



MedCore

IT 497: Graduation Project Report Product Release-2

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Table of Contents

1	<i>Introduction</i>	8
1.1	The Problem	8
1.2	Objectives.....	9
1.3	Scope	10
1.4	Product Vision	10
1.5	Approach.....	10
1.6	The Solution	11
1.7	Summary	12
2	<i>Background</i>	14
2.1	Overview	14
2.2	Healthcare in Saudi Arabia	14
2.3	Communication	15
2.4	Machine learning	15
2.5	Medical history	17
2.6	Summary	17
3	<i>Literature Review</i>	19
3.1	Overview	19
3.2	Competitive Product Analysis	19
3.3	Ministry of Health Applications	20
3.4	Private Hospitals Applications	23
3.5	Comparison Between Similar Applications	25
3.6	Summary	26
4	<i>System Design and Development</i>	28
4.1	Overview	28
4.2	Methodology	28
4.3	System Requirements	30
4.3.1	Overview	30
4.3.2	System Users	30
4.3.3	Requirements Elicitation and Analysis	30
4.3.3.1	Summary and discussion	31
4.2.4	User Interactions	33
4.2.5	Roadmap and Product Backlog	34
4.3	System Design	55
4.3.1	Architectural Diagram	56

4.3.2 Class Diagram /DFD	58
4.3.3 Component Level Design	59
4.4 Data Design	63
4.4.1 Data Models	63
4.4.2 Data Collection and Preparation	75
4.5 Interface Design.....	75
4.6 Implementation	86
4.6.1 System Components	86
4.6.2 Software Implementation	86
4.7 Summary	99
5 System Evaluation.....	101
5.1 Overview	101
5.2 User Acceptance Testing	101
5.2.1 Demographics of Participants	101
5.2.2 Questionnaire Results	103
5.3 Quality Attributes (NFR testing).....	111
5.4 Discussion.....	115
5.5 Summery.....	116
6 Conclusions and Future Work	118
6.1 Global impact	118
6.2 Local impact	118
6.3 Problems and challenges encountered during the software development	119
6.4 Limitations of the system.	120
6.5 The main contribution of the project	120
6.6 Future work	121
7 Acknowledgements.....	125
8 References	126
9 Appendix.....	130
9.1 Appendix A.....	130
9.2 Appendix B	131
9.3 Appendix C	134
9.4 Appendix D	136
9.5 Appendix E	147

List of Figures

Figure 3. 1 Sehhaty Application – Patient interfaces.....	22
Figure 3. 2 Dallah Hospitals Application - Patient interfaces	23
Figure 3. 3 Dr. AlHabib Hospitals Application - Patient interfaces	24
Figure 4. 1 MedCore Use Case Diagram	33
Figure 4. 2 MedCore Roadmap.....	34
Figure 4. 3 MedCore System Architecture	57
Figure 4. 4 MedCore Class Diagram	58
Figure 4. 5 ML flowchart.....	62
Figure 4. 6 MedCore ER Diagram.....	63
Figure 4. 7 MedCore App-Patient home Page	76
Figure 4. 8 MedCore Admin Panel - Hospital	77
Figure 4. 9 MedCore App-SignUp & Patient home page	78
Figure 4. 10 MedCore Admin Panel - Hospital	79
Figure 4. 11 MedCore Admin Panel - Hospital	79
Figure 4. 12 MedCore App-Patient profile page	80
Figure 4. 13 MedCore App-SignUp.....	81
Figure 4. 14 MedCore Admin Panel - Add Hospital Form.....	82
Figure 4. 16 MedCore App-Patient home page	83
Figure 4. 15 MedCore Admin - Hospital	83
Figure 4. 17 MedCore Admin - Hospital	83
Figure 4. 18 MedCore Admin Panel - Delete Hospital.....	84
Figure 4. 19 MedCore app sitemap.....	85
Figure 4. 20 MedCore Admin Sitemap.....	85
Figure 4. 21 MedCore application and MySQL connection	88
Figure 4. 22 Admin Panel and MySQL connection.....	89
Figure 4. 23 Heatmap for Features Correlation	90
Figure 4. 24 Frequency for Each Disease	91
Figure 4. 25 Python Code of ML Model.....	97

Figure 4. 26 Request to the server	98
Figure 4. 27 Python code in the server	98
Figure 6. 1 Future Dataset Components	122
Figure 6. 2 Diagnostic Tool Interface	122

List of Tables

Table 3. 1 Comparison between similar Applications	26
Table 4. 1 Product Backlog.....	55
Table 4. 2 Data Dictionary - Descriptions for Each Entity	66
Table 4. 3 Data Dictionary - Describes Each Relationship	67
Table 4. 4 Data Dictionary - Descriptions for Each Attribute	75
Table 4. 5 Data Exploration – Overview	89
Table 4. 6 Data Quality Report	95
Table 4. 7 Results of the ML model	97
Table 5. 1 System Testing - Demographics of Participants.....	103
Table 5. 2 System Testing - Questionnaire Result.....	111
Table 5. 3 Quality Attributes (NFR testing)	115

MedCore

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Abstract (English):

Patients often visit multiple hospitals throughout their lives, many of which are located in different cities across Saudi Arabia. These visits can range from regular checkups and second opinions to emergency cases. A significant issue with the current healthcare system in Saudi Arabia is that each hospital maintains its own system with separate patient information. Due to the lack of communication between hospitals and physicians, patients frequently undergo unnecessary checkups, tests, or even surgeries, resulting in increased costs, reduced healthcare quality, and wasted medical resources or lives for both patients and public hospitals. To address this issue, we propose the MedCore iOS application, which aims to connect hospitals in Saudi Arabia, allowing physicians, patients, laboratory specialists, and hospitals to access information easily and transparently. Furthermore, MedCore leverages the power of AI and data availability by serving as a diagnostic tool for physicians. We trained this diagnostic model on 4,899 patients with 140 unique symptoms using decision trees, and optimized it via grid and random searches. The optimized model achieved 91% accuracy and 92% F1-score. Combining this model with a physician's own prediction can increase their decision certainty or provide an informative experience, ultimately enhancing healthcare outcomes in Saudi Arabia.

Abstract (Arabic):

يُزور المرضى في الغالب العديد من المستشفيات في حياتهم والتي ينتشر الكثير منها في مختلف المدن في المملكة العربية السعودية. وتختلف هذه الزيارات من الفحوصات المنتظمة والأمراض المختلفة إلى الحالات الطارئة . والمشكلة الحالية في نظام الرعاية الصحية في المملكة العربية السعودية هي أن كل مستشفى لديه نظامه الخاص مع معلومات مرضاه بشكل مستقل عن غيره من المستشفيات. ونظرًا لهذه الاستقلالية ونقص التواصل بين المستشفيات والأطباء، يتبعن على معظم المرضى الخصوص لفحوصات أو اختبارات أو حتى عمليات جراحية غير ضرورية. وبالتالي، تزيد التكلفة المالية وتتأثر جودة الرعاية الصحية والموارد الطبية لكل من المرضى والمستشفيات العامة. لذلك جاء تطبيق MedCore الذي يهدف إلى ربط المستشفيات معاً في المملكة العربية السعودية مما يسمح للطبيب والمريض وأخصائيي المختبرات والمستشفيات بالوصول إلى المعلومات بسهولة وشفافية. بالإضافة إلى ذلك، يستفيد MedCore أيضاً من الفزة التقنية التي يشهدها الذكاء الاصطناعي وتوافر البيانات من خلال العمل كأداة تشخيصية للأطباء. وقد قمنا بتدريب هذا النموذج التشخيصي على 4899 مريضاً و140 عرضاً فردياً باستخدام decision trees وrandom searches grid وgrid وrandom searches. وكان النموذج المحسن دقيق بنسبة 91% وحقق 92% F1-score. وعند الجمع بين نتائج هذا النموذج وتنبؤ الطبيب نفسه فإنه قد يساهم في زيادة يقين الطبيب في اتخاذ القرار.

Keywords: Hospital; Diagnosis; Artificial Intelligence; Machine Learning.

Introduction

1 Introduction

In Saudi Arabia, patients often visit various hospitals located in different areas. Each hospital creates a unique file with information specific to that facility, such as patient visits, medications, lab results, and medical history. Consequently, there is a significant communication gap between doctors across different hospitals, which can negatively impact patient care. A physician may only be aware of a patient's medical information from the current hospital, even if the patient has visited the same physician at another facility. To ensure consistent and efficient healthcare in Saudi Arabia, it is crucial to develop a centralized system that connects all hospitals and unifies patient data.

Physicians occasionally encounter rare cases that are challenging to diagnose, and researching them can be time-consuming. At the same time, similar cases may have been accurately diagnosed by a different physician elsewhere in the country. By leveraging technology, we can facilitate communication, information sharing, and improve the search process for diagnosing rare cases, ultimately enhancing the quality of healthcare in Saudi Arabia.

The MedCore system aims to address these challenges by creating a centralized hospital system, connecting all hospitals and unifying patient files, and providing a diagnostic tool to assist physicians in diagnosing rare cases. This integrated approach will contribute to improved healthcare experiences for both patients and healthcare professionals.

1.1 The Problem

The current issue with our healthcare in Saudi Arabia is the lack of communication between hospitals, physicians, and patients. Patients have different files in different hospitals and cities, and physicians cannot see their patients' medical history in other hospitals. In the past, this has caused multiple patients overdosing or cause major side effects that endanger the patient's life due to different medications from different hospitals and physicians. In addition, the lack of communication with other hospitals will cost hospitals, physicians, and patients a lot of money and resources. For example, in some cases, physicians in separate hospitals ask for the same lab tests for the same patient. Also, physicians may misdiagnose patients when

there could be another case in another hospital where a physician correctly diagnosed a similar case, but they cannot help or benefit from their experience.

1.2 Objectives

The primary objective of the MedCore system is to enhance healthcare in Saudi Arabia by addressing resource consumption, saving costs, and ultimately helping save lives. To achieve this goal, MedCore aims to create a centralized hospital system connecting all hospitals in Saudi Arabia and unifying patients' files. The system will cater to four user roles and provide three user interfaces: physician, patient, and laboratory specialist and admin panel.

1. Physician Interface: Physicians will be able to view their patients' medical information. MedCore will also offer a diagnostic tool with visualization features to assist physicians in making informed decisions during the diagnosis stage and conducting research. Physicians can search for symptoms using the diagnostic tool, and the system will predict the disease and visualize the percentage of each symptom related to the predicted disease. Additionally, the tool will provide contact information for other physicians who have diagnosed the predicted disease.
2. Patient Interface: Patients will have access to their medical information, allowing them to stay informed about their health and treatment plans.
3. Laboratory Specialist Interface: Laboratory specialists will receive lab test requests and upload the results, streamlining the process of sharing critical diagnostic information with physicians.
4. Admin: A separate website will be available for administrative purposes, giving admins the ability to add hospitals and view, edit, and delete hospitals, physicians, laboratory specialists, and patients.

By developing the MedCore system with these key objectives in mind, it will serve as a comprehensive healthcare solution that connects hospitals, unifies patient files, and provides essential tools for physicians, patients, and laboratory specialists. This integrated approach will contribute to improving healthcare quality and efficiency in Saudi Arabia.

1.3 Scope

MedCore is a mobile application that is accessible through all iOS devices. Our system aims to connect all hospitals in Saudi Arabia and unify patients' files. It covers several functionalities including the diagnostic tool. The mobile application is developed using Flutter & Dart language and Python language for building the diagnostic tool model. The admin panel is developed using an Appsmith tool which is a low-code, open-source developer tool based on the JavaScript programming language. The application currently supports the English language only.

1.4 Product Vision

For hospitals, physicians, and patients who face a lack of communication, MedCore is a mobile application that connects all hospitals in Saudi Arabia and unifies patients' files, unlike other hospitals' applications our product enables physicians to search for patient symptoms and get similar cases around the country.

1.5 Approach

MedCore is built using the Agile approach which is an incremental approach that consists of several sprints and aims to deliver working software at the end of each sprint. We started to analyze the domain and define the requirements as user stories in the backlog and divide it into sprints. Then we designed the interfaces and developed the front end. To implement the back end, we created the database and collected the dataset for the model, then we developed the back end including building and evaluating the machine learning model. As a final step, we deployed the python code in the server.

1.6 The Solution

The MedCore Application aims to create a centralized hospital system connecting all hospitals in Saudi Arabia by unifying patient files and facilitating communication between physicians through contact information sharing. Moreover, the application enables physicians to search for symptoms, and the system will predict the disease, aiding physicians in making informed decisions. It will also visualize the percentages of each symptom related to the predicted disease and provide contact information for other physicians who have diagnosed the predicted disease. This diagnostic tool is not available in any other hospital system.

Furthermore, physicians will be able to request lab tests and receive results, which will be included in the patient's file. The primary goal of our application is to save patients' lives and streamline communication between hospitals, reducing unnecessary resource consumption and costs for all parties involved.

MedCore will have a positive global and local impact. Globally, it will contribute to reducing the death rate, while locally, it will decrease funding and resource usage for patients and hospitals by avoiding redundant procedures.

In this project, we will develop a prototype application acting as the Ministry of Health and using synthetic data, such as hospitals, physicians, lab specialists, and patients, to test all required functionalities. Due to limited access to real hospital data and physicians, we will implement all application functionalities to accommodate project requirements. After the second release, we plan to present the application to the Ministry of Health, which will then be able to add and connect all Saudi hospitals and validate physicians' and laboratory specialists' credentials.

Regarding the machine learning model, we will collect and explore symptom-related data to train and test our model. In the future, we can expand the application to include pharmacies, allowing physicians to send patient prescriptions directly to the patient's preferred pharma.

Based on physician feedback collected from the survey in Appendix A, MedCore will be an iOS mobile application tailored to their preferences.

1.7 Summary

This document presents the MedCore application. It contains the necessary information gathered to build and explain the application. It includes the problem that led to the idea and the proposed solution, the product vision, objectives, and scope, and a brief overview of future work. As part of the literature review, we analyze applications similar to the MedCore application. In addition to the background section, which introduced general domain knowledge.

In the system design and development chapter, we introduced the methodology and the requirements we collected from the users. Additionally, we present the data design, interface design, and system design. In the implementation chapter, we also included a description of the implementation procedure. Finally, we assess the system using both quantitative and qualitative methods.

Background

2 Background

2.1 Overview

Nowadays, most people tend to go to more than one physician and more than one hospital, which may cause many problems, as each patient has more than one medical file, and this requires more costs and consumes more resources, and in some cases, may cause a conflict of prescriptions because the physician does not know what medication the patient is taking. In MedCore, an application that works on iOS systems, will gather and unify all patient files, which makes access to information easier and more reliable, in addition to the feature of facilitating the process of patient diagnosis, in which we will use machine learning to apply it.

This chapter contains a background of healthcare in Saudi Arabia, communication, machine learning, and medical history.

2.2 Healthcare in Saudi Arabia

Here are many public and private hospitals. Each hospital contains the medical files of its patients. Each patient usually visits more than one hospital and has more than one medical file. The physician can only access the patient's medical file at the hospital where she\he works.

The terms medical record, health record, and medical chart are used somewhat interchangeably to describe the systematic documentation of a patient's medical history and care across time within one particular health care provider. A medical record includes a variety of types of "notes" entered over time by healthcare professionals, recording observations and administration of medicines and therapies, orders for the administration of medicines and therapies, test results, x-rays, reports, etc. The main purpose of medical files is to ensure that the medical care that patients receive is of high quality, as medical files provide detailed information to all healthcare providers about their patients, and in turn, this helps physicians to diagnose and determine the best course of treatment. Therefore, it is important for the physician to see all the patient's medical files. The maintenance of complete and accurate medical records is a requirement of health care providers and is generally enforced as a licensing or certification prerequisite [1].

2.3 Communication

The physician-physician relationship is one of the most important relationships that should prevail between them in various disciplines, as its strength gives physicians the opportunity for positive cooperation among themselves, whether it is from a scientific or a therapeutic point of view, and therefore, this will have an impact on health workers in general and will have good effects and results on everyone. So, improving how physicians communicate with each other when caring for their patients greatly reduces the risks of medical errors that can harm patients. Globally, as many as 4 in 10 patients are harmed in primary and outpatient health care. Up to 80% of harm is preventable. The most detrimental errors are related to diagnosis, prescription, and the use of medicines. By using good communication, we can reduce the potential of these adverse events and medical errors occurring [2].

2.4 Machine learning

We will use machine learning to implement the model of the diagnostic tool that predict the disease based on the patient symptoms and find similar cases. In addition, the tool will provide the physician with chart that illustrate the symptoms related to that disease. Machine Learning is a sub-category of artificial intelligence that refers to the process by which computers develop pattern recognition, or the ability to continuously learn from and make predictions based on data, then make adjustments without being specifically programmed to do so [3]. ML is one of the most exciting technologies that one would have ever come across. As it is evident from the name, it gives the computer what makes it more similar to humans; the ability to learn. Machine learning is actively being used today [4]. In fact, machine learning has a number of advantages. It allows a variety of technological devices to recognize and analyze patterns. These patterns are frequent in a range of industries. Thanks to machine learning, we gained a lot of free time and reduced costs by lending these tasks to computers. Due to this mechanism, these programmed tasks can be performed autonomously by software. In an age of massive data, human experience is prone to error. Overwhelmed with unstructured amounts of data [5].

In MedCore we used multiple algorithms to implement the model of the diagnostic tool, which are the following:

- **Decisions Tree**

Decision Tree is a Supervised learning technique that can be used for both classification and Regression problems, but mostly it is preferred for solving Classification problems. It is a tree-structured classifier, where internal nodes represent the features of a dataset, branches represent the decision rules, and each leaf node represents the outcome. The decisions are performed on the basis of features of the given dataset. It is called a decision tree because, similar to a tree, it starts with the root node, which expands on further branches and constructs a tree-like structure [6].

- **Randomized Search**

The Randomized Search randomly passes the set of hyperparameters and calculate the score and gives the best set of hyperparameters which gives the best score as an output. We used the Randomized Search to find the best max depth for the decision tree [7].

- **K-Fold Cross Validation**

K-fold cross validation means that you will be training your model k-times and also testing it k-times [8]. It is usually used in machine learning for improving model prediction when we don't have enough data to apply other more efficient methods [9].

2.5 Medical history

Medical history includes past surgical information, family medical background, social or habits history, allergies, and medications the patient is currently taking or may have recently stopped taking. A complete medical history includes a more in-depth inquiry into the patient's medical issues, which includes all diseases and illnesses currently being treated and those which have had any residual effects on the patient's health. A surgical history to include all invasive procedures the patient has undergone. Family history is another aspect of the patient's medical history with potential indicators of genetic predisposition to the disease. Social history is a broad category of the patient's medical history but may include the patient's smoking or other tobacco use, alcohol and drug history and should also include other aspects of the patient's health, including spiritual, mental, relationship status, occupation, hobbies, and pertinent sexual habits [10].

2.6 Summary

We learned about healthcare in Saudi Arabia, communication, machine learning, and medical history which are a broad background needed to implement MedCore in this chapter. The following chapter will analyze our competitors.

Literature Review

3 Literature Review

3.1 Overview

In this chapter, we will provide a review of similar applications to identify their advantages and disadvantages. In the following sections, we will identify similar applications and their important features. Next, we will provide a comparison between MedCore and the other Applications. A summary of our MedCore research is presented in the end.

3.2 Competitive Product Analysis

After doing our research, we discovered that there are a few applications similar to MedCore that the Ministry of Health is currently working on. There are also a few other applications created for private hospitals in Saudi Arabia. In this section, we divided the applications into two categories: applications developed for the Ministry of health and applications developed for private hospitals.

3.3 Ministry of Health Applications

Nphies [11] "نفيس"

The unified electronic services platform Naphies is the National Platform for Health and Insurance Exchange Services launched by the Cooperative Health Insurance Council (CCHI) and the National Center for Health Information (NHIC) and led by the Sehati Company. It aims to transform the healthcare sector in the Kingdom of Saudi Arabia for both governmental and private sector healthcare providers by using the latest technologies to enhance the level and quality of health services.

Naphies provide both insurance and clinical service, such as:

Main clinical service:

- Patient ID Management.
- Sharing Diagnostic Imaging.
- Referral Request/ Response.
- Surgical Notes.
- Medication Prescription.
- Coded Lab Results.
- Tele-Radiology Ordering

Main insurance service:

- Eligibility Management Services.
- User Management Services.
- Claim(s) Management Services.
- CCHI Insurance Management Services.
- Payment Management Services.



Wasfaty [12] “وصفي”

Wasfaty service is one of the services of the National Company for the Unified Purchase of Medicines, Devices and Medical Supplies “Nupco” under the supervision of the Ministry of Health in the Kingdom of Saudi Arabia. Preliminary in community pharmacies so that the medicine is available everywhere and at any time for free.

Wasfaty includes the following features:

- The possibility of prescribing medicines from different geographical locations in the Kingdom.
- View previous prescriptions and physician's instructions at any time.
- Text message alerts for e-prescription status.
- Availability of re-e prescribe option for patients with chronic diseases.
- Auto check for medication conflicts and beneficiary sensitive medications.
- Possibility of direct communication between the pharmacist and the physician.



Sehhaty "صحتي" [13]

Sehhaty is MOH's unified platform (Mobile Application) that provides several health services to all individuals (citizens and residents in the Kingdom); in terms of reviewing their health data as well as achieving an integrated health strategy. Figure 3.1 shows some of the application interfaces.

The platform provides users with a wide range of health services to facilitate the provision of integrated healthcare to individuals. Main services include:

- Immediate Consultations.
 - Booking and reviewing appointments.
 - Virtual appointments.
1. Find medicine.
 2. Digital health wallet.
 3. Reviewing sick leaves and medical reports.
- A physician for every family.
 - Child's vaccination record.
 - Child's appointments.
 - Health tools for everyday use.

The Ministry provides its e-services in Arabic and English.

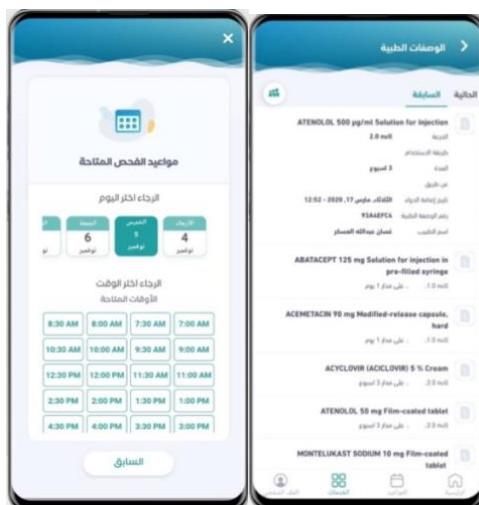


Figure 3. 1 Sehhaty Application – Patient interfaces

3.4 Private Hospitals Applications



Dallah Hospitals Application [14]

Dallah Hospitals' mobile Application gives their physicians access to a wide range of services, including their patients' medical information only in Dallah hospitals. Figure 3.2 shows some of the application interfaces.

The Application supports Arabic & English languages and has the following main features:

- View upcoming appointments.
- View patient visits.
- View patient's results (Lab, X-Ray, and more)
- View patient's insurance approvals
- View patient's medications
- View the patient's medical report
- Referrals

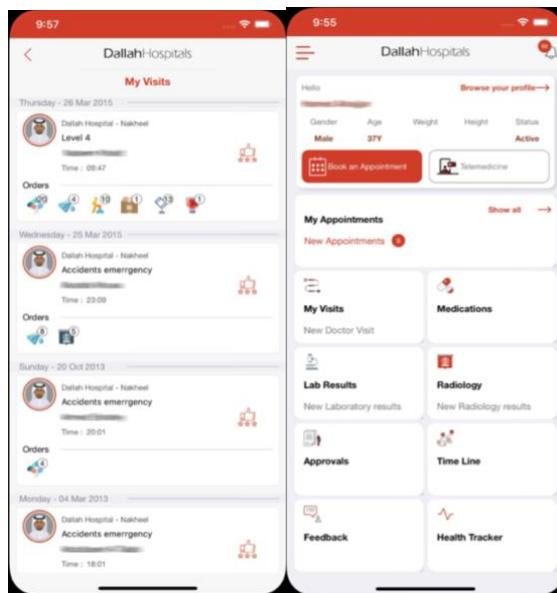


Figure 3.2 Dallah Hospitals Application - Patient interfaces



HMG App for Physicians [15]

AlHabib Medical Group physician app is an exclusively made application for HMG physicians. The app provides easy access to patient's clinical information. Also, physicians can execute some of their daily tasks at any convenient time. Figure 3.3 shows some of the application interfaces.

The app includes the following features:

- Checking insurance approvals
- View lab results and prescriptions
- Radiology reports
- Vital signs
- Referrals
- Scheduled appointments and physician schedule
- Search for available medicines in HMG pharmacies
- Add and view progress notes and orders
- Physician reply to their patient's questions
- Search in blood bank

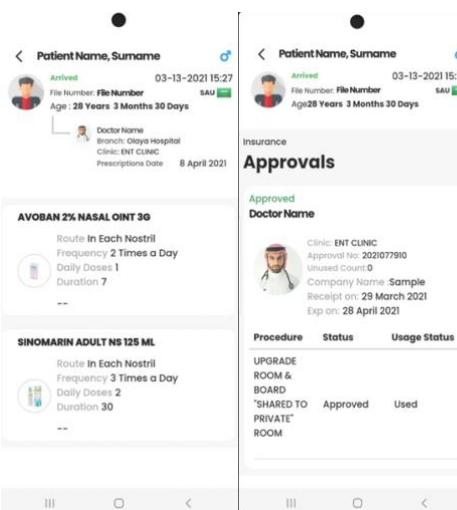


Figure 3. 3 Dr. AlHabib Hospitals Application - Patient interfaces

3.5 Comparison Between Similar Applications

After comparing MedCore with similar applications, a list of the common features and their differences are presented in table 3.1 below. In contrast to all applications, MedCore has the ability to aid the physician in finding the most similar diagnosis using ML models.

Features	Sehhaty[13]	Wafaty [12]	Nphies [11]	Dallah Hospitals[14]	HMG [15]	MedCore
View patients' prescriptions	<input checked="" type="checkbox"/>					
	In all public Hospitals	In all public Hospitals	In all Saudi Hospitals	Only in Dallah hospitals	Only in Dr. AlHabib hospitals	In all Saudi Hospitals
View patients' lab results	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
			In all Saudi Hospitals	Only in Dallah hospitals	Only in Dr. AlHabib hospitals	In all Saudi Hospitals
View patients' medical reports	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	In all public Hospitals		In all Saudi Hospitals	Only in Dallah hospitals	Only in Dr. AlHabib hospitals	In all Saudi Hospitals
Insurance services	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	In all Saudi Hospitals		In all Saudi Hospitals	Only in Dallah hospitals	Only in Dr. AlHabib hospitals	

Referrals	<input checked="" type="checkbox"/>					
			In all Saudi Hospitals	Only in Dallah hospitals	Only in Dr. AlHabib hospitals	
Diagnostic Tool	<input checked="" type="checkbox"/>					

Table 3. 1 Comparison between similar Applications

3.6 Summary

We have examined various existing applications and services that share some features with our proposed MedCore system. These applications are often specific to certain hospital groups, such as private hospitals (e.g., Dallah and Dr. AlHabib hospitals) having their own applications with dedicated functionalities, and public hospitals using the Sehhaty application owned by the Ministry of Health. There is also an upcoming service called Nphies, provided by the Ministry of Health for both public and private hospitals, but it has not been released yet. Another service, Wasfaty, connects healthcare centers under the Ministry of Health with pharmacies only.

These current solutions make tracking a patient's health more challenging and potentially negatively impact patient care due to the lack of a unified system. To address this issue and bridge the gaps between hospitals, the MedCore application will be developed to connect all Saudi hospitals, providing essential functionalities needed for effective healthcare management.

Moreover, MedCore will offer a unique diagnostic tool feature, setting it apart from existing applications and services. This feature will help healthcare professionals diagnose patients more accurately by searching for similar cases and providing a unified patient file system. By creating a comprehensive and connected healthcare solution, MedCore aims to improve patient care and enhance the overall healthcare experience.

System Design & Development

4 System Design and Development

4.1 Overview

We will go into extensive detail on system design and development in this chapter. The process for implementing MedCore will first be explained, followed by discussions of the system requirements, system design, interface design, and implementation.

4.2 Methodology

The MedCore software was developed using Agile methodology, a flexible and iterative approach to project management and software development. Agile methodology helps deliver value to users more quickly and adapt to changing requirements smoothly. It allows developers to produce work in small, consumable increments, making it particularly suited for projects where user requirements are subject to change [16].

For MedCore, the Scrum framework was chosen as the Agile approach. Scrum focuses on delivering value and maintaining high visibility of progress while guiding the product's development. In Scrum, a team creates a product from a concept by working from a dynamic list of the most crucial tasks, using the Scrum structure to promote transparency, inspection, and adaptation [17].

Scrum includes three roles:

1. Scrum Master: Responsible for guiding the Scrum Team.
2. Product Owner: Represents the stakeholders' interests (e.g., hospitals in the case of MedCore).
3. Scrum Team: The development team working on the project.

Scrum consists of three artifacts:

1. Product Backlog: A prioritized list of features and tasks to be completed.
2. Sprint Backlog: A list of tasks selected from the Product Backlog to be completed during a specific sprint.

3. Product Increment: The resulting working product increment at the end of each sprint.

Each sprint in Scrum consists of five events:

1. Backlog Refinement: The process of updating and refining the Product Backlog.
2. Sprint Planning: The event where the team plans the work for the upcoming sprint.
3. Sprint Review: A meeting to review the completed work and the Product Increment at the end of the sprint.
4. Sprint Retrospective: A meeting to reflect on the sprint and identify areas for improvement.
5. Daily Scrum: A daily meeting to synchronize the team's efforts and address any obstacles. [18]

Working with Agile methodology using the Scrum framework provided several benefits for the MedCore project:

- Prioritizing tasks and delivering a working product in a short period.
- Responding to stakeholder feedback and adjusting the product to meet their needs.
- Re-prioritizing tasks based on changing requirements.
- Continuously learning from each sprint and improving in the subsequent sprint.

By adopting Agile methodology and the Scrum framework, the MedCore development team was able to create a responsive, adaptable, and efficient software development process that met the stakeholders' needs and produced a high-quality software product.

Tools used for managing work:

- **Jira**

Jira is a software tool that allows teams to monitor issues, manage projects, and automate operations. We utilized Jira to organize activities by creating a prioritized product backlog and sprints backlog, reporting issues, writing summaries for each sprint review and weekly meetings, and uploading any essential documents. [19]

- **GitHub**

GitHub is an online software development platform. It's used for storing, tracking, and collaborating on software projects. It makes it easy for us to share code files as well as track and control changes to the code within the team. [20]

4.3 System Requirements

4.3.1 Overview

In this section, we describe the general characteristics of the system users, identify the requirement elicitation methods that we will use, and create the use case diagram to show how our system interacts with actors.

4.3.2 System Users

There are four types of users for MedCore application: physician, patient, laboratory specialist, and admin. All users should have previous knowledge of technology and experiences in mobile apps. The educational level of the patient who will use our app should be from middle school and above, in contrast the other users such as physicians and laboratory specialists should have a degree in their majors. Furthermore, the admin should have a background in database management and DB security.

4.3.3 Requirements Elicitation and Analysis

In requirement elicitation, we collect the requirements from the physicians using two methods: interviews and questionnaires.

4.3.3.1 Summary and discussion

4.2.3.1 Interview

In this section, we summarize the results of the interviews that were held with the physicians. We had four interviews with four different physicians who have a long experience in the medical field. We need to benefit from their knowledge and experience and help us develop our application. Below, we present the interview questions and the physicians' replies.

- What do you usually do when you can't diagnose a patient because of a unknown symptom?

Two physicians stated that they would discuss it with their colleagues, and the others replied that they would contact a senior and will search for the symptoms.

- As a physician, what is the impact of not knowing your patient's information in other hospitals?

The physicians all agreed that it's distressing, time-consuming, and may harm the patient, one of the physicians, added that it would delay the diagnosis and may expose the patient to radiation, other physician said that she has to start from scratch with the patient.

- How do you ensure that the patients are giving you the correct information about their medication?

Two of them stated that they would ask the patient to bring her/his medical report from other hospitals, and one of the physicians split the patients into two categories: reliable patient and not reliable patient, if the patient is reliable he will take the medical details from her/him, if not he will ask her/his relative; also one physician said that there is no insurance unless they have an educated caretaker with them.

More detailed answers are presented in Appendix B.

4.2.3.1.2 Questionnaire

A questionnaire was conducted with physicians to gather insights into their experiences with ununified patient files, difficulties in diagnosing rare cases, and their interest in an application that unifies patient files and facilitates searching for similar cases. The questionnaire was distributed using Google Forms and shared via social media. A total of 76 responses were received.

1. Difficulty in Diagnosing Patients: 65.8% of the physicians had encountered a patient whom they were unable to diagnose or were uncertain about the diagnosis based on the patient's symptoms. 23.7% were not sure if they had experienced such a situation, and 10.5% had not encountered a patient they were unable to diagnose.
2. Interest in Technology for Diagnosing Patients: 93.4% of physicians expressed interest in having technology that facilitates searching for cases similar to their patient's symptoms, which could help them diagnose patients more accurately.
3. Prescribing Conflicting Medications: 34.2% of the physicians had prescribed medication that conflicted with another medication the patient was taking, but the patient had not informed their physician. 34.2% were not sure if they had experienced this situation, and 31.6% had not prescribed conflicting medications.
4. Preference for Unified Patient Files: To address the issue of conflicting medications, 97.4% of the physicians preferred having a unified file for their patients, which would cover visits to different hospitals around the country.

The complete questionnaire and its results can be found in Appendix C.

These findings highlight the need for a unified patient file system and a tool for searching similar cases to assist physicians in diagnosing patients more accurately and avoiding medication conflicts. The MedCore application aims to address these needs and provide a comprehensive solution for healthcare professionals.

4.2.4 User Interactions

Figure 4.1 describes the user interactions with the software product using a high-level use case diagram. All users will have the ability to login, however, due to organizational purposes, we are showing all main use cases in the use case diagram below.

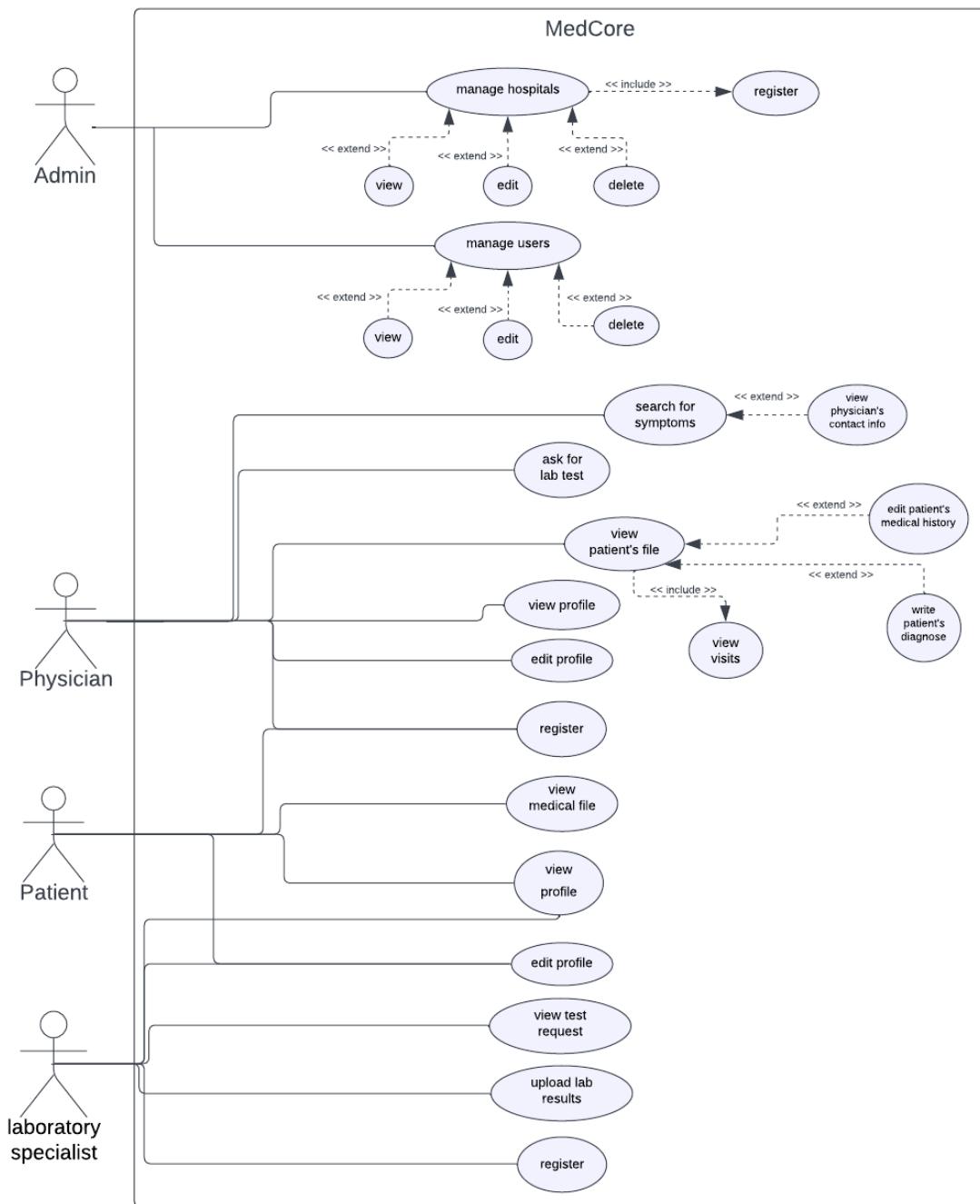


Figure 4.1 MedCore Use Case Diagram

4.2.5 Roadmap and Product Backlog

The figure 4.2 illustrate the roadmap that we are going to follow.

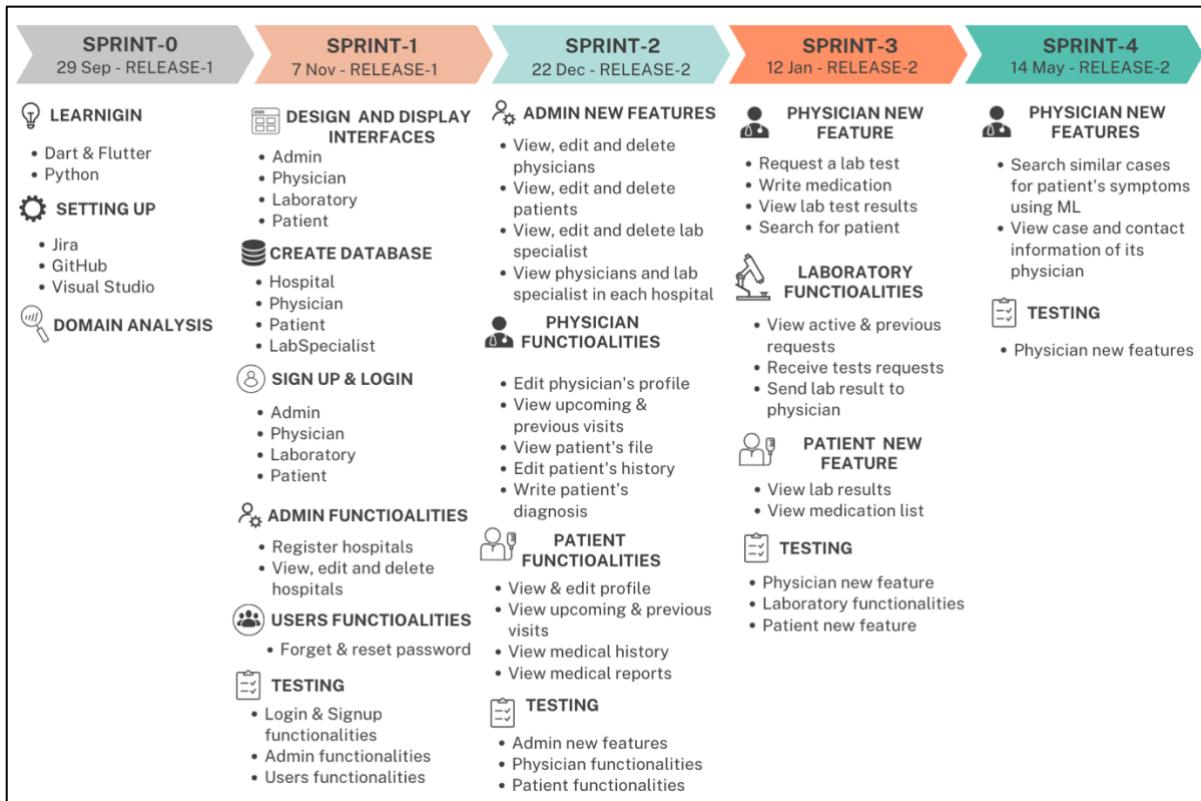


Figure 4. 2 MedCore Roadmap

Table 4.1 includes all the user story that we will implement in detail showing their size, type, status and acceptance criteria. Also, because MedCore is a medical application, the non-functional requirements are just as important as the functional requirements, and they are end of the backlog.

ID	PBI	Size	Type	Status	Acceptance Criteria
1	As an admin, I want to log in so that I can manage the centralized hospital system.	2	Feature	Done	When the admin enters her/his email and password correctly on the log-in page then clicks the “log-in” button, then the system must let the admin in, otherwise the admin will be asked to re-enter her/his log-in credentials.
2	As an admin, I want to register hospitals so that the physicians can register their self in any of those hospitals.	3	Feature	Done	When the admin clicks “Add hospital” button and enters the hospital ID, name, city and district then clicks “Submit” button, the system will first check if the hospitals do not already exist, then the hospital will be added, otherwise a warning message will appear.

3	As an admin, I want to view hospitals so that I can know which hospitals are registered in the system.	3	Feature	Done	When the admin is logged-in and clicks “Hospital” page, then the system will display all the registered hospitals
4	As an admin, I want to edit hospitals so that I update the hospitals information.	5	Feature	Done	When the admin clicks on one of the listed hospitals, the system will display an edit form which will enable the admin to edit the hospital information, after editing the information clicking “Submit” button, the system must update the information.
5	As an admin, I want to delete hospitals so that I manage the system and remove any closed hospital.	3	Feature	Done	When the admin clicks on one of the listed hospitals, the system will activate the “Delete Hospital” button. If the admin clicks that button, then the system will first display a confirmation message, if the admin confirms the deletion action, then the system will delete the hospital, otherwise the hospital will not be deleted.
6	As a physician, I want to register in the system so that I can do my job.	5	Feature	Done	When the physician clicks “Hospital” button in the MedCore homepage and then clicks “Create account” button, the system will ask

					<p>the physician to enter her/his information, after filling the fields and successfully validated, an OTP will be sent to the physician's email. If the physician enters the code correctly her/his account will be created, otherwise the physician will be asked to re-enter the code.</p>
7	As a physician, I want to log in so that I get access to my profile, my patients' visits, and my patients' files.	3	Feature	Done	<p>When the physician clicks “Hospital” button in MedCore homepage and then enters her/his ID and password, the system will check the credentials, if the credentials does not exist in the system or they did not match a warning message will be displayed, otherwise the system will send an OTP to the physician's email. If the physician enters the code correctly her/his will let the physician in, otherwise the physician will be asked to re-enter the code.</p>
8	As a laboratory specialist, I want to register in the system	5	Feature	Done	<p>When the laboratory specialist clicks “Hospital” button in the MedCore homepage and then clicks</p>

	so that I can do my job.				“Create account” button, the system will ask the laboratory specialist to enter her/his information, after filling the fields and successfully validated, an OTP will be sent to the laboratory specialist’s email. If the laboratory specialist enters the code correctly her/his account will be created, otherwise the laboratory specialist will be asked to re-enter the code.
9	As a laboratory specialist, I want to log in so that I can upload patients' results.	3	Feature	Done	When the laboratory specialist clicks “Hospital” button in MedCore homepage and then enters her/his ID and password, the system will check the credentials, if the credentials does not exist in the system or they did not match a warning message will be displayed, otherwise the system will send an OTP to the laboratory specialist’s email. If the laboratory specialist enters the code correctly her/his will let the laboratory specialist in, otherwise the laboratory

					specialist will be asked to re-enter the code.
10	As a patient, I want to register in the system so that I can visit any hospital.	5	Feature	Done	When the patient clicks “Patient” button in the MedCore homepage and then clicks “Create account” button, the system will ask the patient to enter her/his information, after filling the fields and successfully validated, an OTP will be sent to the patient’s email. If the patient enters the code correctly her/his account will be created, otherwise the patient will be asked to re-enter the code.
11	As a patient, I want to log in so that I can view all my medical information.	3	Feature	Done	When the patient clicks “Patient” button in MedCore homepage and then enters her/his ID and password, the system will check the credentials, if the credentials does not exist in the system or they did not match a warning message will be displayed, otherwise the system will send an OTP to the patient’s email. If the patient enters the code correctly her/his will let the

					patient in, otherwise the patient will be asked to re-enter the code.
12	As a user, I want to be able to log out so that I prevent other users from accessing my account.	2	Feature	Done	<p>When the user navigates to her/his profile and clicks “Log-out” button, the system will display a confirmation message, if the user confirms the action, then the system will redirect the user to MedCore homepage.</p> <p>Otherwise, the user will be still logged-in.</p>
13	As a user, I want to reset my password, so that I can update my password regularly.	3	Feature	Done	<p>When the user navigates to her/his profile and clicks “Reset password” button, the system will let the user to enter her/his old password, new password and confirm new password. If the user fills all the field the system will validate the inputs. If the inputs have been successfully validated the system will update the user password, otherwise the user will be asked to re-enter the inputs.</p>
14	As a user, I want to reset my password so that I can use my	3	Feature	Done	<p>When the user navigates to the log-in page and clicks “Forget password” button, the system will send an OTP the</p>

	account if I forget my password.				<p>user email. If the user enters the code correctly, the system will let the user to enter the new password and confirm new password, otherwise the system will ask the user to re-enter the code.</p> <p>If the user fills all the field the system will validate the inputs. If the inputs have been successfully validated the system will update the user password, otherwise the user will be asked to re-enter the inputs.</p>
15	As an admin I want to view the physicians and lab specialist in each hospital so that I know who belong to which hospital	5	Feature	Done	<p>When the admin chooses “Hospital” in the bar at the top, all hospitals will appear to him/her, then he/she clicks on any hospital, then he/she clicks on the “View Physician/Lab Specialist” button, then a page will appear that contains the National/residence numbers of the physicians or lab specialists, he can choose If he wants information about</p>

					physicians or lab specialists by clicking on “Physician” or “Lab Specialists” in the bar at the top of the page, then he/she clicks on the national/residence number in the table, then the physician’s or lab specialists’s information will appear to him/her at the bottom.
16	As an admin, I want to view physicians so that I can know which physicians are registered in the system.	3	Feature	Done	When the admin chooses “Physician” in the top bar, all the physicians and their information will appear to him/her in a table.
17	As an admin, I want to edit the physician so that I can update the physician information.	5	Feature	Done	When the admin clicks on one of the listed physicians, the system will display an edit form which will enable the admin to edit the physician information, after editing the information clicking “Submit” button, the system must update the information.
18	As an admin, I want to delete the physicians	3	Feature	Done	When the admin clicks on one of the listed physicians, the system will activate the

	so that I can manage the system.				“Delete” button. If the admin clicks that button, then the system will first display a confirmation message, if the admin confirms the deletion action then the system will delete the physician, otherwise the physician will remain in the database.
19	As an admin, I want to view patients so that I can know which patients are registered in the system.	3	Feature	Done	When the admin chooses “Patient” in the top bar, all the patients and their information will appear to him/her in a table.
20	As an admin, I want to edit the patient’s information so that I can update his/her information.	5	Feature	Done	When the admin clicks on one of the listed patients, the system will display an edit form which will enable the admin to edit the patient information, after editing the information clicking “Submit” button, the system must update the information.
21	As an admin, I want to delete the patients so that I can manage the system.	3	Feature	Done	When the admin clicks on one of the listed patients, the system will activate the “Delete” button. If the admin clicks that button, then the system will first display a confirmation message, if the admin confirms the deletion

					action then the system will delete the patient, otherwise the patient will not be deleted.
22	As an admin, I want to view laboratory specialist so that I can know which physicians are registered in the system.	3	Feature	Done	When the admin chooses “Lab Specialist” in the top bar, all the laboratory specialists and their information will appear to him/her in a table.
23	As an admin, I want to edit the laboratory specialist so that I can update the laboratory specialist information.	5	Feature	Done	When the admin clicks on one of the listed laboratory specialists, the system will display an edit form which will enable the admin to edit the laboratory specialist information, after editing the information clicking “Submit” button, the system must update the information.
24	As an admin, I want to delete the laboratory specialist so that I can manage the system.	3	Feature	Done	When the admin clicks on one of the listed laboratory specialists, the system will activate the “Delete” button. If the admin clicks that button, then the system will first display a confirmation message, if the admin confirms the deletion action then the system will delete

					the laboratory specialist, otherwise the laboratory specialist will not be deleted.
25	As a physician, I want to edit my profile so that I can update my information at any time.	3	Feature	Done	<p>When the physician clicks on the profile icon on the bottom bar, then clicks on the editing icon on his/ her profile page, and then he/ she can modify his data.</p> <p>When he finishes, he / she clicks on the “Save” button, and the system must update the information.</p>
26	As a physician, I want to view my patients' previous/ upcoming visits so that I can view my patients' file.	3	Feature	Done	<p>When the physician clicks on the homepage icon on the bottom bar, he/she can move between the previous and upcoming visits by clicking on the “Previous” or “Upcoming” button, and then chooses the visit he/she wants, and then he/she can view the patient's file.</p>
27	As a physician, I want to view the patient's file who has a visit so that I can read it and	3	Feature	Done	<p>When the physician selects a visit from the today or previous visits from his/her homepage, then the patient's file that belongs</p>

	view his medical information.				to this visit and all his/her information and medical files are shown to the physician.
28	As a physician, I want to edit the patient history so that I can update patient information.	5	Feature	Done	When the physician chooses visit from today visits, the patient's medical file appears, after that he/she clicks on the "medical history" button, and after the patient's medical history page appears, he/she clicks on the "Edit" button, then he/she modifies the information and then clicks on the "save" button, then a confirmation message should appear, then the system must update the information.
29	As a physician, I want to write the patient's diagnosis in her/his file so that other physicians can view it.	3	Feature	Done	When the physician chooses a visit from today's visits, the patient's medical file appears, after that he/she clicks on the "Write Diagnosis" button, after the patient's diagnosis writing page appears, he/she fills the information

					in the fields and then clicks on the “Save” button, then a confirmation message should appear, then the system must update the information.
30	As a patient, I want to view my profile so that I can access my information anytime.	3	Feature	Done	When the patient clicks on the profile icon on the bottom bar, then his/her information will appear on his/her profile page.
31	As a patient, I want to edit my profile so that I can update my information at any time.	3	Feature	Done	When the patient clicks on the profile icon on the bottom bar, then clicks on the editing icon on his/ her profile page, and then he/ she can modify his data. When he finishes, he / she clicks on the “Save” button, and the system must update the information.
32	As a patient, I want to view my previous/upcoming visits so that I can see the details of a visit.	3	Feature	Done	When the patient clicks the “visits” button on his/her homepage, then his/her visits will appear to him/her in the visits page, then he/she can navigate between his/her previous and upcoming visits by

					clicking on the “Previous” or “Upcoming” button.
33	As a patient, I want to view my medical history so that I can find out what diseases and allergies I have.	3	Feature	Done	When the patient clicks on the “Medical History” button on his/her home page, then his/her medical history will appear on the medical history page.
34	As a patient, I want to view my medical report so that I can see the details of each visit.	3	Feature	Done	When the patient clicks on the “Medical Record” button on his/her home page, all the medical records he/she has belongs to his/her visits will be appear on the medical records page, then if he/she clicks on any of them, all the details related to that visit will be appear to him/her.
35	As a physician, I want to request from the laboratory several tests for my patient so that she/he can take the tests.	3	Feature	Done	When physician clicks on "active" button in his/her home page, clicks on a specific visit, and then either clicks on “request a lab test” button or clicks on "lab results" button and then clicks on the add button in the "lab results" page, clicks on

					"choose lab tests" to select the tests that he/she wants, clicks on save button and then clicks on send button a popup message will appear to confirm the request. If the physician press on send button the request will be sent to laboratory specialist if there is at least one test selected otherwise an error message will appear, if the physician press on cancel button the request will not be sent.
36	As a laboratory specialist, I want to edit my profile so that I can update my information at any time.	3	Feature	Done	When the laboratory specialist clicks on the profile icon on the bottom bar, then clicks on the editing icon on his/ her profile page, and then he/ she can modify his data. When he finishes, he / she clicks on the “Save” button, and the system must update the information.
37	As a laboratory specialist, I want to view the active and previous requests so	3	Feature	Done	When a laboratory specialist log-in to his/her account the home page will display two buttons "active" and

	that I can view their details.				"previous", when the active button is clicked the active requests will be displayed and when the "previous" button is clicked the previous requests will be displayed.
38	As a laboratory specialist, I want to be able to receive physician's test requests so that I can make the test for the patient.	3	Feature	Done	When a physician requests a lab test the laboratory specialist can view the request in his/her home page when the active button is clicked. The laboratory specialist can view the request's details when he/she clicks on the request.
39	As a laboratory specialist, I want to be able to upload the test results to the patient's file so that physician can view them.	3	Feature	Done	When the active button in the home page is clicked and the laboratory specialist clicks on a lab test request, click on "add results" button fill the page with the lab results and then clicks on "upload" button a confirmation message will appear. If he/she press on upload button the results will be uploaded in the patient's file, if he/she press on cancel button the results will not be uploaded.
40	As a physician, I want to view my patient's	2	Feature	Done	When a physician clicks on "previous" button in his/her

	lab results so that I can diagnose her/him correctly.			home page, then clicks on a specific visit or clicks on "active" button in his/her home page, then clicks on today's visit, clicks on "lab results" button, clicks on "previous" button in the lab results page, and then clicks on "view" button on the test request that he\she wants to view its results the test results will appears.
41	As a physician, I want to write a medication for my patients, so that I can treat them	3	Feature	Done When physician clicks on "active" button in his/her home page, clicks on a specific visit, clicks on "medication list" button, clicks on the add button in the " medication list " page, enter the name, dosage, start date, end date and description of the medication, and then clicks on add button a confirmation message will appear. If the physician press on add button the medication will be added to the patient's file if all the fields except the description field are filled otherwise an error message will appear, if the physician

					press on cancel button the medication will not be added.
42	As a physician, I want to search my patient information using patient id, so that I can locate the patient's file quickly.	3	Feature	Done	When physician is logged in his/her account and clicks on the search button on the navigation bar, write the patient's id in the search bar and from the search results he/she clicks on the patient the patient's file will appear
43	As a laboratory specialist, I want to search for my patient, so that I can reach her request quickly.	3	Feature	Done	When a laboratory specialist is logged in to his/her account, write the patient's ID in the search bar, then the system will filter the requests. From the search results he/she clicks on the patient the then, the patient's request will appear
44	As a patient, I want to view my medication list so that I can know my medication history.	3	Feature	Done	When patient is logged in his/her account and clicks on "medication list" button in the home page, the medication list page will display two buttons "active" and "previous", when the active button is clicked, he/she can view the medication that he/she is taking now, and when the previous button is clicked, he/she can view the

					medication that he/she took in the past.
45	As a patient, I want to view my lab test so that I can see the results.	3	Feature	Done	When patient is logged in his/her account and clicks on "lab results" button in the home page, the lab results page will display two buttons "active" and "previous", when the active button is clicked, he/she can view the lab test that he/she did not do it yet or the results not entered yet, and when the previous button is clicked he/she can view the lab test that he/she did it in the past.
46	As a physician, I want to search for my patient's symptoms so that I can find possible diagnosis.	5	Feature	Done	When physician clicks on "diagnostic tool" button in the home page, the diagnostic tool page will display a list of symptoms, physician can select patient's symptoms and then clicks on "show a diagnosis" button.
47	As a physician, I want to view my patient's possible diagnosis using his\her current symptoms, so that it will help me know his\her illnesses.	3	Feature	Done	When physician clicks on "diagnostic tool" button in the home page, the diagnostic tool page will display a list of symptoms, physician can select patient's symptoms and then clicks on "show a

					diagnosis” button, when the button is clicked, he/she can view the predicted diagnosis and a pie chart that represents other patient’s symptoms that diagnosed by the predicted diagnosis.
48	As a physician, I want to be able to contact physicians who had patients with similar symptoms so that I can review the diagnosis with them.	5	Feature	Done	When physician clicks on "diagnostic tool" button in the home page, the diagnostic tool page will display a list of symptoms, physician can select patient’s symptoms and then clicks on “show a diagnosis” button, when the button is clicked, he/she can view the predicted diagnosis and physician’s contact information who diagnosed the predicted diagnosis.

Non-functional requirements

49	As a physician, I want the application to be available 99% of the time I try to access it so that I can help my patients with no delays.				
	As a user, I want to have a familiar UI icon so that I can				

50	understand the system easier and faster.				
51	As a physician, I want the patient's file interface to be easy and simple so that I can enter the patient's information easily.				
52	As a physician, I want to be provided with the up-to-date medical history medical history of patients so that I can diagnose them correctly.				
53	As a patient, I want my file to be viewable to only the physicians I visit so that I can ensure my privacy.				

Table 4. 1 Product Backlog

4.3 System Design

In this section, we will introduce the design of our system and how we build MedCore application. It will cover multiple aspects of the system, which are system architecture, class diagram, component level design, data design, and interface design.

4.3.1 Architectural Diagram

The MedCore application's system architecture is organized using the Model-View-Controller (MVC) architectural pattern. This pattern is widely used in iOS applications and is recommended by Apple. The MVC architecture consists of three main components: Model, View, and Controller.

1. Model: The Model component is responsible for managing the data repository, in this case, the MySQL database. It is not concerned with how the data is displayed in the user interface.
2. View: The View component represents the user interface elements of the application and the admin panel. Its primary purpose is to display the data from the Model and make it available for user interactions.
3. Controller: The Controller is the core layer of the MVC architecture. It handles updates to the View and Model components, and it is responsible for interpreting user actions and triggering changes in the data through the Model. When data changes, the Controller ensures that these changes are communicated to the user interface by updating the View.

In the MVC architecture, the Controller can communicate with both the Model and the View components, while the Model and View components cannot communicate with each other directly [21][22].

Figure 4.3 illustrates the MedCore system architecture and the communication between the components at a high level.

By adhering to the MVC architecture, the MedCore application can maintain a clean separation of concerns, enabling more straightforward development, testing, and maintenance of the application and its components.

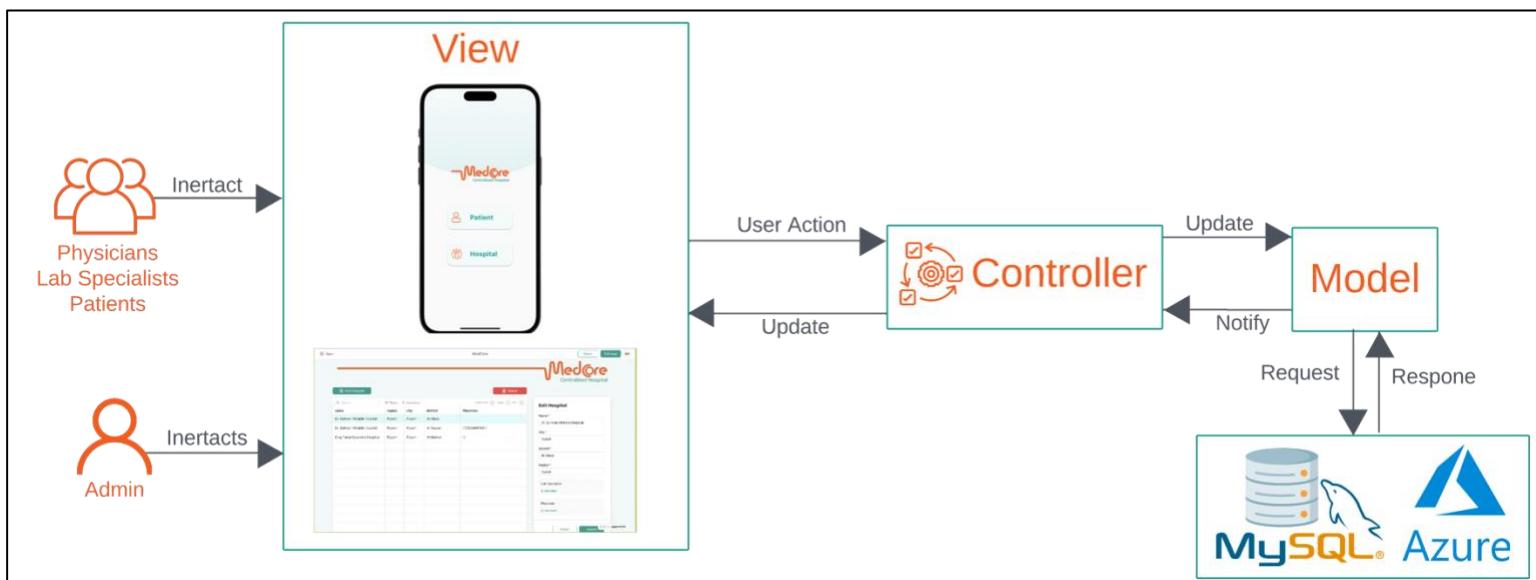


Figure 4.3 MedCore System Architecture

4.3.2 Class Diagram /DFD

In this section, we will present the class diagram, which shows MedCore's individual parts. These parts will provide the desired functionalities and are shown in figure 4.4.

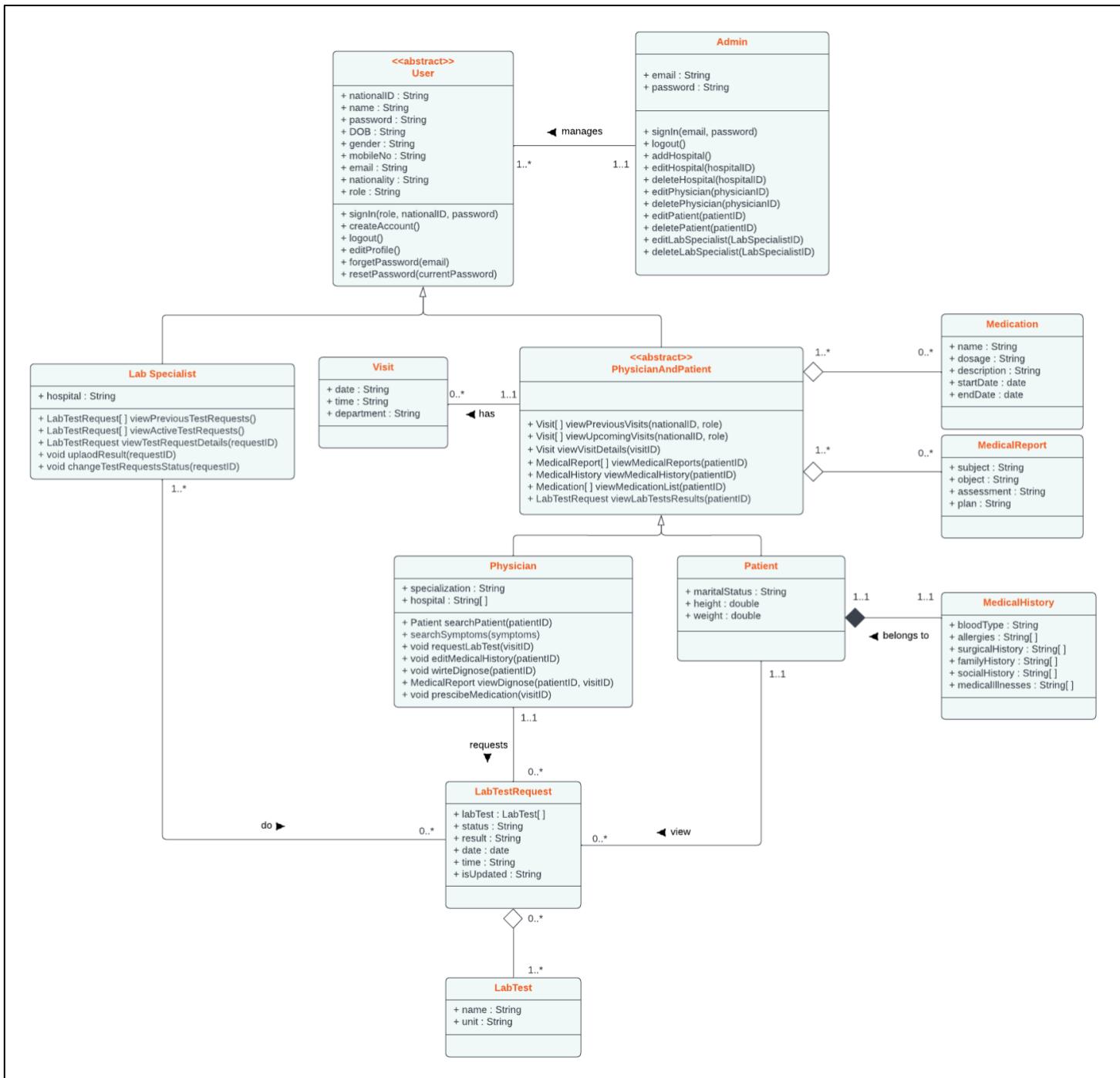


Figure 4.4 MedCore Class Diagram

4.3.3 Component Level Design

This section includes how we implement the main user stories we have done in detail using pseudocode and flowchart for the ML part. All release-1 user stories and referenced stories are included in Appendix D.

- **User story #16:** As an admin, I want to edit the physician so that I can update the physician information.

1. **BEGIN**
2. the admin selects a physician
3. **DISPLAY** physician information in the edit form
4. **READ** the new information
5. **IF** clicks submit **THEN**
6. **DISPLAY** confirmation message
7. **IF** confirm **THEN**
8. update information in the database
9. **END IF**
10. **ELSE IF** clicks reset **THEN**
11. reset the edit form fields to the old one
12. **END IF**
13. **END**

- **User story #29:** As a patient, I want to view my medical history so that I can find out what diseases and allergies I have.

1. **BEGIN**
2. the user selects patient
3. the user log-in (User story #10)
4. the patient select “Medical History” button
5. **END**

- **User story #31:** As a physician, I want to request from the laboratory several tests for my patient so that she/he can take the tests.

1. **BEGIN**
2. the user selects hospital
3. the user log-in (User story #6)
4. the physician selects an active visit
5. the physician selects lab results button
6. the physician selects “Add” icon
7. **READ** required lab test
8. the physician selects “Add” button
9. **DISPLAY** a confirmation message
10. **IF** confirm **THEN**
11. add the request to the database
12. **END IF**
13. **END**

- **User story #34:** As a laboratory specialist, I want to be able to upload the test results to the patient's file so that physician can view them.

1. **BEGIN**
2. the user selects hospital
3. the user log-in (User story #8)
4. the lab specialist selects an active request
5. select “Add Results” button
6. **READ** tests results
7. select “Upload” button
8. **DISPLAY** a conformation message
9. **IF** confirm **THEN**
10. add the results to the database
11. **END IF**
12. **END**

- **User story #41:** As a physician, I want to view my patient's possible diagnosis using his\her current symptoms, so that it will help me know his\her illnesses.

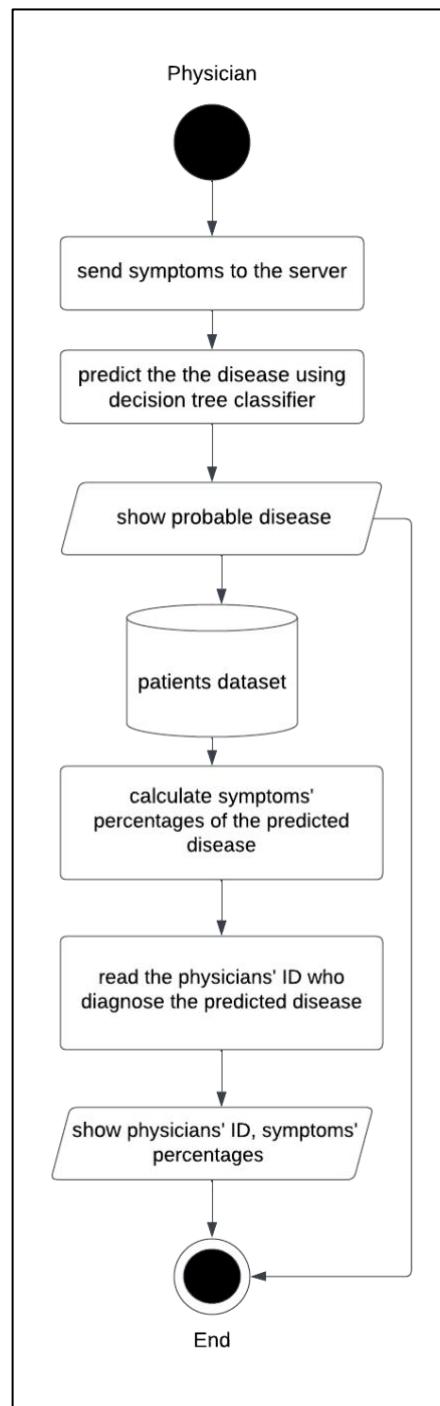


Figure 4. 5 ML flowchart

4.4 Data Design

In this section, we will describe the data model of MedCore application.

4.4.1 Data Models

MedCore application uses a SQL database which is MySQL. ER diagram shows the relationships between the tables and the attributes of each table, as shown in figure 4.6.

- ER Diagram

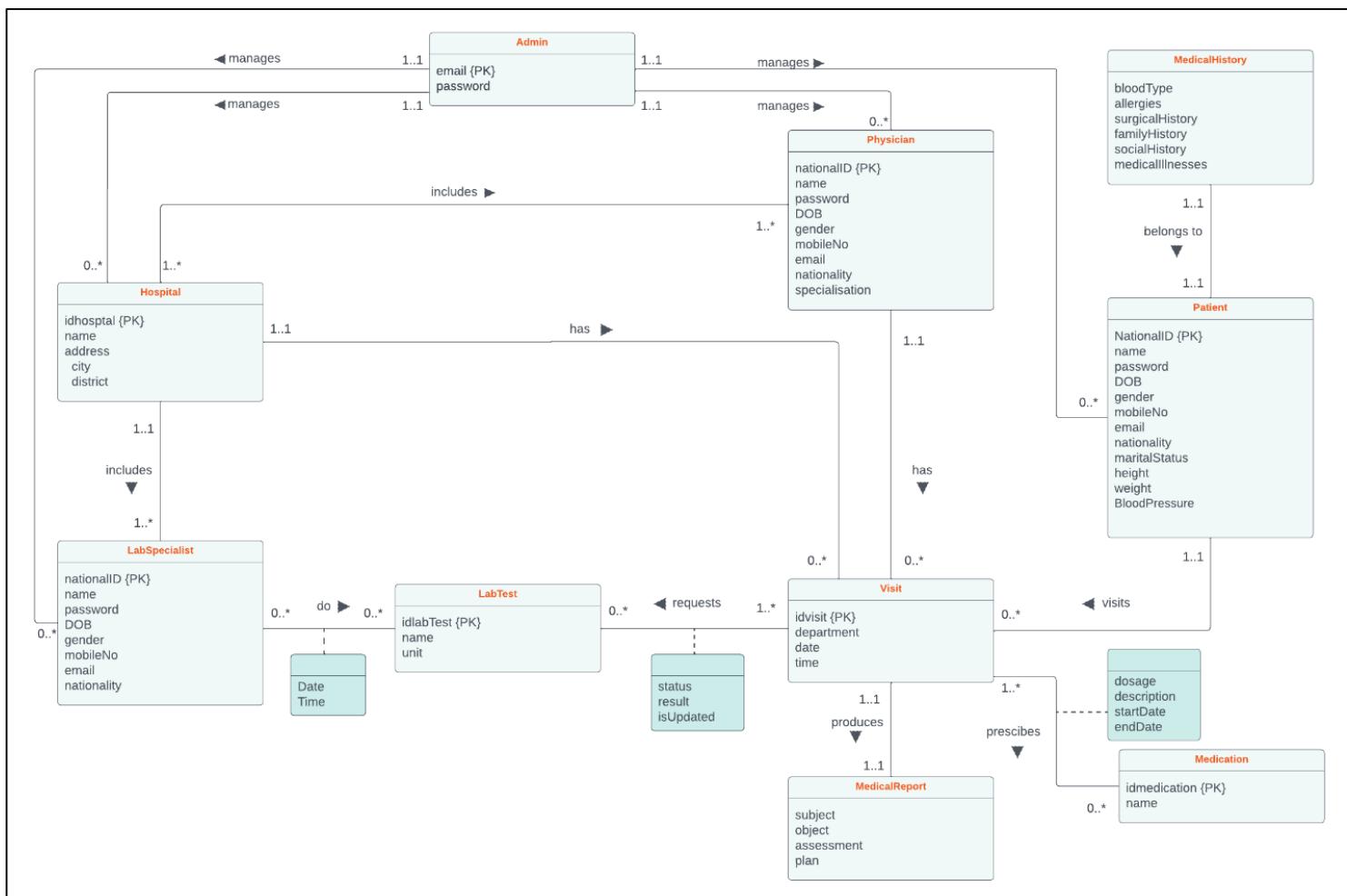


Figure 4.6 MedCore ER Diagram

- Relational Schema

The relational schema is a blueprint that represents the data to be entered into the database and describe how that data is structured in tables.

Hospital(idhospital, name, city, district)

Primary key idhospital

Physician(nationalID, name, password, DOB, gender, mobileNo, email, nationality, specialisation)

Primary key nationalID

LabSpcialist(nationalID, name, password, DOB, gender, mobileNo, email, nationality, idHospital)

Primary key nationalID

Foreign key idHospital references Hospital(idhospital)

Patient(NationalID, name, password, DOB, gender, mobileNo, email, nationality, maritalStatus, height, weight, bloodType, BloodPressure, allergies, surgicalHistory, familyHistory, socialHistory, medicalHistory, medicalIllnesses)

Primary key NationalID

Visit(idvisit, time, date, department, idHospital, idPhysician, idPatient, subject, object, assessment, plan)

Primary key idvisit

Foreign key idHospital references Hospital(idhospital)

Foreign key idPhysician references Physician (nationalID)

Foreign key idPatient references Patient (NationalID)

Medication(idmedication, name)

Primary key idmedication

LabTest(idlabTest, name, unit)

Primary key idlabTest

HospitalPhysician(idHospital, idPhysician)

Primary key idHospital, idPhysician

Foreign key idHospital references Hospital(idhospital)

Foreign key idPhysician references Physician (nationalID)

VisitMedication(visitID, medicationID, dosage, description, startDate, endDate)

Primary key visitID, medicationID

Foreign key visitID references Visit(idvisit)

Foreign key medicationID references Medication(idmedication)

LabSpcialistLabTest(idLabSpecialist, idLabTest, date, time)

Primary key idLabSpecialist, idLabTest, date, time

Foreign key idLabSpecialist references LabSpcialist(nationalID)

Foreign key idLabTest references LabTest(idlabTest)

VisitLabTest(visitID, labTestID, status, result, isUpdated)

Primary key visitID, labTestID

Foreign key labTestID references LabTest(idlabTest)

Foreign key visitID references Visit(idvisit)

- Data Dictionary

Table 4.2 below presents a data dictionary with descriptions for each entity in the ER diagram:

Entity	Description	Occurrence
Admin	A person who manages the MedCore system	Each admin can manage hospitals, physicians, lab specialists, and patients
Hospital	A hospital that is registered in the system	Each hospital has physicians, lab specialists, and visits
Physician	A physician who is registered in the system	The physician assigned to visits
LabSpecialist	A lab specialist who is registered in the system	Lab specialists receive lab tests requests
Patient	A patient who is registered in the system	The patient assigned to visit
Visit	A visit where the physician can see the patient	The physician can write a diagnosis, prescribe medication and request lab tests for a specific patient through the visit
MedicalReport	The medical report that belongs to a visit	Each visit has a one medical report
Medication	A medication that the physician can prescribe	The physician can prescribe this medication through the visits
MedicalHistory	The medical history of the patient	Each patient has one medical history
LabTest	A lab test that the physician can request	The physician can request this lab test through the visits

Table 4. 2 Data Dictionary - Descriptions for Each Entity

Table 4.3 below shows a data dictionary that describes each relationship in the ER diagram:

Entity Name	Multiplicity	Relationship	Entity Name	Multiplicity
Admin	1..1	manages	Hospital	0..*
Admin	1..1	manages	LabSpecialist	0..*
Admin	1..1	manages	Physician	0..*
Admin	1..1	manages	Patient	0..*
Hospital	1..*	includes	Physician	1..*
Hospital	1..1	includes	LabSpecialist	1..*
Hospital	1..1	has	Visit	0..*
Physician	1..1	has	Visit	0..*
Patient	1..1	visits	Visit	0..*
MedicalHistory	1..1	belongs to	Patient	1..1
Visit	1..1	produces	MedicalReport	1..1
Visit	1..*	prescribes	Medication	0..*
Visit	1..*	requests	LabTest	0..*
LabSpecialist	0..*	do	LabTest	0..*

Table 4. 3 Data Dictionary - Describes Each Relationship

Table 4.4 below presents a data dictionary with descriptions for each attribute in the ER diagram:

Entity Name	Attributes	Description	Data Type	Length	Nulls	Multi Value	Default Value	Ragne	PK
Hospital	idhospital	Uniquely identifies a hospital.	int	6	no	no			Y
	name	Hospital's name	varchar	45	no	no			
	city	Hospital's city	varchar	45	no	no			
	district	Hospital's district	varchar	45	no	no			
Physician	nationalID	Physician's national/resident ID	int	10	no	no			Y
	name	Physician's name	varchar	70	no	no			
	password	Physician's password	varchar	200	no	no			
	DOB	Physician's date of birth	date		no	no			
	gender	Physician's gender	varchar	6	no	no		Female, male	
	mobileNo	Physician's mobile number	varchar	12	no	no			

	email	Physician's email	varchar	100	no	no		
	nationality	Physician's nationality	varchar	45	no	no		
	specialisation	Physician's specialization	varchar	45	no	no		
LabSpecialist	nationalID	Lab Specialist's national/resident ID	int	10	no	no		Y
	name	Lab Specialist's name	varchar	70	no	no		
	password	Lab Specialist's password	varchar	200	no	no		
	DOB	Lab Specialist's date of birth	date		no	no		
	gender	Lab Specialist's gender	varchar	6	no	no		Female, male
	mobileNo	Lab Specialist's mobile number	varchar	12	no	no		

	email	Lab Specialist's email	varchar	100	no	no		
	nationality	Lab Specialist's nationality	varchar	45	no	no		
Patient	NationalID	Patient's national/resident ID	int	10	no	no		Y
	name	Patient's name	varchar	70	no	no		
	password	Patient's password	varchar	200	no	no		
	DOB	Patient's date of birth	date		no	no		
	gender	Patient's gender	varchar	6	no	no		Female, male
	mobileNo	Patient's mobile number	varchar	12	no	no		
	email	Patient's email	varchar	100	no	no		
	nationality	Patient's nationality	varchar	45	no	no		
	maritalStatus	Patient's marital status	varchar	15	no	no		Single, married ,

								divorce d, separate d, widow(er)
height	Patient's height	float		yes	no			
weight	Patient's weight	float		yes	no			
bloodType	Patient's blood type	varchar	4	yes	no			A+, A-, B+, B-, O+, O-, AB+, AB-
allergies	Patient's allergies	varchar		yes	no			
BloodPress ure	Patient's blood pressure	float						
surgicalHist ory	Patient's surgical history	longtext		yes	no			
familyHisto ry	Patient's family history	longtext		yes	no			
socialHistor y	Patient's social history	longtext		yes	no			

	medicalHistory	Patient's medical history	longtext		yes	no			
	medicalIllnesses	Patient's medical illnesses	longtext		yes	no			
Visit	idvisit	Uniquely identifies a visit	int	10	no	no			Y
	time	The time of the visit	varchar	45	no	no			
	date	The date of visits	date		no	no			
	department	The department of the visit	varchar	45	no	no			
	subject	Includes what the patients say about their health problems	longtext		no	no			
	object	Includes records of the observation s the	longtext		no	no			

		physician makes after physically examining the patients.						
	assessment	Includes a brief summary of the diagnosis of patients' existing conditions	longtext		no	no		
	plan	Includes the treatment plan and healthcare and lifestyle recommendations for the patients	longtext		no	no		
Medication	idmedication	Uniquely identifies a medication.	int	10	no	no		Y
	name	The name of the medication	varchar	100	no	no		

LabTest	idlabTest	Uniquely identifies a lab test.	int	10	no	no			Y
	name	The name of the lab test	varchar	100	no	no			
	unit	The unit of the lab test	varchar	45	no	no			
VisitMedication	dosage	The dosage of the medication	varchar	45	no	no			
	description	Notes for the prescribed medication	varchar	200	no	no			
	startDate	The start date of the medication	date		no	no			
	endDate	The end date of the medication	date		no	no			
VisitLabTest	status	The status of the lab test	varchar	7	no	no		Done, active	
	result	The result of the lab test	varchar	45	yes	no			

	isUpdated	Indicates whether the request is updated or not	varchar	4	no	no	no	no, yes	
LabSpcialistLa bTest	date	Date of uploading results	date		no	no	no		
	time	Time of uploading results	varchar	11	no	no	no		

Table 4. 4 Data Dictionary - Descriptions for Each Attribute

4.4.2 Data Collection and Preparation

To test the application functionalities, we filled the database with physicians, patients, and lab specialists manually. Also, to implement the diagnostic tool, we needed to gather cases that includes patients' symptoms and the relevant diagnosis. We collected the data from the Kaggle website. We explored the data to decide what prior steps are needed before building a classification model. You can find the data source on the reference [23].

4.5 Interface Design

In designing MedCore app interfaces, we considered a number of UX guidelines to improve user experience [24]. In this section, we will introduce some of them with examples, and at the end of the section, we will provide site maps, figure 4.19 and figure 4.20, which show the navigation for MedCore app and for the admin panel respectively.

- System Match to the Real World

We used icons and images that are familiar to the users and match the real world to improve learnability and facilitate user interaction. Figure 4.7 and Figure 4.8 are examples.

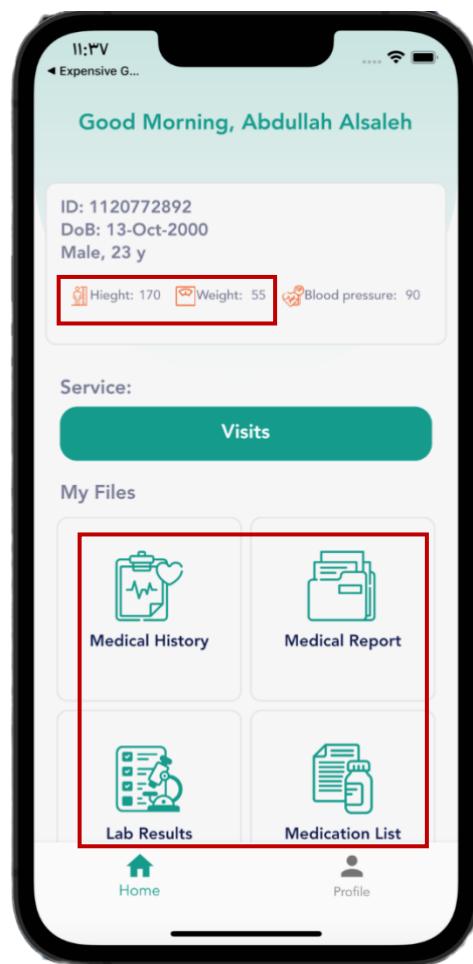
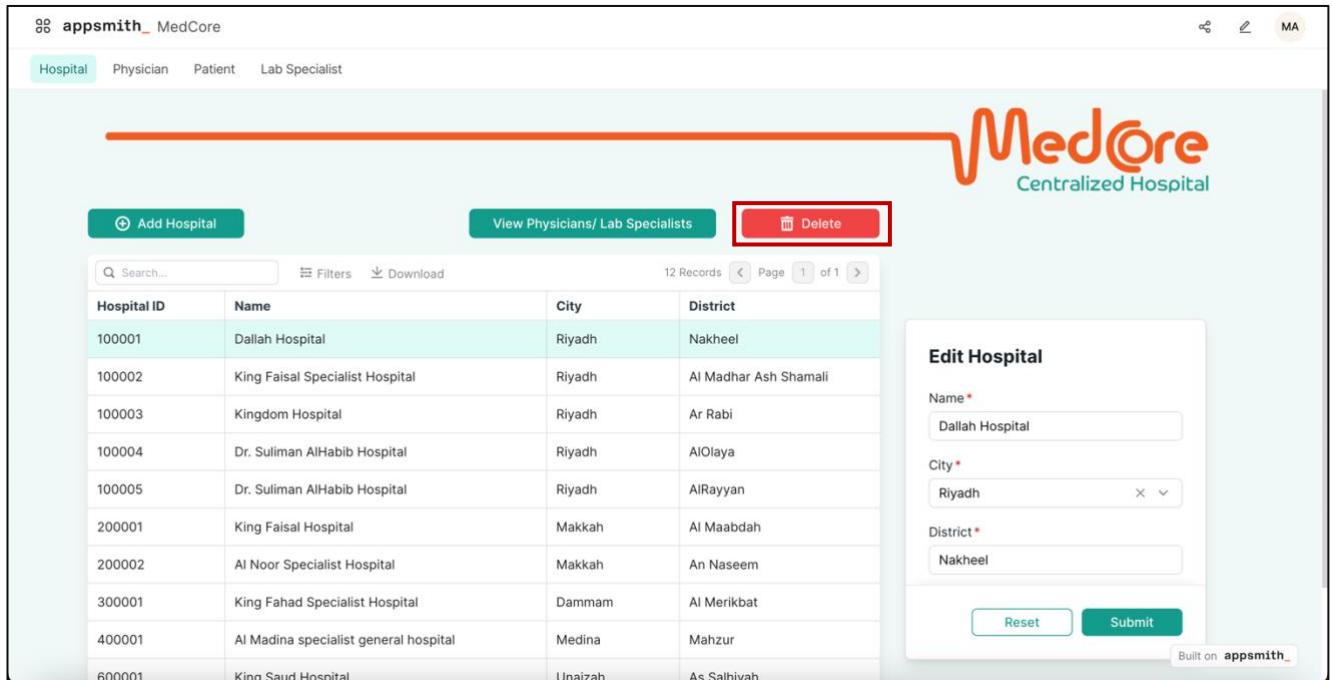


Figure 4.7 MedCore App-Patient home Page



Hospital ID	Name	City	District
100001	Dallah Hospital	Riyadh	Nakheel
100002	King Faisal Specialist Hospital	Riyadh	Al Madhar Ash Shamali
100003	Kingdom Hospital	Riyadh	Ar Rabi
100004	Dr. Suliman AlHabib Hospital	Riyadh	AlOlaya
100005	Dr. Suliman AlHabib Hospital	Riyadh	AlRayyan
200001	King Faisal Hospital	Makkah	Al Maabdah
200002	Al Noor Specialist Hospital	Makkah	An Naseem
300001	King Fahad Specialist Hospital	Dammam	Al Merikbat
400001	Al Madina specialist general hospital	Medina	Mahzur
600001	King Saud Hospital	Unaizah	As Salhiyah

Figure 4.8 MedCore Admin Panel - Hospital

- User Control and Freedom

The user can easily navigate through the pages using the bottom & top bar, as shown in figure 4.9 (A) and figure 4.10. The user also can reach the home page from anywhere in the application using the home button, as shown in figure 4.9 (B). Also, on the registration page, the user can navigate forward and backward, as shown in figure 4.9(C).

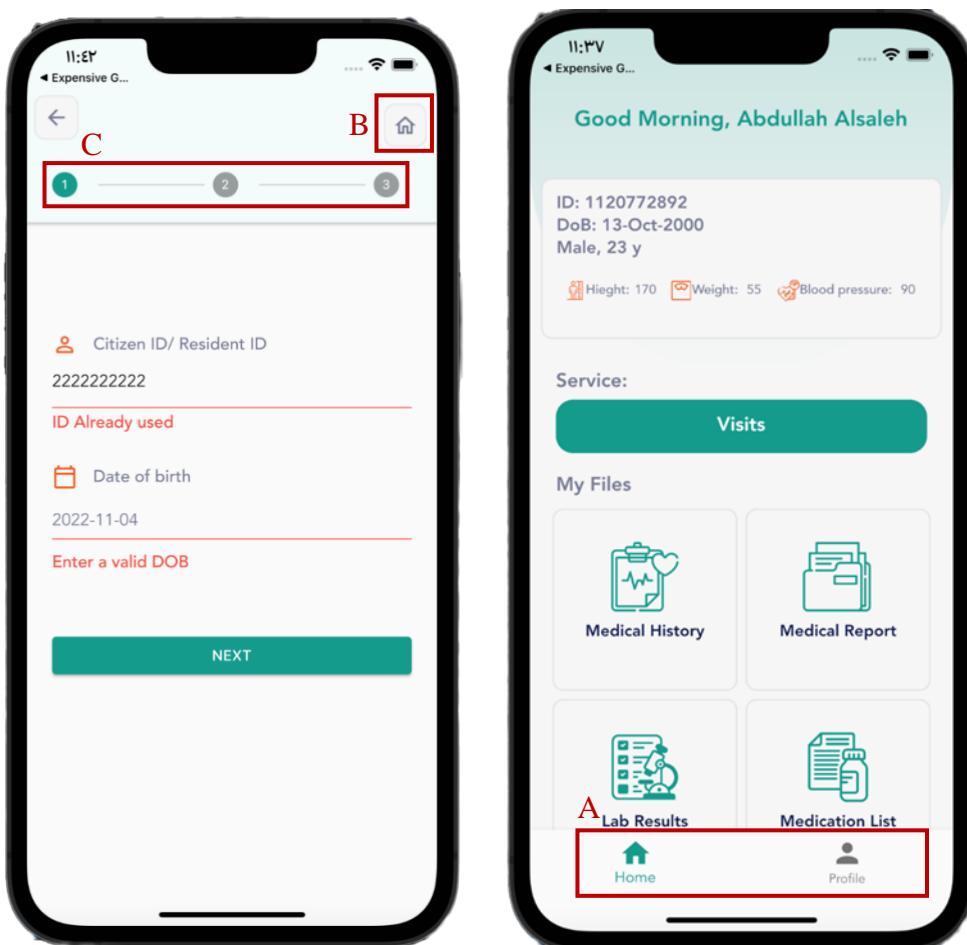


Figure 4.9 MedCore App-SignUp & Patient home page

Hospital ID	Name	City	District
100001	Dallah Hospital	Riyadh	Nakheel
100002	King Faisal Specialist Hospital	Riyadh	Al Madhar Ash Shamali
100003	Kingdom Hospital	Riyadh	Ar Rabi
100004	Dr. Suliman AlHabib Hospital	Riyadh	AlOlaya
100005	Dr. Suliman AlHabib Hospital	Riyadh	AlRayyan
200001	King Faisal Hospital	Makkah	Al Maabdah
200002	Al Noor Specialist Hospital	Makkah	An Naseem
300001	King Fahad Specialist Hospital	Dammam	Al Merikbat
400001	Al Madina specialist general hospital	Medina	Mahzur
600001	King Saud Hospital	Unaizah	As Salhiyah

Figure 4. 10 MedCore Admin Panel - Hospital

- Consistency and Standards

The terms in MedCore are simple and consistent with the most frequently used applications, which makes it easy to learn. Figure 4.11 and figure 4.12 are examples.

Hospital ID	Name	City	District
100001	Dallah Hospital	Riyadh	Nakheel
100002	King Faisal Specialist Hospital	Riyadh	Al Madhar Ash Shamali
100003	Kingdom Hospital	Riyadh	Ar Rabi
100004	Dr. Suliman AlHabib Hospital	Riyadh	AlOlaya
100005	Dr. Suliman AlHabib Hospital	Riyadh	AlRayyan
200001	King Faisal Hospital	Makkah	Al Maabdah
200002	Al Noor Specialist Hospital	Makkah	An Naseem
300001	King Fahad Specialist Hospital	Dammam	Al Merikbat
400001	Al Madina specialist general hospital	Medina	Mahzur
600001	King Saud Hospital	Unaizah	As Salhiyah

Figure 4. 11 MedCore Admin Panel - Hospital

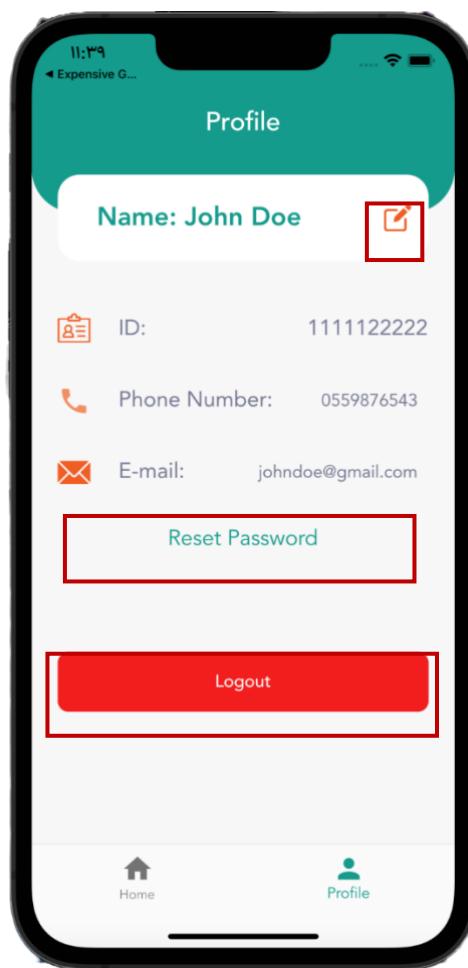


Figure 4. 12 MedCore App-Patient profile page

- **Help Users Recognize, Diagnose and Recover from Errors**

When the user enters an invalid input, the application will provide a meaningful error message which will make the user recover from that error faster. Figure 4.13 and figure 4.14 are examples.

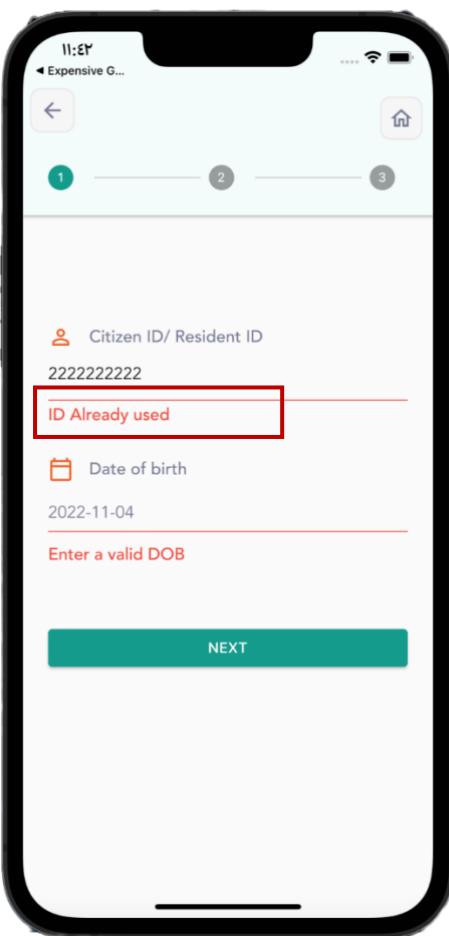


Figure 4. 13 MedCore App-SignUp

The screenshot shows the MedCore Admin Panel interface. At the top, there's a navigation bar with tabs for Hospital, Physician, Patient, and Lab Specialist. Below this is a table listing various hospitals with columns for Hospital ID and Name. A modal window titled 'Add Hospital' is open in the center. It contains fields for Hospital ID (with '11' entered), Name (with an error message 'Invalid hospital ID'), City (a dropdown menu with 'Select' option), and District (an empty input field). At the bottom of the modal are 'Reset' and 'Submit' buttons. The background table has some rows highlighted in blue.

Figure 4. 14 MedCore Admin Panel - Add Hospital Form

- Recognition rather than recall

In MedCore application, we do not rely on the user's memory instead, we provide a button with a relevant icon and descriptive text to make it easier for them to recognize their functionality. Figure 4.15 and figure 4.16 are examples.

The screenshot shows a table of hospital records with columns: Hospital ID, Name, City, and District. A red box highlights the 'Add Hospital' button at the top left. Another red box highlights the 'Delete' button at the top right. To the right, a modal window titled 'Edit Hospital' is open, showing fields for Name (Dallah Hospital), City (Riyadh), and District (Nakheel). Buttons for 'Reset' and 'Submit' are at the bottom of the modal.

Hospital ID	Name	City	District
100001	Dallah Hospital	Riyadh	Nakheel
100002	King Faisal Specialist Hospital	Riyadh	Al Madhar Ash Shamali
100003	Kingdom Hospital	Riyadh	Ar Rabi
100004	Dr. Suliman AlHabib Hospital	Riyadh	AlOlaya
100005	Dr. Suliman AlHabib Hospital	Riyadh	AlRayyan
200001	King Faisal Hospital	Makkah	Al Maabdhah
200002	Al Noor Specialist Hospital	Makkah	An Naseem
300001	King Fahad Specialist Hospital	Dammam	Al Merikbat
400001	Al Madina specialist general hospital	Medina	Mahzur
600001	King Saudi Hospital	Unaizah	As Salhiyah

Figure 4. 16 MedCore Admin - Hospital

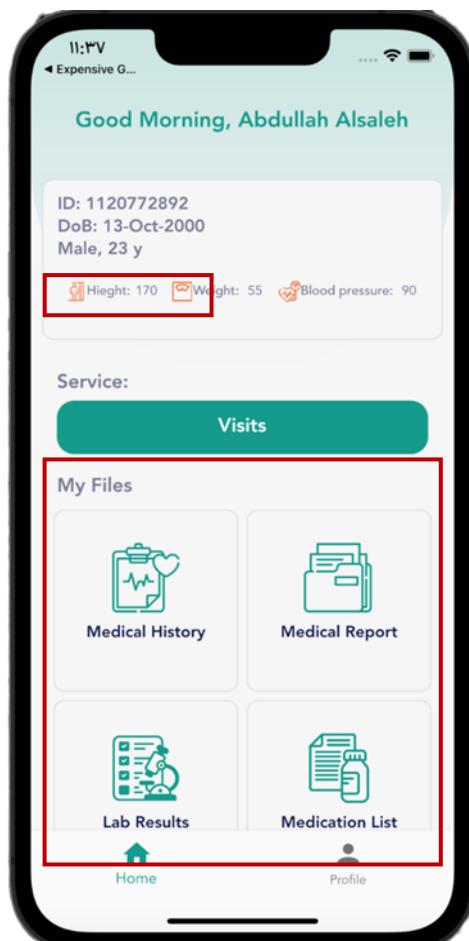


Figure 4. 15 MedCore App-Patient home page

- Error Prevention

To minimize the errors that may occur from the user side, we provide a confirmation message as shown in the figure below. Figure 4.17 and figure 4.18 are examples.

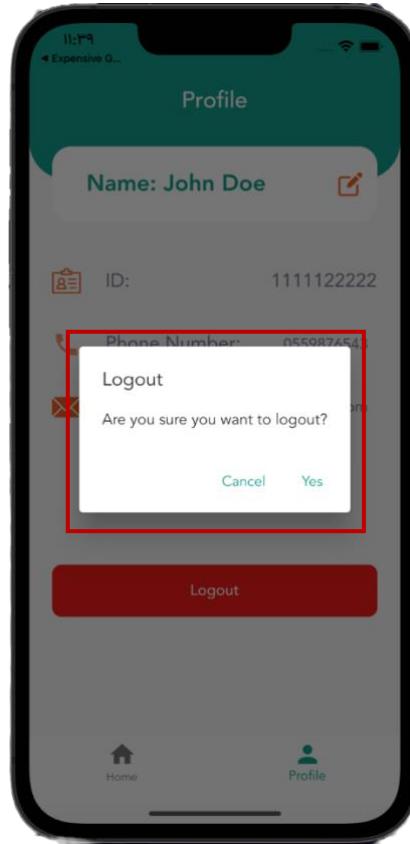


Figure 4. 18 MedCore App-Patient Log out

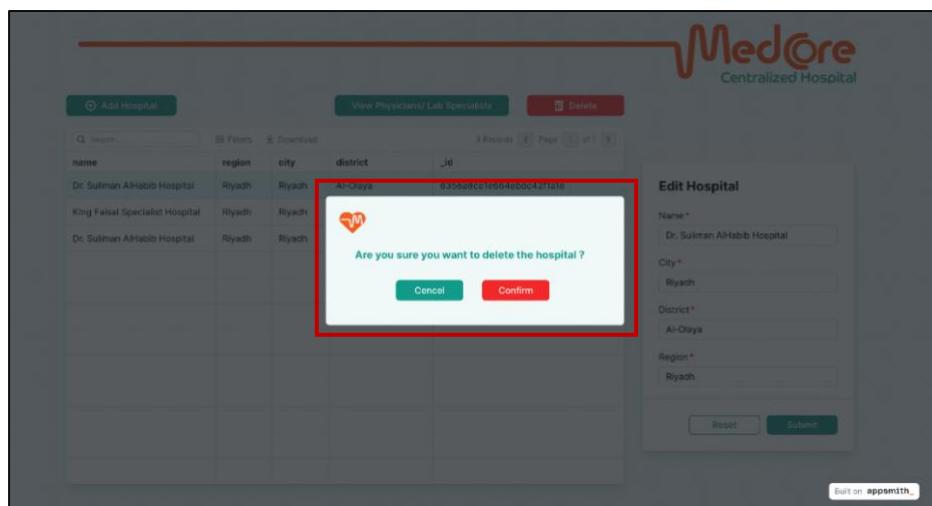


Figure 4. 19 MedCore Admin Panel - Delete Hospital

- User Sitemap:

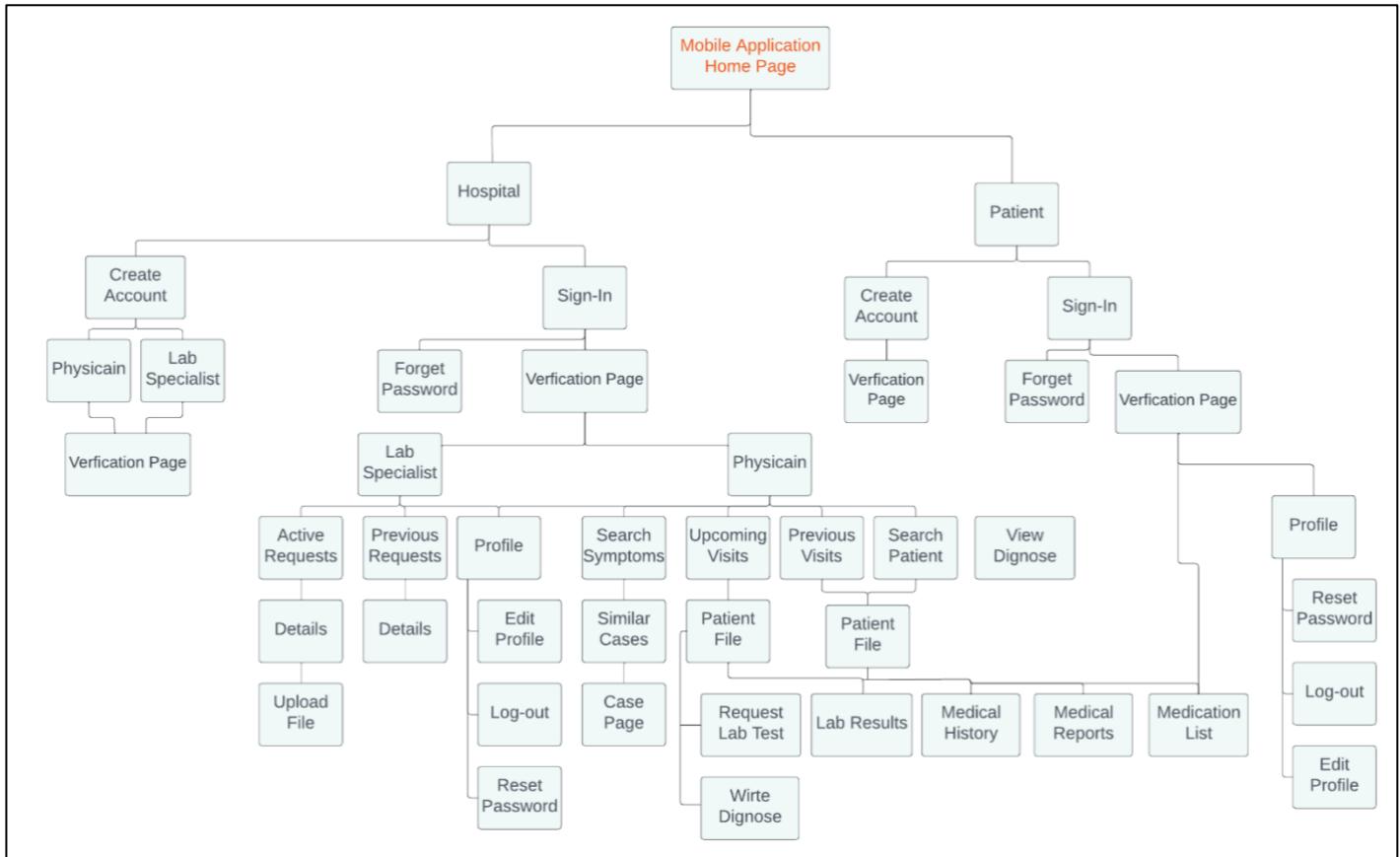


Figure 4. 20 MedCore app sitemap

- Admin Sitemap:

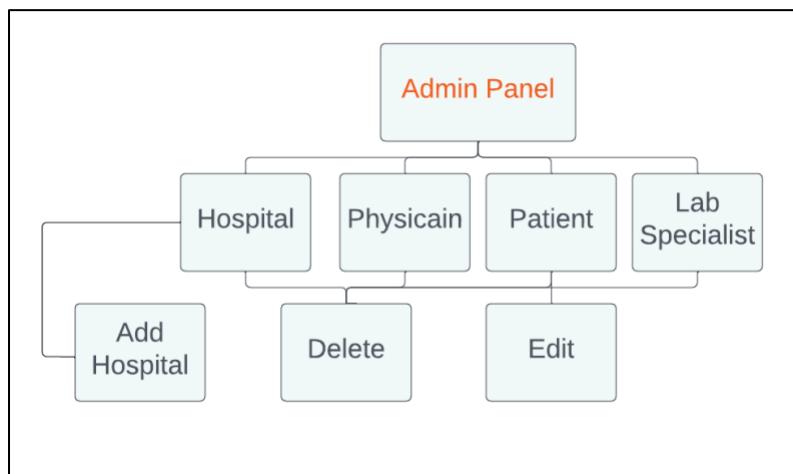


Figure 4. 21 MedCore Admin Sitemap

4.6 Implementation

In this section, we will describe the process and key implementation steps and procedures of MedCore application. Also, we will explain the major and challenging parts in the implementation. This chapter consists of two sections: system components and software implementation including challenging parts.

4.6.1 System Components

The system consists of three main components:

1. Mobile Application Program:

This application will be used by physicians, lab specialists and patients. For developing this application, we used Visual Studio Code IDE and Anaconda software. The application is developed using Python, Flutter & Dart programming languages. To test the application, we used XCode to run it in the emulator.

2. Database Program:

This program is used to store data, and we used MySQL, open-source relational database management system [25].

3. Web-Based Application Program:

This program is a web-based admin panel used to manage the MedCore app. To create this application, we used Appsmith, which is a low-code, open-source developer tool based on the JavaScript programming language used to build internal applications quickly and securely interact with the databases [26].

4.6.2 Software Implementation

We started designing the interfaces and developing the front-end. And then, we create the database and connect it with MedCore application and the admin panel, collect data for the diagnostic tool to start developing back-end functionalities as required. To manage the entire process and avoid conflicts, we used Jira and GitHub.

- Database Selection and Connection:

For the database selection, we first chose MongoDB (NoSQL) database to increase system performance. However, preserving the consistency in such a system is more important. Switching from NoSQL to SQL database was essential.

The first step of switching the database is to find a SQL database that is suitable and compatible with both the Flutter mobile application and the admin web-based application. After researching this issue, the best choice we found is the MySQL database.

The second step is creating the database and finding a host server. We chose the basic plan of the CouldClusters server after the connection the performance of the write operation was good, however, the performance of the read operation was too slow and takes about 3-5 minutes, and most of the time this delay causes a timeout exception. As a result, we upgraded to the premium plan of the CouldClusters server to solve this issue, but this solution did not work. To overcome the issue, we tried another host, which is the Heroku US server, this enhanced the performance, but more improvement was still needed. We consult a member of the MySQL team during Leap Conference, and he said that there are two factors that affect the performance, the first factor is the traffic, and the other one is the location of the server. Based on that we switched to the Heroku UK server which is closer to Saudi Arabia. The performance significantly improved, and the operation does not take more than a minute.

In the development of the MedCore application, selecting an appropriate database and establishing a connection were crucial steps. The process involved the following steps:

1. **Database Selection:** Initially, MongoDB (NoSQL) was chosen to enhance system performance. However, preserving data consistency was deemed more important, leading to the decision to switch to an SQL database. After researching suitable options, MySQL was chosen as the best fit for compatibility with both the Flutter mobile application and the admin web-based application.
2. **Creating the Database and Finding a Host Server:** The basic plan of the CloudClusters server was initially selected, but the read operation performance was slow, causing timeout exceptions. Upgrading to the premium plan did not resolve the issue. The Heroku US server was then tried, which improved performance but still required further enhancement.

3. Server Location and Performance: After consulting a member of the MySQL team during the Leap Conference, it was determined that two factors affected the performance: traffic and server location. Based on this information, the Heroku UK server, which is closer to Saudi Arabia, was chosen. This significantly improved performance, with operations taking no more than a minute. However, it still isn't sufficient to address the socket exception, which occurs as a result of the database's performance and causes the application to lag.

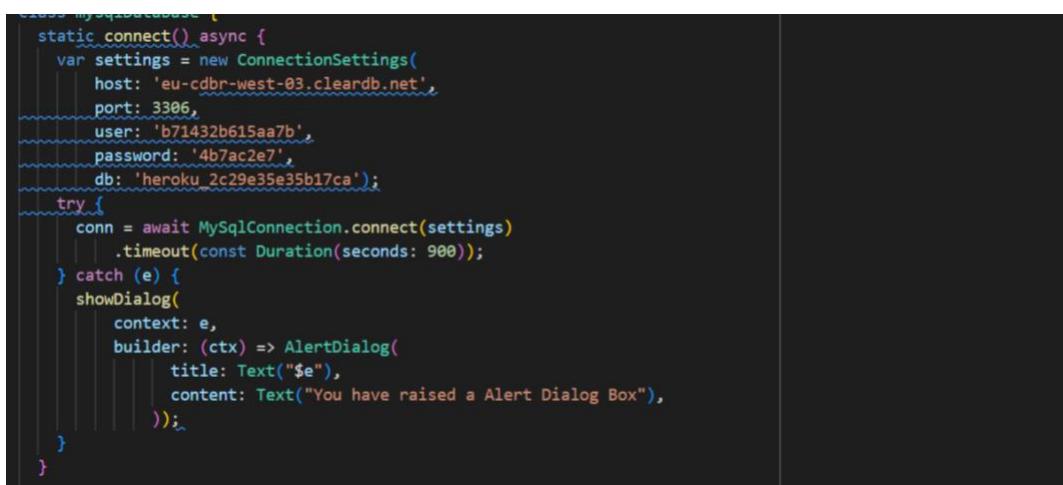
4. Connecting MySQL with Flutter and Appsmith: The final step involved establishing a connection between the MySQL database and the Flutter and Appsmith platforms, which are used for the development of the mobile application and admin web-based application, respectively.

By carefully selecting the appropriate database and optimizing the server location and hosting plan, the MedCore application now boasts improved performance and data consistency. This ensures a smooth user experience and efficient data management, contributing to the overall effectiveness of the application in addressing the challenges of the healthcare system in Saudi Arabia.

The third step is to connect MySQL with Flutter and Appsmith

A. Connect MedCore App with MySQL

Figure 4.21 illustrate the connection between flutter application with MySQL.



```

class MySQLDatabase {
    static Future connect() async {
        var settings = new ConnectionSettings(
            host: 'eu-cdrb-west-03.cleardb.net',
            port: 3306,
            user: 'b71432b615aa7b',
            password: '4b7ac2e7',
            db: 'heroku_2c29e35e35b17ca');
        try {
            conn = await MySqlConnection.connect(settings)
                .timeout(const Duration(seconds: 900));
        } catch (e) {
            showDialog(
                context: e,
                builder: (ctx) => AlertDialog(
                    title: Text("$e"),
                    content: Text("You have raised a Alert Dialog Box"),
                )));
        }
    }
}

```

Figure 4.22 MedCore application and MySQL connection

B. Connect Admin panel (Appsmith) with MySQL

Figure 4.22 indicate the connection between appsmith application with MySQL.



Figure 4. 23 Admin Panel and MySQL connection

- Data Exploration

In the process of developing the MedCore application's machine learning model, data exploration played a crucial role. The dataset collected for this purpose consisted of 4,962 diagnosed cases, with the following characteristics as it is shown in table 4.5:

- Symptoms: The dataset includes 132 distinct symptoms, used to diagnose the diseases in the cases.
- Diseases: There are 41 unique diseases represented in the collected dataset.
- Categorical Data: All features in the dataset are categorical, with values of either zero or one. A value of one indicates that the patient has the symptom, while a value of zero signifies that the patient does not have the symptom.

Overview	
Number of cases (Rows)	4962
Number of symptoms (Features)	132
Number of distinct diseases	41

Table 4. 5 Data Exploration – Overview

The heatmap in figure 4.23 describes the linear relationship between features. For instance, the dataset the blister & red_sore_around_nose have a 0.94 positive correlation coefficient according to Pearson's correlation.

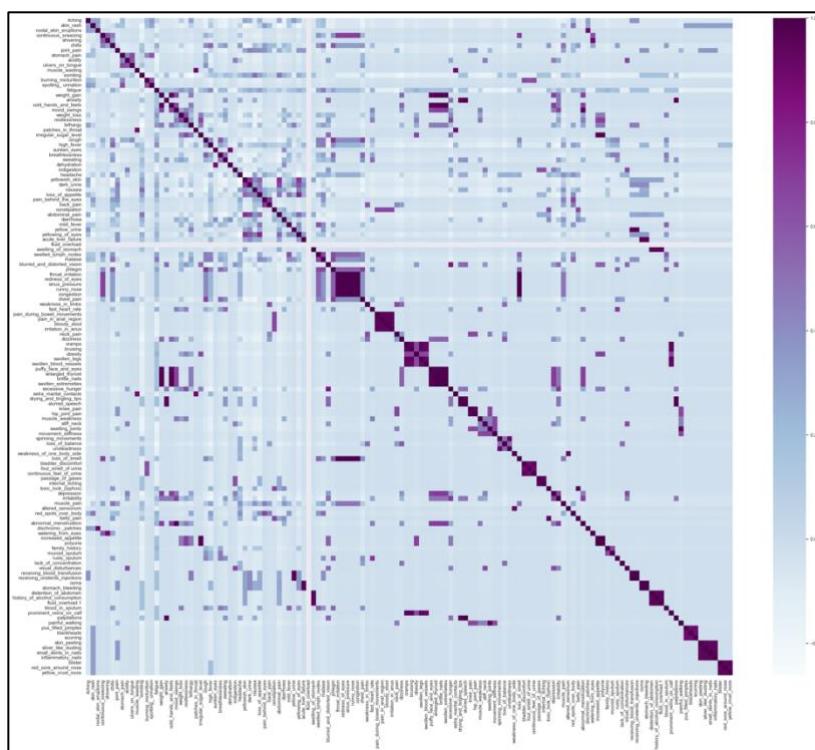


Figure 4. 24 Heatmap for Features Correlation

The classes in the dataset are balanced as it is presented in figure 4.24. With the exception of the fungal infection, which has a frequency of 122, all diseases have a frequency of 121 which is 2% of the total data.

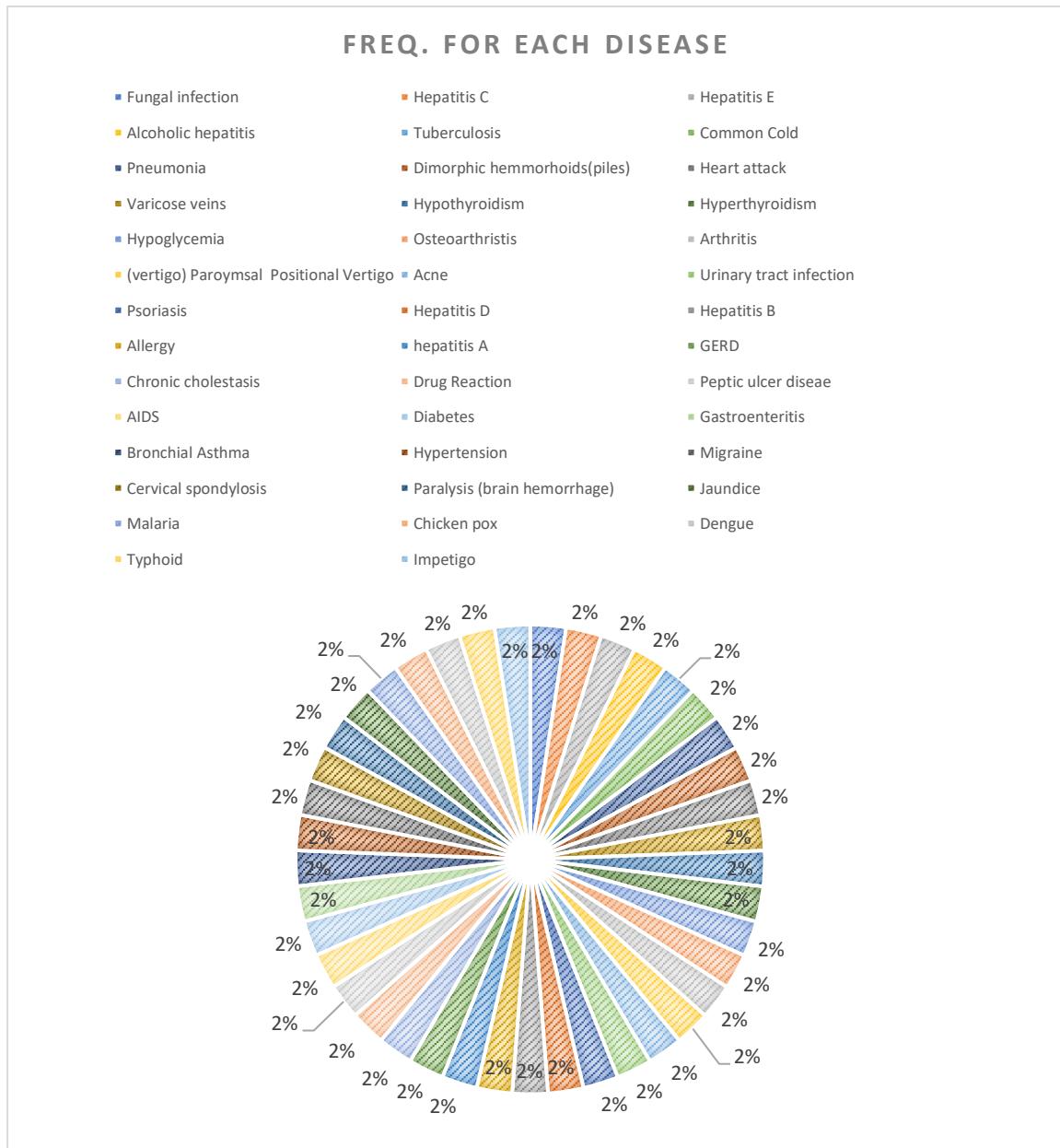


Figure 4. 25 Frequency for Each Disease

The data quality report is presented in table 4.6. The mod of each feature is zero and none of them have any missing values.

Feature Name	Count	Miss %	Card.	Mode	Mode Freq	Mode %
itching	4962	0	2	0	4277	86.2
skin_rash	4962	0	2	0	4168	84
nodal_skin_eruptions	4962	0	2	0	4853	97.8
continuous_sneezing	4962	0	2	0	4738	95.49
shivering	4962	0	2	0	4853	97.8
chills	4962	0	2	0	4157	83.78
joint_pain	4962	0	2	0	4272	86.09
stomach_pain	4962	0	2	0	4738	95.49
acidity	4962	0	2	0	4738	95.49
ulcers_on_tongue	4962	0	2	0	4853	97.8
muscle_wasting	4962	0	2	0	4853	97.8
vomiting	4962	0	2	0	3031	61.08
burning_micturition	4962	0	2	0	4744	95.61
spotting_urination	4962	0	2	0	4853	97.8
fatigue	4962	0	2	0	3013	60.72
weight_gain	4962	0	2	0	4847	97.68
anxiety	4962	0	2	0	4847	97.68
cold_hands_and_feets	4962	0	2	0	4847	97.68
mood_swings	4962	0	2	0	4732	95.36
weight_loss	4962	0	2	0	4502	90.73
restlessness	4962	0	2	0	4732	95.36
lethargy	4962	0	2	0	4502	90.73
patches_in_throat	4962	0	2	0	4853	97.8
irregular_sugar_level	4962	0	2	0	4847	97.68
cough	4962	0	2	0	4393	88.53
high_fever	4962	0	2	0	3588	72.31
sunken_eyes	4962	0	2	0	4853	97.8
breathlessness	4962	0	2	0	4508	90.85
sweating	4962	0	2	0	4278	86.22
dehydration	4962	0	2	0	4853	97.8
indigestion	4962	0	2	0	4738	95.49
headache	4962	0	2	0	3818	76.94
yellowish_skin	4962	0	2	0	4042	81.46
dark_urine	4962	0	2	0	4387	88.41
nausea	4962	0	2	0	3806	76.7
loss_of_appetite	4962	0	2	0	3800	76.58

pain_behind_the_eyes	4962	0	2	0	4841	97.56
back_pain	4962	0	2	0	4732	95.36
constipation	4962	0	2	0	4732	95.36
abdominal_pain	4962	0	2	0	3921	79.02
diarrhoea	4962	0	2	0	4393	88.53
mild_fever	4962	0	2	0	4605	92.81
yellow_urine	4962	0	2	0	4847	97.68
yellowing_of_eyes	4962	0	2	0	4139	83.41
acute_liver_failure	4962	0	2	0	4847	97.68
fluid_overload	4962	0	1	0	4962	100
swelling_of_stomach	4962	0	2	0	4847	97.68
swelled_lymph_nodes	4962	0	2	0	4611	92.93
malaise	4962	0	2	0	4254	85.73
blurred_and_distorted_vision	4962	0	2	0	4617	93.05
phlegm	4962	0	2	0	4605	92.81
throat_irritation	4962	0	2	0	4841	97.56
redness_of_eyes	4962	0	2	0	4841	97.56
sinus_pressure	4962	0	2	0	4841	97.56
runny_nose	4962	0	2	0	4841	97.56
congestion	4962	0	2	0	4841	97.56
chest_pain	4962	0	2	0	4260	85.85
weakness_in_limbs	4962	0	2	0	4853	97.8
fast_heart_rate	4962	0	2	0	4726	95.24
pain_during_bowel_movements	4962	0	2	0	4847	97.68
pain_in_anal_region	4962	0	2	0	4847	97.68
bloody_stool	4962	0	2	0	4847	97.68
irritation_in_anus	4962	0	2	0	4847	97.68
neck_pain	4962	0	2	0	4732	95.36
dizziness	4962	0	2	0	4623	93.17
cramps	4962	0	2	0	4847	97.68
bruising	4962	0	2	0	4847	97.68
obesity	4962	0	2	0	4732	95.36
swollen_legs	4962	0	2	0	4847	97.68
swollen_blood_vessels	4962	0	2	0	4853	97.8
puffy_face_and_eyes	4962	0	2	0	4847	97.68
enlarged_thyroid	4962	0	2	0	4841	97.56
brittle_nails	4962	0	2	0	4841	97.56
swollen_extremeties	4962	0	2	0	4841	97.56
excessive_hunger	4962	0	2	0	4496	90.61
extra_marital_contacts	4962	0	2	0	4853	97.8

drying_and_tingling_lips	4962	0	2	0	4847	97.68
slurred_speech	4962	0	2	0	4841	97.56
knee_pain	4962	0	2	0	4847	97.68
hip_joint_pain	4962	0	2	0	4847	97.68
muscle_weakness	4962	0	2	0	4726	95.24
stiff_neck	4962	0	2	0	4732	95.36
swelling_joints	4962	0	2	0	4732	95.36
movement_stiffness	4962	0	2	0	4847	97.68
spinning_movements	4962	0	2	0	4853	97.8
loss_of_balance	4962	0	2	0	4617	93.05
unsteadiness	4962	0	2	0	4847	97.68
weakness_of_one_body_side	4962	0	2	0	4853	97.8
loss_of_smell	4962	0	2	0	4841	97.56
bladder_discomfort	4962	0	2	0	4847	97.68
foul_smell_of_urine	4962	0	2	0	4859	97.92
continuous_feel_of_urine	4962	0	2	0	4847	97.68
passage_of_gases	4962	0	2	0	4847	97.68
internal_itching	4962	0	2	0	4847	97.68
toxic_look_(typhos)	4962	0	2	0	4847	97.68
depression	4962	0	2	0	4726	95.24
irritability	4962	0	2	0	4484	90.37
muscle_pain	4962	0	2	0	4484	90.37
altered_sensorium	4962	0	2	0	4847	97.68
red_spots_over_body	4962	0	2	0	4725	95.22
belly_pain	4962	0	2	0	4847	97.68
abnormal_menstruation	4962	0	2	0	4720	95.12
dischromic_patches	4962	0	2	0	4853	97.8
watering_from_eyes	4962	0	2	0	4853	97.8
increased_appetite	4962	0	2	0	4841	97.56
polyuria	4962	0	2	0	4841	97.56
family_history	4962	0	2	0	4731	95.34
mucoid_sputum	4962	0	2	0	4847	97.68
rusty_sputum	4962	0	2	0	4841	97.56
lack_of_concentration	4962	0	2	0	4847	97.68
visual_disturbances	4962	0	2	0	4847	97.68
receiving_blood_transfusion	4962	0	2	0	4841	97.56
receiving_unsterile_injections	4962	0	2	0	4841	97.56
coma	4962	0	2	0	4841	97.56
stomach_bleeding	4962	0	2	0	4841	97.56
distention_of_abdomen	4962	0	2	0	4847	97.68

history_of_alcohol_consumption	4962	0	2	0	4847	97.68
fluid_overload.1	4962	0	2	0	4847	97.68
blood_in_sputum	4962	0	2	0	4841	97.56
prominent_veins_on_calf	4962	0	2	0	4847	97.68
palpitations	4962	0	2	0	4841	97.56
painful_walking	4962	0	2	0	4732	95.36
pus_filled_pimples	4962	0	2	0	4853	97.8
blackheads	4962	0	2	0	4853	97.8
scurring	4962	0	2	0	4853	97.8
skin_peeling	4962	0	2	0	4846	97.66
silver_like_dusting	4962	0	2	0	4847	97.68
small_dents_in_nails	4962	0	2	0	4847	97.68
inflammatory_nails	4962	0	2	0	4847	97.68
blister	4962	0	2	0	4847	97.68
red_sore_around_nose	4962	0	2	0	4846	97.66
yellow_crust_ooze	4962	0	2	0	4847	97.68

Table 4. 6 Data Quality Report

Through data exploration, a better understanding of the dataset's composition and structure is achieved, which is essential for the development and optimization of the machine learning model. By analyzing the relationships between symptoms and diseases and understanding the distribution of data, the MedCore application can more effectively utilize machine learning algorithms to assist physicians in making accurate diagnoses.

- Building The Diagnostic Tool Model

To develop a reliable and accurate diagnostic tool model for the MedCore application, several experiments were conducted using different machine learning algorithms and dimensionality reduction techniques. These experiments aimed to identify the best-performing model for disease diagnosis.

Initially, a dataset from Colombia University [27] was used with the Jaccard similarity algorithm, but the cases were found to be dissimilar, leading to the conclusion that this dataset and algorithm were not suitable for building the desired model.

A new dataset was collected from the Kaggle website, and the following machine learning algorithms and dimensionality reduction techniques were applied in various combinations:

- Ensemble algorithm using Random Forest
- Ensemble algorithm using Random Forest with PCA
- Ensemble algorithm using Random Forest with LDA
- Ensemble algorithm using Random Forest with k-fold cross-validation
- Ensemble algorithm using Random Forest with PCA & k-fold cross-validation
- Ensemble algorithm using Random Forest with LDA & k-fold cross-validation
- Decision Tree
- Decision Tree with PCA
- Decision Tree with LDA
- Decision Tree with k-fold cross-validation
- Decision Tree with PCA & k-fold cross-validation
- Decision Tree with LDA & k-fold cross-validation

Since the dataset contained categorical data, the dimensionality reduction techniques were biased towards features containing ones and removed features containing zeros. However, both zeros and ones are important in this context, so all features were retained to enhance model performance.

After conducting these experiments, the best-performing model was identified as a Decision Tree with k-fold cross-validation, where K=120 (the number of distinct classes). To determine the maximum depth of the tree, two search algorithms (Grid search and Randomized search) were employed. The Randomized search provided better results, with `max_depth=36`.

The chosen model's performance (Decision Tree with k-fold cross-validation) proved to be the most suitable for accurate disease diagnosis in the MedCore application, providing a

solid foundation for effective patient care and improved healthcare outcomes. Figure 4.25 shows the python code of the ML model, table 4.7 presents its performance.

```

1 import pandas as pd
2 from sklearn.model_selection import RandomizedSearchCV
3 from sklearn.tree import DecisionTreeClassifier
4 import pickle as pk
5
6 # Read the dataset
7 dataset = pd.read_csv('O.csv')
8 df = pd.DataFrame(dataset)
9
10 # Split features from the class label
11 X = df.iloc[:, 0:132]
12 y = df.iloc[:, 132:133]
13
14 # Determine the best max_depth using randomized search
15 decision_tree = DecisionTreeClassifier()
16 parameter = {'max_depth': range(1, 40, 1)}
17 Random_Search = RandomizedSearchCV(decision_tree, parameter, cv=120)
18 RandomSearchResults=Random_Search.fit(X.values,y)
19
20 # Build the model using decision tree classifier & k-fold cross validation
21 dt = DecisionTreeClassifier(max_depth=36)
22 dt.fit(X.values, y)
23
24 # Save the model dt for future prediction
25 pk.dump(dt, open("dt_cv.pkl","wb"))

```

Figure 4. 26 Python Code of ML Model

The Results of The Model		
Accuracy	Precision	Recall
91	94	91

Table 4. 7 Results of the ML model

- Upload Python Code in The Server and Linking it With Flutter

After building the ML model, we deployed the python code in the Microsoft Azure server, and an URL has been generated. In order to link Flutter with the python code we used this URL to send requests and receive a response. A vector of the selected symptoms must be sent in each request to serve as an input to the python code as presented in figure 4.26

```
Future<http.Response> postData(List<dynamic> vector) {
  return http.post(
    Uri.parse('https://medcoreapp.azurewebsites.net/search'),
    headers: <String, String>{
      'Content-Type': 'application/json; charset=UTF-8',
    },
    body: jsonEncode(<String, List<dynamic>>{
      'vector': vector,
    }),
  );
}
```

Figure 4. 27 Request to the server

The python code will use the input to predict the diagnosis, retrieve 3 physicians who diagnose the predicted disease, and the percentage of each symptom of this disease as shown in figure 4.27.

```
def tasks():
    if(request.method == 'POST'):
        request_data = request.data #getting the response data
        request_data = json.loads(request_data.decode('utf-8')) #converting it from json to key value pair
        vector = request_data['vector'] #assigning it to vector
        dataset = pd.read_csv('https://github.com/zsenani/medcoreML-2/blob/d9f5a98d70510682258f1e23bc3663c86a19455d/00.csv?raw=true')
        df = pd.DataFrame(dataset)
        with open("dt_cv.pkl", 'rb') as dt:
            dt = pk.load(dt)
        predict = dt.predict([vector])

        #Get physID
        df_physID = df.query('prognosis == @predict[0]').iloc[:, 132:134]
        getPhys = df_physID.sample(n = 3)
        getPhys = getPhys.physID.drop_duplicates()

        #Symptoms pie chart
        df_Symptoms = df.query('prognosis == @predict[0]').iloc[:,0:132]
        symptoms = list(df_Symptoms.columns)
        symptoms_dic = dict()
        for i in symptoms:
            counts = Counter(df_Symptoms[i])
            if(counts[1] != 0):
                symptoms_dic[i] = counts[1]
        return jsonify({'vector' : predict[0], 'physID' : list(getPhys), 'symptomsDic' : symptoms_dic})
```

Figure 4. 28 Python code in the server

Mobile application GitHub repository link: <https://github.com/zsenani/2022-GP-10.git>

Admin panel GitHub repository link: <https://github.com/zsenani/2022-GP-10-Admin-Panel.git>

Diagnostic Tool (Python code) repository link: <https://github.com/zsenani/medcoreML-2.git>

4.7 Summary

In this chapter we discussed system design and development. We first discussed our approach, which was followed by a discussion of the system's requirements, design, and implementation. The system evaluation will be covered in the following chapter.

System Evaluation

5 System Evaluation

5.1 Overview

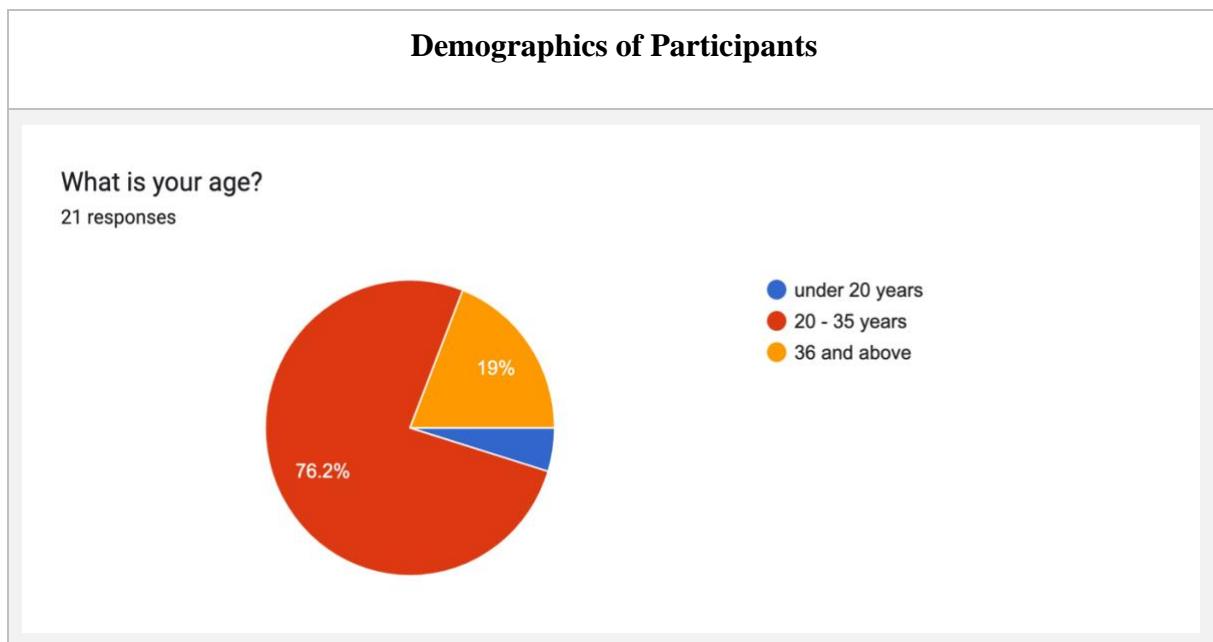
In this chapter, we will perform system testing to ensure that the application functions work as required. We will use user acceptance testing to test our application.

5.2 User Acceptance Testing

In this section, we perform the user acceptance testing on 21 end users from three different types of stakeholders who will be using the system which are physicians, laboratory specialists, and patients who understand English language as our application only support English. First, we let them try our application then we collect information by asking them to answer a questionnaire which include questions about them and about their experience of using the application.

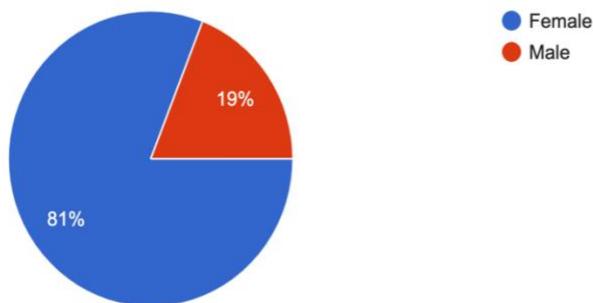
5.2.1 Demographics of Participants

We asked our participant about their age, gender, educational level, their experience with mobile applications in general, and what type of users are they. Their answers displayed in table 5.1.



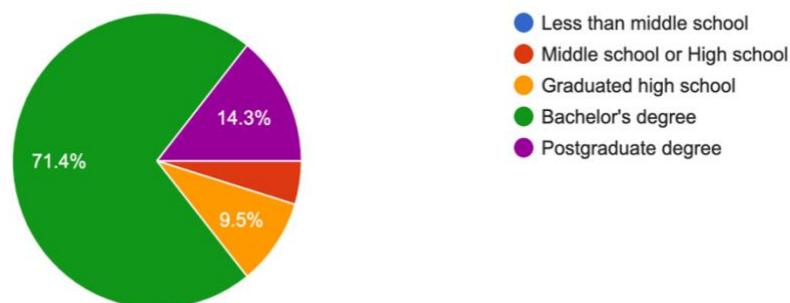
What is your gender?

21 responses



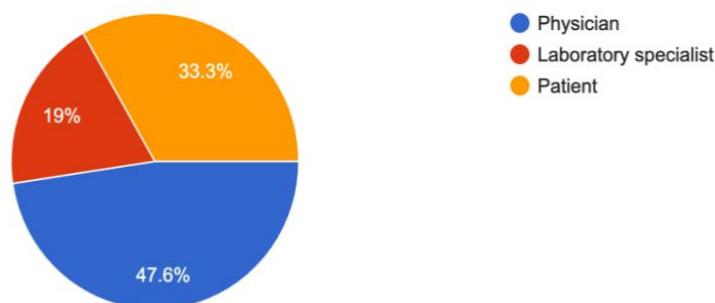
What is the highest degree or level of education you have completed?

21 responses



Are you physician, laboratory specialist, or patient?

21 responses



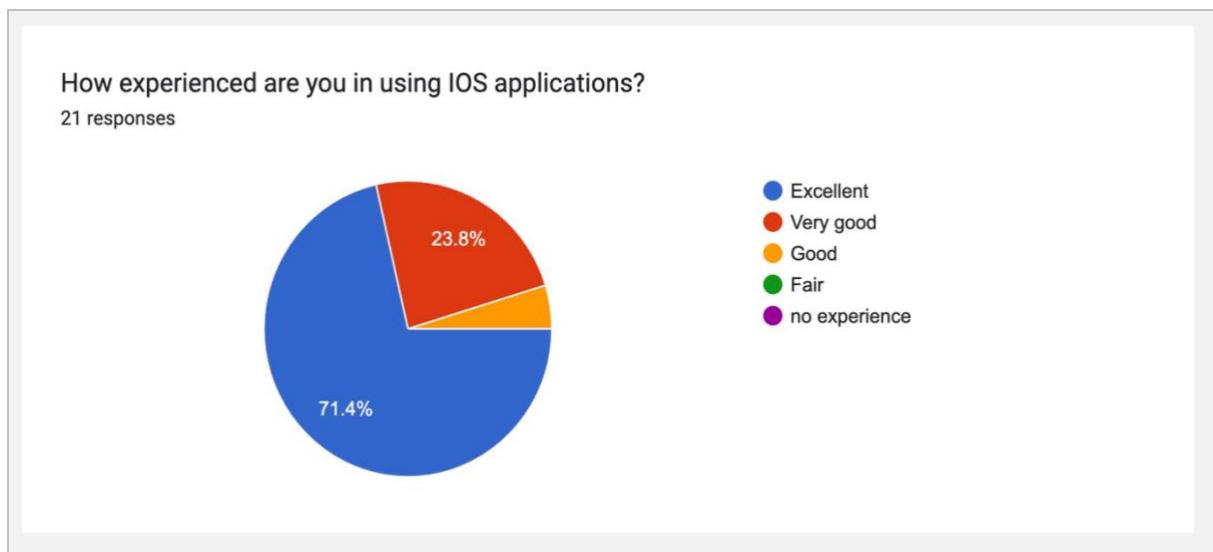
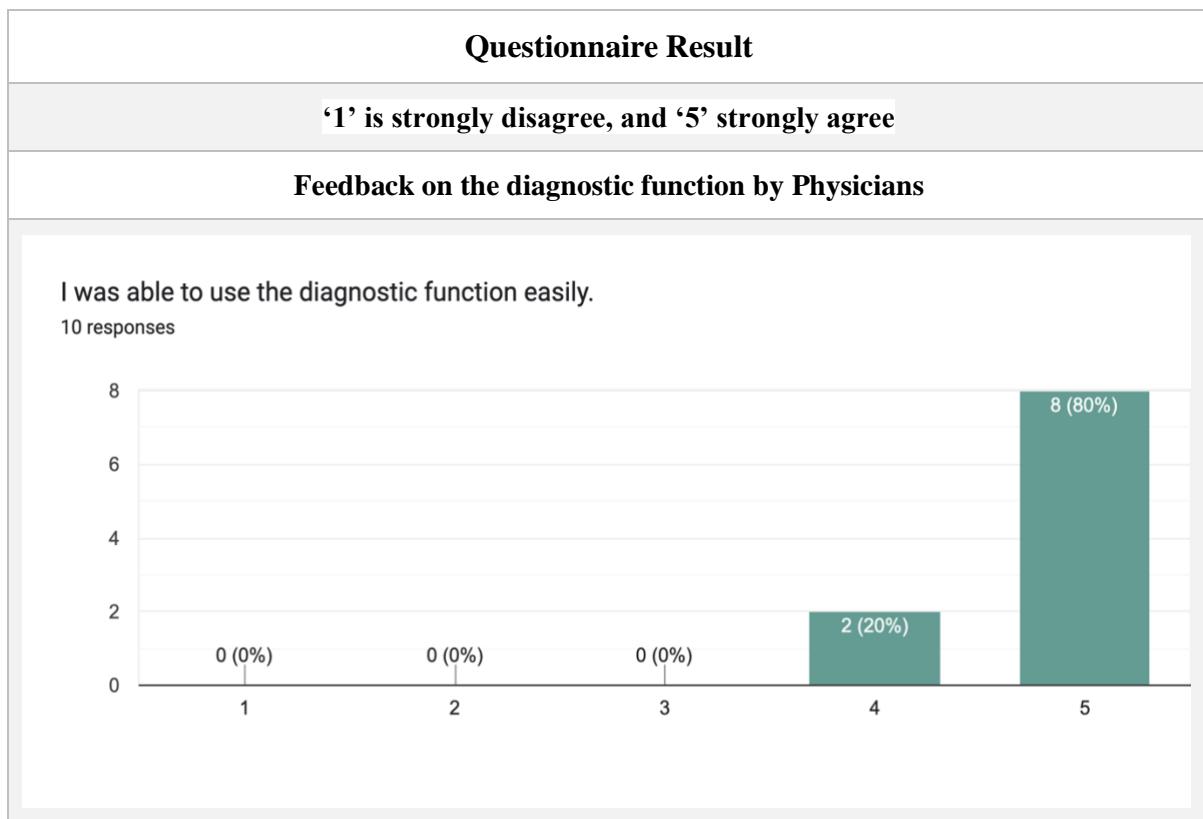


Table 5. 1 System Testing - Demographics of Participants

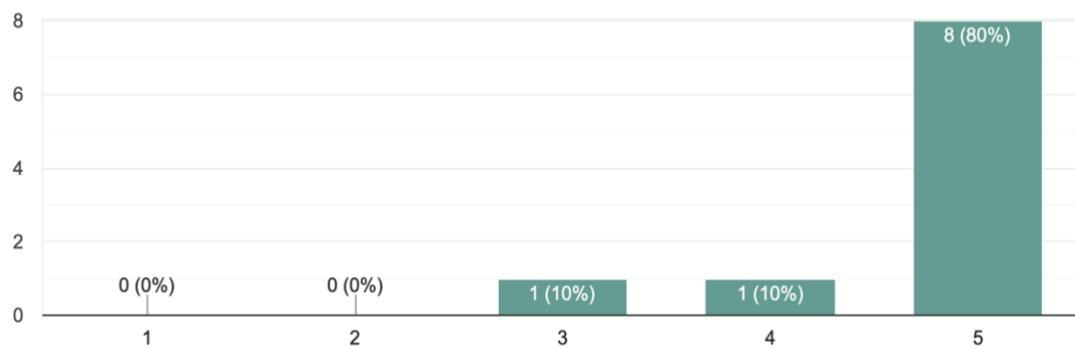
5.2.2 Questionnaire Results

We asked our participant about their experience with MedCore application. Their answers displayed in table 5.2. Questionnaire link in Appendix E.



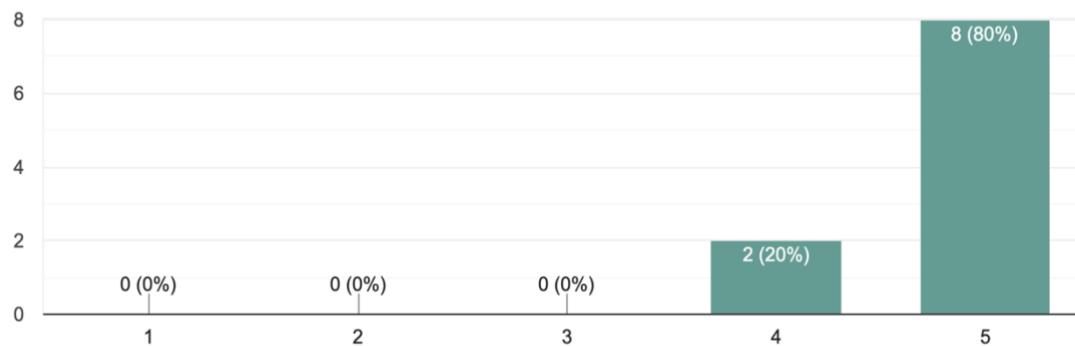
Was the pie chart of symptoms a helpful functionality in the application.

10 responses



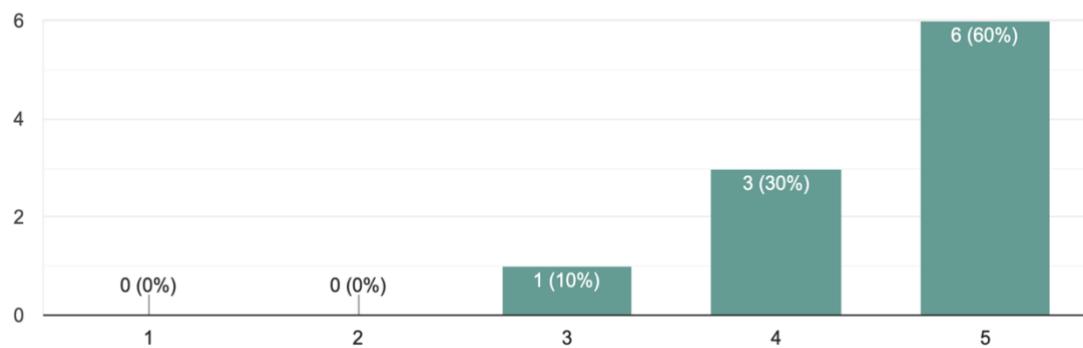
Do you think providing physician's information is helpful for you as a physician?

10 responses



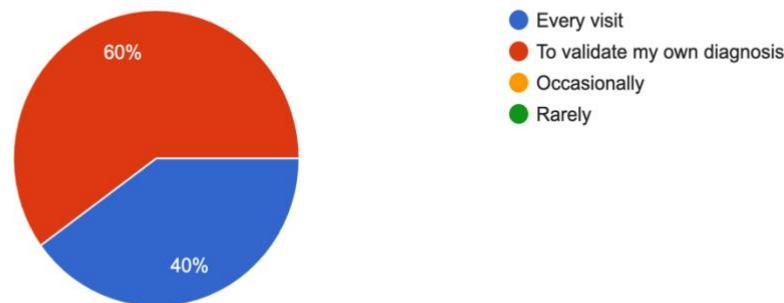
How satisfied are you with the predicted diagnosis ?

10 responses



How frequently will you be using the diagnosis tool ?

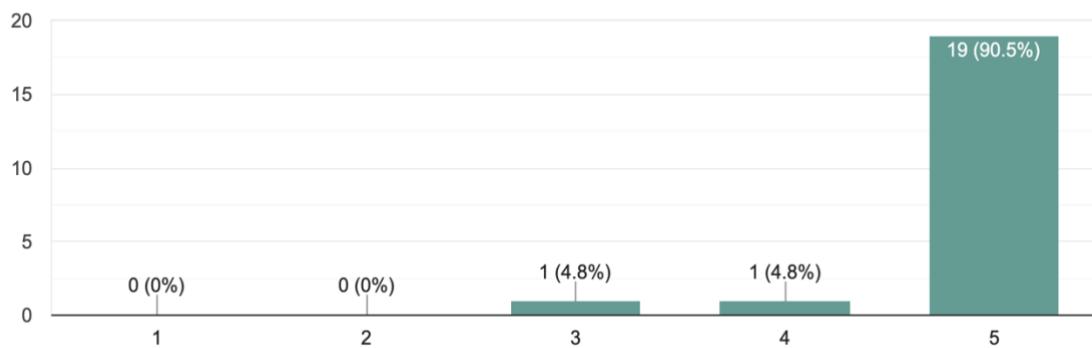
10 responses



Feedback on the application by all participants

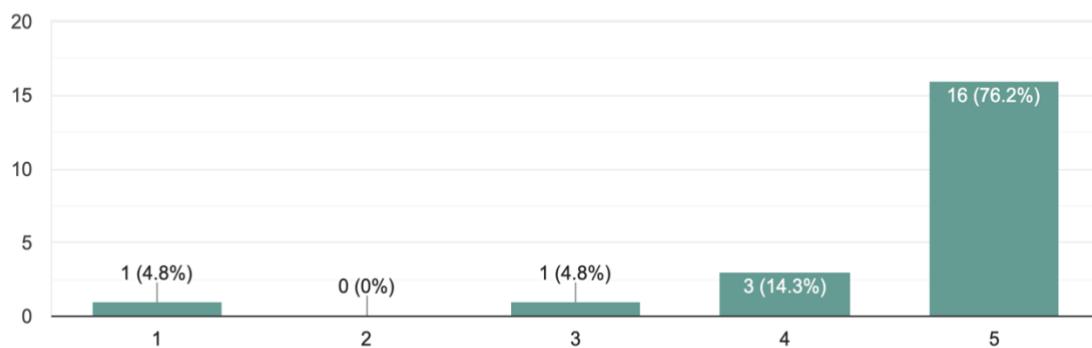
I found the application interfaces clear and easy to use.

21 responses



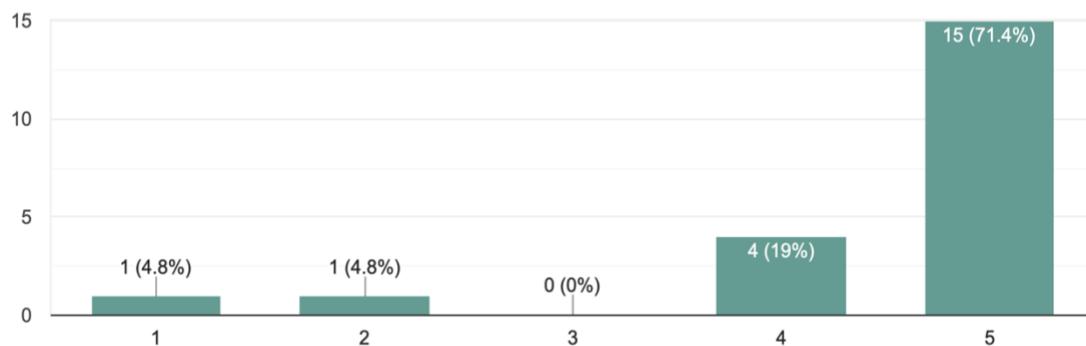
I found it easy and smooth to navigate between the application's pages .

21 responses



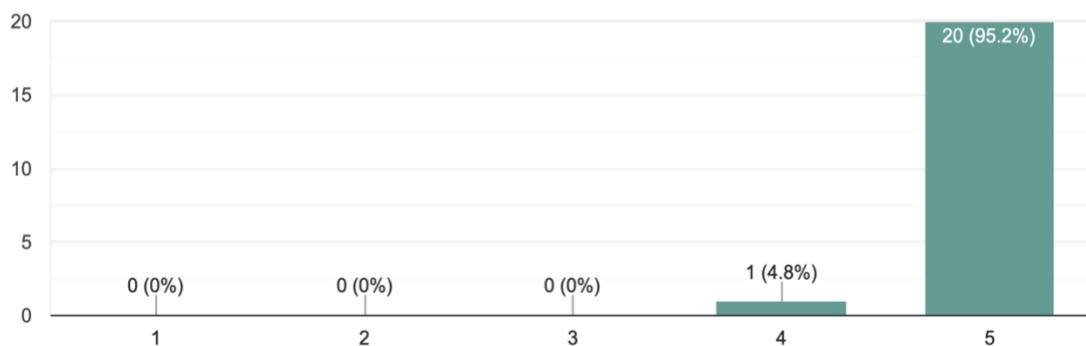
I found error messages in the application are clear and informative.

21 responses



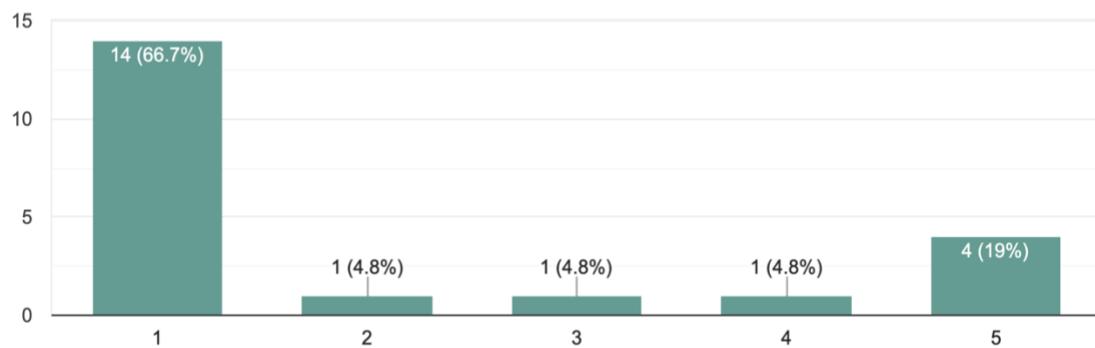
The icons found in the application are understandable and indicate what it does.

21 responses



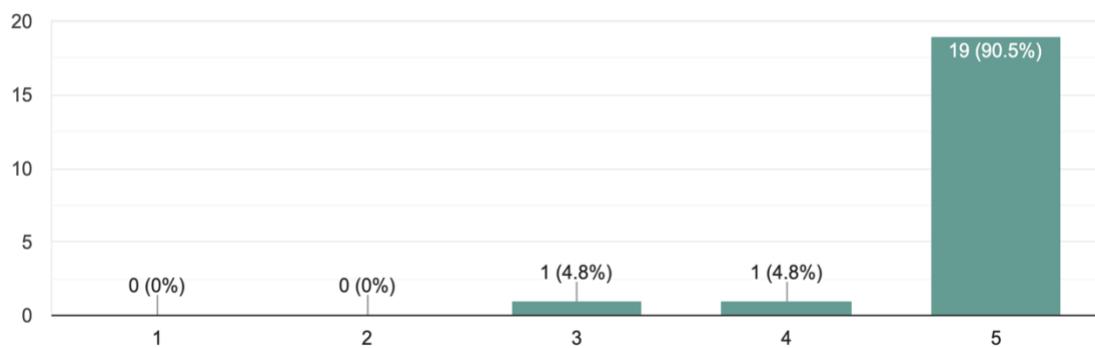
I needed help while using the application.

21 responses



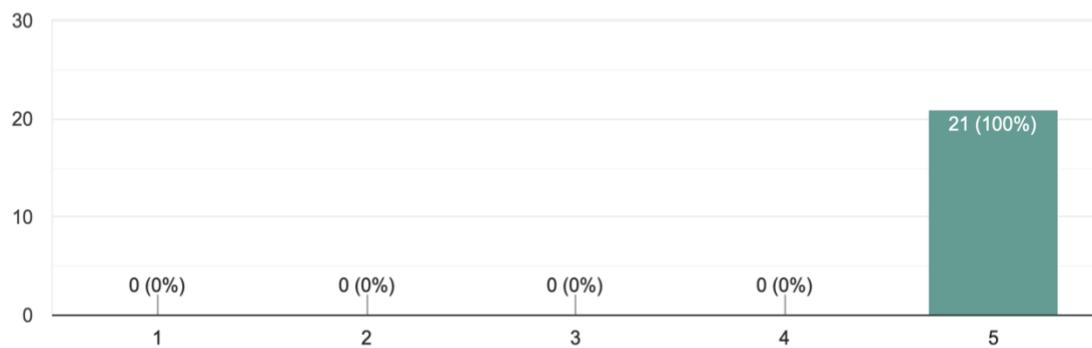
Are all features working as you expected.

21 responses



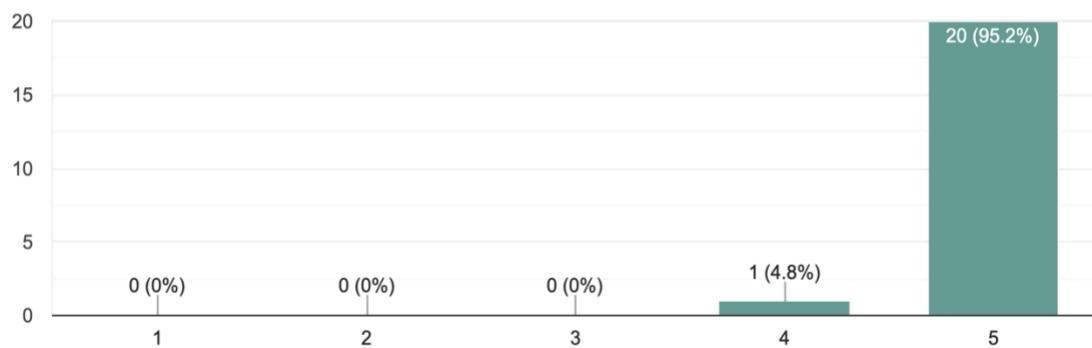
I believe that I can get benefits from unified my\patient files by using MedCore application.

21 responses



The application was available whenever I use it.

21 responses



Comments & Suggestions

Do you have any suggestions to improve our application?

21 responses

Good luck ❤️

جداً سهل في الاستخدام والبيانات واضحة جداً

اضافه خانه عند التقارير او الوصفات المقدمه للاستفسارات والرد عليها من قبل الدكتور او الشخص المكلف بتقديم التقرير

بالتوفيق

.

nothing

I suggest that the app supports multiple languages

فكرة رائعة نتمنى لها تتحقق على ارض الواقع بذنب الله ✨❤️

I really liked the app interfaces ❤️❤️ good luck

No, It's was a great experience

Good luck 👍 the idea of the application is so helpful and time saving

I would like to thank you guys for the amazing effort on this amazing application 🙏❤️

إضافة دارك مود

اذا ممكن تكون حجم medical للهوم بيج والعودة للخلف واضافة buttons التطبيق ممتاز وبنستفيد منه جداً لكن عندي نقطه اللي هي تختار من ناحية الـ ❤️ اكبر اما باقي التطبيق جداً ممتاز بالتوفيق لكم

فكرة جباره ! ،اعان الله و ساعد من ساهم فيها اقترح تحسين سرعة اداء التطبيق و كمقترح إضافة تواصل مباشر بين الطبيب والمريض لتسهيل عملية التواصل والتلخيص

متمنون ان يرى النور قريباً 😊 فكرة بتساعد و تيسر القطاع الصحى بلا شك

يكون البرنامج أسرع شوي وشكراً لمجهودكم الجميل

بالتوفيق يارب ومن أعلى لأعلى ... مجهود جميل ولكن أتمنى اضافة صور شخصيه للشخص

Good luck lovely girl

Add feature filter the lab results using the test name, make the diagnostic prediction relies on achieving a certain percentage of symptoms to improve its reliability.

I suggest adding imaging reports in the patient files

Table 5. 2 System Testing - Questionnaire Result

5.3 Quality Attributes (NFR testing)

User story	Quality Attribute	Measure	Results
As a physician, I want the application to be available 99% of the time I try to access it so that I can help my patients with no delays.	Availability: the proportion of time that the system is operational under normal conditions.	Compute the level of application availability.	MedCore depends on clearDB MySQL (in Heroku) to store data. And according to clearDB website [28], the uptime for clearDB is 100%.
As a user, I want to have a familiar UI icon so that I can understand the system easier and faster.	Usability: How fast a user may become familiar with a system through interaction with an	Calculate the average time of completing the main tasks successfully by the users.	21 users tested the log-in features, and 21 out of 21 completed it successfully within

	<p>application to complete a task.</p>	<p>an average of 15 seconds.</p> <p>10 physicians tested 2 main features, which are: search for patient's possible diagnosis, and Search for a patient by ID.</p> <p>Search for the patient's possible diagnosis: 10 out of 10 completed it successfully within an average of 38 seconds.</p> <p>Search for a patient by ID: 10 out of 10 completed it successfully within an average of 15 seconds.</p> <p>Physician's feature effectiveness is $10/10 \times 100 = 100\%$</p>	<p>4 laboratory specialists tested “upload test results” feature, and 4 out of 4 completed it successfully within</p>
--	--	--	---

			<p>an average of 80 seconds.</p> <p>Lab specialist's feature effectiveness is $4/4*100=100\%$</p>
As a physician, I want the patient's file interface to be easy and simple so that I can enter the patient's information easily.	<p>Usability:</p> <p>How fast a physician may become familiar with a system through interaction with an application to complete a task.</p>	<p>Calculate the average time of completing the main tasks on the patient's file successfully by the physician.</p>	<p>10 physicians tested 3 main features, which are: request lab tests, and add medication.</p> <p>request lab tests: 10 out of 10 completed it successfully within an average of 40 seconds.</p> <p>add medication: 10 out of 10 completed it successfully within an average of 126 seconds.</p> <p>Write a diagnosis: 10 out of 10 completed it successfully within an average of 41 seconds.</p> <p>Physician's feature effectiveness is $10/10*100=100\%$</p>

<p>As a physician, I want to be provided with the up-to-date medical history medical history of patients so that I can diagnose them correctly.</p>	<p>Reliability: the likelihood that the system will work as expected and produce accurate results for a given period of time.</p>	<p>Compute the likelihood of failure</p>	<p>MedCore depends on an SQL database to store data, which is MySQL, to maintain consistency, ensure a high degree of data integrity, and provide the physician with the latest changes that have been made in the medical history. But since the server speed depends on its location and type, and the nearest server that we found was located in Europe, the application may face some failure and stop responding, so it will need to be restarted. We calculated the average number of failures that the 10</p>
---	--	--	---

			physicians had when they tested our application, which was 3.
As a patient, I want my file to be viewable to only the physicians I visit so that I can ensure my privacy.	Security: how to ensure that the access privileges are implemented correctly.	Compute the level of application security.	The system prevents the physician from viewing the patients' files unless they visited her\him by using a method that checks if there is a row that combines the patient ID and physician ID in the visit table in the database.

Table 5. 3 Quality Attributes (NFR testing)

5.4 Discussion

After conducting user acceptance testing, we concluded that the MedCore application received an overall positive evaluation. The application was deemed clear and easy to understand, as evidenced by the questionnaire results: 90.5% of users found the interfaces clear and easy to use, with all features functioning as expected. Additionally, 76.2% strongly agreed that navigation between pages was smooth, 71.4% agreed that error messages were clear, and 95.2% found the icons to be well-known and indicative of their functions. Furthermore, 66.7% strongly disagreed that they needed help while using the application.

Regarding application availability, 95.2% of users strongly agreed that it was available whenever they needed it. All users (100%) believed that they could benefit from unified patient files provided by the MedCore application, whether they were patients, physicians, or laboratory specialists. Some users suggested improvements, such as adding a chat feature

between patients and physicians to facilitate communication and incorporating a "filter by test name" feature on the lab tests page.

When asked about the diagnostic function, 80% of physicians were able to use it easily and found the pie chart and contact information provided helpful. Additionally, 60% of physicians were very satisfied with the predicted diagnosis. In terms of frequency of use, 40% of physicians planned to use the diagnostic function every visit, while 60% intended to use it to validate their own diagnoses.

Non-functional requirements, including availability, security, reliability, and usability, were implemented and tested in our application. We have illustrated our methods for measuring availability and security in the NFR testing table above. Usability and reliability were assessed during the testing phase when a number of users tried our application, and we observed their interactions with the tasks. Based on their experiences, we made adjustments to improve the interface and will incorporate their suggestions in future work to provide the best possible experience with the MedCore application.

5.5 Summery

In this chapter, we use a questionnaire to gather information on the participants' demographics and their experiences with the MedCore application. In addition, we measured MedCore's non-functional requirements and then reviewed the overall results.

Conclusion & Future Work

6 Conclusions and Future Work

In this document, we start from the introduction to explain and clarify the main idea of our project, "MedCore application," and then in the background chapter, we explain all the domain knowledge that the user needs to understand our application, such as medical terminology and the machine learning concept since we will implement it in our application. In the third chapter, the literature review, we compare our application with others in the same field to see the similarities and differences between them. Afterwards, we started system design and development to simplify the implementation of our functionalities and make them more understandable; furthermore, it clarified the components of the application and their interactions. Once we finish analyzing and designing our application, we start developing it using Flutter framework and Dart programming language and testing it to ensure that all the functionalities work as expected and are free from errors.

6.1 Global impact

MedCore is a mobile application that will help physicians save patients' lives and reduce the death rate by accelerating and facilitating the disease detection process, so they can start the treatment in the early stages and curb the spread of an epidemic that may cause significant economic, social, and political disruption [28].

6.2 Local impact

In Saudi Arabia, we struggle with a lack of communication between hospitals since physicians will not be able to see their patients' files in other hospitals. MedCore application will solve this issue by unifying patient files; consequently, it will reduce funding resources for patients or even the hospitals by avoiding repetitions of some procedures. In addition, patients visiting different hospitals may have different applications for each hospital to view their medical information. To reduce the effort taken, MedCore application gathers their medical information in one place, which will also help physicians view their patients' medical history from all hospitals.

6.3 Problems and challenges encountered during the software development

In this project, we faced several challenges, which we will discuss in this section.

One of the primary challenges we encountered was the need for MacOS computers for MedCore's iOS application development. Half of our team used Windows OS, and although Flutter was intended for cross-platform development, we faced numerous challenges when running the code developed on Windows OS and during the integration process. Sections of the code stopped functioning correctly when we attempted to run it on MacOS. To resolve this issue, we had to debug and modify the code to comply with iOS requirements. Furthermore, we experienced several issues with the simulator on both MacOS and Windows OS, which significantly delayed our work as we searched for solutions online.

As first-time users of the Flutter platform, we had to learn and develop simultaneously, which required substantial time spent researching and exploring Flutter and the Dart language.

Another challenge arose while deciding on the type of application to use for the admin panel, considering both security and ease of use. After evaluating the options, we chose to use the Appsmith web application. Since this was our first experience with such an application, we spent considerable time researching and contacting the support team.

When we start developing the application, we have to search for a way to add an OTP feature since we don't use firebase. There is only one way that we found, which is the email_Auth package. At first, we used the test server, which had a limit of 30 OTP a day. It was working fine until release 1 discussion, when the server crashed. To avoid this from happening again, we build a server and deploy the OTP code into it to have unlimited OTP and avoid the server crashes as much as we can.

Deploying the ML model proved difficult as we sought a secure server to minimize crashes. We ultimately chose Microsoft Azure, but the deployment process was time-consuming and complicated. Any changes to the code packages required us to investigate their requirements, as the generated "requirement.txt" file was often incomplete or incorrect, leading to deployment failures.

Publishing our app on the AppStore necessitated joining the Apple Developer Program, which initially rejected our apple accounts without explanation. After creating a new Apple account and contacting Apple Support, we managed to enroll successfully. However, our app was rejected by the AppStore for collecting sensitive data using individual account instead of an organizational one. We appealed this decision by clarifying that the app was a prototype and a university graduation project, but the rejection persisted.

Overall, we gained from developing this project several technical and soft skills. For the technical skills, we learned how to program an application using Flutter framework and Dart programming language, how to use NoSQL MongoDB and how to integrate it with our application also we learned how to use MySQL database and how to integrate it with our application since we had to change our database from NoSQL to SQL database, how to build and upload a machine learning model and how to gather our code using GitHub, and it also enhanced our searching skills. whereas our soft skills improved in multiple aspects, such as communication skills, teamwork, and time management, taking into consideration that we were implementing the application while studying other subjects and solving problems in a limited time frame that are encountered during system development also looking for an alternative plan if the problem can't be solved.

6.4 Limitations of the system.

MedCore is a centralized hospital application that aims to connect all hospitals exclusively in Saudi Arabia and unify patient files. However, due to the size of the project, we had to eliminate some functionalities such as: patients will not be able to schedule appointments and the system only supports English language.

6.5 The main contribution of the project

The main contribution of the project is to improve and assist the healthcare system in Saudi Arabia. By uniting them all into one coherent system, it serves as a link between hospitals, physicians, and patients. MedCore application may help in reducing unnecessary resources caused by misdiagnosis or a lack of transparency between hospitals and physicians. MedCore employs machine learning algorithms to assist physicians in making sound

diagnosis decisions. After training and optimizing the model, we were able to build a model with 91% accuracy and 92% F-1 score.

6.6 Future work

The MedCore project has significant potential for expansion and improvement in various aspects, ranging from new features and functionalities to enhancements in the machine learning model. Future work for the project includes:

1. Language Support: Implement Arabic language support to cater to a broader user base and enhance the user experience.
2. Appointment Booking: Enable patients to book appointments directly through the application, streamlining the scheduling process.
3. Radiology Integration: Incorporate radiology reports and images into patients' files, providing physicians with a more comprehensive understanding of their patients' medical history.
4. Advanced Filtering: Add filter functions to the physician's visit page, allowing them to display visits by date and other relevant criteria.
5. Physician Communication: Introduce a chat feature to facilitate communication and collaboration among physicians.
6. Pharmacy Integration: Include pharmacies in the application, enabling physicians to send prescriptions directly to patients' preferred pharmacies.
7. Machine Learning Model Improvement: Continuously collect and utilize information entered by physicians during the diagnosing process, along with relevant patient data as shown in the figure 6.1, to retrain and optimize the machine learning model for increased precision.

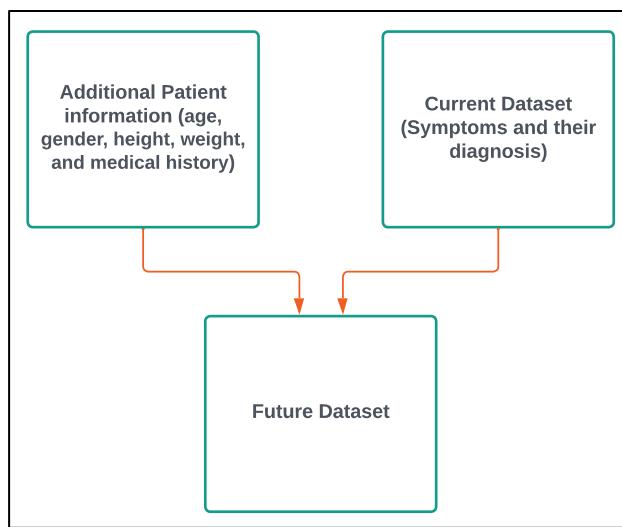


Figure 6. 1 Future Dataset Components

8. Interactive Interface Enhancements: Update the "most common symptoms" section on the diagnostic tool page as shown in the figure 6.2 to reflect real-time data, making it more convenient for physicians when searching for diagnoses.

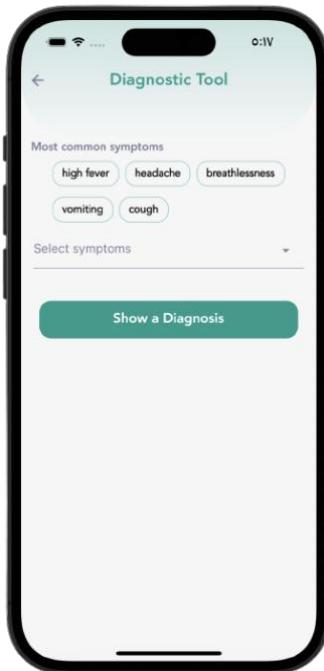


Figure 6. 2 Diagnostic Tool Interface

9. Location-Based Physician Information: Display contact information for physicians in the same hospital or nearby hospitals as the user, fostering better collaboration and communication.

10. Symptom Correlation Visualization: Utilize heat maps to help physicians identify correlations between symptoms, further assisting them in their diagnostic process.

By incorporating these additional features and improvements, MedCore can continue to evolve and provide an even more comprehensive and effective solution for the healthcare system in Saudi Arabia. This will ultimately lead to better patient care, enhanced communication among healthcare providers, and more efficient processes within the industry.

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Appendix

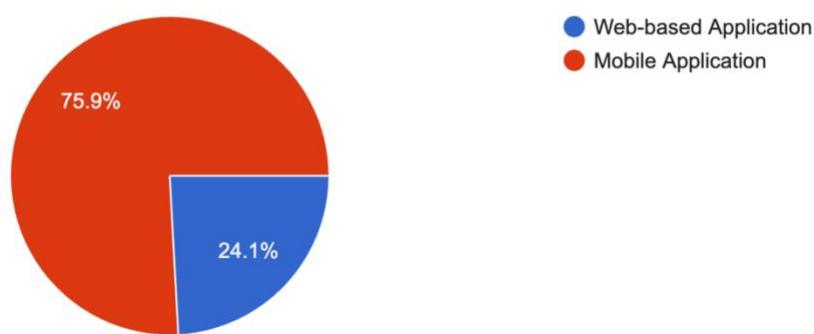
9 Appendix

9.1 Appendix A

- physicians' preferences survey:

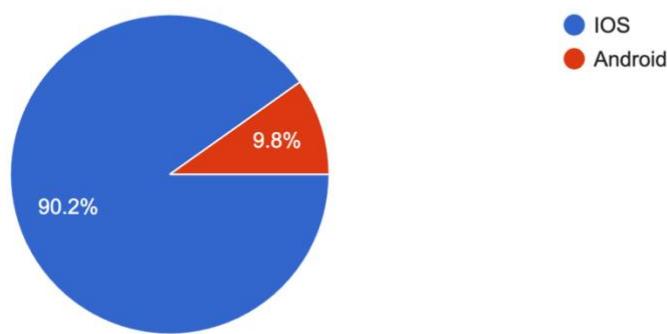
For this kind of application, which platform do you prefer?

58 responses



If you choose Mobile Application which operating system do you prefer?

51 responses



9.2 Appendix B

- physicians' interviews:

Interview1:

Interviewer: Futoon Alshaiddi

Interviewee: Dr.Abdullah Almazyad

- What do you usually do when you can't diagnose a patient because of a rare symptom?

Discuss with other colleges

- As a physician, what is the impact of not knowing your patient's information in other hospitals?

It is sad because it may harm the patient

- How do you ensure that the patients are giving you the correct information about their medication?

Ask them to bring medical reports from other hospitals

Interview2:

Interviewer: Futoon Alshaiddi

Interviewee: Dr. Awadh Alenezi

- What do you usually do when you can't diagnose a patient because of a rare symptom?

Contact a senior or search for the symptoms

- As a physician, what is the impact of not knowing your patient's information in other hospitals?

Difficulty in giving the patient the appropriate treatment and wasting everyone's time

- How do you ensure that the patients are giving you the correct information about their medication?

If the medication is major and can make an impact on my work, I will request a report from his/her doctor.

Interview3:

Interviewer: Leen AlDekhayyel

Interviewee: Dr. Waleed Alharbi

- What do you usually do when you can't diagnose a patient because of a rare symptom?

I would ask my senior and do a quick review or research in the literature

- As a physician, what is the impact of not knowing your patient's information in other hospitals?

It has multiple negative points: delaying the diagnosis may expose the patient to radiation (repeating imaging) and time-consuming

- How do you ensure that the patients are giving you the correct information about their medication?

If the patient is known to us, it will appear in the system; if not, then there are two categories:

Reliable patient: I will take the medical details from him/her

Not reliable patient: ask her/his relative

Interview4:

Interviewer: Leen AlDekhayyel

Interviewee: Dr. Salwa Alhazzaa

- What do you usually do when you can't diagnose a patient because of a rare symptom?

Consult my Colleagues abroad -Usually, in the US

- As a physician, what is the impact of not knowing your patient's information in other hospitals?

Very distressing as I have to start from base 1 with the patient, and patients are not medically enlightened most time. Patients do not have a medical report which is intentional as they say they want a fresh start which is, of course, medically compromising to both patients & health care providers.

- How do you ensure that the patients are giving you the correct information about their medication?

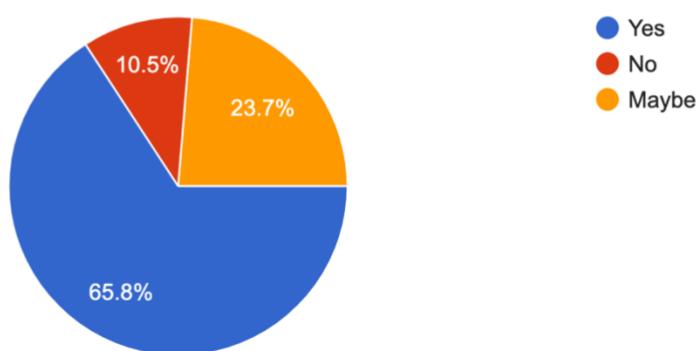
No insurance unless they have an educated caretaker with them (offspring/nurse).

9.3 Appendix C

- Questionnaire:

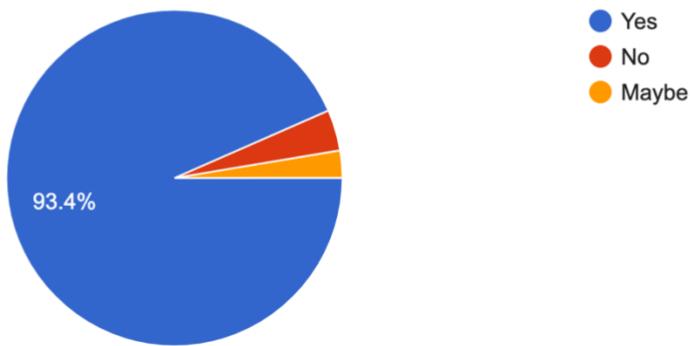
Have you ever had a patient where you were not able to diagnose or not sure of your outcome given his/her rare symptoms?

76 responses

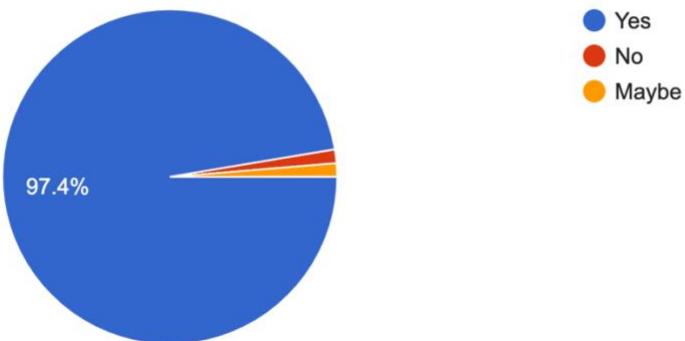


Would you like to have a technology that facilitate searching for cases that are similar to your patient symptoms and determine their diagnosis?

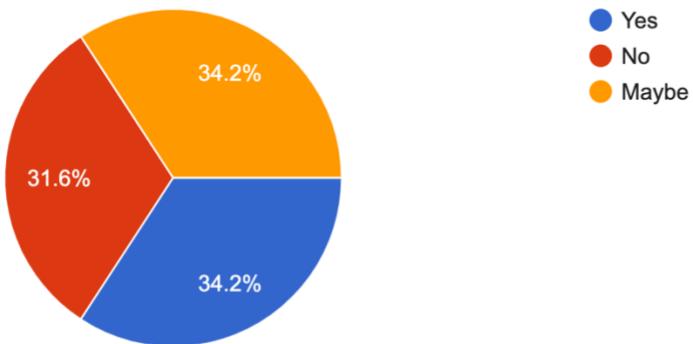
76 responses



Do you prefer to have a unified file for your patient visited different hospitals around the country?
76 responses



Did you prescribe medication to a patient, and it conflicted with another medication because he/she was taking and did not mention it to you?
76 responses



9.4 Appendix D

- **Send OTP function**

1. **BEGIN**
2. sent an OTP to the email
3. **READ** OTP from the user
4. **IF** time exceeds 1 minute **THEN**
5. The user can click resend OTP
6. **IF** user clicks resend **THEN**
7. A new OTP will be sent
8. **END IF**
9. **END IF**
10. **WHILE** the entered OTP does not match the sent OTP
11. **DISPALY** a warning message
12. **READ** OTP from the user
13. **END WHILE**
14. **END**

- **User story #1:** As an admin, I want to log in so that I can manage the centralized hospital system.

1. **BEGIN**
2. admin select log-in
3. **READ** admin information (email, password)
4. **IF** the entered email has permission **THEN**
5. Redirect the admin to the admin panel

6. ELSE

7. The system will deny access to the admin panel

8. END IF

9. END

- **User story #2:** As an admin, I want to register hospitals so that the physicians can register their self in any of those hospitals.

1. BEGIN

2. admin select add hospital

3. **READ** hospital information (name, city, region, district)

4. **IF** the information fields are empty **THEN**

5. admin will fill all the fields

6. END IF

7. **IF** the hospital already exists in the database **THEN**

8. **DISPLAY** “the hospital is already exists”

9. ELSE

10. add the hospital to the database

11. END IF

12. END

- **User story #3:** As an admin, I want to view hospitals so that I can know which hospitals are registered in the system.

1. **BEGIN**

2. admin logged-in
3. click hospital
4. **DISPLAY** list of hospitals

5. **END**

- **User story #4:** As an admin, I want to edit and delete hospitals so that I manage the system.

- **Delete hospital**

1. **BEGIN**

2. the admin selects a hospital
3. clicks delete button
4. **DISPLAY** confirmation message

5. **IF** confirm **THEN**

6. delete the hospital from database

7. **END IF**

8. **END**

- **Edit hospital**

1. **BEGIN**

2. the admin selects a hospital
3. **DISPLAY** hospital information in the edit form
4. **READ** the new information
5. **IF** clicks submit **THEN**
6. **DISPLAY** confirmation message
7. **IF** confirm **THEN**
8. update information in the database
9. **END IF**
10. **ELSE IF** clicks reset **THEN**
11. reset the edit form fields to the old one
12. **END IF**
13. **END**

- **User story #5:** As a physician, I want to register in the system so that I can do my job.

1. **BEGIN**
2. The user selects hospital
3. The user select create account
4. **READ** user information (national/ resident ID, DOB, role)
5. **IF** role is physician **THEN**
6. **READ** user information (name, email, confirm email, nationality, gender, phone number, hospitals, specialization, password, confirm password)
7. **END IF**
8. **IF** the information fields are empty **THEN**
9. The user will fill all the fields
10. **END IF**

11. **IF** the national/ resident ID is already exist or password less than 8 or password does not contain (number, capital letter, small letter, special character) **THEN**
12. **IF** password and confirm password do not match or email and confirm email do not match **THEN**
13. The user will re-enter the information
14. **END IF**
15. **END IF**
16. verify user using OTP sent to email
17. **IF** verified **THEN**
18. add physician to database
19. Redirect the user to homepage
20. **END IF**
21. **END**

- **User story #6:** As a physician, I want to log in so that I get access to my profile, my patients' visits, and my patients' files.
- **User story #8:** As a laboratory specialist, I want to log in so that I can upload patients' results.

1. **BEGIN**
2. The user selects hospital
3. **READ** user information (role, national/ resident ID, password)
4. **IF** the information fields are empty **THEN**
5. The user will fill all the fields
6. **END IF**
7. **IF** the national/ resident ID and password exist in the database **THEN**

8. authenticate user using OTP sent to email
 9. **IF** authenticated **THEN**
 10. redirect user to homepage
 11. **END IF**
 12. **ELSE**
 13. **PRINT** “Incorrect password or national/ resident ID”
 14. **END IF**
 15. **END**
- **User story #7:** As a laboratory specialist, I want to register in the system so that I can do my job.
1. **BEGIN**
 2. The user selects hospital
 3. The user select create account
 4. **READ** user information (national/ resident ID, DOB, role)
 5. **IF** role is lab specialist **THEN**
 6. **READ** user information (name, email, confirm email, nationality, gender, phone number, hospital, password, confirm password)
 7. **END IF**
 8. **IF** the information fields are empty **THEN**
 9. The user will fill all the fields
 10. **END IF**
 11. **IF** the national/ resident ID is already exist or password less than 8 or password does not contain (number, capital letter, small letter, special character) **THEN**

12. **IF** password and confirm password do not match or email and confirm email do not match **THEN**
13. The user will re-enter the information
14. **END IF**
15. **END IF**
16. verify user using OTP sent to email
17. **IF** verified **THEN**
18. add lab specialist to database
19. Redirect the user to homepage
20. **END IF**
21. **END**

- **User story #9:** As a patient, I want to register in the system so that I can visit any hospital.

1. **BEGIN**
2. The user selects patient
3. The user select create account
4. **READ** user information (national/ resident ID, DOB ,name, email, confirm email, nationality, gender, phone number, marital status, password, confirm password)
5. **IF** the information fields are empty **THEN**
6. The user will fill all the fields
7. **END IF**
8. **IF** the national/ resident ID is already exist or password less than 8 or password does not contain (number, capital letter, small letter, special character) **THEN**
9. **IF** password and confirm password do not match or email and confirm email do not match **THEN**
10. The user will re-enter the information

11. **END IF**

12. **END IF**

13. verify user using OTP sent to email

14. **IF** verified **THEN**

15. add patient to database

16. Redirect the user to homepage

17. **END IF**

18. **END**

- **User story #10:** As a patient, I want to log in so that I can view all my medical information.

1. **BEGIN**

2. the user selects patient

3. **READ** user information (national/ resident ID, password)

4. **IF** the information fields are empty **THEN**

5. the user will fill all the fields

6. **END IF**

7. **IF** the national/ resident ID and password exist in the database **THEN**

8. authenticate user using OTP sent to email

9. **IF** authenticated **THEN**

10. redirect user to homepage

11. **END IF**

12. **ELSE**

13. **PRINT** “Incorrect password or national/ resident ID”

14. **END IF**

15. END

- **User story #11:** As a user, I want to be able to log out so that I prevent other users from accessing my account.

1. **BEGIN**

2. user clicks profile
3. user clicks log-out
4. **DISPLAY** confirmation message
5. **IF** confirmed **THEN**
6. redirect user to sign-in page
7. **END IF**
8. **END**

- **User story #12:** As a user, I want to reset my password, so that I can update my password regularly.

1. **BEGIN**

2. the user clicks reset password in her/ his profile
3. **READ** current password, new password and confirm password
4. **IF** fields are empty **THEN**
5. the user will fill the field
6. **END IF**
7. **IF** the current password is not correct **THEN**
8. **PRINT** “Incorrect password”
9. **END IF**
10. **ELSE IF** new password **AND** confirm password do not match **THEN**
11. **DISPLAY** warning message

12. **END IF**

13. **ELSE IF** current password equal new password

14. **DISPLAY** warning message

15. **END IF**

16. **END**

- **User story #13:** As a user, I want to reset my password so that I can use my account if I forget my password.

1. **BEGIN**

2. the user selects hospital/ patient

3. **IF** user select hospital **THEN**

4. select forget password

5. **READ** role and email

6. **END IF**

7. **ELSE IF** user select patient **THEN**

8. select forget password

9. **READ** email

10. **END IF**

11. **IF** email exists in the database **THEN**

12. authenticate user using OTP sent to email

13. **READ** password and confirm password

14. **IF** field are empty **THEN**

15. user will fill the fields

16. **END IF**

17. **ELSE IF** password and confirm password do not match **THEN**

18. **DISPAL** warning message

19. **END IF**

20. update password in the database

21. redirect user to homepage

22. **ELSE**

23. **DISPLAY** “Invalid email”

24. **END IF**

25. **END**

- **User story #14:** As an admin I want to view the physicians and lab specialist in each hospital so that I know who belong to which hospital

1. **BEGIN**

2. admin select hospital

3. admin clicks “view physicians/ lab specialist” button

4. **DISPLAY** physicians and lab specialist

5. **END**

9.5 Appendix E

Link of the questionnaire:

<https://forms.gle/rF1s6P3XUTZxwvua7>

Questions:

- What is your age?
- What is your gender?
- What is the highest degree or level of education you have completed?
- Are you physician, laboratory specialist, or patient?
- How experienced are you in using mobile applications?
- I was able to use the diagnostic function easily.
- Was the pie chart of symptoms a helpful functionality in the application.
- Do you think providing physician's information is helpful for you as a physician?
- How satisfied are you with the predicted diagnosis ?
- How frequently will you be using the diagnosis tool ?
- I found the application interfaces clear and easy to use.
- I found it easy and smooth to navigate between the application's pages .
- I found error messages in the application are clear and informative.
- The icons found in the application are understandable and indicate what it does.
- I needed help while using the application.
- Are all features working as you expected.
- I believe that I can get benefits from unified my\patient files by using the MedCore application.
- The application was available whenever I use it.
- Do you have any suggestions to improve our application?