DEPARTMENT OF

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Month, year

MASTER IN MSC PROGRAM NAME

A VERY LONG AND IMPRESSIVE

THESIS TITILE WITH A FORCED LINE BREAK

SOME THOUGHTS ON THE LIFE, THE UNIVERSE,

AND EVERYTHING ELSE

JOHN VERY LONGNAME DOE

BSc in name of previous degree

DEPARTMENT OF  
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A VERY LONG AND IMPRESSIVE

THESIS TITLE WITH A FORCED LINE BREAK

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AND EVERYTHING ELSE

**JOHN VERY LONGNAME DOE**

BSc in name of previous degree

**A Very Long and Impressive Thesis Title with a Forced Line Break**

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Dedicatory lorem ipsum.

Acknowledgments

Acknowledgments are personal text and should be a free expression of the author.

However, without any intention of conditioning the form or content of this text, I would like to add that it usually starts with academic thanks (instructors, etc.); then institutional thanks (Research Center, Department, Faculty, University, FCT / MEC scholarships, etc.) and, finally, the personal ones (friends, family, etc.).

But I insist that there are no fixed rules for this text, and it must, above all, express what the author feels.

“You cannot teach a man anything; you can only help him  
discover it in himself.” (Galileo).

Abstract

The identification of cancer cells is a critical task in biomedical research and clinical practice, with significant implications for disease diagnosis, treatment, and prognosis. However, current methods often rely on manual annotation and interpretation of large datasets, which can be time-consuming, labor-intensive, and prone to human error.

This thesis explores the potential application of **Large Language Models (LLMs)** to identify cancer cells from various data sources, more specifically ultrasound, mammogram and thermogram images, tomosynthesis 3D images and histopathology slides. While LLMs are typically trained on text-based data, their ability to learn patterns and relationships within language can be leveraged in conjunction with other methods to analyze images and signals associated with cancer cells and masses. The challenge lies in finding ways to integrate these different approaches effectively, and to develop novel methods that can take advantage of the unique strengths of each technique. By exploring the potential applications of LLMs in image analysis, we may uncover new insights into the possibilities for combining language-based and visual-based approaches to solve complex problems in biomedical research.

The proposed research is interesting and challenging because it pushes the boundaries of what is possible using LLMs. By investigating the feasibility of applying LLMs to this problem, we aim to contribute to a deeper understanding of the potential applications of language models in biomedical research. This thesis can bring new insights into the strengths and limitations of LLMs for breast cancer identification and has the potential to contribute to the development of novel diagnostic tools and approaches.

**Keywords**: Breast Cancer, Large Language Models, Deep Learning, Artificial Inteligence.

Resumo

A identificação de células cancerígenas é uma tarefa crítica na investigação biomédica e na prática clínica, com implicações significativas no diagnóstico, tratamento e prognóstico da doença. No entanto, os métodos actuais baseiam-se frequentemente na anotação e interpretação manual de grandes conjuntos de dados, o que pode ser moroso, trabalhoso e propenso a erros humanos.

Esta tese explora a potencial aplicação de modelos de linguagem de grande dimensão (LLM) para identificar células cancerígenas a partir de várias fontes de dados, mais especificamente imagens de ultra-sons, mamografias e termogramas, imagens 3D de tomossíntese e lâminas histopatológicas. Embora os LLMs sejam normalmente treinados em dados baseados em texto, a sua capacidade de aprender padrões e relações dentro da linguagem pode ser aproveitada em conjunto com outros métodos para analisar imagens e sinais associados a células e massas cancerígenas. O desafio reside em encontrar formas de integrar eficazmente estas diferentes abordagens e desenvolver novos métodos que possam tirar partido dos pontos fortes únicos de cada técnica. Ao explorar as potenciais aplicações de LLMs na análise de imagens, podemos descobrir novas perspectivas sobre as possibilidades de combinar abordagens baseadas na linguagem e visuais para resolver problemas complexos na investigação biomédica.

A investigação proposta é interessante e desafiadora porque ultrapassa os limites do que é possível fazer com LLMs. Ao investigar a viabilidade da aplicação de LLMs a este problema, pretendemos contribuir para uma compreensão mais profunda das potenciais aplicações de modelos de linguagem na investigação biomédica. Esta tese pode trazer novos conhecimentos sobre os pontos fortes e as limitações dos LLMs para a identificação do cancro da mama e tem o potencial de contribuir para o desenvolvimento de novas ferramentas e abordagens de diagnóstico.

(Traduzido com a versão gratuita do tradutor - DeepL.com)

**Palavras chave**: Cancro da mama, *Large Language Models*, *Deep Learning*, Inteligência Artificial.

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[Figure 1.2 — How to start a new section in an odd numbered page. 2](file:////Users/jml/LOCAL/Repos/GIT/novathesis_word/novathesis_word-FINAL-EN.dotx#_Toc67158032)

[Figure 3.1 — Looks list the April’s 25 bridge in Lisbon, but it is the Golden Gate, in S. Francisco in California, USA. 10](file:////Users/jml/LOCAL/Repos/GIT/novathesis_word/novathesis_word-FINAL-EN.dotx#_Toc67158033)

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Glossary

|  |  |
| --- | --- |
| **Computer** | A programmable usually electronic device that can store, retrieve, and process data. |
| **Cell phone** | A portable usually cordless telephone for use in a cellular system. |

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Acronyms

|  |  |
| --- | --- |
| **LLM** | Large Language Model |
| **NATO** | North Atlantic Treaty Organization. |

Symbols

|  |  |
| --- | --- |
| **π** | The ratio of the circumference of a circle to its diameter, having a value rounded to eight decimal places of 3.14159265 (symbol: π). |
| ***r*** | The radius of a circle. |

# Introduction

The accurate identification of cancer cells is a critical task in biomedical research and clinical practice, with significant implications for disease diagnosis, treatment, and prognosis. The exponential growth of medical imaging technologies has led to an overwhelming volume of image data, which must be analyzed and interpreted by clinicians and researchers. However, current methods for analyzing these images often rely on manual annotation and interpretation, a time-consuming process that is prone to human error.

The limitations of traditional image analysis methods have been compounded by the increasing demand for precision medicine and personalized healthcare. The development of targeted therapies and immunotherapies requires a deep understanding of individual patient biology, which can only be achieved through detailed analysis of large-scale imaging data. However, the manual annotation of these images is often a significant bottleneck in research and clinical settings.

Researchers have been exploring various solutions to overcome the challenges of image analysis, including the development of novel algorithms and techniques that leverage advances in machine learning and computer vision. However, more work is needed to develop practical and effective methods for analyzing complex imaging data. This thesis aims to contribute to this effort by investigating the potential application of **Large Language Models (LLMs)** in analyzing images of cancer cells and masses.

## The problems

The process of identifying cancer cells from medical images is a complex and time-consuming task, often requiring extensive expertise and specialized knowledge. Clinicians and researchers are faced with the daunting challenge of analyzing vast amounts of imaging data, which can be overwhelming even for experienced professionals. The consequences of inaccurate or delayed diagnoses can be severe, highlighting the need for more effective and efficient image analysis methods.

One of the primary limitations of current image analysis approaches is their rigid structure and reliance on standardized protocols. While these methods have been refined over time, they can struggle to adapt to emerging trends and technologies in medical imaging. The increasing availability of high-resolution images and advanced imaging modalities has created a need for more flexible and dynamic analysis techniques that can accommodate the diverse range of data being generated

The potential integration of LLMs into image analysis presents both opportunities and challenges. On one hand, these models have been successfully applied to a wide range of natural language tasks and may offer new insights into visual data representation. However, their adaptation to image analysis requires significant modifications to address the unique characteristics of visual information. For instance, language-based models must be able to interpret complex spatial relationships and patterns within images, which can be difficult to articulate in textual form.

Furthermore, the implementation of language-based models in medical imaging raises important questions about bias, accuracy, and transparency. It is essential that these models are designed with careful consideration of the potential pitfalls associated with their use, such as perpetuating existing biases or introducing new ones through their training processes. Additionally, the need for clear and interpretable results cannot be overstated, particularly in high-stakes medical decision-making environments.

## Proposed Solution

To address the challenges of image analysis in cancer cell identification, we propose a multi-modal approach that leverages the strengths of various Large Language Models (LLMs) to analyze different types of medical images. Specifically, we will utilize a combination of publicly available LLMs trained on natural language processing tasks to extract relevant features from mammograms, ultrasounds, thermograms, tomosynthesis images, and histopathology slides. To facilitate the integration of these models with visual data, we will convert the image pixels into base64-encoded strings, enabling the LLMs to process and analyze the images in a textual format.

We will utilize a combination of pre-trained LLMs and adapt them to our specific task by fine-tuning them on publicly available medical imaging datasets. This approach allows us to leverage the strengths of each LLM architecture while also ensuring that they are optimized for our particular application. We will compare the performance and accuracy of several different models, including XLNet and Longformer, as well as other state-of-the-art architectures.

Then, to evaluate the effectiveness of our proposed solution, we will conduct an extensive analysis of the models’ accuracy, precision, recall, and F1-score on various image types. We will also investigate the impact of different hyperparameters, such as learning rates and batch sizes, on model performance and select the most suitable settings for each LLM architecture.

Our proposed multi-modal approach using LLMs offers a promising framework for analyzing medical images and identifying cancer cells. By leveraging the strengths of multiple models, we can develop a more robust and reliable system that improves upon existing methods. While our study focuses on comparing the performance of several different LLM architectures, it also highlights the need for further research into this area. Future work could involve exploring other LLM architectures or developing more sophisticated methods for combining multiple models to improve overall performance.

## Document Structure

The current chapter 1 is an introductory text to contextualize the reader and present the currrent challenges at hand, as well as the brief solution to implement our work.

On chapter 2 we will present the research made by other researchers in this regard, as well as the state-of-the-art technologies that are currently used regarding this subject.

Next, on chapter 3 we will dive a bit deeper in the technical details of the implementation of our system while also presenting a work schedule and the work that is alrready beign developed.

Finally, on chapter 4 we will analyze our results and take our conclusions from it, deciding on the acccurracy (mostly) of the different models in all the situations considered durring the study.

# How to Use this Word Template

In this chapter you will find some simple instructions on how to use this template. However, consider using the NOVAthesis template in LaTeX ... in the end you will have a professional quality document, equivalent to what a book publisher would produce.

## The Document Structure

A dissertation/thesis, in its final version, should contain the following elements (the elements marked with [\*] are optional):

1. Cover (simplified version)
2. Inner cover (naming the advisers and evaluation committee)
3. C*opyright* message from NOVA School of Science and Technology
4. [\*] Dedicatory
5. [\*] Acknowledgments
6. [\*] Quote
7. Abstract in the same language as the main text (e.g., in English)
8. Abstract in an alternative language (e.g., in Portuguese)
9. Table of Contents
10. List of figures (only if you have more than three)
11. List of tables (only if you have more than three)
12. [\*] Other lists (of code listings, equations, …)
13. [\*] Glossary
14. [\*] Acronyms
15. [\*] Symbols
16. The main text organized into chapters
17. Bibliography
18. [\*] Appendices
19. [\*] Annexes

## The Chapters

Each chapter begins with a sequentially numbered title. How this effect was achieved in Word is one of the possible ways, there are others. If any Word expert can do it better (for example, with the bar on the right placed by Word itself and not a vertical line as it is now), please send it to me and I will incorporate it into this Word template.

To start a new chapter, the easiest approach is to duplicate the header of a previous chapter (by copying and then pasting elsewhere) and then replace the text.

## The Types of Text

The template defines five text styles:

* + **Normal** — for the main text, using the Palatino font, with paragraph indentation and line spacing of 1.2x.
  + **Heading 1** — style for the chapter title.
  + **Heading 2** — style for the sections.
  + **Heading 3** — style for the subsections.
  + **Heading 4** — style for the sub-subsections.

## The Table of Contents and other Lists

The document will have several indexes, all of them starting on a unique page, namely:

1. **Table of contents** [required]
2. **List of Figures** [if you have more than three figures]
3. **List of Tables** [if you have more than three tables]
4. **List of Equations** [if you have more than three equations/formulas]
5. **List of Listings** (code/programs) [if you have more than three listings]
6. **Other lists** [glossary, acronyms, symbols, etc]

## References to Chapters, Sections, Figures, Tables, etc.

Whenever you refer to a numbered object present in the text, you should not insert the number as text, but insert a cross-reference using the appropriate menu. In this way, if the objects are renumbered (for example, because inserting a new figure in the middle of two existing figures), the curated references will also be updated automatically.

## The Bibliography

The bibliography appears after the main body of the text and before the Appendices and Annexes.

There are many bibliographic standards and styles. Each scientific area has its own way of presenting both citations and bibliographic references. The most common styles are the APA (American Psychological Association - author/date), now in its 7th edition, and the IEEE (Institute of Electrical and Electronics Engineers - numerical).

There is more than one way to cite/quote other authors in a text, however these can be divided in 2 big classes:

• **Indirect or conceptual citations**, in which we reproduce someone else's ideas in our own words through paraphrases;

• **Direct or formal quotations**, in which we transcribe exactly the words of an author using quotation marks.

The citation models follow 3 systems:

• **Author-date system**, in which the citation appears like this: (Santos, 2003), if there are two authors (Santos and Correia, 2003) and if there are more than 5 authors (Santos, et al., 2003), of which the best known and most used is the [APA style](https://apastyle.apa.org/);

• **Numerical system**, in which each citation is identified with a number [1] and the list of bibliographic references is compiled at the end of the work (bibliography), of which the best known and used style is the [IEEE](https://ieeeauthorcenter.ieee.org/wp-content/uploads/IEEE-Reference-Guide.pdf).

There are also **mixed systems**, in which the citation/quotation in the text is numeric, but the bibliography is sorted alphabetically by the author's surname. Examples of mixed styles are: Springer Lecture notes in Computer Science (alphabetically sorted) and the Council of Science Editors, Citation-Name (numeric alphabetically sorted), amongst others.

The most used styles, in general, are APA and IEEE, FCT is no exception, however you should always define with your advisor the standard or style to use.

The Library of FCT-NOVA provides training on these subjects, as well as support in the use of bibliographic management tools such as Mendeley and Zotero.

# Let’s Create Another Chapter

## And Now some Text to Fill in the Document

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Figure 3.1 — Looks list the April’s 25 bridge in Lisbon but it is not. It is the Golden Gate, in S. Francisco in California, USA.

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Table 3.1 — Portuguese population by age range.

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| --- | --- | --- | --- | --- |
|  | 1971 | 1980 | 1990 | 2000 |
| 0–24 | 3 861 916 | 4 131 825 | 3 660 978 | 3 176 450 |
| 25–49 | 2 658 361 | 3 015 450 | 3 312 011 | 3 705 865 |
| 50–74 | 1 851 909 | 2 245 875 | 2 482 266 | 2 718 007 |
| +75 | 271 575 | 373 125 | 527 967 | 689 581 |
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Figure 3.2 — And another figure with a caption.

Table 3.2 — This table is identical to the previous one, but it is here so that we have not only one but rather two tables in our docuemnt. And as this caption is very long, it should be justified and not centered.

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| --- | --- | --- | --- | --- |
|  | 1971 | 1980 | 1990 | 2000 |
| 0–24 | 3 861 916 | 4 131 825 | 3 660 978 | 3 176 450 |
| 25–49 | 2 658 361 | 3 015 450 | 3 312 011 | 3 705 865 |
| 50–74 | 1 851 909 | 2 245 875 | 2 482 266 | 2 718 007 |
| +75 | 271 575 | 373 125 | 527 967 | 689 581 |
| Total | 8 643 756 | 9 766 275 | 9 983 218 | 10 289 898 |

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# And Another Chapter with some More Text to Increase the Document Size

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Bibliografia

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[1] C. Artho, K. Havelund e A. Biere. High-Level Data Races. 2003. url: citeseer.ist. psu.edu/artho03highlevel.html.

[2] C. Artho, K. Havelund e A. Biere. “Using Block-Local Atomicity to Detect Stale- Value Concurrency Errors”. Em: ATVA. Ed. por 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 e J. Aldrich. “Verifying Correct Usage of Atomic Blocks and Typestate”. Em: SIGPLAN Not. 43.10 (2008), pp. 227–244. issn: 0362-1340. doi: <http://doi.acm.org/10.1145/1449955.1449783>.

[4] C. Flanagan e S. N. Freund. “Atomizer: a dynamic atomicity checker for multithrea- ded programs”. Em: POPL ’04: Proceedings of the 31st ACM SIGPLAN-SIGACT sym- posium 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. Cam- bridge, MA, USA: Massachusetts Institute of Technology, 1985. isbn: 0-262-13200- 1.

[7] N. Shavit e D. Touitou. “Software transactional memory”. Em: PODC ’95: Procee- dings of the fourteenth annual ACM symposium on Principles of distributed computing. Ottowa, 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 e S. Sudarshan. Database System Concepts. Fifth. McGraw- Hill, 2006. isbn: 007-124476-X.

[9] C. von Praun e T. R. Gross. “Static Detection of Atomicity Violations in Object- Oriented Programs”. Em: Journal of Object Technology. 2003, p. 2004.

[10] F. Wang, ed. Automated Technology for Verification and Analysis: Second International Conference, ATVA 2004, Taipei, Taiwan, ROC, October 31-November 3, 2004. Procee- dings. Vol. 3299. Lecture Notes in Computer Science. Springer, 2004. isbn: 3-540- 23610-4

[11] J. M. Lourenço. The NOVAthesis LATEX Template User’s Manual. NOVA University Lisbon. 2021. url: <https://github.com/joaomlourenco/novathesis/raw/main/template.pdf>.

1. An Appendix

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