ROBERT GORDON UNIVERSITY ABERDEEN

School of Computing

Honours Report

Mobile applications and the digital transformation of healthcare.

Simona Georgieva 2023

This report is submitted as part of the requirements for the degree of

BSc (Hons) in Computing Science

at Robert Gordon University, Aberdeen, Scotland

I confirm that the work contained in this Honours project report has been composed solely by myself and has not been accepted in any previous application for a degree. All sources of information have been specifically acknowledged and all verbatim extracts are distinguished by quotation marks.

Signed: Simona Georgieva Date: 28/04/2023

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Technical Terms

Term	Explanation
Framework	A tool that provides ready-made components or solutions that are customized in order to speed up development
IDE	Integrated development environment
Dev community	Types of marketing channels where peer-to-peer conversations and authentic engagement are most likely to take place among developers
Android Emulator	Is a software application that allows your mobile to imitate Android OS features into your PC
APIs	Application Programming Interface
Frontend	Visual elements of a website or mobile app
Backend	Parts of a computer application or a program's code that allow it to operate and that cannot be accessed by a user
Widget	Central class hierarchy in the Flutter framework
No-SQL	Database design
Package	A namespace that contains a group of similar types of classes, interfaces, and sub-packages
Dependency	Another package that your package needs in order to work
GDPR	General Data Protection Regulation
StatelessWidget	A widget that does not require mutable state.
StatefulWidget	A widget that has mutable state.
HTTP	Hypertext Transfer Protocol
StreamBuilder	Widget that builds itself based on the latest snapshot of interaction with a Stream
UI	User Interface

Abstract

The primary objective of this paper is to present a telehealth mobile app designed not only to allows users to book appointments but also provides access to useful features such as a BMI calculator and a tool to find the nearest hospitals. In order to develop the app with the most useful features and options, several existing apps in the field of health services were researched to determine the most commonly used functionalities. The app was developed using Flutter, allowing it to run on various platforms, and Firebase was used to offer users security and privacy as well as real-time connectivity between the user and the software.
Furthermore, a thorough testing had been conducted to assess the app's performance and identify any potential issues or bugs.

Introduction

The covid 19 pandemic has had an unprecedented impact on the way we live our lives and access life services, including access to healthcare. Fortunately, some technologically advanced countries were able to handle the pandemic by digitizing their daily routines. This not only helped to limit the spread of COVID-19 but also improved access to healthcare services. However, there are still some countries who are slowly adapting to the new technological health services.

To address this issue, the author has decided to create a mobile app that offers the most common digital health functionalities. This app is intended to provide a starting point for less developed communities to access digital health services free of charge. Taking small steps to gradually integrate digital tools and technologies into their healthcare systems can improve the quality of the provided services and establish a solid foundation for future growth and development.

It is important to note that any personal data collected by the app will be subject to GDPR regulations, and failure to comply can result in fines.

1. Project Scope

The healthcare industry plays a vital role and is integral to every human being's life. According to the World Health Organization (WHO), the global strategy relies on the further development of different technology applications for the health domain to support or to improve health behaviors, quality of life, and people's well-being and contribute to the overall performance of digital health (WHO, 2021). The pandemic has brought a lot of inconvenient situations, such as social isolation, anxiety, online education, etc. What is more, it further complicated arranging hospital appointments and accessing them. Recent years have seen increased integration of smartphones among healthcare professionals as well as the public. Therefore, an increasing number of healthcare centers are digitalizing their approach and implementing their mobile health apps to enable easier access to care for their patients and an organized work environment for the staff (Imran et al. 2020).

1.1. Paper-Based Appointment System

Waiting for a service is one of the most unpleasant events in everyday life. According to, World Health Organization, every year, an inadmissible number of patients suffer injuries or die because of unsafe and inadequate quality health care, although most of these injuries are avoidable (Patient Safety 2022). Undoubtedly, every patient deserves timely help and treatment (Zhang, X 2017). However, this may only be partially satisfied using the traditional medical scheduling approach. In this globalized world, hospitals still use the old-fashioned way of booking appointments or registering for a doctor over the telephone or in person (Nikolova 2019). Using the traditional method, clinics utilize a system in which patients are automatically allocated to an appointment time and a specialist based on the free slot. Without proper queue management, the consequences might be harmful to both sides. For example, long waiting times contributes to a wide range of health issues, including impaired access to care or patient dissatisfaction, which may also directly affect the financial viability of the institution, and its reputation, and impose great stress over the clinic (Xie, Z 2017). In addition, this type of system has a wide range of constraints. For example, there needs to be a mechanism to cancel an appointment or get a reminder. Patients must fill out a registration form when arriving at the hospital, expanding the overall time spent at the clinic. Moreover, the patient information on the papers must be corrected when changes need to be made, and the risk of misplacing a record is transparent (SoftClinic 2021).

1.1.1 The popularity of appointment scheduling

Waiting times have been a subject of discussion since 1984, when Lindsay and Feigenbaum introduced the queuing model, proving that considerable delays in patient booking impose costs (Lindsay et al. 1984). Thirty-eight years later, enhancing patient care experience is still a topic of conversation. As seen in Figure 1, appointment scheduling has been discussed in many literature review topics (Ali Ala & Feng Chen 2022). There has been a substantial increase in the number of papers. In 2012 the total number of manuscripts was 40, whereas, in 2020, the number of articles doubled. Consequently, the public healthcare sector realizes the benefit of reforming the healthcare system.

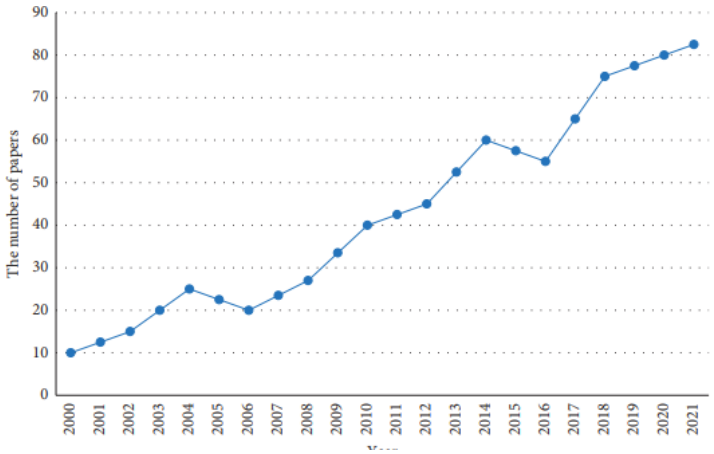

Figure 1. *The trend of the published articles in appointment scheduling 2000–2021*

With the rapid development of the Internet, verbal and paper-based scheduling appointments are getting replaced by web-based appointment systems. More countries worldwide realize the need to change their service approach by adapting technologies to maximize their services' effectiveness and efficiency, offer a positive working environment for the medics, and deliver a better patient experience (Morris, R.H.J. 2022).

1.2. Web-based Application System

In 2013 Xiuju Zhan and Xiufeng Liu developed an interactive clinic appointment registration system consisting of several data operation functions, including appointment booking and data management, for example, addition, deletion, and searching, which is one of the most significant disadvantages in the past. (Xiuju Zhan, Xiufeng Liu 2013). According to Zhan and Lui, the system can be divided into two user categories. The first category is for those who want to make an appointment, while the second is for the hospital staff. Compared to the old-fashioned queuing methods, the web-based appointment system could significantly increase patients` satisfaction, reduce total waiting time spent in the clinic, and effectively help the staff to manage their time. Figure 2 shows the system function structure. Regarding patient functionalities, it is evident that patients do not have the option to cancel, defer or get a notification about an appointment.

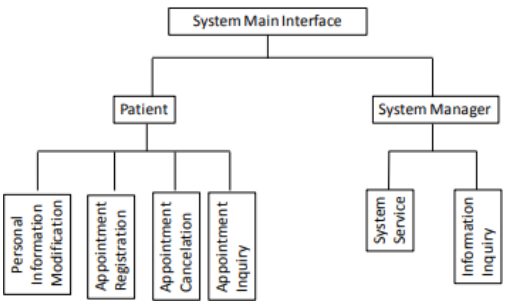

Figure 2. *System function structure (Xiuju Zhan, Xiufeng Liu, 2013).*

Due to the lack of these functions missed appointments are a common occurrence. Non-attendance is a persistent problem in the medical industry. During 2014 and 2015, around 5.6 million NHS outpatient appointments were in England, according to Quarterly Hospital Activity Data (Nhs.uk 2015). Research regarding adult patients missing an appointment shows that "the mean rate of missed appointments was 15.2%" (Parsons et al. 2021). It should be highlighted that patients with long-term mental health conditions who missed more than two appointments had a greater chance of deteriorating the condition (McQueenie, R. et al. 2019). Failing to attend a hospital appointment harms a clinic's workflow and wastes NHS resources. The problems mentioned above lead to the improvement of the web-based approach.

In 2014 the research work by Idowu proposed a user-friendly, dependable medical appointment system for a Nigerian Teaching Hospital (Idowu et al. 2014). The proposed website empowers the patient to book and manage their appointments, shortening the unnecessary waiting time for consultation and notifying them via email or SMS 2 hours before the actual session. The administrator interface allows the staff to easily edit, insert, delete and check the overall report of registered patients. Undoubtedly, a responsive website can compensate for the distance between doctors and patients and provide fast and adequate medical services. However, web apps need an active internet connection, while mobile apps may work offline. In addition, VWO - the world's leading web testing and conversion optimization platform, reported that users prefer mobile apps rather than mobile websites (Deshdeep N. 2015)

Based on the discussion above the aim of the current project will be the implementation of a mobile application which gives the user a chance not only to book an appointment but also to manage it with the help of different features such as editing an appointment, cancelling it and getting a remainder.

1.2.1. The improvement of Telemedicine

After SARS-CoV-2 has hampered every aspect of our life, but most of all, the healthcare system, some countries have found new opportunities and methods to combat it. To the American Medical Association, 74% of the population did not have access to or were unaware of telemedicine before the pandemic (Truex, G. 2022). Nevertheless, in 2020, a survey showed that nearly 45% of Americans used telemedicine during the pandemic (DrFirst 2020). The pandemic has rapidly accelerated the use of telemedicine, which imposes the need to implement new features in healthcare software development such as smoothly moving towards mobile development.

1.3. Mobile Application System

The current section will focus on reviewing the literature on different mobile applications. It will discuss the limitations and strengths that this project needs to be aware of.

1.3.1. Popular App Categories

Looking back at 2017, the most popular app store categories among Android users were Games, Dating, Shopping, Communication, etc. The statistic in Figure 5 shows that Android consumers are not interested in Health apps. A few years later, after the global impact of the pandemic, the health category moved further up in the statistics. The outcomes of the illness, such as lockdown, including not being able to see Health and social staff, could be considered as a reason, according to the Organization for the Review of Care and Health App (ORCHA) research. ORCHA expected that digital Health would move forward and be

entirely integrated into care pathways to achieve a better patient experience and an improved working environment for the physicians (ORCHA 2021).

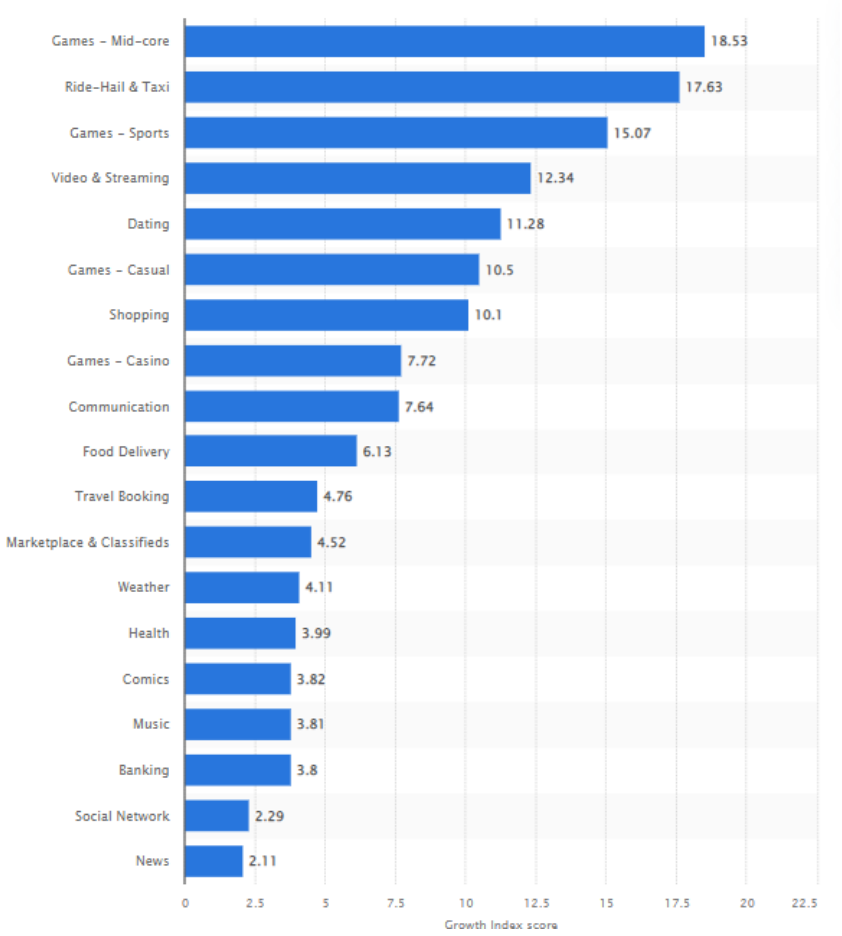

Figure 3. *Leading Android app categories in the UK 2017,(Statista, 2022)*

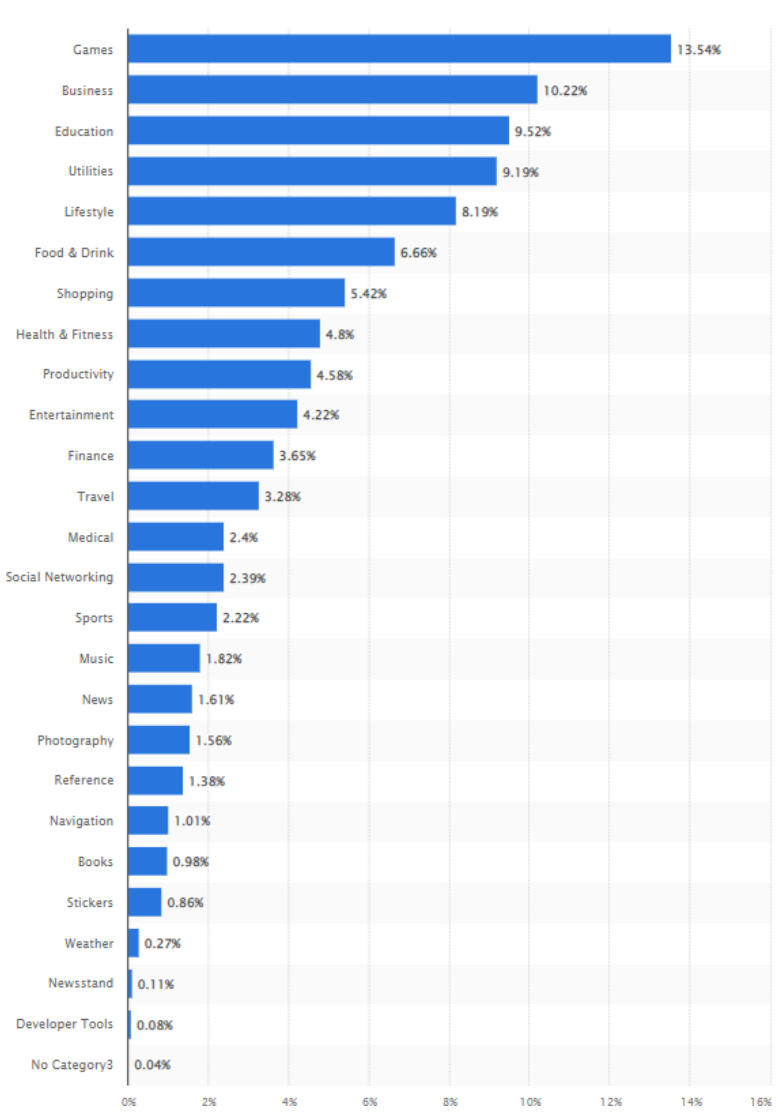

Figure 4. *Most popular app categories in 2022 (Statista 2022)*

According to Malaysian Family Physician website establishing effective communication between a doctor and a patient can result in better patient care, might decrease stress, improve emotional health, and prevent other communication challenges (Kabir, M.J. et al. 2022). Consequently, the integration of a In-App Chat widget feature is getting widely popular in many health apps.

1.3.2. Comparison between existing mobile apps on the market

An example is Medici which is a simple mobile app for patients to see their doctor virtually. As the coronavirus took hold, more GP (General Practitioner) surgeries closed for in-patient appointments and began offering only video consultations through mobile application. The health-tech company Visionable surveyed around 3000 people in 2020 and the responders are agreeing that “you do not always need to see a doctor in person to receive appropriate care (Highland Marketing 2020). The appetite for virtual appointments is getting higher in recent years and made it a preferable option among the population.

Using Medici consumers can search for and connect with their doctors or healthcare providers. From a doctor`s perspective, they can easily set up their accounts and begin connecting with patients. Regarding functionality, the app is limited only to virtual conversations. The examination of ratings and reviews shows that consumers exhibit contradictory opinions.

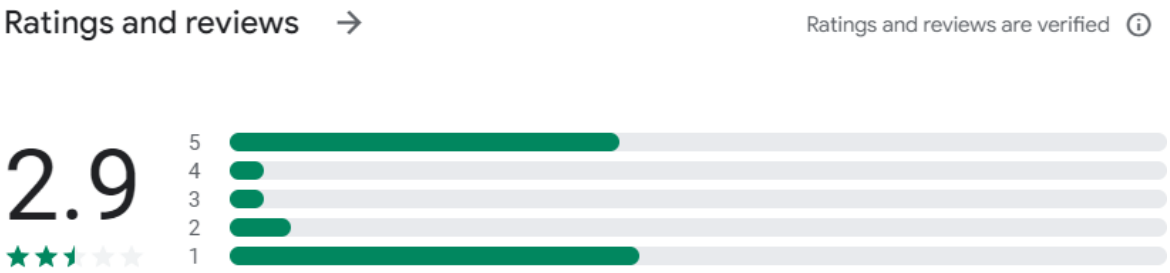

Figure 5. *Ratings and reviews of Medici for Patients (Google Play 2022)*

On the contrary, the MFine health app also offers online connecting or chatting with a doctor like Medici. The reason that it implements more features is set to be more preferred to Medici. MFine is a step further compared because it has added features like AI (Artificial Intelligence) bots, booking appointments not only for a health check but also for a lab test, Heart Rate Monitor, BMI Calculator and reminders. That is the reason it has a 4.4 Rating and 5M+ downloads compared with Medici. Nevertheless, MFine has a pricing list for some of its premium features. Setting the right price for a product is a balancing act. A premium mobile app needs to be significantly better than free alternatives to monetize from it. The market continues to grow and boom and free apps always appeal to new customers (MFine 2022).

The technology that involves mobile phones is taking speed. According to Cisco Annual Internet Report, global mobile data traffic has doubled for the fourth year in a row and looking towards the future over 70% of the global population will have mobile connectivity by 2023.
In 2019, Freaktemplate organisation released a Doctor Finder App. It is an end-to-end medical solution to find doctors, pharmacies, and hospitals near you. Undoubtedly, the geolocation implemented in the application is of utmost benefit because it supplies driving locations and shows the nearest health department in case of an emergency. However, a major downside of the inability to book an appointment or order any medications online which is a drawback in case of need. According to UNECE persons aged 65 years and older are almost 17% of the population in 2020. The proportion of the population aged over 80 is expected to double over the next thirty years. Consequently, this population trend might affect challenges in emergencies, since older people tend to be more affected (Springer International Publishing 2021).

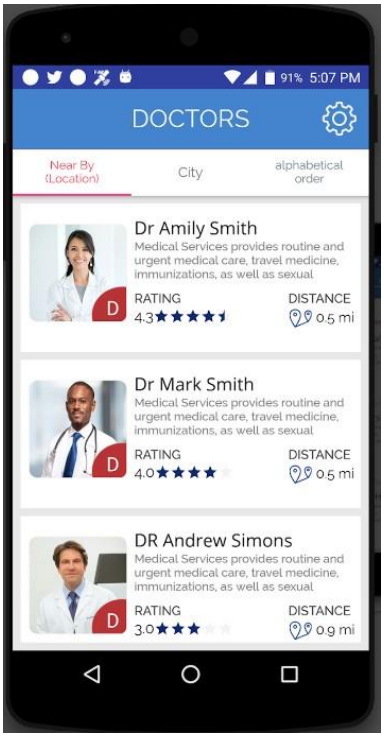

Figure 6. *List of the doctors near the user (Doctor Finder – complete medic, 2022)*

With a rating of 4.6 out of 5, ZocDoc is a two-sided popular online appointment scheduling system which widely used all over the healthcare industry. (ZocDoc 2022) It gives the patient a convenient way to book appointments on-the-go while taking into consideration the location. Also, the appointment system enables patients to reschedule appointments, receive confirmation messages, and get push notifications before the arrangement. Doctors, in turn, can choose to be listed on ZocDoc and allow the platform to access and integrate their timetables so the patient can view available slots. The award-winning app is also further preferred because it gives the user a chance to choose between an online visit or attending a hospital. A different comparison between DoctorFinder and ZocDoc shows that ZocDoc is undoubtedly more convenient, interactive, and beneficial for both patients and doctors. Furthermore, the geo-location implemented in the application is an effective way for elderly or their carers to book an appointment and find the closest hospital in case of an emergency. Consequently, one of the main goals of the current project is going to be the implementation of that feature.

Despite Zocdoc's aesthetic design and very tech approach, it does come with a few disadvantages. It is not an accurate scheduling software because it does not sync with most doctors' practice management software and does not read or write into the system (David Chen et al. 2022). Here comes the double-booking problem. It is a term when multiple patients are accidentally scheduled to see a health provider at the same time slot (Bano, R. 2022). Being double-booked might be a nightmare for everyone, especially if the patient has a surgery appointment or their life is at risk. Undoubtedly, one of the aims of the current project will be focused on valuable and correct time management to avoid duplicating appointments and causing a commotion between patients and doctors.

Teledoc looked at the possibility of pulling data from HealthKit in their application. They have spent 20 years perfecting their services and-what makes them most unique compared with the applications above is the HealthKit feature they offer (Teledoc 2022). Teledoc imports the most recent details on blood

pressure, temperature, heart rate, and average sleeping time right into the user profile. The stored information is visible to the medic during the visit. A study in 2020 reported that by directly reviewing the strip generated by the Apple Watch that visually shows a user's heart rate, doctors were able to flag more cases of abnormal heart rhythms (Seshadri et al. 2020). Therefore, Physicians, especially cardiologists, can make more meaningful evaluations with the collected data.

1.3.3. Mobile User Interface

1.3.3.1. Colour blindness

An estimated 300 million people worldwide have colour vision deficiency (ClintonEye no date). On average, one out of 12 men and 1 out of 200 women see the colour differently than everyone else (ClintonEye no date). Although many tools and concepts in the modern world support online user accessibility sometimes, the coverage of colour blindness or vision deficiency is inefficient or simply not enough. A few colour palettes are available to handle various colour vision deficiencies. For example, Trello, a web-based application, allows users to organize their tasks and activate a colour-blind mode. Briefly, it adds a simple textured overlay to the colour labels everywhere they are shown. While being a simple and lightweight feature, it is remarkably effective without changing the overall interface and feel of the final product.

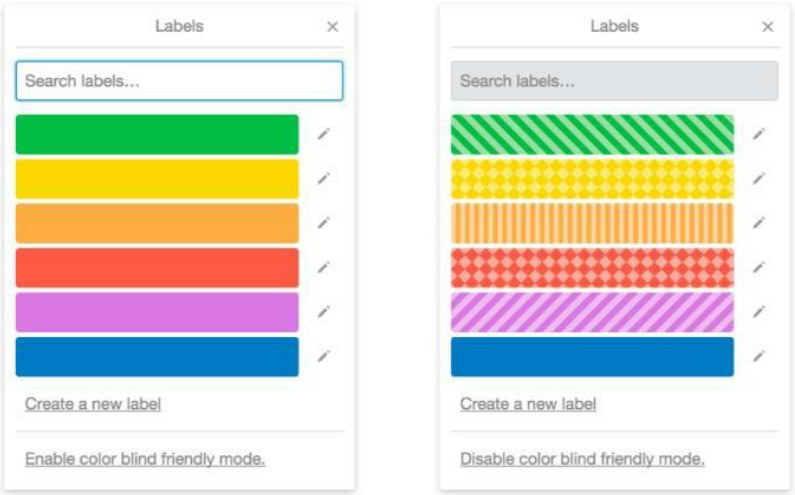

Figure 7. *The Trello interface with the Colourblind Friendly mode on/ off (Trello 2022)*

Some colour combinations to avoid for people with colour blindness include Red and Green, Green and Blue (Collinge, R. 2017). In contrast to Trello, the aforementioned Doctor Finder App has a lower level of accessibility and could be further developed. Since the app uses a red-green-blue colour combination and does not offer colour-blind mode, it could pose a difficulty for colour blind users.

Figure 8.*Doctor Finder App Login Screen (Doctor Finder 2022)*

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Regarding interface, the aim of the current project is to make a use of a modern and minimalistic design which will keep the user at ease with the product. It will be combined with colour blind friendly palettes.

1.4. Technology Stacks for Mobile App Development

There is a wide range of modern-day mobile app development frameworks. They supply built-in benefits like speed, effectiveness, and a bug-free atmosphere. One of the biggest debates that are continually going on among mobile developers is Flutter Vs. React Native and which one is better. React Native is a JavaScript-based open-source mobile application framework released by Facebook in 2015 (Maciej Budziński 2021). It is used to build some of the world`s most popular mobile apps, including Instagram, Pinterest, and Skype. Developer communities widely prefer it as it gives a clean, fluid, and responsive user experience.

Contrary to React, Flutter was developed by the tech giant Google and used Dart as a programming language. It is used for cross-platform mobile application development (Flutter no date). In other words, it allows you to create a native mobile project with only one codebase and work seamlessly in Android and iOS. A look at Google Trends results reveals a fierce battle between the two opponents. Figure 9 shows that Flutter became a more often searched query globally and continues to be so in 2022.

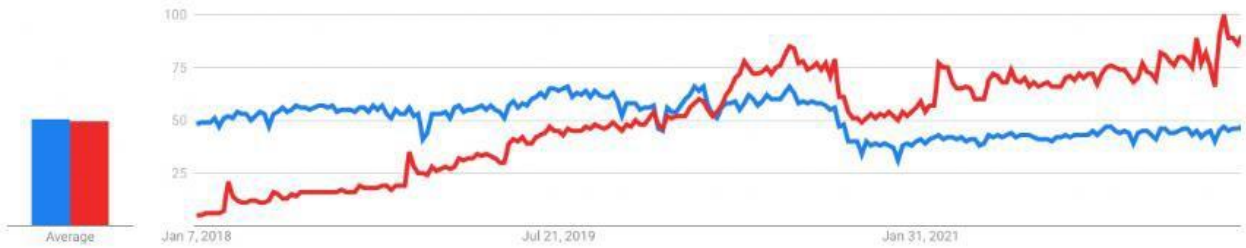


Figure 9.*Worldwide Flutter (red) and React Native (blue) popularity trend (2018–2022) (Google Trends 2022)*

The latest research from Statista proves that the new leader among cross-platform mobile development frameworks is Flutter. In 2021 Flutter surpasses React Native by 4%.

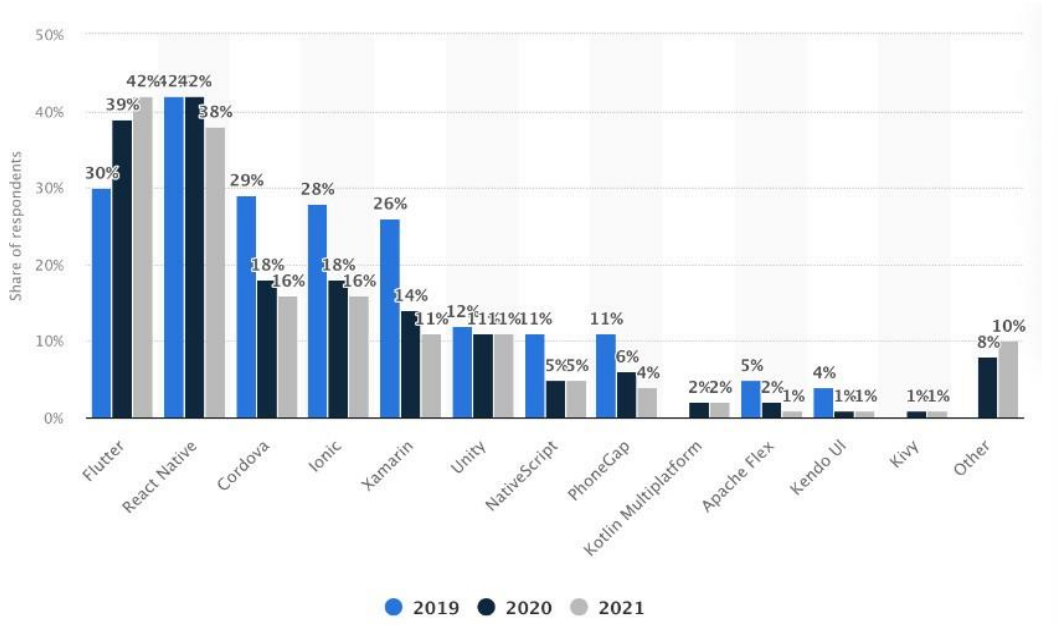


Figure 10. *Cross-platform mobile frameworks used by global developers 2019-2022*(Statista 2021)

In conclusion, the current project will make use of Flutter. It allows you to develop native iOS and Android platforms simultaneously, thus eliminating the need to write different code. Consequently, this cuts development time significantly and removes costs.

1.5. Requirements Analysis

1.5.1. Functional:

- All Users:
  - o Users must be able to create new account in the application.
  - o Users must be able to login after they created their account.
  - o Every user must be able to delete their account.
  - o Every user must be able to log out.
  - o Every user must be able to change their credentials.
  - o Every user must have only one profile associated with their email.
- Patients:
  - o Patients must be able to see doctor`s timetable with latest available timeslots.
  - o Patients must be able to book an appointment.
  - o Patients must be able to cancel/reschedule an appointment.
  - o Patients should be able to access the info page about every doctor.
  - o Patients must be able to access the BMI calculator page.
  - o Patients must be able to see their upcoming appointments.
  - o Patients should be able to see a list with their past appointments.
  - o Patients should be able to enable their geo location on the phone and search for the nearest doctor.
  - o Patients should be able to see the directions on a map to the doctor`s location.
  - o The patient should be able to see a list of all doctors in alphabetical order.
  - o Patients should receive a notification if their appointment is cancelled by the doctor.
  - o Patients should receive a notification 2h before their appointment
  - o Patients should be able to leave feedback using star rating
  - o Patients should be able to search doctors based on categories (e.g., Eye-doctor, Aesthetic
    Doctor, Cardiologist, etc.)
  - o When the user is done with the details about the appointment, they should be able to see a summary before proceeding further.
- Application
  - o The application must have a navigation menu.
  - o App must be free.
- Doctors:
  - o Doctors must be able to create a profile page filling information about their background.
  - o Doctors must be able to create a personalized timetable based on their working hours and edit it if needed.
  - o Doctors must be able to cancel an appointment (e.g. an emergency might occur)
  - o Doctors must have access to all upcoming appointments.

1.5.2. Non-functional

- Interface/ Design:
    - o The application must have simple and clean design.
    - o The application should be colour-blind friendly.
- Security
    - o The application should define a way of confidential access for example using passwords and username.
    - o The application should offer security and privacy to the users.
    - o Users must be logged in in order to interact with the bookings and other features the app offers.
- Maintainability
    - o The mobile should use standard accepted design patterns in the construction of the base architecture.
- Data storage
    - o A Google Firebase platform should be used.
    - o The system must store data effectively.
    - o The system should be responsible for taking backups
- Device requirements
    - o The mobile application should support Android OS version 4.0(API 14), IOS 14 or later
- Performance
    - o The application may be able to provide services to at least 20 users concurrently.
    - o When the application is start-up, it should not take more than 3-4 seconds to load home screen.
    - o When the application gets interrupted by call, then the information must be saved and return the same page which was there before it got interrupted.
    - o The application should be easy to use, efficient, and accessible.
    - o The application must be scalable to different screen sizes.
- Support
    - o Users should have access to contact us page in case of bug.
    - o Users could be helped appropriately to fill in the mandatory fields, in case of invalid input such as identifying the missing requirements.
- Testing
    - o The testing should involve analysing the app for functionality, usability, visual appearance, and consistency across multiple mobile devices.
- Availability
    - o The system should be available during rush hours. If any maintenance needs to be done it should be outside these times.

1.6. Conclusion

The purpose of this review is to examine the different types of booking systems in a chronological timeline and highlight their benefits and disadvantages for the community and health staff. In the real world, patients face significant problems related to appointments, registration, searching locations, and long waiting times. The research looked at useful features to prevent users from facing the aforementioned problems. The use of mobile health apps could improve not only patient satisfaction but also the functionality of the health centre and its workers. Therefore, adopting a mobile health app in healthcare settings to improve the physician-patient experience is encouraged.

2. Design & Methodology

This chapter covers topics such as user experience and types of actions included in the app. Additionally, it provides comprehensive overview of the approach and framework used in the development of the current telehealth app.

2.1. Methodology

This section will discuss the set of technologies required in the different phases of the mobile application`s workflow to develop a functional project from scratch.

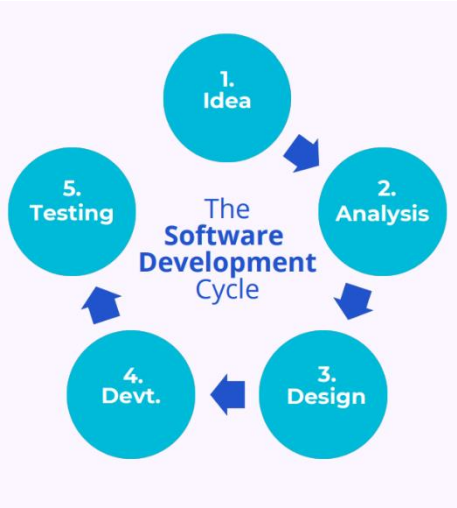


Figure 11: *App Development Stages*

Table 1: *List of technologies used to build the mobile app*

Name:	Description:
Mind Map	Using a mind map was a great starting strategy to formulate the main functionalities of the mobile app and make decisions about the technologies. This process involved writing down key user requirements, looking for connections between them, and different technological stacks. The fundamental mind app was designed using the Miro app. It is an online whiteboarding platform intended to plan and manage workflows effectively.

GitHub	GitHub is an online software development platform. It is preferable to the dev community because you can easily store, track, and collaborate on software projects. It contains powerful control versioning software so that it can handle branching and merging easily. All code changes were regularly committed during the development stage with helpful comments as shown in Figure 12.
MarvelApp	The Marvel App was used to create mock-ups and interactive prototypes for the project. With its provided features, the compatibility of the user interface and user experience were tested thoroughly. As can be noticed the mock-ups(Figure 13) use different shades of blue and white to create a sense of calm. Small details like replacing the traditional sharp lines and angles with rounded corners interfere with relaxation based on the need of the application(Tey, B., 2022).
Android Studio	The current project uses Android Studio as it is the official IDE for Flutter development. It provides a dynamic environment full of built-in features from a layout editor and a fast emulator to give a real-time experience.
Flutter & Dart	Flutter & Dart together can offer a powerful and efficient solution for creating a telehealth mobile app. Dart is a modern object-oriented language with strong static typing and can lead to the development of a more stable and secure app. On the other hand, Flutter offers a native performance allowing execution on both iOS and Android platforms. Thus, the project can reach a larger audience and increase the accessibility of the app. Some apps used with a huge volume of users based on the same technological stack are Alibaba Group, eBay and BMW (Flutter website, 2023).
Google Firebase	Google Firebase is a Google-backend application software for building dynamic web and mobile apps. It offers build tools and APIs like database management, authentication and push notifications. It is a real-time database that allows storing and syncing data which makes the users' collaboration easier. As mentioned in 3.2.5 if the app faces a high volume of users as a no-SQL database, Firebase is able to handle large data sets

	effectively. Managing a high volume of data in telehealth mobile apps is crucial to support patient data management and providing safe and secure services to patients.

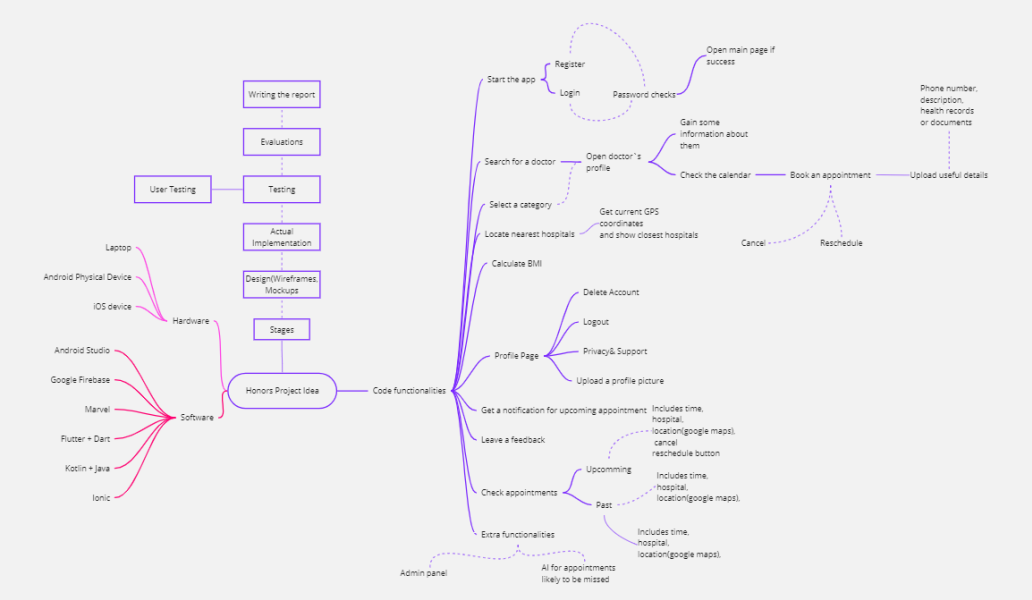


Figure 12*: Mind Map to organize some thoughts and ideas.*

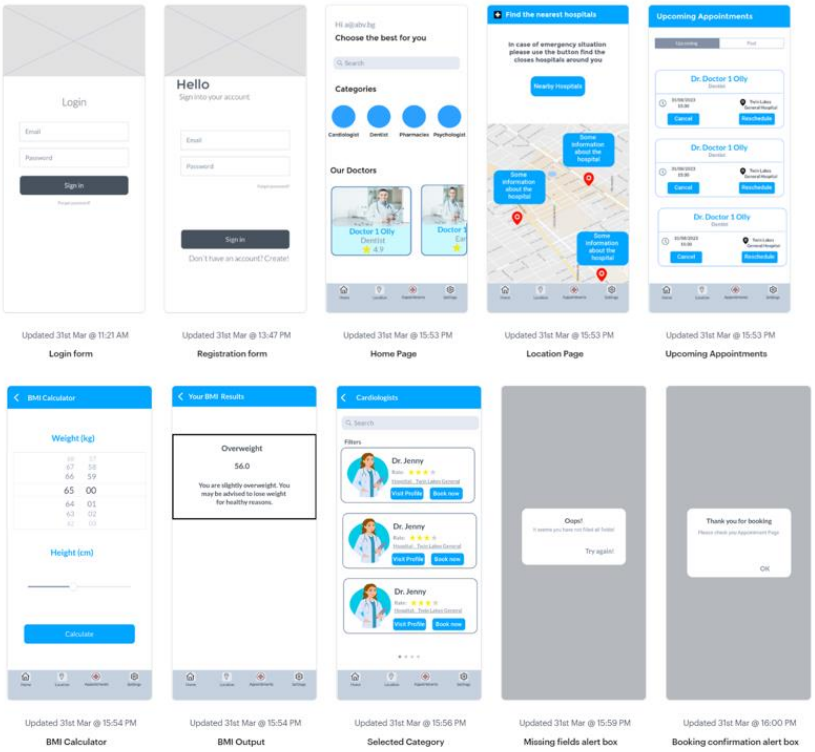


Figure 13: *Example of some mock-ups created in MarvelApp.*

2.2. Design

The design chapter provides an overview of the architecture implemented in the project, accompanied by visual representation that help to illustrate the app functionalities and their contribution to the system.

2.2.1. Architecture

The project code follows the Model-View-Controller (MVC) pattern, which involves dividing the application into three main components: models, views, and controllers. This approach results in a clear separation between the user interface and the business logic.

For instance, the model folder contains dart classes such as our_doctors.dart, which consists of an array of Doctor objects. The view folder, on the other hand, has three subfolders: assets, screens, and widgets, based on their function. All files within this folder are used to build the user interface and display data from the model.

To ensure better code separation, the controller folder has subfolders for each main functionality, such as booking, locating the nearest hospitals, or the BMI calculator. All files inside the controller layer listen to events from the view and update the model accordingly.

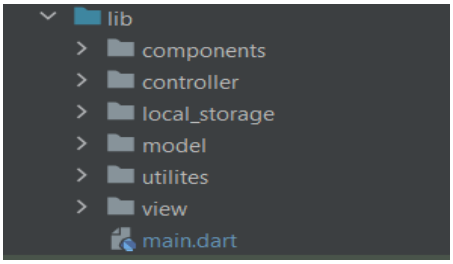


Figure 14: *Project Structure*

2.2.2. Sequence Diagram

Using such type of a diagram was very helpful to document and understand the dynamic aspects of the current project in depth. It provided clear visualizations of the workflow between the objects and discovered functionalities that were initially hidden in the diagram used in Figure 12. The figure below depicts a high level of interaction and displays the logic between the client(patient) and the program.

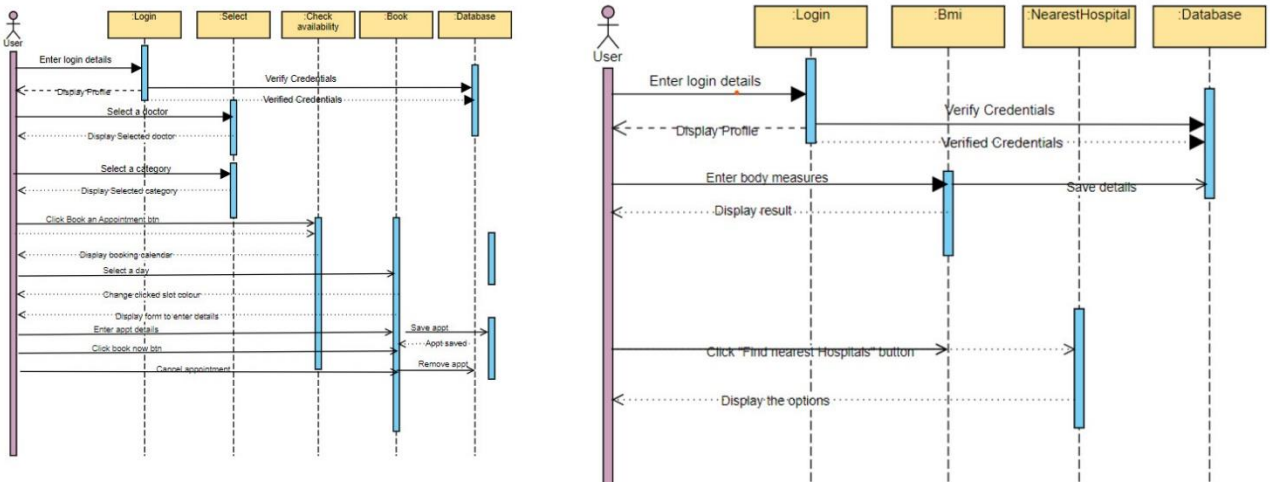


Figure 15: *Sequence Diagram showing 2 scenarios.*

One possible scenario which depicts the sequence of actions where data is passed between objects could be the following:

1	When a user is logged in the data is validated in the Firebase Authentication console.
2	The database will send them a response indicating whether the login is successful.
3	Once the user is logged in to the system, they can see the profile page and select a doctor.
4	The user selects a doctor from the category section.

5	Data is retrieved from google sheets.
6	The user checks the doctor's profile.
7	The user wants to book an appointment.
8	The user fills in the needed details.
9	The details are stored in the database.
10	Cancels the appointment because of an unexpected event.
11	Uses the cancel button to remove the appointment from the database.

Table 2: *Scenario how data is transferred during app usage*

3. Implementation

After the prototype was tested and the workflow approved, the implementation phase could begin. This chapter will be divided into two parts. The first part will provide a brief introduction how Flutter was setup and its packages according to the app's requirements. The second part will cover the creation of specific functionalities, explained with code snippets, and how different obstacles were fixed.

3.1. Application setup

This section will outline the process of setting up the needed software, including installation and configuration tasks.

3.1.1. Flutter

To set up Flutter for creating a telehealth mobile app it was downloaded from the official website and extracted to a preferred location on the computer. The path environment variable was updated to run Flutter commands in the console and running “flutter doctor” verified it is installed correctly as shown in the figure below.

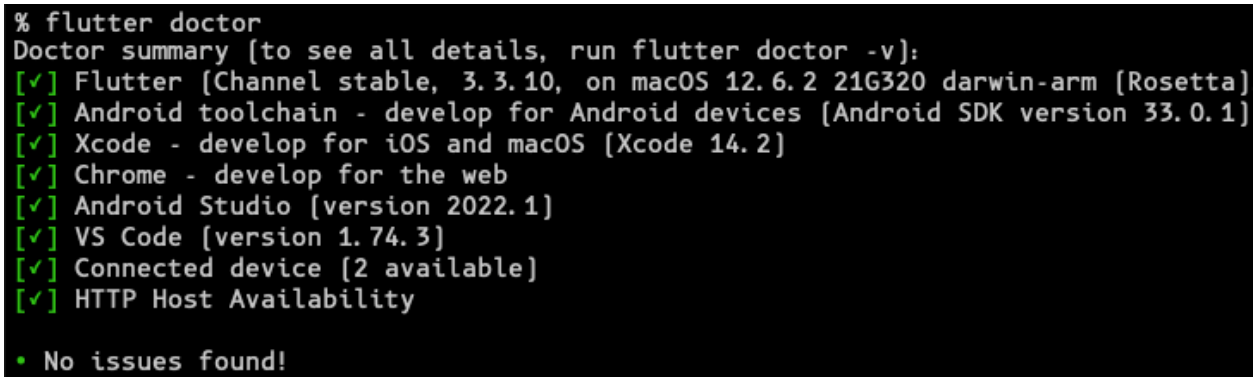


Figure 16: *Output after flutter doctor*

When the configuration was done both “Flutter” and “Dart” plugins were installed in Android Studio and the project was created following the steps from Figure 17.

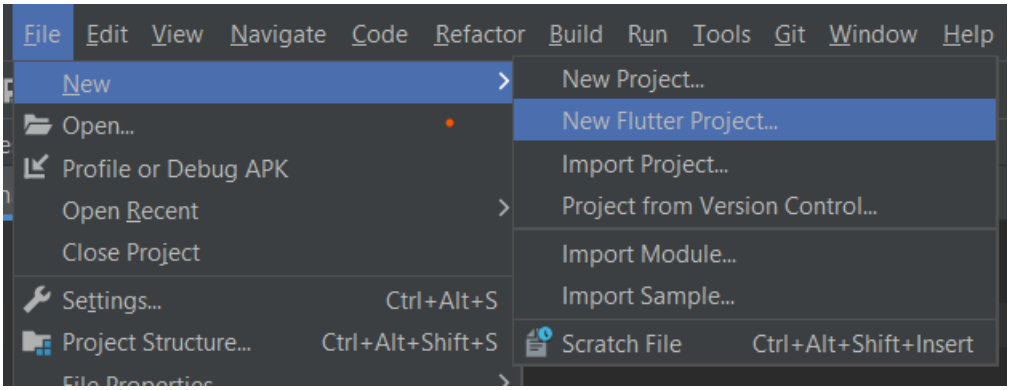


Figure 17: *Create a new flutter project.*

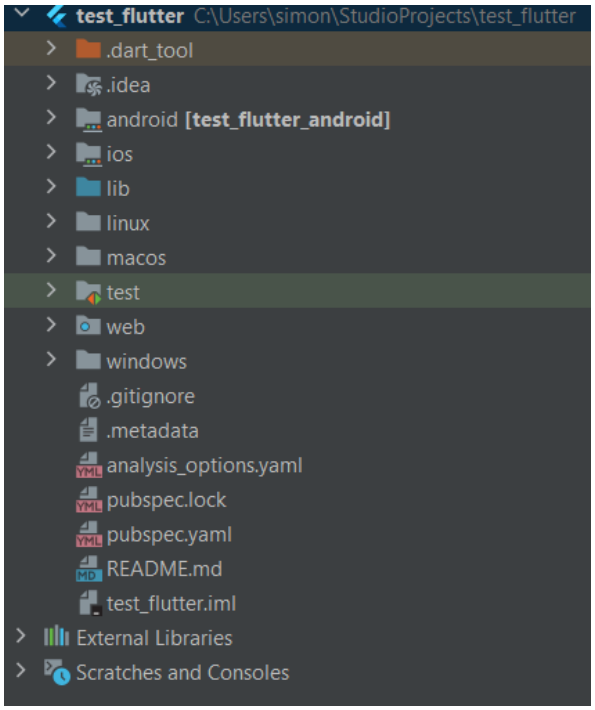


Figure 18: *Folders created by default.*

3.1.2. Firebase

As mentioned in section 3.2.2, the mobile app incorporates several essential features, including authentication, file uploading to cloud storage, and real-time data exchange with the frontend. In this process, the requested data is sent to the database for processing and displayed as a response to the clients on the app.

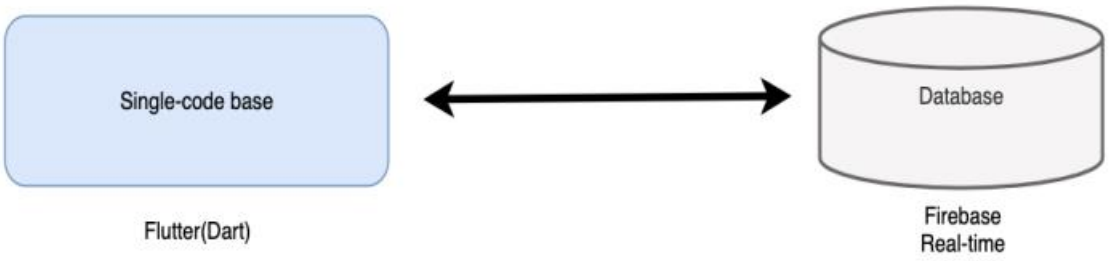


Figure 19: *The connection between Flutter and Firebase*

To meet the non-functional requirements outlined in section 3.5.2, Google Firebase was integrated as a backend. This involved creating a project within the Firebase console and downloading a 'google-services.json' file, which was then added to the Android folder. To properly set up Firebase inside a Flutter application, two additional packages were added to the pubspec.yaml file: firebase_auth: ^4.4.1, which allows access to the Firebase Authentication API for verifying users of the app, and cloud_firestore: ^4.5.1, which allows access to the Cloud Firestore API for retrieving the values of documents or collections.

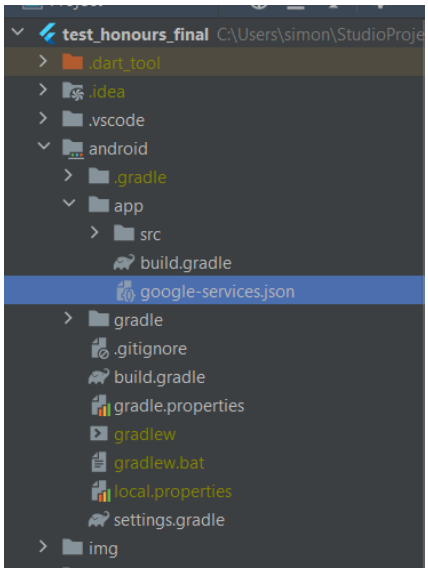


Figure 20: *google-services.json*

3.1.3. Other package dependencies required in that project.

The project relies on some software package dependencies that are available to make the development faster and make the most innovative idea possible. One commonly used package in the project was a Flutter-based library for making HTTP requests to send requests to the Google Maps API for obtaining coordinates from addresses. Another useful package was the 'provider'. This package was particularly helpful in preventing double booking and keeping slots booked when users navigate away from the page.

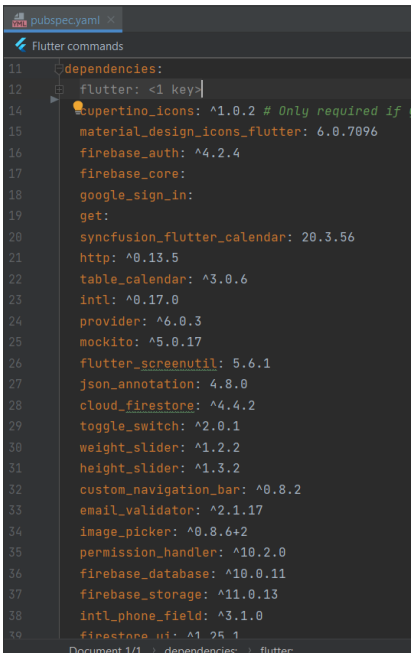


Figure 21: *More project package dependencies*

3.2. Code development

This section will outline how specific requirements have been implemented and discuss any issues encountered during the process.

3.2.1. Main.dart

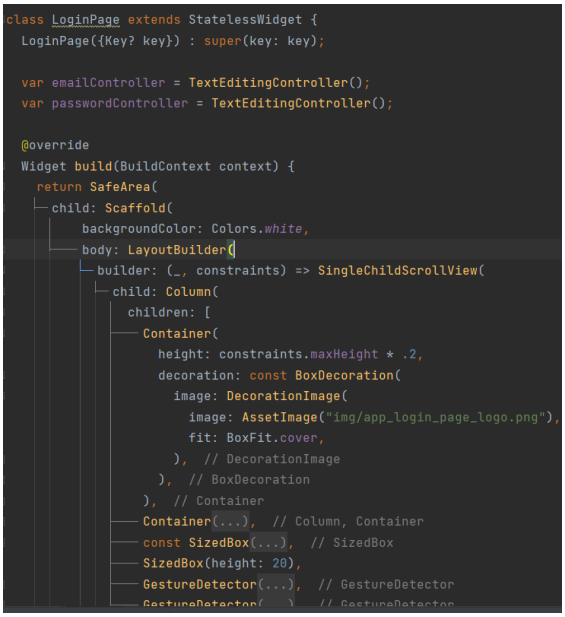
The main.dart file serves as the entry point for the Flutter application. A runApp() method was initialized, which took LoginPage() as a parameter and added it as the root screen of the app. The asynchronous main function was used to call Firebase.initializeApp() and inject the Auth Controller. The AuthController.dart file was created to store authentication properties and methods such as login() and signInWithGoogle().

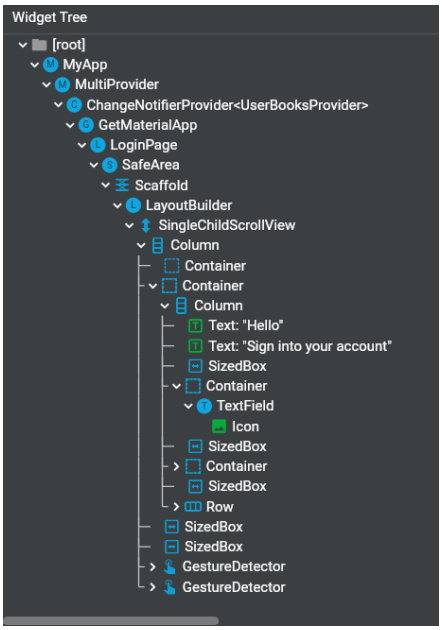
main.dart

```dart
import 'dart:core';

Future<void> main() async {
  WidgetsFlutterBinding.ensureInitialized();
  await Firebase.initializeApp().then((value) => Get.put(AuthController()));

  runApp(const MyApp());
}

class MyApp extends StatelessWidget {

  const MyApp({key});

  // This widget is the root of your application.
  @override
  Widget build(BuildContext context) {
    return MultiProvider(
      providers: [
      ChangeNotifierProvider(create: (_) => UserBooksProvider()),
      ],
      child: GetMaterialApp(
          title: 'Honours Project',
          theme: ThemeData(primarySwatch: Colors.blue,),
          home: new LoginPage()),  // GetMaterialApp
    );  // MultiProvider
  }
}
```

Figure 22: *Code snippet from Main.dart*

3.2.2. Login Interface:





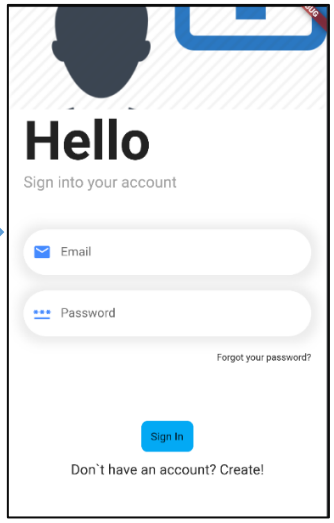


Figure 23: *Code snippet from login page*

Figure 2: *Widget tree of the login page*

Figure 25: *Login design*

The login page is the first visible screen to the user when opening the app for the first time. The login and registration processes involves managing various states such as user input, validation and displaying error messages on the screen. After a few attempts were made using the “Provider” package for state management and additional research, it was concluded that “GetX” would be a better solution. It is known for its convenient methods such as Get.snackbar() and Get.dialog() which were used later on, in showing notifications to the user.
The email and password text fields are used to allow the user to enter their credentials. The obscureText property of the password text field is set to true, which theoretically prevents anyone from looking over users' shoulders. The provided information is obtained via the two controllers and passed to the AuthController`s login method, which is responsible for authorizing the “Sign In” button when pressed, as shown in the code snippet below.

```
onTap: () {
  AuthController.instance.login(emailController.text.trim(),
      passwordController.text.trim());
},
```

Figure 26: *Login method*

If an error occurs, it will be reported on the screen using a snack bar widget coming from the “GetX” as stated above.

```
Get.snackbar("Login", "Login message",
    snackPosition: SnackPosition.BOTTOM,
    backgroundColor: Colors.red,
    titleText: Text(
      "Login failed failed",
      style: TextStyle(color: Colors.white),
    ),  // Text
    messageText: Text(
      e.toString(),
      style: TextStyle(color: Colors.white),
    ));  // Text
```

Figure 27: *Snackbar`s code for unsuccessful login*

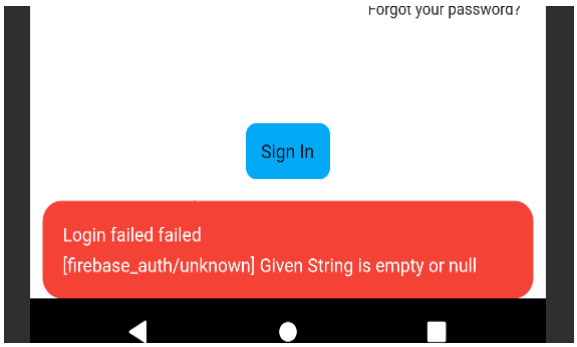


Figure 28: *Snackbar`s design*

The 'Don't have an account? Create!' container is wrapped with a GestureDetector(). In this case, when the user taps on the container, they will be redirected to the sign-up page if they are not registered yet.

3.2.3. Register Interface

Initially the signup page extended a StatefulWidget. When running the application, an error occurred with a message stating that the method 'super' cannot be invoked on a null value. After some reading and experimentation, it was learned that GetX cannot be used in combination with a StatefulWidget, as GetX provides its own reactive state management system.
As a result, the SignUpPage class extends a StatelessWidget and shares the same design as the Login Page.
If successfully registered the user accounts will be stored in the Authentication section in the Firebase console. This allows the app to save user data rapidly and securely in the cloud.

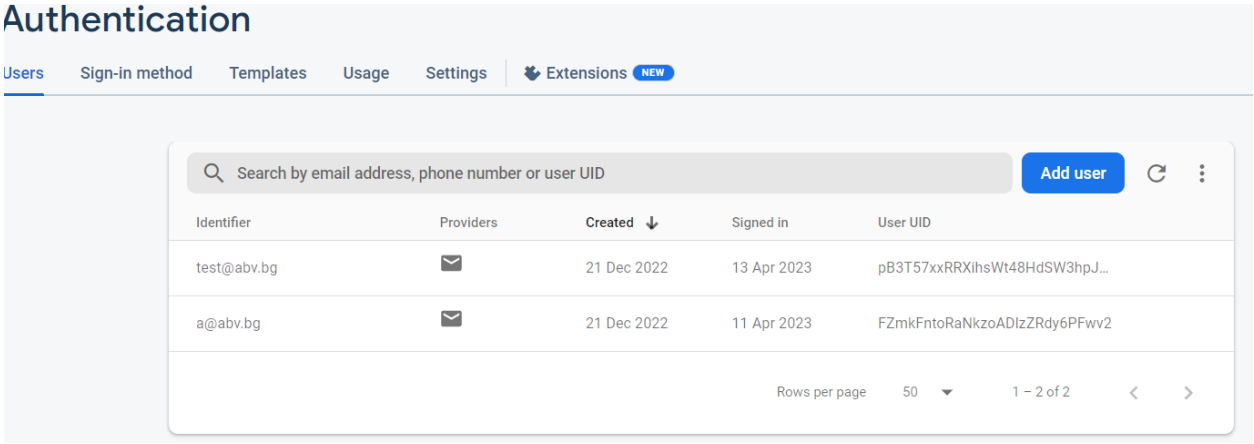


Figure 29: *Authentication Panel in Firebase*

Otherwise, a short and meaningful description will be displayed to the user.
A Wrap widget was used to horizontally align the available sign-in methods(Google and Facebook) and their corresponding images, which were added in the pubspec.yaml file. To reduce the hassle of dealing with extra fields such as creating your own username and strong password an attempt to

integrate the Google sign-in method was made. However, some issues were encountered such as the inability to close the dialogue after selecting an account and the non-authorization of the user. Despite efforts made, the functionality is not working as expected.

3.2.4. Welcome Interface

After logging into the application, the welcome_page() is displayed as part of the Flutter element tree, which defines the logical structure of the user interface. A search bar is displayed at the top, allowing the user to find the content they need.
To create a horizontal slider, a ListView.builder is used to dynamically builds a widget for each doctor-category declared in the list. Tapping on any of the items on the screen redirects the user to a page displaying content based on their selection, which is fetched from a Google Sheet.
If the user wants to have a look at some doctors and navigate to their profile for more information, they can use the functionality provided by the DoctorsScreen() class at the bottom of the page.

3.2.5. DoctorsScreen()

This class uses ListView.Builder to iterate through a list of “Doctor” objects and builds display the data inside the slider.

```
class Doctor {
  String name;
  String type;
  String patients;
  String info;
  String star;
  String imageUrl;
  String hospitalName;
  DateTime startHour;
  DateTime endHour;
  DateTime startBreakHour;
  DateTime endBreakHour;
  double apptLat;
  double apptLng;
  int duration;
  int experience;
  final now = DateTime.now();
```

Figure 30: *Doctor`s object properties*

Each created item is wrapped within an InkWell. If pressed the user will be navigated to the current doctor's Appointment Page via the onTap handler. The index of the selected doctor was passed as a parameter to the AppointmentScreen(), enabling access to it in the subsequent dart.file, which allows for generating a calendar with the appropriate timetable.

```
InkWell(
  onTap: () {
    Navigator.push(
      context,
      MaterialPageRoute(
        builder: (context) => AppointmentScreen(
            doctor,
            currentDoctorIndex: index), //TODO:  // Appo
      ),  // MaterialPageRoute
    );
  },
```

Figure 31: *Navigating to Appointment Screen*

3.2.6. Appointment Screen:

The AppointmentScreen() offers the ability to learn more about the physician and book an appointment by clicking the "Book Appointment" button which leads to the calendar screen.

3.2.7. BookingCalendarApp Screen

The screen is used to schedule appointments using an interactive and easy-to-use interface.

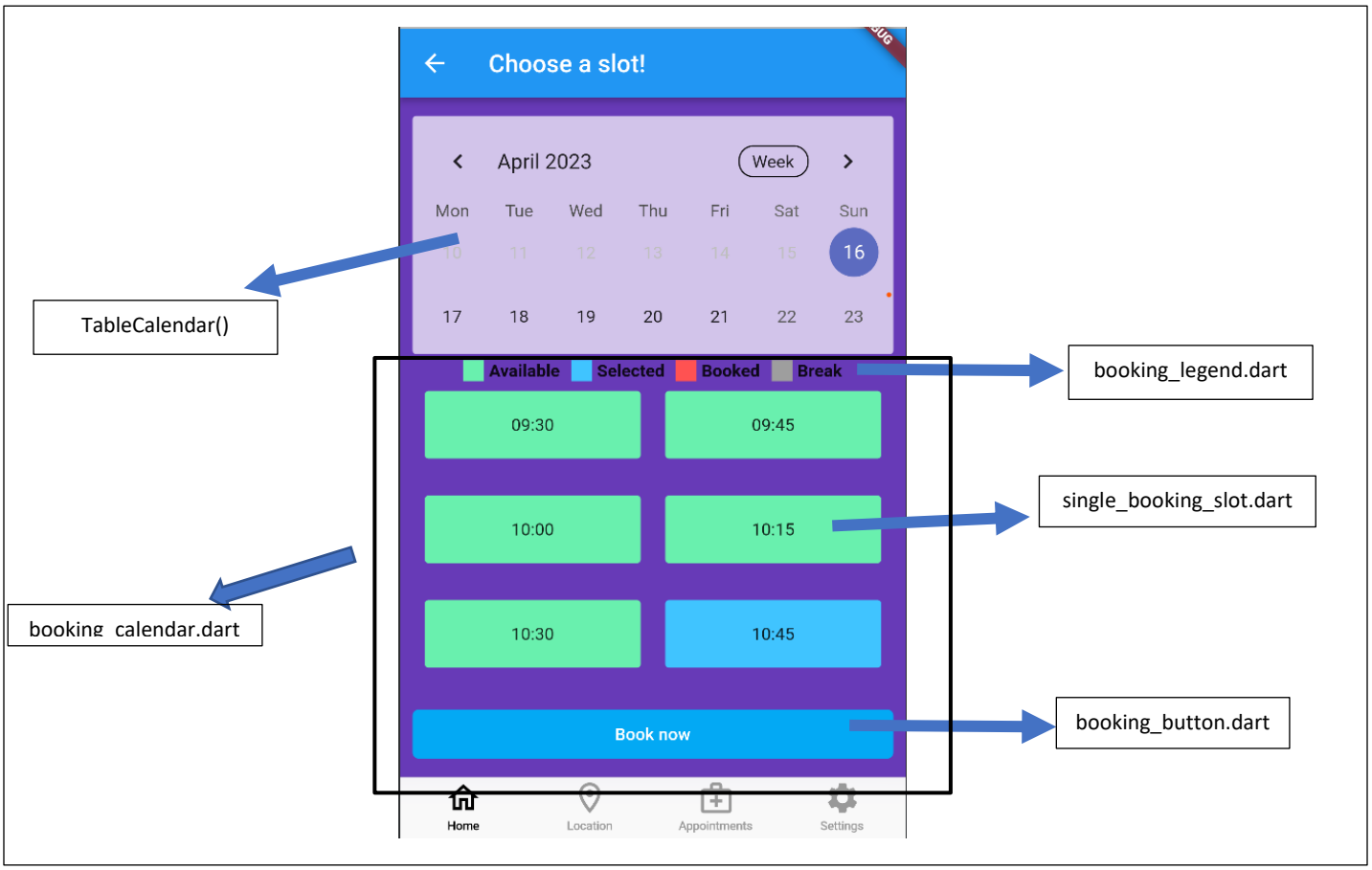


Figure 32: *Booking calendar structure.*

It is a combination of controllers and widgets with different functions and visual elements as shown in the figure above. Any changes on that screen like different slot colours when clicked/booked, number of slots or disabled ones if it is a break time depend upon the logic declared in booking_contoller.dart. This model class extends a ChangeNotifier and provides change notifications to its listeners.
To make the BookingController accessible in booking_calendar.dart, it is wrapped with a ChangeNotifierProvider.

```
@override
Widget build(BuildContext context) {
  return ChangeNotifierProvider(
    create: (_) => BookingController(
        bookingModel: bookingService, breakSlots: pauseSlots),
    child: BookingCalendarInterface(
      key: key
```

Figure 33: *Dependency Injection*

In this example, the create parameter takes a callback function that returns an instance of the BookingController. The BookingController will then be available to the widgets and any changes made to the BookingController will trigger change notifications to its listeners.

3.2.8. Appointment Details Screen:

That screen involves a text field, ImagePicker and a phone field. If the camera icon is clicked it will call onPressed callbacks that will open the camera and the user can take a photo of the necessary documents.

```
IconButton(
  onPressed: () async {
    ImagePicker imagePickerObject = ImagePicker();
    XFile? healthRecordImage = await imagePickerObject
        .pickImage(source: ImageSource.camera);
    print('${healthRecordImage?.path}');

    if (healthRecordImage == null) return;

    String uniqueHealthRecordImageName =
        DateTime.now().millisecondsSinceEpoch.toString();

    Reference healthRecordsRoot =
        FirebaseStorage.instance.ref();
    Reference referenceDirImages = healthRecordsRoot
        .child("past_health_records_collection");

    Reference healthRecordToUpload = referenceDirImages
        .child(uniqueHealthRecordImageName);

    try {
      await healthRecordToUpload
          .putFile(File(healthRecordImage!.path));
      healthRecordURL =
          await healthRecordToUpload.getDownloadURL();
      print("Successfully added image");
    } catch (error) {
      print(error.toString());
      print("Unsuccessful");
    }
```

Figure 34: *Take an image of a document related to the appointment.*

Pressing the “Submit” button will store the selected time slot from the previous screen and the appointment details in the database. If there are missing fields an appropriate message will be displayed on the screen.

3.2.9. Appointments List Screen:

On the top of the screen, a convenient button that allows patients to view all their past appointments was implemented. Initially, a ToggleButton group with two buttons(Upcoming and Past) with a single selection at a time were used, inspired by modern app design patterns. However, using stream builder together with toggle buttons lead to time-consuming issues so they were replaced with an Elevated button for a more efficient solution.
Small generated boxes displaying information for upcoming appointments are displayed after that. A StreamBuilder was used to fetch the data from Firebase and visualize it on the screen using ListView.builder. Using the StreamBuilder a query to the database was performed and gave access to the documents in the collections so we can approach the needed fields. To enhance usability, when the user clicks on the hospital name the openApptMap() method is triggered. It retrieves the latitude and longitude coordinates from the local storage file(our_doctors.dart) and constructs a URL. The method generates a Google Maps view enabling the patients to easily follow the directions.
A “Cancel” button was implemented to provide the users with flexibility and let them modify their choice.

3.2.10. Nearest Hospitals Screen:

This screen involves locating the nearby hospitals. The Scaffold method contains a button at the top of the page, and when pressed, it makes an HTTP request to the Google Maps API using the “http” package. Initially, to make the screen more interactive, a Google Map widget was integrated but it resulted in a white screen when starting the app. An attempt was made to fix the issue by adding the widget in a fresh Flutter project as suggested in some forums, but unfortunately, it did not resolve the issue. After spending considerable time debugging it was switched to a simpler approach (current solution).

3.2.11. BMI Calculator

Text fields for weight and height are placed within a Scaffold Widget. When the data is filled and calculated the final results are displayed on the screen so the user can be informed. Initially, weight and height sliders were implemented. Due to state management issues when passing the values from the sliders to the controller file for calculation they were replaced with text fields.

```
// child: WeightSlider(
//   weight: weight,
//   minWeight: 40,
//   maxWeight: 120,
//   onChange: (val) => setState(() => this.weight = val),
//   unit: 'kg', // optional
// ),
```

Figure 35: *Weight slider code.*

3.2.12. Profile Page

The profile page is structured with four elevated buttons, designed to serve as an information panel. Clicking on the top three buttons takes user to pages that contain content related to privacy policy, logout, and account deletion. This content is related to the discussion in 6.1.2.

4. Testing

This chapter is divided into two parts and will discuss the different tests performed during the 5th stage – Testing(Figure 11). The first part discusses the feedback gathered from a small focus group and provides an example of a test case template used during the process. The second part discusses the testing of a small portion of the app.

4.1. User testing

User testing was a crucial aspect of the whole project. It involved testing the product and analysing and measuring the user experience comprehensively. As a result, valuable insights were yielded. For example, identification of errors based on different user behaviours, areas for improvement and elements that frustrate or confuse the users.

To gather valuable feedback Quota sampling has been used as a method for recruiting participants in the survey. A small group of people participated in the testing stage. They matched desired characteristics such as different age groups, technical knowledge and likelihood to use the app in real-world scenarios.

During the testing, every user used their own phone to measure the flow of data between different devices. All devices used for testing were based on the Android platform.

All users were provided with an Excel sheet that included the following information:

Test Case Title	Informing the user what to expect
Test Steps	Detailed instructions about specific steps they need to perform
Test Data	Data they can use as an example while performing the tests.
Passed (Yes/No)	A field where users can assess the test case.
Design Preferences Notes	Design Preferences Notes: The testing also focused on the user experience with the interface design. Users were encouraged to provide feedback in this field, expressing what they would change regarding design and visual elements or what confused them.

Table 3: *Test case guide*

The following functionalities have been included in the testing stage:

- App launching
- Login
- Registration
- Select a doctor from the home page
- Book an appointment
- Provide appointment details
- Check upcoming and past appointments
- Check the nearest hospitals
- Use the BMI Calculator
- Logout and Close the app

During the testing phase, the users were intentionally put in situations to “break” the app in order to identify potential errors and vulnerabilities. The instructions in the Excel sheets encouraged them to use wrong data, leaving fields blank and other various errors to see how the app reacts to “bad” user behaviour. This approach contributed to in-depth testing, helping to identify and address potential issues and thus improve the overall performance and user experience.
Extra testing has been performed to determine the nearest hospitals. The latitude and longitude coordinates were also tested at Robert Gordon University – outside of the typical developer environment to ensure their accuracy.

4.1.1. User Testing Results

After summarizing the feedback from the users regarding the app’s performance some important issues were identified. Following are some reported bugs, usability problems and some suggestions that were considered as important and potentially added to the final version of the application:

- Bugs
    - All users experienced an issue with booking time slots where the same time slot is booked for multiple days. After the code has been carefully reviewed it was found out the issue is caused because of incorrect logic in the booking_inderface_widget.dart. The booked slot is carried over the next days without properly resetting and clearing the state related to that slot.
- Usability Problems
    - All users reported difficulties in understanding the displayed error messages on the screen during the login and registration process. They described them as “very technical”. After conducting further investigation, it was discovered that the error message displayed on the screen is intended for developers and is not formatted in a way that is user-friendly. This feedback highlighted the importance of simple and clear messages so the client can get the correct actions and fix the problem.
    - Several users described the legend entries text on the calendar as “not visible”, because they found the black font colour hard to read. This may require increasing the text size and improving the current page colours to obtain contrast between the elements for better usability.
    - User would like to see their name on the initial screen rather than the email. This feedback requires adding an extra name field during the registration process.
- Other feedback
    - Users would like to have a sorting function in the Location screen so they can categorize the nearby hospitals by popularity.
    - Users want to be able to check all of their submitted health records in the app.
    - Users want to have the ability to clear their past appointments
    - Users would like to add doctors to their favourites.
    - It was suggested to replace the hospital coordinates with a street name or a link to the website similar to the approach applied in the Appointment screen.

4.1.2. Test case template

Test Case ID:							
Test Cases - Honours application							
ID	Test Case Title	Test Steps	Test Data / This is an example/ It is recommended to use other values	Expected Output	Passed (Yes/No)	Design Preferences Notes	How was fixed?
HP_1	Initial app launching	Click on the app icon		Registration Form			
HP_2	Create a registration with valid credentials.	1. Insert an email 2.Insert a password 3. Click on Register button	useremail: username@gmail.bg pass:1900745	Home page is displayed			
HP_3	Create a registration with 1 missing field	1.Insert only a username	email: username@gmail.bg	Relevant Error message is displayed on the bottom of the page in red			
HP_4	Verify login with correct credentials	1. Insert an email 2.Insert a password 3. Click on login button	Use the data used in HP_1	Home page is displayed			
HP_5	Verify login with incorrect credentials	1. Insert email 2.Use incorrect password	useremail: username@gmail.bg pass:1900748	Relevant Error message is displayed on the bottom of the page in red			
HP_6	Create an account via Login Form	1. Click on "Don`t have an account? Create!	useremail: username@gmail.bg pass:1900748	Redirected to Registration Form			
HP_7	"Our Doctors" Section	Scroll horizontally		More doctor profiles should appear			
HP_8	Select a doctor from the slider	Scroll horizontally, click on a random doctor from the options		Info page for that doctor should be displayed			
HP_9	Check doctor`s availability	1. Repeat HP_7 2.Click on Book an Appointment 3. Expand the calendar 4. Click on different slots 5.Click on a "Break" slot		You should see a calendar, a legend and time slots. The time slot should change the colour			
HP_10	Booking an appointment/in the next days/	1. Repeat HP_8 2.Select available time slot for a specific date from the calendar after todays date 3. Click on Book Now		You should be redirected to "More Details " page			
	Submit	1.Add a description 2.Click on the camera 2.1 Your phone camera should be opened 2.2 Take a photo of any document 2.3 Click on the submit icon 3. Enter your phone		Pop up message displaying confirmation should be displayed			

Figure 36: *Screenshot from a blank test case template.*

4.2. Unit Testing

Unit testing is a software development process associated with testing small components of the application during the implementation stage(Dāsa, R, 2016). Flutter`s hot reload feature was used to quickly test how the app behaves on different screen sizes and when the user interacts with it. This helped to experiment and debug faster.

5. Reflection & Evaluation

This section will be divided into two parts. The first part will discuss potential issues and prevention strategies to develop a more effective solution. The second part will provide an overview of the strengths and weaknesses of the project.

5.1. Reflection

Creating a telehealth mobile app that will be used by people requires careful consideration of different ethical manners to provide safe healthcare services. World Health Organization (WHO) highlights that adhering to ethical principles is crucial to protect the dignity and welfare of all projects involving human beings.

Further discussion will follow to explore how these principles can be integrated with the current functionality of the app.

5.1.1. Ethical

The application uses various methods to calculate the doctors availability based on their start and end time, appointment duration and break time. Wrong calculations might result in false bookings and leading to potential harm, which is a prerequisite for ethical issue. Consequently, the app should offer accurate and up-to-date information by regularly reviewing and checking the calculations.

5.1.2. Legal

The development of a doctor panel that requires proving their reference number before they offer health services in the app is taken into account. This approach will ensure that the physicians listed on the app are licensed and verified according to the local regulations.

The telehealth app allows users to upload files such as medical images or documents Since these images are stored in the database, users should be granted the right to access and delete them in compliance with GDPR regulations and be informed how their data will be used.

5.1.3. Social

As mentioned in 3.1.5, if the project encounters high volume of users, it might result in a diverse population, including individuals with disabilities. As a result, it is important to ensure that the app is free from discrimination and provides equal health services to all users, regardless of their abilities and nationality.

5.1.4. Professional

A professional issue that has been further researched is the use of push notifications to inform individuals about their upcoming appointments. This automated reminder will prepare the patient for the upcoming visit and enhance the in-app communication.

5.2. Personal Evaluations

Several aspects went well in the project. Regular supervisor meetings, combined with brainstorming sessions and a clearly defined timetable, contributed to a smooth and efficient process. Creating mock-ups and different diagrams before the actual development helped me to better understand how the functions will look and work together. Experimenting with different Flutter widgets in combination with third-party services contributed to new knowledge and offered a seamless experiences to the users. Another aspect that went well was the quick adapting to Dart, as it is similar to Java. This made it easier to learn and apply in the telehealth app project.

I encountered some challenges during the project. At the beginning, there was no defined architecture. The code was stored in two folders, “screens” and “ widgets”, without clear separation between the front end and back end. As the development progressed, it became apparent that proper file organization is needed, as it was time-consuming to search through files when debugging an issue. I decided to go for MVC architecture as I had experience with it and it is recommended way to organize any Flutter code.

The booking system took a significant amount of time because it required advanced knowledge of state management patterns. As a result, I prioritized certain functions so I can have time to familiarize myself with them before starting to build the booking system. I realized that starting with simpler projects to learn the fundamentals of state management patterns could be beneficial before tackling more complex projects like the booking system. The method I approached was creating a file widget for each visual element on the booking screen for better readability and debugging. I used the package provider, which is the preferred choice for updating state across multiple widgets. This approach was implemented in various booking systems such as restaurant and hairdresser, where the majority of them utilized the same provider.

When the database was integrated a few issues were encountered, as the app failed to start on the emulator. After reading the posts from the Flutter community, I learned that the issue was related to the type of emulator. Although it was switched to another Android Emulator, ensuring the device is connected to the Wi-Fi the issue still was not resolved. After further research, I switched to a physical device, which ultimately resolved the problem.

Upon further consideration, I realized that my approach of storing doctor's details in a large array list is not elegant. Instead, creating a collection with the necessary details and fetching them from Firebase would be a better solution as I can take advantage of its powerful querying capabilities.

If I had known about the flutter_pw_validator package earlier I would use it to add password validation with pre-defined rules.

The method for displaying past appointments is suboptimal, as it repeats a significant amount of code from the upcoming appointment page, with the addition of an 'if' statement to render appointments after the current time. In my opinion, a better approach would be to combine both solutions into a single page to avoid code repetition.

6. Limitation

The current project is a good starting point for offering the basic functionalities for a telehealth mobile app. While the system satisfies the majority of the initial requirements, there are opportunities for improvement, particularly in the prevention of double booking and the optimization of its design. Although it is functional, there are some stage management errors that need to be fixed.

As mentioned In 6.1.5, some requirements were prioritized, including the ability for doctors to have their own app portal to register. This feature was temporarily replaced with hardcoded data and requires further development.

The requirement for editing personal details has not been implemented yet. However, it is considered in the development process as the necessary data is successfully stored, and the next steps involve fetching and implementing the functionality into the profile page.

Storing the booking details in a date format rather than string is one more limitation that should be mentioned as it might lead to the ethical issue discussed in 6.1.1.

The development of the interface responsible for displaying additional doctors based on a category (as shown in Figure 37) has been started but remains incomplete due to issues displaying the fetched fata from a google sheet to a ListView.builder.

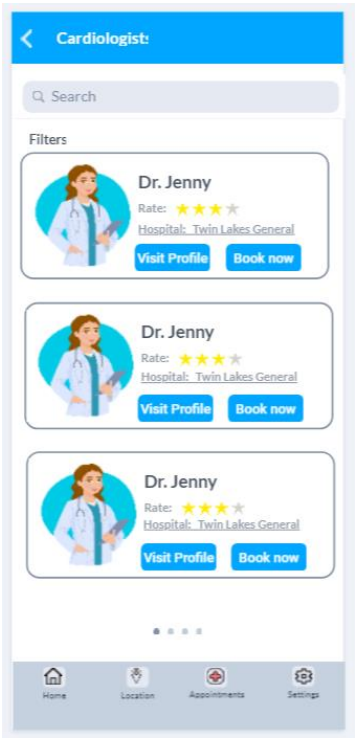


Figure 37: *Selected category page(mockup)*

7. Future work

The project's development is currently on hold at this stage. However, based on the initial research and the analyzed feedback from the users a list of features that would be valuable for the telehealth app`s purpose have been considered.

- If the number of physicians offering their services increases, sorting feature will become increasingly important. Although that was stated as a requirement, it was not implemented, and suggested from users during testing emphasized its significance. Allowing users to filter doctors based on factors like experience or category would prevent them from having to scroll through large amounts of data.
- As mentioned in the research (3.2.2 section) some of the most popular health apps have Google Fit and Apple HealthKit integrated into their systems. Accessing data points from this APIs and displaying under the user profile when an appointment is booked is definitely a functionality that will be approached. This would provide doctors with a more comprehensive and personalized view of their patient health data.
- By setting up a doctor panel that includes a verification system, will not only automate the process of adding physicians to the app but also avoid the legal concerns outlined in section 7.1.2.
- In order to provide additional security measures, it is recommended to include the integration of Google Sign-In in the future work, as the initial attempt to implement it has not been completed yet.
- Lastly, a critical feature that will be implemented in future work is the overriding of some packages to ensure compatibility with iOS devices. Additionally, extra testing will be conducted to guarantee that the project provides the same environment for both iOS and other platforms.

This project is intended for academic purposes only and has not been approved by the relevant regulatory bodies. The author cannot be held responsible for any misuse of the project.

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8. Appendices

Appendix A

Detailed Project Proposal

Defining your Project

1.1 Project title

Mobile applications and the digital transformation of healthcare.

1.2 Background

It goes without saying that smartphone usage is rapidly growing in many areas including the healthcare system with a high number of potential and realised benefits. In the past few years, we all observed the adoption of digital health apps and how this process enhanced the interaction between patients and healthcare providers across different aspects. However, there are still many medical institutions in different developing countries around the world that face issues like overtime for medics, and long hospital wait times which places great stress on clinic staff as well as a heavy workload for administrative personnel. Consequently, this has led to the creation of a wide range of mobile and web-based apps which automate the booking and appointment scheduling processes and makes them run more efficiently. There are many medical emergencies which arise in our daily life and require the nearest doctor around the patients. By using the Internet and different mHealth apps the patient is offered the routing feature which provides the option of reaching the nearest doctor in the fastest and most convenient way. There are different kinds of applications for both IOS and Android which helps the patients to locate the nearest doctors. The closest position is calculated with a built-in feature of GPS in smartphones and finds the path from their current location through any navigation and mapping tools with the use of a location API. During the research on different mobile apps on the market, a must-have feature appears to be a BMI calculator. It`s a useful tool for patients to know whether their weight is in healthy proportion and for the GP to determine and risks the patient may face if it is outside the healthy range. The right information at right time saves lives, So an E-health mobile app which combines key features could satisfy users' needs to a great extent and provide a platform for perfect doctor-patient management. This project is important because technology, when combined with healthcare, contributes exceptional results, offers better and smarter ways to deliver services to a large number of people and last but not least prevents the issues mentioned above. It will help anyone to book an appointment instantly based on the doctor`s available time slots and receive a notification. Patients can search for the nearest doctor around their current area based on a selected category and rate or post reviews on the doctor`s profile. This app will be beneficial for medics as well. They can keep track of their appointments and save time. Moreover, both sides can change their personal information, and login credentials or delete the account. The app will offer a chat where patients and doctors can communicate if necessary. Scheduling appointments appropriately, communicating freely with the medic and sharing your honest opinion are one of the many vital steps in enhancing the process of hospitals` service delivery.

1.3 Aim & Objectives

Example:
Aim: To create a functioning attendance application that efficiently automates the taking of class registers.
Objective 1: Study existing register system in place at RGU and identify weaknesses
Objective 2: Research existing automation technology's and identify and evaluate those that may be appropriate to taking in class registers
Objective 3: Implement chosen technologies to create prototype application
Objective 4: Conduct user trials to evaluate capabilities of prototype application
Objective 5: Create a refined application incorporating feedback from user trials

Aim: To develop an effective mobile app which delivers better interaction between the doctor and patients.
Objective 1: Research existing mHealth apps on the market and identify weakness and strengths.
Objective 2: Conduct a focus group to identify the criteria by which people prefer to choose their doctors.
Objective 3: Implement chosen technologies and create user friendly wireframes.
Objective 4: Create User Flow Diagrams for each user to capture their major actions.
Objective 5: Development
Objective 6: Prepare test cases that address all aspects of the app and perform the testing.
Objective 7: Additional testing on different locations.

1.4 Tools & Technologies

Figma, Android Studio, GitHub,

Flutter + Dart

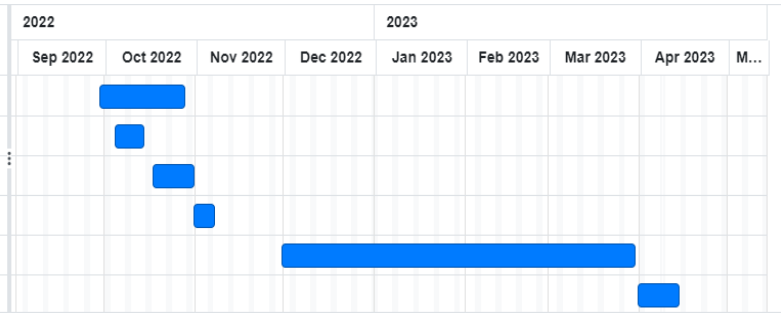
or

Java,

The Google Firebase platform, MongoDB

1.5 Project Plan

ID	Name	Start Date	End Date	Duration
1	Research existing mHealth ap…	Sep 29, 2022	Oct 28, 2022	22 days
2	Conduct a focus group to iden…	Oct 04, 2022	Oct 14, 2022	9 days
3	Create user friendly wireframes	Oct 17, 2022	Oct 31, 2022	11 days
4	Create User Flow Diagrams fo…	Oct 31, 2022	Nov 07, 2022	6 days
5	Development	Nov 30, 2022	Mar 30, 2023	87 days
6	Testing	Mar 31, 2023	Apr 14, 2023	11 days



Appendix B

Honours Poster

The poster created for the Honours is added on the next page

Mobile applications and the digital transformation of healthcare.

Simona Georgieva & Dr John Isaacs

Introduction

This project focuses on the development of a mobile application which allows and enables the patient to have a real-time scheduling of appointments with a doctor and gain valuable experience using different built-in features.

Aims

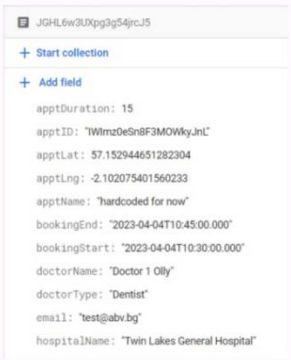
Although we live in the Information Age, many people still search for prescribed medications or wait to see their doctors for extended periods of time. One of the main aims of the project is to replace the traditional queue management system in countries with low access to digital healthcare and thus ease the pressure on the reception. Moreover, the app is focused on improving the doctor-patient interaction and providing fast and adequate services. Allowing the user to upload their recent health records and useful medical information is a necessary tool for the medic to diagnose the condition and prescribe appropriate treatment during the procedure. My hope is that the application will bring current innovations to some developing countries and represent a good starting point for further developments and bringing the metaverse in healthcare.

Methods

In order to come up with an intuitive and clean design, mockups have been created using the Marvel App. The technology stack used through the app development stage includes Flutter, Dart and Google Firebase

Diagram showing how the app and the database link together.

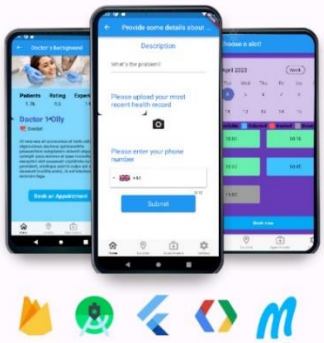
Furthermore, connecting Flutter with Firebase is a very powerful technological combination for creating highly scalable and up-to-date content. Using Flutter hot reload feature the app interface has been validated thoroughly with a series of testing criteria whereas the functionality has been tested using mobile app usability testing(including actual users).



Document sample representing a booking model

Conclusion

The project has been able to successfully offer convenient telemedicine services and bring together patients and physicians at any time. The mobile app gives the opportunity to maintain your health condition as well as use it in an emergency situation. The application provides useful information about different doctors including their background which is essential to good decision-making for the patient. To enhance user experience, each hospital`s GPS coordinates have been linked with Google Maps for detailed information about the location.



If I was going to continue developing my project, I would like to implement Artificial Intelligence (AI) that predicts whether an appointment is likely to be missed based on a wide range of external insights such as weather, traffic and previous experience with that patient.

Acknowledgments

I would like to express my special thanks to my supervisor John Isaacs for his time and efforts provided throughout the year.
I sincerely appreciate my parents' support, especially during my last semester of graduate studies.

RGU SCHOOL OF COMPUTING

Computer Science
BSc (Hons)

Appendix C

Link to the GitHub repository

Serve as a proof to my code and project log.

Appendix D

Ethics Form

You must include in your signed ethics form in this submission, or you will not be able to continue the project.

STUDENT PROJECT ETHICAL REVIEW (SPER) FORM

The aim of the University's *Research Ethics Policy* is to establish and promote good ethical practice in the conduct of academic research. The questionnaire is intended to enable researchers to undertake an initial self-assessment of ethical issues in their research. Ethical conduct is not primarily a matter of following fixed rules; it depends on researchers developing a considered, flexible and thoughtful practice.

The questionnaire aims to engage researchers discursively with the ethical dimensions of their work and potential ethical issues, and the main focus of any subsequent review is not to 'approve' or 'disapprove' of a project but to make sure that this process has taken place.

The *Research Ethics Policy* is available at
www.intranet.rgu.ac.uk/credo/staff/page.cfm?pge=7060

Student Name	Simona Georgieva
Supervisor	John Isaacs
Project Title	Mobile applications and the digital transformation of healthcare.
Course of Study	Computer Science
School/Department	School of Computing

Part 1 : Descriptive Questions			
1	Does the research involve, or does information in the research relate to:	Yes	No
	(a) individual human subjects	x	
	(b) groups (e.g. families, communities, crowds)		
	(c) organisations		
	(d) animals?		
	Please provide further details:		
	During my research, I am planning to create a survey to identify the criteria by which people prefer to choose their doctors. For		

	example gender, rating, experience, etc. After the final product is ready to be tested I am planning to ask a group of people to test the functionality. For this purpose, only test data will be used and the Research Ethics Policies will be followed strictly.		
2	Will the research deal with information which is private or confidential?	Yes	No
			x
	Please provide further details:		

Part 2: The Impact of the Research			
3	In the process of doing the research, is there any potential for harm to be done to, or costs to be imposed on	Yes	No
	(a) research participants?		x
	(b) research subjects?		x
	(c) you, as the researcher?		x
	(d) third parties?		x
	Please state what you believe are the implications of the research:		
4	When the research is complete, could negative consequences follow:	Yes	No
	(a) for research subjects		x
	(b) or elsewhere?		x
	Please state what you believe are the consequences of the research:		

Part 3: Ethical Procedures			
5	Does the research require informed consent or approval from:	Yes	No x
	(a) research participants?		
	(b) research subjects		
	(c) external bodies		
	If you answered yes to any of the above, please explain your answer:		
6	Are there reasons why research subjects may need safeguards or protection?	Yes	No
			x
	If you answered yes to the above, please state the reasons and indicate the measures to be		x
7	Has PVG membership status been considered?		x
	(a) PVG membership is not required.		
	(b) PVG membership is required for working with children.		
	(c) PVG membership is required for working with protected adults.		
	(d) PVG membership is required for working with both children and protected		
	If you answered yes to (b), (c) or (d) above, please give details:		
8	Are specified procedures or safeguards required for recording, management, or storage of data?	Yes	No
			x
	If you answered yes to the above, please outline the likely undertakings:		

Part 4: The Research Relationship			
9	Does the research require you to give or make undertakings to research participants or subjects about the use of data?	Yes: x	No:
	If you answered yes to the above, please outline the likely undertakings: The system will entirely rely on simulated patient data rather than a real one. I am planning to advise the testers to use usernames and emails containing words like the "test", "user", "demo", etc, rather than sharing their personal credentials. Regarding the personal images used for profile pictures I am planning to use a random face generator so no real images are used. For this purpose I will create a few images, store it in a folder and share it with the participants.		
10	Is the research likely to be affected by the relationship with a sponsor, funder or employer?	Yes:	No: x
	If you answered yes to the above, please identify how the research may be affected:		

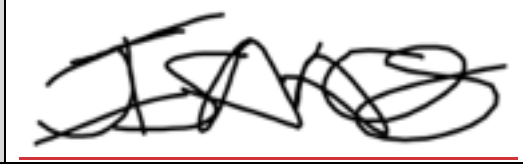
Part 5: Other Issues			
11	Are there any other ethical issues not covered by this form which you believe you should raise?	Yes:	No: x

Statement by Student			
I believe that the information I have given in this form is correct, and that I have addressed the ethical issues as fully as possible at this stage.			
Signature	Simona Georgieva	Date	28/09/2022

If any ethical issues arise during the course of the research, students should complete a further Student Project Ethical Review (SPER) form.

Part 6: To be completed by the supervisor			
12	Does the research have potentially negative implications for the University?	Yes:	No: x
	If you answered yes to the above, please explain your answer:		

13	Are any potential conflicts of interest likely to arise in the course of the research?	Yes	No x
	If you answered yes to the above, please identify the potential conflicts:		
14	Are you satisfied that the student has engaged adequately with the ethical implications of the work? [In signifying agreement, supervisors are accepting part of the ethical responsibility for the project]	Yes x	No
	If you answered no to the above, please identify the potential issues:		
15	**Appraisal:** Please select one of the following		
	The research project should proceed in its present form – no further action is required	x	
	The research project requires ethical approval by the School Ethics Review Panel		
	The research project needs to be returned to the student for modification prior to further action		
	The research project requires ethical review by an external body. If this applies please give details		
	Title of External Body providing ethical review		
	Address of External Body		
	Anticipated date when External Body may consider project		

Affirmation by Supervisor			
I have read the student's responses and have discussed ethical issues arising with the student. I can confirm that, to the best of my understanding, the information presented by the student is correct and appropriate to allow an informed judgement on whether further ethical approval is required.			
Signature		**Date**	28/09/2022

Research Ethics Policy is available at
www.intranet.rgu.ac.uk/credo/staff/page.cfm?pge=7060

Appendix E

Test cases

Test Case 1

Test Case ID:	User_01					
Test Cases - Honours application						
ID	Test Case Title	Test Steps	Test Data / This is an example/ It is recommended to use other values	Expected Output	Passed (Yes/No)	Design Preferences Notes
HP_1	Initial app launching	Click on the app icon		Registration Form	Yes	
HP_2	Create a registration with valid credentials.	1. Insert an email 2.Insert a password 3. Click on Register button	useremail: username@gmail.bg pass:1900745	Home page is displayed	yes	
HP_3	Create a registration with 1 missing field	1.Insert only a username	email: username@gmail.bg	Relevant Error message is displayed on the bottom of the page in red	yes	error message does not make sense to me
HP_4	Verify login with correct credentials	1. Insert an email 2.Insert a password 3. Click on login button	Use the data used in HP_1	Home page is displayed	yes	I like If my name is displayed not my email
HP_5	Verify login with incorrect credentials	1. Insert email 2.Use incorrect password	useremail: username@gmail.bg pass:1900748	Relevant Error message is displayed on the bottom of the page in red	no	I don't understand it
HP_6	Create an account via Login Form	1. Click on "Don`t have an account? Create!	useremail: username@gmail.bg pass:1900748	Redirected to Registration Form	yes	
HP_7	"Our Doctors" Section	Scroll horizontally		More doctor profiles should appear	yes	
HP_8	Select a doctor from the slider	Scroll horizontally, click on a random doctor from the options		Info page for that doctor should be displayed	yes	the background is not very nice
HP_9	Check doctor`s availability	1. Repeat HP_7 2.Click on Book an Appointment 3. Expand the calendar 4. Click on different slots 5.Click on a "Break" slot		You should see a calendar, a legend and time slots. The time slot should change the colour	yes	
HP_10	Booking an appointment/in the next days/	1. Repeat HP_8 2.Select available time slot for a specific date from the calendar after todays date 3. Click on Book Now		You should be redirected to "More Details " page	yes	
HP_10.1	Submit	1.Add a description 2.Click on the camera 2.1 Your phone camera should be opened 2.2 Take a photo of any document 2.3 Click on the submit icon 3. Enter your phone number 4.Click on Submit button		Pop up message displaying confirmation should be displayed	yes	
HP_10.2	Submit with a missing phone number	1. Add a description 2. Add a file(refer to HP_10.1, step 2) 3.Leave the phone number empty 4.Click on the submit button		Pop up message displaying you have missing fields should pop up	yes	
HP_11	Check your upcoming appointments	Click on the Appointments tab from the bottom menu		You should see a box with details about your future appointments	no	I can see the box but the appointment date is wrong
HP_12	Check if the box opens google maps	Cick on the hospital name		Google maps should be opened on your phone	yes	
HP_13	Booking an appointment/in the past days/	2.Select available time slot for a specific date from the calendar from the past 3. Click on Book Now			yes	
HP_13.1	Submit	Repeat HP_10.1		Pop up message displaying confirmation should be displayed	yes	
HP_13.2	Check your appointment	1. Repeat HP_11 2. Click on the Past Appointments button on the top of the page		You should see a box with details about your past appointments	yes	I would like to have an ability to clean some of them
HP_14	Check nearest hospitals	1. Click on Location tab on the bottom menu 2.1. Click on Find Nearest Hospitals button		You should see a boxes showing information about the nearest hospital around you	yes	can you remove the coordinates and add the street name?
HP_15	Check BMI Calculator	1. Click on Setting tab from the botto menu 2.Click on BMI Calculator tab 3. Fill the fills with a relevant information		Result indicating your bmi and an advice should be displayed	yes	
HP_16	Logout	1. Click on the Setting tab from the bottom menu 2. Click on Logout button		You should be redirected to Login Page	yes	

Test Case 2

Test Case ID:	User_02					
Test Cases - Honours application						
ID	Test Case Title	Test Steps	Test Data / This is an example/ It is recommended to use other values	Expected Output	Passed (Yes/No)	Design Preferences Notes
HP_1	Initial app launching	Click on the app icon		Registration Form	Yes	
HP_2	Create a registration with valid credentials.	1. Insert an email 2.Insert a password 3. Click on Register button	useremail: username@gmail.bg pass:1900745	Home page is displayed	yes	
HP_3	Create a registration with 1 missing field	1.Insert only a username	email: username@gmail.bg	Relevant Error message is displayed on the bottom of the page in red	yes	I know what the error means becasuse I am developer I am not sure if non-technical person will now
HP_4	Verify login with correct credentials	1. Insert an email 2.Insert a password 3. Click on login button	Use the data used in HP_1	Home page is displayed	yes	
HP_5	Verify login with incorrect credentials	1. Insert email 2.Use incorrect password	useremail: username@gmail.bg pass:1900748	Relevant Error message is displayed on the bottom of the page in red	yes	
HP_6	Create an account via Login Form	1. Click on "Don`t have an account? Create!	useremail: username@gmail.bg pass:1900748	Redirected to Registration Form	yes	
HP_7	"Our Doctors" Section	Scroll horizontally		More doctor profiles should appear	yes	can you add arrows in left/right so I know it is scrollable
HP_8	Select a doctor from the slider	Scroll horizontally, click on a random doctor from the options		Info page for that doctor should be displayed	yes	I would like to have the ability to add the doctor to my favourites
HP_9		2.Click on Book an Appointment 3. Expand the calendar 4. Click on different slots 5.Click on a "Break" slot		calendar, a legend and time slots. The time slot should change the colour	yes	the text on the legend is not visible enough
HP_10	Booking an appointment/in the next days/	1. Repeat HP_8 2.Select available time slot for a specific date from the calendar after todays date 3. Click on Book Now		You should be redirected to "More Details " page	yes	
HP_10.1	Submit	1.Add a description 2.Click on the camera 2.1 Your phone camera should be opened 2.2 Take a photo of any document 2.3 Click on the submit icon 3. Enter your phone number 4.Click on Submit button		Pop up message displaying confirmation should be displayed	yes	fields are very close, dividing them better would be nice
	Submit with a missing phone number	1. Add a description 2. Add a file(refer to HP_10.1, step 2) 3.Leave the phone number empty		Pop up message displaying you have missing fields should pop up		
HP_10.2	Submit with a missing phone number	1. Add a description 2. Add a file(refer to HP_10.1, step 2) 3.Leave the phone number empty 4.Click on the submit button		Pop up message displaying you have missing fields should pop up	yes	indicating which field is missing might be helpfu;
HP_11	Check your upcoming appointments	Click on the Appointments tab from the bottom menu		You should see a box with details about your future appointments	yes	I can see the box but the appointment date is wrong
HP_12	Check if the box opens google maps	Cick on the hospital name		Google maps should be opened on your phone	yes	
HP_13	Booking an appointment/in the past days/	1. Repeat HP_8 2.Select available time slot for a specific date from the calendar from the past 3. Click on Book Now			no	the previous slot is booked for all days, so I cant book same time slot for different day
HP_13.1	Submit	Repeat HP_10.1		Pop up message displaying confirmation should be displayed	yes	
HP_13.2	Check your appointment	1. Repeat HP_11 2. Click on the Past Appointments button on the top of the page		You should see a box with details about your past appointments	yes	
	Check nearest hospitals	1. Click on Location tab on the bottom menu		You should see a boxes showing information		

HP_14	Check nearest hospitals	1. Click on Location tab on the bottom menu 2.1. Click on Find Nearest Hospitals button		You should see a boxes showing information about the nearest hospital around you	yes	can you increase the size of the text
HP_15	Check BMI Calculator	1. Click on Setting tab from the botto menu 2.Click on BMI Calculator tab 3. Fill the fills with a relevant information		Result indicating your bmi and an advice should be displayed	yes	
HP_16	Logout	1. Click on the Setting tab from the bottom menu 2. Click on Logout button		You should be redirected to Login Page	yes	

Test Case 3

Test Case ID:	User_03					
Test Cases - Honours application						
ID	Test Case Title	Test Steps	Test Data / This is an example/ It is recommended to use other values	Expected Output	Passed (Yes/No)	Design Preferences Notes
HP_1	Initial app launching	Click on the app icon		Registration Form	Yes	takes more time to load compared with other apps i am using?..
HP_2	Create a registration with valid credentials.	1. Insert an email 2.Insert a password 3. Click on Register button	useremail: username@gmail.bg pass:1900745	Home page is displayed	yes	
HP_3	Create a registration with 1 missing field	1.Insert only a username	email: username@gmail.bg	Relevant Error message is displayed on the bottom of the page in red	yes	
HP_4	Verify login with correct credentials	1. Insert an email 2.Insert a password 3. Click on login button	Use the data used in HP_1	Home page is displayed	yes	
HP_5	Verify login with incorrect credentials	1. Insert email 2.Use incorrect password	useremail: username@gmail.bg pass:1900748	Relevant Error message is displayed on the bottom of the page in red	yes	
HP_6	Create an account via Login Form	1. Click on "Don`t have an account? Create!	useremail: username@gmail.bg pass:1900748	Redirected to Registration Form	yes	
HP_7	"Our Doctors" Section	Scroll horizontally		More doctor profiles should appear	yes	
_	Select a doctor from the slider	Scroll horizontally, click on a random doctor from the		Info page for that doctor should be		i would add a functionality to have a chat with
HP_9	Check doctor`s availability	1. Repeat HP_7 2.Click on Book an Appointment 3. Expand the calendar 4. Click on different slots 5.Click on a "Break" slot		You should see a calendar, a legend and time slots. The time slot should change the colour	yes	
HP_10	Booking an appointment/in the next days/	1. Repeat HP_8 2.Select available time slot for a specific date from the calendar after todays date 3. Click on Book Now		You should be redirected to "More Details " page	yes	
HP_10.1	Submit	1.Add a description 2.Click on the camera 2.1 Your phone camera should be opened 2.2 Take a photo of any document 2.3 Click on the submit icon 3. Enter your phone number 4.Click on Submit button		Pop up message displaying confirmation should be displayed	yes	can i access my previously added images?
HP_10.2	Submit with a missing phone number	1. Add a description 2. Add a file(refer to HP_10.1, step 2) 3.Leave the phone number empty 4.Click on the submit button		Pop up message displaying you have missing fields should pop up	yes	
HP_11	Check your upcoming appointments	Click on the Appointments tab from the bottom menu		You should see a box with details about your future appointments	yes	i would change the data format, it is a bit confusing
HP_12	Check if the box opens google maps	Cick on the hospital name		Google maps should be opened on your phone	yes	
HP_13	Booking an appointment/in the past days/	1. Repeat HP_8 2.Select available time slot for a specific date from the calendar from the past 3. Click on Book Now			no	
HP_13.1	Submit	Repeat HP_10.1		Pop up message displaying confirmation should be displayed	yes	
HP_13.2	Check your appointment	1. Repeat HP_11 2. Click on the Past Appointments button on the top of the page		You should see a box with details about your past appointments	yes	
HP_14	Check nearest hospitals	1. Click on Location tab on the bottom menu 2.1. Click on Find Nearest Hospitals button		You should see a boxes showing information about the nearest hospital around you	yes	can we sort it by any filters e.g. rating? i would like to know which is the best hopital around me
HP_15	Check BMI Calculator	1. Click on Setting tab from the botto menu 2.Click on BMI Calculator tab 3. Fill the fills with a relevant information		Result indicating your bmi and an advice should be displayed	yes	i would remove the black border
HP_16	Logout	1. Click on the Setting tab from the bottom menu 2. Click on Logout button		You should be redirected to Login Page	yes	

Appendix F

Link to the mockups

https://marvelapp.com/prototype/2iei966g