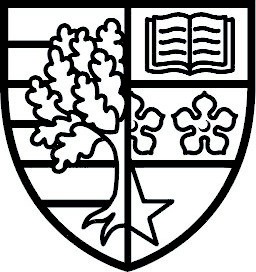
MLOps-Driven Music Recommendation System

Usman Jamshaid Khan

BSc (Hons.) Computer Science Honours Dissertation

*Supervised by* Dr Abrar Ullah

Deliverable 1: Final Year Dissertation



Heriot-Watt University

School of Mathematical and Computer Sciences

BSc Computer Science (Software Engineering)

September 2024

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DECLARATION

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Signed: Usman

Date: 14/10/24

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ABSTRACT

The goal of Machine Learning Operations (MLOps) is to build and implement a program to have quick production. It has gained recognition as a critical answer to the problems presented in the Machine learning (ML) sector. Like DevOps, MLOps uses development, testing, and monitoring to enhance ML production. MLOps comprises procedures for automation, continuous integration and continuous development (CI/CD), and model governance to guarantee that ML models can be swiftly and reliably deployed to production. These days, ML projects executed without MLOps may result in subpar management and sluggish deployment cycles. Development may be sped up in the long run by using MLOps to address these problems using practices, ideas, and development.

With the help of MLOps, this project develops a music recommendation system that makes song recommendations based on face expression detection. The recommendation system will make use of machine learning techniques like Convolutional Neural Networks (CNNs), which are essentially capable of identifying human emotions and recommending music in line with those feelings. The system may achieve efficiency, maintainability, and risk reduction by incorporating MLOps, ensuring that the deployment is ongoing and under observation. It can facilitate automation for model deployment, training, and ongoing monitoring, all of which will eventually result in problems-free improvements. In the end, this project demonstrates the effectiveness of using facial recognition to offer personalized, emotion-matched music recommendations in real time, as well as the resilience of MLOps in managing the complex demands of machine learning.

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# INTRODUCTION

Machine learning has greatly improved many systems and one of them is the recommendation systems which can be related to music, e-commerce, movies, etc. These systems are advanced, but the deployment and maintenance of these systems remains challenging because of the complexity of maintaining the scalability and efficiency of models. This is where MLOps emerges, which is a DevOps concept modified for the management and optimization of machine learning processes. In order to ensure that machine learning models operate dependably and efficiently in production settings, MLOps optimizes the whole machine learning lifecycle, from data preprocessing and model development to deploying, and monitoring. This dissertation’s main goal is to create a music recommendation system that uses face recognition to determine the user’s moods and make appropriate song suggestions. The project intends to guarantee effective deployment and maintenance of the face recognition-based music recommendation system by implementing MLOps techniques. Using the music recommendation system as a use case, this research will investigate how MLOps concepts may enable the continuous delivery, oversight, and scalability of recommendation system that uses machine learning.

## Motivation

The specific subject of this dissertation is the implementation of MLOps practices into face recognition-based music recommendation system. The challenge is in maintaining consistent performance in machine learning systems, where models may alter as a result of several inconsistencies. By using MLOps techniques, this gap will be addressed, and the scalability, maintainability and reliability of the music recommendation system will be enhanced.

## Aim and Objectives

In this dissertation, we aim to apply MLOps processes to develop and assess face recognition-based music recommendation system that will suggest music based on emotions.

The main objectives are:

* Ensure seamless delivery and effective maintenance by integrating MLOps methods such as continuous integration, development, and monitoring.
* Implement a recommendation system that uses face emotions to suggest music.

## Contributions

The contributions of this project are:

* + 1. Adapting MLOps methods to meet the demands of machine learning systems, such as recommendation systems.
    2. Evaluation of how MLOps procedures affect the scalability and reliability of the system.
    3. Implementation of music recommendation system using facial recognition with MLOps procedures.

## Organization

Here is how this dissertation is organized. Following the introduction, motivation, and contribution, Section 2 presents a Background that covers the state-of-the-art research in MLOps, DevOps, and music recommendation systems. Section 3 presents the Methodologies and Requirements where the research methods and requirements analysis will be suggested. Section 4 will display the system architecture and Section 5 will show the evaluation methods that will be utilized to focus on the MLOps pipeline efficiency.

# BACKGROUND

This background discusses recent studies done on the importance of Machine Learning Operations or (MLOps), focusing on why MLOps is a crucial framework in the field of machine learning and its relevance in music recommendation system using facial recognition. The emphasis is on comprehending how MLOps can improve Machine learning systems, recognizing the difficulties, and investigating relevant research in the field.

## Machine Learning Development Challenges

The field of machine learning (ML) enables machines to independently learn from data and previous events in order to recognize patterns in data, categorize data, and forecast outcomes with little assistance from humans (Mitchell & Jordan, 2015). Previously, the machine learning models were typically few in number, making them easier to oversee, or there was lesser organizational interest in comprehending these models and their relationships but with the emergence of decision automation, where choices are made more frequently without human input, machine learning models have become increasingly vital and the management of risk related to these models have become more significant at elevated levels withing the organization (Treveil et al., 2021).

It has always been difficult to integrate machine leaning (ML) models into production, with data scientists, machine learning engineers and other groups encountering various obstacles during the development of production ready models, which results in very small percentage of ML projects even getting to the stage of production and this is why several tools have emerged to enhance processes such as creating models, processing data, training, all aimed to address those challenges and advance in this field (Symeonidis et al., 2022). Figure 1 illustrates the workflow of machine learning life cycle.

A diagram of a process

Description automatically generated

Figure 1: The Machine Learning Life Cycle (Testi et al., 2022)

Three key factors make managing machine learning life cycles challenging. First there are many dependencies since business demands and data are ever-changing, necessitating ongoing alignment between the model’s performance and its initial objectives. Second, because business, data science, and IT teams employ distinct technologies and expertise, communication gaps develop between them. Finally, juggling several responsibilities strain data scientists, who are frequently not software engineers, and this is particularly true when the number of models increases, and they are expected to manage models that they did not initially develop (Treveil et al., 2021).

## DevOps

Prior to the development of Machine Learning Operations principles, businesses faced considerable difficulties in implementing solutions developed with the newest machine learning technology because of the substantial resources needed, which is why MLOps was so important (Alla & Adari, 2020). To understand MLOps we need to comprehend the definition of Development Operations (DevOps). DevOps is a collection of procedures that blends the work procedures of the operations groups with developers of software to provide a shared set of procedures that acts as a cross for both positions (Alla & Adari, 2020). A graph depicting the DevOps workflow is shown in Figure 2. It’s a change in structure where, rather than dispersed groups handling tasks independently, collaborative teams focus on ongoing operational feature deployments (Ebert et al., 2016).

With the implementation of DevOps, software development cycles are accelerated, guaranteeing continued software supply, and lowering overall expenses through reduced service costs-achieved through improved process efficiency in maintaining applications (Alla & Adari, 2020). DevOps tools like continuous integration (CI), continuous delivery (CD), automated testing, and monitoring enable those advantages. By using a continuous integration approach, software development companies aim to incorporate code created by developers and make frequent improvements to it (Deza & Gift, 2021). Continuous delivery is a practice of developing and testing code constantly without human involvement. Among the crucial techniques the most practiced are continuous integration and continuous delivery. Automated testing guarantees that modifications to the code do not create any new bugs or errors (Liu et al., 2023).

Monitoring allows teams to observe and evaluate the system's performance, enabling them to identify any problems. According to Kreuzberger et al. (2023), implementing DevOps techniques may enhance software quality and drastically cut time-to-market by encouraging an increasingly reactive and agile development process.

Diagram of software development process

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Figure 2: An illustration of a DevOps environments cycle (Alla & Adari, 2020).

## MLOps

Since DevOps has been successfully implemented, businesses are searching for continuous methods for creating machine learning systems (John, Olsson and Bosch, 2021). To handle the difficulties of implementing and maintaining ML models, MLOps applies that concept of DevOps and the procedures of Data Engineering to the ML lifecycle as shown in Fig 3. Model creation, deployment, monitoring and maintenance are all included in MLOps which aims to optimize ML processes and guarantee that models are flexible, repeatable and maintained (Singla, 2023). A fundamental element of MLOps is the implementation of continuous integration and continuous deployment for machine learning models, which streamlines the training, validation and deployment processes for these models, and it allows models to be enhanced progressively without the need for human involvement (Kreuzberger et al., 2023). MLOps brings forth a new approach, alongside continuous integration and continuous deployment, known as continuous training (CT), which focuses on the automatic retraining of models when necessary. Continuous monitoring is also essential as it involves the ongoing evaluation of model performance to identify and resolve issues like model drift or poor data quality (Hymel et al., 2022). Version control is also crucial, which involves continuously developing different stages of machine learning models in order to keep track and revert to earlier versions as necessary. MLOps automates the process of machine learning models, extending beyond traditional software processes and it also combines the workflows of data scientists and Data engineers with those of the developers to enable the continuous delivery of high-quality machine learning models (Alla & Adari, 2020). Figure 4 shows a typical MLOps workflow.

A diagram of machine learning

Description automatically generated

Figure 3: MLOps involves DevOps, ML, and Data Engineering (Hewage and Meedeniya,2022)

A diagram of a model development

Description automatically generated

Figure 4: The MLOps Workflow (Testi et al., 2022)

## MLOps Challenges

MLOps offers advantages, but it also encounters various difficulties. Technical problems like versioning models might be difficult because the models must be reproducible. Since models can act differently in development and production contexts, it can be difficult to ensure reliable performance across a variety of scenarios (Singla, 2023). This is in accordance with the difficulties mentioned by Ruf et al. (2021), and (Ghantous and Gill, 2017), which emphasizes how crucial it is to choose the appropriate tools for MLOps pipelines in order to guarantee quality and conformity with DevOps procedures. Implementing MLOps is further complicated by the intricacy of the deployment of machine learning systems numerous clouds settings (Banerjee et al., 2020). Implementing effective version control system and containerization methods can make the models reproducible and the deployment consistent (Singla, 2023).

The Organization difficulties include promoting teamwork among cross-disciplinary groups, like data scientists, ML engineers, and operations personnel, who might prioritize different objectives and operate with varying processes and diverse technologies and frameworks are frequently used by organizations, which can cause integrity issues and inefficiency (Singla, 2023). Granlund et al. (2021), discusses the difficulties in implementing hybrid models in various businesses and offers strategies to make deploying easier in these situations. The creation of specialized MLOps teams that prioritize interaction and information exchange can promote cross-functional cooperation. Organizational silos may be reduced, and processes streamlined by incorporating MLOps into current DevOps procedures.

Because implementing MLOps methods requires a change in processes and thinking, cultural difficulties include a reluctance to change, and the lack of skills is also a problem because teams must train and develop in order to use MLOps procedures effectively (Singla, 2023). Moreover, it is essential for everyone involved to have a common grasp of ML concepts to ensure effective implementation and training and skill development initiatives can help close gaps in skill while fostering a culture of constant progress and flexibility. (Singla, 2023). Furthermore, as suggested (Hewage and Meedeniya, 2022), the accessibility of technologies that are open source might improve interoperability and facilitate incorporation ain many environments.

Overall, with implementing ML-specific automated testing and continuous integration and continuous deployment the dependability of ML systems will be increased, and the standards and compatibility are enhanced by open-source tools, which make integration into many ecosystems easier (Singla, 2023).

## Recommendation System as a Use Case

The necessity for real-time adaptation to users changing preferences, which traditional models cannot provide, makes recommendation systems an ideal application for MLOps. Every time new data is produced, traditional recommendation systems must be retrained, which reduces efficiency and slows the improvements. On the other hand, MLOps automates the deploying and retraining of models, allowing for continuous procedures and quick response to changes. This feature is essential for recommendation systems in customized domains like music, where rapid response of appropriate recommendations improves user engagement. Given the vast number of products accessible online there is a demand for systems that help users find their desired items and recommendation system is a key service that assists users in overcoming the challenges of excessive information (Chen & Chen, 2005).

A recommendation system is a software application that provides strategies to propose recommendations to a user based on the likelihood of their preference. Collaborative filtering, content-based filtering, and hybrid systems are three of the prevalent methods utilized in recommendation systems. Collaborative filtering is based on the actions of user’s similar tastes to generate recommendations. Content-based filtering focuses on the characteristics of items to suggest similar options. In collaborative filtering, if a user prefers X, and Y is identical to X, eventually the user might also prefer Y and in content-based filtering, if a user X and a user Y are identical, then user X may prefer what user Y prefers (Fessahaye et al.) Hybrid systems merge both strategies to improve precision and resilience. Strong machine learning models that can manage massive data sets, update instantly and adjust to shifting consumer suggestions are necessary for recommendation systems to function well. The application of cutting-edge ML methods, such as deep learning and reinforcement learning has significantly enhanced the effectiveness of recommendation system making them more precise and effective (Wang et al., 2023).

## Music Recommendation System using Facial Recognition

The Music Recommendation system that uses facial recognition can provide incredibly customized experiences by recognizing user emotions and pairing music appropriately. This system examines the user's facial expressions via a camera and employs machine learning algorithms to understand the emotions being shown and recommend music based on the users’ mood (Pradhan et al., 2022). According to Mishra et al. (2024), the system assesses the user’s mood to provide a playlist that corresponds with the way they are feeling. For example, it may select lively songs from a playlist to change a depressed mood or offer melodies to enhance positive thoughts when the user’s mood is good. Emotion detection using facial recognition can be achieved by deep learning techniques. Deep Leaning, utilizing artificial neural networks that feature numerous hidden layers to replicate the human brains cerebral cortex has greatly progressed the field of computer vision, especially via convolutional neural network (CNN), a robust algorithm, effectively handles millions of parameters by employing filters to analyze 2D images and generate data (Chauhan et al., 2018). A CNN model for face detection analyzes face images to identify features, such as facial landmarks, and works with a dataset containing emotions and this dataset goes through preprocessing steps that include reshaping, resizing and converting to arrays and the CNN then interprets the pixel information to determine the user’s emotions (Shakti et al., 2023). When the emotion is detected, a song will be played that matches the emotion.

## MLOps in Music Recommendation System

The implementation of a music recommendation system using MLOps practices is crucial as it will manage the life cycle of a model. MLOps automates machine learning operations and improves dependability to expedite the development and deployment of a music recommendation system. According to Susila (2022), MLOps creates a systematic pipeline for model creation, deployment and monitoring by including continuous integration and continuous delivery (CI/CD) into the systems model lifecycle, drawing inspiration from DevOps. The report further explains that the systems speed and precision in suggesting music according to identified emotions are improved by this method, which guarantees that every update of model, trained on face recognition data and emotion signals, is effectively evaluated and implemented. In order to maintain an efficient and flexible recommendation system that keeps up with changing user information MLOps automates the models process, which makes it more scalable and permits immediate changes, and facilities the continuous monitoring. All things considered, MLOps will offer crucial protocols for setting up and managing music recommendation systems that are always updated effortlessly.

## Related Work

There have been numerous studies where MLOps has been implemented in systems to enhance development and deployment. In the study of Susila (2022), MLOps was used to implement the music recommendation system in order to avoid the problem of manually training data every time there’s update in data, which is time consuming. Furthermore, they mentioned that the stages are separated into Continuous Integration where model measurements are evaluated for superior precision and Continuous Delivery, where the properly verified model is implemented.

In the area of electricity market forecasting, Subramanya et al. (2022) emphasize how MLOps tackles the operational difficulties encountered with machine learning models in production. The difficulties in the field include model drift, which occurs when models become less accurate over time due to changing market conditions and the challenges associated with the frequent retraining and deployment of models that can lead to delays. It was further elaborated that since DevOps doesn’t address the complexities of Machine learning cycles MLOps is proposed as a solution which automates the workflow of machine learning models. Subramanya et al. (2022) suggests an MLOps pipeline that is appropriate to the electricity market and incorporate technologies for continuous integration and deployment that will allow for quicker responsiveness to updates while preserving model correctness.

## Summary

In summary, MLOps contributes to addressing major issues in ML development and stressing how crucial it is to simplify the development and monitoring of ML models. With an emphasis on face recognition enhanced music recommendation system, it explores how MLOps may streamline processes for systems that tailor user experiences according to emotions. These systems are made more adaptable, reliable, and flexible by the procedures of MLOps. MLOps is crucial for contemporary ML systems since it greatly fortifies the structure required for recommendation systems based on emotions.

# METHOD

In the Method chapter, clearly explain your research methodology, including the theoretical basis and practical execution. Justify your choice of methods, discussing how they align with the objectives of your study. Consider other methods, explaining why you preferred your chosen approach. This chapter should also address ethical aspects, ensuring your research adheres to ethical standards. Discuss both the strengths and limitations of your methodology to provide a balanced perspective, reinforcing the reliability and validity of your research outcomes.

Here are some development specifications. We follow the steps for concept A, as highlighted in [Section 2,](#_bookmark11) [Section 2.1.](#_bookmark12) In [Section 3.1](#_bookmark16) we discuss the back-end, while [Section 3.2](#_bookmark22) will focus on front-end development.

## Back-end

Server stuff here. See [Equation (1)](#_bookmark17) and [Equations (2)](#_bookmark18) and [(3)](#_bookmark19) that explain the maths behind the application.

𝐵 = ∑︁ 𝛼 × 𝜖 (1)

𝛼∈𝐴

𝑋 = 𝑎𝜖

√𝐴 × 𝐵

𝑍 =

l:𝛾∈Γ

(2)

𝛾

𝑎2 + √3𝑏 if 𝑟 is even

𝑥 (𝑟 ) = 2



𝑎 +

√3

1. 𝑏 if 𝑟 is odd

If you want to have an unnumbered equation:

(3)

∑︁∞

𝑖=0

𝑥 + 1

The algorithm for X [(Algorithm](#_bookmark21) 1) has such and such advantages. The Python implementation is shown in [Code Listing 1.](#_bookmark20)

1

|  |
| --- |
| **import** library |
|  |
| # GCD of a and b |
| **def** my\_gcd (a, b): |
| t = b |
| **while not** b == 0: |

2

3

4

5

6

6 • Author Student

**Algorithm 1** Euclidean Algorithm

1: **function** Euclid(𝑎, 𝑏) ⊲ Finding the GCD of 𝑎 and 𝑏

2: **while** 𝑏 ≠ 0 **do**

3: 𝑡 𝑏

←

4: 𝑏 𝑎 mod 𝑏

←

5: 𝑎 𝑡

←

6: **end while**

7: **return** 𝑎

### 8: end function

7

|  |
| --- |
| t = b |
| b = a % b |
| a = t |
| **return** a |

8

9

10

Code Listing 1. Python example of GCD

## Front-end

Interface specs here. See the mockup for the interface in [Figure 1](#_bookmark23)1.

In [Figure 2a](#_bookmark25) we detail the data flow for process A while process B is shown in [Figure 2b.](#_bookmark25)

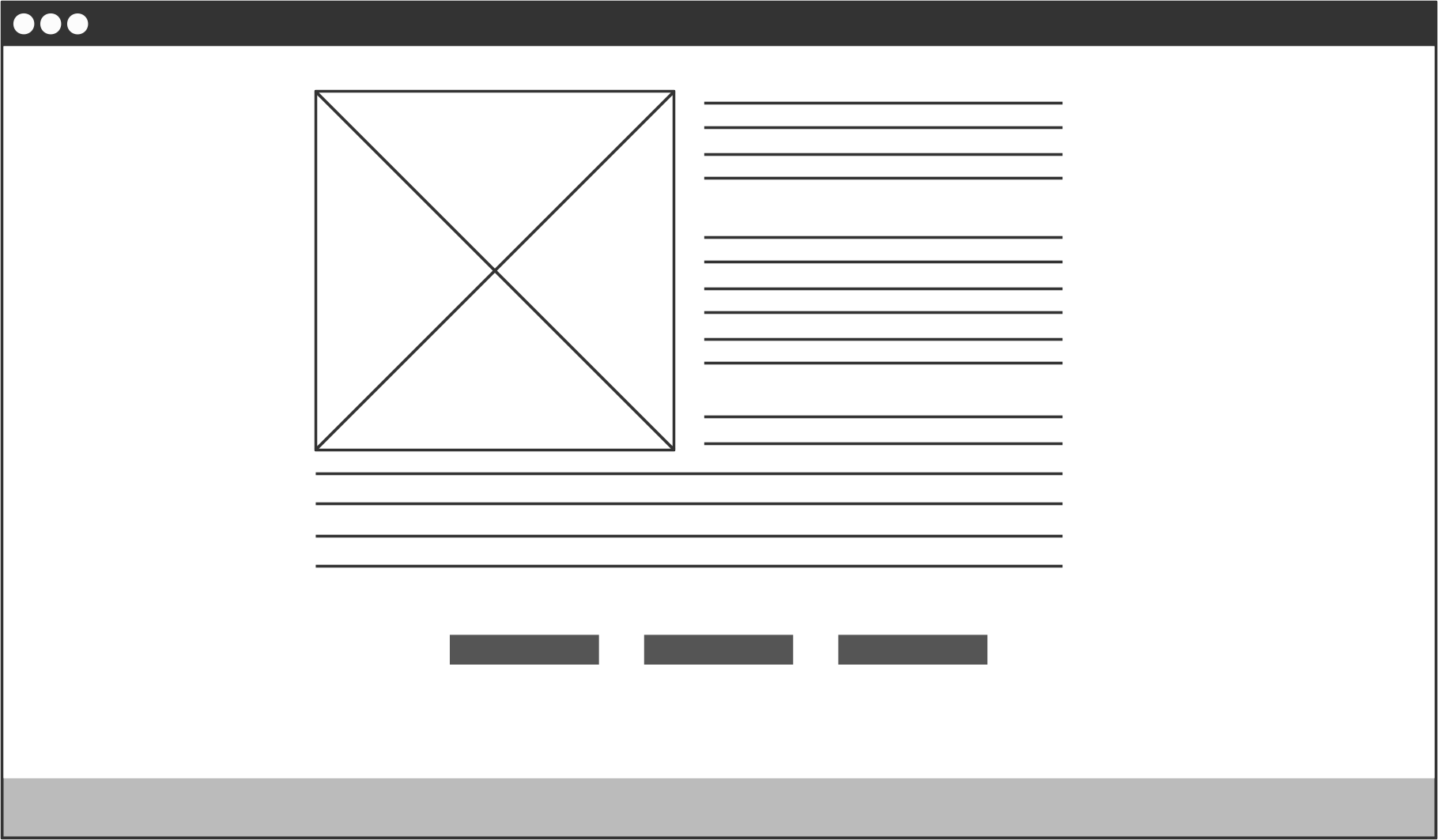
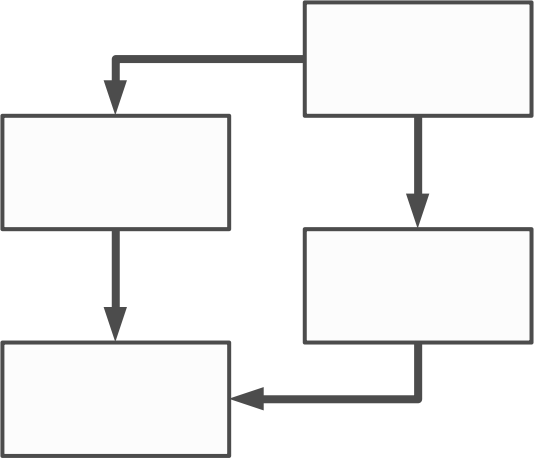
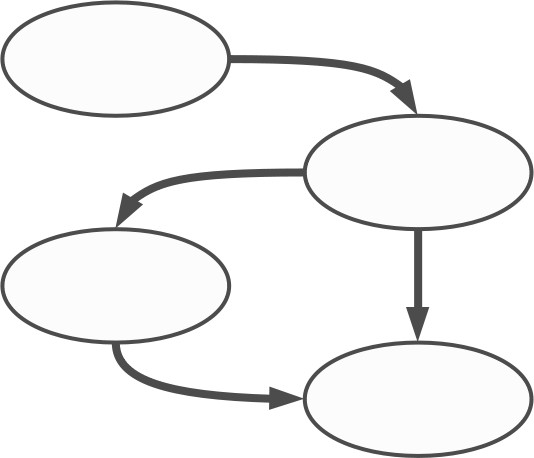


Fig. 1. Front-end mockup. With an added description to help the reader (it won’t appear in the list of figures).

1Complete details in [Appendix B,](#_bookmark47) page [21](#_bookmark47)

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(a) Flowchart A. (b) Flowchart B.

Fig. 2. Flowchart for some processes.

## Summary

This chapter has detailed our system implementation. In particular, we have divided the processes into the back-end [(Section 3.1)](#_bookmark16) and the front-end [(Section](#_bookmark22) 3.2).

In the next chapter, [Section 4,](#_bookmark27) we present the findings of our research.

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# RESULTS

In the Results chapter of your thesis, present the findings of your research in a clear, factual manner. This section should be free from interpretation, focusing solely on reporting what the data reveals. Organize your results logically, often mirroring the sequence of your methods section. Use tables, graphs, and charts to effectively communicate your data, ensuring each is clearly labeled and explained. This chapter should provide a straightforward account of what you discovered, setting the stage for deeper analysis in the following chapters.

In this section, we will present the result of the work described in [Section 3.](#_bookmark15)

## Results about B

## Results about A

## Summary

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# ANALYSIS

In the Analysis chapter, interpret your data by linking it to your research questions and theoretical framework. Critically evaluate your findings, highlighting patterns, correlations, and unexpected results, while acknowledging any potential biases. Importantly, compare your results with existing literature to contextualize them within your field. This approach not only validates your findings but also underscores their uniqueness and relevance to your research area. This chapter is key to demonstrating the derivation of meaningful conclusions from your data, forming a crucial part of your research contribution.

In this section, we evaluate the system developed in [Section 3](#_bookmark15) and the results described in [Section 4](#_bookmark27) with two tests, first Test 1 [Section 5.1](#_bookmark32) and then Test 2 [Section 5.2.](#_bookmark33) We then explore concept B with users in [Section 5.3,](#_bookmark34) as laid out in the Background [(Section](#_bookmark13) 2.2).

## Test 1

## Test 2

## User Study

[Table 1](#_bookmark35) listed the many properties highlighted by users.

Table 1. Table of some properties

**Property Freq. A Freq. B Total**

**X** 2 3 5

**S** 7 0 7

## Summary

In this section, we have carried out the evaluations. Tests 1 and 2 [(Sections 5.1](#_bookmark32) and [5.2)](#_bookmark33) have proved this and that, but highlighted these limitations due to that aspect of the algorithm.

Presented to users, the interface was said to be such and such.

This chapter concludes the work carried out during the project. In the next chapter, [Section 6,](#_bookmark37) we discuss our findings and their implications.

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# DISCUSSION

The Discussion chapter is where you explore the meaning and implications of your findings, in contrast to the Analysis chapter that focus on data interpretation. Here, you should con- nect your results to broader themes and theories in your field, considering the real-world implications and contributions of your work. Discuss how your findings extend, support, or challenge existing knowledge. Reflect on the limitations of your study and propose areas for future research. This chapter is crucial for showcasing your critical thinking and situating your research within the larger academic conversation.

This section provides a discussion of the methodology, results and analysis presented in [Sections 3](#_bookmark15) to [5.](#_bookmark31)

You can cross-examine your findings with items from the literature:

Some quote to include - [Doe](#_bookmark44) [[2017]](#_bookmark44) The next section, [Section7,](#_bookmark38) concludes our project.

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# CONCLUSION

The Conclusions chapter distinctively encapsulates your dissertation, summarizing key findings and their implications. It revisits your research objectives and questions, highlighting how your work fills the identified gap. This chapter also briefly reiterates the study’s limitations and suggests future research directions, focusing more on summarizing the overall contributions and outcomes of your research, as opposed to the detailed examination and implications discussed in the Analysis and Discussion chapters.

This is the conclusion of this dissertation. We re-contextualise the motivation for the project [(Section](#_bookmark39) 7.1), list our contributions [Section 7.2,](#_bookmark40) and finally discuss the limitation of the project and suggest future work [Section 7.3.](#_bookmark41)

## Motivation and Goals

Here we will summarise briefly what were the motivations for the project, and the main objectives we tried to achieve.

## Contributions

Here we will summarise the main contributions and achievements of this project, in relation to the initial objectives, and in contrast with similar work found in the background chapter [(Section](#_bookmark11) 2).

We will also summarise the methodologies used to achieve goals and tackle problems.

## Limitations and Future Work

Here we will highlight the main limitations of the project, and suggest possible corrections, extensions, or uses for our work in future projects.

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