main.tex` file contains the structure of the thesis. There are plenty of written comments that explain what pages, sections and formatting the \LaTeX code is creating. Each major document element is divided into commented blocks with titles in all capitals to make it obvious what the following bit of code is doing. Initially there seems to be a lot of \LaTeX code, but this is all formatting, and it has all been taken care of so you don't have to do it.

Begin by checking that your information on the title page is correct. For the thesis declaration, your institution may insist on something different than the text given. If this is the case, just replace what you see with what is required in the `DECLARATION PAGE` block.

Then comes a page which contains a funny quote. You can put your own, or quote your favourite scientist, author, person, and so on. Make sure to put the name of the person who you took the quote from.

Following this is the abstract page which summarises your work in a condensed way and can almost be used as a standalone document to describe what you have done. The text you write will cause the heading to move up so don't worry about running out of space.

Next come the acknowledgements. On this page, write about all the people who you wish to thank (not forgetting parents, partners and your advisor/supervisor).

The contents pages, list of figures and tables are all taken care of for you and do not need to be manually created or edited. The next set of pages are more likely to be optional and can be deleted since they are for a more technical thesis: insert a list of abbreviations you have used in the thesis, then a list of the physical constants and numbers you refer to and finally, a list of mathematical symbols used in any formulae. Making the effort to fill these tables means the reader has a one-stop place to refer to instead of searching the internet and references to try and find out what you meant by certain abbreviations or symbols.

The list of symbols is split into the Roman and Greek alphabets. Whereas the abbreviations and symbols ought to be listed in alphabetical order (and this is *not* done automatically for you) the list of physical constants should be grouped into similar themes.

The next page contains a one line dedication. Who will you dedicate your thesis to?

Finally, there is the block where the chapters are included. Uncomment the lines (delete the `%` character) as you write the chapters. Each chapter should be written in its own file and put into the *Chapters* folder and named `Chapter1`, `Chapter2`, etc... Similarly for the appendices, uncomment the lines as you need them. Each appendix should go into its own file and placed in the *Appendices* folder.

After the preamble, chapters and appendices finally comes the bibliography. The bibliography style (called *authoryear*) is used for the bibliography and is a fully featured style that will even include links to where the referenced paper can be found online. Do not underestimate how grateful your reader will be to find that a reference to a paper is just a click away. Of course, this relies on you putting the URL information into the BibTeX file in the first place.

6.7 Thesis Features and Conventions

To get the best out of this template, there are a few conventions that you may want to follow.

One of the most important (and most difficult) things to keep track of in such a long document as a thesis is consistency. Using certain conventions and ways of doing things (such as using a Todo list) makes the job easier. Of course, all of these are optional and you can adopt your own method.

6.7.1 Printing Format

This thesis template is designed for double sided printing (i.e. content on the front and back of pages) as most theses are printed and bound this way. Switching to one sided printing is as simple as uncommenting the *oneside* option of the `documentclass` command at the top of the `main.tex` file. You may then wish to adjust the margins to suit specifications from your institution.

The headers for the pages contain the page number on the outer side (so it is easy to flick through to the page you want) and the chapter name on the inner side.

The text is set to 11 point by default with single line spacing, again, you can tune the text size and spacing should you want or need to using the options at the very start of `main.tex`. The spacing can be changed similarly by replacing the *singlespacing* with *onehalfspacing* or *doublespacing*.

6.7.2 Using US Letter Paper

The paper size used in the template is A4, which is the standard size in Europe. If you are using this thesis template elsewhere and particularly in the United States, then you may have to change the A4 paper size to the US Letter size. This can be done in the margins settings section in `main.tex`.

Due to the differences in the paper size, the resulting margins may be different to what you like or require (as it is common for institutions to dictate certain margin sizes). If this is the case, then the margin sizes can be tweaked by modifying the values in the same block as where you set the paper size. Now your document should be set up for US Letter paper size with suitable margins.

6.7.3 References

The `biblatex` package is used to format the bibliography and inserts references such as this one (**Reference1**). The options used in the `main.tex` file mean that the in-text citations of references are formatted with the author(s) listed with the date of the publication. Multiple references are separated by semicolons (e.g. (**Reference2**; **Reference1**)) and references with more than three authors only show the first author with *et al.* indicating there are more authors (e.g. (**Reference3**)). This is done automatically for you. To see how you use references, have a look at the `Chapter1.tex` source file. Many reference managers allow you to simply drag the reference into the document as you type.

Scientific references should come *before* the punctuation mark if there is one (such as a comma or period). The same goes for footnotes¹. You can change this but the most important thing is to keep the convention consistent throughout the thesis. Footnotes themselves should be full, descriptive sentences (beginning with a capital

¹Such as this footnote, here down at the bottom of the page.

letter and ending with a full stop). The APA6 states: “Footnote numbers should be superscripted, [...], following any punctuation mark except a dash.” The Chicago manual of style states: “A note number should be placed at the end of a sentence or clause. The number follows any punctuation mark except the dash, which it precedes. It follows a closing parenthesis.”

The bibliography is typeset with references listed in alphabetical order by the first author’s last name. This is similar to the APA referencing style. To see how L^AT_EX typesets the bibliography, have a look at the very end of this document (or just click on the reference number links in in-text citations).

A Note on bibtex

The bibtex backend used in the template by default does not correctly handle unicode character encoding (i.e. "international" characters). You may see a warning about this in the compilation log and, if your references contain unicode characters, they may not show up correctly or at all. The solution to this is to use the biber backend instead of the outdated bibtex backend. This is done by finding this in `main.tex`: `backend=bibtex` and changing it to `backend=biber`. You will then need to delete all auxiliary BibTeX files and navigate to the template directory in your terminal (command prompt). Once there, simply type `biber main` and biber will compile your bibliography. You can then compile `main.tex` as normal and your bibliography will be updated. An alternative is to set up your LaTeX editor to compile with biber instead of bibtex, see [here](#) for how to do this for various editors.

6.7.4 Tables

Tables are an important way of displaying your results, below is an example table which was generated with this code:

```
\begin{table}
\caption{The effects of treatments X and Y on the four groups studied.}
\label{tab:treatments}
\centering
\begin{tabular}{l l l}
\toprule
\thead{Groups} & \thead{Treatment X} & \thead{Treatment Y} \\
\midrule
1 & 0.2 & 0.8 \\
2 & 0.17 & 0.7 \\
3 & 0.24 & 0.75 \\
4 & 0.68 & 0.3 \\
\bottomrule
\end{tabular}
\end{table}
```

You can reference tables with `\ref{<label>}` where the label is defined within the table environment. See `Chapter1.tex` for an example of the label and citation (e.g. Table ??).

6.7.5 Figures

There will hopefully be many figures in your thesis (that should be placed in the *Figures* folder). The way to insert figures into your thesis is to use a code template like this:

TABLE 6.1: The effects of treatments X and Y on the four groups studied.

Groups	Treatment X	Treatment Y
1	0.2	0.8
2	0.17	0.7
3	0.24	0.75
4	0.68	0.3

```

\begin{figure}
\centering
\includegraphics{Figures/Electron}
\decoRule
\caption[An Electron]{An electron (artist's impression).}
\label{fig:Electron}
\end{figure}

```

Also look in the source file. Putting this code into the source file produces the picture of the electron that you can see in the figure below.



FIGURE 6.1: An electron (artist's impression).

Sometimes figures don't always appear where you write them in the source. The placement depends on how much space there is on the page for the figure. Sometimes there is not enough room to fit a figure directly where it should go (in relation to the text) and so \LaTeX puts it at the top of the next page. Positioning figures is the job of \LaTeX and so you should only worry about making them look good!

Figures usually should have captions just in case you need to refer to them (such as in Figure ??). The `\caption` command contains two parts, the first part, inside the square brackets is the title that will appear in the *List of Figures*, and so should be short. The second part in the curly brackets should contain the longer and more descriptive caption text.

The `\decoRule` command is optional and simply puts an aesthetic horizontal line below the image. If you do this for one image, do it for all of them.

L^AT_EX is capable of using images in pdf, jpg and png format.

6.7.6 Typesetting mathematics

If your thesis is going to contain heavy mathematical content, be sure that L^AT_EX will make it look beautiful, even though it won't be able to solve the equations for you.

The “Not So Short Introduction to L^AT_EX” (available on CTAN) should tell you everything you need to know for most cases of typesetting mathematics. If you need more information, a much more thorough mathematical guide is available from the AMS called, “A Short Math Guide to L^AT_EX” and can be downloaded from: <ftp://ftp.ams.org/pub/tex/doc/amsmath/short-math-guide.pdf>

There are many different L^AT_EX symbols to remember, luckily you can find the most common symbols in [The Comprehensive L^AT_EX Symbol List](#).

You can write an equation, which is automatically given an equation number by L^AT_EX like this:

```
\begin{equation}
E = mc^2
\label{eqn:Einstein}
\end{equation}
```

This will produce Einstein's famous energy-matter equivalence equation:

$$E = mc^2 \tag{6.1}$$

All equations you write (which are not in the middle of paragraph text) are automatically given equation numbers by L^AT_EX. If you don't want a particular equation numbered, use the unnumbered form:

```
\[ a^2=4 \]
```

6.8 Sectioning and Subsectioning

You should break your thesis up into nice, bite-sized sections and subsections. L^AT_EX automatically builds a table of Contents by looking at all the `\chapter{}`, `\section{}` and `\subsection{}` commands you write in the source.

The Table of Contents should only list the sections to three (3) levels. A `\chapter{}` is level zero (0). A `\section{}` is level one (1) and so a `\subsection{}` is level two (2). In your thesis it is likely that you will even use a `\subsubsection{}`, which is level three (3). The depth to which the Table of Contents is formatted is set within `MastersDoctoralThesis.cls`. If you need this changed, you can do it in `main.tex`.

6.9 In Closing

You have reached the end of this mini-guide. You can now rename or overwrite this pdf file and begin writing your own `Chapter1.tex` and the rest of your thesis. The easy work of setting up the structure and framework has been taken care of for you. It's now your job to fill it out!

Good luck and have lots of fun!

Guide written by —
Sunil Patel: www.sunilpatel.co.uk
Vel: LaTeXTemplates.com

Appendix A

Frequently Asked Questions

A.1 How do I change the colors of links?

The color of links can be changed to your liking using:

```
\hypersetup{urlcolor=red}, or  
\hypersetup{citecolor=green}, or  
\hypersetup{allcolor=blue}.
```

If you want to completely hide the links, you can use:

```
\hypersetup{allcolors=.}, or even better:  
\hypersetup{hidelinks}.
```

If you want to have obvious links in the PDF but not the printed text, use:

```
\hypersetup{colorlinks=false}.
```