

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE SCIENTIFIQUE

UNIVERSITÉ ABDELHAMID IBN BADIS - MOSTAGANEM



Faculté des Sciences Exactes et d'Informatique
Département de Mathématiques et informatique
Filière : Informatique

RAPPORT DE MASTER 2

Option : **Intelligence Artificielle pour l'internet des objets**
(IA4IoT)

THÈME :

Heipox Continuous Glucose Monitoring

Étudiant(e) : Bounouri Nadjat
Belkacem Amani
Derdour Amira

Encadrant : Habib Zahmani Mohamed

Projet soutenu dans le cadre de l'arrêté 1275

Année Universitaire 2023-2024

Résumé

Cette thèse s'inscrit dans le cadre de la conception et du développement d'une application de gestion du diabète. L'objectif est de développer une application permettant de surveiller la glycémie en continu, de prédire les niveaux de glycémie et d'informer l'utilisateur en cas d'urgence. L'application doit être simple et facile à utiliser pour tous les groupes d'âge.

Pour développer notre application, nous avons utilisé le langage de programmation JAVA, dans l'environnement de développement Android Studio, ainsi que le langage de programmation Python. Nous avons utilisé le moteur de gestion de base de données NoSQL et le langage de modélisation UML.

Mots-clés:

Gestion du diabète, surveillance de la glycémie, prédiction de la glycémie, alertes d'urgence, application conviviale, utilisation multi-âge, programmation JAVA, Android Studio, Python, base de données NoSQL, modélisation UML

Abstract

This thesis is part of the design and development of a diabetes management app. The aim is to develop an app for continuous blood glucose monitoring, predicting blood glucose levels and informing the user in case of an emergency. The app should be simple and easy to use for all age groups.

When developing our application, we used the JAVA programming language, within the Android Studio development environment, in addition to the Python programming language. We used the NOSQL database management engine and the UML modeling language

Keywords:

Diabetes management, Blood glucose monitoring, Blood glucose prediction, Emergency alerts, User-friendly application, Multi-age usability, JAVA programming, Android Studio, Python, NOSQL database, UML modeling

ملخص

هذه الأطروحة هي جزء من تصميم وتطوير تطبيق لإدارة مرض السكري. الهدف منها هو تطوير تطبيق للمراقبة المستمرة للجلوكوز في الدم وكذلك التنبؤ بمستوياته وإعلام المستخدم في حالة الطوارئ. يجب أن يكون التطبيق بسيطاً وسهل الاستخدام لجميع الفئات العمرية.

عند تطوير تطبيقنا، استخدمنا:

- Android Studio، ضمن بيئة تطوير JAVA لغة البرمجة.
- لغة البرمجة بايثون.
- محرك إدارة قاعدة بيانات NoSQL.
- UML لغة النمذجة.

كلمات مفتاحية:

- إدارة مرض السكري
- مراقبة نسبة الجلوكوز في الدم
- التنبؤ بنسبة الجلوكوز في الدم
- تنبيهات الطوارئ
- تطبيق سهل الاستخدام
- قابلية الاستخدام متعدد الأعمار
- JAVA برمجة
- استوديو أندرويد
- بايثون
- NoSQL قاعدة بيانات

اهداء

(وَأَخِرُ دَعْوَاهُمْ أَنْ الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ).

الحمد لله الذي يسر لي البدايات وأكمل لي النهايات وبلغني الغايات. الحمد لله الذي لا يتم جهد إلا بعونه ولا يُختم سعي إلا بفضله. اللهم انفعني بما علمتني واجعله حجة لي لا علي.

ها أنا اليوم أعيش اللحظات الأخيرة في ذلك الطريق الذي كان يحمل في باطنه العثرات والأشواك. ورغم ذلك، ظلت قدمي تخطو بكل صبر وطموح وعزيمة وتفائل وحسن ظن بالله. وكم من أيام مرت شعرت بثقلها ومرارتها، ولكن لم تعقني، بل كانت نكزى تمر لتتير الأحلام.

أهدي بكل حب ثمرة جهدي وتخرجي:

إلى نفسي العظيمة القوية التي تحملت كل العثرات وأكملت رغم الصعوبات.

إلى رفاق الخطوة الأولى والخطوة ما قبل الأخيرة، إلى من كانوا في السنوات العجاف سحاباً ممطراً، أنا ممتنة لكم.

إلى التي تعجز كل الكلمات عن وصفها، إلى التي كانت النور في عتمتي، إلى التي كان دعاؤها سر نجاحي، إلى المضحية من أجلي ورافقتني في كل أوقاتي، إلى من تعبت بدون مقابل وتحملت العناء من أجل إسعادي وإتمام مسيرتي الدراسية.

إلى من هي جزء من القلب والفؤاد، إلى معلمتي وسيدتي العظيمة، إلى قدوتي وخير مثال، أُمي الحبيبة، متعها الله بالصحة والعافية.

إلى ذلك الرجل العظيم، إلى من كان لي عموداً فقرياً ساندني بكل حب في ضعفي، إلى الذي أخرج أجمل ما في داخلي وشجعني دائماً للوصول إلى طموحاتي.

إلى أول من انتظر هذه اللحظات ليفتخر بي، إلى من أعطاني ولا يزال يعطيني بلا حدود، إلى سندي ومسندي والضوء الذي ينير حياتي.

إلى من أحمل اسمه بكل فخر وعزة وشرف، إلى والدي وسيدي وحببي، أدامك الله ظلاً لنا.

إلى من وهبني الله نعمة وجودهم في حياتي، إلى العقيد المتين، من كانوا مشجعين و مؤازرين لي في رحلة بحثي، إخواني وأخواتي.

إلى من كاتفوني ونحن نشق الطريق معاً نحو النجاح في مسيرتنا العلمية، إلى رفيقتي دربي، أدامكم الله ورعاكم.

وإلى خاتم الأنبياء محمد صلى الله عليه وسلم، الذي أضاء لنا طريق العلم والنور، وإلى آل بيته الأطهار الذين كانوا مثلاً للصدق والأمانة والعلم.

وأخيراً، إلى كل من ساندني وساعدني، وكان له دور، من قريب أو بعيد، في إتمام هذه الدراسة. سائلة المولى أن يجزي الجميع خير الجزاء في الدنيا والآخرة.

Thanks

First and foremost, we express our heartfelt gratitude to God for granting us the strength, wisdom, and perseverance to complete this project.

We extend our sincere thanks to our supervisor, Mr. Zahmani, professors at Abdelhamid Ibn Badis University, university jury members, and startup program mentors for their invaluable support and guidance.

Special appreciation goes to Mr. Zahmani for his unwavering support and insightful guidance, shaping the direction of our work. We're also grateful to the professors for their dedication to teaching and commitment to academic excellence, to the jury members for their time and expertise in evaluating our project, and to the startup mentors for their strategic guidance and encouragement.

Additionally, we thank all supporters, whether direct or indirect, for their contributions to our project's completion.

In conclusion, we express heartfelt gratitude to everyone involved for their support, encouragement, and expertise, which have been instrumental in our growth and learning throughout this journey.

List of figures

Figure N°	Titre de la figure	Page
Figure 1	Types of diabetes	8
Figure 2	Glucose & Insulin	11
Figure 3	Continuous glucose monitoring devices for diabetes management	13
Figure 4	different type of current CGM Sensors	14
Figure 5	CGM sensor react with interstitial fluid	19
Figure 6	CGM device components	21
Figure 7	CGM Pack details	22
Figure 8	Step guide to insert your CGM device	23
Figure 2.1	The hierarchy of artificial intelligence	28
Figure 2.2	BiLSTM Explained	30
Figure 2.3	Root mean square error Formula	31
Figure 2.4	R-squared Formula	32
Figure 2.5	Mean Relative Error Formula	32
Figure 2.6	The Pearson correlation Formula	33
Figure 3.1	Diagram of use cases associated with user	38
Figure 3.2	Class Diagram	39
Figure 3.3	Authentication Sequence Diagram	40
Figure 3.4	Sequence diagram Registration	42
Figure 3.5	Sequence diagram Edit profile	45
Figure 3.6	Sequence diagram Change password	48
Figure 3.7	Sequence diagram reset password	51

Figure 3.8	Sequence diagram change email	54
Figure 3.9	Sequence diagram update glucose data.	57
Figure 4.1	Java logo	61
Figure 4.2	Python logo	62
Figure 4.3	Firebase	63
Figure 4.4	Git logo	64
Figure 4.5	GitHub logo	64
Figure 4.6	Android studio logo	65
Figure 4.7	Anaconda logo	66
Figure 4.8	Jupyter notebook logo	67
Figure 4.9	Modelio logo	68
Figure 4.10	Figma logo	68
Figure 4.11	Adobe illustrator logo	69
Figure 4.12	Firebase authentication	70
Figure 4.13	Firebase realtime database	70
Figure 4.14	Launch interface	71
Figure 4.15	login interface	72
Figure 4.16	Registration interfaces	73
Figure 4.17	Home page interface	74
Figure 4.18	Prediction interface	75
Figure 4.19	Profile interface	76
Figure 4.20	Edit profile interface	77
Figure 4.21	Settings interface	78
Figure 4.22	Change password interface	78
Figure 4.23	Change email interface	79

Figure 4.24	Notification interface	80
Figure 4.25	Download data Interface	81
Figure4.26	Sharing interface	82

List of table

Tableau 1 – Model Evaluation Results	35
--	----

Table of contents

General introduction	5
Chapitre 1 Background and Aim of the thesis	7
1.1 Introduction	7
1.2 Definition of diabetes	7
1.3 Types of diabetes	8
1.3.1 Type 1 diabetes	8
1.3.2 Type 2 diabetes	9
1.3.3 Gestational diabetes	9
1.4 The Glucose-Insulin Control Mechanism	10
1.5 Diabetes-Related High and Low Blood Glucose Levels	11
1.5.1 High blood sugar (hyperglycemia)	11
1.5.2 Low blood sugar (hypoglycemia)	12
1.6 Problematic	12
1.7 Continuous Glucose Monitoring (CGM)	13
1.8 Current types of CGM Sensors	14
1.8.1 Invasive CGM Sensors	15
1.8.2 Minimally Invasive CGM Sensors	15
1.8.3 Non-Invasive CGM Sensors	15
1.9 State of the Art in Diabetes Management	16
1.10 Exploring Leading CGM Technologies in Algeria	16
1.10.1 Free Style Libre 2 System	16
1.10.2 Dexcom G6 System	17
1.11 Introducing a Novel CGM Solution	18
1.11.1 Sionics GS1 System	18
1.12 Sionics GS1 CGM System Component	19
1.12.1 Minimally invasive CGM Sensor	20

1.12.2 The transmitter	20
1.12.3 Display Device (Smart Device/Application)	21
1.13 Inserting and fixing the Sionics GS1 sensor	21
1.14 Utilization of Sionics GS1 System in Our Project	23
1.15 Needs Analysis	24
1.15.1 Functional requirements	24
1.15.2 Non-functional requirements	24
1.16 Conclusion	25
Chapitre 2 Application of AI in Healthcare	26
2.1 Introduction	26
2.2 Definition and Fundamentals of Artificial intelligence (AI)	26
2.2.1 Definition of AI	26
2.2.2 Machine learning	27
2.2.3 Deep learning	27
2.3 Application of Machine learning and deep learning models in Health Care	28
2.3.1 Recurrent neural network (Simple RNN)	29
2.3.2 Long short-term memory (LSTM)	29
2.3.3 Support Vector Regression (SVR)	29
2.3.4 Bidirectional LSTM	30
2.4 Predictive Model Evaluation Metrics	30
2.4.1 Root mean square error	31
2.4.2 R-Squared	31
2.4.3 Mean Relative Error	32
2.4.4 Correlation	32
2.5 Comparative Analysis of Evaluation Metrics: RMSE, MRE, and R - Squared	33
2.6 Dataset Description	34
2.6.1 Why we use this dataset	34
2.6.2 Future use of patient data	34
2.7 Discussion of Model Evaluation Results	34

Conclusion	35
Chapitre 3 System design	37
3.1 Introduction	37
3.2 General use case diagram	37
3.3 Diagramme de classe	39
3.4 Sequence diagram	39
3.4.1 Sequence diagram « Authentication »	40
3.4.2 Sequence diagram « Registration »	41
3.4.3 Sequence diagram « Edit profile »	45
3.4.4 Sequence diagram « Change password »	47
3.4.5 Diagramme de séquence « Forgot password »	51
3.4.6 Sequence diagram « Change email »	53
3.4.7 Sequence diagram « Update glucose data »	57
3.5 Conclusion	59
Chapitre 4 Conception and implementation	60
4.1 Introduction	60
4.2 Development environment	60
4.2.1 Material environment	60
4.2.2 Software environment	61
4.3 Utilizing Firebase services in our application	69
4.3.1 Firebase Authentication	69
4.3.2 Firebase Real-time Database:	70
4.4 Implementation of the application	71
4.4.1 Launch interface	71
4.4.2 Authentication interface	72
4.4.3 Registration interface	72
4.4.4 Home interface	73
4.4.5 Prediction interface	74
4.4.6 Profile interface	75

4.4.7 Edit profile interface	76
4.4.8 Setting interface	77
4.4.9 Notification Interface	79
4.4.10 Download data interface	81
4.4.11 Sharing data Interface	81
4.5 Conclusion	82
Conclusion Générale	83
Bibliographie	84

General introduction

The field of medical technology represents an area of innovation and progress where technology meets health to profoundly transform the delivery of healthcare to citizens in a country facing various health challenges including the way we manage diabetes, which has become a major health problem in Algeria due to its impact on a growing number of people of all ages and groups. Therefore, in light of the revolution of medical innovation and our deep-rooted commitment to face this reality in the management of diabetes in our country, our mission is to provide accurate and continuous blood glucose monitoring solutions to ensure optimal control of the disease and prevent complications.

Our solution is to develop a blood glucose monitoring application that is perfectly suited to the reality of the needs of people living in Algeria, as this application will provide many features such as ease of use and customized alerts to help users manage their cases proactively and this is due to its availability of prediction features .

In the future, we also aspire to develop the glucose sensor to make this easy-to-use portable sensor made by Algerian hands an indispensable addition to our continuous diabetes monitoring application, providing a complete integrated solution to improve the lives and independence of people with diabetes in Algeria.

This dissertation is made up of four chapters:

Chapter 1: Background and aim of the thesis

In this chapter, we discuss diabetes and current methods for glucose monitoring, focusing on recent advancements and technologies available for continuous glucose monitoring (CGM).

Chapter 2: Application of AI in healthcare

This chapter delves into the application of artificial intelligence, specifically Machine Learning and Deep Learning, to enhance glucose level prediction and diabetes management.

Chapter 3: System Design

In this chapter, we present the design part of our system. For this, we opted for the UML language and used several diagrams:

- Use case diagrams for representing user needs.
- Sequence diagrams for representing the use cases.
- The class diagram for representing the objects of the system.

Chapter 4: Realization and Implementation

The last chapter includes a small presentation of the environment in which our application was realized, the tools and technologies used and the interfaces of our application.

Chapitre 1

Background and Aim of the thesis

1.1 Introduction

In this chapter, we provide an overview of the Continuous Glucose Monitoring (CGM). We have carried out a study of the existing situation which will help us lay the foundations for the needs of the system to be created. We conclude this chapter with a solution for the CGM.

1.2 Definition of diabetes

Diabetes is a chronic (long-lasting) health condition that affects how your body turns food into energy. Your body breaks down most of the food you eat into sugar (glucose) and releases it into your bloodstream. When your blood sugar goes up, it signals your pancreas to release insulin. Insulin acts like a key to let the blood sugar into your body's cells for use as energy. With diabetes, your body doesn't make enough insulin or can't use it as well as it should. When there isn't enough insulin or cells stop responding to insulin, too much blood sugar stays in your bloodstream. Over time, that can cause serious health problems, such as heart disease, vision loss, and kidney disease. There isn't a cure yet for diabetes, but losing weight, eating healthy food, and being active can really help. Other things that someone could also help are:

- Take medicine as prescribed.
- Get diabetes self-management education and support.
- Make and keep health care appointments.[\[1\]](#)

1.3 Types of diabetes

There are three main types of diabetes: type 1, type 2, and gestational diabetes (diabetes while pregnant). The following figure 1 represents an image of the difference between diabetes type 1 and type 2.

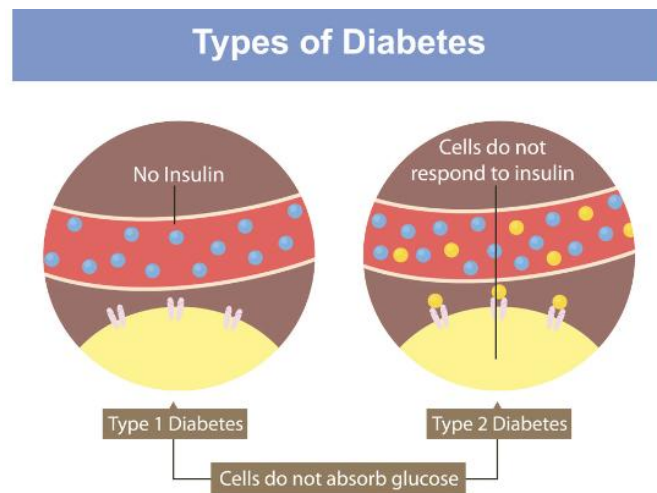


Figure 1 – Types of diabetes

1.3.1 Type 1 diabetes

Type 1 diabetes (previously known as insulin-dependent, juvenile or childhood-onset) is characterized by deficient insulin production and requires daily administration of insulin. In 2017 there were 9 million people with type 1 diabetes; the majority of them live in high-income countries. Neither its cause nor the means to prevent it are known. In most cases, type 1 diabetes has an autoimmune origin and affects children or young adults, and in fact it is also called “juvenile diabetes”.[\[2\]](#)

1.3.2 Type 2 diabetes

Type 2 diabetes affects how your body uses sugar (glucose) for energy. It stops the body from using insulin properly, which can lead to high levels of blood sugar if not treated. Over time, type 2 diabetes can cause serious damage to the body, especially nerves and blood vessels. Type 2 diabetes is often preventable. Factors that contribute to developing type 2 diabetes include being overweight, not getting enough exercise, and genetics.

Early diagnosis is important to prevent the worst effects of type 2 diabetes. The best way to detect diabetes early is to get regular check-ups and blood tests with a healthcare provider.

Symptoms of type 2 diabetes can be mild. They may take several years to be noticed. Symptoms may be similar to those of type 1 diabetes but are often less marked. As a result, the disease may be diagnosed several years after onset, after complications have already arisen.

More than 95% of people with diabetes have type 2 diabetes. Type 2 diabetes was formerly called non-insulin dependent, or adult onset. Until recently, this type of diabetes was seen only in adults but it is now also occurring increasingly in children.

1.3.3 Gestational diabetes

Gestational diabetes is hyperglycemia with blood glucose values above normal but below those diagnostic of diabetes. Gestational diabetes occurs during pregnancy.

Women with gestational diabetes are at an increased risk of complications during pregnancy and at delivery. These women and possibly their children are also at increased risk of type 2 diabetes in the future.

Gestational diabetes is diagnosed through prenatal screening, rather than through reported symptoms.

1.4 The Glucose-Insulin Control Mechanism

The glucose substrate represents the main source of fuel for the human body. Thanks to a complex regulatory mechanism, glucose concentration in blood of healthy subjects is tightly kept in a limited range, i.e. 70-180 mg/dL, although it is subject to fluctuations due to utilization and production processes. Different hormones are involved in this regulation. The most important one is insulin, which is produced by the beta-cells of the pancreas, and is responsible for lowering the glucose concentrations. Insulin is also the principal control signal for conversion of glucose to glycogen for internal storage in the liver.[\[3\]](#)

As depicted in Figure 2, glucose is used by many organs, tissues and cells. Some, like brain or red blood cells, consume glucose continuously and independently of insulin and the interruption of this supply may cause severe damages. For muscles, fatty tissue, and liver the absorption of glucose is proportional to insulin concentration. Glucose in blood derives both from intestinal absorption of carbohydrates and from internal production.

In particular, the latter consists in the conversion to glucose of glycogen stored in the liver or in the so-called gluconeogenesis (the “re-construction” of glucose using substrate derived from glucose degradation).

An increase in blood glucose concentration causes an increase in insulin secretion. Glucose and insulin concentration have the same effect on the glucose production and utilization: an increase in insulin (or glucose) concentration causes a decrease of glucose production and an increase of glucose utilization by muscle, while there is no influence on glucose utilization by the brain. The following figure 2 represents an image of the Glucose & Insulin system. The following figure 2 represents an image of the Glucose & Insulin system.

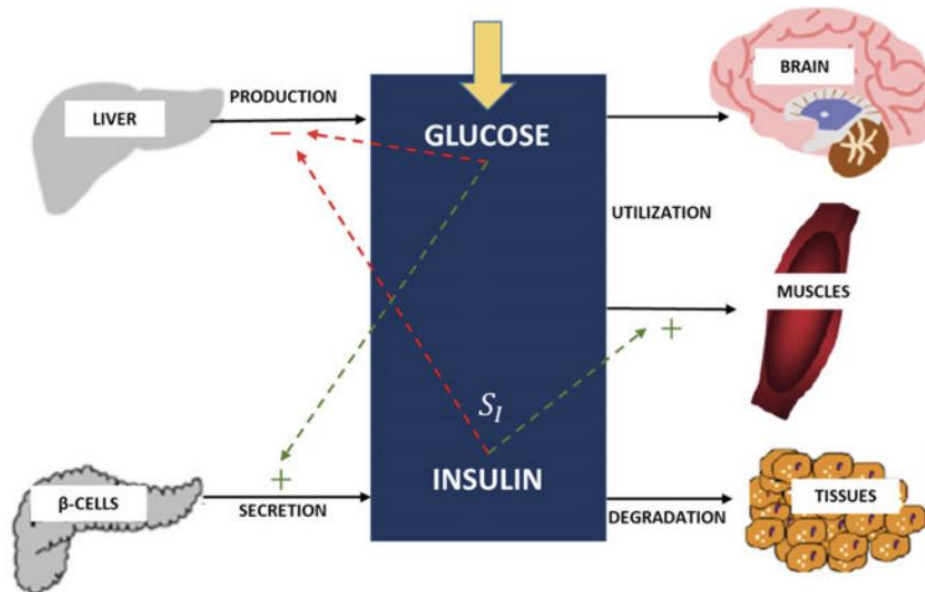


Figure 2 – Glucose & Insulin

1.5 Diabetes-Related High and Low Blood Glucose Levels

When you have diabetes, you may have high blood sugar levels (hyperglycemia) or low blood sugar levels (hypoglycemia) from time to time. A failure of the glucose counter-regulatory system causes Blood Glucose Levels (BGL) to exceed the euglycemic range. Hypoglycaemia and hyperglycaemia might lead to short and long term complications, respectively.

1.5.1 High blood sugar (hyperglycemia)

High blood sugar occurs when the sugar (glucose) level in your blood rises above the target range. Blood sugar can rise when you eat too many calories or miss taking your medicines (insulin or pills). It can also rise when you have an infection or illness, an injury, or surgery. Even emotional stress can cause your blood sugar to rise. High blood sugar usually happens slowly over a period of hours to days. But missing a dose of insulin can cause a quick rise in blood sugar levels. Blood sugar levels just above your target range may

make you feel tired and thirsty. If your blood sugar stays higher than your target range for weeks, your body will adjust to that level. You may not have as many symptoms of high blood sugar.[\[4\]](#)

1.5.2 Low blood sugar (hypoglycemia)

Low blood sugar occurs when the sugar (glucose) level in your blood drops below what your body needs. Your blood sugar can drop quickly if you don't eat enough food or you skip meals. It can also happen if you take too much medicine (insulin or pills), exercise more than usual, or take certain medicines that lower blood sugar.

People who lose weight or develop kidney problems may not need as much insulin or other medicines as they did before they lost the weight or had kidney problems. Their blood sugar may drop too low, so when the body goes through such changes, blood sugar should be checked frequently.

When your blood sugar level drops below 70 mg/dL, you will usually have symptoms of low blood sugar. This can happen quickly, in 10 to 15 minutes.[\[4\]](#)

1.6 Problematic

Self Monitoring Blood glucose Level (SMBG) is the most common test for measuring BGL. It involves pricking a finger with a lancet device to obtain a small blood sample, applying a drop of blood onto a reagent test-strip, and determining the glucose concentration by inserting the strip into a measurement device. Different manufacturers use different technologies, but most systems measure an electrical characteristic proportional to the amount of glucose in the blood sample.

Although it is widely used, SMBG has limitations that can affect its effectiveness.

- SMBG can be time-consuming and require a significant amount of effort.

- Variability and inaccuracies in measurements caused by blood sampling, environmental conditions.
- SMBG involves pricking the finger with a lancet to obtain a blood sample, this can cause pain and discomfort, especially if the individual needs to test their blood glucose levels frequently.
- SMBG can only give the instance of blood glucose and not the whole story.
- Failing to capture blood glucose fluctuations throughout the day.
- Provides only a snapshot of blood glucose levels at a single moment in time.

1.7 Continuous Glucose Monitoring (CGM)

The CGM is a continuous glucose measurement system. It mainly makes it possible to monitor glucose levels 24/24 and 7/7, a few minutes apart, thanks to a small sensor placed on the abdomen or arm using an automatic insertion device. The sensor measures your interstitial glucose level, that is to say the level of glucose contained in the liquid that is between the cells. [\[5\]](#)



Figure 3 – continuous glucose monitoring devices for diabetes management.

1.8 Current types of CGM Sensors

Continuous glucose monitoring sensors include a variety of technologies designed to monitor blood glucose levels in individuals with diabetes. These sensors can be classified into different types according to: a) the kind of measure (direct or indirect); b) to the level of invasiveness; c) to the physical principle the sensor is based.

There are three different categories of CGM sensors:

- Invasive
- Minimally invasive
- Non-invasive

Each type of SGM sensor offers certain advantages and challenges. Their understanding is critical for healthcare providers and patients alike in choosing the most appropriate CGM that meets the diverse needs of individuals for optimal diabetes management.

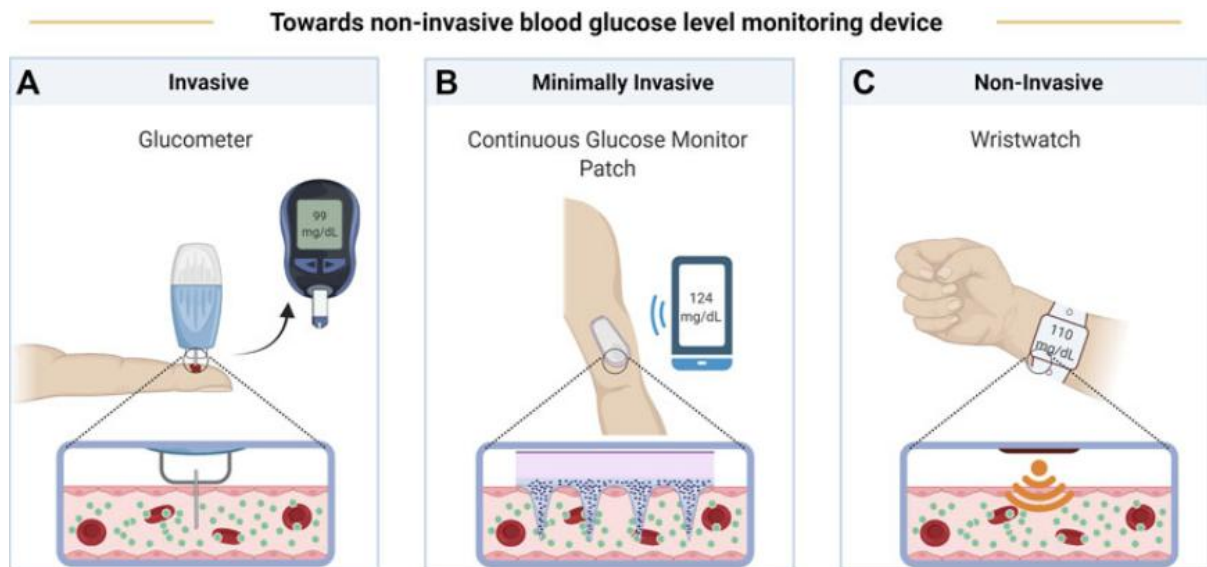


Figure 4 – different type of current CGM Sensors

1.8.1 Invasive CGM Sensors

Measurement of BGL could be obtained invasively by using sensors implanted into the body. These sensors are extremely accurate, but given their level of invasiveness they are particularly suited for operating rooms and intensive care units.

There are different technologies allowing transducer glucose concentration into an electrical signal, most of them are based on the glucose-oxidase principle. Other sensors are based on competitive binding of glucose with other molecules or glucose spectral properties.

[\[6\]](#)

1.8.2 Minimally Invasive CGM Sensors

Instead of implanting the sensor into the body, a subcutaneous needle may be used to sense glucose. Usually these systems are based on enzyme electrodes, most of the time exploiting a glucose-oxidase principle. Subcutaneous needles provide much more information about dynamics and glucose excursions if they are compared to a finger-prick system, providing readings every 1-5 minutes for up to 14 days. [\[6\]](#)

1.8.3 Non-Invasive CGM Sensors

Non-invasive Continuous Glucose Monitoring NI-CGM sensors measure glucose concentration through the skin without extracting blood or interstitial fluid or without a needle penetrating the skin for reaching these fluids. Hence, these sensors are more comfortable for the patient than the previously described sensors and do not cause displeasing physiological reactions. However, the measure is affected by different confounding factors, making it more difficult to perform an accurate measurement. [\[6\]](#)

1.9 State of the Art in Diabetes Management

Continuous glucose monitoring (CGM) has advanced diabetes management, providing real-time insights into blood sugar levels while enabling personalized interventions. In this brief overview of the latest technology at CGM, we dive into the latest developments, challenges, and implications for individuals with diabetes.

1.10 Exploring Leading CGM Technologies in Algeria

1.10.1 Free Style Libre 2 System

The Freestyle Libre CGM system is available for individuals aged 4 years and older with diabetes, including pregnant women. It offers a convenient, accessible, and easy-to-use solution for continuously measuring interstitial fluid glucose levels. The system consists of a microsensor and either a reader or a smartphone app.[\[7\]](#)

- **Connectivity** : All sensors in the FreeStyle Libre system must be started with an initial scan with App 16 or Reader 8.
- **Accurate** : FreeStyle Libre 2 has a Mean Absolute Relative Difference (MARD) of 9.3% (9.2% for adults and 9.7% for children), making it the only iCGM sensor to maintain a high level of accuracy over a 14-day period.

MARD: Mean Absolute Relative Difference (measure of accuracy), The lower the MARD the better.[\[9\]](#)

- **Reliable** : With optional real-time glucose alarms, patients can be notified immediately when their glucose levels are high or low.
- **Convenient** : The FreeStyle Libre system offers the option to check glucose readings either on the FreeStyle Libre 2 reader or on the smartphone app.
- **Affordable** : The most affordable CGM system, even without insurance coverage [\[7\]](#).

- **Data Sharing and Remote Monitoring** : Share Data in Real Time Remotely in the FreeStyle Libre and LibreLinkUp apps, you can share data with doctors or caretakers.

1.10.2 Dexcom G6 System

The Dexcom G6 Continuous Glucose Monitoring System consists of a small sensor that is worn on the body for 10 days and transmits data on glucose levels to a compatible smart device or receiver every 5 minutes. [\[10\]](#)

- **Connectivity** : The Dexcom G6 continuous glucose monitoring (CGM) system uses Bluetooth connectivity to transmit glucose data to compatible devices such as smartphones or receivers .
- **Accurate** : Dexcom CGM systems are known for the accuracy of their sensors, providing reliable glucose readings that help users make informed decisions about managing diabetes.
- **Reliable** : Simple alerts warn you of highs and lows and this is only by setting your personal range to be notified when it is too high and before it drops too much.
- **Convenient** : It allows the sensor to connect to a compatible receiver or smart device (your smartphone or smartwatch, ...). This allows users to easily access their glucose data on their favorite devices with just a quick glance.
- **Affordable** : Dexcom strives to provide affordable options for users seeking continuous glucose monitoring solutions. Additionally, Dexcom offers assistance programs and resources to help individuals navigate insurance coverage and access financial support if needed. Overall, Dexcom aims to balance the affordability of their CGM systems with the high-quality features and benefits they provide to users managing diabetes. Widely covered and affordable This includes most commercial plans. [\[10\]](#)
- **Data Sharing and Remote Monitoring** : Similar to the FreeStyle Libre, Dexcom CGM systems enable users to share their glucose data with caregivers or healthcare providers remotely. This feature facilitates remote monitoring and support, allowing healthcare

professionals to review glucose trends and provide personalized guidance. The Dexcom Follow app allows your circle of support to be there for you, even when you're apart. You can also share your progress with your doctor right from the Dexcom Clarity app. [\[10\]](#)

1.11 Introducing a Novel CGM Solution

1.11.1 Sionics GS1 System

Sionics CGM has the advantage of being the first real-time glucose monitoring system in China and is for people aged 18 years and older. It's calibration-free for 14 days using Bluetooth, providing users with a hassle-free experience without the need for frequent calibration .

- **Connectivity** : Thanks to a robust Bluetooth connection between the GS1 and the Heipox app, patients won't have to scan the sensor using their phone to get glucose readings. The GS1 will automatically transmit your glucose numbers every 5 minutes - a total of 288 readings per day to your smartphone.
- **Accurate** : Sionics distinguishes itself from competing brands in a below-average MARD value of 8.83%, which translates to higher accuracy in glucose level readings. The majority of users can obtain accurate glucose data within the first 48 hours of sensor application. The EU Quality Management System (MDR) also testified to the compliance of the SIBIONICS GS1 CGM system with the stringent health and safety standards required by the European Union (EU). This certification confirms the quality, safety and superior efficacy of the SIBIONICS GS1 CGM system as a medical device. [\[11\]](#)
- **Reliable** : Alerts that keep you informed. Customize your glucose notification settings in our application to be alerted of high and low glucose levels, so you can act quickly to prevent complications. You also can turn on the Override Do Not Disturb option to receive alerts.

- **Convenient** : Application of the GS1 Sensor is completely hassle-free, with no fingersticks or calibration needed. Upon connecting to the Our Heipox app, accessing your glucose levels, trends, time in range, and more are just one click away, eliminating the need to scan the sensor with your phone.
- **Affordable** : Sibionics provides a longer 14-day sensor service life and sensor memory, compared to most of its counterparts, reducing the frequency of replacements and lowering overall costs.
- **Data Sharing and Remote Monitoring** : GS1 supports blood glucose data sharing with friends, family. Keeping your family, friends and health care team informed about your glucose levels.

1.12 Sibionics GS1 CGM System Component

Continuous Glucose Monitoring (CGM) systems typically consist the following three parts:

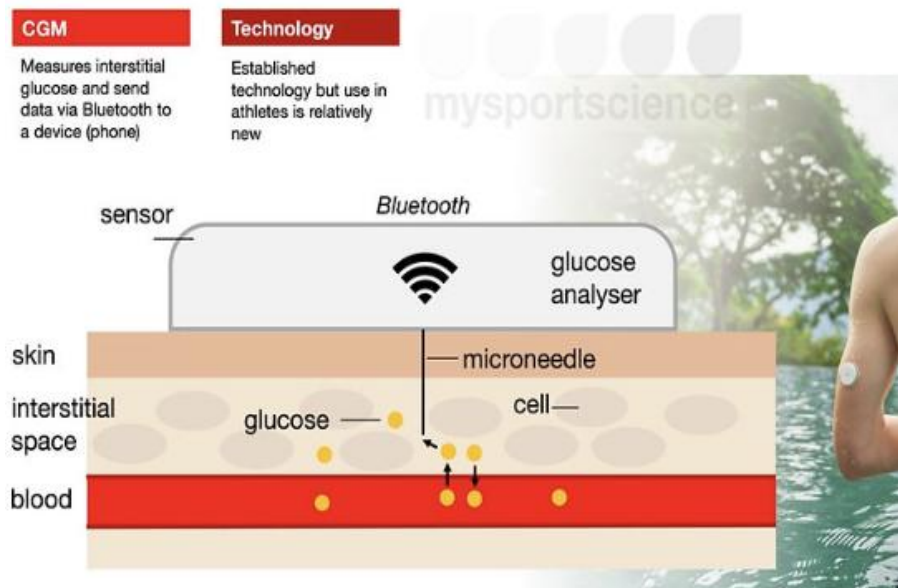


Figure 5 – CGM sensor react with interstitial fluid

1.12.1 Minimally invasive CGM Sensor

A minimally invasive electrode called a "sensor" is inserted just under the skin, typically placed on the abdomen or arm, ensuring user comfort and remains for 7–14 days.

The CGM Sensor continually measures glucose levels using an electrode equipped with glucose oxidase enzyme, by measuring electron movement in the interstitial fluid, and sends glucose information to the transmitter at regular intervals, typically every few minutes.

1.12.2 The transmitter

The transmitter is attached to the sensor and converts the electrical signals sent by the sensor into digital signals (using signal amplification and filtering mechanisms). It then sends data every 5 min via Bluetooth Low Energy (BLE) technology to a receiver or smart device where you can see your current glucose level.

- **Bluetooth Low Energy (BLE) :** Bluetooth low energy (BLE) is transforming geolocation. BLE is designed with similar features as Bluetooth but with a focus on low power. As a result, it is not as fast as Bluetooth and is not suitable for transferring large files, but it's ideal for moving small amounts of data with minimal power consumption.
- BLE has made it possible for a wide range of small IoT devices, such as sensors and tags, to communicate despite limited batteries. Most smartphones and devices today are equipped with Bluetooth capability.
- BLE uses very little energy compared to other wireless technologies and can operate for extended periods of time on a single battery charge.
- BLE uses about 1/10 of the energy Bluetooth devices use
- BLE excels at transmitting small and infrequent data packets using low amounts of power and low latency. [\[8\]](#)

1.12.3 Display Device (Smart Device/Application)

The Heipox application provides real-time glucose, as well as historical trends, graphs, customizable alarms, and glucose prediction features. This allows users to ensure the best management of diabetes.



Figure 6 – CGM device components

1.13 Inserting and fixing the Sionics GS1 sensor

The insertion of the sensor takes place in several steps:

- **Step 1 :** Select a site on the back of your upper arm or your abdomen
- **Step 2:** Use an alcohol wipe to remove any oily residue and allow your skin to dry before applying the sensor.
- **Step 3:** Peel off the lid on the sensor pack.
- **Step 4:** Uncover the cap from the sensor applicator then press the sensor applicator firmly down on the pack until it comes to a stop.
- **Step 5:** Lift the sensor applicator out of the sensor pack. If the sensor is not ready to apply, repeat Step 4.
- **Step 6:** Press and pull the safety clip out.

- **Step 7:** Place the sensor applicator over the site and push the button down. Now your sensor is well applied.
- **Step 8 :** After you finish putting the CGM on your hand, put the sensor-patch to protect your CGM device and keep it for a longer time.[\[12\]](#)

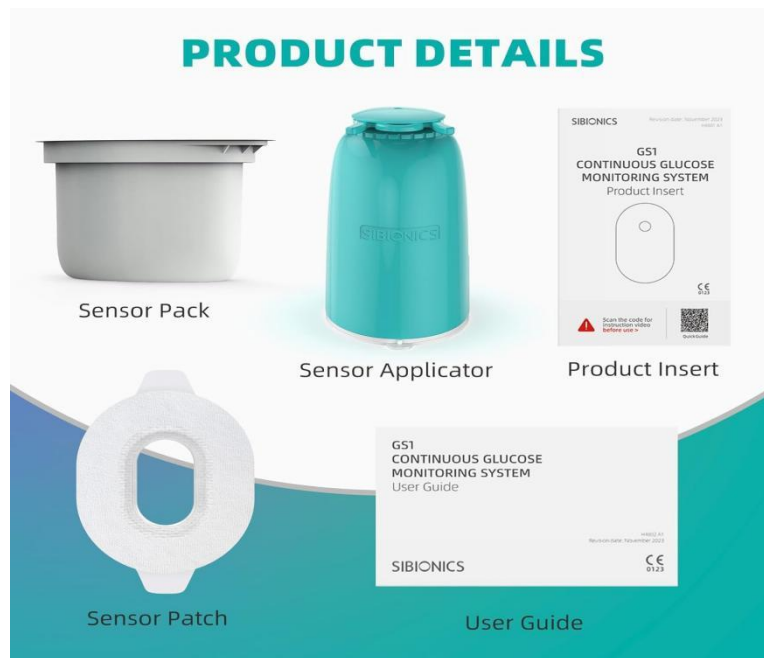


Figure 7 – CGM Pack details



Figure 8 – Step guide to insert your CGM device

1.14 Utilization of Sibionics GS1 System in Our Project

In our startup, we exclusively use Sibionics Continuous Glucose Monitoring sensor. Taking advantage of its previously mentioned advanced features and the most important of which is Bluetooth, our application called Heipox extends far beyond traditional glucose monitoring to offer a comprehensive set of functions aimed at improving diabetes management. The Sibionics sensor serves as the basis for real-time glucose monitoring, providing users with accurate and reliable data insights. However, in this project, we decided to integrate additional functions along with sensor data, where integrating predictive analytics into our application is a pivotal aspect of our project. By harnessing the data generated by the Sibionics sensor, our app uses advanced algorithms and machine learning techniques to predict users' future glucose levels (The Next Hour). This predictive capability enables individuals with diabetes to anticipate potential fluctuations in their blood sugar levels, empowering them to take preemptive measures to maintain optimal glycemic control.

1.15 Needs Analysis

1.15.1 Functional requirements

This application must allow :

- ✓ Manage glucose data
 - Collect glucose data from a connected sensor.
 - Analyze and process glucose data to provide valuable information.
 - Display the current and historical glucose levels graphically.
 - Display a graph of the predicted glucose levels for the next hour.
 - Display statistics about glucose.
- ✓ Manage notifications and alerts.
 - Send alerts in case of abnormal glucose levels.
 - Send alerts in the event of abnormal predicted glucose trends.
 - Activate / disable notifications.
 - Customize the alarm tone.
- ✓ Manage profile.
 - Modify personal information.
 - Edit the profile picture.
 - Change the email and password.
 - Change the diabetes type and the ideal glucose range.
- ✓ Download data and share it with others.

1.15.2 Non-functional requirements

These are the requirements that characterize the system. Our application must meet

the following criteria:

- **Ergonomics and flexibility:** The application must provide a user-friendly and ergonomic interface, usable by the user considering all possible interactions on the screen of the held device.
- **Speed:** The application must optimize processes to have a reasonable time for generating diagrams.
- **Multi-device support:** The application must be compatible with a variety of smartphone models.
- **Effectiveness:** The application must be functional regardless of any circumstances that may surround the user.
- **Maintainability and scalability:** The application code must be readable and understandable to ensure its evolutionary and extensible state in relation to market needs.
- **Stability:** The application must be very stable during its execution.
- **Security:** Data handling by the application must be secure to avoid any unauthorized use.

1.16 Conclusion

The implementation of a continuous glucose monitoring system with Bluetooth connectivity, predictive capabilities and alerts in Algeria holds great promise for both healthcare and the economy. This technology will greatly benefit the Algerian people, especially children aged four years and older. It provides proactive diabetes care, enhances health outcomes and quality of life.

Chapitre 2

Application of AI in Healthcare

2.1 Introduction

In recent years, artificial intelligence (artificial intelligence) has emerged as a transformative force in the healthcare field, providing novel solutions for diagnostics, treatment planning, and patient care.. This chapter explores the intersection of artificial intelligence and healthcare, focusing on its role in predictive analytics, particularly in continuous glucose monitoring (CGM). The ability of AI to analyze vast amounts of healthcare data and make accurate predictions holds tremendous promise in improving patient outcomes and revolutionizing medical practice. In this chapter, we dive into the core principles of artificial intelligence, its applications in healthcare forecasting, and its transformative impact on diabetes management..

2.2 Definition and Fundamentals of Artificial intelligence (AI)

Artificial Intelligence (AI) has become an integral part of our lives whether we realize it or not. It can perform tasks that require human intelligence, such as learning, thinking, and troubleshooting. Now, let's dive into the core concepts and components that underpin AI.[\[13\]](#)

2.2.1 Definition of AI

Artificial intelligence (AI) is the theory and development of computer systems capable of performing tasks that historically required human intelligence, such as recognizing speech, making decisions, and identifying patterns. AI is an umbrella term that encompasses

a wide variety of technologies, including machine learning, deep learning, and natural language processing (NLP). [\[13\]](#)

2.2.2 Machine learning

Machine learning is a form of artificial intelligence that can adapt to a wide range of inputs, including large sets of historical data, synthesized data, or human inputs. These algorithms can detect patterns and learn how to make predictions and recommendations by processing data, rather than by receiving explicit programming instruction. Some algorithms can also adapt in response to new data and experiences to improve over time. [\[14\]](#)

There are three types of machine learning algorithms:

- **Supervised learning:** Data sets are labeled so that patterns can be detected and used to label new data sets.
- **Unsupervised learning:** Data sets aren't labeled and are sorted according to similarities or differences.
- **Reinforcement learning:** Data sets aren't labeled but, after performing an action or several actions, the AI system is given feedback. [\[15\]](#)

2.2.3 Deep learning

Deep learning is a more advanced version of machine learning that is particularly adept at processing a wider range of data resources (text as well as unstructured data including images), requires even less human intervention, and can often produce more accurate results than traditional machine learning. Deep learning uses neural networks—based on the ways neurons interact in the human brain—to ingest data and process it through multiple neuron layers that recognize increasingly complex features of the data. For example, an early layer might recognize something as being in a specific shape; building on this knowledge, a later layer might be able to identify the shape as a stop sign. Similar to machine learning, deep learning uses iteration to self-correct and improve its prediction capabilities.

For example, once it “learns” what a stop sign looks like, it will be able to recognize a stop sign in a new image. [14]

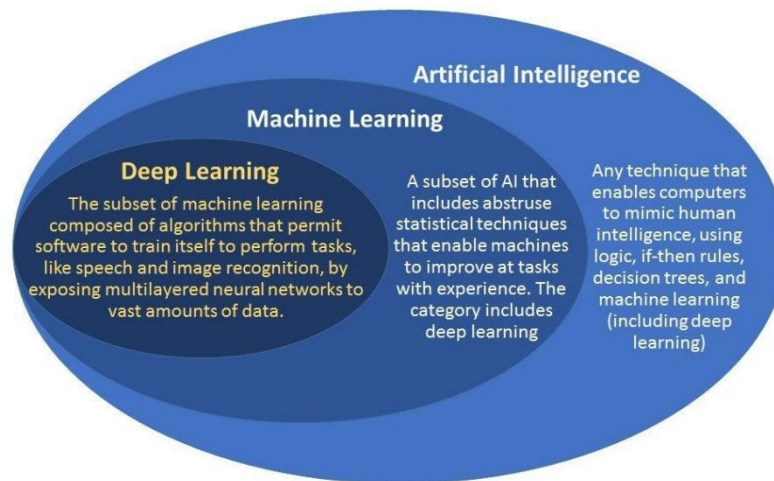


Figure 2.1 – The hierarchy of artificial intelligence.

2.3 Application of Machine learning and deep learning models in Health Care

In healthcare, predictive modeling is an essential tool for determining future health outcomes. It is a process that uses statistical methods, data mining, and machine learning to identify patterns in data and recognize the chance of certain outcomes. The goal of predictive modeling is to answer the question: "What is likely to happen in the future based on known past behavior?". [16]

The predictive modeling process involves running algorithms on the data to make predictions. Since the process is iterative, it trains the model that is most applicable to the

goal or task at hand. In our study, which focused on predictive analytics for continuous glucose monitoring (CGM) for predicting trends and predicting diabetes events, we trained four distinct models to predict glucose levels and diabetes events :

2.3.1 Recurrent neural network (Simple RNN)

Recurrent neural network (RNN) is capable of extracting dynamic temporal behaviour from an input time sequence. Basic RNNs are a network of nodes emulating neurons, each with a directed (oneway) connection to every other node. Each node has a time varying real-valued activation. Each connection (synapse) has a real-valued weight which can be modified during every iteration. Nodes are either input nodes to receive data from outside of the network, output nodes that yield results, or hidden nodes that modify the data which passes through them via their route from input to output. The difference from the traditional feedforward neural networks is that RNN is capable of using its internal state, otherwise known as memory, to process sequences of inputs.[\[17\]](#)

2.3.2 Long short-term memory (LSTM)

Long short-term memory (LSTM) units are a special type of building units for RNN. It can analyze,, classify and predict temporal data sequences of time lags of any size. A typical LSTM network is made up of memory, input, output and forget gates. The memory in LSTM can remember values over arbitrary time intervals. Each of the three gates is a form of neuron (which computes an activation function of a weighted sum). More than that, these gates control the passage of values in LSTM layers; hence these special neurons are named as gates. By long short-term, the fact underlined is that LSTM's memory can really last for a long time. LSTM tackles the issue of exploding and vanishing gradient problems which is an important issue while training traditional RNNs. [\[17\]](#)

2.3.3 Support Vector Regression (SVR)

Support Vector Regression (SVR) is a type of machine learning algorithm used for regression analysis. The goal of SVR is to find a function that approximates the relationship

between the input variables and a continuous target variable, while minimizing the prediction error. [18]

It is a variant of Support Vector Machines (SVM) and is designed to predict continuous numeric values, making it suitable for tasks like time series forecasting, which includes CGM data. [19]

2.3.4 Bidirectional LSTM

BiLSTM is a type of recurrent neural network (RNN) that processes sequential data in both forward and backward directions. It combines the power of LSTM with bidirectional processing, allowing the model to capture the past and future context of the input sequence, making it well suited for time-series prediction tasks. Unlike traditional neural networks, BiLSTM networks include memory cells and gates that enable them to selectively retain and update information over time.

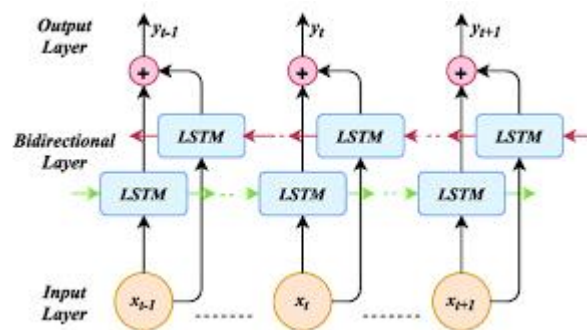


Figure 2.2 – BiLSTM Explained.

2.4 Predictive Model Evaluation Metrics

Model evaluation involves using different metrics to understand a model's performance. It is crucial for assessing a model's effectiveness and plays a significant role in ongoing model monitoring. To determine whether the models used in our application work

well with the data and to select the best model, we considered four widely used evaluation metrics.:

2.4.1 Root mean square error

Root mean square error or root mean square deviation is one of the most commonly used measures for evaluating the quality of predictions. It shows how far predictions fall from measured true values using Euclidean distance.[\[20\]](#)

To compute RMSE, calculate the residual (difference between prediction and truth) for each data point, compute the norm of residual for each data point, compute the mean of residuals and take the square root of that mean. RMSE is commonly used in supervised learning applications, as RMSE uses and needs true measurements at each predicted data point.

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (Predicted_i - Actual_i)^2}{N}}$$

Figure 2.3 - Root mean square error Formula.

2.4.2 R-Squared

R-squared (R²) is defined as a number that tells you how well the independent variable(s) in a statistical model explain the variation in the dependent variable. It goes from 0 to 1, where 1 indicates a perfect fit of the model to the data. [\[21\]](#)

$$R^2 = 1 - \frac{MSE(\text{model})}{MSE(\text{baseline})}$$

$$\frac{\text{MSE}(\text{model})}{\text{MSE}(\text{baseline})} = \frac{\sum_{i=1}^N (y_i - \hat{y}_i)^2}{\sum_{i=1}^N (\bar{y}_i - \hat{y}_i)^2}$$

Figure 2.4 - R-squared Formula.

2.4.3 Mean Relative Error

Mean Relative Error (MRE) is an error measure often used in machine learning for regression problems. MRE measures the mean relative error, i.e. how much the model's predictions differ in percentage from the ground truth. [22]

$$\begin{aligned} \text{Absolute error} &= |V_{\text{true}} - V_{\text{observed}}| \\ \text{Relative error} &= \frac{|V_{\text{true}} - V_{\text{observed}}|}{V_{\text{true}}} \\ \text{Percentage error} &= \frac{|V_{\text{true}} - V_{\text{observed}}|}{V_{\text{true}}} \times 100 \end{aligned}$$

Figure 2.5 - Mean Relative Error Formula

2.4.4 Correlation

Correlation is the statistical measure of the relationship between two variables. There are different types of correlation coefficients like Pearson coefficient (linear) and Spearman coefficient (non-linear) which capture different degrees of probabilistic dependence but not necessarily causation. The correlation coefficient, or Pearson's, is calculated using a least-squares measure of the error between an estimating line and the actual data values,

normalized by the square root of their variances. The coefficients range in value from -1 (perfect inverse correlation) to 1 (perfect direct correlation), with zero being no correlation.

[23]

The diagram shows the Pearson correlation coefficient formula:
$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$$
 Four green arrows point from text annotations to parts of the formula: 1. An arrow from the top left points to x_i in the numerator, with the text " x_i are the individual values of one variable e.g. age". 2. An arrow from the top right points to y_i in the numerator, with the text " y_i are the individual values of the other variable e.g. salary". 3. An arrow from the bottom left points to the variable r , with the text "Where r is the Pearson correlation coefficient,". 4. An arrow from the bottom right points to the mean terms \bar{x} and \bar{y} in the denominator, with the text " \bar{x} and \bar{y} are respectively the mean values of the two variables."

Figure 2.6 - the Pearson correlation Formula.

2.5 Comparative Analysis of Evaluation Metrics: RMSE, MRE, and R - Squared

Each metric serves a unique purpose in evaluating model performance in a CGM application:

In short, RMSE measures the average error in the model's predictions, lower RMSE indicates better predictive accuracy, while R2 measures the percentage of variance explained by the model. RMSE is for understanding the accuracy of the predictions, and R2 is for understanding the overall fit of the model. MRE evaluates the average size of the errors relative to the actual values, indicating consistency in predictions.

2.6 Dataset Description

Based on a training dataset containing features such as glucose levels measured in mg/dL obtained every 5 minutes with timestamps (minutes, hours, day and year) as well as the type of diabetes, namely Type 1 and Type 2.

2.6.1 Why we use this dataset

This dataset was chosen due to its comprehensive nature in accurately capturing and predicting glucose trends over time. Thanks to the detailed timestamps, we are able to perform precise temporal analysis, which is critical for understanding daily and long-term fluctuations in glucose levels. The use of type 1 and type 2 diabetes data allows the development of robust models that are applicable across different patient groups, and in the future, more data will be added such as insulin, food intake, and any data relevant to the glucose trend to improve the accuracy of the prediction.

2.6.2 Future use of patient data

In the future, patient data will be used to improve the accuracy and reliability of predictive models for glucose prediction and validation. Furthermore, this data will support the development of personalized treatment plans and real-time monitoring systems. This will help patients manage their diabetes more effectively and proactively.

2.7 Discussion of Model Evaluation Results

We experimented with several machine learning and deep learning models to predict blood glucose values.

Based on a training dataset that contains a set of features such as: Continuous glucose monitoring data obtained every 5 minutes.

Based on the results shown in the table below, among these models, BiLSTM stands out with the lowest root mean square error (RMSE) of 0.0857, indicating superior predictive accuracy compared to other models, i.e. it produces the lowest average prediction errors. This makes it the best choice if minimizing prediction errors is the key, closely followed by LSTM and SVR, with equal RMSE values, while RNN indicates less accurate predictions overall. It also has the highest R^2 and correlation scores, indicating that it explains the greatest amount of variance in the data and has the strongest linear relationship between predictions and actual values.

However, for predicting glucose levels, accuracy and consistency are critical, so RSME will be the basis for our selection given the importance of minimizing prediction errors in healthcare applications such as CGM: BiLSTM was chosen as the best model for predicting glucose levels.

Tableau 1 – Model Evaluation Results

Models	RSME	R^2	MRE	Correlation
BiLSTM	0.0857	0.677	0.365	0.832
LSTM	0.0877	0.679	0.363	0.835
SVR	0.0876	0.675	0.122	0.834
RNN	0.0882	0.694	0.365	0.842

Conclusion

In conclusion, in this chapter we highlighted how artificial intelligence can greatly improve healthcare, especially in continuous glucose monitoring. We touched on the basic concepts of artificial intelligence, including machine learning, deep learning, and the

evaluation metrics used, where we found that BiLSTM networks showed their superiority in capturing the past and future context compared to other traditional models such as SVR and RNN achieving accurate results in terms of glucose level predictions.

Chapitre 3

System design

3.1 Introduction

In this chapter, we will present the design of our system using UML modeling including use case diagrams, class diagram, and sequence diagrams to better understand the operations of the system, its components and its relationships, which will provide a more accurate picture of our application.

3.2 General use case diagram

The following figure 3.1 represent the general use case diagram of our application from the user's point of view :

3.3 Diagramme de classe

The following figure 3.2 represents the class diagram of our application which expresses in a general way the static structure of our system, in terms of class and the relationship between these classes:

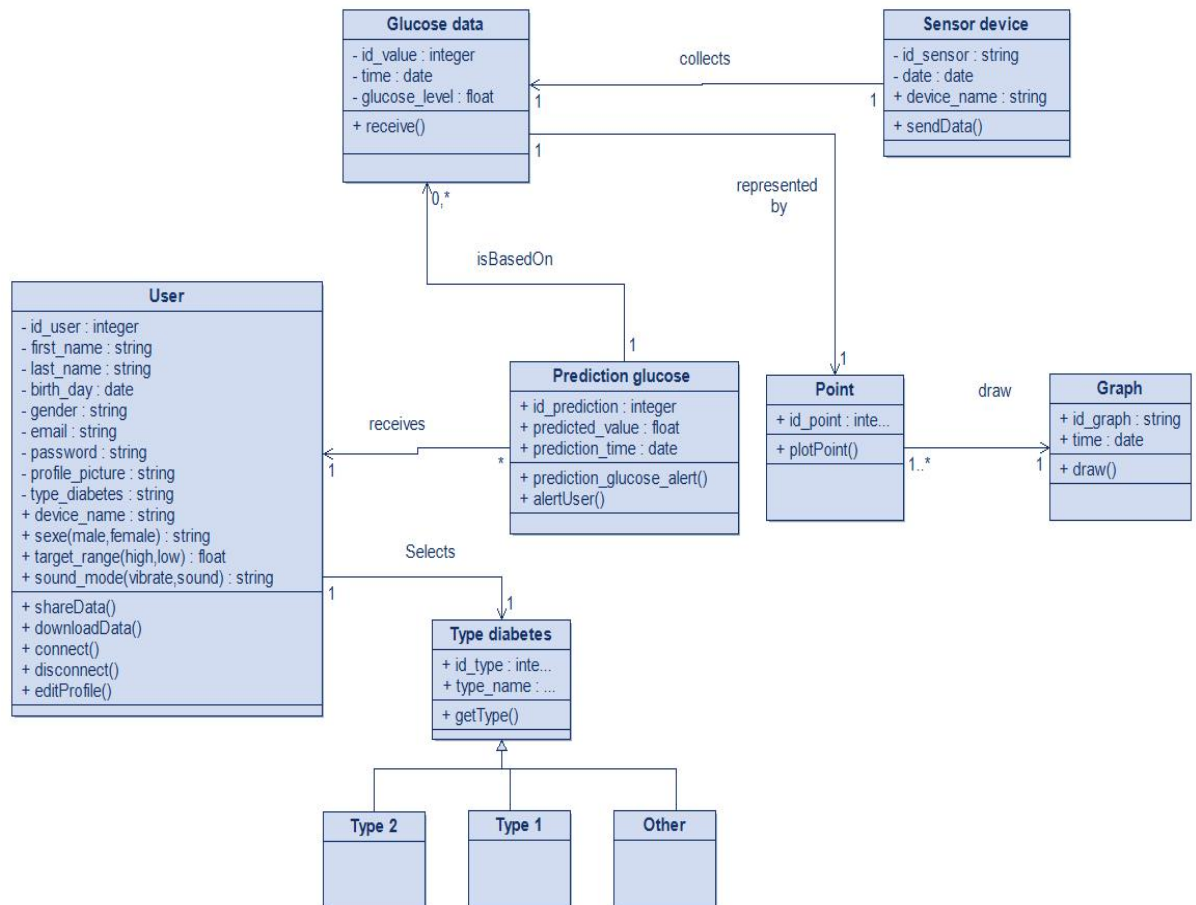


Figure 3.2 - Class Diagram.

3.4 Sequence diagram

In the following section, we present the sequence diagrams of our application :

3.4.1 Sequence diagram « Authentication »

Figure 3.3 below represents the Authentication sequence diagram:

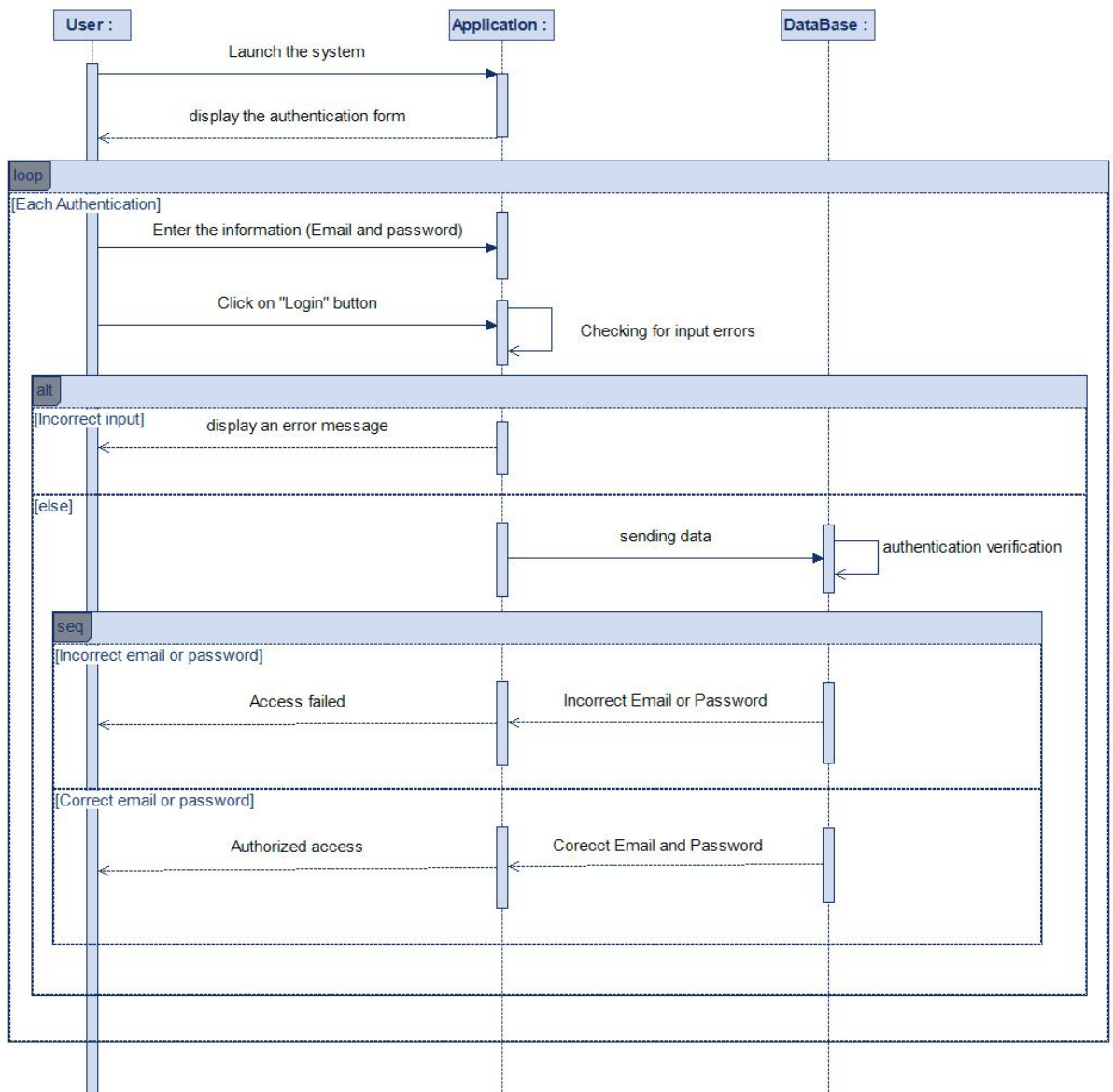


Figure 3.3 - Authentication Sequence Diagram.

Title: authenticate.

Summary: a username and a password are required to login.

Actors: user (patient).

Precondition: the user can access the application only if it is authenticated, in order to ensure the confidentiality and integrity of the data.

Post conditions: the user is authenticated, so access to the interfaces is authorized.

Nominal scenario:

1. The user launches the application.
2. The system displays the “login form” interface.
3. The user must fill out the form with his email and password, then he clicks on the «login» button.
4. The system performs a check on the input fields.
5. The system checks the validity of the account.
6. Successful authentication, the user can start using our application.

Alternative scenario:

The alternative scenario can happen starting from step 3 of the nominal scenario.

- 1) **Authentication error:** when the user enters invalid contact information, he will have an authentication failure and the access to the application will be denied.
- 2) **Empty mandatory field:** the connection fails if the user leaves one of the fields empty; the system displays an error message accordingly.
- 3) **Incorrect nature of the fields entered:** the system signals an error if the information entered doesn't match the expected type.

- The scenario goes back to step 3 of the nominal scenario if one of these problems is encountered.

3.4.2 Sequence diagram « Registration »

Figure 2.4 below, shows the registration sequence diagram:

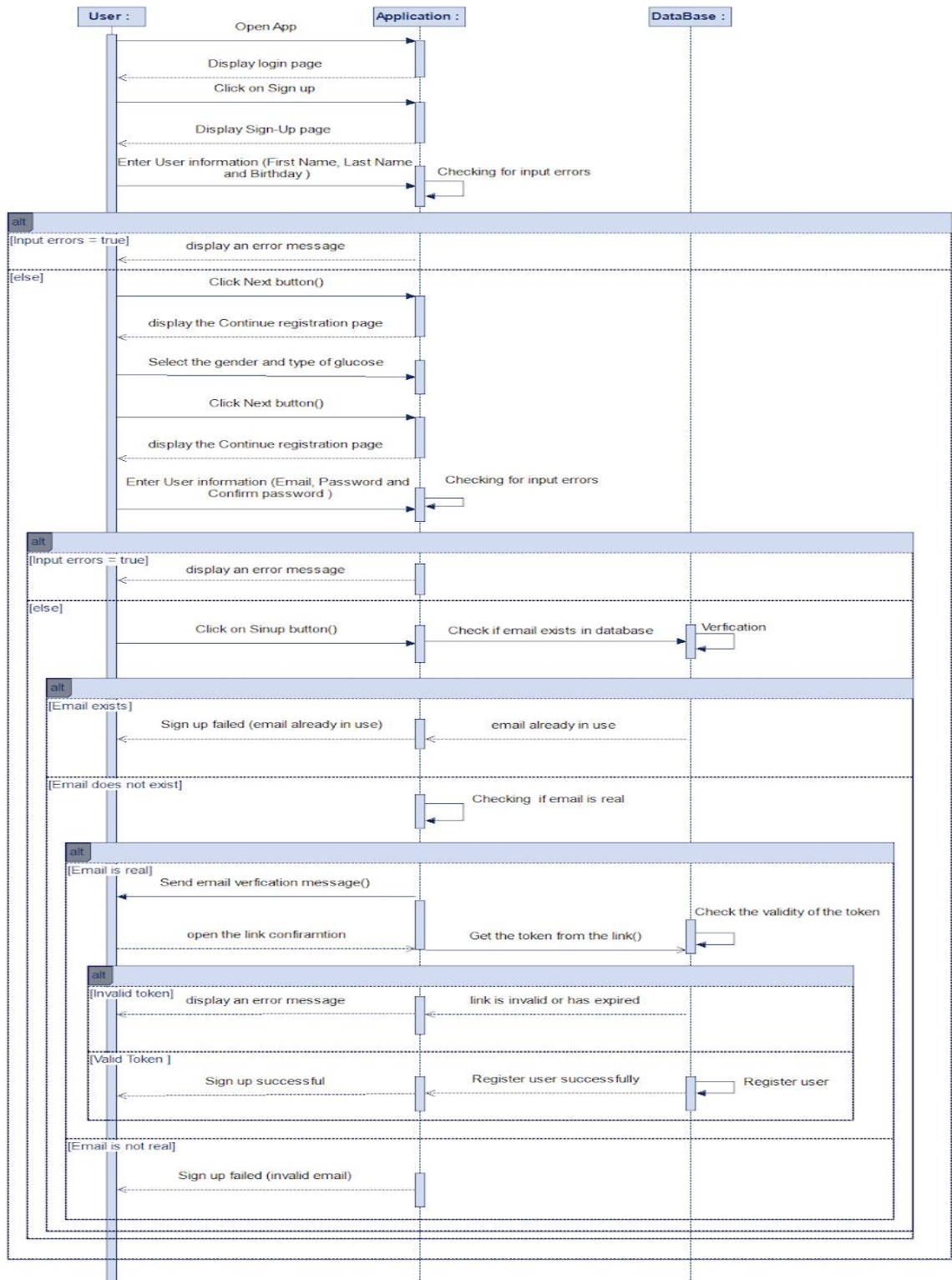


figure 3.4 – Sequence diagram Registration.

Title: user registration.

Actors: user (patient).

Pre conditions: user unregistered previously.

Post conditions: a new user will be added.

Nominal scenario:

1. The user launches the application.
2. The system displays the "login form" interface and then clicks on the "Sign up" button.
3. The system displays the "sign up form" interface.
4. The user enters the First name, last name and date of birth in the sign up form and then clicks on the «Next» button.
5. The system performs a check on the input fields.
6. The system displays the completion of the registration form.
7. The user chooses his type of glucose and his genre and then clicks on the «Next» button.
8. Once again, the system displays the completion of the registration form.
9. The user fills in the form with the email, password and confirms the password then clicks on the «Sign up» button.
10. The system checks the validity of the data.

Note 1: the system sends a confirmation email containing a unique link to the email address provided by the user. The user must click on this link to verify and activate his account, thus confirming that the email address is valid and accessible.

Note2: the system displays an error message if it finds that the user who registered has the same email as another one that is in the user database, in this case the user should just login.

Note3: if the token is expired or invalid an error message is displayed to inform the user that the confirmation link is expired or invalid then he must request a new confirmation link.

11. The system displays a user registration confirmation message.

12. Authorized access, the system displays the "Home" interface.

Alternative scenario :

1) Empty mandatory field :

- The sequence starts at point 5.
- The system signals the existence of empty mandatory fields (error message).
- The system returns to the form already filled out.
- The scenario returns at point 4.

2) Incorrect nature of the fields entered :

- The sequence starts at point 5.
- The system signals an error of the entered fields.
- The scenario returns at point 4.

3) User already exists :

- The sequence starts at point 10.
- The system displays an error message indicating that the user already exists (previously registered with the same email)
- The system asks the user to make the login authentication because the user is already registered in the application.

4) Link invalid or expired :

- The sequence starts at point 10.
- Token is invalid (for example, expired, already used, or incorrect).

- The system displays an error message indicating that the link is invalid or has expired.
- The system offers the user to request a new confirmation link.

3.4.3 Sequence diagram « Edit profile »

Figure 3.5 below, represent the edit profile sequence diagram

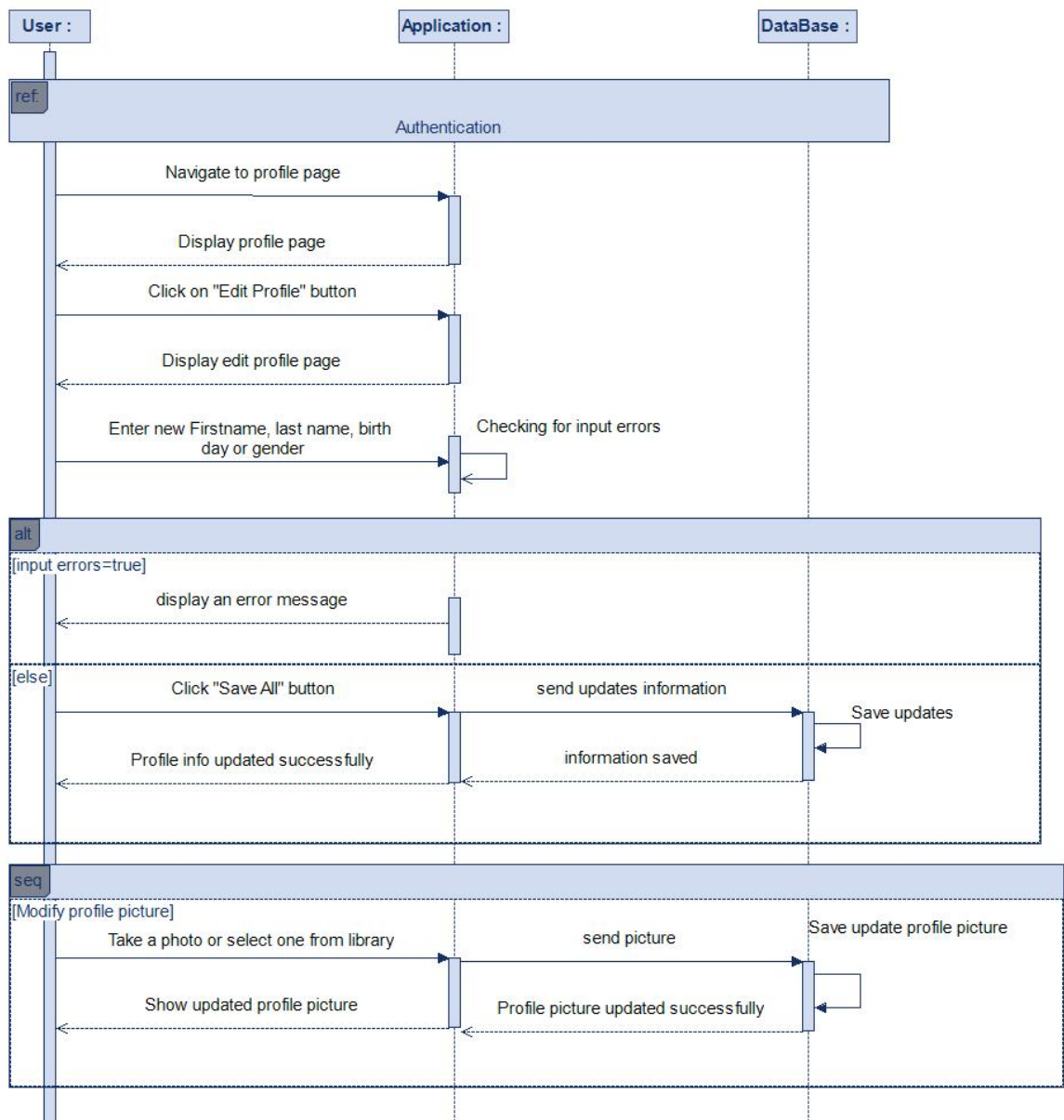


Figure 3.5 – Sequence diagram Edit profile

Title: edit user profile information.

Summary: the user can modify his first name, last name, birthday or profile picture at any time.

Actors: user.

Pre conditions: user already logged in (authenticated).

Post conditions: modified user information.

Nominal scenario:

1. The user launches the application.
2. The system displays the “login form” interface.
3. The user enters the email and the password in the login form.
4. The system checks the validity of the data.
5. Authorized access, the system displays the "Home" interface.
6. The user navigates to the “profile” page.
7. The system displays the “profile” page.
8. The user clicks on the «Edit Profile» button.
9. The system displays the “edit profile form” interface.
10. The user fills out the form and then clicks on the «Save all» button.
11. The system performs a check on the input fields.

Note 1 : upon the user accessing the form, the system displays the previous values in the fields, allowing the user to see and modify the existing data. If no data is changed, the system displays a message indicating that the user has not made any changes.

Note 2 : the user has to change at least one field before saving the modification.

Note 3: the user must click save all to apply the changes to the last name, first name, gender and date of birth.

Important note: edits to the profile picture are saved automatically without the need to click on the "Save all" button.

12. The user can edit his profile picture by either taking a picture or choosing a picture from the phone album.
13. The system saves the changes and then displays a message confirming the success of the modifications.

Alternative scenario :

1) **Authentication error:** invalid login details, so access to the application is denied, the scenario returns at point 3.

2) **Empty mandatory field:**

- The sequence starts at point 11.
- The system informs that all fields are empty (error message).
- The system returns to the form.
- The scenario returns at point 10.

3) **incorrect nature of the fields entered:**

- The sequence starts at point 11.
- The system signals an error of the entered fields.
- The scenario returns at point 10.

3.4.4 Sequence diagram « Change password »

The following figure 3.6 represents the change password sequence diagram.

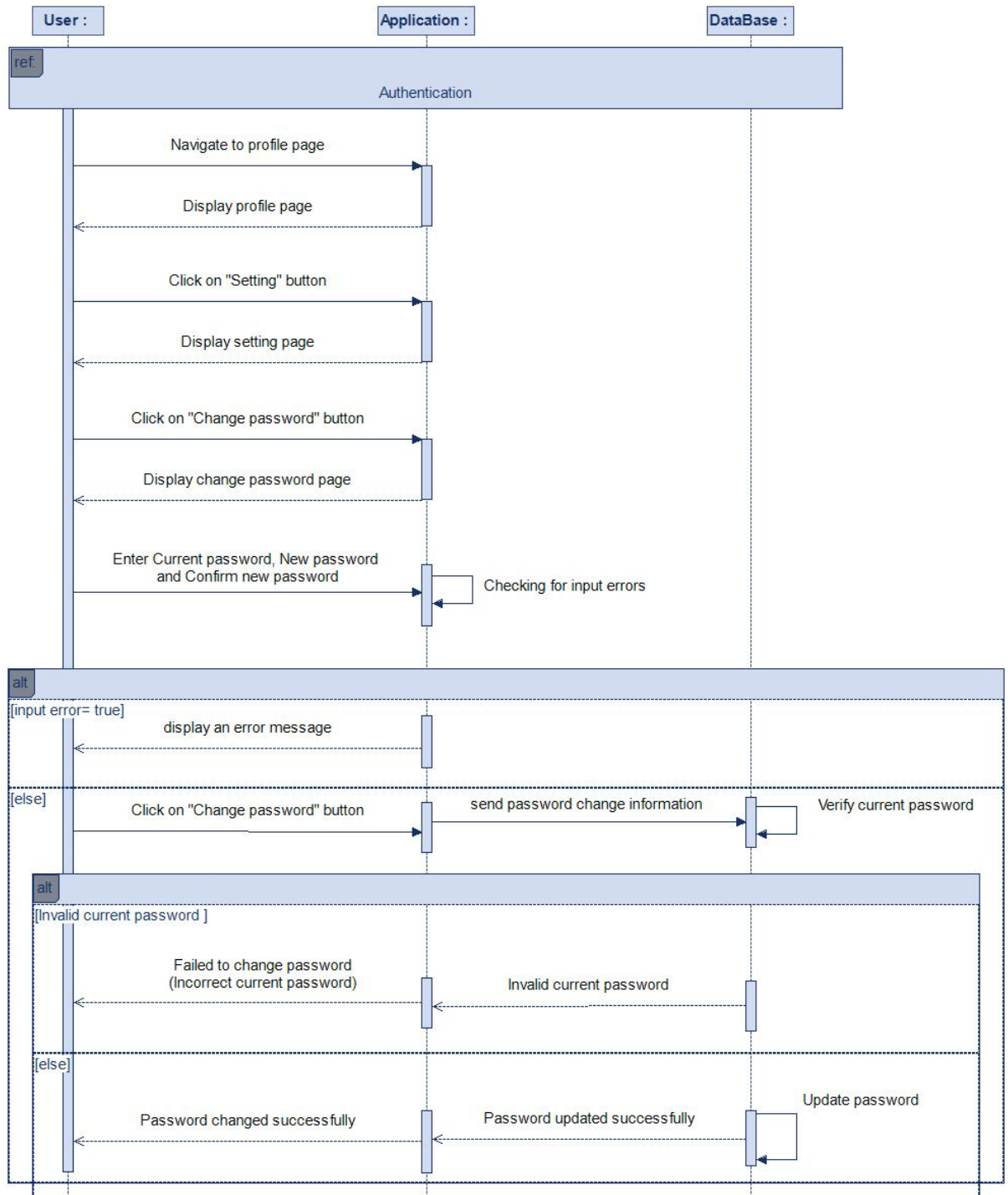


Figure 3.6 – Sequence diagram Change password

Title: change password.

Summary: the user can modify his password at any time.

Actors: user.

Pre conditions: user already logged in (authenticated).

Post conditions: modified user password.

Nominal scenario:

1. The user launches the application.
2. The system displays the "login form" interface.
3. The user enters the email and the password in the login form.
4. The system performs a check on the input fields.
5. The system checks the validity of the data.
6. Authorized access, the system displays the "Home" interface.
7. The user navigates to the "profile" page.
8. The system displays the "profile" page.
9. The user clicks the «Setting» button.
10. The system displays the "setting " page.
11. The user clicks on the «Change password» button.
12. The system displays the "Change password form" interface.
13. The user fills in the form with the current password, new password and confirms the password, then clicks on the «Change password» button.
14. The system performs a check on the input fields.
15. The system checks the validity of the data.

16. The system saves the changes and then displays a message confirming the success of the password modification.

Alternative scenario :

1) Authentication error:

- Invalid contact details, so access to the application is denied, the scenario returns to point 3.

2) Empty mandatory field:

- The sequence starts at point 4 and 14.
- The system signals the existence of empty mandatory fields (error message).
- The system returns to the form already filled out.
- The scenario returns at point 3 and 13.

3) Incorrect nature of the fields entered:

- The sequence starts at point 4 and 14.
- The system signals an error of the entered fields.
- The scenario returns at point 3 and 13.

4) Incorrect current password :

- The sequence starts at point 15.
- The system signals that the entered current password is wrong (invalid password).
- The scenario returns at point 13.

5) New password and confirm password don't match :

- The sequence starts at point 14.
- The system displays an error message indicating that the new passwords and the confirmation password do not match.
- The scenario returns at point 13.

3.4.5 Diagramme de séquence « Forgot password »

The following Figure 3.7 represents the forgot password sequence diagram.

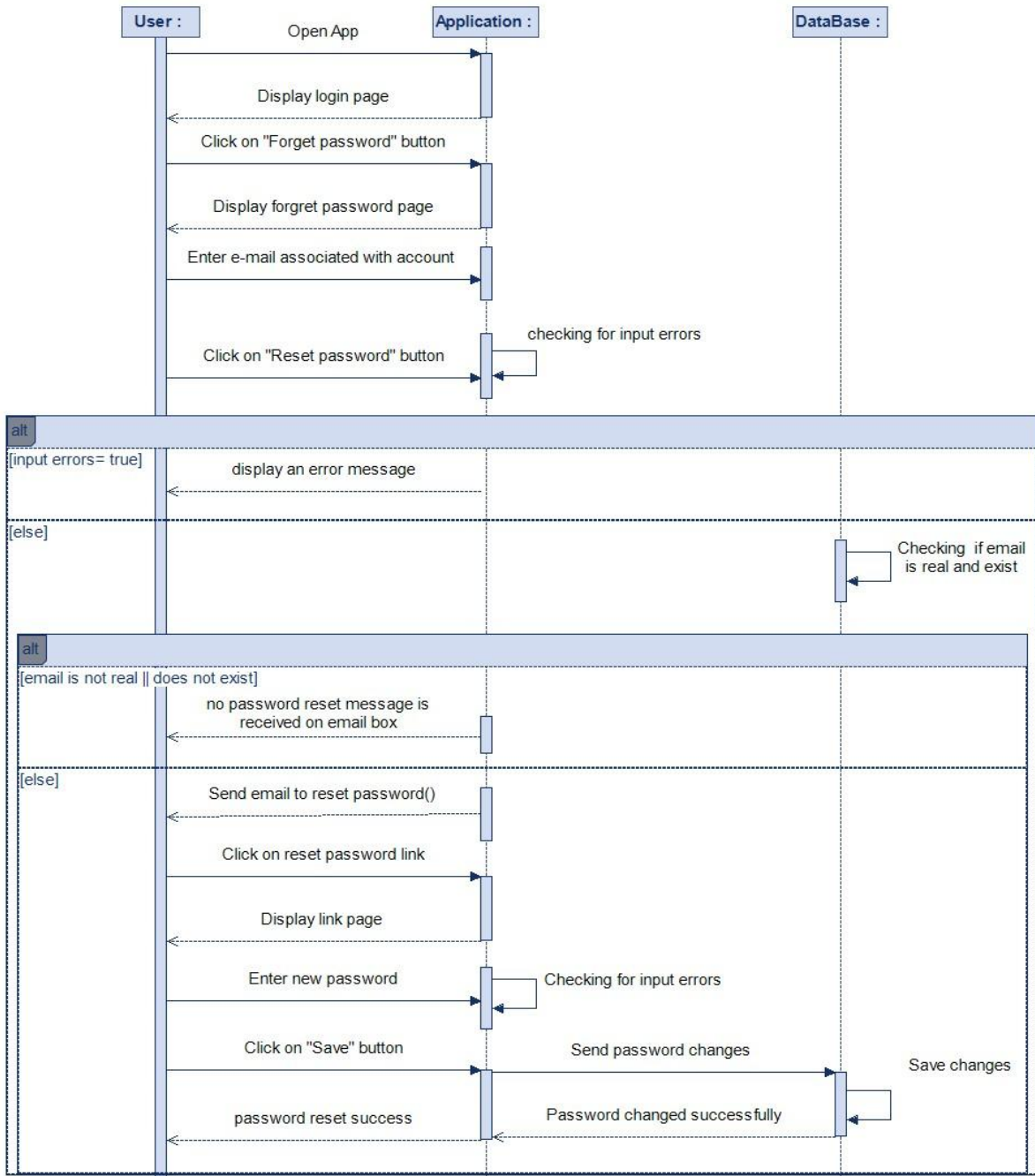


Figure 3.7 - Sequence diagram forgot password.

Titre: forgot password.

Acteurs: user.

Pré conditions: user already registered in the application with a valid email address.

Post conditions: user's password successfully updated

Scénario nominale:

1. The user launches the application.
2. The system displays the "login form" interface.
3. The user clicks on the «Forget password» button.
4. The system displays the "Forget password form" interface.
5. The user enters the email address associated with their account then clicks on the «Reset password» button.
6. The system performs a check on the input fields and checks the validity of the data.
7. The application sends a reset password email.
8. The user clicks on the reset password link in the email.
9. The user enters the new password in the reset form then clicks on the «Save» button.
10. The system performs a check on the input fields.
11. The new password is validated, The system displays a password reset confirmation message.

Alternative scenario:

1) Empty mandatory field:

- The sequence starts at points 6 and 10.
- The system signals the existence of empty mandatory fields (error message).
- The system returns to the form already filled out.

- The scenario returns at point 5 and 9.

2) Incorrect nature of the fields entered:

- The sequence starts at points 6 and 10.

- The system signals an error of the entered fields.

- The scenario returns at point 5 and 9.

3) Link invalid or expired :

- The sequence starts at point 8.

- Link is invalid (for example, expired, already used or incorrect).

- The system displays an error message indicating that the link is invalid or has expired.

- The system offers the user to request a new restoration link.

3.4.6 Sequence diagram « Change email »

The following figure 3.8 represents the change email sequence diagram

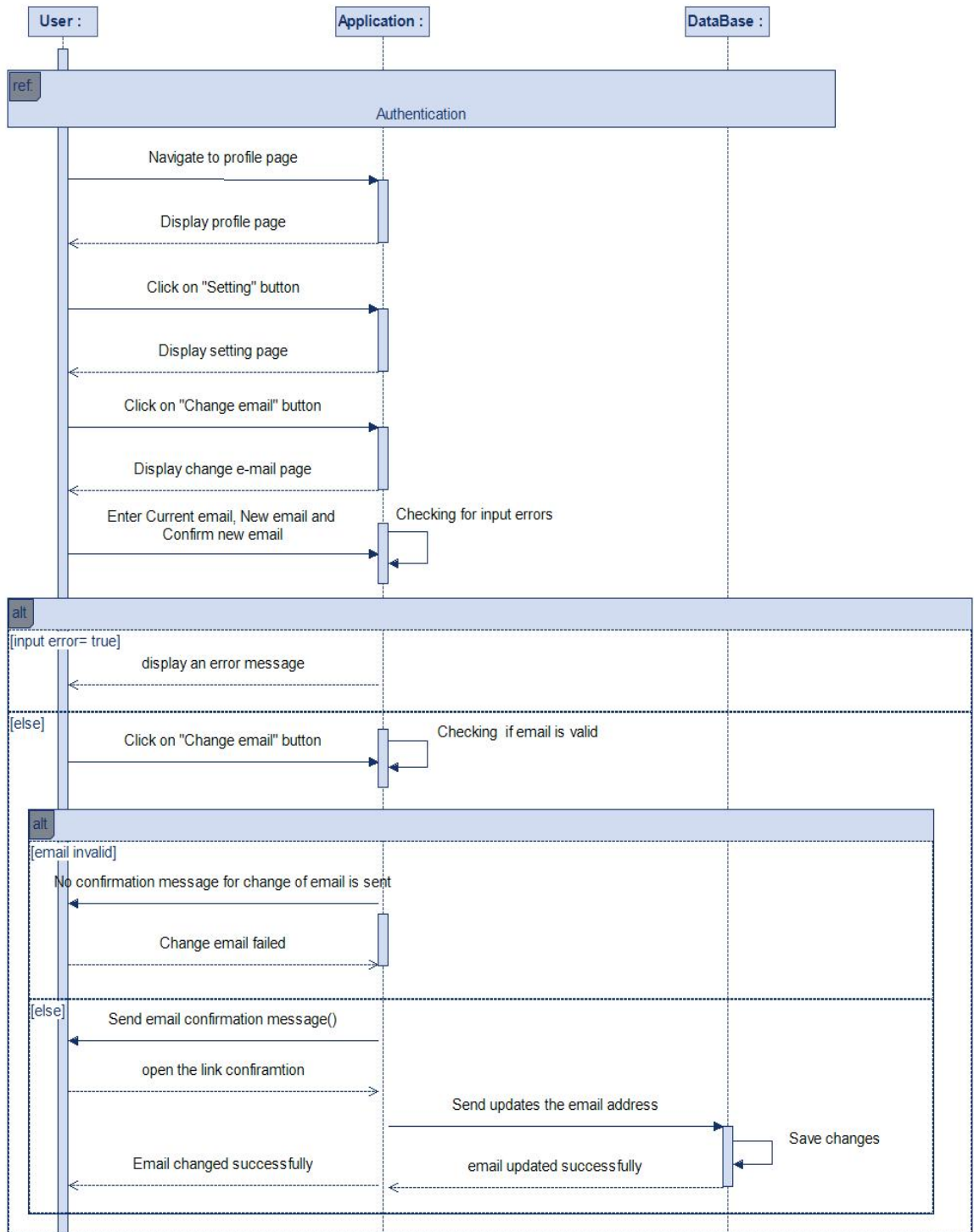


Figure 3.8 - Sequence diagram change email

Title: change email.

Summary: the user can modify his email at any time as he wishes.

Actors: user.

Pre conditions: user already logged in (authenticated).

Post conditions: user email changed successfully..

Nominal scenario:

1. The user launches the application.
2. The system displays the "login form" interface.
3. The user enters the email and the password in the login form.
4. The system performs a check on the input fields.
5. The system checks the validity of the data.
6. Authorized access, the system displays the "Home" interface.
7. The user navigates to the "profile" page.
8. The system displays the "profile" page.
9. The user clicks on the «Setting» button.
10. The system displays the "setting " page.
11. The user clicks on the «Change email» button.
12. The system displays the "Change email form" interface.
13. The user fills in the form with the current email, new email and confirms the email, then clicks on the «Change email» button.

Note: if the confirmation e-mail is not validated or is not received at the new email, the user's email address remains unchanged.

14. The system performs a check on the input fields.
15. The system checks the validity of the data.

16. The application sends a confirmation email to the new email address provided by the user.
17. The user clicks on the confirmation link to validate the change.
18. The system updates the user's email address, and displays a confirmation success message.

Alternative scenario :

1) Authentication error:

-Invalid contact details, so access to the application is denied, the scenario returns at point 3.

2) Empty mandatory field:

- The sequence starts at point 4 and 14 .
- The system signals the existence of empty mandatory fields (error message).
- The system returns to the form already filled out.
- The scenario returns at point 3 and 13.

3) Incorrect nature of the fields entered:

- The sequence starts at point 4 and 14.
- The system signals an error of the entered fields.
- The scenario returns at point 3 and 13.

4) Invalid new email :

- The sequence starts at point 15.
- The system displays an error message, the email address remains unchanged.
- The scenario returns at point 13.

5) New email and confirm email don't match :

- The sequence starts at point 14.

- The system displays an error message indicating that the new email and the confirmation email do not match.
- The scenario returns at point 13.

3.4.7 Sequence diagram « Update glucose data »

The following figure 3.9 represents the update glucose data sequence diagram

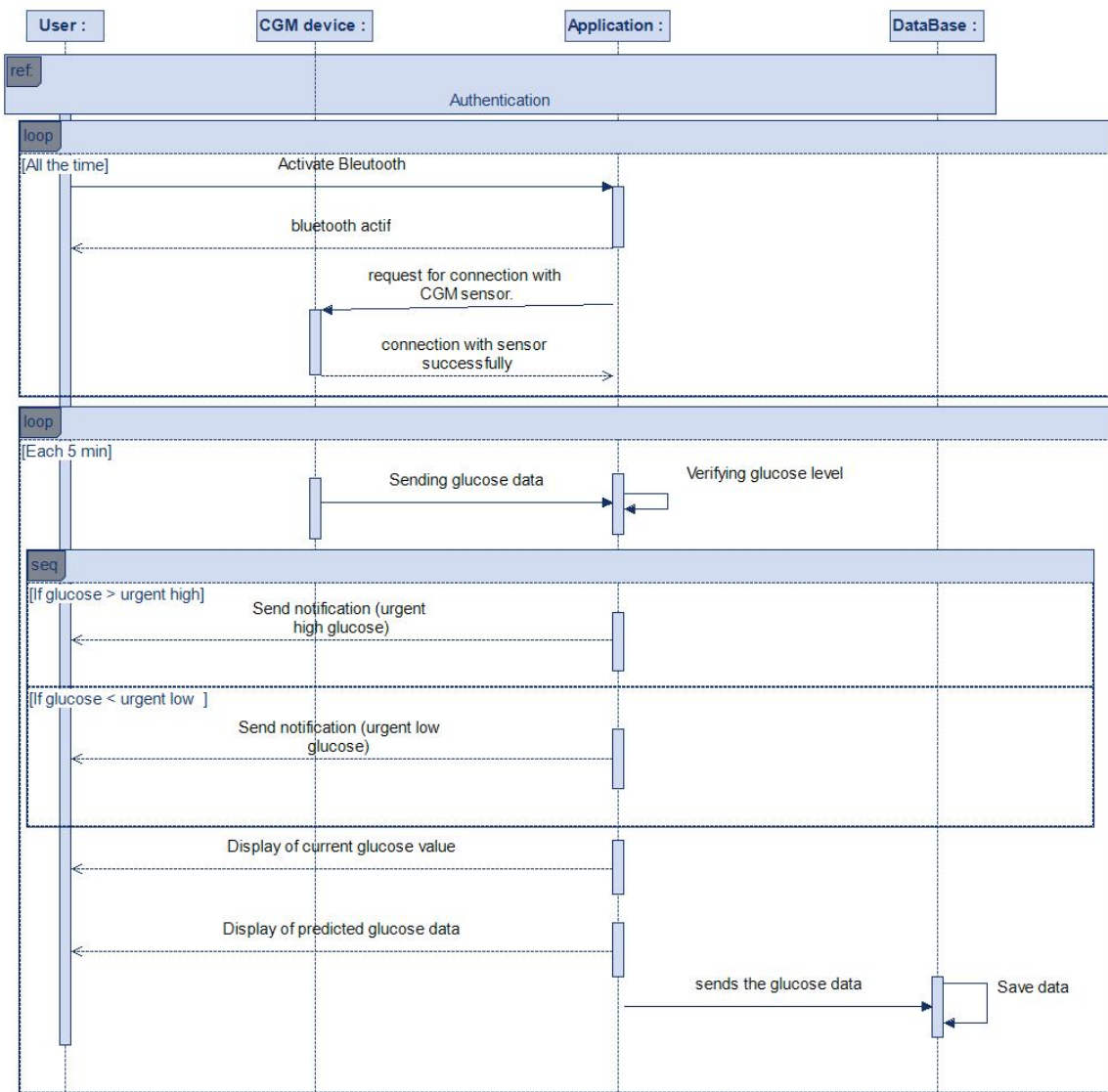


Figure 3.9 - Sequence diagram update glucose data.

Title: update glucose data.

Actors: user.

Pre conditions: user is already registered in the application with a valid email address and connected with Bluetooth.

Post conditions: successfully sending data from the sensor to the application.

Nominal scenario:

1. User already authenticated.
2. The user activates Bluetooth on his device.
3. The application automatically searches and connects to the CGM sensor via Bluetooth.
4. The CGM sensor sends the glucose data to the application every 5 minutes.
5. The application regularly checks the glucose levels against the thresholds defined by the user.
6. The system checks Glucose Levels and sends notifications.

Note: The application checks the glucose levels to determine if they are outside the normal range defined by the user and here are two types of notifications here :

- **Low Urgent glucose notification:** if the glucose level is lower than the defined urgent low target , the application sends a notification to warn the user that the glucose is low.
- **High Urgent glucose notification:**if the glucose level is higher than the defined urgent high target , the application sends a notification to warn the user that the glucose is high.

7. The system displays the current glucose value.
8. The system displays the predicted glucose data.

Alternative scenario:

1) Authentication error:

- Invalid contact details, so access to the application is denied.

2) Sensor Connection problem :

- If the connection fails for any reason, the application displays an error message indicating that the connection to the CGM sensor has failed and prompts the user to try again.

3.5 Conclusion

In this chapter we have presented the conceptual architecture of our application using the object-oriented approach, and this with the help of the various modeling tools of the UML language.

In the next chapter we will present the implementation phase of our application as well as the development tools that we used.

Chapitre 4

Conception and implementation

4.1 Introduction

In this last chapter, we will present the development environment as well as the tools that were used to create our application, and we will end with the presentation of the main user interfaces.

4.2 Development environment

4.2.1 Material environment

In our development we used a laptop with the following configuration:

A DELL Machine, Intel(R) Core(TM) i5-8250 U CPU @ 1.60GHz 1.80 GHz, a Random Access Memory (RAM) of 16.0 GB with Windows 10 Professional Experience Pack.

An HP ProBook Machine, 11th Gen Intel(R) Core(TM) i5-1135G7 @ 2.40GHz 2.42 GHz, a Random Access Memory (RAM) of 16.0 GB with Windows 11 Professional Feature Experience Pack.

An ASUS ZenBook ,Intel(R) Core(TM) i5-1035G4 CPU @ 1.10GHz 1.50 GHz a Random Access Memory (RAM) of 8.0 GB with Windows 11 Professional Feature Experience Pack.

4.2.2 Software environment

During the development of our application, we used the softwares/tools mentioned below:

❖ The JAVA language

Java is an object-oriented programming language developed by Sun Microsystems, a company best known for its high-end Unix workstations. Modeled after C++, the Java language was designed to be small, simple, and portable across platforms and operating systems, both at the source and at the binary level.[\[24\]](#)



Figure 4.1 - Java logo.

❖ The Python language

Python has become the lingua franca for many data science applications. It combines the power of general-purpose programming languages with the ease of use of domain-specific scripting languages like MATLAB or R. Python has libraries for data loading, visualization, statistics, natural language processing, image processing, and more. This vast toolbox provides data scientists with a large array of general- and special-purpose functionality.

One of the main advantages of using Python is the ability to interact directly with the code, using a terminal or other tools like the Jupyter Notebook, which we'll look at shortly.

Machine learning and data analysis are fundamentally iterative processes, in which the data drives the analysis. It is essential for these processes to have tools that allow quick iteration and easy interaction.

As a general-purpose programming language, Python also allows for the creation of complex graphical user interfaces (GUIs) and web services, and for integration into existing systems. [\[25\]](#)



Figure 4.2 - Python logo.

❖ **Fire Base**

Firebase is not just a database but a set of tools; it is often called a back-end-as-a-service (BaaS). Firebase contains a variety of services, as listed here:

- Authentication: User login and identity
- Real-time database: Real-time, cloud-hosted, NoSQL database
- Cloud Firestore: Real-time, cloud-hosted, NoSQL database
- Cloud storage: Massively scalable file storage
- Cloud functions: Serverless, event-driven back-end functions
- Firebase hosting: Global web hosting
- ML Kit: An SDK for common machine learning tasks

Firestore makes it easy for front-end developers to integrate a back end into their application, without creating any API routes and other back-end code. Figure 4.3 shows an example of a traditional web app, which does API requests to the server from the client apps. The rest of the code is handled by the server. As you can see in Figure 4.3, Firestore eliminates the back-end work, and you communicate directly with Firestore, hosted on the Google platform with an SDK. [26]

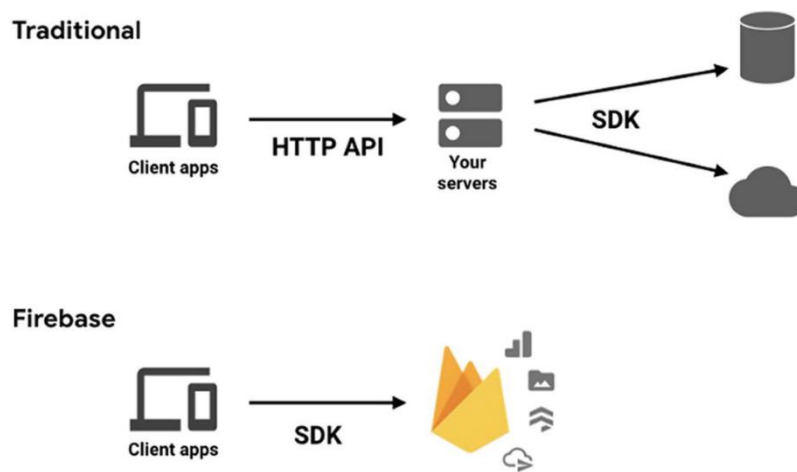


Figure 4.3 - Firestore.

❖ Git et GitHub

1) *Git*

Git is a technology that can be used to track changes to a project and to help multiple people to collaborate on a project. At a basic level, a project version controlled by Git consists of a folder with files in it, and Git tracks the changes that are made to the files in the project. This allows you to save different versions of the work you're doing which is why Git is called a version control system. [27]



Figure 4.4 - Git logo

2) *GitHub*

GitHub creates an environment that allows you to store your code on a remote server, gives you the ability to share your code with other people, and makes it easy for more than one person to add, modify, or delete code to the same file and project, while keeping one source of truth for that file. [\[28\]](#)



Figure 4.5 - GitHub logo

❖ **Android studio**

Android is the world's most popular mobile platform. At last count, there were over three billion active Android devices worldwide, and that number is still growing.

Android devices come in all shapes and sizes including, but not limited to, the following types of devices such as smartphones, tablets, e-reader devices, internet TVs, Automobiles, smartwatches, etc. [\[29\]](#)

The main advantage to adopting Android is that it offers a unified approach to application development. Developers need only develop for Android in general, and their applications should be able to run on numerous different devices, as long as the devices are powered using Android. In the world of smartphones, applications are the most important part of the success chain. [30]

Android devices come in all shapes and sizes including, but not limited to, the following types of devices such as smartphones, tablets, e-reader devices, internet TVs, Automobiles, smartwatches, etc. [30]



Figure 4.6 - Android studio logo

❖ **Anaconda**

Anaconda is a distribution of the Python and R programming languages for scientific computing that aims to simplify package management and deployment. The distribution includes data-science packages suitable for Windows, Linux, and macOS.

Anaconda® Distribution is a free Python/R data science distribution that contains:

- conda: a package and environment manager for your command line interface
- Anaconda Navigator: a desktop application built on conda, with options to launch other development applications from your managed environments
- 250 automatically-installed packages that work well together out of the box

- Access to the Anaconda Public Repository, with 8000 open-source data science and machine learning packages

Anaconda Distribution is free, easy to install, and offers free community support. [\[33\]](#)



Figure 4.7 - Anaconda logo

❖ Jupyter Notebook

The Jupyter Notebook is a browser-based graphical interface to the IPython shell, and builds on it a rich set of dynamic display capabilities. As well as executing Python/IPython statements. Notebooks allow the user to include formatted text, static and dynamic visualizations, mathematical equations, JavaScript widgets, and much more. Furthermore, these documents can be saved in a way that lets other people open them and execute the code on their own systems. [\[31\]](#)

Though you'll view and edit Jupyter notebooks through your web browser window, they must connect to a running Python process in order to execute code. [\[31\]](#)



Figure 4.8 - Jupyter notebook logo

❖ **Modelio**

Modelio is a modeling solution offering a wide range of functionality based on commonly used standards for Enterprise Architecture, Process Modeling, Software Development, and Systems Engineering.

Written for developers, analysts, and software and systems architects, Modelio is first and foremost a modeling environment, supporting a wide range of models and diagrams and providing many services facilitating the modeling of your architectures, such as model consistency-checking. Support for modeling and business processes (BPMN) is also integrated into Modelio. These BPMN models can be linked to other standards supported by the tool, for example UML, so as to integrate these business processes into a larger context such as an enterprise architecture. [\[34\]](#)



Figure 4.9 - Modelio logo

❖ Figma

Figma design is for people to create, share, and test designs for websites, mobile apps, and other digital products and experiences. It is a popular tool for designers, product managers, writers and developers and helps anyone involved in the design process contribute, give feedback, and make better decisions, faster.

Figma design files are powerful, collaborative environments where you turn your ideas into responsive and interactive designs. They're useful for creating and maintaining artifacts and assets, where detail and precision are of the utmost importance. [\[35\]](#)

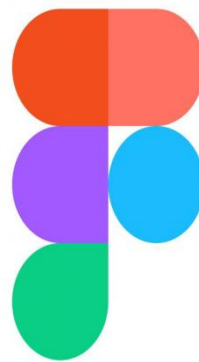


Figure 4.10 - Figma logo

❖ Adobe illustrator

Adobe® Illustrator® is the industry-standard illustration application for print, multimedia, and online graphics. Whether you are a designer or a technical illustrator producing artwork for print publishing, an artist producing multimedia graphics, or a creator of web pages or online content, Adobe Illustrator offers you the tools you need to get professional-quality results. [\[32\]](#)



Figure 4.11 - Adobe illustrator logo

4.3 Utilizing Firebase services in our application

In our app, we use firebase to boost our backend capabilities. Here, we'll explore the firebase services we've employed and how they enhance the functionality and reliability of our application.

4.3.1 Firebase Authentication

Our application uses firebase authentication to ensure secure user login and identity management. Below, we showcase an illustrative screenshot of our user database:

Identifier	Providers	Created ↓	Signed In	User UID
amanibdj@gmail.com	✉	May 20, 2024	May 20, 2024	EjDiuQvD7g9CqRr1JEAfj607193
med-hitman@hotmail.c...	✉	May 20, 2024	May 20, 2024	NTu77euEkaeB8YzucOYIsYm6...
mder455@gmail.com	✉	May 15, 2024	May 15, 2024	0ManICb7aNUYyc36HG26cZH...
amanibelkacem2022@...	✉	May 15, 2024	May 22, 2024	7xPwg6qIEgcUav7MgnE7arT2...
bounourinadjet5@gmai...	✉	May 13, 2024	May 13, 2024	46fvyNWJ8qRKbSDT4DZ7mZ...
derdour.amira44@gmai...	✉	May 5, 2024	May 15, 2024	ho4E90SEr1RKZSYcF8AyYnS...

Figure 4.12 - Firebase authentication.

4.3.2 Firebase Real-time Database:

We employ a firebase realtime database to guarantee seamless, real-time data synchronization throughout our app.

Realtime Database

Data Rules Backups Usage Extensions

Protect your Realtime Database resources from abuse, such as billing fraud or phishing [Configure App Check](#) ×

https://cgm-app-56737-default-rtadb.firebaseio.com

- 46fvyNWJ8qRKbSDT4DZ7mZ6Rge73
 - 7xPwg6qIEgcUav7MgnE7arT2Xho1
 - DateOfBirth: "15/1/2016"
 - DiabetesType: "Type 1"
 - FirstName: "amani"
 - Gender: "Male"
 - LastName: "belkacem"
 - generatedData
 - 2024-05-23
 - Nyab9fEhpd8Qa90YxN
 - NyacItWSCU51IWdm9Sm

Figure 4.13 - Firebase realtime database.

4.4 Implementation of the application

In this section we will present the different graphical interfaces of our application.

4.4.1 Launch interface

Once the application is launched, this interface appears with the logo and the name of the application. Figure 4.14 below shows the launch window.



Figure 4.14 - Launch interface

4.4.2 Authentication interface

This interface allows users to authenticate by entering their email and password. A "Forgot password" button is available in case of forgetting. Figure 4.15 shows the connection window.

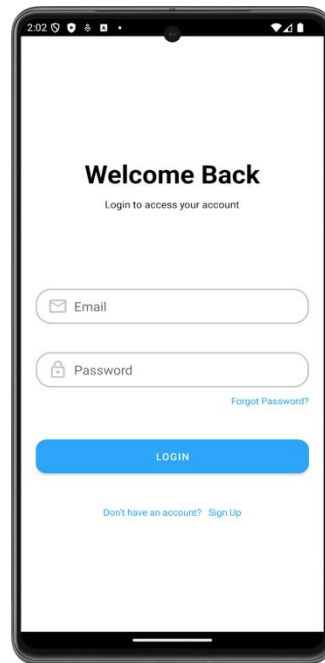


Figure 4.15 - login interface

4.4.3 Registration interface

If the user does not have an account, they will be directed to the account creation page by pressing the "Sign Up" button from the login page. He will then be able to create an account by following the instructions on the form.

The user will enter their last name, first name, choose their gender and type of diabetes, and then enter their email and password. The password must contain at least seven characters or digits.

Figure 4.16 shows the registration windows, which consist of multiple pages.

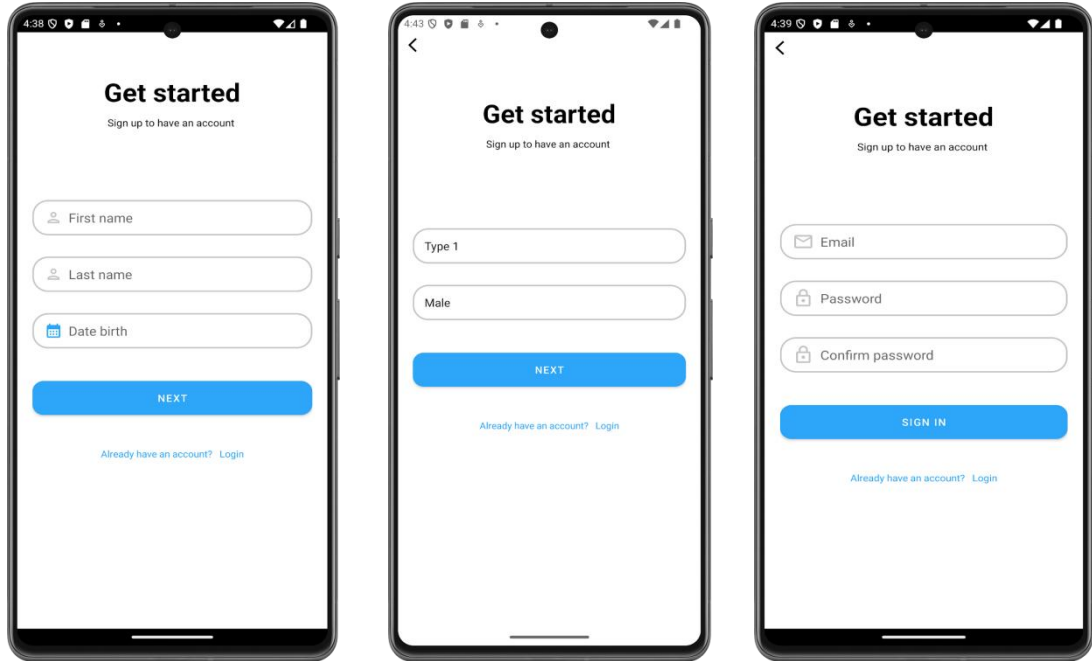


Figure 4.16 - Registration interfaces

4.4.4 Home interface

Once the user has been authenticated or registered, the home page appears represented by Figure 4.17.

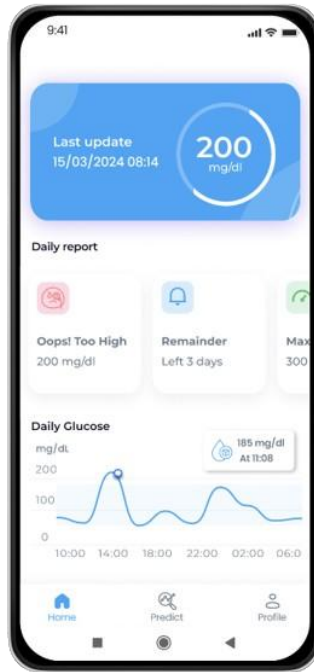


Figure 4.17 - Home page interface

4.4.5 Prediction interface

The prediction page contains information about the expected glucose values in the next hour. and it's shown in the figure below:

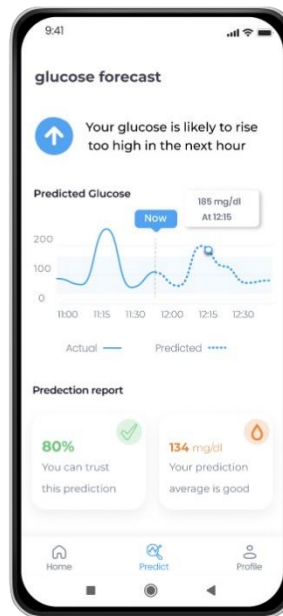


Figure 4.18 - Prediction interface

4.4.6 Profile interface

Figure 4.19 shows the profile interface , which, in turn, contains pages with all the information associated with the user.

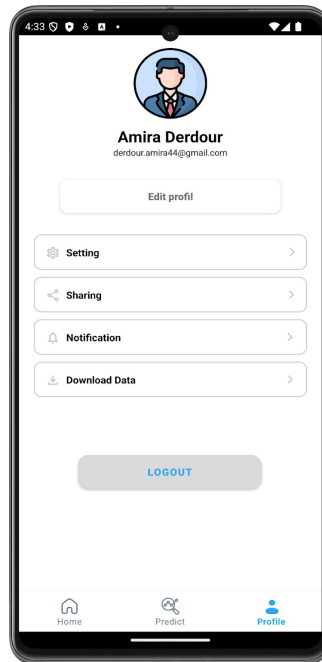


Figure 4.19 - Profile interface

4.4.7 Edit profile interface

To access the edit profile page, users can click on the "edit profile" button displayed on the profile page (refer to figure 4.19). Figure 4.20 represents the appearance of the edit profile page, where the user can fill out the form in order to modify his first name or last name, date of birth, and gender. Additionally, users have the option to take a profile picture or choose one from their phone library.

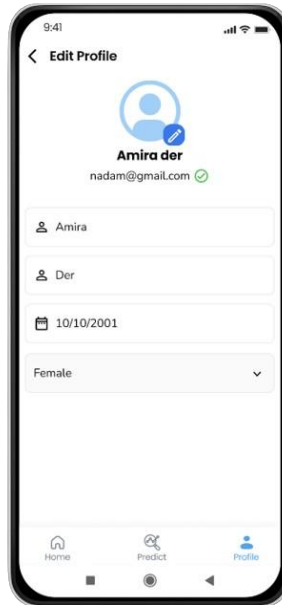


Figure 4.20 - Edit profile interface

4.4.8 Setting interface

The Settings page is accessible by clicking on the "Settings" button found on the profile page (refer to figure 4.19). Within the settings page, users have the option to modify their diabetes type, password, email, and target glucose range.

To update their email address or password, users can simply click on either 'change email' or 'change password'. Clicking on these options will redirect them to separate pages. The subsequent figures illustrate these pages.

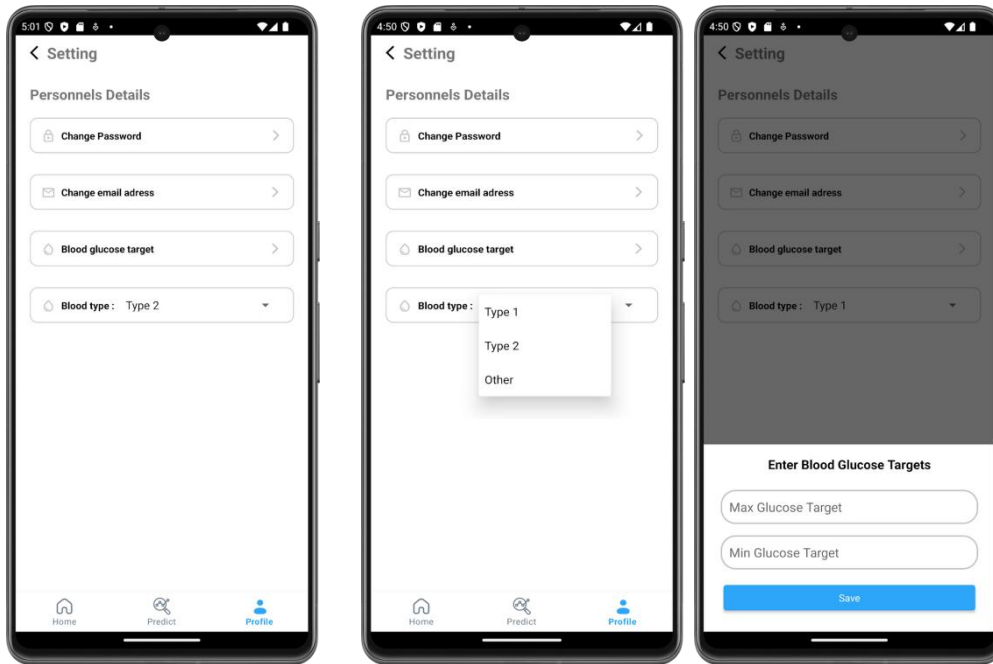


Figure 4.21 - Settings interface

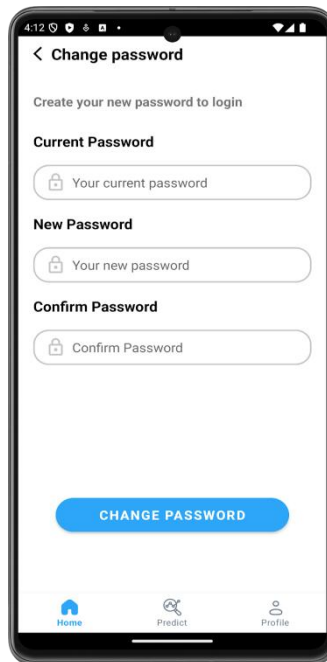


Figure 4.22 - Change password interface

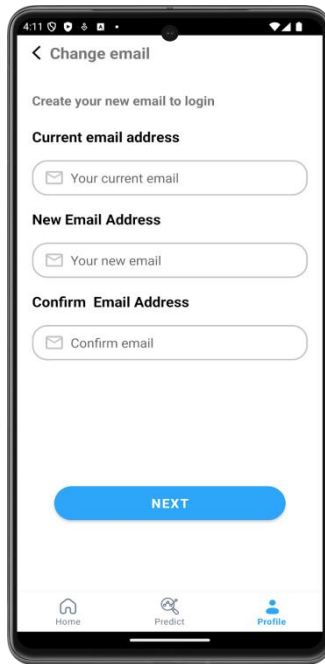


Figure 4.23 - Change email interface

4.4.9 Notification Interface

To access the Notifications page, users can click on the "Notifications" button displayed on the profile page (See Figure 4.19).

The Notifications page is illustrated in figure 4.24. In our application, there are four types of notifications:

1. Low glucose alerts
2. High glucose alerts
3. Glucose prediction alerts
4. Reminder alerts (sensor expiration).
5. Each type of notification has distinctive characteristics:
 - Users have the option to toggle them on or off according to their preference.

- Users can customize the alarm tone associated with each notification by pressing the "sound modes" button, and a page will appear where they can select the one they prefer.
- Users can turn off a certain type of notifications and leave the others activated, as they are independent of each other.
- Users can see the glucose level for both urgent high and low glucose alerts, which can be adjusted on the settings page as previously explained (refer to 4.21 setting interface).
- Users can also set the time duration for the sensor expiration reminder notification to be repeated, such as: sending a notification every 10 minutes to remind the user that the sensor needs to be changed.

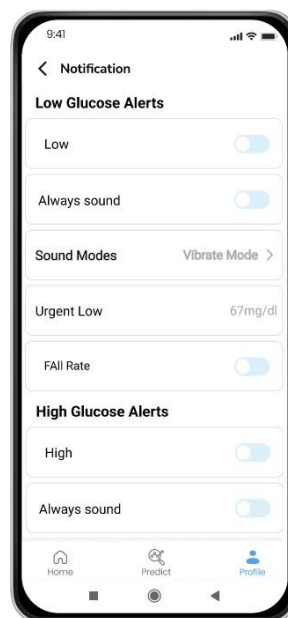


Figure 4.24 - Notification interface

4.4.10 Download data interface

Users can upload their data by clicking on the " download data" button . As shown in the figure 4.25 below.

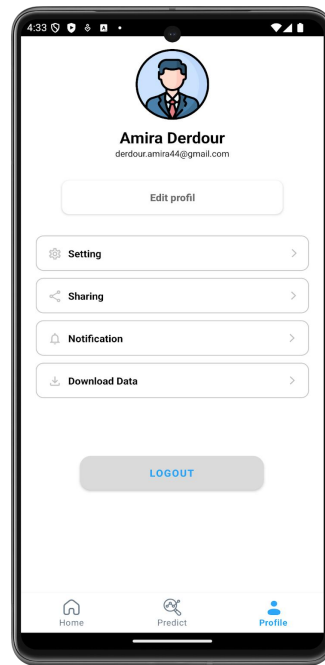


Figure 4.25 - Download data Interface

4.4.11 Sharing data Interface

Users can share data by clicking on the " sharing" button in profile page . As shown in the figure 4.26 below.

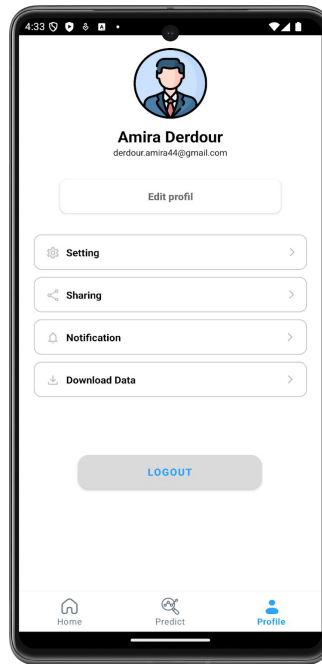


Figure 4.26 – Sharing interface

4.5 Conclusion

In this chapter, we have presented our hardware and software working environment, and we have briefly described the operation of our application by presenting these various interfaces and the different treatments that each user can do.

Conclusion Générale

In this thesis, we have presented the different stages in the design and production of an app to continuously monitor blood glucose levels.

The main goal of our project was to facilitate the management of diabetes by developing a customized app that contains only the functions that the user needs and is as easy to use as possible.

The second most important goal was to provide a forecast for the next hour. The predictive aspect of the app is a key asset in anticipating and preventing fluctuations in blood sugar levels, providing users with peace of mind and a better quality of life. However, the goals were many as we planned to pursue several development paths to improve and expand Heipox's capabilities, including the integration of a dedicated module for physicians. This module enables doctors to monitor their patients' data in real time, analyze blood glucose trends and proactively intervene if necessary. This function facilitates close communication between patient and doctor, promoting personalized and responsive care, as well as allowing patients' data to be backed up and restored if necessary. In order to meet the user requirements, we designed the system using UML formalism. For implementation, we used a NO SQL database manager, the application was developed using the JAVA programming language, and the predictor was developed using Python.

In short, the CGM device and Heipox app, with a module for physicians to be added later, is the perfect solution to transform the way individuals monitor and manage their diabetes. Through continuous innovation and strategic expansion, Heipox is paving the way for a new era of healthcare, promising a healthier and safer future for diabetics and finally, we hope that our project will be able to meet the ongoing needs and satisfy all the people who will use it.

Bibliographie

Book, monograph

- [24] Lemay, L., Perkins, C.: Teach Yourself Java in 21 Days. Sams Publishing, 1996.
- [25] Müller, A. C., Guido, S.: Introduction to Machine Learning with Python. O'Reilly Media, 2016.
- [26] Demian, S.: Beginning React and Firebase: Create Four Beginner-Friendly Projects Using React and Firebase. Apress, 2020.
- [27] Skoulikari, A.: Learning Git. O'Reilly Media, Inc., 2023.
- [28] Smith, S. W.: GitHub For Dummies, 2nd Edition. For Dummies, 2022.
- [29] Griffiths, D., Griffiths, D.: Head First Android Development, 3rd Edition. O'Reilly Media, 2017.
- [30] DiMarzio, J. F.: Beginning Android® Programming with Android Studio. John Wiley & Sons, Inc., 2017.
- [31] VanderPlas, J.: Python Data Science Handbook. O'Reilly Media, Inc., novembre 2016.
- [32] Wood, B.: Adobe Illustrator Classroom in a Book (2023 Release). Adobe Press, décembre 2022.

Journal articles

- [3] Saltiel, A. R., & Kahn, C. R. (2001). Insulin signalling and the regulation of glucose and lipid metabolism. *Nature*, 414(6865), 799-806.

[17] Swapna G., Vinayakumar R., Soman K.P. "Diabetes detection using deep learning algorithms." ICT Express, Volume 4, Issue 4, December 2018, Pages 243-246. Center for Computational Engineering and Networking (CEN), Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, Inde. Reçu le 4 septembre 2018, Accepté le 15.

Technical Report

[6] Zanon, M.: Non-Invasive Continuous Glucose Monitoring: Identification of Models for Multi-Sensor Systems. Ph.D. School in Information Engineering, XXV Series, 2013. School Director: Prof. Matteo Bertocco, Bioengineering Coordinator: Prof. Giovanni Sparacino, Advisor: Prof. Giovanni Sparacino.

Web documents

[1] Centers for Disease Control and Prevention (CDC). Definition of diabetes. Retrieved April 26, 2024

<https://www.cdc.gov/diabetes>

[2] World Health Organization (WHO). Types of diabetes. 5 April ,2023. Retrieved April 26, 2024

<https://www.who.int/news-room/fact-sheets/detail/diabetes>

[4] MyHealth.Alberta.ca. Health information and tools. Retrieved April 26, 2024

<https://myhealth.alberta.ca/Health>

[5] Medtronic Diabetes. Qu'est-ce que la mesure du glucose en continu ?. Retrieved April 26, 2024

<https://www.medtronic-diabetes.com/fr-CH/a-propos-du-diabete/qu-est-ce-que-la-mesure-du-glucose-en-continu>

[7] Abbott. Système FreeStyle Libre 2. Retrieved April 26, 2024

<https://www.freestyle.abbott/lu-fr/products/freestyle-libre-2.html#:~:text=IMPORTANT%20%3A%20Le%20Syst%C3%A8me%20FreeStyle%20Libre,y%20compris%20les%20femmes%20enceintes>

[8] Sensolus. (n.d.). How does Bluetooth Low Energy (BLE) work?. Retrieved April 26, 2024

<https://www.sensolus.com/how-does-bluetooth-low-energy-ble-work/>

[9] Abbott. "FreeStyle Libre 2 Next Gen is Here". June 15, 2020. Retrieved April 26, 2024

<https://www.abbott.com/corpnewsroom/strategy-and-strength/freestyle-libre-2-next-gen-is-here.html>.

[10] Dexcom. G6 CGM System. Retrieved April 26, 2024

<https://www.dexcom.com/g6-cgm-system>.

[11] SIBIONICS. Certification du produit. Retrieved April 26, 2024

<https://www.sibionicscgm.com/fr/pages/product-certification>.

[12] SIBIONICS. SIBIONICS GS1 CGM System User Guide. Retrieved April 26, 2024

https://cdn.shopify.com/s/files/1/0669/6078/5660/files/Quick_Start_Guide_New.pdf?v=1703210161

[33] Anaconda Distribution. Anaconda Software Distribution. Retrieved April 26, 2024

<https://docs.anaconda.com/free/anaconda/index.html>

[34] Modelio. Retrieved April 26, 2024.

<https://www.modelio.org/index.htm>.

[35] Figma. D. Retrieved April 26, 2024

<https://help.figma.com/hc/en-us/articles/14563969806359-What-is-Figma>.

Online article

[13] Coursera Staff. "What Is Artificial Intelligence? Definition, Uses, and Types." Mise à jour à 3 avr. 2024.

<https://www.coursera.org/articles/what-is-artificial-intelligence>.

[14] McKinsey & Company. "What is AI (artificial intelligence)?" 3 avril 2024.

<https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-ai>.

- [15] Laskowski, N., Tucci, L. "AI (Artificial Intelligence)."
<https://www.techtarget.com/searchenterpriseai/definition/AI-Artificial-Intelligence>.
- [16] Petrova, B. "Predictive Analytics in Healthcare." Mis à jour par B. Petrova, le 15 février 2024.
<https://www.revealbi.io/blog/predictive-analytics-in-healthcare#:~:text=Predictive%20analytics%20in%20healthcare%20refers,manage%20the%20spread%20of%20diseases>.
- [18] Sethi, A. "Support Vector Regression Tutorial for Machine Learning." Publié par A. Sethi le 27 mai 2024.
<https://www.analyticsvidhya.com/blog/2020/03/support-vector-regression-tutorial-for-machine-learning/#>.
- [19] Verma, N. "An Introduction to Support Vector Regression (SVR) in Machine Learning." Publié par N. Verma.
<https://medium.com/@nandiniverma78988/an-introduction-to-support-vector-regression-svr-in-machine-learning-681d541a829a>.
- [20] C3.ai, Inc. "What is Root Mean Square Error?" © 2024 C3.ai, Inc. Tous droits réservés.
<https://c3.ai/glossary/data-science/root-mean-square-error-rmse/>.
- [21] Fernando, J. "R-Squared: Definition, Calculation Formula, Uses, and Limitations." Mis à jour par J. Fernando le 2 mai 2024. Révisé par A. Smith. Vérifié par Y. Perez.
<https://www.investopedia.com/terms/r/r-squared.asp>.
- [22] Haibal. "Mean Relative Error (MRE)." Update 22 avril 2024.
[https://haibal.com/documentation/metric-mean-relative-error/#:~:text=Mean%20Relative%20Error%20\(MRE\)%20is,percentage%20from%20the%20ground%20truth](https://haibal.com/documentation/metric-mean-relative-error/#:~:text=Mean%20Relative%20Error%20(MRE)%20is,percentage%20from%20the%20ground%20truth)
- [23] C3.ai, Inc. "Correlation." Retrieved April 26, 2024
<https://c3.ai/glossary/data-science/correlation/>.