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PHD THESIS SUMMARY

Telemetry in Medical Applications and Wearable Medical Devices
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CONTENTS

ABSTRACT

Human-computer interaction in the context of digital healthcare systems refers to the use of technology, such as computers and software, to enhance the delivery of healthcare services. This may involve the utilization of electronic health records (EHRs), telemedicine, and other digital tools to enhance communication and collaboration between healthcare practitioners and patients. The aim of these systems is to make healthcare more efficient, accessible, and personalized for patients. Human-computer interaction plays a key role in the design and implementation of these systems, as it focuses on creating technology that is easy to use and intuitive for both healthcare providers and patients.

This thesis proposes an user friendly approach to building medical solutions in order to empower both the patient and the doctor. Our main concerns and goals proposed are related to finding the limitations of current solutions for monitoring movement disorders, bridging the gap between current technology advancements and the actual users with a focus on older patients, and creating benefits by constant doctor-patient monitoring and medication management. By interviewing and analysing neurologists and ear-nose-throat (ENT) doctors about their diagnosis procedures, we have proposed and built two wearable medical devices that diagnose balance diseases and monitor people with movement disorders, such as Parkinson's Disease. We developed an application for medication management and reminders and a platform for finding drug-to-drug interactions in order to avoid treatment non-adherence. Finally, a mobile application for diabetes journal was implemented for a better patient-doctor communication. The contributions developed were tested with experts and patients, as part of our user-centered methodology.

Keywords: *human-computer interaction, medtech, movement disorders, wearable medical devices, medical applications, medication reminders, treatment adherence, drug-to-drug interactions, diabetes journal*

1 INTRODUCTION

In this chapter, we will describe the context for the digitization of healthcare systems and how the user (professional or non-professional) is involved in this process. We will present the primary research questions and contributions for the domain of wearable medical devices and medical applications, taking in consideration the most important stakeholder: the user, be it patient or doctor.

1.1 Context

Nowadays, technology is continuously evolving, aiming to revolutionize each domain where it can be applied: from agriculture and education to healthcare and finances. There is a wide range of projects, researches and companies that are either trying to improve the current processes or to build a disruptive innovation in their field.

One of the most interesting and sensitive innovation domain is research and development in the healthcare system. Alas, it falls behind other domains in terms of/with regard to popularity. It all started with a very simple pedometer created by Thomas Jefferson in 1788 [9] and it has come to medical devices that diagnose our diseases or even to more advanced solutions, such as nanobot implants [10]. All this new technology in the medical field is trying, at the end of the day, to improve the quality of life of humans.

The current context of healthcare systems is one of rapidly evolving technology and increasing demand for healthcare services. There is a growing focus on preventative care and the use of data and technology to improve the efficiency and effectiveness of healthcare delivery.

Many healthcare systems are also dealing with the challenges of an aging population and chronic disease management. At the same time, there is increasing pressure on healthcare systems to contain costs and improve access to care. Overall, the current context of healthcare systems is one of ongoing change and adaptation to new technologies and healthcare needs.

Wearable medical devices are devices that are designed to be worn on the body and are often used to monitor or track various aspects of a person's health. These devices may be used to monitor metrics like heart rate, physical activity, sleep, and other vital signs. They are often connected to a smartphone or other device, allowing users to track their health data and share it with their healthcare provider.

Medical applications, on the other hand, are software programs that are designed to help healthcare providers diagnose and treat patients. These applications may be used to record and track patient information, as well as to provide medical education and support to healthcare professionals. Overall, the use of wearable medical devices and medical applications is becoming increasingly common in the healthcare industry, as they provide a convenient and efficient way to monitor and track a person's health.

Overall, the involvement of the user in the development process can help ensure that the medical device or application is designed to meet the needs and preferences of the people who will be using it.

1.2 Research Questions

The brain is one of the most complex parts of the human body. Therefore, any disease or condition related to it is extremely hard to diagnose and, at the current moment, almost impossible to treat.

Neurodegenerative diseases is an umbrella concept for a range of conditions which affect the neurons in the brain, by progressive deterioration in neuron structure and function, including death of neurons [14]. Unfortunately, there is no cure for this process. The only way to improve or to maintain the quality life for a patient is to constantly monitor their condition and change their medication accordingly, while at home or while proving at home medical care. The only problem here is that even if the medication may be efficient at a certain moment, the state of the patient still degenerates in time. So until we discover a cure, constant self-monitoring and adaplively adjusting prescriptions is vital for the long-term positive outcome/maintaining the quality of life.

A very common group of neurodegenerative diseases are the movement disorders. Here we can name a few well known examples: Parkinson's Disease, Essential Tremor, Huntington's Chorea. These disorders have in common the following debilitating symptoms: tremor, poor gait, loss of balance and bad posture [15]. These parameters need to be constantly monitored and periodically, the doctor needs to adjust the treatment based on positive or negative symptomatic feedback.

Patients now have access to a wide variety of wearable medical gadgets that attempt to allow self-monitoring in the comfort of their own homes in order to combat this problem. Nevertheless, the majority of them have certain undesirable drawbacks, such as not being appealing to wear, that they do not offer user-friendly information for the patient, and that they are prohibitively expensive.

More often than not, patients who have trouble following treatments do so due to the complexity of the prescription and other issues in their lives. For example, research indicates that approximately 69% of Chinese epilepsy patients report forgetfulness as the primary factor associated with treatment non-adherence [46]. Similar research conducted in Brazil demonstrates that treatment complexity is strongly related to decreased adherence [47]. The study also suggests that reducing treatment complexity significantly increases the likelihood that patients will adhere to their prescribed treatment. However, this is not always the case for other diseases such as diabetes, congestive heart failure, and kidney disease [48].

Therefore, forgetfulness and treatment complexity are the primary obstacles to proper medication administration, and these are the issues that our project will attempt to address in the following chapters.

To address these issues, we propose the following research questions:

- Q1 What are the main limitations of current solutions for monitoring movement disorders and how do they impact medical treatment?
  - How can we design a medical device for ear-nose-throat (ENT) doctors that would provide sufficient quality data while intruding as less as possible in the patient's life?
  - What are the optimal parameters for monitoring a nonintrusive monitoring device for Parkinson's Disease - that would enable doctors to have additional quality data on their patient's evolution?
  - How can we empower neurologists to have at their disposal long-term data on their patients, to enable new diagnostic options based on long-term monitoring?
- Q2 How can we bridge the gap between current technology advancements in terms of mobile devices and cloud services and the actual users - with a focus on older patients that are not that technology savvy?
  - How can technology enable caregivers to support long-term treatment patients to follow their medication plan?
  - How can we determine an equilibrium between enough notifications and an acceptable level of intrusion?
- Q3 Can constant doctor-to-patient monitoring and communication provide additional medical benefits to patients suffering from diabetes?

1.3 Thesis Contributions

This thesis began with an analysis of the issues that doctors and senior patients have with specific treatments that become standard in the patient's life once they have been diagnosed. We have validated these challenges by conducting user interviews with patients to better comprehend their issues and demands surrounding home monitoring, activity tracking, medication management, and, in certain cases, keeping disease evolution journals.

To summarize the contributions and relate them to the research topics outlined in the preceding section, the following overview is provided:

C1 We have built and tested two wearable devices for diagnosing equilibrium diseases [8], [7] and monitoring movement disorders [2], respectively.

- By conducting user interviews and observational researches with doctors and patients, we determined the problem and need they have.
- We have developed a software application and a postural wearable device that records the movements of a patient and offers an assessment for equilibrium disorders.
- We have implemented a software application, a postural wearable device and a wrist wearable device for monitoring movement disorders.
- We have tested both solutions with experts (neurologists and ENT doctors) and their patients to conclude that our products offer better output data and the same outcome as other healthcare systems combined.

C2 We have implemented an application for medication management and reminder [3], along with a platform that detects drug-to-drug interactions [1].

- We have conducted user interviews with doctors and patients and we have analysed their behavior regarding medication management and their awareness regarding treatment adherence.
- We have implemented a mobile application where patients add their treatment and set different timers for medication reminders. A journal of how they took the medication will be generated and their doctor can use it at their checkup.
- We have developed a platform where both patients and doctors can search for a drug based on its substance and find drug-to-drug interactions.
- We have tested both solutions with doctors and patients to validate if the applications can support long-term treatment patients to follow their medication plan.

C3 We have developed a mobile application for digital journals and doctor-patient communication for diabetics [4].

- We have conducted user interviews with diabetologists and their patients and we have analysed their behavior regarding tracking progress of certain parameters of their disease.
- We have implemented a mobile application where patients journal about their diabetes' evolution.
- We have tested the solution with doctors and patients to validate if the applications can support long-term treatment patients to follow their medication plan.

2 WEARABLE DEVICES FOR MONITORING MOVEMENT DISORDERS AND DIAGNOSING BALANCE DISEASES

2.1 Medical Overview

2.1.1 Context

In this chapter, we explore the limitations of current solutions for diagnosing and monitoring balance and movement disorders. By proposing a methodology for developing and designing user friendly wearable medical devices, we implemented ENTy and IRIS. The first contribution consists in a postural device that records the movements of a patient and can diagnose a balance disorder. The second contribution is a set of two wearable devices (postural and wrist) for monitoring people with movement disorders, such as Parkinson's disease.

Neurons in the brain can die as a result of neurodegenerative illnesses, which cause the neurons in the brain to gradually lose their structure or function. It is essential to closely evaluate a patient's condition and make ongoing adjustments to their treatment based on their current living situation in order to enhance or maintain the patient's quality of life. Tremor, bad gait, loss of balance, and poor posture are among symptoms caused by these illnesses. There is currently no objective measurement for monitoring neurodegenerative disorders, which means that the judgments that are being made are subject to an element of subjectivity. The patients have to monitor themselves at home and subsequently revisit the doctor's office for treatment evaluation and improvement.

In an effort to counteract this issue, patients now have access to a broad array of wearable medical devices that are designed to make it possible for them to perform self-monitoring in the convenience of their own homes. However, the vast majority of them have a number of unfavorable limitations, such as the fact that they are uncomfortable to wear, that they do not provide the patient with data that is easy to understand, and that they are excessively expensive.

2.1.2 Monitoring

The next phase after being diagnosed with a neurodegenerative disease is the monitoring of the patient. Unfortunately, due to the lack of cures for movement disorders, the only solution to alleviate/reduce the symptoms is to continuously monitor the patient and adapt their treatment regularly, based on medical data collected and analysed while at home.

This process of monitoring starts from the first day of diagnosis. A doctor or a nurse will perform a test on the patient called the Unified Parkinson's Disease Rating Scale (UPDRS) to define the current state of the patient [23]. This test consists of in 50 questions about the patient's life and how easy they can use the hands or the body to perform simple actions. In order to have objective results, the answers to the questions are given on a 5-point unipolar scale from 0 to 4, each meaning being shown in Table 1.

Table 1: Evaluation for Unified Parkinson's Disease Rating Scale.

Number	**Meaning**	**Clinical Severity**	**Frequency Percentage**
0	Normal	Absent	0% of the day
1	Slight	Slight and infrequently present	less than 25% of the day
2	Mild	Mild and persistent	26-50% of the day
3	Moderate	Moderate and present most of the time	52-75% of the day
4	Severe	Marked and present most of the time	more than 75% of the day

Following this evaluation, the neurologist prescribes a basic first-line treatment for the patient and asks them to return in 6 months for a follow-up. During this time, while the patient is living at home, it is advised that they a journal recording all observations regarding their condition, focusing on key symptoms which include balance, posture, gait, and tremor, for a full clinical picture.

After the specified number of months, the patient will return to the hospital and undergo the aforementioned tests, including the Unified Parkinson's Disease Rating Scale [24]. Based on the observational diary and the new tests, the doctor will determine which symptoms have improved and make the appropiate adjustments to the treatment. Depending on the patient's condition, the doctor may advise them to return in 6 or 12 months.

This process is repeated throughout the patient's life. As the condition progresses and the symptoms become more severe or in some cases they are attenuated to some degree, the patient must be assessed on a regular basis and given adjusted doses and combinations of medication. The main reason for changing the prescription on a regular basis is that if the symptoms are not rapidly managed, they can develop into serious negative events such as falls and accidents, due to the side-effect of disregulated orthostatic blood pressure.

The biggest issue with this procedure is that all home monitoring is usually performed by the patient and sometimes by a non-proffesional caregiver. This results in a subjective evaluation and, as a result, unsuitable and delayed treatment for the patient.

2.2 ENTy - A Wearable Device for Equilibrium Testing

2.2.1 Proposed Solution

A brief summary of the positive and negative developments could be stated up-front before we begin: The good news is that modern technology standards are enabling more reliable and straightforward hardware and software module installation into products. The bad news is that even if technology is developing more quickly, it can still be challenging for developers to choose the right hardware or software to use in order to best serve their product's demands.

This proposal offers a solution for a medical equipment that will help any ear-nose-throat specialist diagnose a patient's balance with precision. In the current medical field, diagnosing vertigo or any other sort of disequilibrium issue in patients is primarily done through specific medical testing. In these examinations, the postural evaluation is the end goal, and patient motions are captured and sensed using either a big equipment or photo cameras. A modest hardware-assisted computer application and cutting-edge business tools are used to implement our approach.

Hardware units, often known as live units, are those parts of a system that take precise measurements or enable real-time monitoring of the patient's motions. Sensors, data collecting modules, and over-the-air communication modules are examples of such components. They serve as the first set of decoders for postural changes made by patients during medical examinations, alterations that enable clinicians to identify any crucial signs regarding the patient's evolution. The magnetometer sensor, gyroscope sensor, and accelerometer sensor are the stability sensors contained within the inertial measurement unit (IMU) which is the active unit controlling them and joining their outputs into a higher level result. The input is obtained from the patient, and the IMU output is transmitted to the client's static unit—which will be discussed in more detail—over the air through Bluetooth.

Software units, often referred to as static units, are recognized as data processors that process feedback from patient movements throughout time as well as units like rendering, a user interface, or test results that operate independently of changes in the physical environment. Figure 1 shows the layered software architecture of the ENTy application. Bluetooth technology is used to connect the device and the client application.

Depending on hardware advancements, requirements, or the compatibility issues of the doctors conducting the review, the application went through three different versions. Although the most apparent advantage in the most recent version over the previous one is its low energy usage, currently several Windows platforms are not supported by this technology.

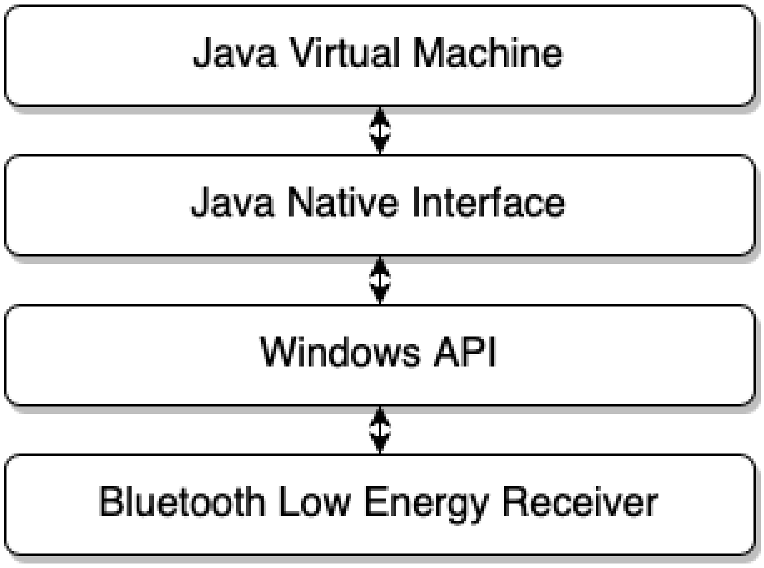

Figure 1: Software Architecture proposed for the ENTy Solution.

2.2.2 Graphical User Interface

The second version of the GUI has a different approach than the first one. The doctor chooses the tests that will be performed on the patient second step in the doctor user flow, which is represented by a tiny list of checkboxes. This version of the application incorporates four balance tests, as illustrated in Figure 2. This is a crucial stage in the preogress of the application and the improvements that have been achieved. As was previously noted, the doctors saw the need for a protocol that would allow them to skip the permanent need to hit the start buttons in order for the desired tests to be performed. This feature is now available with this version of the software. Additionally, four different sorts of tests are available to the doctor: the simple Romberg, two sensitized Romberg tests (left and right), and the Unterberger test. The Unterberger exam takes two minutes, whereas the Romberg tests collectively roughly 60 seconds. This will provide a doctor a total of three minutes to do four tests on a single patient while having the results sent directly to their PC or laptop. The tests will be performed in the checking order rather than the selecting order. For instance, if a doctor chose the Unterberger first and the Romberg second, the procedure would run Romberg first and then Unterberger, not the other way around.

The doctors viewed the real-time rendering as a benefit, hence there were not many changes made to the charts in Figure 3. The chart that shows the fore-posterior balance to conduct the Unterberger test underwent the most significant alteration. The placement of the graphical elements differs somewhat between the two versions. On the left, there are two human-like figures that can rotate front-back or sideways mapping the movement of the patient in real time. Additionally, a real-time numeric value of the inclination's angle will be shown. As the test's timer ticks and the patient moves, two charts will be drawn in the screen's middle. The lateral balance and fore-posterior balance parameters, which are two unique parameters that are being observed, will be drawn in different colors so that the doctor can easily distinguish

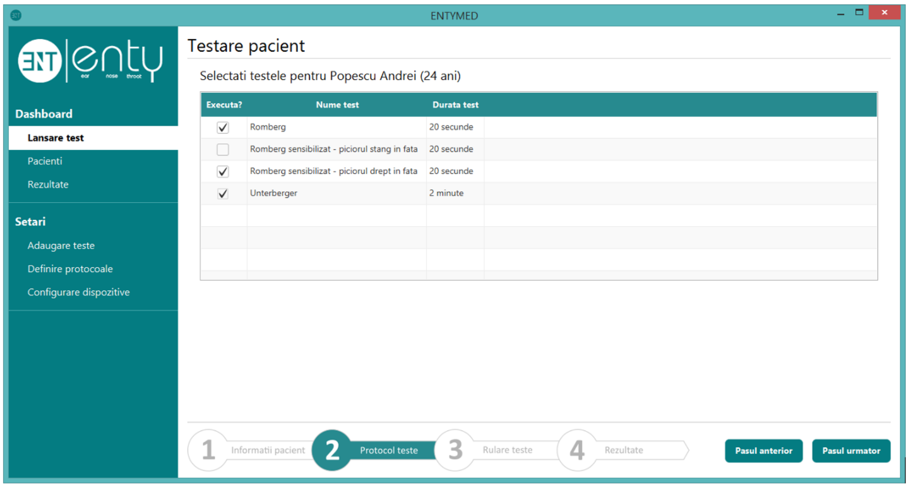

Figure 2: Representation of ENTy when Selecting the Balance Tests to be Performed - version 2 of the GUI

between them. We have a quadrant on the right with a red dot inside a green region that shows the safety limit which is considered the normal range. The red dot will follow one's action and evolution as soon as the patient begins to move. Moving outside the limit region is a necessary diagnostic criteria for a patient to be suffering from balance disorders. In that situation, the safety boundary will change from green to red, as shown in Figure 3, alerting the doctor that the patient had a poor performance, exhibiting abnormal inclination angles. As we can see, the graphic elements are designed so that anyone, medical professional or non-expert, may readily understand them.

Figure 3: Representation of ENTy while Observing Real-Time Data from Patients - version 2 of the GUI

The final action and screen are virtually identical to those shown for the software's initial release. The design of the buttons and the overall appearance of the program are the only changes that can be seen in Figure 4. When attempting to watch the evolution of the center of gravity, this specific panel displays all the information related to the outcome. It is clear from

Figure 4 that the results are displayed in three distinct boxes. For varous displayed parameters, each of these visualizations makes use of the patient's movement and coordinates throughout the exam. The lateral balance of a patient's Romberg test will be shown in the first box. The two green lines represent the test's acceptable limits, while the red line represents the patient's real lateral balance movement range. The test would be considered a failure if the patient went beyond either of these boundaries, at which point the doctor would diagnose vertigo and perform other testing procedures to look for any associated commorbidities. The second box operates on the same principles, but lacks the frontal balance movement from back to front. The front boundary is clearly much higher than the back boundary. Due to the fact that a patient tilting backward is at a greater risk of falling than if they were tilting forward. A green oval in the last box designates a the normal acceptable range of movement/tilt. During the 20 seconds of the test, the precise coordinates of the patient are shown by the red dots. As we can see, the data is highly exact, and the doctor will be able to determine whether a patient has a balance condition and whether they need additional testing according to the presence and amount of dots indicating abnormal movements.

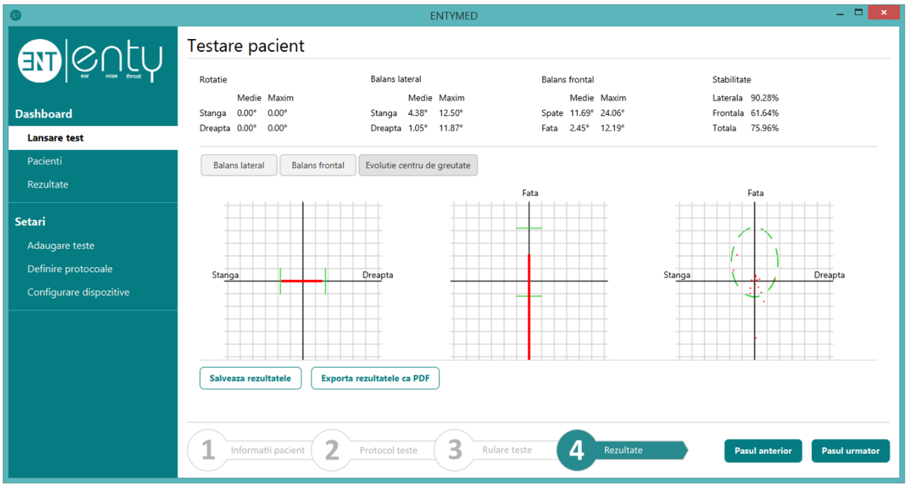

Figure 4: Representation of ENTy with the Final Results of the Patient

2.3 IRIS - A Wearable Device for Monitoring Movement Disorders

2.3.1 Proposed Solution

As a result, we want to build two primary devices: one that will be attached to the hand of the patient and will monitor the tremor in the wrist, and another that will be attached to the back of the patient and will evaluate the patient's gait, balance, and posture. Additionally, the wristwatch will come with a smart ring that can monitor the tremor in the user's finger.

Bluetooth will be the medium via which both primary devices will communicate with an application. We will store and process the sensitive data of the patient in the cloud. This will allow us to guarantee the data's total anonymity as well as its safety. The results of this processing will subsequently be delivered to the apps. The fact that the patient is allowed to move around freely during the examinations and that the physician is able to have portable devices is the main benefit of this scenario. This allows for greater scheduling flexibility and accommodates patients who may not be able to travel to the hospital for their appointments. The streamlined architecture of the suggested solution is broken down and illustrated in Figure 5.

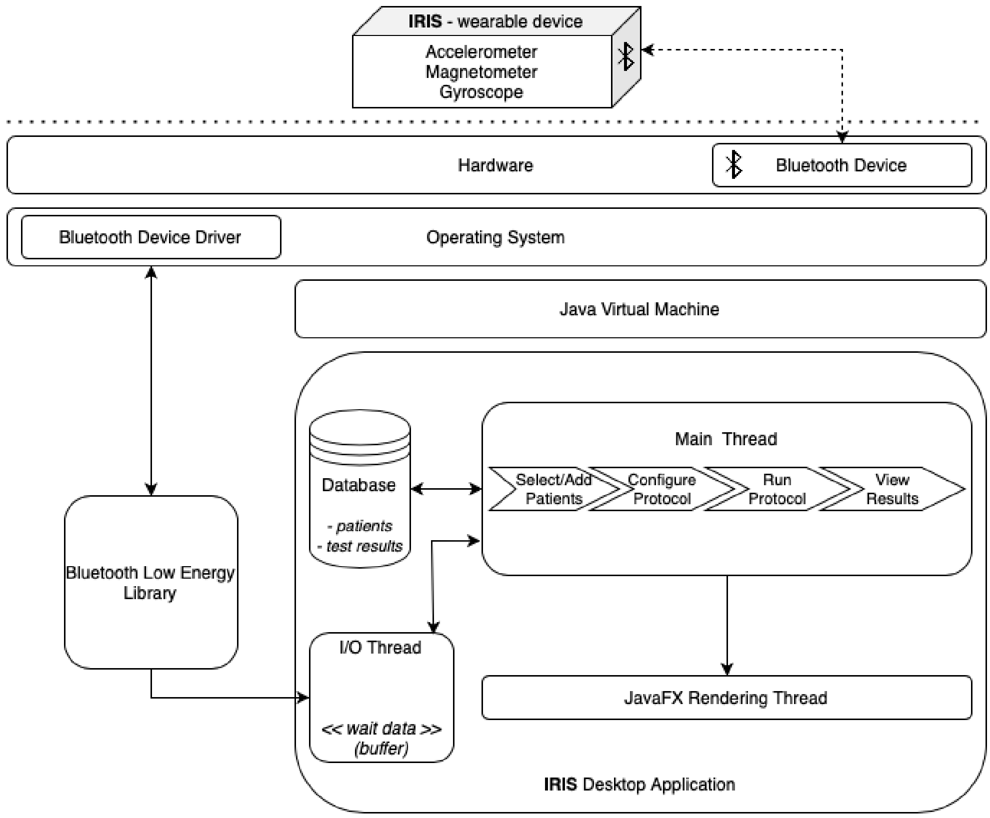

Figure 5: Software architecture for IRIS.

2.3.2 Graphical User Interface

A Graphical User Interface (GUI), a communication layer between software and hardware units, an input and output (I/O) unit, a runtime environment, and a post-processing database are all components of the software solution. Each of these components is handled in a distinct manner, and each is responsible for running its own thread. The first step a doctor will perform is mounting the devices needed on their patient, depending on the type of tests that need to be assessed. One device will be mounted on the wrist as a smartwatch and one device will be mounted on the back of the patient with the help of a harness that molds on the waist. Now, the doctor can connect to the IRIS application.

The following step will include selecting which devices are going to be connected. This is due to the fact that in certain tests and instances, we may need to connect various devices, including a device worn on the wrist and a device worn on the back. Bluetooth is IRIS's primary form of communication technology, hence the availability of this capability is directly attributable to that fact.

In addition, for a later version, we plan to attach more IRIS devices to various sections of the body. These will give us the ability to assess additional parameters, which will be of assistance in the process of diagnosing and monitoring a variety of disorders.

Following this step, the physician will choose the Resting Tremor Assesment for the test to be performed on the patient's hand. In Figure 6 we can observe the frequency and amplitude of the hand's and finger's tremor. The doctor can choose the live display of data produced by either finger or hand tremor.

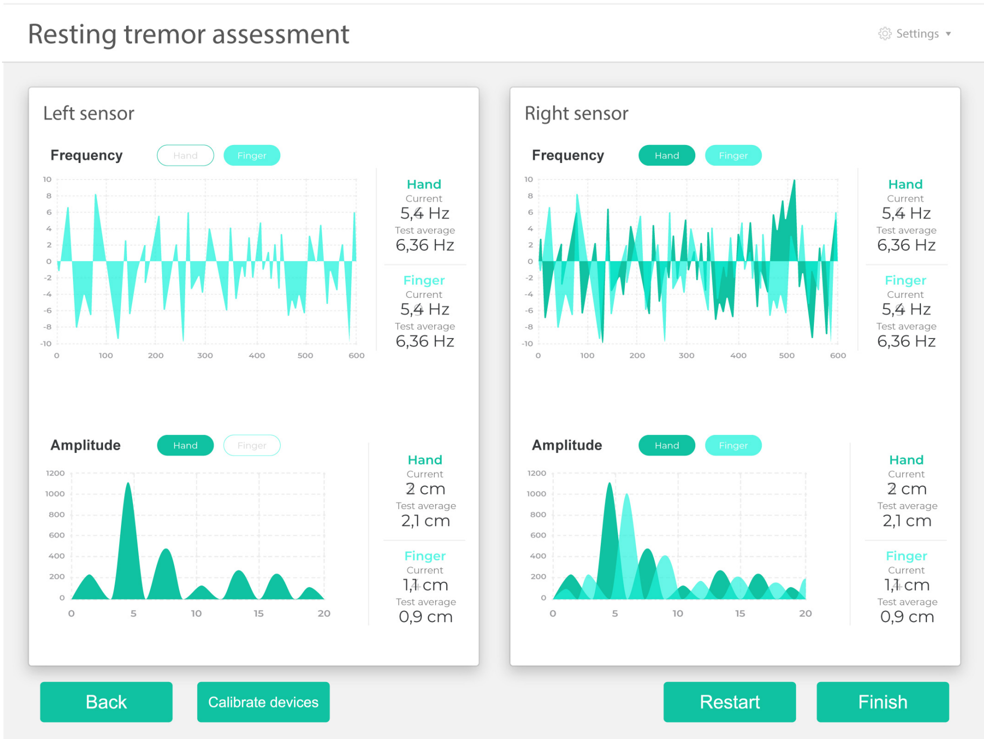

Figure 6: Representation of the IRIS' GUI on the tremor assessment.

One device is installed on the patient's wrist, and the other device is mounted on the patient's back. At the beginning of each evaluation, the physician must calibrate the devices that they have just mounted on the patient. Because people's heights, body types, and natural postures vary, it was essential for us to take into consideration while designing products.

According to the same study [41], the Romberg test is merely a diagnostic tool that a medical professional would use to establish whether or not a patient is suffering from any kind of disease. This test has the potential to detect vertigo at first glance; nonetheless, it will always be necessary to do additional investigations, such as the sensitized Romberg test or Unterberger's Stepping test [42].

Finally, the data will be presented, and the attending physician will be able to examine the patient's medical history, as is demonstrated in Figure 8. On the left side of the screen, we can

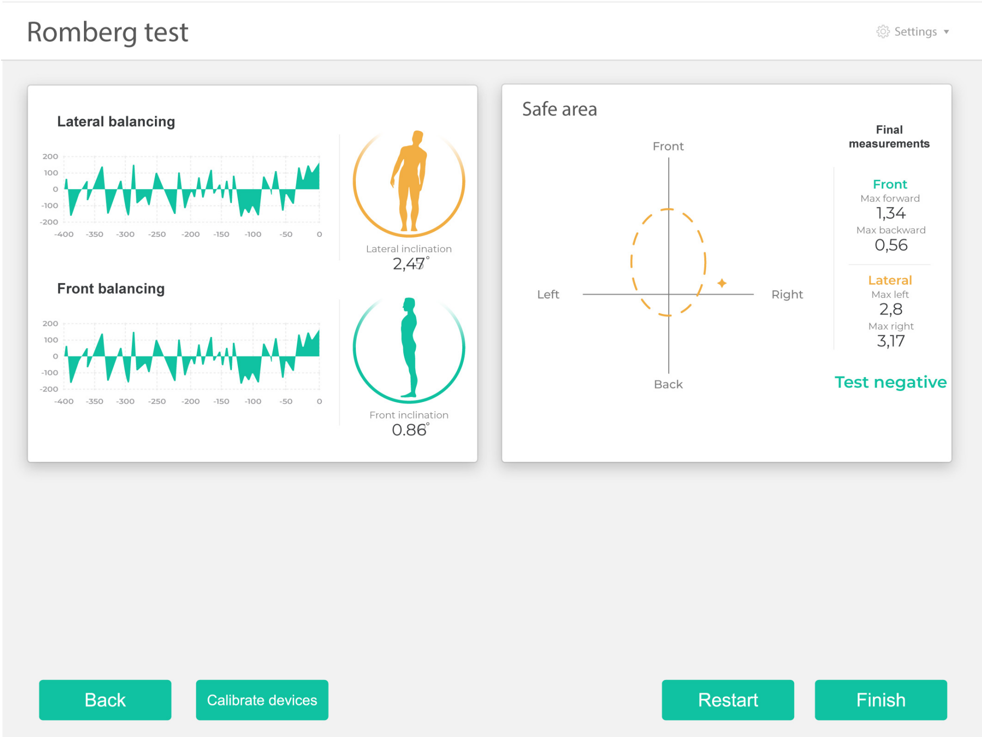

Figure 7: Representation of the IRIS' GUI when the Romberg test is running.

see general data about the patient, such as their identification number, height, weight, date of birth, and the official diagnosis of their condition, as well as the time when it first appeared and any unique symptoms that they may be experiencing. Additionally, any linked conditions, past testing, and current medications are considered to be relevant, and as a result, they are presented in green framing boxes.

On the right-hand side of the screen in Figure 8, we have the patient's medical history, which includes the IRIS tests that have been performed on them in the past. The tests that the patient has successfully passed are marked in green, whilst the tests that frame potential problems along with symptoms that the patient may have are noted in red.

2.3.3 Testing and Validating IRIS

In this section, we will present the insights and knowledge gathered regarding the product that is dedicated to feedback and testing. Our objective was to conduct the implemented tests of specific symptoms on ten different patients and to obtain feedback from the attending physician regarding the correctness of our solution and its similarity to other potential solutions. The Romberg test, which evaluates a patient's balance and posture, was performed on each of the first ten patients individually at the start of the evaluation process. The patient will be asked to remain still for 20 seconds with their eyes closed while the following metrics, including rotation, frontal balance, lateral balance, and the movement of the gravity center, will be examined.

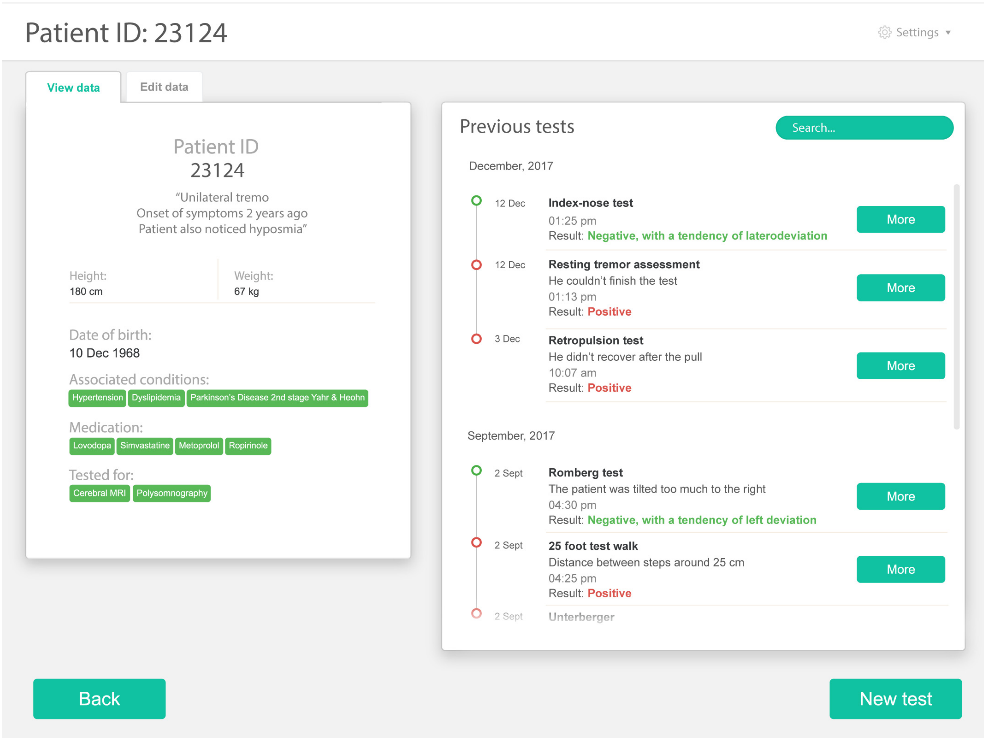

Figure 8: Representation of the IRIS' GUI with the medical results screen.

We are able to examine the whole outcomes of the Romberg tests by looking in Table 2. These were carried out under the supervision of medical professionals, and the diagnoses obtained were compared with one another in order to ascertain the degree to which they diverge from the results of other Romberg tests. The reached conclusions as well as the reached diagnosis were the same.

We decided to use the Unterberger test for the second set of evaluations that we carried out. During this procedure th epatient is required to be marching in place with one's eyes closed for a period of two minutes. The following criteria will be evaluated: lateral and frontal stability; frontal and lateral balance; and left-to-right and right-to-left frontal and lateral balance. Evaluating the balance and gait of a patient, which refers to how the patient walks from point A to point B, is a very crucial test to perform. It could appear to be a trivial examination at first glance, but in reality, when performed in a room that has been soundproofed, the patients have a tendency to move away from where they started and form an angle from their initial frontal axis. The rotation of the patient as well as their starting position and their final position at the end of the test are the two aspects of this assessment that are given the most weight by the attending physician. The outcomes of the Unterberger test carried out on 10 different patients are shown in Table 3 for your perusal.

Table 2: Results for the Romberg test.

Tests	**Rotation - average**		**Frontal Balance - average**		**Lateral Balance - average**	
Side	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
P1	4.27°	1.89°	0.49°	0.81°	1.53°	1.18°
P2	1.03°	3.34°	0.22°	0.54°	0.91°	1.12°
P3	7.36°	4.99°	2.95°	3.12°	1.78°	2.31°
P4	3.66°	1.12°	0.89°	0.98°	1.39°	0.89°
P5	6.25°	4.98°	1.42°	1.89°	2.72°	1.72°
P6	2.34°	1.36°	0.62°	0.91°	1.34°	1.63°
P7	4.10°	2.37°	0.55°	0.83°	1.28°	1.18°
P8	7.88°	5.87°	11.98°	2.48°	4.57°	2.73°
P9	1.09°	1.92°	1.29°	0.99°	1.83°	0.29°
P10	2.36°	2.28°	0.93°	1.29°	1.48°	0.93°

Table 3: Results for the Unterberger test.

Tests	**Stability - average**		**Frontal Balance - average**		**Lateral Balance - average**	
Side	**Lateral**	**Frontal**	**Left**	**Right**	**Left**	**Right**
P1	98.12%	98.89%	1.27°	1.79°	2.10°	1.98°
P2	98.89%	99.95%	0.38°	0.74°	0.82°	1.32°
P3	98.45%	99.78%	0.73°	0.98°	1.76°	1.24°
P4	99.01%	99.92%	0.53°	0.82°	0.91°	0.89°
P5	99.78%	98.89%	1.38°	1.01°	1.29°	0.25°
P6	99.56%	99.78%	0.63°	0.91°	1.23°	1.02°
P7	95.45%	91.12%	11.69°	3.48°	4.37°	1.05°
P8	98.45%	97.56%	2.08°	3.65°	1.72°	2.12°
P9	98.89%	99.12%	0.84°	1.46°	1.29°	0.72°
P10	98.99%	99.95%	0.55°	0.89°	1.61°	1.19°

3 MEDICATION MANAGEMENT AND REMINDERS INCLUDING DRUG-TO-DRUG INTERACTIONS

In this chapter, we analyze the implications of treatment adherence, the reasons and consequences of patient non-adherence. By conducting user interviews with professionals and non-professionals, we propose two complementary solutions for medication management and for finding drug-to-drug interactions. In the first contribution, we develop a mobile application for treatment management designed to aid patients in following their prescription, improving treatment adherence, and preventing overdose. In the second contribution, we implement a platform where users can be alerted about potentially harmful drug interactions by providing the patient with an easily accessible drug storage and a better understanding of the interactions between the medicine supplied.

3.1 Mediminder - Medication Management and Reminder Application

3.1.1 Proposed Solution

A mobile application is proposed in this section as a solution to the problem of low treatment adherence. The functionality and usage scenarios of the mobile application-based software solution will be described. As depicted in Figure 9, the application's software architecture consists of three primary elements: the frontend, the backend, and the database. The front-end is linked to the back-end via a REST API, which is linked to the database via a CRUD Interface. The client-side of the application is a Flutter application due to its performance, excellent documentation, and ready-made and customizable widgets. Flutter also permits rapid development, which is a significant benefit for our incremental approach with prototyping - improvement cycle. The next section will detail the frontend architecture.

3.1.2 Frontend Implementation

As described in the preceding chapter, the client-side of the project is built with Flutter. Flutter is Google's mobile UI toolkit with three essential components. First, a Software Development Kit (SDK), a collection of tools that aid in the application's development, including code compilation into native machine code.

Second, a framework consisting of a user interface (UI) Library based on widgets that includes

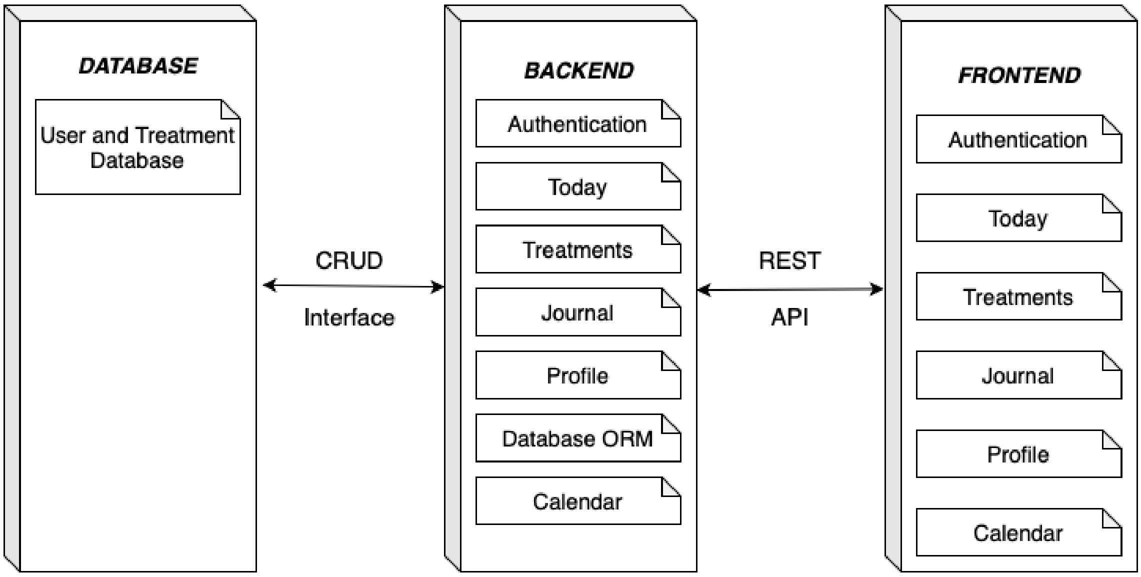

Figure 9: Software Architecture for the Mediminder Application.

customizable elements such as buttons, text boxes, and sliders.

Third, a quick 2D rendering engine that draws its widgets with no bridge between the framework and widgets, resulting in more efficient rendering and animation. Another benefit of utilizing Flutter is that it enables the development of applications for both Android and iOS from a single codebase while adhering to platform conventions. The representation for the two screens of "Today" menu are shown in Figure 10. The user can visualize the medication they need to take in that day, separated by color and with a short description for the time when the pill needs to be taken. Additionally, a pill that has been marked has taken will change its icon in a check mark.

The next important menu for the user is the "Treatments" Screen, as displayed in Figure 11. The user can view the medication that they have to take regularly, add a new treatment or edit the current treatment. The interfaces have been developed as friendly as possible, considering that the age of patients who suffer from chronic diseases and have to undergo heavy treatments vary from 20 years old to 70 years old. The pills can be separated through color codes at the choice of the patient and there are multiple fields to be filled when adding a new treatment: dosage quantity, when should a pill be takend and other observations.

3.1.3 Backend Implementation

The backend, or server, is an intermediary between the frontend and the database, as well as a computational engine for resource-intensive tasks that could slow down the user's device. Due to its flexibility and performance, the backend is written in the Rust programming language, which is extended by two frameworks: Rocket, for RESTful endpoints, and Diesel, an Object Relational Mapping framework for database communication. Within the application, the user has access to various information and can perform a variety of operations.

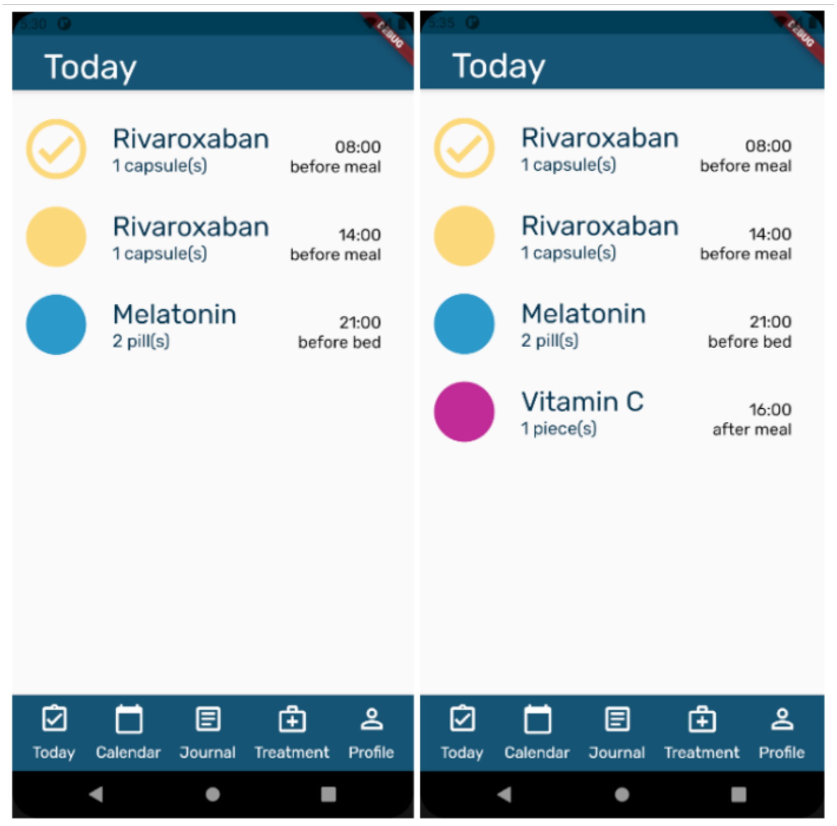

Figure 10: User Views for "Today" Screen of the Mediminder Application.

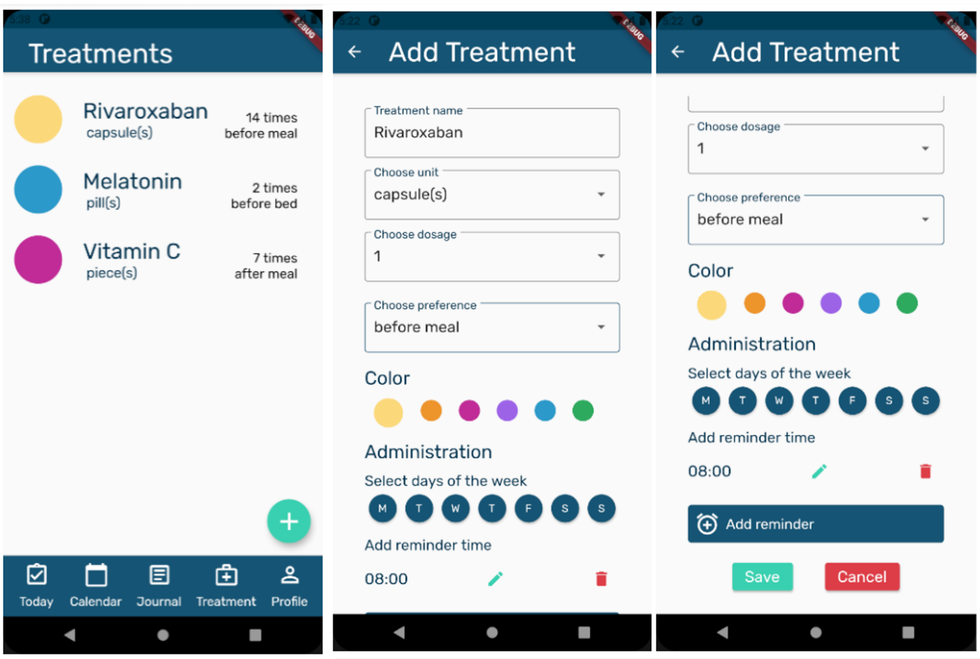

Figure 11: User Views for "Treatments" Screen of the Mediminder Application.

Through the information accessed during a request, the following actions or work flows have been segmented: authentication, today screen, calendar screen, journal screen, treatments screen, and profile screen.

The backend code Figure 12 consists of two major sections: routes for endpoints and models for database interaction and serialization and deserialization of endpoint data. Connecting each component to the other packages or components it employs to compute data are arrows. The Routes package utilizes Models to retrieve and insert data into the database, as well as two additional packages: JWT (JSON Web Token) for authentication purposes, and CORS (Cross-Origin Resource Sharing), a security measure implemented by the majority of web browsers to prevent malicious redirects.

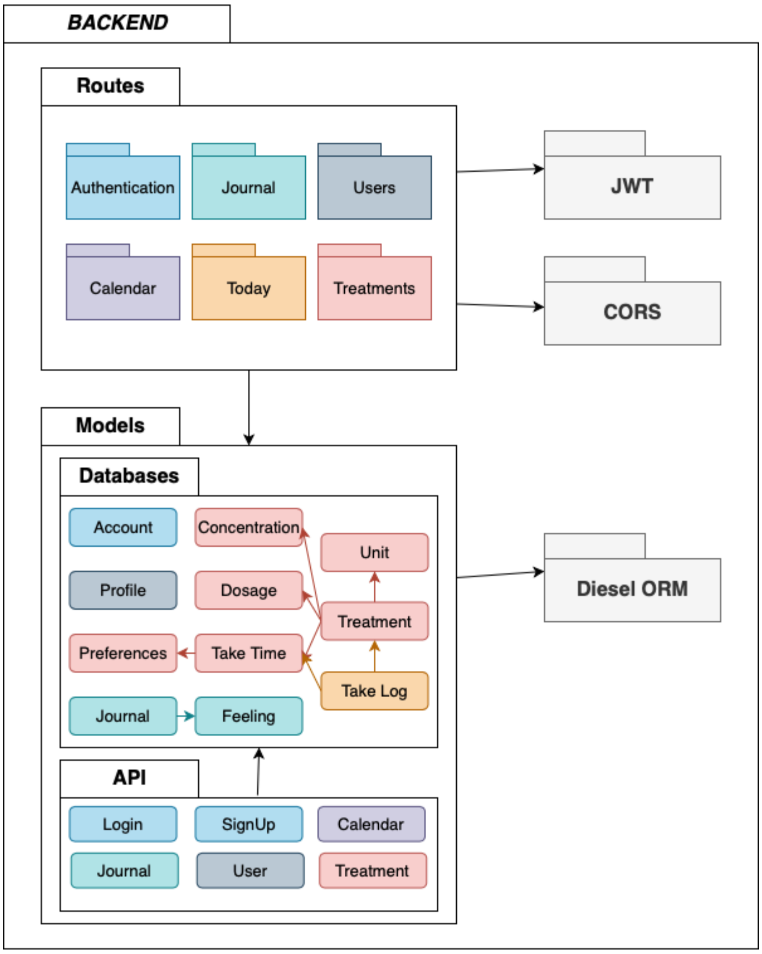

Figure 12: Package Diagram for the Backend Implementation.

3.1.4 Testing and Validating

In this section, we will describe the testing and validation procedure for our application development. During the testing phase of our project, we attempt to determine the intuitiveness of the application's navigation for potential users. There are currently two versions of the application because we wanted to improve the application's accessibility by incorporating user feedback. Therefore, the testing phase of development consists of two iterations separated by two weeks. The second part of the evaluation seeks to determine the ease with which first-time users navigate the application and whether they are able to perform a set of actions required for managing a treatment. Gathering a number of users who had never interacted with the application before and asking them to complete a series of tasks within the application was the approach we chose for this challenge. Throughout the execution of each task, we observed their actions and areas of hesitation or difficulty. We also measured how long it took them to complete each task.

Table 4: User Testing Results for the Mediminder Application

Tasks	**Reference Time**	**Average Time**
Creating and account	25 seconds	46 seconds
Adding a treatment with a reminder	70 seconds	81 seconds
Editing a treatment and adding an administration	30 seconds	62 seconds
Finding treatments scheduled for the current day and marking one as taken	7 seconds	25 seconds
Creating a journal entry	10 seconds	44 seconds
Finding administrations for tomorrow	8 seconds	6 seconds
Updating profile details	40 seconds	42 seconds
Logging out of the account	5 seconds	12 seconds

The environment used for testing consists of an android emulator run on a desktop machine. The mobile device simulated was a Pixel 2 with Android 10. We invited potential users to videoconferences, where we explained to them the tasks they needed to perform using the remote control on our emulator.

It is worth mentioning that the group we tested was primarily composed of people in their fourties and fifties. Consequently, we expect the time values we measured while testing to be higher for older patients (70+). Nevertheless, we managed to identify patterns in their behaviour and gather insight into a good amount of possible changes that could improve the user experience. The sample included 43 users aged on average 54 years old.

Our solution falls in the second category and consists of a mobile application in which users can add treatments, schedule reminders, mark administrations as “taken” or “not taken”, enter symptoms in their journal, and plan using a “calendar” tool. What sets Mediminder apart from other applications is its simple, easy to use UI, specially designed for inexperienced users interested not necessarily in the most advanced features but rather in its accessibility. We developed the application in two iterations, the first one consisting of an MVP and an improved version based on users’ feedback.

3.2 PADDY - A Digital Assistant for Medical Prescriptions and Drug Interactions

3.2.1 Proposed Solution

In a client-server architecture known as an N-tier architecture or a multilayer architecture, the display, application processing, and data management tasks are separated both physically and logically from one another. Another important aspect of this architectural pattern is that the layer above can access resources from the layer below, but the other way around is impossible. Considering that, the tiers can easily be hosted on several machines or clusters ensuring that services are provided without resources being shared. The widespread use of multilayer architecture is represented by the three-tier architecture [64].

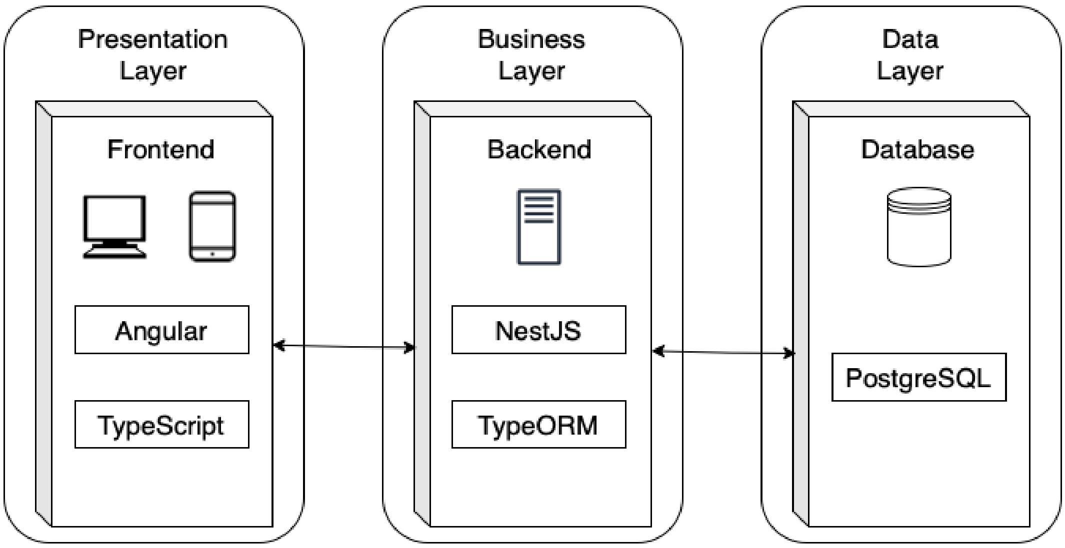

Figure 13: Architecture of Proposed Solution for PADDY

The Presentation tier is the first layer present, and it has the responsibility to display information related to the business logic. This tier can communicate with the business layer directly and displays the result to the user. The Business tier is the second layer, and it contains the application logic. The Data tier is the last layer, and it includes the data persistence mechanism such as database server as well as the data access layer that should allow the retrieving of data.

The three layers of the architecture will be split into three servers each handling its own function. The first server will oversee the presentation layer, the second server will contain the business logic while the third will be responsible for data storage, as shown in Figure 13.

3.2.2 Frontend Implementation

The design for the main screen of the PADDY platform can be visualized in Figure 14. In this section we will briefly describe the technologies that were used in order to achieve our platform's design and frontend development.

To implement the presentation layer, the technology used is Angular 2+. Angular is a Typescript open-source application framework developed by the Angular team from Google and individuals for single page applications. The framework architecture relies on eight building blocks, which are: modules, components, templates, metadata, data binding, directives, services, and dependency injection.

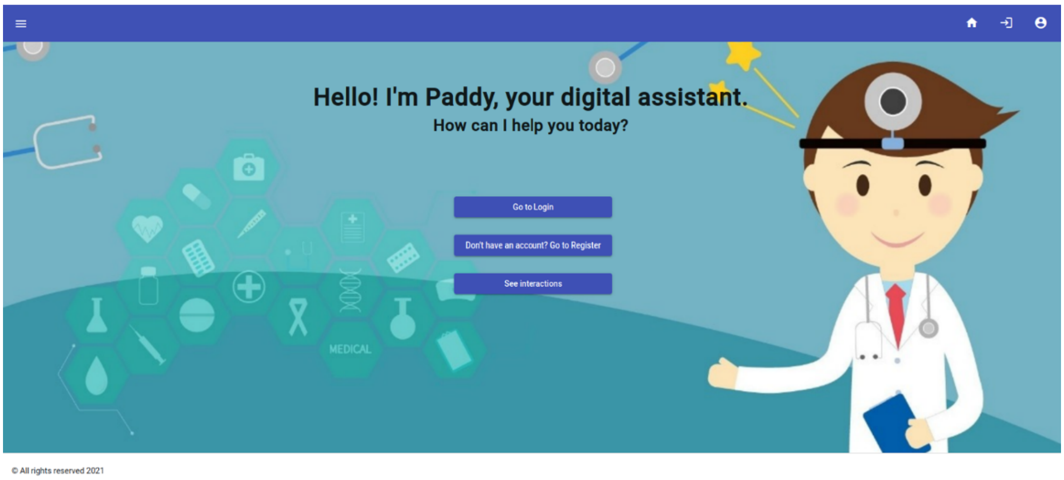

Figure 14: Interface of the Home Screen

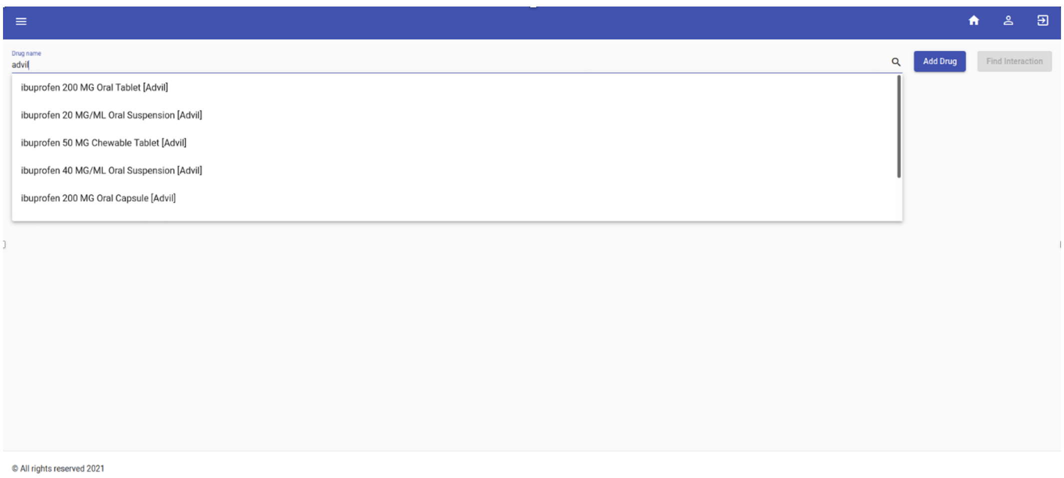

Figure 15: Appearing Screen and Results Returned when Searching for the Medication "advil"

In Figure 15 we can observe how the results of a drug term are displayed when being typed or searched. In the example depicted in Figure 15 the user searches for the term "advil". Details on how the results are found, retrieved, and how the drug-to-drug interaction is identified will be explained in the section Backend Implementation.

To manage the styling of user interfaces in an easier way, Angular proposes a library called Angular Material. It helps to quickly create visually pleasing, intuitive to use web pages or applications that can be ported and used on any device. The following components can be created through this library: buttons, dialog boxes, autocomplete, forms, icons, menus, tables and many other elements.

3.2.3 Backend Implementation

Medication Controller

The medication controller oversees the following operations:

- Create prescription – gives the possibility to a user to create a prescription
- List prescriptions – returns a list will all the prescription a user has
- Modify prescription – gives the ability to a user to modify an existing prescription
- Spell suggestion – helps a user to find a drug with a certain name
- Share prescription – allows a user to share its prescription
- Find interactions – allows the user to check the interaction between various drugs

Spelling suggestion is a feature is intended to assist users in searching for medications by name. To use the resource, an HTTP GET request is sent to the endpoint "/medication/suggestions" with the drug name as a query argument. Only the authentication guard protects this endpoint. If the user is not authenticated, an HTTP 401 Unauthorized response will be delivered. After passing the guard, the drug's name will be entered into the "MedicationService," which will begin the search process. RxNav will use a third-party API to obtain appropriate information [62]. The endpoint of Interaction Checker, "/medication/ interactions," can be accessed by sending an HTTP GET request along with a query parameter containing a list of strings (drug names). To access the functionality, the user must be authenticated; otherwise, an HTTP 401 Unauthorized response and an error message will be delivered. Following successful authentication, the endpoint will always provide a response with the status HTTP 200 Ok and a list of interactions (the list can be empty). The query parameter is extracted and inserted into the "MedicationService."

After obtaining a list of drug names, the next step is to obtain an RXCUI (RxNorm concept unique identifier) for each drug [63]. A request will be sent to the "Get Drug API" for each drug name in the list to acquire all RXCUIs. The final step will be to make another request to the "findInteractionsFromList" API to retrieve the list of interactions. The user will receive a response with the status HTTP 200 OK and a list of interactions after processing the response to obtain only the interaction.

In Figure 16 can be observed how our solution displays the interaction between the three drugs that were selected: ibuprofen 200mg, aspirin 650mg and sodium chloride. Using a red exclamation point, the user is informed that Ibuprofen may decrease the antiplatelet activities of Acetylsalicic acid (aspirin).

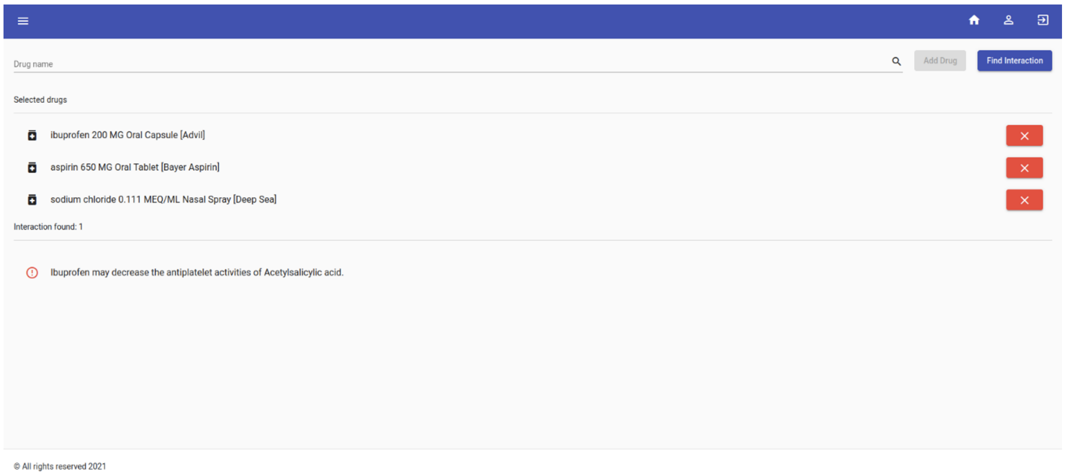

Figure 16: Interactions found by PADDY between Ibuprofen, Aspirin and Sodium Chloride

3.2.4 Testing and Assessment

The behavior of the application's server or database is monitored via the backend testing process. Before the product is distributed to end users, this is done with the intention of discovering undefined and undesirable behaviors such as deadlock, data loss, and corruption. The validation method was divided into two parts so that a robust solution could be developed: manual testing and user testing.

The manual testing was done using Postman [60]. Each endpoint received multiple requests, both valid and invalid, in order to be certain that the application behavior is defined. A valid HTTP POST request with postman can be seen in Figure 17. Each endpoint was tested with multiple requests to cover all the possible responses.

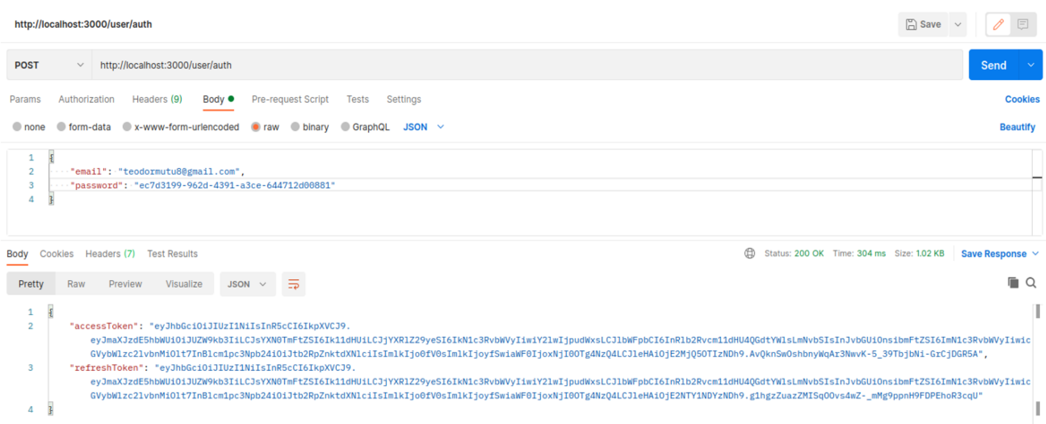

Figure 17: Postman Login Requests Testing Results

In order to test the application, two doctors and 39 non-professionals were asked to spend at least one week using the platform PADDY. In the first phase of the user testing, the users were asked to perform certain tasks for the first time and during their completion, we observed their action and where and if they hesitated or encountered difficulties. We also measured the amount of time they required for completing each task.

In Table 5 we can observe that difference between the reference time and average user time for each task is narrow, except for the complex longer tasks: creating an account, creating a prescription and deleting an account. Nonetheless, the average time a user takes to complete all the listed tasks is still ideal for a beginner.

Table 5: User Testing Results - Task's Performance and Timing

Tasks	**Time of Reference**	**Average User Time**
Tasks	Time of Reference	Average User Time
Creating an account	26 seconds	45 seconds
Searching for a drug	10 seconds	12 seconds
Selecting and adding three drugs	30 seconds	47 seconds
Checking for interactions	6 seconds	13 seconds
Creating a prescription	92 seconds	110 seconds
Listing a prescription	10 seconds	14 seconds
Sharing a prescription	7 seconds	10 seconds
Modifying a prescription	12 seconds	13 seconds
Deleting an account	25 seconds	62 seconds

4 DIGITAL JOURNAL AND DOCTOR-PATIENT PLATFORM FOR DIABETICS

In this chapter, we delve into the routine of a diabetes patient to better understand their behavior towards treatment, disease journal and doctor-patient communication. By observing the limitations of current solutions, we propose a solution that brings benefits in the life of a diabetes patient. We implemented an application for diabetes patients to track their critical metrics and improve the communication with their doctor using telemetry through the application.

4.1 Proposed Solution

In this section, we will describe our project's proposed solution for assisting patients and physicians with diabetes monitoring through the use of readily available digital resources. Our project is primarily a mobile application, so the solution will be presented from a software engineering perspective.

This project proposes a solution for a mobile application that diabetic patients and physicians can use to monitor certain aspects of the disease. The application will facilitate the task of logging the patient's glucose, blood pressure, and cholesterol levels, as well as the patient's weight and the quantity of insulin taken in the case of insulin-based diabetes, while also enabling the physician to observe and respond to the patient's logged data. Our solution is a response to the existing monitoring methods in the medical field, such as using a specialized notebook or medical log sheets, or digital ones, such as the applications described in the previous section. The technologies utilized in the development of our project include server communication and development, database design for storing users' logged values so that they are easily accessible to both patients and doctors, and mobile application technologies for making the user-facing environment visible.

Patients and physicians alike require the logged information for future reference, so our proposed solution requires constant communication with the data storage databases for data retrieval. As a result, the architectural overview of our application is displayed in Figure 18, where the user interacts only with the mobile application, which further solicits data from the housing databases via server communication.

In light of the fact that our project handles sensitive user information, particularly in the case of patients, we have separated data stored on different servers to eliminate the risk of privacy breaches. Consequently, a patient's logged metrics cannot be directly associated

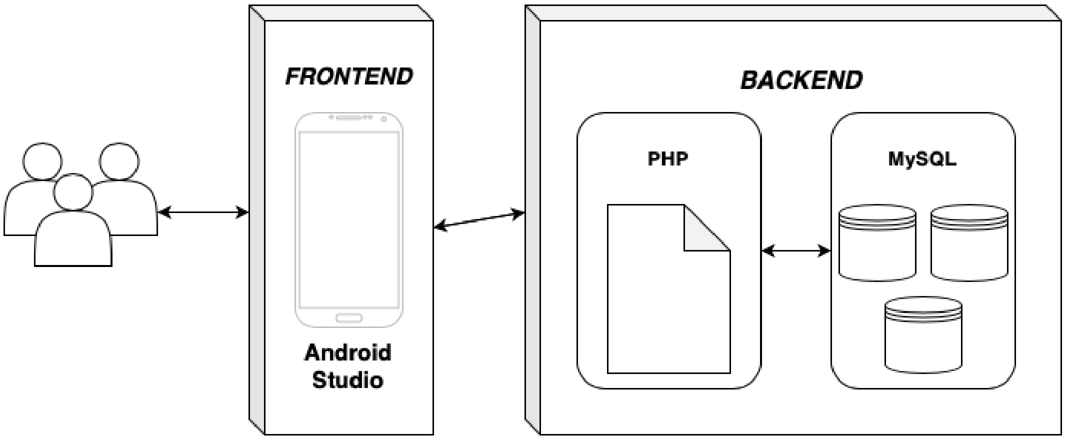

Figure 18: Product Architecture for the ORION Application.

with their corresponding individual, nor can a patient be directly associated with a doctor, as evidenced by the fact that neither can be directly associated with one another in Figure 19. As such, user's information is protected through anonymity in the context of our project, while respecting the European Commission's laws regarding data protection in the European Union (the General Data Protection Regulation [236]).

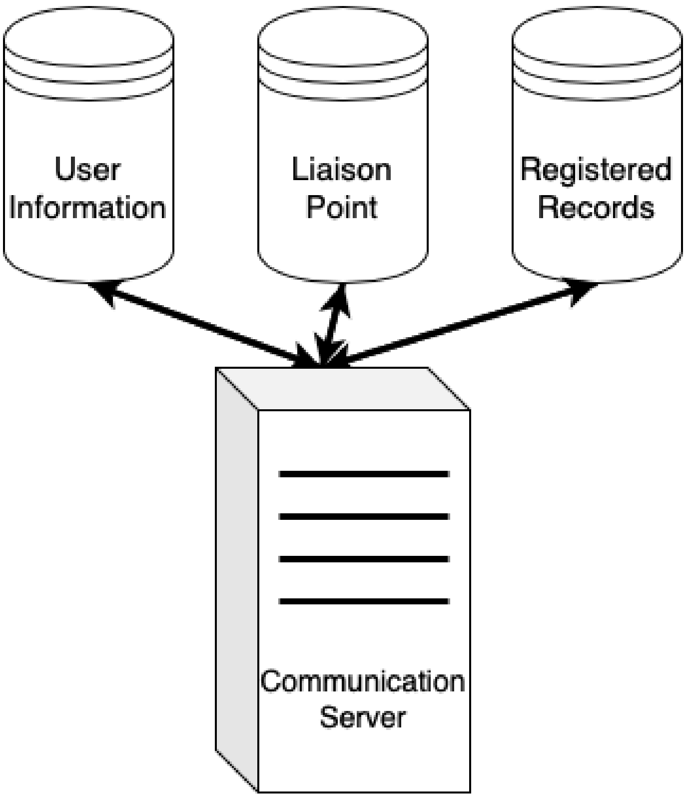

Figure 19: Database Architecture for the ORION Application.

4.2 Implementation

4.2.1 Backend Implementation

IIn software engineering, the backend of a project is typically referred to as the data accessing layer, whereas the frontend is referred to as the presentation layer. Consequently, the backend portion of our project consists primarily of processing requests received from the presentation component and accessing stored data via SQL (Structured Query Language), such as retrieving/storing or updating existing cached records.

As structural composition, this project follows a three-tier architecture, where the layers are as follows: the highest component in the architecture is the presentation layer, which is closest to the user experience. The second tier is the backend section or the data access layer, which acts as a link between the user-facing section and the storage section. The third tier, the storage section, is where data is stored permanently. As illustrated in Figure 20, the technologies used in creating the backend part are PHP and MySQL, while the frontend has been developed using Android Studio and Java. The choice of working with these technologies came as a result of their many advantages that we will go into detail in the succeeding paragraphs.

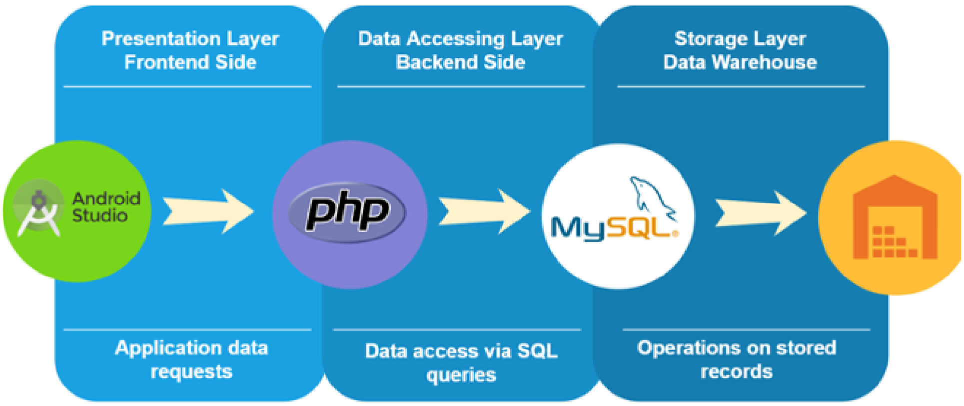

Figure 20: Technologies Linked and Used for the ORION Application.

PHP is used in this project to manage database accesses in response to data requests from the upper layer. PHP has been employed for the two most common types of database access operations, namely data retrieval and data storage. The storing component appears in the scenario of creating new users, both patients and physicians, when their minimal information is stored in accordance with the data protection regulations described in the preceding section. Similarly, when registering patient logs, PHP handles the necessary SQL queries for storing data.

The other primary database operation, data fetching, occurs multiple times in our application: first, when logging in, the database is checked to ensure that the user's credentials exist and an error message is displayed if they do not. In order to accomplish this, a SQL operation is executed on the project's backend, which queries the database containing information about the accounts and their credentials. Based on the response, the user will either be logged into the application successfully, or he/she will be notified of an error regarding their entered credentials.

When a patient creates an account, one of the required fields is a doctor code - a code given to the doctor during registration that facilitates the connection between a doctor and their patients. This code can be viewed as a doctor-type user in the application at all times. The doctor code must be communicated to the patient upon account creation in order to establish a connection between the patient and their doctor. In addition, the entered code must be validated before proceeding with the registration, and if an error occurs, the user is notified that the code is invalid. The process of validating this code involves a backend SQL query that interrogates the database responsible for storing doctor-related information for the entered code. If the code is found, the patient will be able to continue registering; however, if the code is not found, the user will be prompted with a message indicating that the entered value does not exist.

Thirdly, when both types of users create an account, they are required to provide an email address and a password for future login to the application; this email address is verified to prevent the creation of multiple accounts with the same email address. In order to accomplish this, a SQL query is executed to retrieve entries matching the provided email address. Upon receiving a non-zero result, the user is notified that the email address is already in use by another account and asked to provide a new one. When both types of users interact with our application and request to view the registered logs, PHP handles the data retrieval. In the case of patient-type users, requests to view their previously registered personal logs are processed. Currently, the patient can either view all existing logs by clicking a button, or they can filter the results specifically by date by selecting a date from the calendar on their main page. In the case of a doctor-type user, only their patients' log entries are viewable. As with the patient user, the doctor has the option of viewing all logs unfiltered or filtering them by patient name or registration date.

4.3 Testing and Results

Since this project was created with the assistance of physicians, the testing and validation phase included their input, as well as that of some patients. Considering that the goal of this project is to make the lives of both patients and physicians easier, it seemed only appropriate to include them in the testing of our system and to consider their feedback.

4.3.1 Doctor's Outlook

In order to validate our project from the perspective of how intuitive our application is for someone who is not so accustomed to using technology to manage their patient's diabetes, we have devised the following test: we have timed ourselves while accessing the application as a doctor in order to compare the time it would take an actual doctor to navigate the application. The test consists of the following steps: creating an account, logging in, reviewing the patient's logs, filtering the patient's logs according to the specified criteria, and notifying the patient. In the Table 6, we can compare the results of two doctors who followed this scenario to those of our reference time.

Table 6: User Testing Results for the ORION Application - by doctors

Tasks	**Reference Time**	**Average Time**
Creating and account	57 seconds	70 seconds
Logging in	10 seconds	13 seconds
Accessing a patient's logs	24 seconds	40 seconds
Filtering a patient's logs	12 seconds	16 seconds
Notifying a patient	13 seconds	20 seconds

The conclusion of this test, from the perspective of a doctor-type user, indicates that the assumed intuitiveness of our project corresponds to the actual outcome, which is a huge success for our application given that one of our primary goals was to create the simplest user interface possible for our users.

The second scenario tested and validated by the physician was to determine how much of an improvement our application offered over the conventional method previously employed by physicians. Since the entire project was developed in close collaboration with a physician, the application is an immediate improvement in terms of the communication of metrics between doctor and patient, given that routine checkups are typically scheduled weeks or months apart. By using this application, the doctor can access the patient's metrics at any time, as soon as they are registered by the patient, which is an obvious improvement over routine check-ups that are not immediate. Given that our application was created in response to a genuine need for doctors to have easier access to patient status information, this test is more of a formality given that the outcome was one of the primary pillars of our project.

4.3.2 Patient's Outlook

Using the same procedures as in the case of a doctor-type user, we validated the intuitiveness of our project for a patient-type user. In order to make a fair comparison between our team's performance on this test and the patient's performance, we have devised a series of tasks whose sole metric is the time required to complete them. For the patient, the assignments included creating an account, logging into the application (same as for the doctor, but the steps for creating an account differ because more information is required for the patient), registering a log, accessing registered logs, and filtering registered logs by date (using the calendar on the patient's main page). In the adjacent table 7 we can compare the outcomes of 27 patient following this scenario to those of our team.

Table 7: User Testing Results for the ORION Application - by patients

Tasks	**Reference Time**	**Average Time**
Creating and account	104 seconds	131 seconds
Logging in	10 seconds	16 seconds
Registering a log	40 seconds	60 seconds
Accessing registered logs	5 seconds	11 seconds
Filtering registered logs	6 seconds	15 seconds

Concerning the question, "Is our application faster to use than the user's current method? ", we must take into account the fact that the majority of diabetes patients keep a diary-like notebook in which they record their daily measurements and other pertinent information about their disease. If the journal is formatted, patients need only write their metrics by hand and need not worry about the journal's structure. If the journal is simply a notebook with blank pages, the patients must also organize their information, which takes additional time. However, there is still the question of how the patient's data is shared with their physician: whether it is brought to the consultation in person on occasion or shared through existing environments utilized by both parties. Both data sharing scenarios necessitate an additional step from the patient. Considering the points provided, our application is quicker than the current method in any of the possible combinations from the provided examples, as the patient does not need to be concerned with the sharing process and the data logging procedure is similar to filling out a standard form, in which they only need to record the values and not the additional labels for which the measurements are intended.

5 CONCLUSIONS

The work and research for this thesis began when we received a collaboration invitation from an ear-nose-throat (ENT) doctor. We then participated in her office at multiple sessions of assessment and diagnosing patients with equilibrium disorders. We had the chance to observe for the first time state of the art technology that was designed by engineers for engineers, and not for doctors and their patients. We started to research more about the limitations of current solutions and good practices on developing wearable medical devices. By conducting user interviews with both doctors and patients, we started to wonder on how can we bridge the gap between current technological breakthroughs in terms of mobile devices and cloud services and the actual users, with an emphasis on older, less tech-savvy patients. Moreover, we observed that patients who constantly kept in touch with their doctor (most often through Whatsapp), had a better treatment adherence and had a higher confidence in the healthcare system.

In this chapter, we summarize the journey that we made while building our contributions: from the doctor's office to building and testing relevant medical products for experts and their patients. In chapter 3, we explore the pains of movement disorder patients and we develop wearable medical devices to help them in gaining more control in the quality of their life. In chapter 4, we prioritize treatment adherence and build an application that can help and remind patients of their medication, with an addition of a drug-to-drug interaction platform. In chapter 5, we analyze the needs of a diabetes patient and we develop a medical application that aids them in the process of accounting the metrics and evolution of their disease. Plus, the doctor can visualize the journal of the diabetes patient and easily alert them when it's time to set up an appointment. The conclusions for these contributions are described in the following sections.

5.1 Contributions

Wearable Devices for Monitoring Movement Disorders and Diagnosing Balance Diseases

- We conducted user interviews and observational studies with experts (neurologists and ENTs) and patients to validate the common and separate needs they have regarding home monitoring, medication management and treatment adherence.
- We developed a methodology for designing wearable medical devices easy to use and friendly with the doctor and patient.

- We implemented a solution composed of a wearable device on the back of the user and an application (ENTy) that collects, processes and displays the data gathered from the device for diagnosing and assessing patients suffering from balance disorders, such as vertigo [8], [7].
- We build the postural wearable device with a microprocessor and an inertial measurement unit (IMU) for acquiring the data about the balance and posture of the patient.
- Along with two ear-nose-throat doctors, we developed a methodology for testing ENTy on 42 patients and compared the output data, final results, and diagnoses to determine how they differ from the Pro Balance Master, the Polaroid-based system, and the doctor's empirical measurement. The diagnoses and final conclusions were both identical.
- We observed that poor balance, posture and gait are symptoms of a much larger spectrum of movement disorders, so we conducted a market research and doctor-patient interviews where we noted the lack of digital and objective measurement systems for motion disease patients.
- Using the device development methodology that we previously developed, we implemented a medical solution (IRIS) for diagnosing and monitoring people with movement disorders (e.g. Parkinson's Disease) taking in consideration the specifications validated in the research conducted: low cost, low weight, flexibility, digital output data, patient history, treatment evolution, medical use and patient use [2].
- We improved the ENTy devices using newer, smaller sensors and wireless charging to build a smartwatch and a smart ring for assessing hand and finger tremor (frequency and amplitude) and a wearable back device for collecting data to monitor balance, posture and gait
- By using the testing methodology we realized a contrast between IRIS and and other similar solutions (healthcare systems)

Medication Management and Reminders including Drug-to-Drug Interactions

- We conducted a market research with experts (doctors) and users (patients) to validate the need of a solution for tracking treatment adherence, using drug-to-drug interactions
- We proposed Mediminder, an Android application for treatment management designed to aid patients in following their prescription, improving treatment adherence, and preventing overdose.
- We designed the UI of Mediminder for inexperienced used interested not necessarily in the most advanced features but rather in its accessibility, as the testing process validated with real users.
- We implemented a mobile application in which users can add treatments, schedule reminders, mark administrations as "taken" or "not taken", enter symptoms in their journal, and plan using a "calendar" tool [3].
- We tested our medication reminder application with a group of 18 users for two weeks and we validated that our intuitive interaction design helps the end-users in achieving

their goals towards taking the treatment at the right time and building a journal of their medication journey

- We developed a medical platform where users can be alerted about potentially harmful drug interactions by providing the patient with an easily accessible drug storage and a better understanding of the interactions between the medicine supplied [1].
- We designed the application both for patients and doctors to access a patient's drug history with ease, update the current medical prescription and check interactions between various drugs. Users of the application can write and distribute prescriptions in addition to discovering drug interactions.

Digital Journal and Doctor-Patient Platform for Diabetics

- We conducted interviews with two diabetologists and nine patients suffering from diabetes, and we identified that the main solutions for monitoring and journaling a patient's treatment adherence, weight, glucose, blood pressure, cholesterol levels are not reliable and do not provide a continuous communication between the patient and their doctor.
- We implemented ORION an application for diabetes patients to track their critical parameters and improve the communication with their doctor [4].
- We tested our diabetes monitoring application with two doctors and their patients and we discovered that the most valued feature was the ability for the medical professional to remotely view their patient's journal. It enabled the opportunity to verify the patient status without the need of a face-to-face consultation, which was a newly discovered problem in the state of a pandemic.

5.2 List of Publications

5.2.1 Journals

Oprea, F., Costinescu, T., Mutu, T., Rosner, D.(2022). PADDY - A Digital Assistant for Medical Prescriptions, U.P.B. Sci. Bull., Series C, Vol. 84, Iss. 4, 2022, ISSN 2286-3540

Accepted for Publication

Oprea, F., Pătru, C., Rosner, D., Alexandrescu, C., Radovici, A.(2023). ENTy - A wearable Device for Monitoring Movement Disorders, U.P.B. Sci. Bull., Series C, Vol. 85, Iss. 1, 2023, ISSN 2286-3540

5.2.2 Conferences

Oprea, F., Rosner, D., Popescu, F., Scrab, A.(2021) Mediminder – Medication Management and Reminder Application, 20th RoEduNet Conference: Networking in Education and Research

Oprea, F., Rughiniș, R., Sevastre, A., Antohi, A.(2021) ORION – Diabetes Management Platform for Patients, 20th RoEduNet Conference: Networking in Education and Research

Radovici, A., Culic, I., Rosner, D., **Oprea, F.**(2020) A Model for the Remote Deployment, Update, and Safe Recovery for Commercial Sensor-Based IoT Systems, Sensors

Oprea, F., Velciu, H., Seritan, A., Olteanu, L.(2019) Voice Based Dating Application, 19th RoEduNet Conference: Networking in Education and Research

Georgescu, M., Rosner, D., Alexandrescu, C., **Oprea, F.**, Osman, A.(2019) ENTY–A ROMANIAN SYSTEM FOR THE OBJECTIVE EVALUATION OF BALANCE IN HUMANS, ICPESK Physical Education, Sport and Kinetotherapy Journal

Rosner, D., Georgescu, M., **Oprea, F.**, Matesica, I., Alexandrescu, C., Vasile, S.(2016) ENTy—Automated diagnostic and assessment system for equilibrium testing, 15th RoEduNet Conference: Networking in Education and Research

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