الجمهورية الجزائرية الديمقراطية الشعبية
People's Democratic Republic of Algeria
وزارة التعليم العالي و البحث العلمي
Ministry of Higher Education and Scientific Research

Nº Ref: ....

Abdelhafid Boussouf University Center
of Mila

Science and Technology Institute
Department of Mathematics and Computer Science

Thesis prepared for the Master's degree

In: Computer Science
Speciality: Science and Technologies of Information and Communication (STIC)

TIS COVID-19: Telemonitoring Intelligent System for COVID-19

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University year: 2021/2022

Abstract

During the COVID-19 pandemic, AI technology has emerged strongly to contribute to improving the healthcare sector and fighting this virus.

In this thesis, we present « TIS COVID-19 », a smart system for telemonitoring and diagnosing people from home, to relieve pressure on hospitals and medical clinics and reduce the spread of infection. The system contains a wearable, mobile application, and web application.

The wearable will collect the citizen's vital signs, and send them to the mobile application using IoT technology. To give more accurate information, the citizen can express his physical feelings using the vocal mode.

The mobile application will analyze all this information using NLP and ML technologies, and then evaluates the diagnostic results depending on the gravity of the citizen's state, to give him the correct instructions he must follow.

In dangerous state cases, the application will contact the citizen's caretakers and personal doctors or send an ambulance request to the nearest hospital.

To be more practical, the doctors and hospitals will use the web application that will be managed by the admin.

The whole system is developed in Python, Java, and PHP programming languages, using Android Studio, Sublime text, and PyCharm IDEs, Android framework for the mobile application and Laravel for the web application.

Keywords: COVID-19 application, Telemonitoring System, Healthcare Intelligent System, ML algorithms.

Résumé

Pendant la pandémie de COVID-19, la technologie de l'IA a fortement émergé pour contribuer à l'amélioration du secteur de la santé et à la lutte contre ce virus.

Dans cette thèse, nous présentons « TIS COVID-19 », un système intelligent de télésurveillance et de diagnostic des personnes à domicile, pour soulager la pression sur les hôpitaux et les cliniques médicales et réduire la propagation des infections. Le système contient un dispositif portable, une application mobile et une application web.

Le dispositif portable va collecter les signes vitaux du citoyen et les envoie à l'application mobile à l'aide de la technologie IoT. Pour donner des informations plus précises, le citoyen peut exprimer ses sensations physiques en utilisant le mode vocal.

L'application mobile analysera toutes ces informations à l'aide des technologies NLP et ML, puis évaluera le résultat en fonction de la gravité de l'état de citoyen pour lui donner les bonnes instructions qu'il doit suivre.

Dans les cas critiques, l'application contactera les soignants et le médecin personnel de citoyen ou enverra une demande d'ambulance à l'hôpital le plus proche en cas d'urgence.

Pour être plus pratique, les médecins et les hôpitaux utiliseront l'application web qui sera gérée par l'administrateur.

Tout le système est développé avec les langages de programmation Python, Java et PHP en utilisant les IDE Android Studio, Sublime text, et PyCharm, le framework Android pour l'application mobile et Laravel pour l'application Web.

تلخيص

خلال جائحة COVID-19 ، ظهرت تكنولوجيا الذكاء الاصطناعي بقوة للمساهمة في تحسين قطاع الرعاية الصحية ومكافحة هذا الفيروس.

نقدم في هذا البحث «TIS COVID-19» ، وهو نظام ذكي للمراقبة عن بعد وتشخيص الناس من المنزل لتخفيف الضغط على المستشفيات والعيادات الطبية وتقليل انتشار العدوى. يحتوي النظام على تطبيق هاتف وتطبيق ويب و جهاز يمكن ارتداؤه.

يقوم الجهاز القابل للارتداء بجمع الإشارات الحيوية للمواطن وإرسالها إلى الهاتف المحمول باستخدام تقنية إنترنت الأشياء. لإعطاء معلومات أكثر دقة، يمكن للمواطن التعبير عن مشاعره الجسدية باستخدام الوضع الصوتي.

يقوم تطبيق الهاتف المحمول بتحليل كل هذه المعلومات باستخدام تقنيات البرمجة اللغوية العصبية و تعلم الالة ، ثم يقوم بتقييم نتائج التشخيص اعتمادًا على خطورتها لإعطاء المواطن التعليمات الصحيحة التي يجب عليه اتباعها.

في الحالات الخطيرة، سيتصل التطبيق بمقدمي الرعاية للمواطنين و الأطباء الشخصيين أو إرسال طلب سيارة إسعاف إلى أقرب مستشفى. لكي تكون أكثر عملية ، يستخدم الأطباء والمستشفيات تطبيق الويب الذي تتم ادارته من قبل مدراء النظام.

تم تطوير النظام بأكمله بلغات البرمجة Python و Java و PHP ، باستخدام Android Studio و Sublime text و PyCharm ، إطار عمل Android للجوال و Laravel لتطبيق الويب.

Acknowledgment

First of all, we are grateful to ALLAH, the almighty God that gave us the strength and the wisdom to make our project come true.

Also, as all successful research works can be achieved by discussions, collaborations, and support, it is a pleasure to thank those who have been so helpful to us. The following lines are dedicated to all of them.

First, we would like to express our gratitude to our supervisor Dr. Nardjes BOUCHEMAL, from Mila University, for her precious advice during this dissertation. We are also very thankful to the members of our jury, Mrs Mounira Bouzahzah and Mr. Aissa Boulmerka, who are also from Mila University, for their willingness to be reviewers of this thesis and members of the jury board.

We would also like to deeply thank in the warmest terms all the teachers of Mila University for their huge efforts to improve our education.

We express our best thanks to all the supportive family and friends. I would like to extend my ineffable thanks to my sister Amel who has made to guide me to the best of her abilities all these past years.

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List of Abbreviations

AI	Artificial Intelligence
AVA	All vs. All
ANN	Artificial Neural Networks
DL	Deep Learning
DBMS	Database Management System
DT	Decision Tree
EHR	Electronic Health Records
GPS	Global Position System
GMM	Gaussian Mixture Model
HMM	Hidden Markov Models
IoT	Internet of Things
IDE	Integrated Development Environment
IoMT	Internet of Medical Things
ML	Machine Learning
NLP	Natural Language Processing
PPE	Personal Protective Equipment
PDA	Personal Digital Assistant
QoS	Quality of Service
SR	Speech Recognition
SVM	Support Vector Machine
UML	Unified Modeling Language
TIS	Telemonitoring Intelligent System
VOC	Variants of Concern
WHO	World Health Organization

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General Introduction

Technology has always been known as a forerunner in the medical field. It played a major role helping in the early diagnosis of different diseases, discovering many new ones, and arriving at precise medical solutions, especially in the field of surgery and radiology. Today, technology is emerging strongly to fight the disease of the age COVID-19.

Because of this pandemic, hospitals have been overcrowded with COVID-19 patients. This led to dysfunctional healthcare facilities that neglect non-COVID-19 patients' clinical demands due to infection. It also caused harm to the citizens and public health and added a lot of pressure on the medical staff. All of that pushes us to exploit our field and help in fighting this disease by automating the diagnosis to discover COVID-19 patients, guide them towards the correct medical procedures, and increase the likelihood of saving their lives.

Our project is a telemonitoring simple and easy-to-use smart system, based on AI technologies like IoT, ML, and NLP, as an improvement of the existing systems, and at the same time fits with the state of the technology in our country. It will consist of a mobile smart application, a web application in addition to a wearable.

We will develop this system to relieve pressure on hospitals, and monitor the state of people to detect whether or not they are infected with COVID-19 and determine their risk level, especially the elderly or those with chronic diseases that should be under constant surveillance to ensure their stable health.

The mobile application permanently tracks the citizen's health state using the collected data sent from the wearable, which represents the vital signs of the citizen like body temperature, pulse rate, respiration rate, in addition to his physical feelings like fever, fatigue, and difficulty breathing, using the vocal or text mode. The intelligent system will analyze all of this information using ML and NLP technologies to diagnose the citizen's state.

The application will display the diagnostic result and instructions that the citizen must follow, and make decisions depending on the gravity of the result. If there is some doubt about the result, the system will give the citizen a set of instructions, while contacting his doctor who will give the final result and instructions. In critical situation, the system will send an alert message to the citizen's caretakers, and send an ambulance request to the nearest hospital. To make it more flexible, the doctors and hospitals will use the web application.

For the conceptual design part, we will use the Unified Modeling Language (UML), while in the implementation part we will use Python, Java and PHP programming languages, Android Studio, PyCharm and Sublime text IDEs, Android framework for the mobile application and Laravel framework for the web application.

This thesis consists of four chapters organized in the following way:

- The first chapter: we will talk about the general concepts of E-health and the main AI technologies in healthcare.
- The second chapter: will be composed of COVID-19 description and the related work of AI in telemonitoring healthcare of COVID-19 systems.
- The third chapter: contains the most important part of our project, which is the system description, analyze, and conception, in which we present the different diagrams of our system.
- The fourth chapter: presents the implementation part, where we explain the different programming languages, tools, platforms, and technologies used to build our system, and describe the system architecture and its main algorithms. To present the application's interface, we add the main screens captured from the system's execution.

Chapter 1

E-Health General Concepts

1. Introduction

E-health has played a crucial role in the pandemic period. The high infection risks in the outside environment, exit restrictions, and even lockdowns of entire cities have jointly overshadowed the traditional offline model of diagnosis and treatment in physical medical institutions like hospitals, clinics, and outpatient departments, which has made e-health a highly attractive and alternative option in a risky and insecure period.

In this chapter, we'll see the e-health basic concepts and get to know which AI technologies played an important role in the e-health field.

2. E- Health definition

According to the World Health Organization (WHO), e-health is defined as "digital services for human well-being", i.e. the application of information and communication technologies (ICT) to health and well-being [1].

Briefly, e-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology [2].

The "e" in e-health does not only stand for "electronic," but implies a number of other "e's," which together best characterize what e-health is all about, the essential e's are:

- Efficiency: increase efficiency in health care, thereby decreasing costs. One possible way of decreasing costs would be by avoiding duplicative or unnecessary diagnostic or therapeutic interventions [3].
- Enhancing quality of care: by allowing comparisons between different providers, involving consumers as additional power for quality assurance, and directing patient streams to the best quality providers [3].
- Education**:** teach doctors online through continuing medical education and consumers with health education, tailored preventive information for consumers [3].
- Ethics**:** e-health involves new forms of patient-physician interaction and poses new challenges and threats to ethical issues such as online professional practice, informed consent, privacy and equity issues [3].

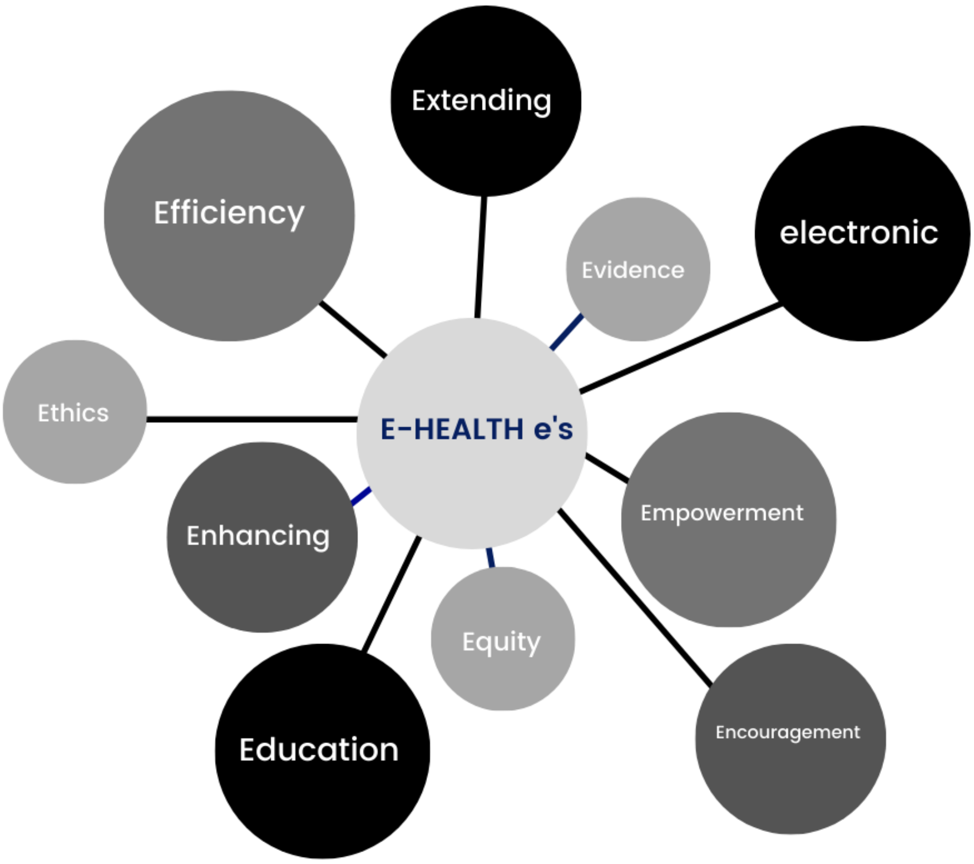


Figure 1.1: The essential e's of e-health

3. E- Health types

With the development of e-health, new subfields have appeared. Based on different approaches to e-health, its types can include:

3.1. Tele-health

Tele-health is the use of medical information that is exchanged from one site to another through electronic communication to improve a patient’s health [4]. I’s is defined as the delivery and facilitation of health and health-related services including medical care, provider and patient education, health information services, and self-care via telecommunications and digital communication technologies. Live video conferencing, mobile health apps, “store and forward” electronic transmission, and telemonitoring are examples of technologies used in tele-health [5].

3.2. Intelligent health

Intelligent health is the use of artificial intelligence technologies in healthcare section to improve the speed and accuracy of diagnosis and screening for diseases, assist with clinical care, strengthen health research and drug development, and support diverse public health interventions, such as disease surveillance, outbreak response, and health systems management [6].

3.3. Mobile health

Term used to refer to the practice of medicine and public health using mobile devices such as mobile phones, tablet computers, and personal digital assistants (PDAs), and wearable devices such as smart watches, to health services, information and data collection [37].

4. Artificial Intelligence in e-health

4.1. AI definition

Artificial intelligence (AI), the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from past experience [7].

Since the development of the digital computer in the 1940s, it has been demonstrated that computers can be programmed to carry out very complex tasks as, for example, discovering proofs for mathematical theorems or playing chess with great proficiency. Still, despite continuing advances in computer processing speed and memory capacity, there are as yet no programs that can match human flexibility over wider domains or in tasks requiring much everyday knowledge. On the other hand, some programs have attained the performance levels of human experts and professionals in performing certain specific tasks, so that artificial intelligence in this limited sense is found in applications as diverse as medical diagnosis, computer search engines, and voice or handwriting recognition [7].

4.2. AI history

AI is not new; the idea was brought up by John McCarthy in collaboration with Marvin Minsky from the MIT AI Group in Boston in 1950. We've summarized the AI history in the table 1.1:

1950s	1960s	1970s	1980s
• Hope to develop some kind of electronic brains. • Turing test. • Lisp language.	• The huge complexity of the system. • Reduced budgets. • Beginning of strong criticism.	• Experts systems. • Prolog language. • Hybrid systems.	• The technology of neural network. • Problems solving. • Natural language processing.
1990s	**2000s**	**2010s**	**2020s**
• Emotional AI. • Robotics.	• Self-driving cars. • Intelligent games.	• Machine learning. • Deep learning. • Computer vision. • Face recognition.	• Language translation. • Text classification. • Questions-answers systems.

Table 1.1: AI history

4.3. The Turing test

The Turing test, made by Alan Turing in 1950, is a test of a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human [8].

Turing proposed that a human evaluator would judge natural language conversations between a human and a machine designed to generate human-like responses. The evaluator would be aware that one of the two partners in conversation is a machine, and all participants would be separated from one another. The conversation would be limited to a text-only channel such as a computer keyboard and screen so the result would not depend on the machine's ability to render words as speech. If the evaluator cannot reliably tell the machine from the human, the machine is said to have passed the test. The test results do not depend on the machine's ability to give correct answers to questions, only how closely its answers resemble those a human would give [8].

Figure 1.2 below, the standard interpretation of the Turing test. In which player C, the interrogator, is given the task of trying to determine which player A or B is a computer and which is a human. The interrogator is limited to using the responses to written questions to make the determination [8].

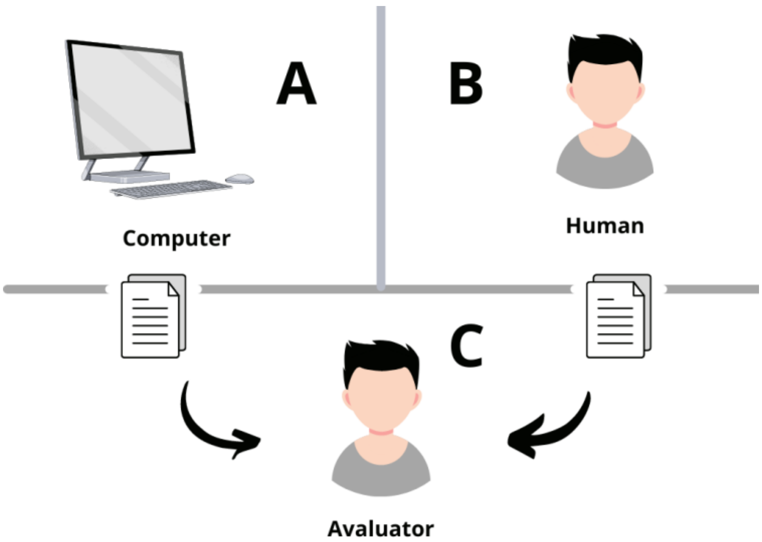


Figure 1.2: The standard interpretation of the Turing test

4.4. E-health and Artificial Intelligence technologies

AI is a wide-ranging branch of computer science which contains a lot of technologies. The approach has been through a striking evolution in the last decade especially in the healthcare sector, and it’s becoming an increasingly important part of the world's healthcare infrastructure.

4.4.1. Machine Learning and Deep Learning

Machine Learning (ML): is a subfield of artificial intelligence. Its goal is to enable computers to learn on their own. A machine' s learning algorithm enables it to identify patterns in observed data, build models that explain the world, and predict things without having explicit pre-programmed rules and models [9].

These days, machine learning plays a key role in many health-related realms, including developing new medical procedures, handling patient data and records, and treating chronic diseases. Computer scientist Sebastian Thrum told the New Yorker: "Just as machines made human muscles a thousand times stronger, machines will make the human brain thousand times more powerful." [39].

Deep Learning (DL): is a set of machine learning methods attempting to model with a high level of data abstraction through articulated architectures of different nonlinear transformations. These techniques have enabled significant and rapid progress in the fields of sound or visual signal analysis and in particular face recognition, voice recognition, computer vision and natural language processing [10].

Deep learning attempts to ensure that the right treatment is delivered to the right patient at the right time by taking into account several aspects of patient's data, including variability in molecular traits, environment, and electronic health records (EHRs) and lifestyle [40].

Machine Learning Methods: Machine Learning has three general categories which are:

- **Supervised learning methods:** In these cases, algorithms specifically designed to achieve the optimization of an error function established by comparison between the current output obtained from the algorithm and the response we know that the system should give are used. A supervised learning is an iterative algorithm that adapts certain parameters of the AI computer model that we intend to adjust, according to the reference previously defined gold standard. This system needs a quality labeled data, in accordance with the experience of experts, and, in summary, this corresponds to the knowledge that is to be integrated into the system itself. Examples of concrete algorithms are Artificial Neural Networks (ANN), Support Vector Machines (SVM), Decision Trees (DT), Hidden Markov models (HMM) and many more [28].

We can use healthcare supervised learning in Clinical Decision Support Systems, Smart Recordkeeping, Medical Imaging, and Personalized Medicine.

- **Non-supervised learning methods:** in which a priori there is no prior knowledge about the structure of the data, and of course there is no labeling process. It is therefore necessary to apply certain strategies aimed at discovering certain patterns of relationships that can be established between the data, depending on parameters of a statistical nature. Generally, a learning system of this type, leads us to the definition of similitude characteristics between subsets of data, as a function of a defined metrics. As typical examples, we can mention the K-means clustering or the Gaussian mixture model (GMM) [28].

Some applications of non-supervised learning in healthcare are, Drug Discovery and Production, Clinical Research, and Infectious Disease Outbreak Prediction.

- **Reinforcement learning methods**: to make a sequence of decisions. The algorithm learns to achieve a goal in an uncertain, potentially complex environment. In reinforcement learning, an artificial intelligence faces a game-like situation. The computer employs trial and error to come up with a solution to the problem. To get the machine to do what the programmer wants, the artificial intelligence gets either rewards or penalties for the actions it performs. Its goal is to maximize the total reward.

Although the designer sets the reward policy–that is, the rules of the game–he gives the model no hints or suggestions for how to solve the game. It's up to the model to figure out how to perform the task to maximize the reward, starting from totally random trials and finishing with sophisticated tactics and superhuman skills. By leveraging the power of search and many trials, reinforcement learning is currently the most effective way to hint machine's creativity. In contrast to human beings, artificial intelligence can gather experience from thousands of parallel game plays if a reinforcement learning algorithm is run on a sufficiently powerful computer infrastructure, some examples: Criterion of optimality, Brute force and value function [9].

We can use healthcare reinforcement learning in Behavior Adjustments, Predictive Approach to Treatment, Elderly and Low-Mobility Groups Care, Robotic Surgery.

4.4.2. Natural Language Processing

Natural Language Processing (NLP) is the use of human languages, such as English or French, by a computer. Computer programs typically read and emit specialized languages designed to allow efficient and unambiguous parsing by simple programs. More naturally occurring languages are often ambiguous and defy formal description. Natural language processing includes applications such as machine translation, in which the learner must read a sentence in one human language and emit an equivalent sentence in another human language. Many NLP applications are based on language models that define a probability distribution over sequences of words, characters or bytes in a natural language [15].

NLP helps the healthcare industry to make the best use of unstructured data. This technology facilitates providers to automate the managerial job, invest more time in taking care of the patients, and enrich the patient's experience using real-time data.

4.4.3. Speech Recognition

Speech Recognition (SR) is the ability of a machine or program to identify words spoken aloud and convert them into readable text. Rudimentary speech recognition software has a limited vocabulary and may only identify words and phrases when spoken clearly [16].

In recent years, speech recognition technology has been developed for a number of applications. In the healthcare field, this is often used to help patients with cognitive impairments and those who have difficulty using their hands or fingers due to injury or disability. The introduction of this new type of technology will make it much easier for physicians to listen to patients with hearing impairments or those who speak a different language. It can also help them deal with other issues like getting information at the same time as they are performing an exam [41].

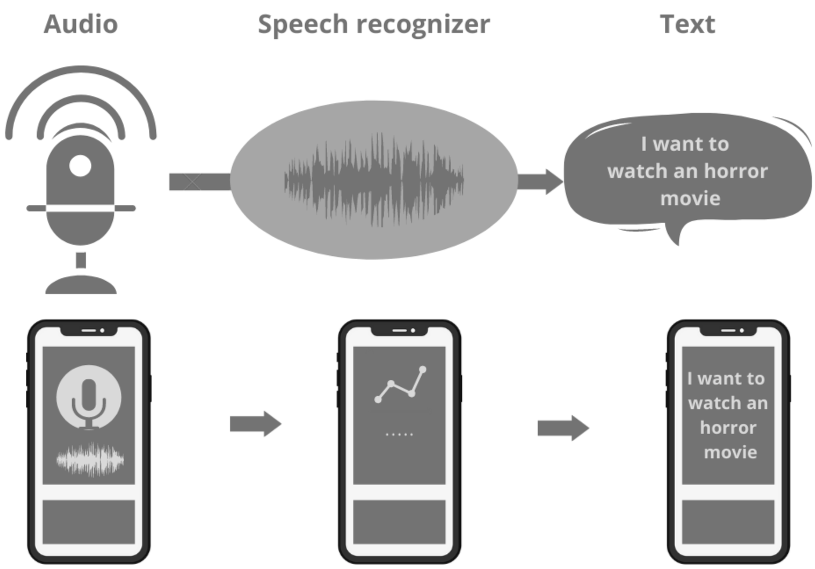


Figure 1.3: Speech Recognition process

4.4.4. Internet of Things

Internet of Things (IoT) represents objects that have virtual personalities and identities, where they are embedded with smart interfaces that allow them to communicate and connect with user contexts and social environments [11].

So IoT is the idea of connecting any device or hardware that we use every day with on/off switch and monitor via Internet. The basic operation of the IoT is that we can control and monitor anything, anywhere, and at any time the hardware using control devices that are connected to the internet [12].

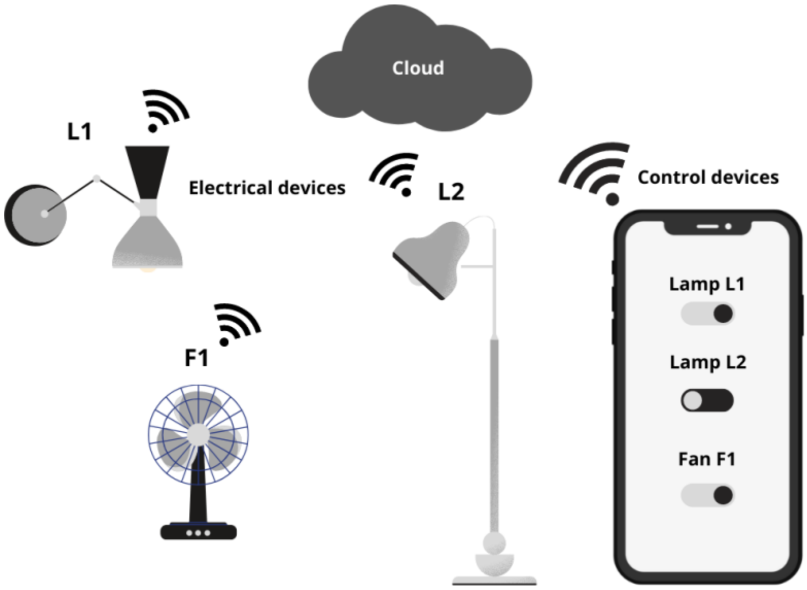


Figure 1.4: Basic IoT application

IoT connects millions of smart objects, which need for large data processors and storages. IoT will face challenges regarding QoS, privacy, and security. Thus, IoT architecture must take into consideration many issues such as interoperability, scalability, quality of service (QoS), reliability, etc. Various IoT architectures have been suggested. Nevertheless, each proposed architecture brings many shared drawbacks and fails to cover all of the IoT characteristics, which are summarized as distributive, interoperability, scalability, resources scarcity, security [13].

There is no global consensus on the architecture of IoT, so different IoT architectures have been suggested by many researchers. To the best of our knowledge, we found that the superior model with respect to the elements that compose this environment is the "Three Based Architecture" model that is described in. This architecture composes of three layers: *IoT layer, Fog layer, Cloud layer* [14].

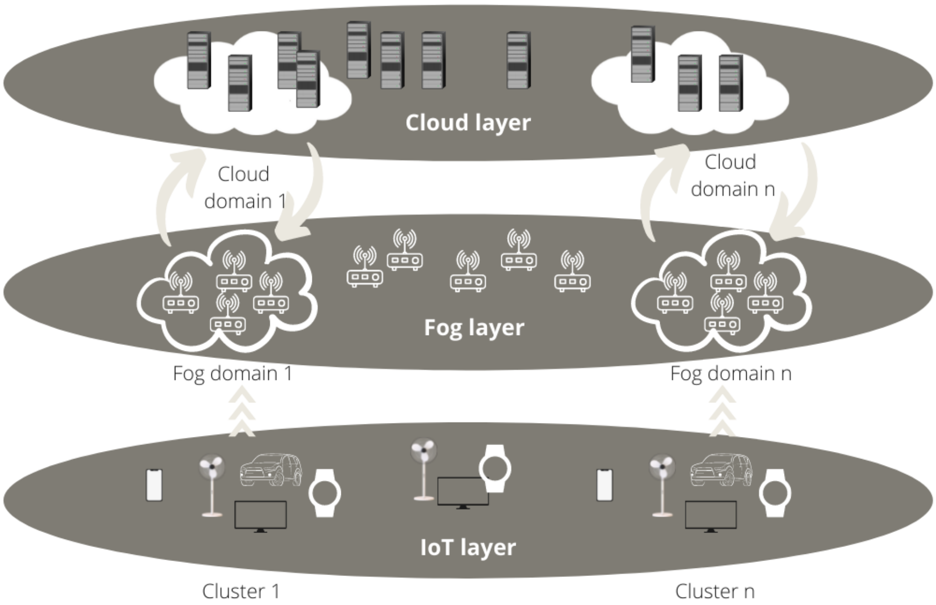


Figure 1.5: IoT three-based architecture layered

4.4.5. Internet of Medical Things

Internet of Medical Things (IoMT), also known as healthcare IoT refers to the interconnectedness of medical equipment, software applications, and data pertaining to the health-care industry. This technology can provide a solution to the challenges of detection, monitoring, contact tracing, and control of this disease [17].

IoMT is the collection of medical devices and applications that connect to healthcare IT systems through online computer networks. Medical devices equipped with Wi-Fi allow the machine-to-machine communication that is the basis of IoMT. IoMT devices link to cloud platforms such as Amazon Web Services, on which captured data can be stored and analyzed.

4.4.6. Medical sensors:

A sensor is a device transforming the state of an observed physical quantity into a usable quantity, such as an electric voltage, a height of mercury, intensity or the deviation of a needle. We often (wrongly) confuse sensor and transducer: the sensor is at least made up of a transducer. The sensor is distinguished from the measuring instrument by the fact that it is only a simple interface between a physical process and manipulable information. In contrast, the measuring instrument is an autonomous device sufficient in itself, having a display or a data storage system. The sensor does not have it.

Sensors play an ever more important role in medical technology with the aim of making medical devices even more effective and safer, while simplifying their operation. As a long-standing manufacturer and supplier of sensor system solutions for medical technology, we understand your applications. At First Sensor, you can find not only the standard but also the ideal sensor system solution for your measuring task.

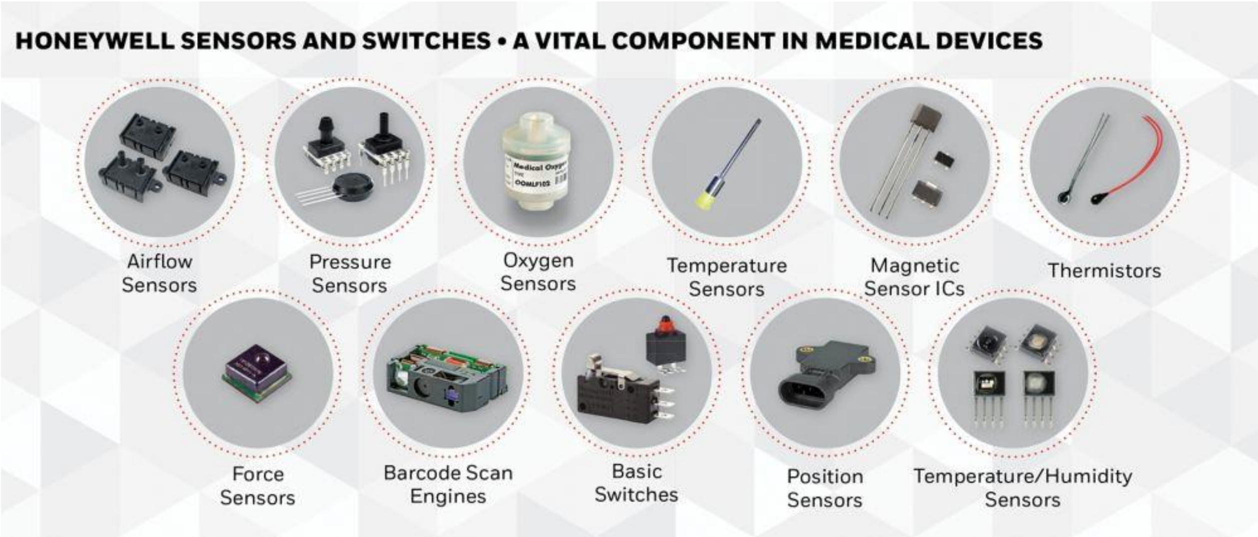


Figure 1.6: Different types of medical sensors

5. Conclusion

In this chapter, we talked about general concepts of e-health, and then we mentioned the main AI technologies used in the healthcare sector, some representing the technologies we will use to develop our system.

In the next chapter, we will specify more information about COVID-19 disease and see the state of the art of COVID-19 telemonitoring applications.

Chapter 2

COVID-19 Description and Solutions

1. Introduction

After the emergence of COVID-19 disease, numerous tracing applications have been proposed and developed, especially in the AI field which has appeared strongly in the arena.

In this chapter, we will present a description of COVID-19 and summarize the existing research, products, and systems, then explain why our proposed system is better than or different from what already exists.

2. COVID-19

2.1. Description

Corona virus disease 2019 (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus. It’s certainly the worst worldwide crisis in the 21st century which has provoked a real disaster [20].

This disease which was reported in December 2019 in the city of Wuhan in China has been reported in almost all countries. The current count shows a total of more than 100 million cases and more than 2.1 million deaths [19]. Despite the applied preventive measures to control the disease, the number still increases [19]. Thus, understanding the diffusion feature of this disease is of great importance for the national authorities to adopt and adapt the best preventive measures. In this way, since the first days of its emergence, multiple studies were carried out to understand the epidemic spreading and estimate the epidemiological parameters of this disease.

These studies used various categories of models including Agent-based models, ML and AI approaches, Bayesian models, Compartmental models, Network models, Statistical models, and Hybrid models. Also, researchers applied and developed different approaches that give the best performance according to the countries' data [20].

2.2. Symptoms

COVID-19 affects people in different ways. Most infected people develop a mild to moderate form of the disease and recover without hospitalization. In what follows we present the COVID-19 symptoms.

- **Most common symptoms:** represents the symptoms that appeared in all COVID-19 patients, which are: fever, cough, tiredness, and loss of taste or smell [18].
- **Less common symptoms:** represents the symptoms that appeared in some COVID-19 patients, which are: inflammation of the throat, headache, aches, pains, diarrhea, rash or discoloration of the fingers or toes, and eye redness or irritation [18].
- **Serious symptoms:** represents the dangerous symptoms that appeared in some COVID-19 patients and may lead them to death, which are: difficulty breathing or shortness of breath, loss of speech, difficulty moving or confusion, chest pain [18].

After screening 3209 studies, a total of 63 studies were eligible, with a total COVID-19 population of 257 348. The most commonly reported symptoms were fatigue, dyspnea, sleep disorder, and difficulty concentrating (32%, 25%, 24%, and 22%, respectively, at 3- to <6-month follow-up); effort intolerance, fatigue, sleep disorder, and dyspnea (45%, 36%, 29%, and 25%, respectively, at 6- to <9-month follow-up); fatigue (37%) and dyspnea (21%) at 9 to <12 months; and fatigue, dyspnea, sleep disorder, and myalgia (41%, 31%, 30%, and 22%, respectively, at >12-month follow-up).

There was substantial between-study heterogeneity for all reported symptom prevalences. Meta-regressions identified statistically significant effect modifiers: world region, male sex, diabetes mellitus, disease severity, and overall study quality score. Five of six studies including a comparator group consisting of COVID-19–negative cases observed significant adjusted associations between COVID-19 and several long-term symptoms [38].

2.3. COVID-19 Variants

Multiple severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) variants are now circulating globally.

Those with mutations in functional domains such as the receptor binding domain of the spike protein are of particular concern. In December 2020, three new variants of concern (VOC) with a common mutation at position 501 in the spike protein were reported: VOC-202012/01 (B.1.1.7, 501Y.V1, 20I) was first identified in the United Kingdom, 501Y.V2 (B.1.351, 20H) was first described by South African researchers, and P.1 (501Y.V3, 20J) was first identified in Japan and described by Brazilian researchers.

The descriptions are also inaccurate. It is not known whether patient zero of each variant was a resident of or visitor to that country, and all variants have been identified well beyond the first countries in which they were identified. Variants that are more transmissible quickly become the dominant circulating variant in many countries, just like the D614G variant that rapidly became the dominant global variant early in the COVID-19 pandemic.
Admittedly, mutation-based or lineage names are difficult to say and write. The World Health Organization is expected to announce a standard nomenclature soon. Until then, scientific and media reports should not refer to variants by country names [36].

2.4. COVID-19 in Algeria

Algerian state television reported that Algeria announced the first confirmed case of the COVID-19 on Wednesday, February 25, 2020, and it is for an Italian man who arrived in the country on Tuesday, February 17, 2020 [21]. The true starting point of the epidemic is reported on March 1st of two national citizens who came from France in the department of Blida which became the epicenter of the epidemic [22]. Since May 1st, all the 48 departments of Algeria were affected with a number varying from 2 to 865 of positive cases [23].
Regarding age and gender of the positive patients, data shows that the most affected categories are those aged between 25 and 49 (38.5%) and older person of more than 60 years (34.8%) and men (56.5%) seem to be more affected than women (43.5%) [23].

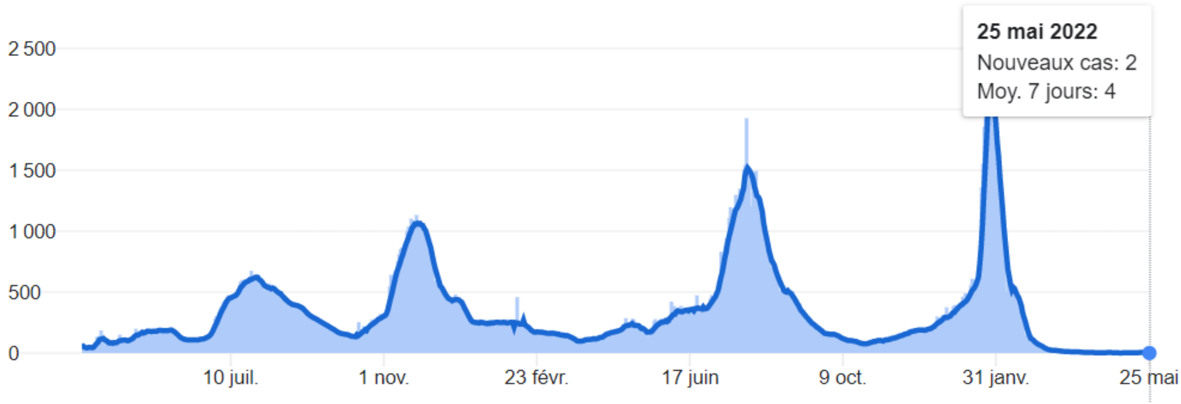


Figure 2.1: Statistics of new cases of coronavirus per day in Algeria

According to HU CSSE COVID-19 Data and Our World in Data, The total number of cases with COVID-19 in Algeria is 266K cases, while the mortality total number is 6 875 persons.

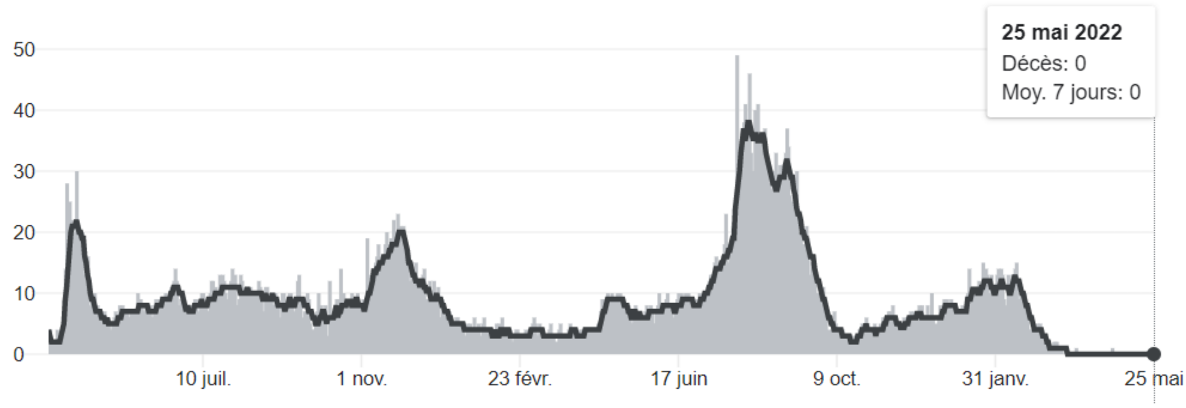


Figure 2.2: Statistics of deaths with coronavirus per day in Algeria

COVID-19 is going through waves of different intensities. Today in Algeria, we have already gone through four waves. In every wave that comes, the number of cases is increasing constantly and rapidly until it reaches its climax, then the number of cases will decrease again until another wave comes.

2.5. Medical Procedures

In what follows we present the most important COVID-19 medical procedures depending on the risk level of the patient.

- **Patients with low risks:** Level 1 PPE should be used as a minimum for routine patient care. Level 1 PPE includes a surgical mask, gown, gloves and eye protection. In addition, it is recommended that patients wear surgical masks and physical distancing should be maintained whenever possible [24].
- **Patients with intermediate risk**: Level 2 PPE is preferable in symptomatic patients even if they test negative. Standard cleaning protocols should be strictly followed, appropriate cleansing of the room, taking shower every day, exercising and eating healthy to boost immunity [25].
- **Patients with high risk:** a higher level of protection is recommended, like Level 3 PPE. Contamination of mucous membranes is probably the most important mode of infection transmission. Hence, respirators and goggles are essential as they provide a tight seal minimizing the risk of direct aerosol transmission and can prevent accidental self-contamination caused by touching mucosal surfaces. Full face or hood Powered Air-Purifying Respirators (PAPRs) are designed to provide even higher protection against hazardous

particles and to reduce the risk of potential face seal leakage, especially in those who cannot be successfully fit-tested with respirators [36]; in addition to the medication protocol that must be strictly followed [24].

2.6. Vaccination

Equitable access to safe and effective vaccines is essential to end the COVID-19 pandemic; it is therefore extremely encouraging to see so many vaccines in the testing and development phase. WHO works tirelessly with its partners to develop, manufacture and deploy safe and effective vaccines [27].

However, it is not the vaccines that will stop the pandemic, but the vaccination. We must ensure fair and equitable access to vaccines, ensuring that every country receives them and can deploy them to protect its people, starting with the most vulnerable [27].

According to HU CSSE COVID-19 Data and Our World in Data, The total number of vaccinated people in Algeria today is 5, 55 M (12, 7 %).

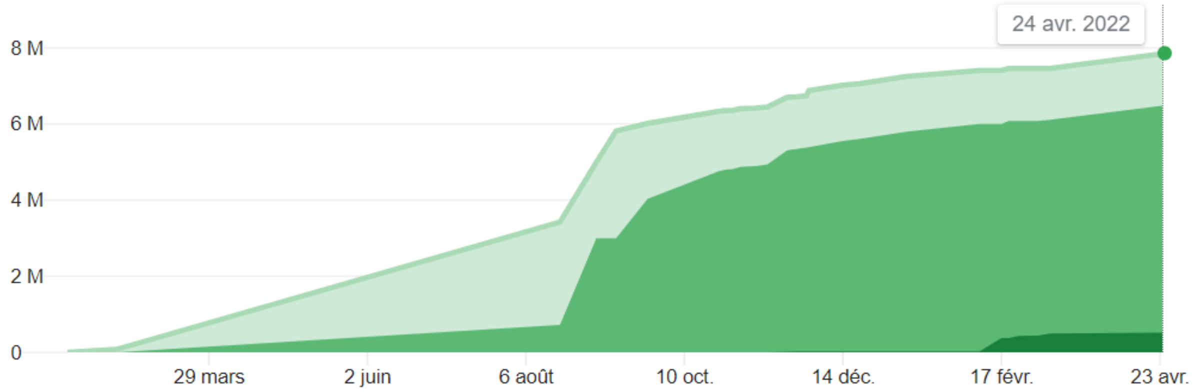


Figure 2.3: Statistics of vaccinations against corona virus in Algeria

2.7. Personal Experience

During the third wave of COVID-19 that occurred specifically after Eid al-Adha 2021, I got infected with Coronavirus. It all started on the first days of Eid, I was feeling very tired with a slight rise in my temperature. I thought it was just plain tired, then it started getting worse where I got a splitting headache with so much pain in my joints and muscles that I could not even walk. It all happened overnight.

The next day I went straight to the doctor in a very bad state, my temperature was too high; every muscle in my body was hurting, and I was feeling very cold and had a slight cough. The doctor immediately assured me that it was COVID-19 and that I have to abide by the medical protocol he gave me.

Since COVID-19 has no cure, the doctor gave me D, C, and Zinc vitamins to strengthen my immunity, in addition to some medications to reduce headache and muscle pain. He also urged me to commit the necessary medical procedures and follow the standard cleaning protocols and commit the quarantine.

I followed the doctor's instructions strictly. I stayed in the same state with the same symptoms for a week. Then I gradually started to improve while the pain seemed to lack, but the fatigue lasted over a month to disappear. It was a very difficult experience, and thanks to God I recovered because unfortunately a lot of people died during this wave.

3. State of the Art

In this part, we'll discuss the covid-19's research themes, products and systems that are similar to ours, and talk about trends in the field.

3.1. Mobile applications

- ***Tabaud*** application, is a way to notify those who are in contact with people infected with COVID-19, so individuals can download and use "Tabaud" application to achieve the health and safety purposes of developing the application.

Once the application is downloaded into the smart phone, it can detect, via Bluetooth technology, other nearby smart phones that are also using the same application.

If the user of the application reports that he is infected with the COVID-19, and is confirmed by linking the application with the Ministry of Health, then users of all smart phones close to him during the 14-day period prior to the infection will receive a notification to take the necessary precautions for that. The application can know how close it is to other smart phones that are also using the same application. This allows it to get an idea of the closest smart phones, and thus notify their most vulnerable users through the application [31].

Discussion: The idea is helpful to reduce the spread of infection in the country. But the application seems incomplete; the infection reports must be confirmed by linking the application with the Ministry of Health. For that, the system should contain a web application used by the Ministry of Health and the hospitals, in which the hospitals will confirm the infection of the citizen and contact the Ministry of Health.

- ***COVID safe*** application. Including COVID-Safe behaviors in people's daily routine will require a coordinated program to shape the financial, physical and social infrastructure.

Education, organization, communication, social marketing, and provision of resources will be required to ensure that all segments of society have the capacity, opportunity, and motivation to enact behaviors in the long term. The behaviors that are prioritized and how to enable them should be part of a community-wide conversation, informed by epidemiological evidence regarding which behaviors are likely to have the greatest impact in various situations. These long-term changes depend critically on changes in the financial, physical and social infrastructure at the societal level, in all the places where people mingle. Only if this happens will people be in a position to act in ways that keep themselves, their families, and their communities safe. All this is available in COVID safe application [32].

Discussion: The idea of the application has a major role to raise awareness for the citizens, by disseminating the necessary instructions and actions that they must apply before, during, and after the waves of the pandemic. The application must be updated whenever a new COVID19 variant came because each variant has its instructions and actions to deal with.

- ***COVID watch.*** Was an open source nonprofit founded in February 2020 with the mission of building mobile technology to fight the COVID-19 pandemic while defending digital privacy. The Covid Watch founders became concerned about emerging, mass surveillance-enabling digital contact tracing technology and started the project to help preserve civil liberties during the pandemic using CEN Protocol.

A description of the CEN Protocol: the first anonymous, decentralized Bluetooth exposure notification protocol to be published online in Covid Watch's whitepaper on 20 March 2020 and open sourced on the Covid Watch [34].

Discussion: using the IT field and making a community to develop the mobile applications, is a good way for fighting the pandemic because mobile applications are frequently used by the different segments of society.

- ***NHS COVID-19.*** Mobile phone application records proximity events between application users, and when a user tests positive for COVID-19, their recent contacts can be notified instantly. Here we investigate the impact of the National Health Service (NHS) COVID-19 app for England and Wales, from its launch on 24 September 2020 to the end of December 2020. It was used regularly by approximately 16.5 million users (28% of the total population), and sent approximately 1.7 million exposure notifications: 4.2 per index case consenting to contact tracing [35].

Discussion: The same as Tabaud, NHS COVID-19 is used to reduce the spread of infection in the country; the application is already used by millions of citizens, helping in registering infection cases and warning citizens to not be close to the patients.

- In [33] ***COVID symptom study.*** Research mobile app developed in the United Kingdom that runs on Android and IOS. It is a collaboration between King's College London, Guy's and St Thomas' Hospitals and Zoe Global Limited, with funding granted by the UK government. The purpose of the app is to track symptoms and other salient data in a large number of people to enable epidemiological results to be calculated.

Discussion: The application is very important for pandemic statistics to track the evolution of the virus. This helps the medical sector to know in a global way the effect of the virus on the citizens.

3.2. Researches

- [29] Has identified a mobile application that may be potentially useful to mitigate the COVID-19 pandemic. In this proposed work, a model is suggested to detect the type of the disease for which (covid-19 or influenza) with high accuracy and detection rate. Also, it was able to detect the class of the pandemic.

It was shown from the experiments that, the sample of data that was incorrectly classified as covid-19 in the first level may be recognized as unknown classes in the second step of the model. In addition, this work is expanded to detect pandemic subtypes such as classified covid-19 to covid-19(mild) and covid-19(severe) sup classes, and classified influenza class to flu and asymptomatic sup classes. Furthermore, smart watches and smart bands are used as symptom monitoring because they became more popular and incorporated into people's everyday lives and potentially assisting in the critical monitoring of vulnerable populations' health statuses. In the future, automated and rapid detection of suspected infections will become more effective using a convolution neural network (CNN). Also, the diagnosis accuracy can be increased by improving the symptom management algorithm and adapting it to the pandemic. Mobile doctors would be the way to go in situations like this where self-isolation is needed, however, as technology advances, "digital humans" could be a viable option for reducing the burden on healthcare workers in future pandemics.

Discussion: This research used AI technology to detect whether the patient has COVID-19 or influenza, in addition, to specifying the pandemic type and class, which guides the patient through the correct diagnosis and increases the likelihood of saving their lives. The research needs a big dataset of information about COVID-19 type, classes, and other information about the diseases that make the same symptoms as COVID-19 to reach the optimal results.

- In [30], this post would go into a Dual Diagnostic Strategy that has been suggested in detail (HDS). The primary objective of HDS is to classify COVID-19 incidents easily and reliably. Early diagnosis of COVID-19 cases allows for prompt care and separation of patients, which slows the transmission of the pandemic. HDS is given a training series consisting of laboratory findings from COVID-19 and non- COVID-19 individuals. Since the model has learned to recognize trends, new cases can be added to it (including laboratory findings). HDS determines whether or not the input case has COVID-19 infection.

Discussion: this research uses AI technology to determine whether or not the citizens have COVID-19 infection, and classify the cases. This helps in early diagnosis and avoids getting into dangerous situations.

After we summarized the existing applications and research, we can say that telemonitoring applications are too few. Most of the research themes were made for biological and statistics research. The other few diagnostic applications only determine whether the citizen has COVID-19 or not. We aim with our project to achieve a COVID-19 system that regroups all the needs in one system that is capable of diagnosing and telemonitoring citizens, determining their risk level, giving them the right instructions, and contacting doctors, caretakers, and hospitals when needed to increase the likelihood of saving their lives.

4. TIS COVID-19

4.1. Description

TIS COVID-19 is a telemonitoring intelligent system, based on AI technologies like IoT, ML, and NLP. It is consisting of a mobile application, a web application in addition to a wearable.

Our system aims to relieve pressure on hospitals, and telemonitoring the state of citizens from home to detect whether or not they are infected with COVID-19 and determine their gravity level by diagnose their state to give them the right instructions they must follow.

The system is simple and easy to use. The mobile application permanently tracks the citizen's health state using the collected data sent from the wearable, which represents the vital signs of the citizen: body temperature, pulse rate, respiration rate, blood pressure, O_2 saturation, and blood sugar using IoT technology. The citizen can also use the vocal or text mode to express his physical feelings of his current state: fatigue, stomach ache, diarrhea, pain, and vertigo. The system will analyze the vocal data using the NLP technology.

Based on all of this information and taking into account the citizen's age, gender, and chronic diseases if any, the intelligent algorithm will analyze it and display the result on the mobile screen with the appropriate instructions.

The application has to make a decision depending on the gravity of the state. If there is some doubt about the state, then the system will give the citizen a set of instructions, while contacting his doctor who will give the final result and instructions. In the second case where the state represents a dangerous situation, the system will contact the citizen's caretakers that have been added before by the citizen into his proper account, and send them an alert message including the citizen's position. The system can also call an ambulance by sending an ambulance request to the nearest hospital.

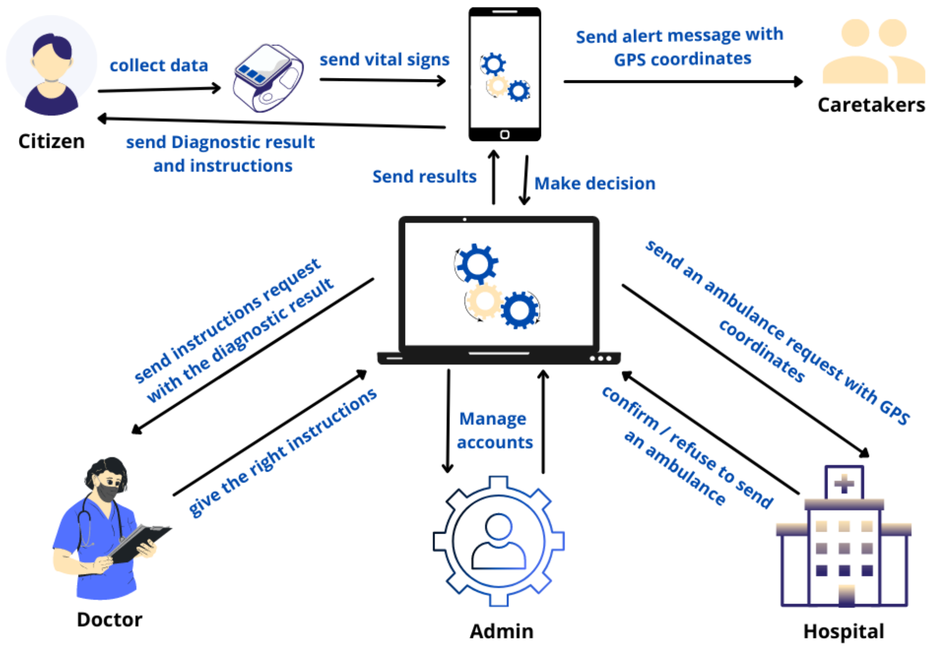


Figure 2.4: System architecture

4.2. Comparison between TIS COVID-19 and related works

The main difference between the applications mentioned before and TIS COVID-19 is that:

- TIS COVID-19 represents one integrated system that has a lot of functionalities: telemonitoring and diagnosing the citizen's state, guiding him through the right instructions, and make the right decision depending on the diagnostic result by contacting his caretakers, doctors and call for hospital ambulance in the critical cases. While each one of the mentioned applications has only one main functionality.
- The system represents an improvement of the existing systems, and at the same time fits with the state of technology in our country. For the citizens, they need to have a smartphone and buy the wearable which doesn't cost much. It will be easy to connect the

wearable with the mobile application using Bluetooth or Wi-Fi as well as the application is simple and can be used by anyone at any place.

- The system is very practical, for each different user, there's different appropriate access to the system. For the citizens, they use the mobile application which will be very easy to send data and consult the result. While doctors, hospitals, and admins will use the web application.

5. Conclusion

Notwithstanding the increasing significance of digital medicine, we have noticed that even during the pandemic, online medicine cannot fully substitute for traditional forms of offline medicine. As we note that in our system we have not dispensed with the role of the doctor which will be present when the system can't decide whether the citizen's state is stable or dangerous.

In the next chapter, we are going to see the system description, analyze and conception design.

Chapter 3

System Description

1. Introduction

In this chapter, we will move to the design part. For modeling our application we will use the Unified Modeling Language (UML).

First, we talk about the system actors, functional and non-functional requirements of our application. Then, we present use case diagram. After that, we give a detailed conception of our application through different appropriate diagrams available in the UML formalism, namely the sequence diagram, the activity diagram, and the class diagram. Finally, we add the detailed Data Logic Model for the database of our application.

2. Analyze

To describe the behavior of our application, we need to specify the requirements, both functional and non-functional, and hence clarify its objective. Indeed, this phase consists in describing the context of the application and determining the most relevant functionalities and features that must be satisfied. For doing that, we first need to identify the actors interacting with our system, and then we present all the functional needs for each one as well as the non-functional needs for the system.

2.1. Actors

An actor is an external entity that interacts with the system. Our system could be realized by the following actors:

- **TIS algorithm:** intelligent algorithm that analyzes the citizens' data and makes decisions depending on the diagnostic result.
- **Citizen:** user that uses the mobile application as a telemonitoring system.
- **Admin:** responsible of the system, uses the web application to manage the user accounts.
- **Hospital:** hospital managers that use the web application to receive and respond to the system ambulance requests.
- **Doctor:** doctors that use the web application to receive and respond to the system instructions requests.

2.2. Functional requirements

The functional requirements are the system functionalities. They are the requirements that specify the input/output behavior of the system. Each actor has a set of specific functionalities. The system must allow the actors to mainly do the following:

- **Create new account:**
  - ✓ Citizens: can create new account from the mobile application.
  - ✓ Doctors and hospitals: can create new accounts from the web application. The account won't be used unless it has been accepted by the admin.
  - ✓ Admin: his account is already created by default in the system database.
- **Authenticate (Login/ Logout):** the system must allow all the users to open and close the session whenever they want.
- **Manage account:** each user can consult and modify his account information.
- **Manage the user accounts:** the admin can consult or search for a user account.
- **Manage the new doctor/ hospital account requests:** the admin can manage the new hospitals/ doctors accounts requests by accepting or refusing the new account request.
- **Send diagnostic data using vocal or text mode:** the citizen send his vital signs data and vocal/ text data to see his diagnostic result.
- **Consult diagnostic result and instructions:** the citizen can consult his current state's diagnostic result and instructions after sending his diagnostic data.
- **Manage doctors:** the citizen can manage his doctors list by:

- ✓ Add a new doctor
- ✓ Rate a doctor
- ✓ Delete an existing doctor
- ✓ Consult doctors list
- ✓ Search for a doctor by speciality

- **Manage caretakers:** a caretaker represents another citizen that can reach to the citizen in the critical state to help him.

The citizen can manage his caretakers list by:

- ✓ Add a new caretaker
- ✓ Delete an existing caretaker
- ✓ Modify favorite of caretaker
- ✓ Consult the caretakers list
- ✓ Search for a caretaker by name
- ✓ Consult the caretakers alerts list
- ✓ Call citizen
- ✓ Consult citizen’s position
- ✓ Delete a caretaker alert

- **Analyze diagnostic data and make decisions:** the TIS algorithm analyzes the citizen’s diagnostic data and displays the diagnostic result, instructions and make a decision:
  - ✓ Send an instructions request to the specialist doctor.
  - ✓ Send an ambulance request to the nearest hospital and an alert message to the favorite caretakers.

Diagnostic algorithm

The main module, representing the inference engine of the system, is the diagnostic algorithm.

This algorithm is a ML algorithm applied on the input diagnostic data to generate the diagnostic result. For that, we've chosen:

- The supervised ML method: the system is a medical system that should have precise results, for that, the dataset should be composed of the inputs and outputs and we can’t use a data that has no outputs.
- The multi-classification type: the diagnostic result can be one of the three values: stable, warning, or dangerous. That's why we've chosen the classification type over the

regression, and because there are three types of results, we should use the multi-classification over the binary classification, and apply the All vs. All (AVA) multi-classification method. The method used is logistique regression.

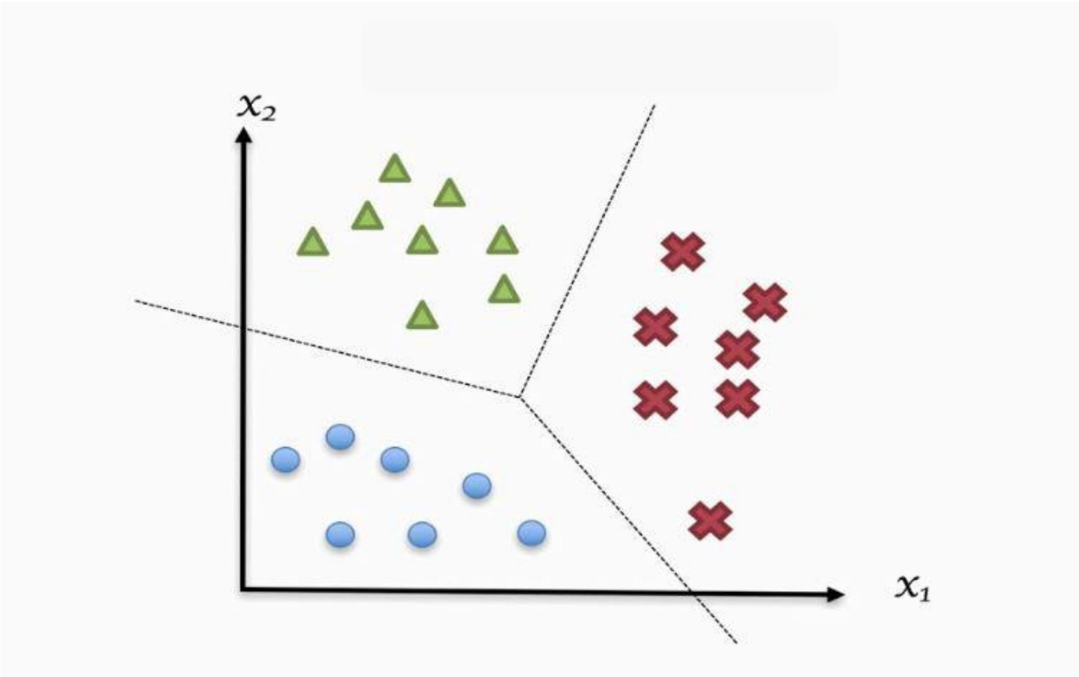


Figure 3.1: AVA multi-classification

Dataset

The dataset represents the training data for the algorithm. The data is stored in a file that represents a matrix of (50*10) composed of 9 features which are: Temperature, pulse rate, respiration rate, blood pressure, oxygen saturation, blood sugar, diseases, medicines, and physical feelings. If the citizen has any of the diseases, medicines or physical feelings, the value will be 1, otherwise it will be 0. The last column represents the result which can be: 1 for warning, 2 for dangerous and 3 for stable.

Unfortunately, we couldn't find a prepared dataset composed of all these features. For that, we've combined the data together based on the precise values of each feature for COVID-19, and sorted it into three categories (1, 2, 3).

Algorithm equations

In what follows we take: X the inputs matrix, Y the outputs matrix, and θ_j the X_j parameter. The algorithm stands for the three equations:

- The Sigmoid function, which represents the appropriate function used for the classification.

$$\frac{1}{1+e^{-\theta T x}}$$

- The cost function (the error value) based on the sigmoid function:

$$J(\theta) = -\frac{1}{m}\left[\sum_{i=1}^{m} y^{(i)} \log h_\theta(x^{(i)}) + (1-y^{(i)}) \, log(1-h_\theta(x^{(i)}))\right]$$

- The θ equation, each feature x_j must have a corresponding θ_j.We use the θ values to find the result of the new diagnostic data.

$$\theta_j := \theta_j - \alpha \sum_{i=1}^{m} (h_\theta(x^{(i)}) - y^{(i)} x_j{}^{(i)})$$

- The goal is to find the θ value by minimizing the cost function using the gradient descent method $min_\theta \, J(\theta)$.

$$\theta_j \leftarrow \theta_j - \alpha \frac{1}{m} \sum_{i=1}^{m} (h_\theta(x^{(i)}) - y^{(i)}) \, x_j{}^{(i)}$$

The pseudo code of the diagnostic algorithm represents in the Figure 3.2:

```
function one_vs_all(X, Y, labels_num, learningRate):
    theta = zeros(rowsNum = labels_num, colsNum = Xcols+1)
    X = insert(row = 0, values= ones(Xrows))
    loop (i=0, i=labels_num, i++):
        theta(i,:) = minimize(function = cost, method = gradient)


function diagnostic(Xnew, theta)
    theta = one_vs_all(X, Y, 3, 1)
    h = sigmoid(Xnew*theta.T)
    result = argmax(h)
```

Figure 3.2: Diagnostic pseudo algorithm

Make decision algorithm

In the stable case, the algorithm will do nothing, in the other two cases:

- Warning case: Send instructions request to the best doctor depending on the factors: speciality, pep, available, and rate. The request will be send to the first available doctor who have any of the specialties pulmonology or infectious, with the max pep and rate.

- Dangerous case: Send ambulance request to the best hospital depending on the factors: hospital services, distance between citizen and hospital, pep, and available. The request will be send to the first available hospital with the nearest distance to the citizen, with the COVID-19 services and the max pep. The algorithm also sends an alert request to the favorite available caretakers.
- **Activate / deactivate availability mode:** doctors, citizens (as a caretakers), and hospitals can activate the availability mode to specify whether they are available and ready to receive requests from the system or not. This helps the TIS algorithm chooses the users to whom send requests.
- **Consult citizens list:** doctor can consult the list of citizens who chose him as a personal doctor.
- **Manage the instructions requests:** doctor can consult the list of instructions requests to give the right instructions to the citizen.
- **Manage the ambulance requests:** hospital can manage the requests list by:

✓ Consult the requests list.

✓ Accept to send an ambulance.

✓ Refuse to send an ambulance.

✓ Search for a request by citizen’s name.

2.3. Non-functional requirements

They are requirements that specify criteria that can be used to judge the operation of a system, rather than specific behaviors. In other words, they are the technical requirements that are not mentioned as functionalities of our system, and they are the following:

- **Performance:** loading time of a web page for the web applications or a mobile screen for the mobile application should not take more than 10 seconds in nominal condition.
- **Security:** The application should be highly secured, and the information should not be accessible to everyone. We note that our system has different types of users; each one must access to his appropriate area and could manage only his specific authorized actions, after authenticating.
- **Ergonomic:** the system must be manageable and easy to use. By designing an effective, efficient and satisfactory HMI interface that matches the characteristics of the target user.
- **Extensibility:** The system should be extensible, which means we can add other functionalities to the applications easily.

2.4. Use case diagram

- **Main functionalities**

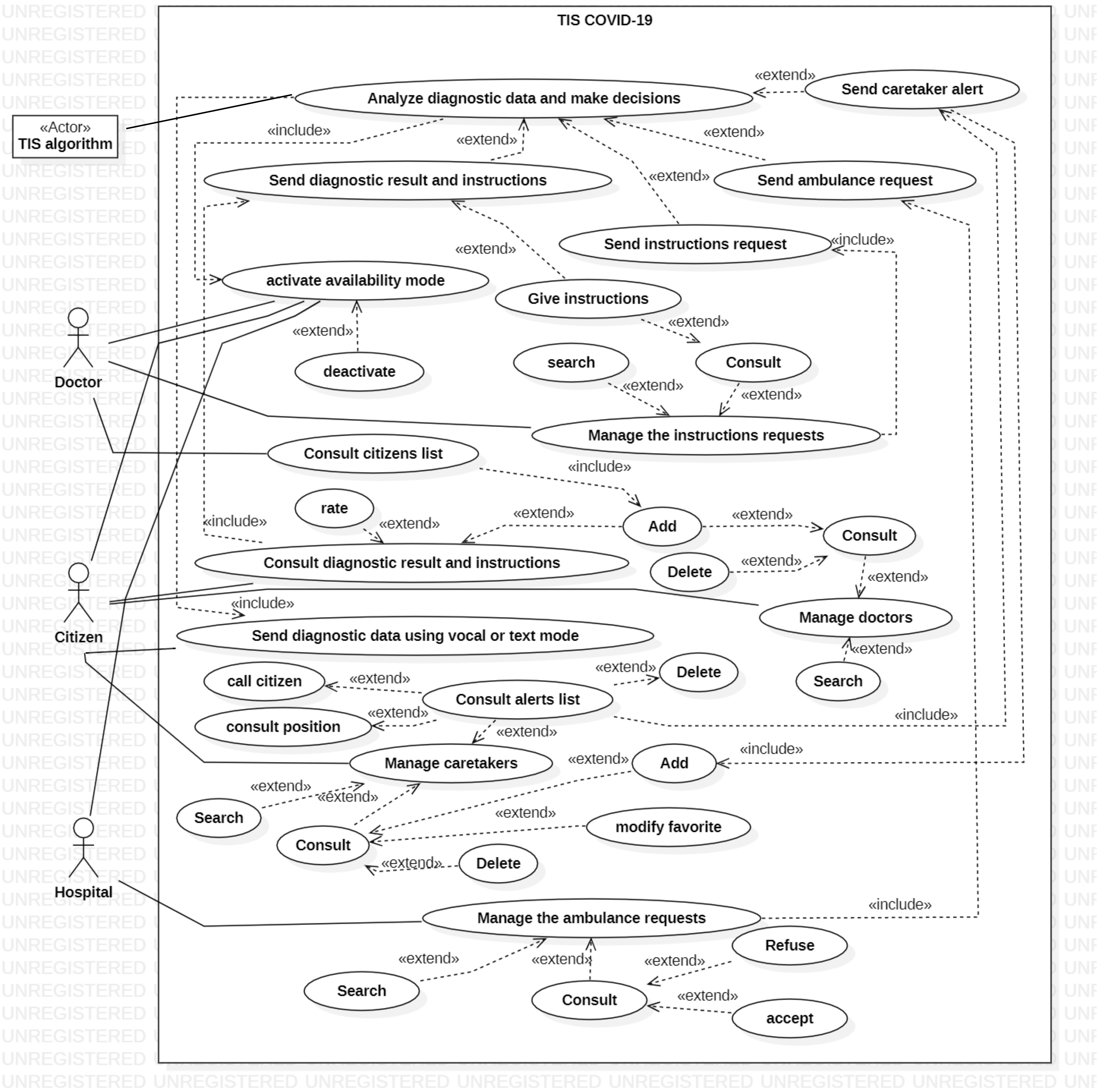


Figure 3.3: Use case diagram for main functionalities

- **Accounts functionalities**

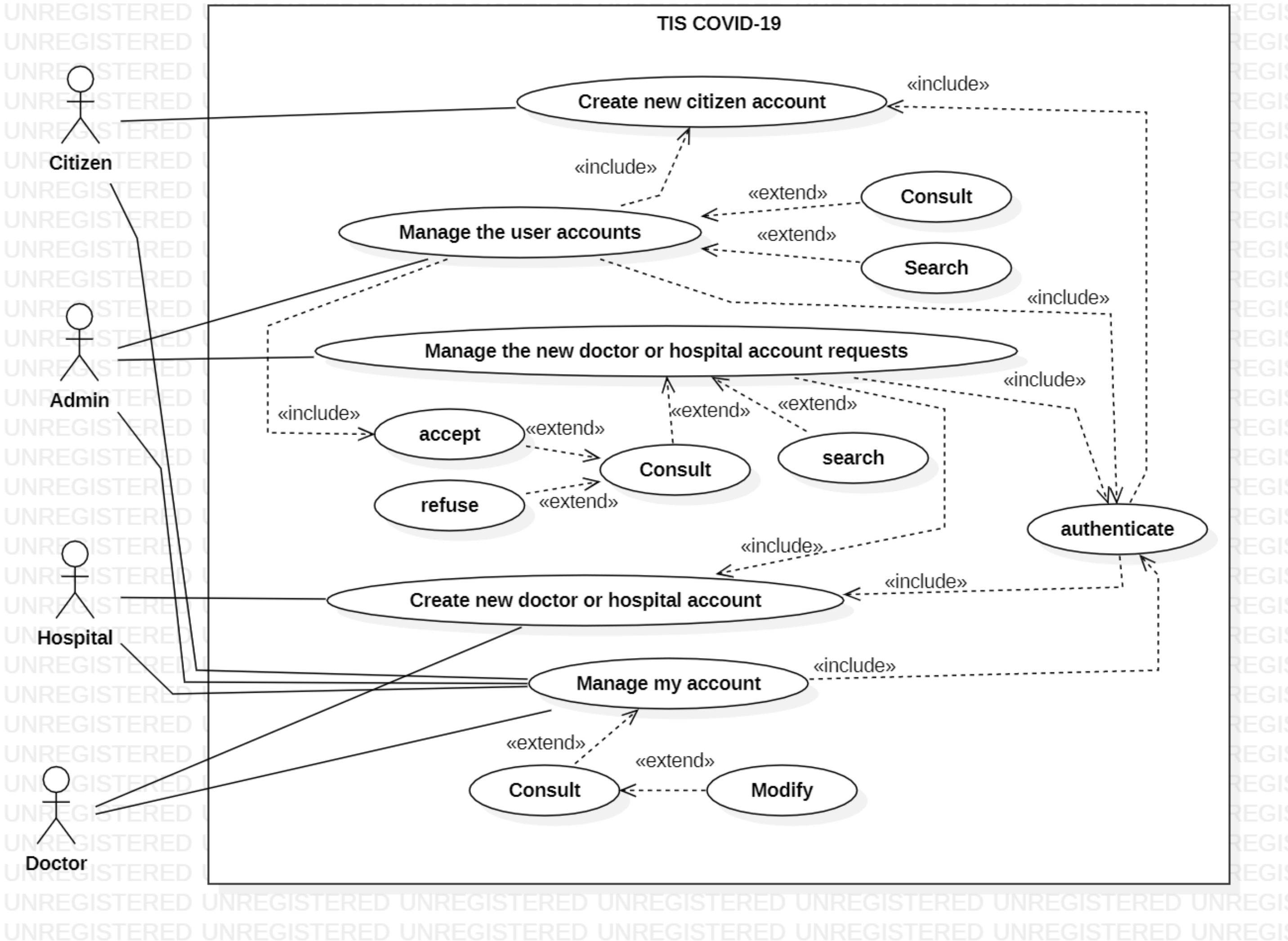


Figure 3.4: Use case diagram for accounts functionalities

3. Conceptual design

In this part, we will present the conceptual design of the system using activity diagram, class diagram, and data relational model.

3.1. Textual description and Sequence diagram

In what follows, we give a detailed description, by adding a text description and a sequence diagram for the most important use cases.

- **Manage account**

Summary description	
Title	Manage account.
Goal	Allowing the actor to manage his account.
Actor	Admin, citizen, doctor and hospital.
Precondition	The actor is already authenticated.
Postcondition	The actor manages his account successfully.
Detailed description	
Nominal scenario	1. The actor demands to manage his account. 2. The system displays the "Manage my account" page. 3. The actor consults his account information. 4. The actor modifies his account information. 4.1. The system displays a confirmation message.
Alternative scenario	4.2. The system denies the inserted information (wrong information or empty fields) and displays an error message. 5. Go back to the second step.

Table 3.1: Manage account textual description

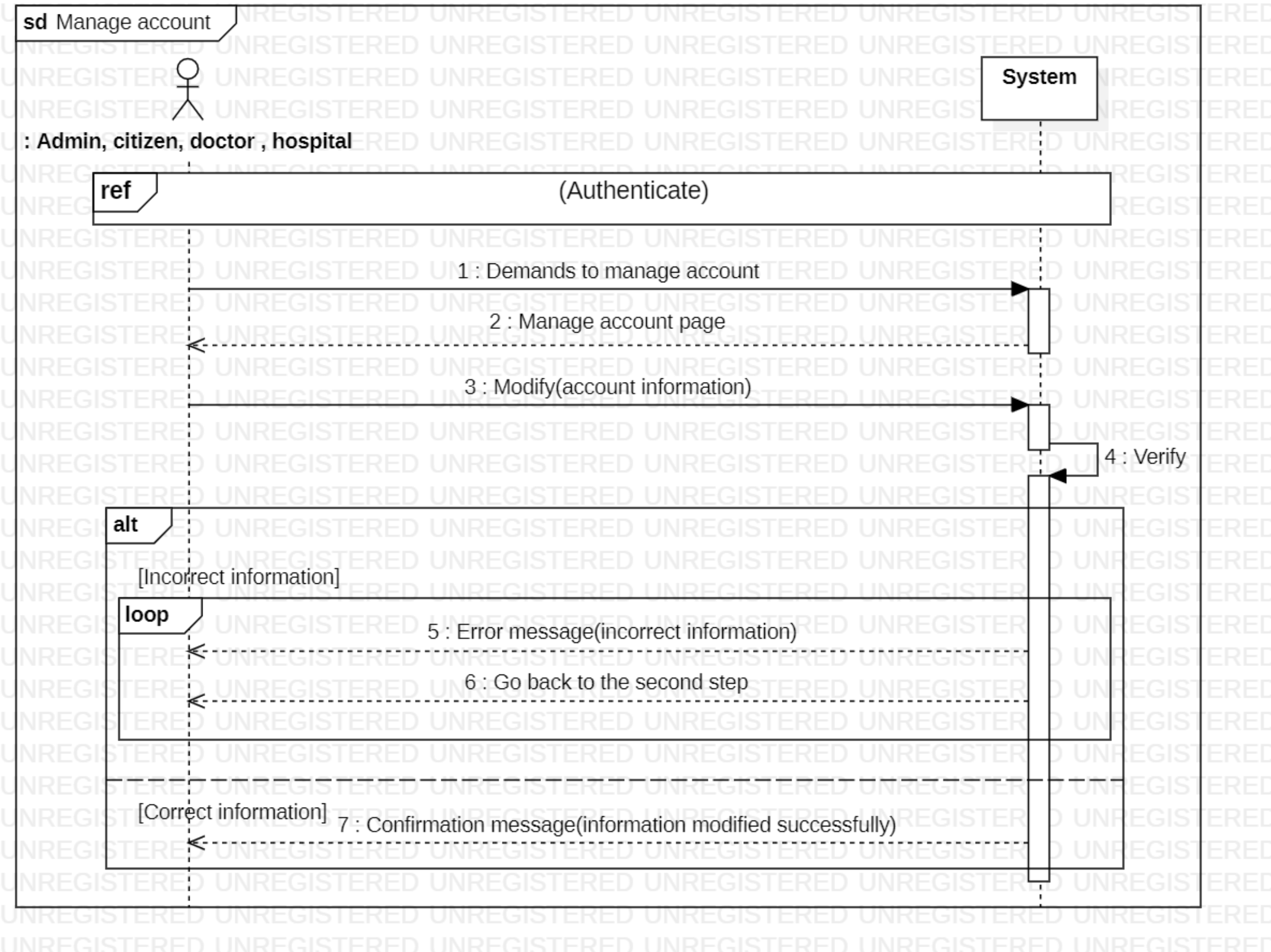


Figure 3.5: Manage account sequence diagram

- **Manage the user accounts**

Summary description	
Title	Manage the user accounts.
Goal	Allowing the admin to manage the user accounts.
Actor	Admin.
Precondition	The admin is already authenticated.
Postcondition	The admin manages the user accounts list successfully.
Detailed description	
Nominal scenario	1. The admin demands to manage the user accounts. 2. The system displays the “Manage the user accounts” page. 3. The admin chooses the manage operation. 3.1. The admin consults the user accounts list. 3.2. The admin searches for account. 3.2.1. The system displays the search result.
Alternative scenario	/

Table 3.2: Manage the user accounts textual description

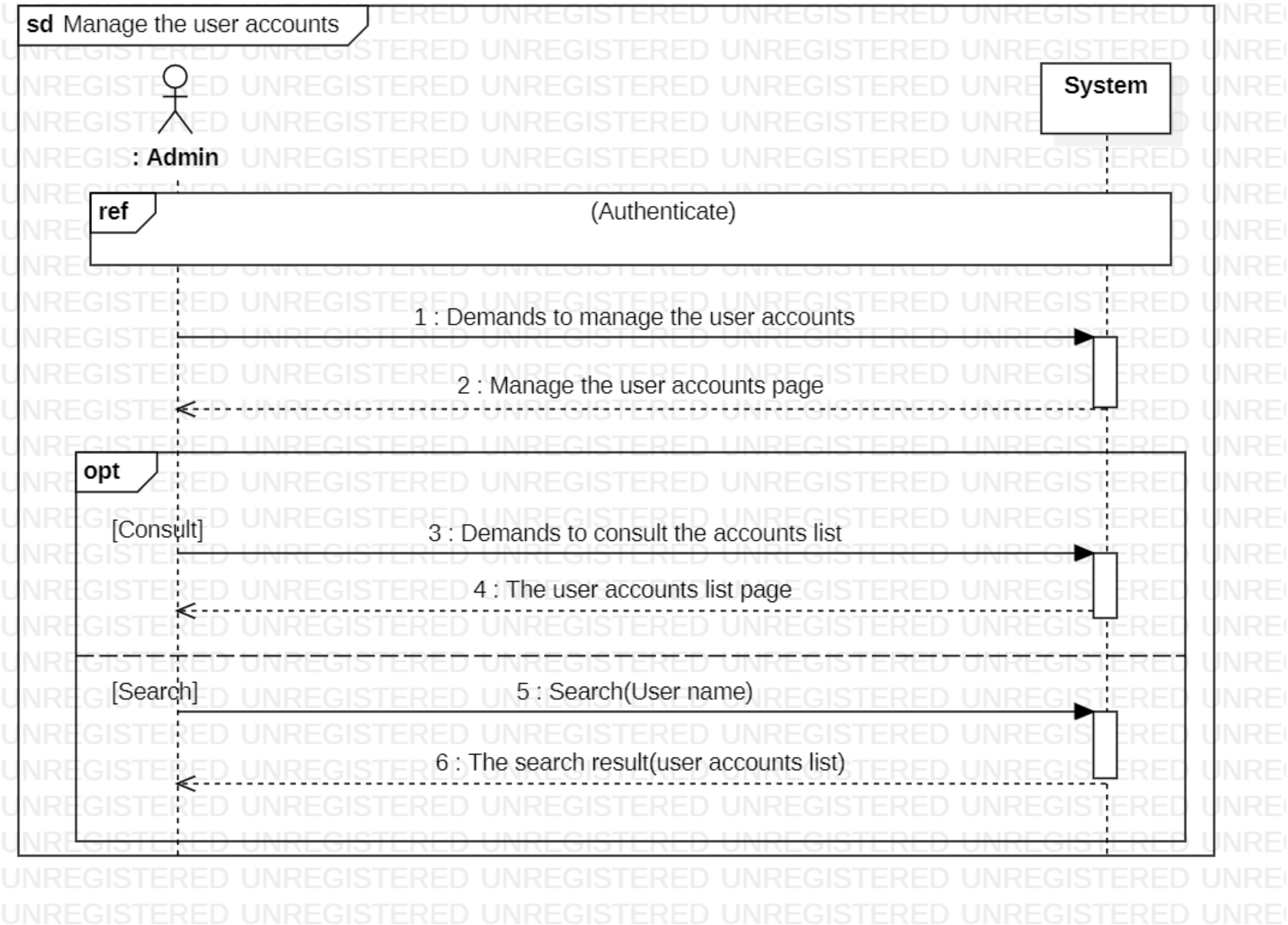


Figure 3.6: Manage the user accounts sequence diagram

- **Manage the new doctor or hospital account requests**

Summary description	
Title	Manage the new doctor or hospital account requests.
Goal	Allowing the admin to manage the new accounts requests list.
Actor	Admin.
Precondition	The admin is already authenticated.
Postcondition	The admin manages the new account requests successfully.
Detailed description	
Nominal scenario	1. The admin demands to manage the new doctor or hospital account requests. 2. The system displays the "Manage the new doctor or hospital account requests" page. 3. The admin chooses the manage operation. 3.1. Accept a request. 3.2. Refuse a request.
Alternative scenario	/

Table 3.3: Manage the new doctor or hospital account requests textual description

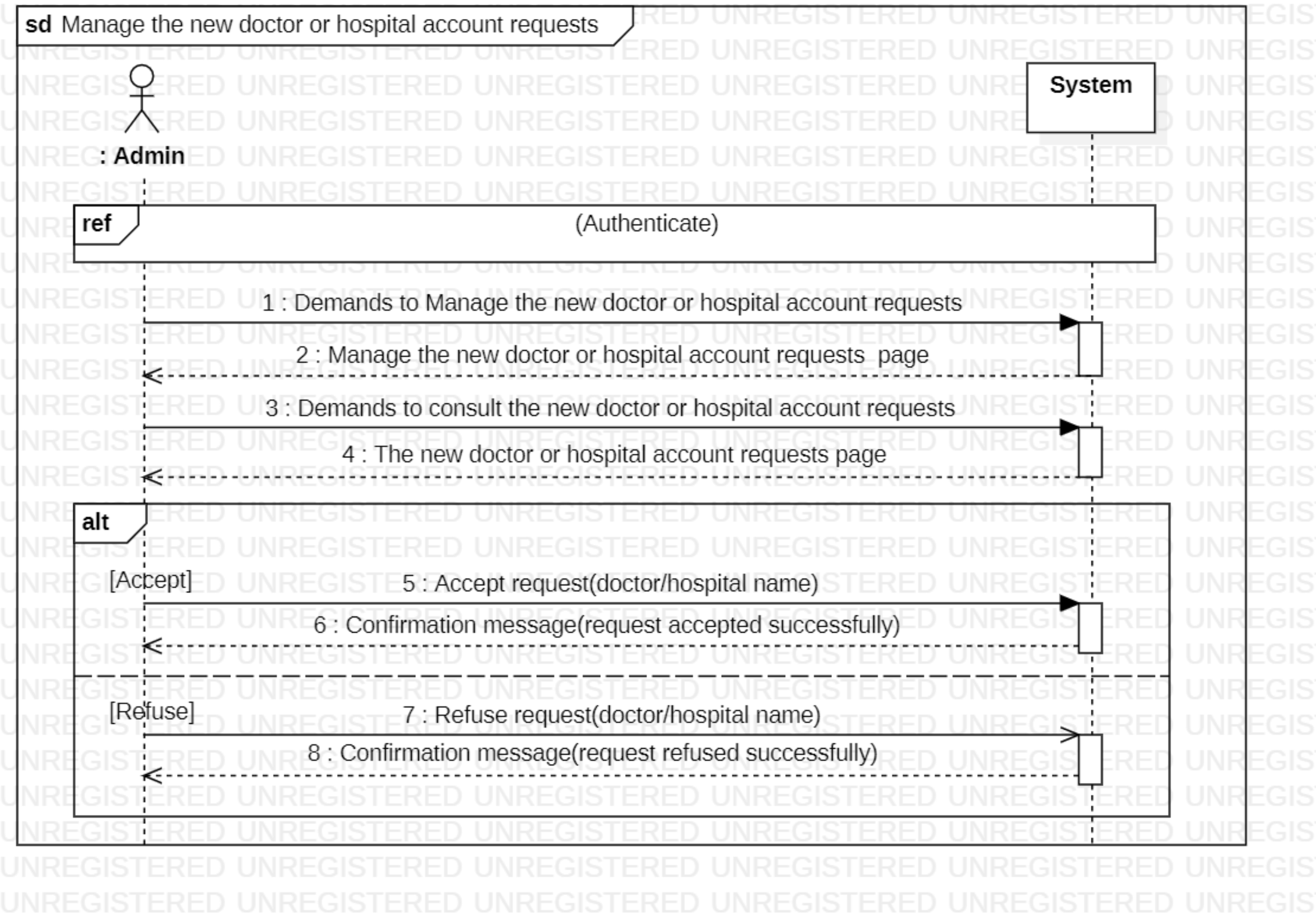


Figure 3.7: Manage the new doctor or hospital account requests sequence diagram

- **Consult diagnostic result and instructions**

Summary description	
Title	Consult diagnostic result and instructions.
Goal	Allowing the citizen to consult his diagnostic result.
Actor	Citizen.
Precondition	The citizen is already authenticated and sent his diagnostic data.
Postcondition	The consults his diagnostic successfully.
Detailed description	
Nominal scenario	1. The citizen demands to make a diagnostic. 2. The system displays the "Diagnostic" page. 3. The citizen inputs and sends the diagnostic data. 3.1. The system analyses data and displays the diagnostic result with the instructions. 3.1.1. The system displays the doctor's name who gives the instructions. 3.1.2. The citizen adds and rates the doctor to his doctors list.
Alternative scenario	3.2. The system denies the inserted information (wrong information or empty fields) and displays an error message. 4. Go back to the second step.

Table 3.4: Consult diagnostic result and instructions textual description

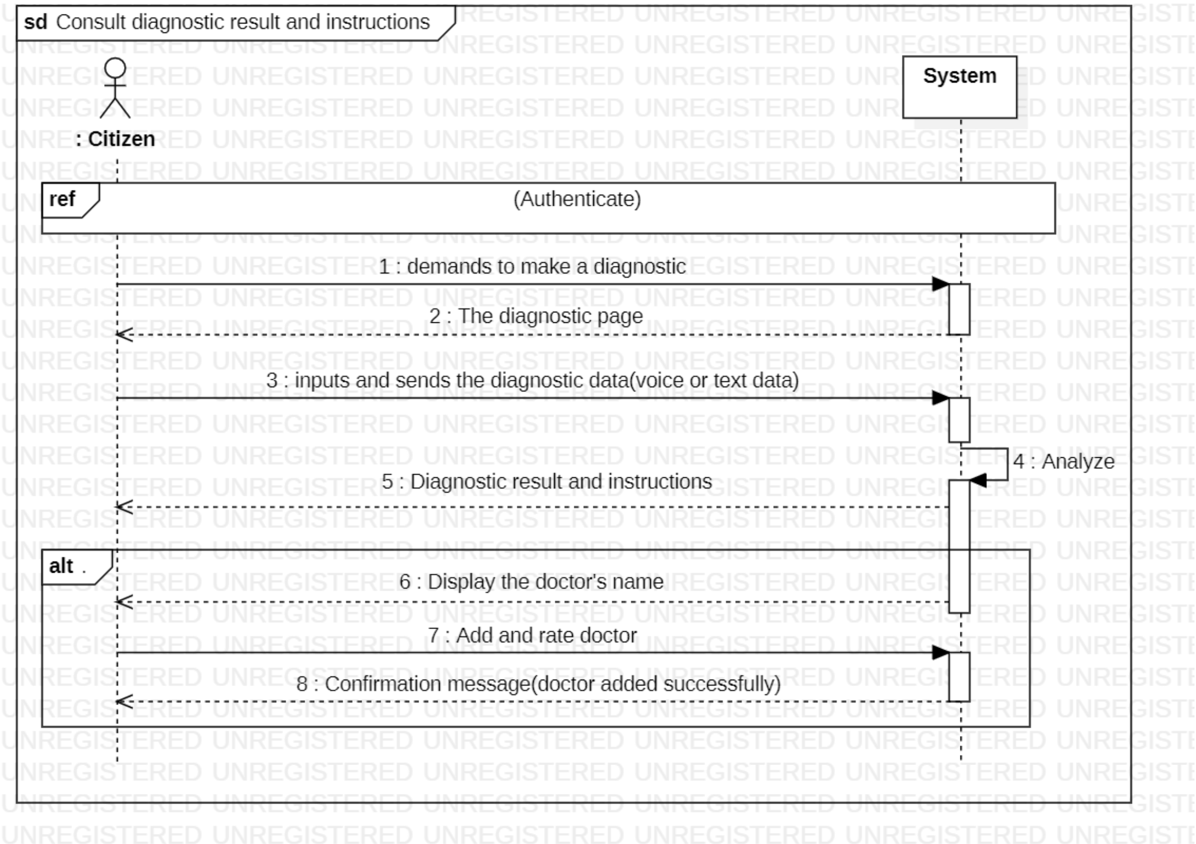


Figure 3.8: Consult diagnostic result and instructions sequence diagram

- **Manage doctors**

Summary description	
Title	Manage doctors.
Goal	Allowing the citizen to manage his doctors.
Actor	Citizen.
Precondition	The citizen is already authenticated.
Postcondition	The citizen manages his doctors successfully.
Detailed description	
Nominal scenario	1. The citizen demands to manage his doctors. 2. The system displays the “Manage doctors” page. 3. The citizen chooses the manage operation. 3.1. The citizen consults doctors list. 3.2. The citizen adds a new doctor to his list. 3.3. The citizen deletes an existing doctor from his list. 3.4. The citizen searches for a doctor. 3.4.1. The system displays the search result.

Table 3.5: Manage doctors textual description

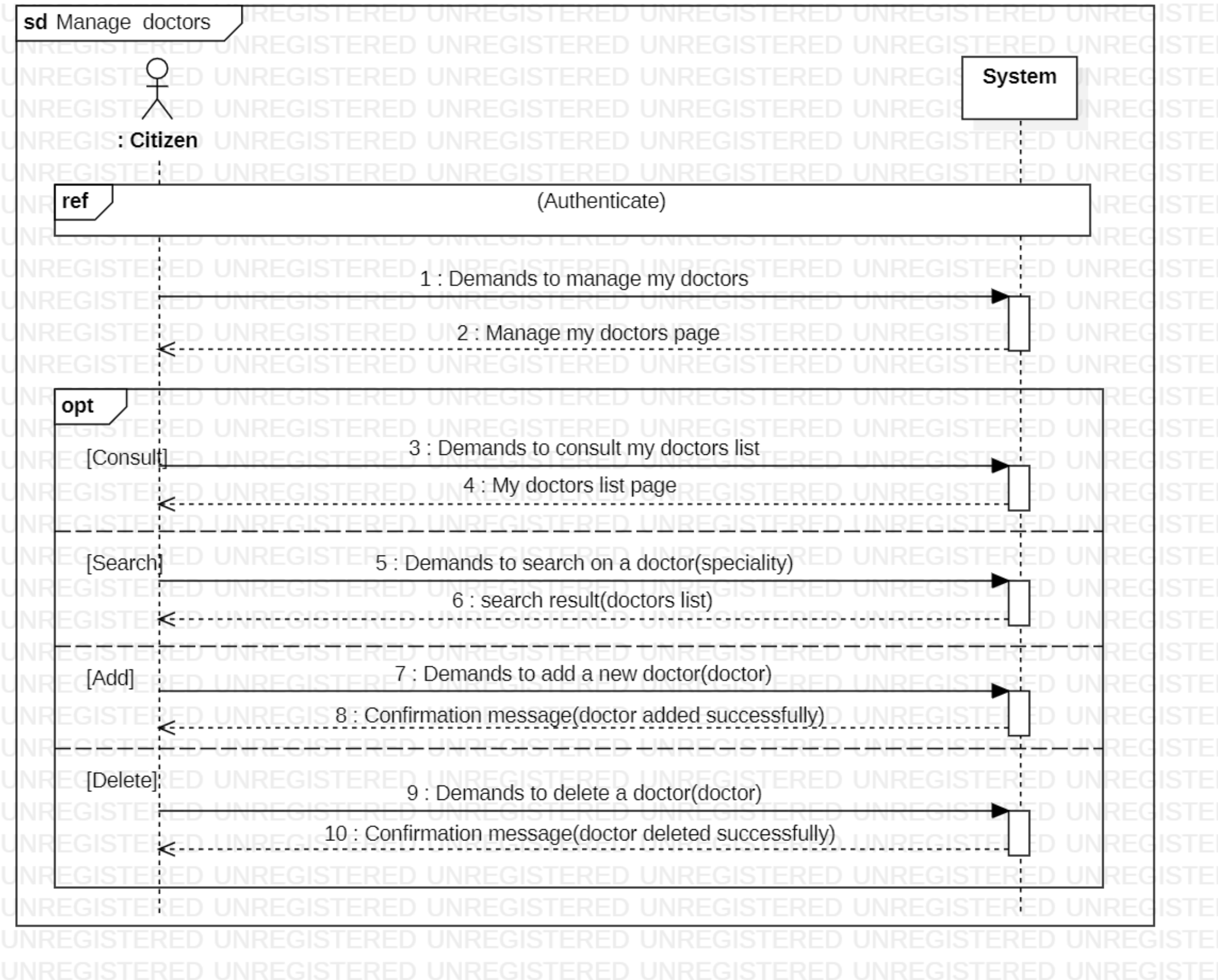


Figure 3.9: Manage doctors sequence diagram

- **Manage caretakers**

Summary description	
Title	Manage caretakers**.**
Goal	Allowing the user to manage his caretakers.
Actor	Citizen.
Precondition	The citizen is already authenticated.
Postcondition	The citizen manages his caretakers successfully.
Detailed description	
Nominal scenario	1. The citizen demands to manage his caretakers. 2. The system displays the “Manage my caretakers” page. 3. The citizen chooses the manage operation. 3.1. The citizen consults his caretakers list. 3.2. The citizen adds a new caretaker to the list. 3.3. The citizen deletes an existing caretaker from the list. 3.4. The citizen searches for a caretaker. 3.4.1. The system displays the search result. 3.5. The citizen modifies the favorite list of a caretaker. 3.5.1. The system displays a confirmation message.

Table 3.6: Manage caretakers textual description

- **Manage caretakers alerts**

Summary description	
Title	Manage caretakers alerts**.**
Goal	Allowing the user to manage his caretakers alerts.
Actor	Citizen.
Precondition	The citizen is already authenticated.
Postcondition	The citizen manages his caretakers alerts successfully.
Detailed description	
Nominal scenario	1. The citizen demands to manage his caretakers alerts. 2. The system displays the “Manage my caretakers alerts” page. 3. The citizen chooses the manage operation. 3.1. The citizen consults his caretaker alerts list. 3.2. The citizen deleted a caretaker alert. 3.3. The citizen searches for a caretaker alert. 3.3.1. The system displays the search result. 3.4. The citizen makes a phone call. 3.5. The citizen consults position.

Table 3.7: Manage caretakers alerts textual description

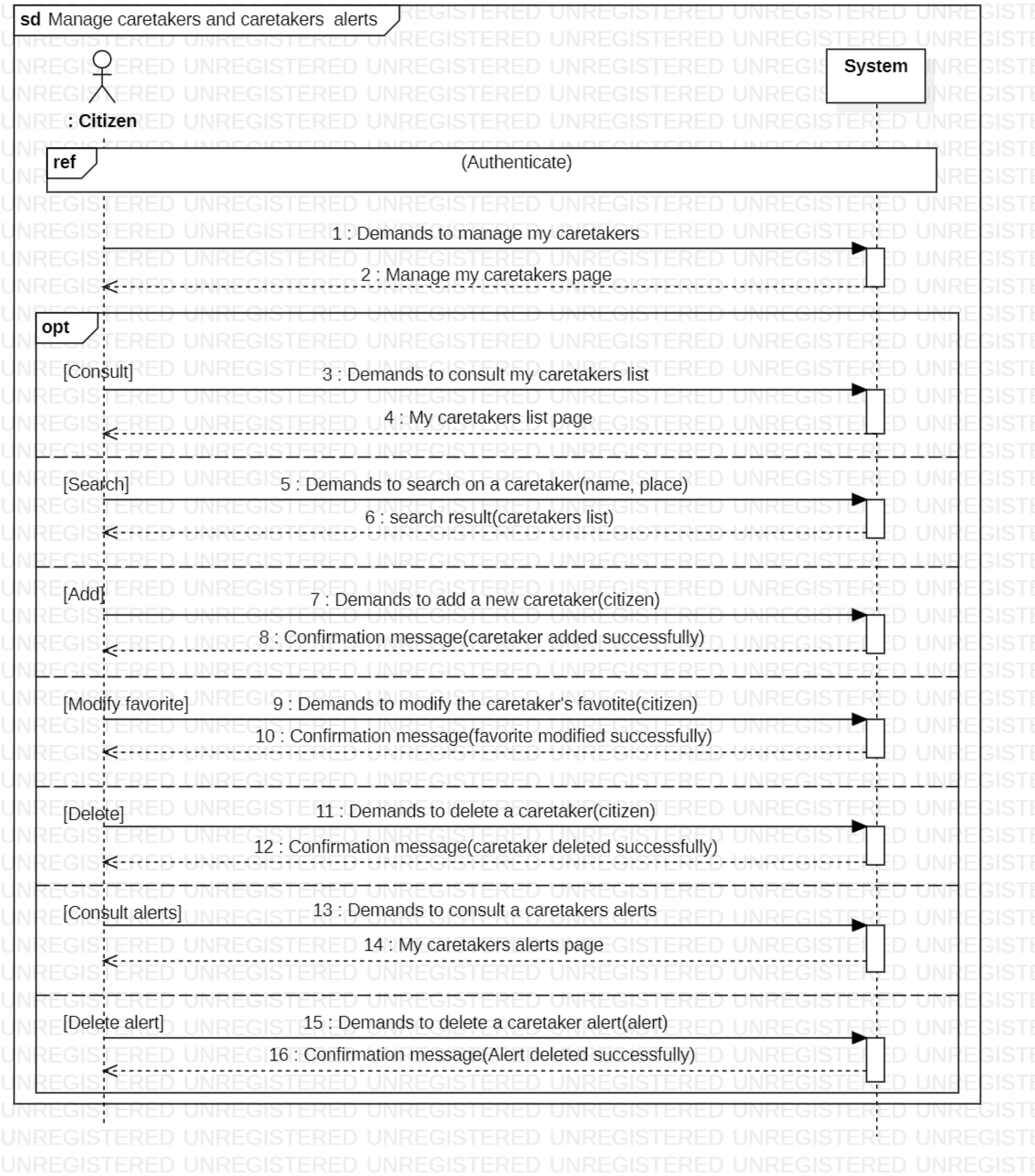


Figure 3.10: Manage caretakers sequence diagram

- **Analyze diagnostic data and make decisions**

Summary description	
Title	Analyze diagnostic data and make decisions.
Goal	The system analyzed diagnostic data and made decisions.
Actor	System.
Precondition	Citizen's diagnostic data are already sent to the system.
Postcondition	The system is analyzed diagnostic data and made decisions successfully.
Detailed description	
Nominal scenario	1. The system analyzed the information. 2. The system sends the diagnostic result and instructions to the citizen. 3. The system makes a decision. 3.1. Warning state: Send an instructions request to the doctor. 3.2. Dangerous state: Send an ambulance request to the nearest hospital and send an alert message to the favorite caretakers.

Table 3.8: Analyze diagnostic data and make decisions textual description

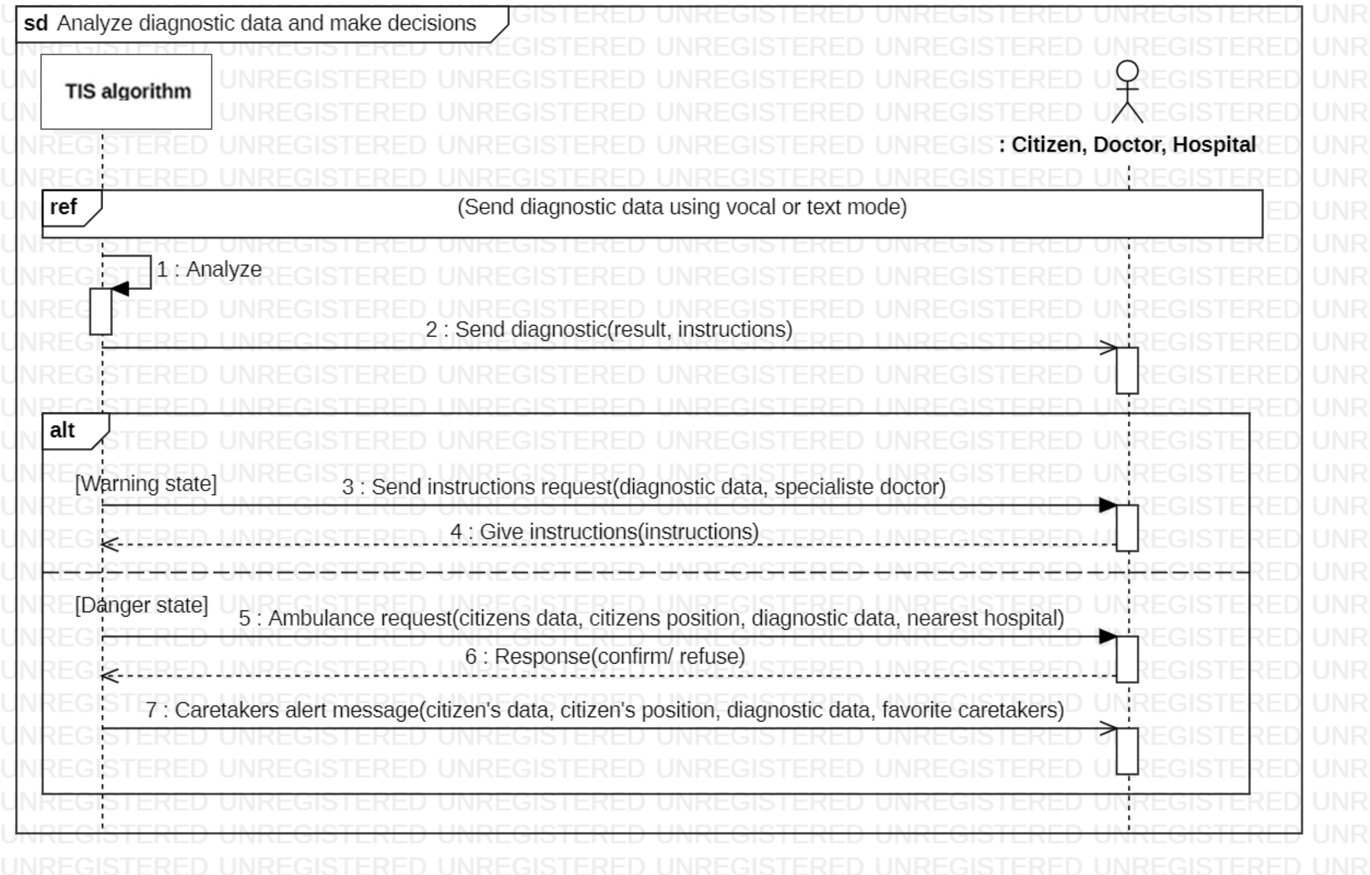


Figure 3.11: Analyze diagnostic data and make decisions sequence diagram

- **Manage the instructions requests**

Summary description	
Title	Manage the instructions requests**.**
Goal	Allowing the doctor to manage the instructions requests.
Actor	Doctor.
Precondition	The doctor is already authenticated.
Postcondition	The doctor is managed the instructions requests successfully.
Detailed description	
Nominal scenario	1. The doctor demands to manage the instructions requests. 2. The system displays the “Manage the instructions requests” page. 3. The user chooses the manage operation. 3.1. The doctor consults the instructions requests list. 3.2. The doctor gives instructions for a request. 3.2.1. The system displays a confirmation message. 3.3. The doctor searches for a request. 3.3.1. The system displays the search result.
Alternative scenario	/

Table 3.9: Manage the instructions requests textual description

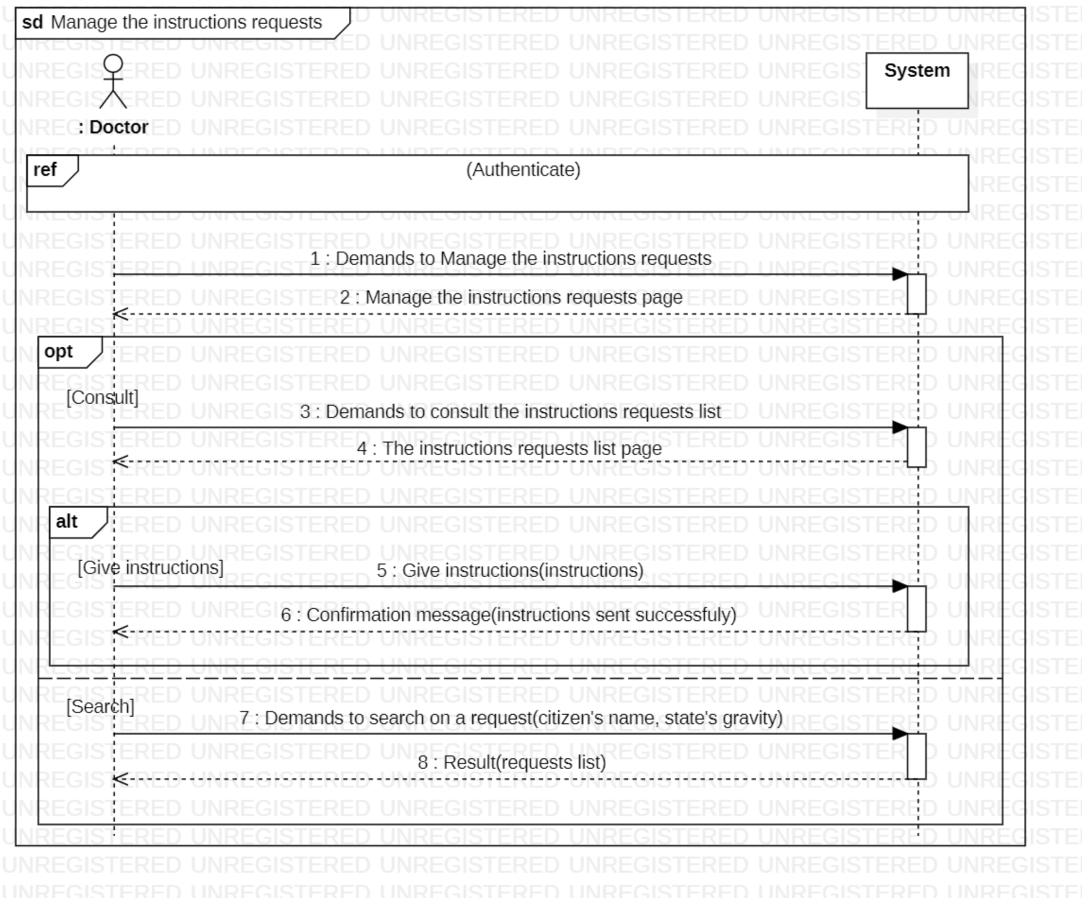


Figure 3.12: Manage the instructions requests sequence diagram

3.2. Activity diagram

The activity diagrams help to put the accent on the treatments. They are particularly suitable for modeling the routing of control flows and data flows. They thus make it possible to graphically represent the behavior of a method or the progress of a use case.

In the design phase, activity diagrams are particularly used to illustrate and consolidate the textual description of use cases. In what follows, we'll make an activity diagram for each actor.

- **TIS algorithm**

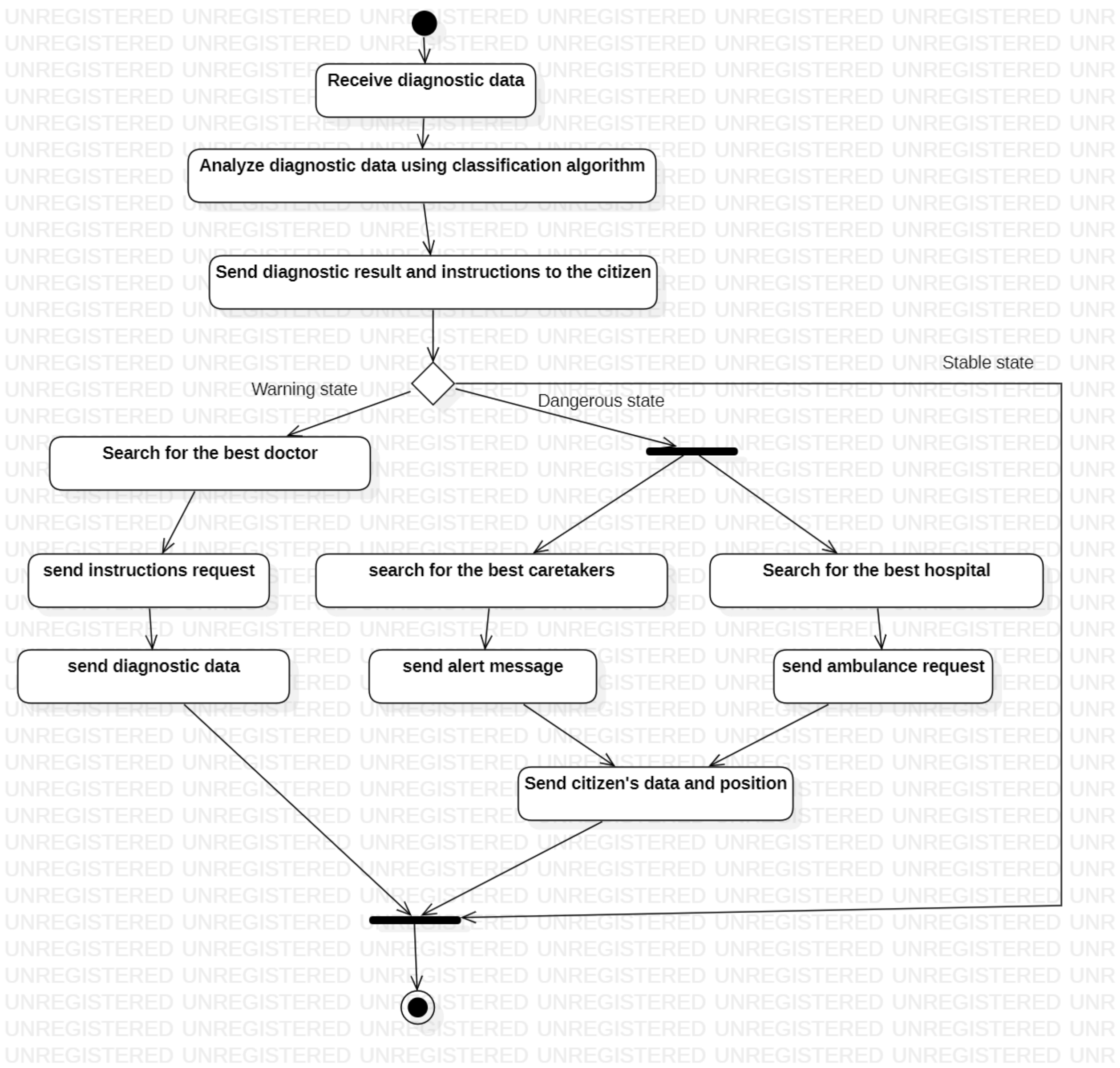


Figure 3.13: TIS algorithm's activity diagram

- **Admin**

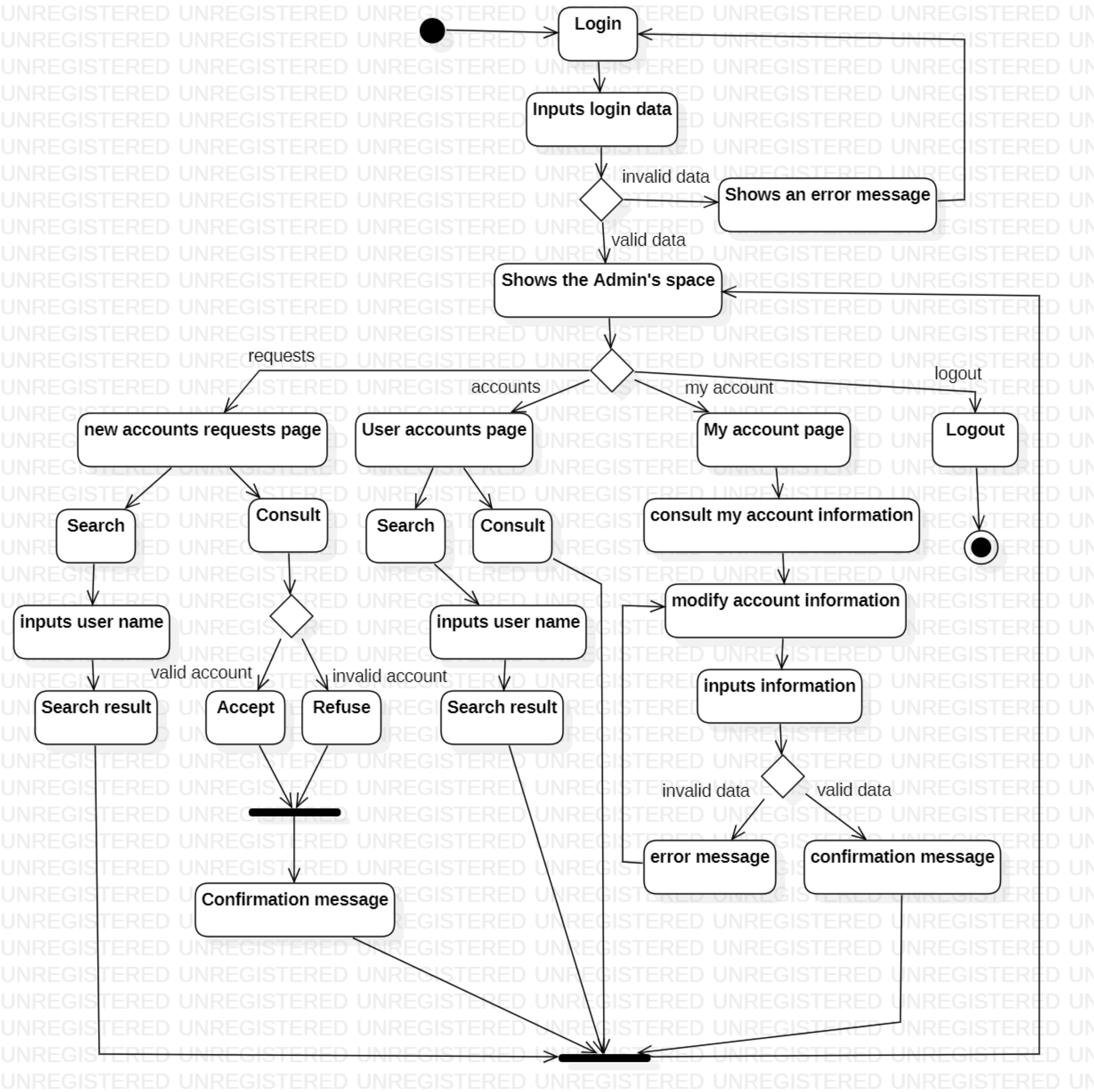


Figure 3.14: Admin’s activity diagram

- **Hospital**

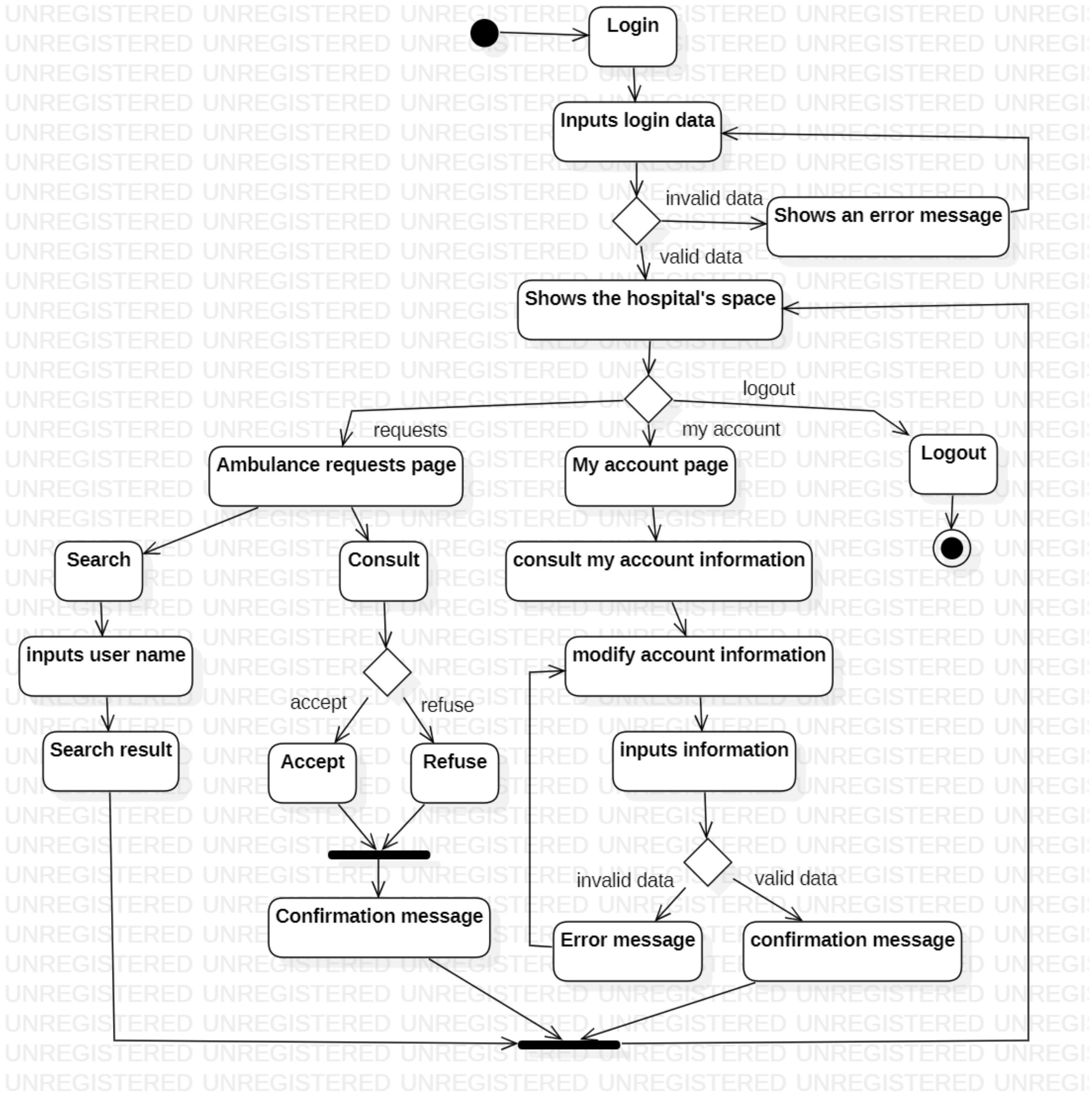


Figure 3.15: Hospital’s activity diagram

- **Doctor**

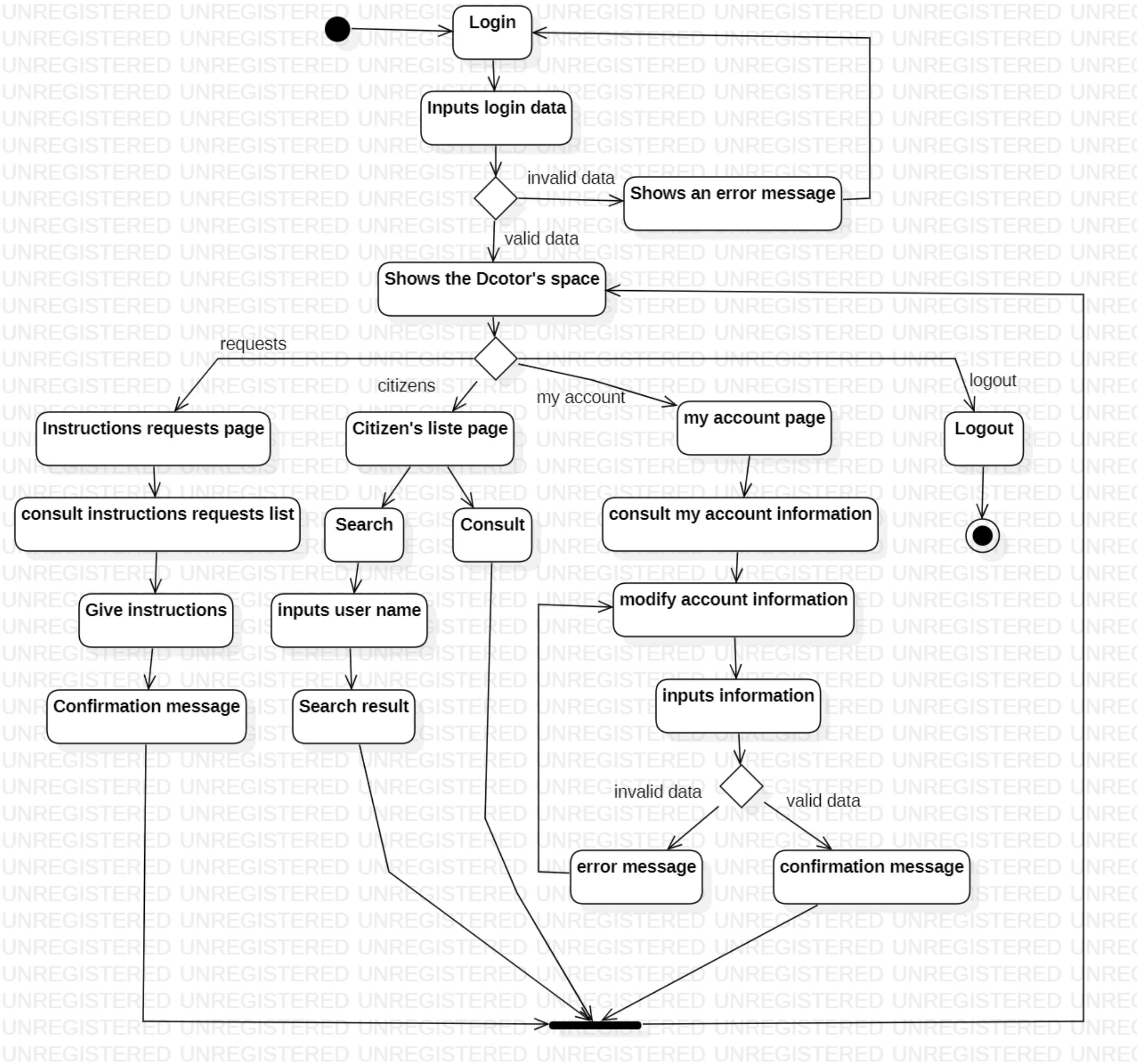


Figure 3.16: Doctor's activity diagram

- **Citizen**

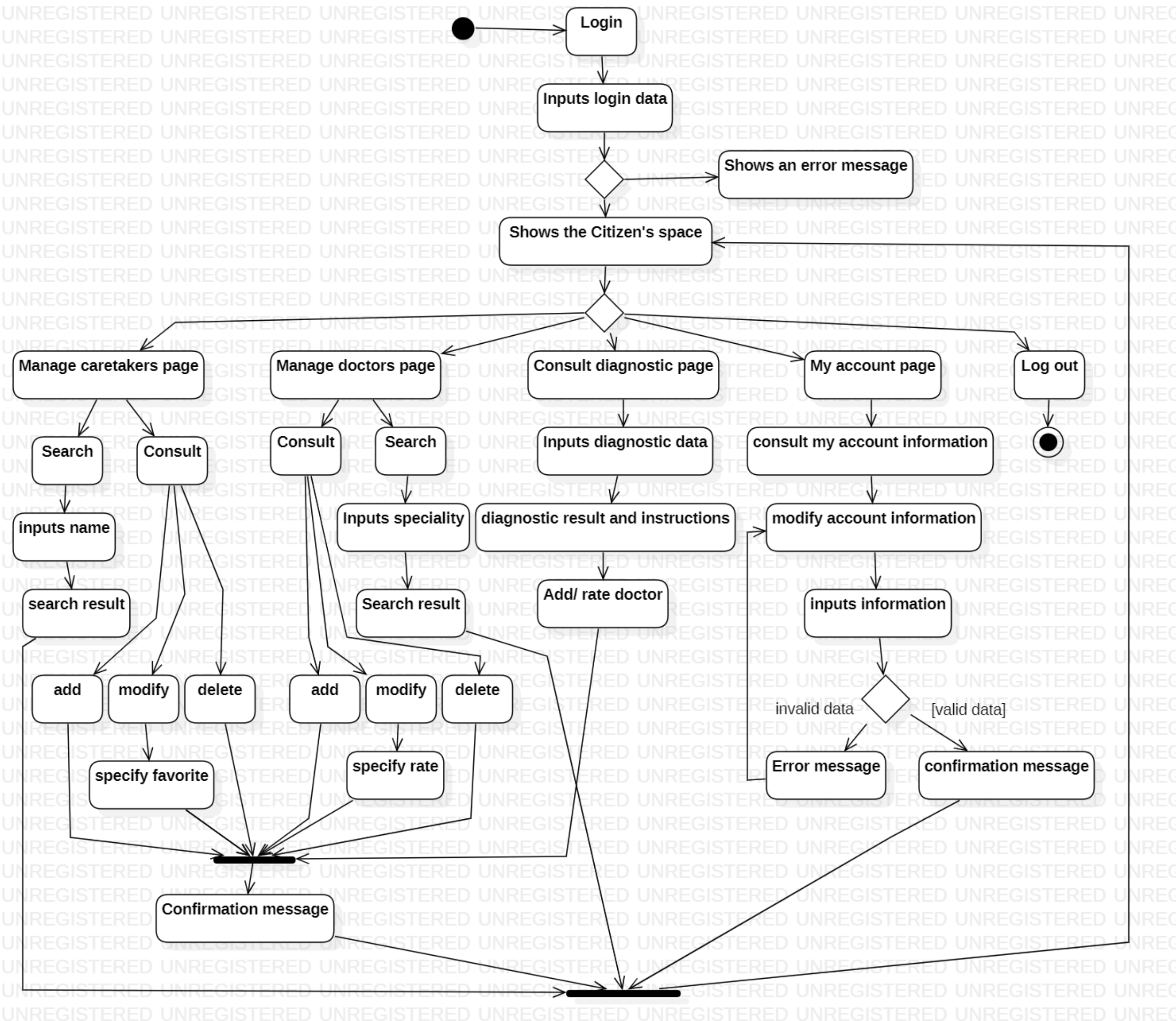


Figure 3.17: Citizen's activity diagram

3.3. Global class diagram

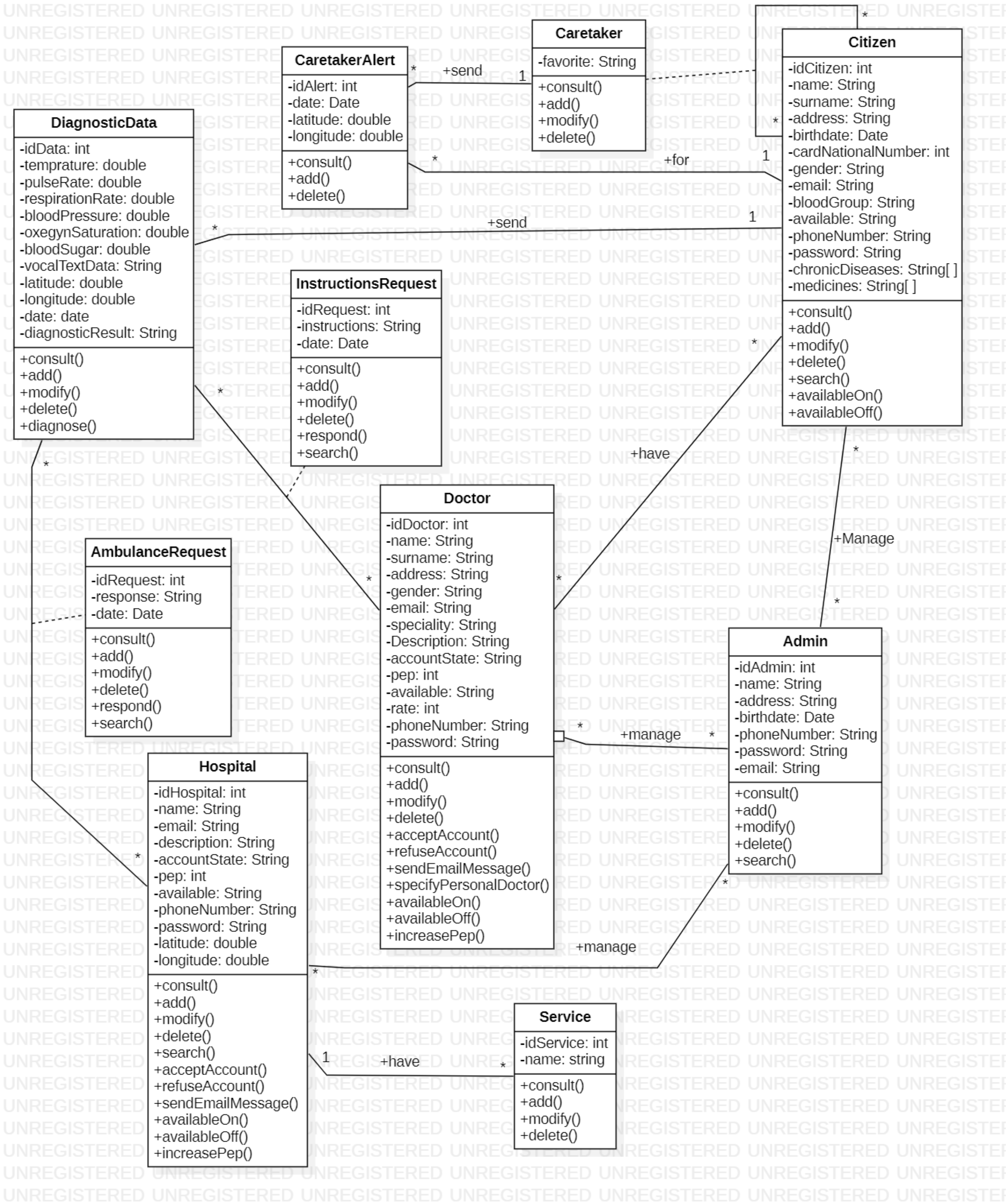


Figure 3.18: Class diagram

3.4. Data relational model

Passage to the relational model

To move from the object model to the relational model, a representation between the class structure and the relational data structure is imposed, while a class defines a data structure to which instances subscribe, it therefore corresponds to a table of the model relational.

The following table represents the correspondence between the concepts of the object and relational model:

Object Model	Relational Model
Class	Table
Attribute with simple type	Column
Attribute with complex type	Column or foreign key
Id	Primary key
Association	Foreign key
Inheritance	Identical primary key on multiple tables

Table 3.10: Equivalence between object and relational

The passing rules

This model must respect a number of rules that must be used to make the passage:

- **Rule 1:** any class becomes a relation, the attributes of the class become attributes of the relation, if the class has an identifier it becomes the primary key of the relation, otherwise an arbitrary primary key must be added.
- **Rule 2:** to represent a 1 to 1 (1..1) association between two relations, the primary key of one of the relations must appear as a foreign key in the other relation.
- **Rule 3:** to represent a 1 to many association (1..*), we proceed like a 1 to 1 association, except that it is necessarily the relation on the many side which receives as foreign key the primary key of the relation of the side 1.
- **Rule 4:** to represent a many-to-many association (*..*), a new relation must be introduced whose attributes are the primary keys of the associated relations, and whose primary key is the concatenation of these two attributes, if the association has attributes, they become attributes of the corresponding relation.
- **Rule 5:** case of inheritance, transform each subclass into a relationship, the primary key of the super class becomes the primary key of each subclass.

- **Rule 6:** case of composition, the primary key of the composite class becomes the foreign key of the component class.
- **Rule 7:** case of aggregation, the same principle as Rule 3.

Database tables

- **Admin** (**idAdmin**, name, address, birthdate, phoneNumber, password, email).
- **Ambulance_request** (**idRequest**, date, response, #**idData**, #**idHospital**).
- **Caretaker** (**idInstance**, favorite, #**idCaretaker**, #**idCitizen**).
- **Caretaker_alert** (**idAlert**, date, latitude, longitude, #**idCaretaker**, #**idCitizen**).
- **Chronic_disease** (**idDisease**, name, #**idCitizen**).
- **Citizen** (**idCitizen**, name, surname, address, birthdate, cardNationalNumber, gender, email, bloodGroup, available, phoneNumber, password).
- **Citizen_doctor** (**idCitizenDoctor**, # **idCitizen**, # **idDoctor**).
- **Diagnostic_data** (**idData**, temprature, pulseRate, respirationRate, bloodPressure, oxegynSaturation, bloodSugar, vocalTextData, latitude, longitude, date, diagnosticResult, #**idCitizen**).
- **Doctor** (**idDoctor**, name, surname, address, gender, email, speciality, description, accountState, pep, rate, available, phoneNumber, password).
- **Hospital** (**idHospital**, name, email, description, accountState, pep, available, phoneNumber, password, latitude, longitude).
- **Instructions_request** (**idRequest**, instructions, date, #**idData, #idDoctor**).
- **Medecines** (**idMedecine**, name, #**idCitizen**).
- **Service** (**idService**, name, #**idHospital**).

NB: Primary keys are bolded and underlined, while foreign keys are bolded and start with the symbol #.

4. Conclusion

In this chapter, we presented a comprehensive design of our system.

Now, we are ready to start the implementation, detailed in the next chapter, where we will show how we have interpreted the design model to a real application.

Chapter 4

System Implementation

1. Introduction

This chapter deals with the implementation of the system based on the analysis and conceptual design of the previous chapter.

First, we will present the system architecture and main algorithms of the system. Then, we will give an overview of the different tools and programming languages used to build our system. Lastly, we will present the system main windows and screens.

2. System architecture

According to the system description (see chapter 3), it consists of four main parts:

1. The input part: consists of all interfaces developed for acquiring diagnostic data and citizen's information, including his personal information, caretakers, doctors, diseases, and medicines. Same thing for doctors and hospitals information.
2. The diagnostic part: represents the main part. It consists of the TIS algorithm for generating diagnostic result based on the classification method, and according to the data inputted by the citizen. The result will be stable, warning, or dangerous.
3. The make decision part: After generating the diagnostic result, the make-decision algorithm will act depending on the result. If warning, the algorithm will search for the best doctor to send him an instructions request. If dangerous, it will search for the best caretaker to send alert to, and best hospital to send ambulance request to.

4. The response part: The last part, which each of the caretakers, doctors, and hospitals will respond to the system's requests.

The mobile and web applications shared the same phpMyAdmin database. For that, we developed a REST web service that read and write from the android application to the database.

3. Work environment

In this section, we will present both the hardware and the softwares configurations of our work environment.

3.1. Hardware

In order to achieve the objective of our work, we implemented our system on the Windows 11 professional version on a machine DELL Latitude 5490:

- Processor Intel(R) Core (TM) i5-8250 CPU @ 1,60 GHZ 1,80 GHz.
- Memory installed (RAM): 8,00 Go.
- Operating system 64 bits.

Note that this configuration is not the minimal.

3.2. Softwares

- **IDEs and applications:**

Android Studio

Android Studio is a development environment; smart code editor and flexible approach for developing Android mobile applications based on IntelliJ IDEA and uses the Gradle build engine. Android Studio provides super-fast Android app building tools [42].

Sublime Text

Sublime Text is a generic text editor coded in C++ and Python, available on Windows, Mac and Linux. The software was designed primarily as a feature-rich extension for Vim [43].

Xampp

XAMPP is a set of software for setting up a local web server, an FTP server and an e-mail server. It is a distribution of free software offering good flexibility of use, renowned for its simple and quick installation [44].

Postman

Postman is an application for testing APIs, created in 2012 to address a shareable API testing problem. First Google Chrome add-on, then thick client, and finally thin client, it is now used by more than 500,000 companies worldwide [45].

StarUML

StarUML is open source UML (Unified Modeling Language) modeling software that can replace commercial and expensive software like Rational Rose or Together in many situations [46].

PyCharm

PyCharm is an integrated development environment used to program in Python. It allows code analysis and contains a graphical debugger. It also allows unit test management, version control software integration, and supports web development with Django [53].

- **Programming languages and frameworks:**

JAVA

Java technology defines both an object-oriented programming language and a computing platform. It is therefore found on computers, but also on mobile phones, game consoles, etc [47].

XML

XML stands for Extensible Markup Language. It is a text-based markup. XML tags identify the data and are used to store and organize the data, rather than specifying how to display it like HTML tags, which are used to display the data [48].

PHP

Stands for "Hypertext Preprocessor." PHP is an HTML-embedded Web scripting language. This means PHP code can be inserted into the HTML of a Web page, which can be read by the browser [49].

Laravel

Laravel is an open-source web framework written in PHP respecting the model-view-controller principle and entirely developed in object-oriented programming. Laravel is distributed under the MIT license [50].

HTML 5

Stands for "Hypertext Markup Language." HTML is the language used to create webpages. With Html we created and manipulated the application interface (create tables, buttons, etc.) [51].

Bootstrap

Bootstrap is a framework developed by the Twitter social network team. Offered in open source (under MIT license), this Framework using HTML, CSS and JavaScript languages provides developers with tools to easily create a site [52].

Python

Python is an interpreter, cross-paradigm, cross-platform programming language. It promotes structured, functional and object-oriented imperative programming. It has strong dynamic typing, automatic memory management by garbage collection [54].

4. System presentation

In this section, we give the main windows presenting different use cases. We note that there is a mobile application used by the citizens and a web application used by admins, doctors and hospitals (see Chapter 3).

4.1. The mobile application

Figure 4.1: Splash screen

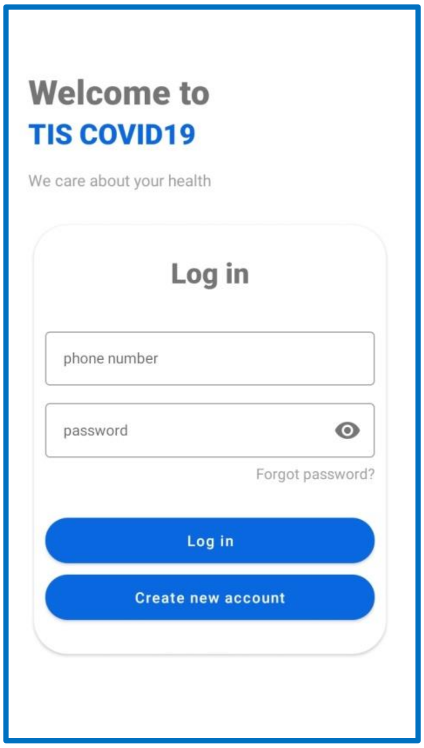


Figure 4.2: Login screen

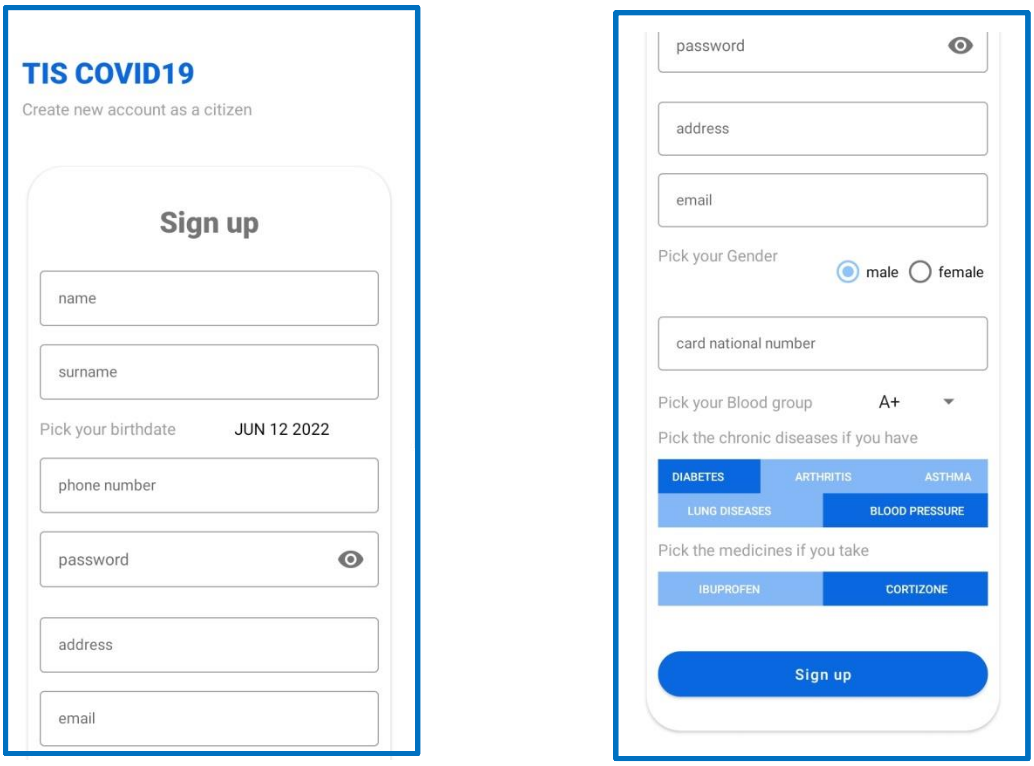


Figure 4.3: Sign up screen

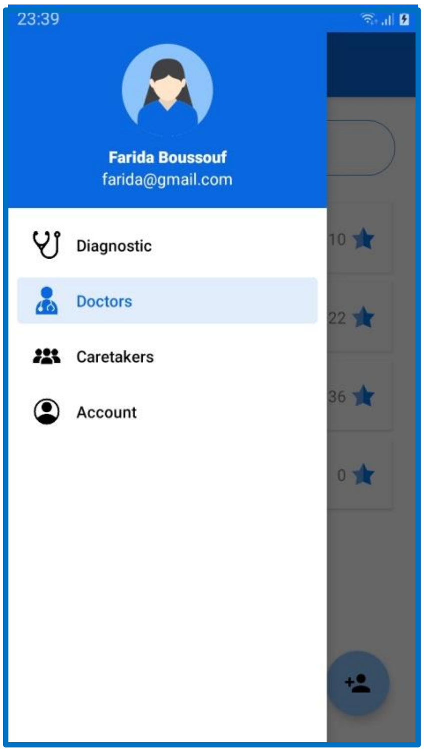


Figure 4.4: Citizen's space screen

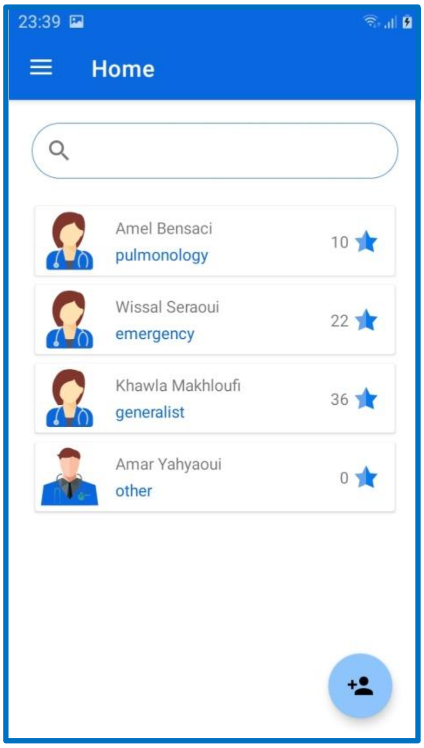


Figure 4.5: Manage doctors screen

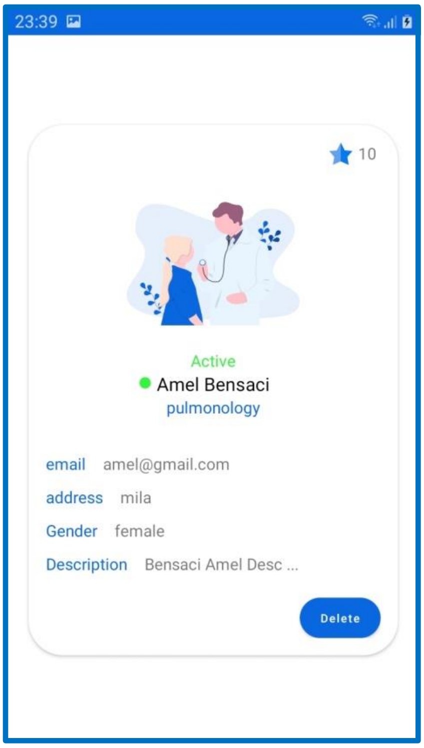


Figure 4.6: Delete an existing doctor screen

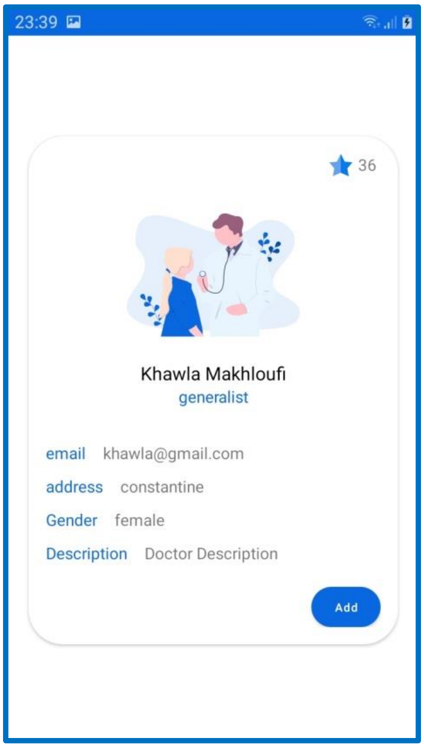


Figure 4.7: Add a new doctor screen

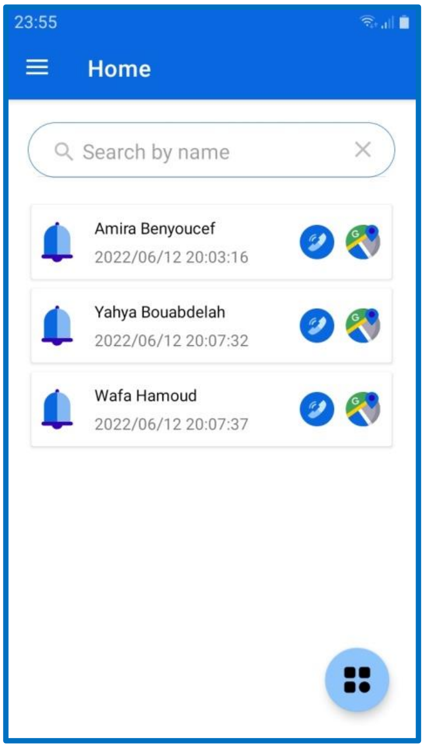


Figure 4.8: Manage caretakers alerts screen

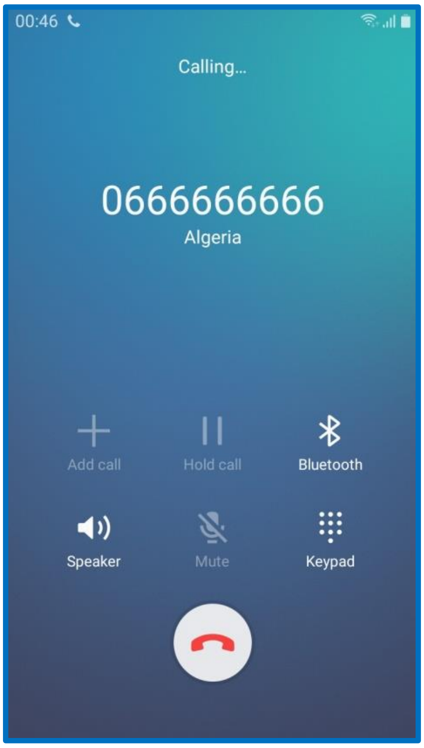


Figure 4.9: Call citizen screen

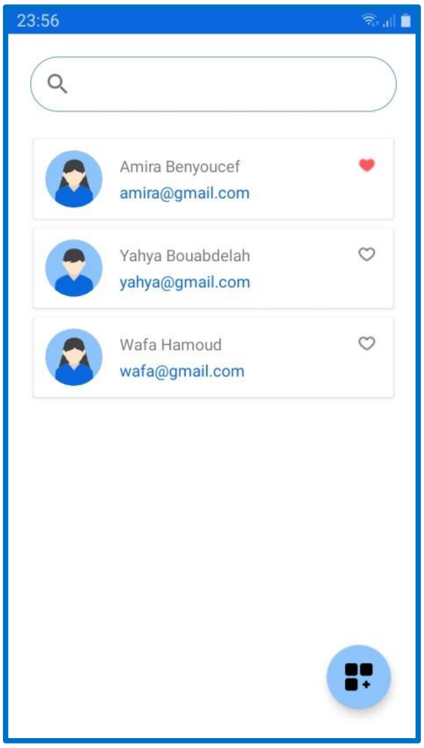


Figure 4.10: Manage caretakers list screen

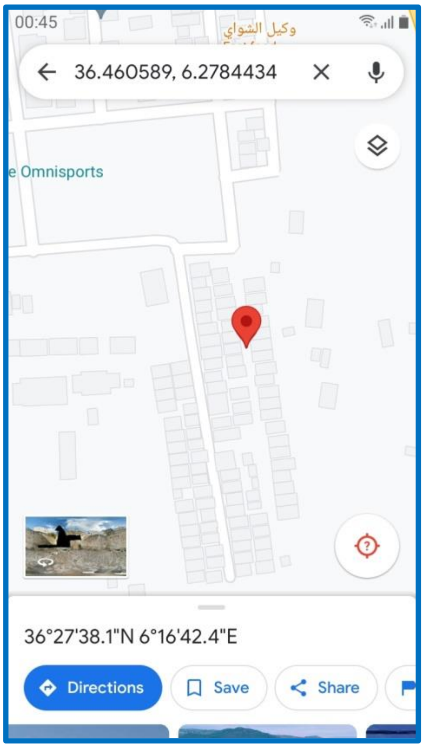


Figure 4.11: Show citizen position screen

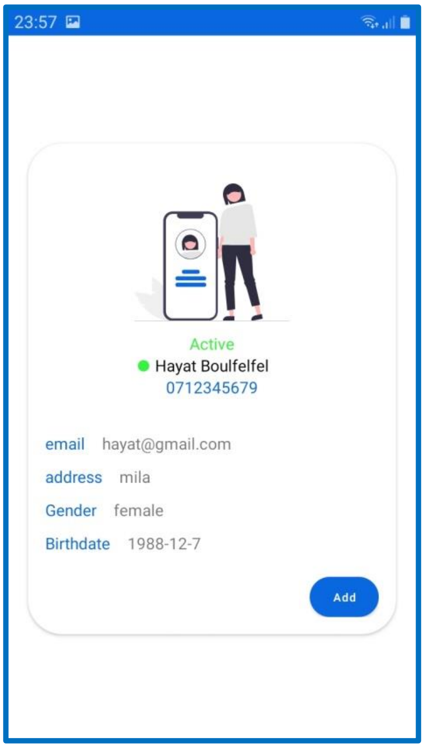


Figure 4.12: Add a new caretaker screen

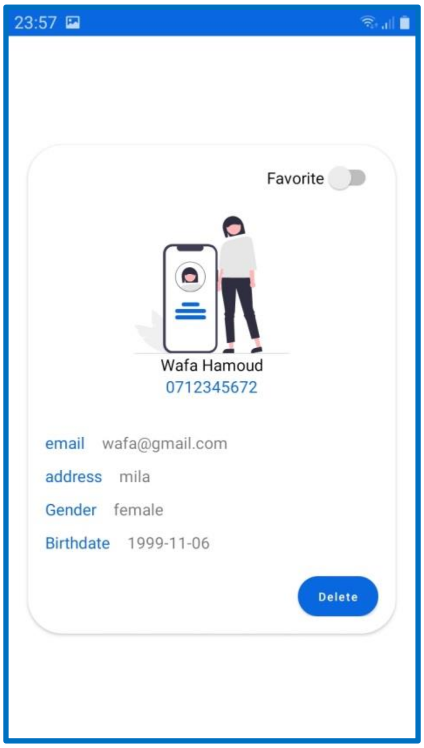


Figure 4.13: Delete an existing caretaker screen

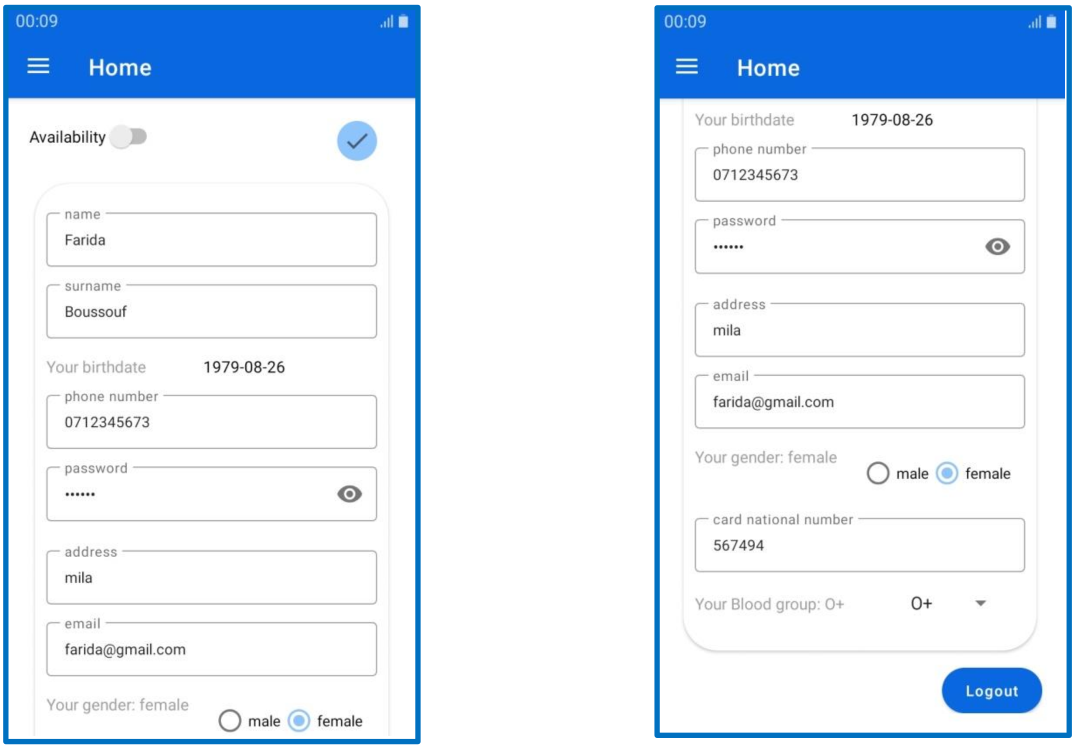


Figure 4.14: Manage citizen account screen

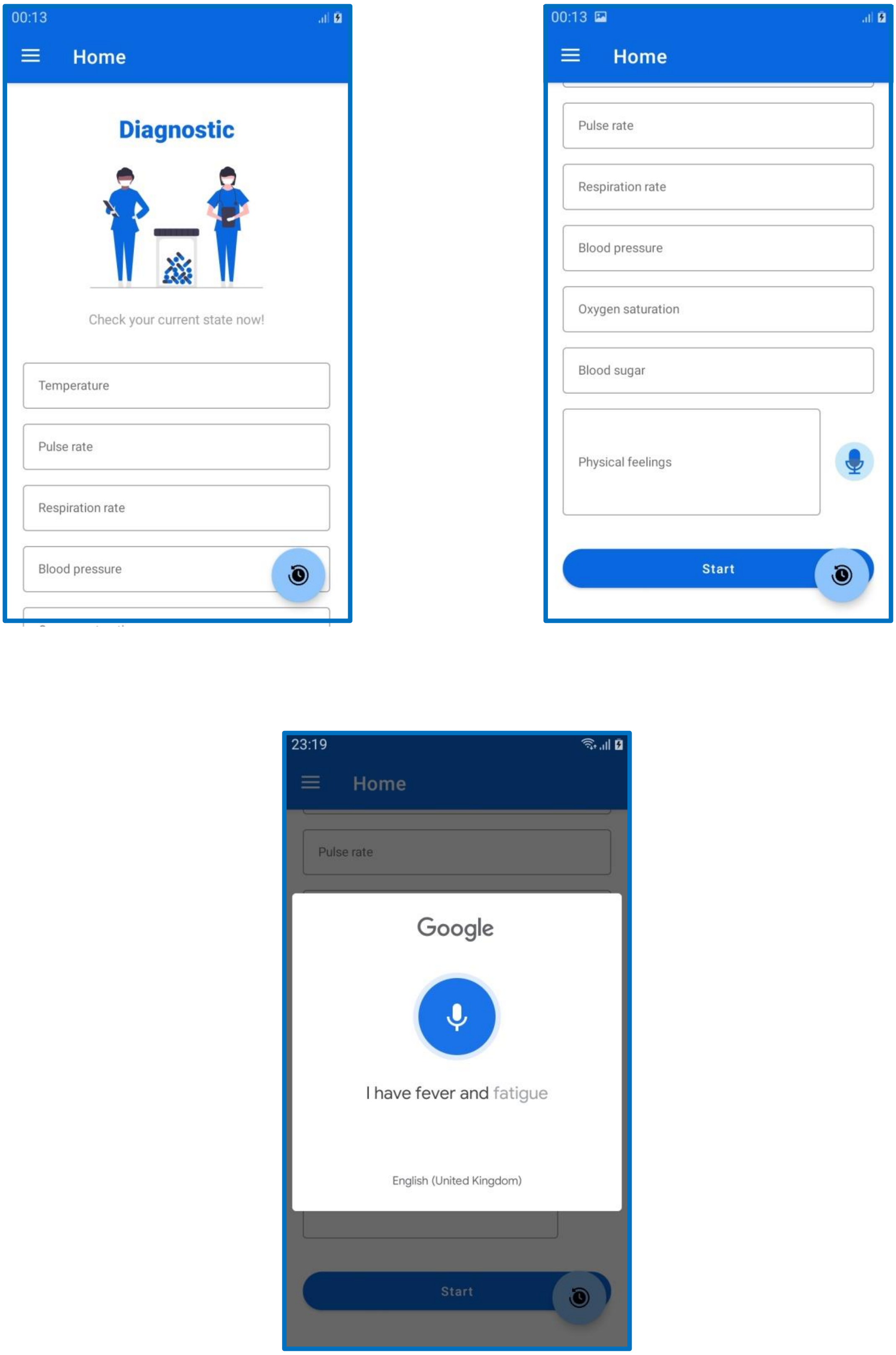
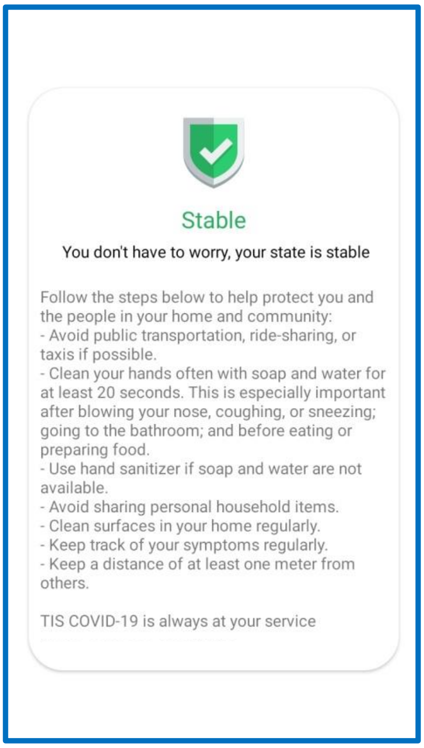
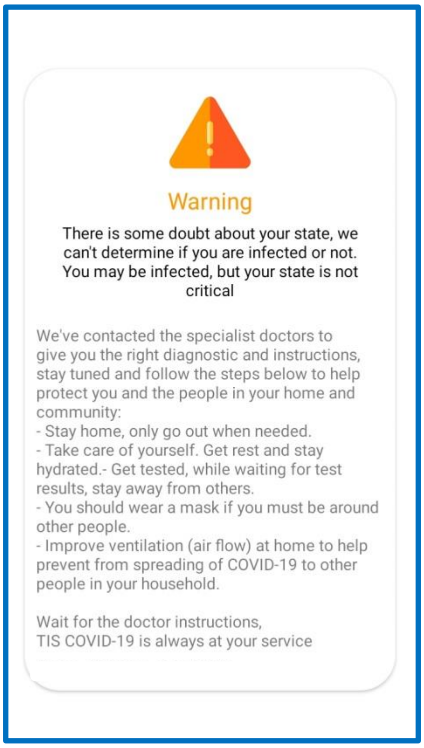


Figure 4.15: Diagnostic screens





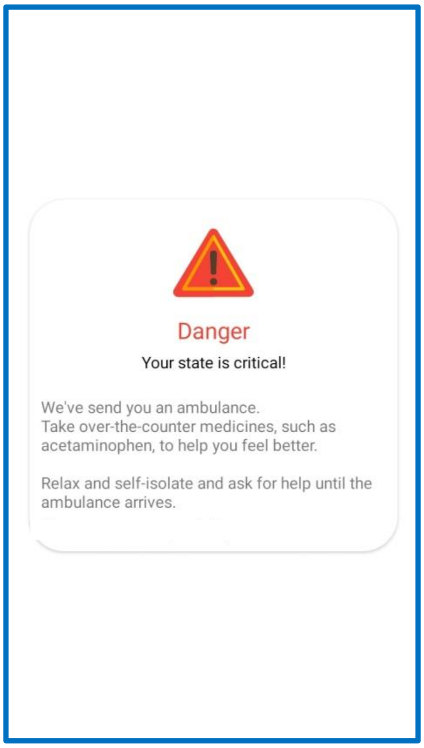


Figure 4.16: Diagnostic result screens

4.2. The web application

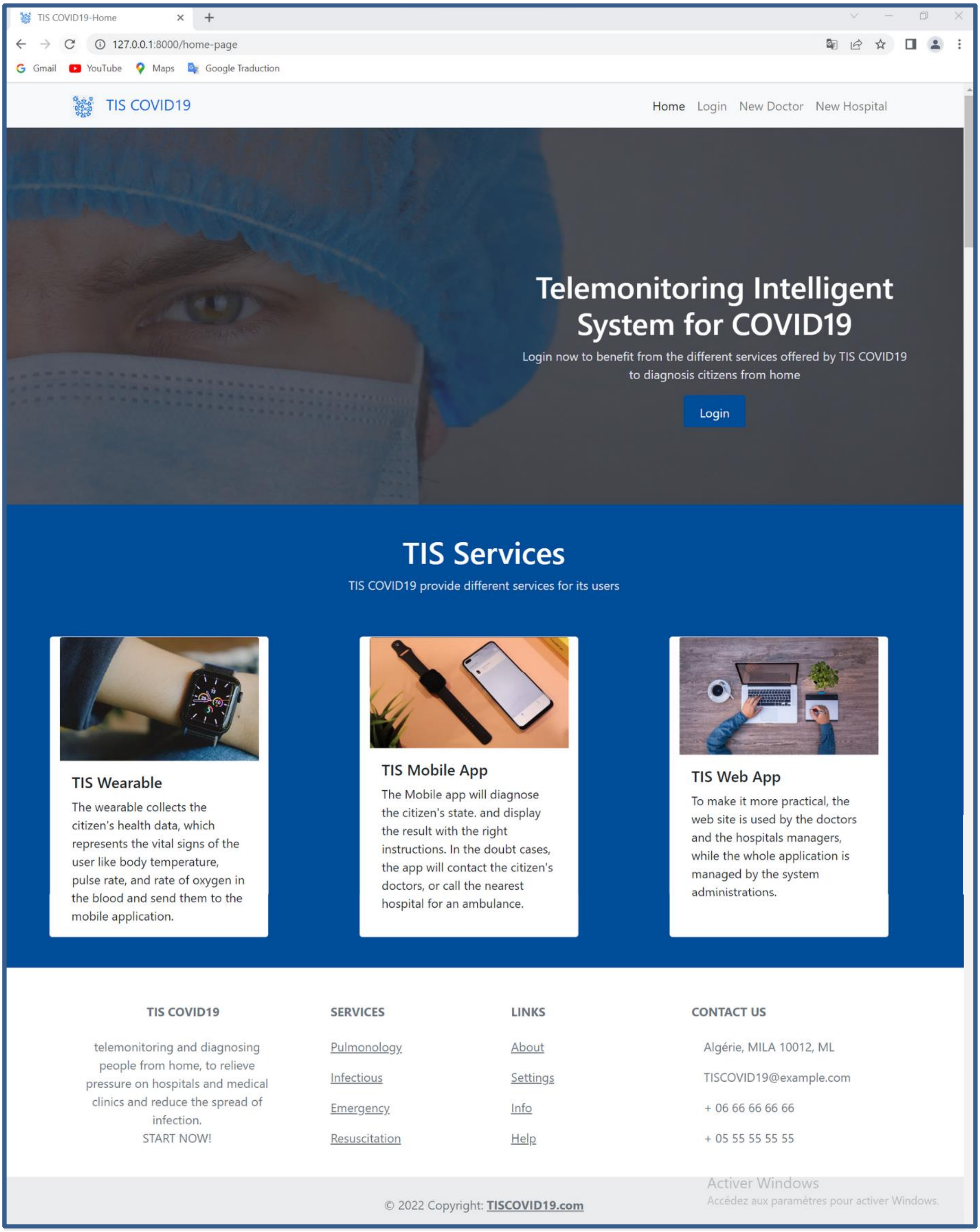


Figure 4.17: Home page

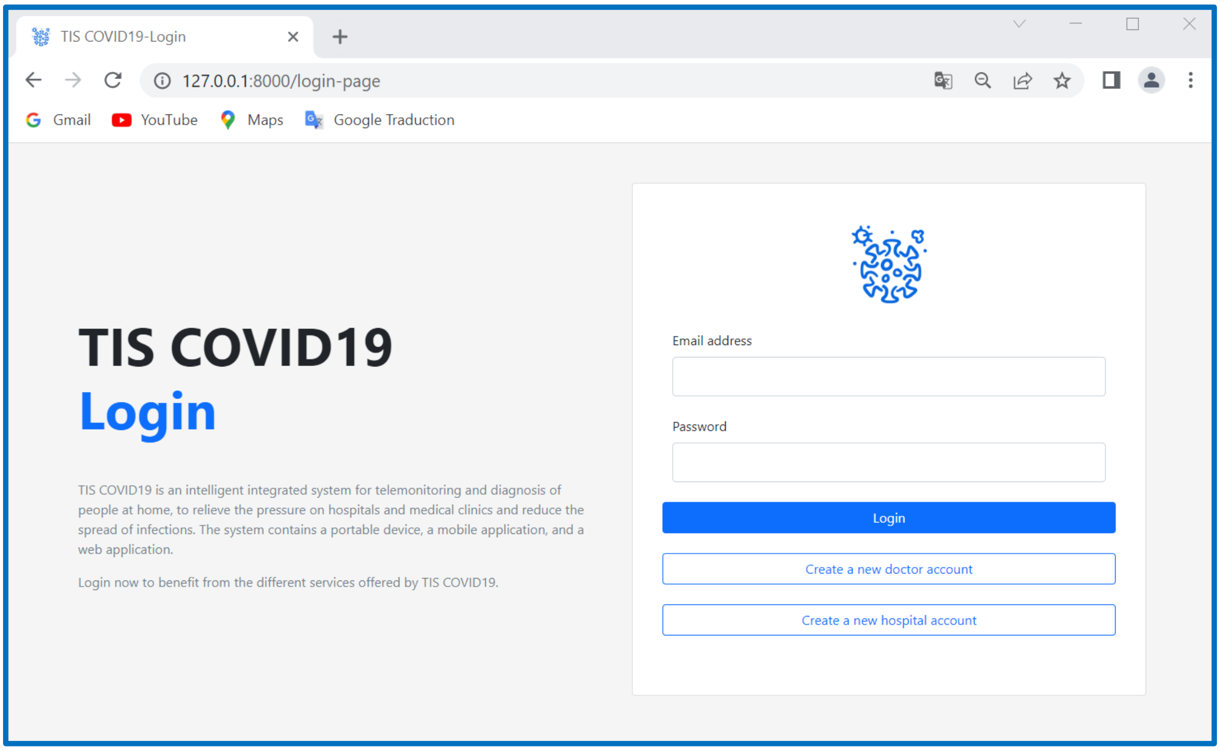


Figure 4.18: Login page

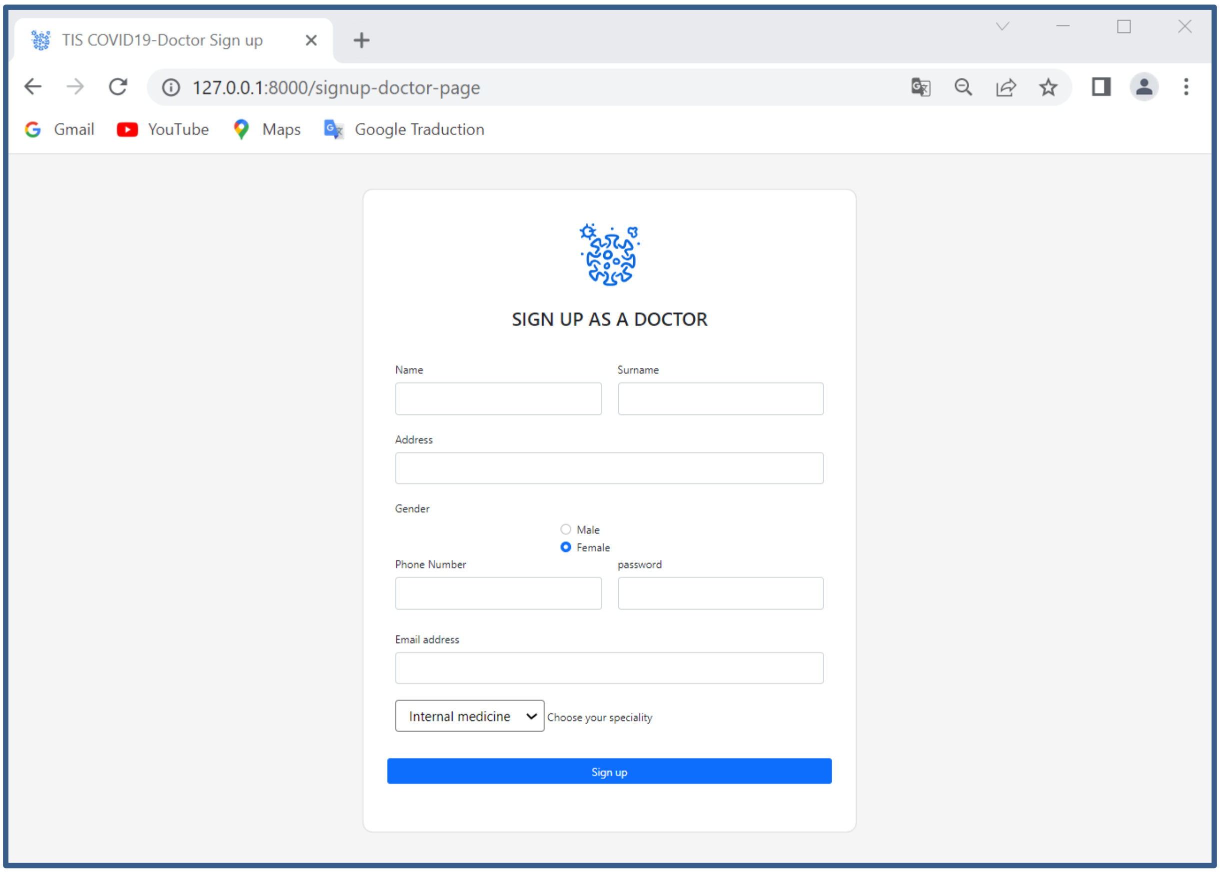


Figure 4.19: Sign up as a doctor page

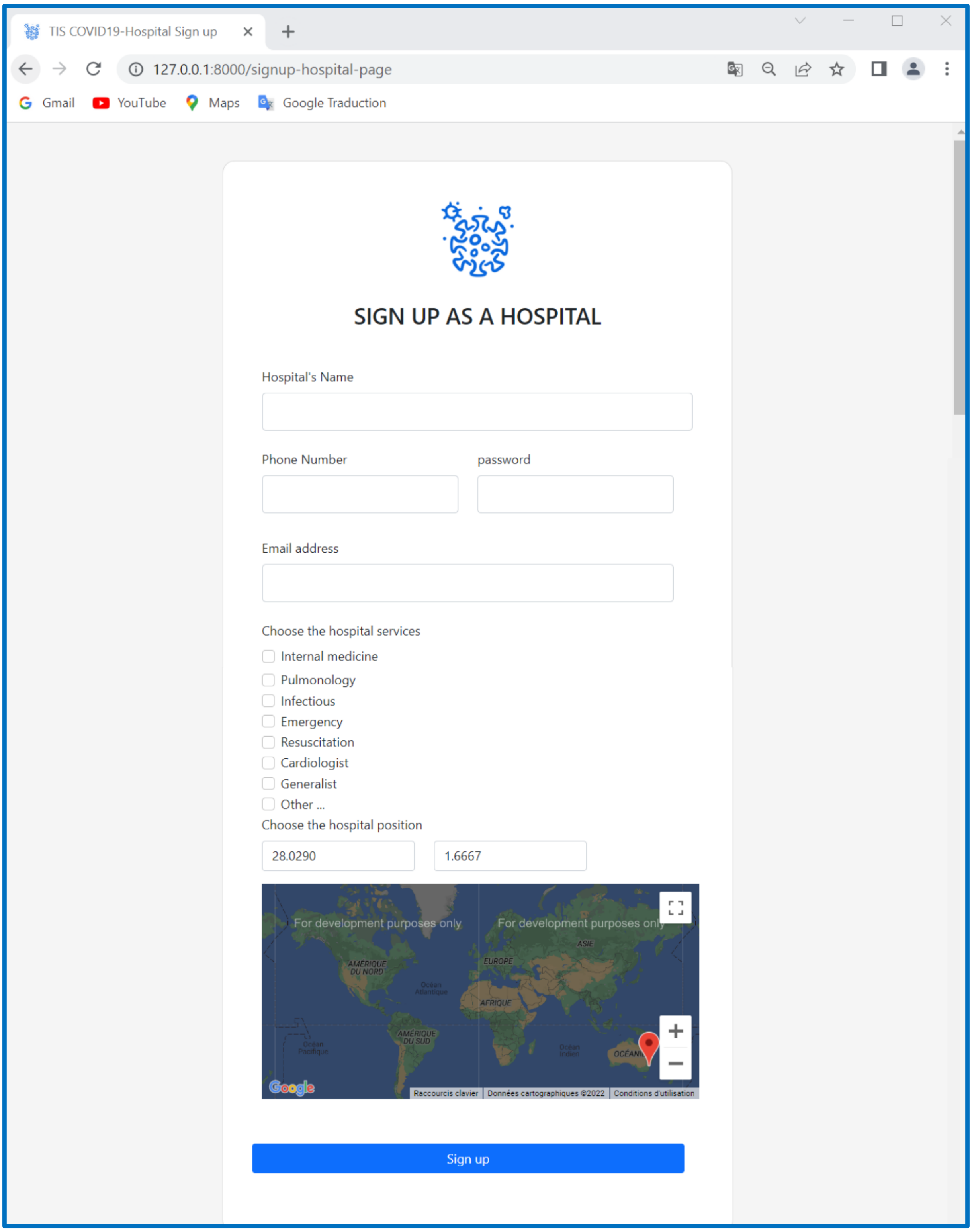


Figure 4.20: Sign up as a hospital page

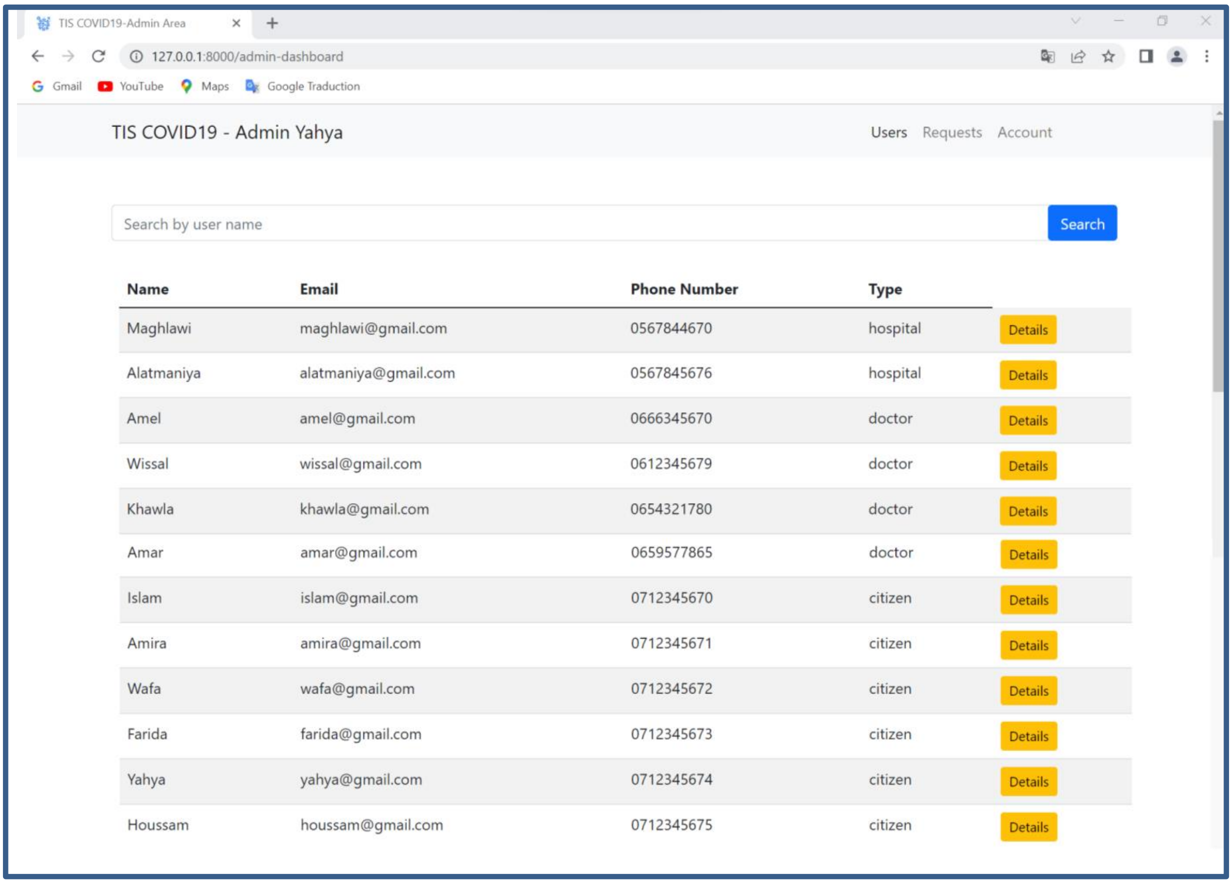


Figure 4.21: Manage the user accounts page

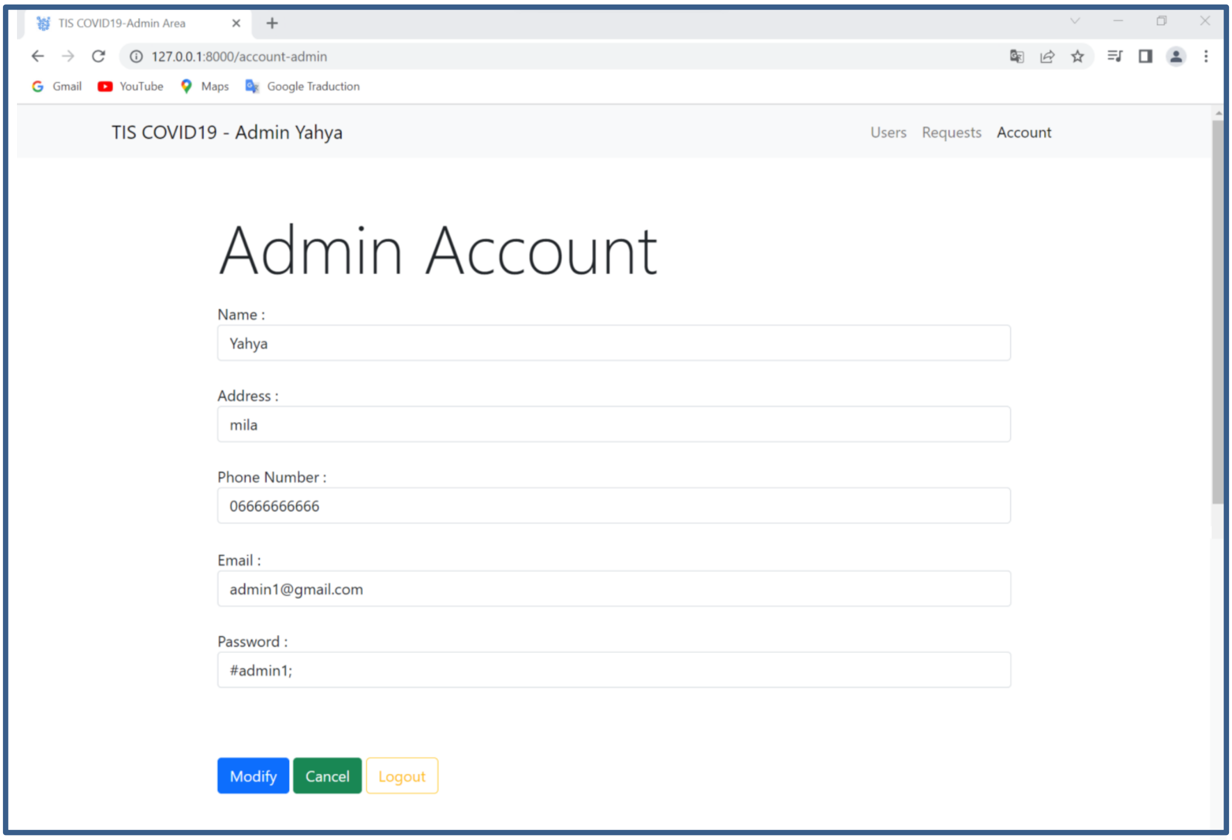


Figure 4.22: Manage admin account page

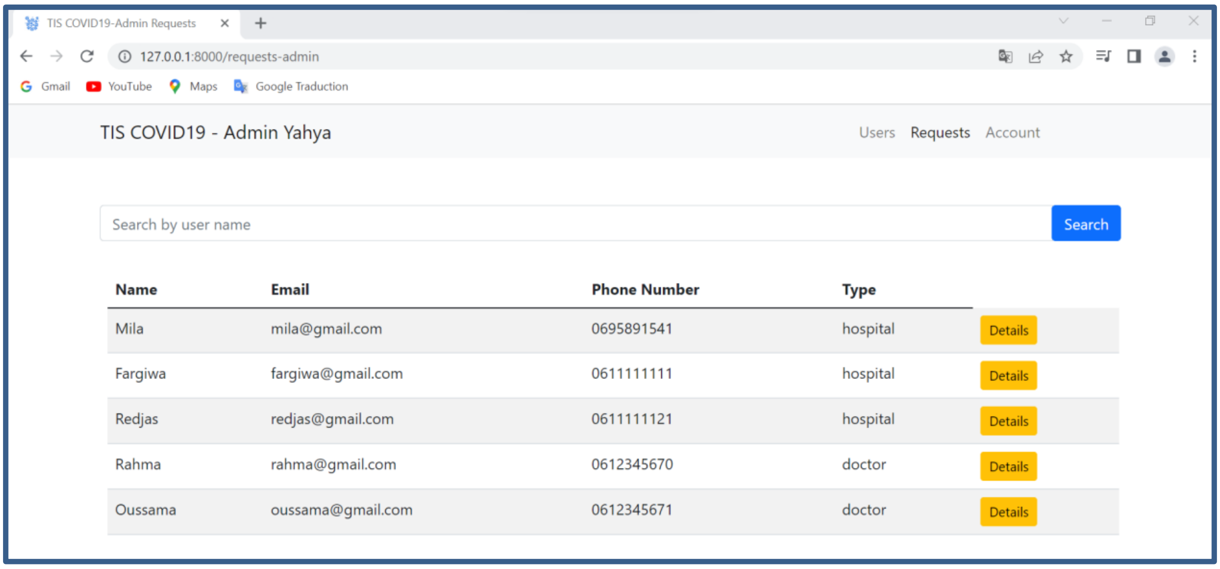


Figure 4.23: Manage the new doctor/ hospital account requests page

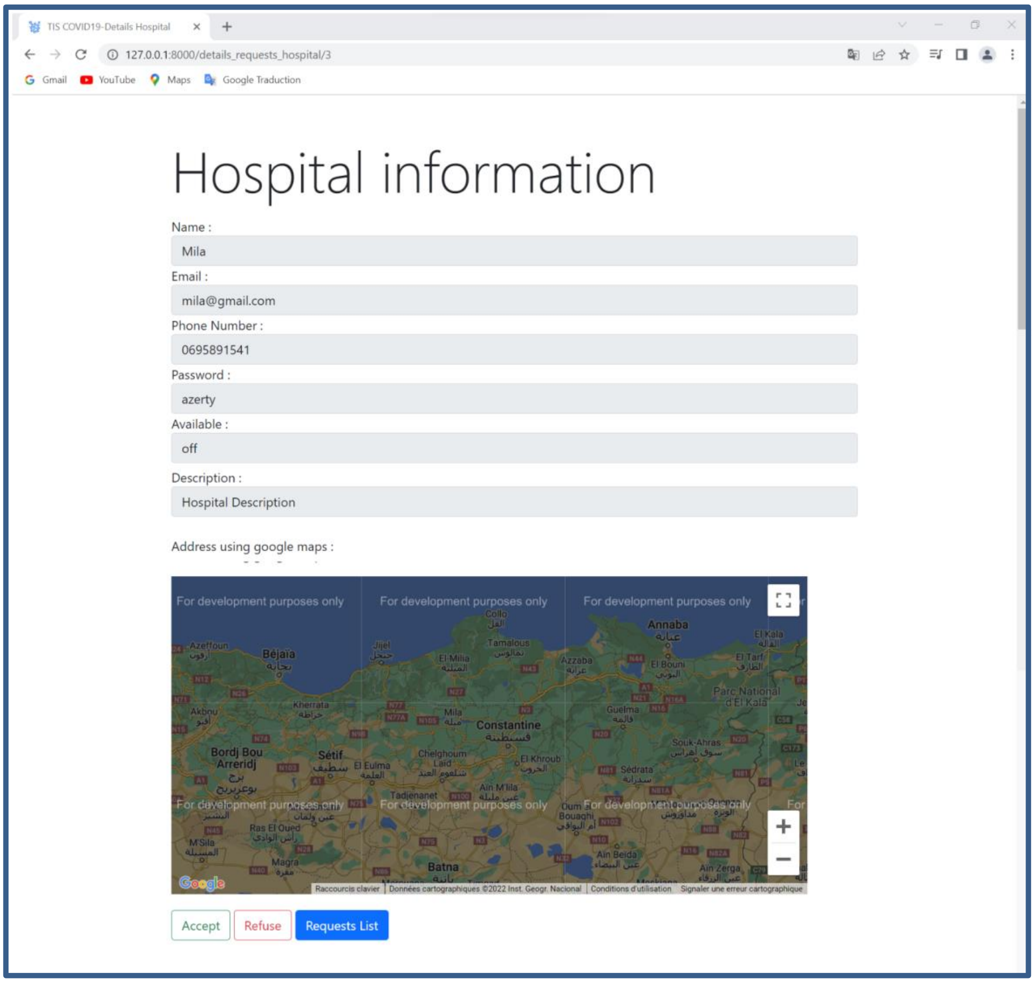


Figure 4.24: Accept/ Refuse the new doctor/ hospital account requests page

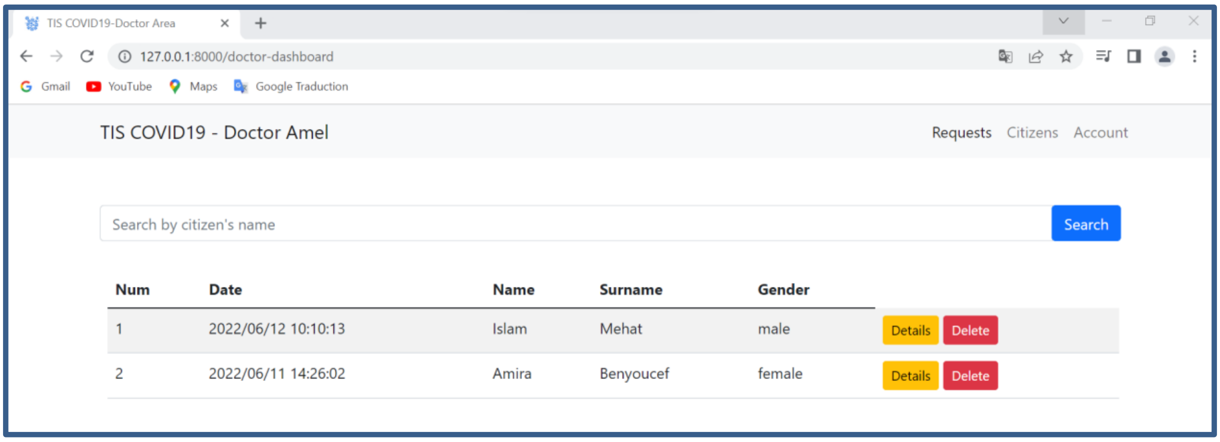


Figure 4.25: Manage the instructions requests page

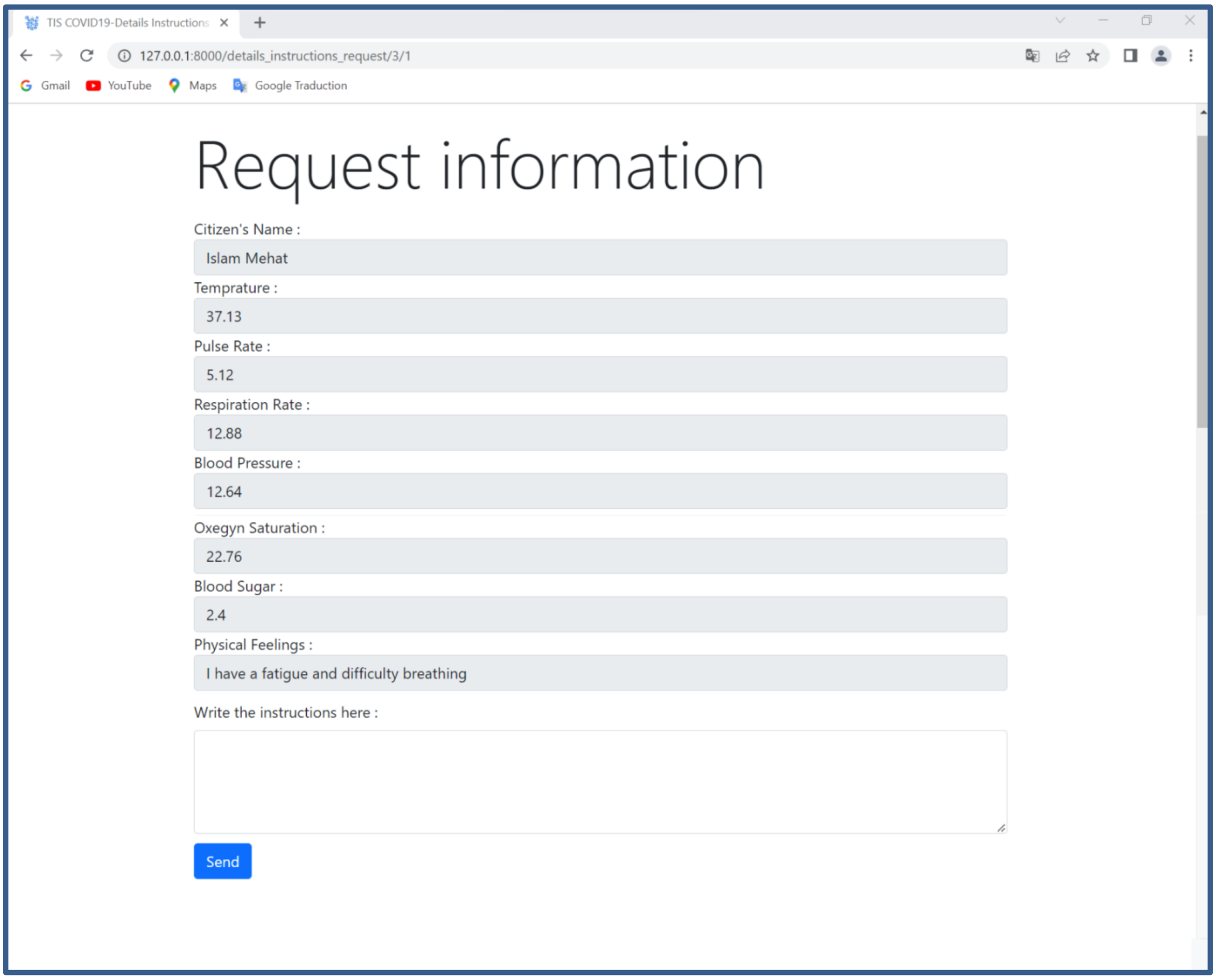


Figure 4.26: Send instructions page

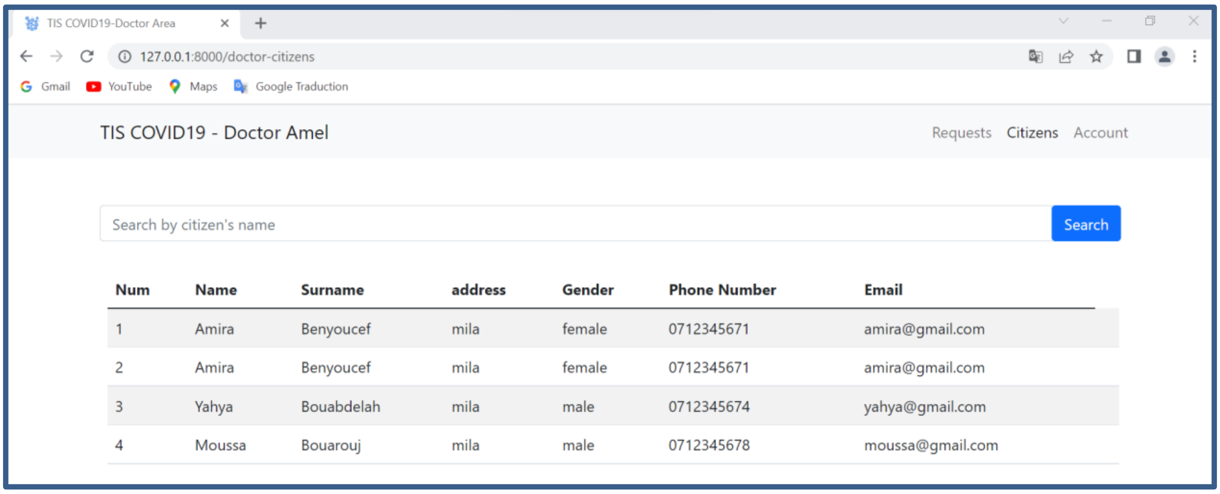


Figure 4.27: Consult citizens list page

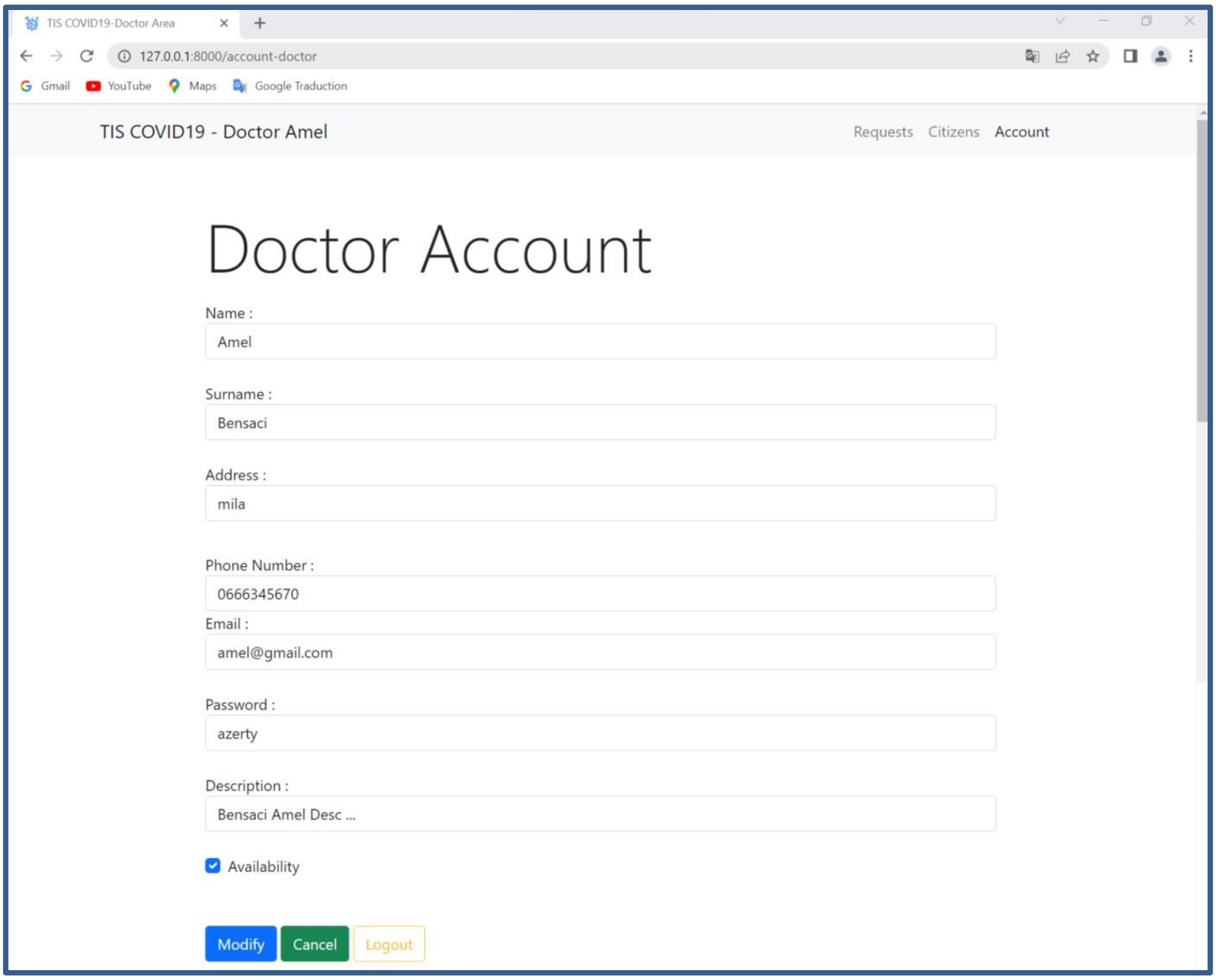


Figure 4.28: Manage doctor account page

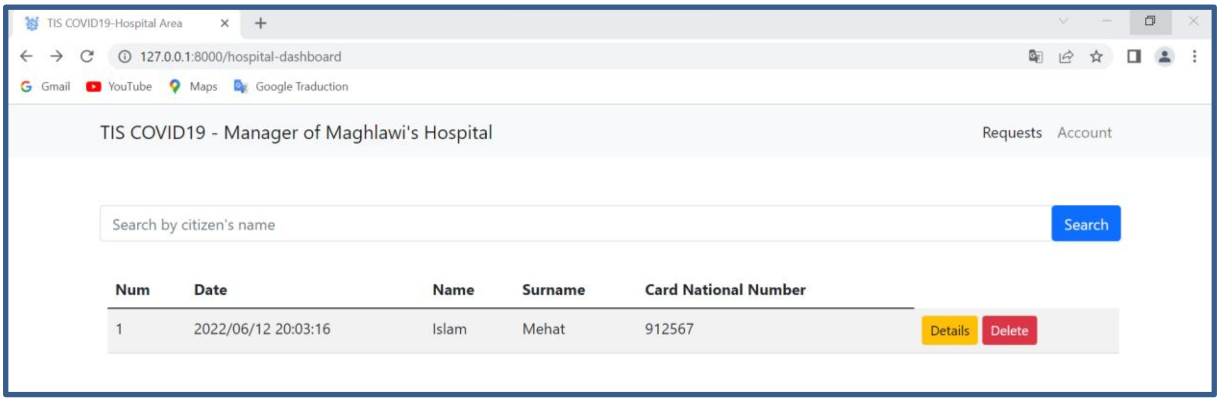


Figure 4.29: Manage the ambulance requests page

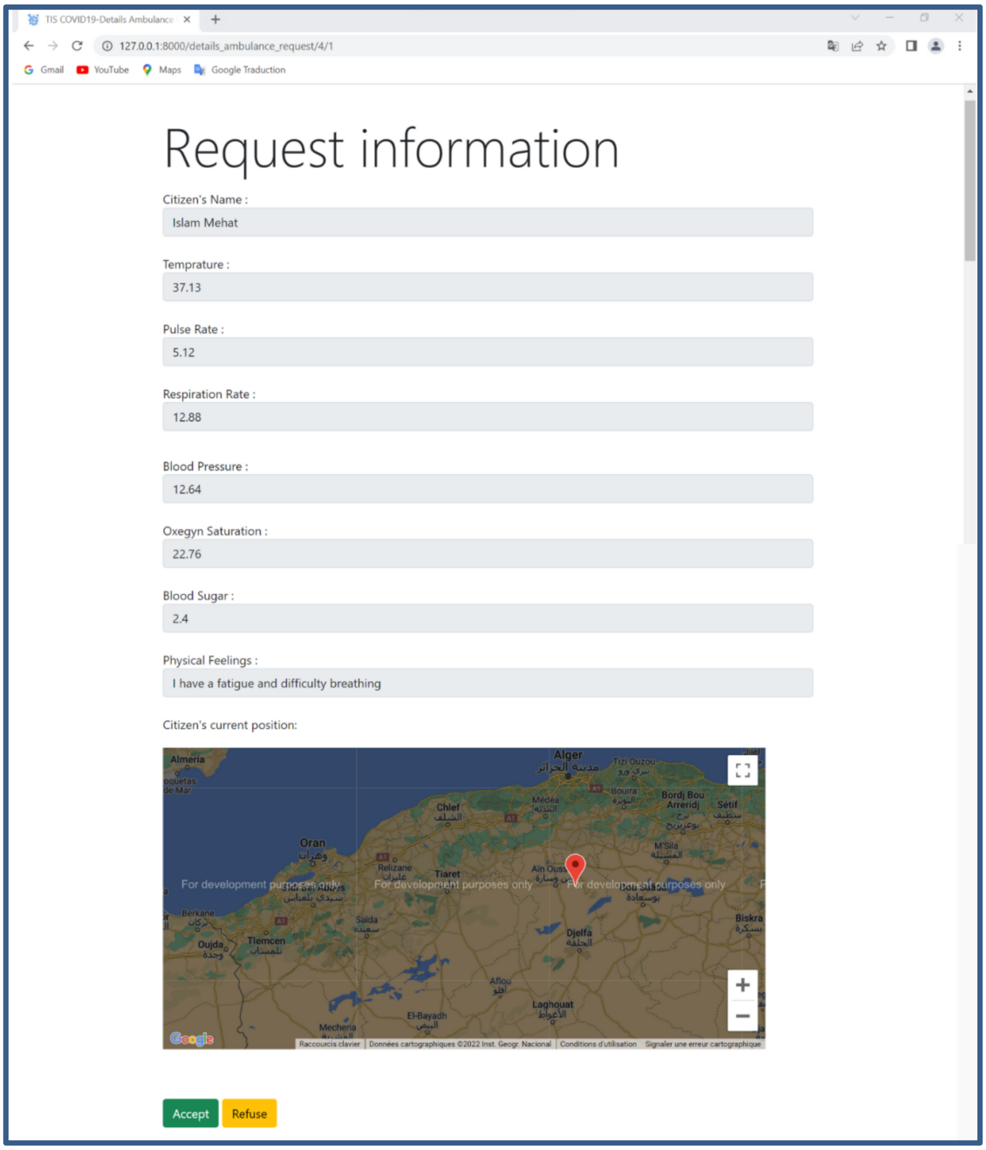


Figure 4.30: Accept/ refuse ambulance requests page

5. Conclusion

In this last chapter, we presented system architecture, different tools, languages and technologies used for developing our system. Also, we presented the use cases for all the users by means of some screen-shots.

General Conclusion

Artificial Intelligence is an innovative technology that is helpful to fight the COVID-19 pandemic. This technology is used for proper screening, tracking, and predicting current and future patients. Some applications of AI are for early detection, and diagnosis of the infection, with promising results close to the optimal.

Our project consists in developing a smart system based on ML and NLP technologies. We have tried to adopt the best possible solutions to achieve our goal.

The system consists of two applications. A mobile application that is used by the citizens, to make them capable of consulting their diagnostic results after inputting their diagnostic data. The application uses the three languages Arabic, French and English.

The TIS algorithm in the application is capable of specifying the result type which can be stable, warning, or dangerous using multi-classification method.

In the warning cases, the algorithm will choose the best doctor to send him an instructions request, including the citizen's diagnostic data. While in dangerous cases, the algorithm will send a caretaker alert to the favorite citizen's caretakers, and choose the best hospital to send an ambulance request to. The caretakers can contact the citizen using a phone call, and see their current position using Google maps.

The web application will be used by admins, doctors, and hospital managers to receive and manage the sent requests.

Unfortunately, we couldn't use the wearable to collect the diagnostic data, because no wearable can take the place of blood pressure, glucose, oxygen meters, and the other appliances that can measure the diagnostic data. Therefore, the values must be entered manually by the citizen. Also, we couldn't apply all NLP features due to the lack of time and data. However, we implemented a simple code that analyzes the voice and text data so that we can use them in the diagnostic operation.

We can consider from a perspective, different points to improve our system. First, dispensing with the doctor and placing him by a DL algorithm that uses the current database records of the doctor's instructions as a dataset. Second, add a smart NLP and SR algorithm as a personal assistant that can analyze the citizen's physical feelings data to guide him through the right actions they must make. Third, use a cross-platform technology to develop the mobile app to be able to use by the IOS devices.

Bibliography

[1] Marie-Odile Safon. (2019). Institute for Research and Information in Health Economics. \E-Health: Telehealth, digital health or connected health".

[2] Knitza, J., Simon, D., Lambrecht, A., Raab, C., Tascilar, K., Hagen, M., ... & Hueber, A. J. (2020). Mobile health usage, preferences, barriers, and eHealth literacy in rheumatology: patient survey study. JMIR mHealth and uHealth, 8(8), e19661.

[3] World Health Organization. (2017). Global diffusion of eHealth: making universal health coverage achievable: report of the third global survey on eHealth. World Health Organization.

[4] Tuckson, R. V., Edmunds, M., & Hodgkins, M. L. (2017). Telehealth. New England Journal of Medicine, 377(16), 1585-1592.

[5] NEJM Catalyst. (2018). “What Is Telehealth?”

[6] Saeed, F. (2021). Innovative Systems for Intelligent Health Informatics: Data Science, Health Informatics, Intelligent Systems, Smart Computing. Springer Nature.

[7] Lane, D. (2021). Machine Learning: An Interactive Introduction to Artificial Intelligence. No Starch Press.

[8] Natale, S. (2021). *Deceitful media: Artificial Intelligence and social life after the Turing Test*. Oxford University Press, USA.

[9] Kwekha-Rashid, A. S., Abduljabbar, H. N., & Alhayani, B. (2021). Coronavirus disease (COVID-19) cases analysis using machine-learning applications. Applied Nanoscience, 1-13.

[10] Shorten, C., Khoshgoftaar, T. M., & Furht, B. (2021). Deep Learning applications for COVID-19. Journal of big Data, 8(1), 1-54.

[11] V. Aleksandrovičs, E. Filičevs and J. Kampars, "Internet of Things: Structure, Features and Management," Information Technology and Management Science,Walter de Gruyter Gmbh , vol. 19, no. 1, p. 78–84, 2016.

[12] Idris, Muhammad Ridzuan & Mat Nashir, Irdayanti & Nordin, Alif & Ramlee, Mohd. (2021). The Internet of Things (IoT) Practical Book using Arduino WeMos D1 R1 Microcontroller.

[13] M. R. Abdmeziem and D. Tandjaoui, "Architecting the Internet of Things: State of the art," in Robotics and Sensor Cloud, Springer, Cham, 2015, pp. 55-75

[14] KASSAB, Wafa'a et DARABKH, Khalid A. A–Z survey of Internet of Things: Architectures, protocols, applications, recent advances, future directions and recommendations. Journal of Network and Computer Applications, 2020, vol. 163, p.

102663.

[15] GOODFELLOW, Ian, BENGIO, Yoshua, et COURVILLE, Aaron. Deep learning. MIT press, 2016.

[16] Haeb-Umbach, R., Heymann, J., Drude, L., Watanabe, S., Delcroix, M., & Nakatani, T. (2020). Far-field automatic speech recognition. *Proceedings of the IEEE*, *109*(2), 124-148.

[17] Swayamsiddha, S., & Mohanty, C. (2020). Application of cognitive Internet of Medical Things for COVID-19 pandemic. Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 14(5), 911-915.

[18] World Health Organization, Corona Virus, url : https://www.who.int/fr/health-topics/coronavirus#tab=tab_3

[19] Torres-Ruiz, J., Pérez-Fragoso, A., Maravillas-Montero, J. L., Llorente, L., Mejía-Domínguez, N. R., Páez-Franco, J. C., ... & Gómez-Martín, D. (2021). Redefining COVID-19 Severity and Prognosis: The Role of Clinical and Immunobiotypes. Frontiers in immunology, 3695.

[20] Gnanvi, J., Salako, K. V., Kotanmi, B., & Kakaï, R. G. (2021). On the reliability of predictions on Covid-19 dynamics: A systematic and critical review of modelling techniques. Infectious Disease Modelling.

[21] World Health Organization

[22] Lounis M. COVID-19 in Algeria: Chronology and evaluation of preventive actions. European Journal of Medical and educational Technologies 2020;13(1):em2001.

[23] Algerian health and hospital reform minister: Carte épidémiologique (2021).

[24] Lammers, M. J., Lea, J., & Westerberg, B. D. (2020). Guidance for otolaryngology health care workers performing aerosol generating medical procedures during the COVID-19 pandemic. Journal of Otolaryngology-Head & Neck Surgery, 49, 1-8.

[25] World Health O. Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages: interim guidance, 6 April 2020. Geneva: World Health Organization; 2020.

[26] Luo M, Cao S, Wei L, et al. Precautions for intubating patients with COVID19. Anesthesiology. 2020;132:1616–8

[27] World Health Organization, COVID-19 vaccines, https://www.who.int/fr/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines

[28] Joan Cabestany Carlos P_erez Albert Sama Daniel Rodriguez-Mart__n. \Arti_cial Intelligence Contribution to eHealth Application". In: (2018).

[29] Al-zubidi, A. F., AL-Bakri, N. F., Hasoun, R. K., Hashim, S. H., & Alrikabi, H. T. (2021). Mobile Application to Detect Covid-19 Pandemic by Using Classification Techniques: Proposed System. International Journal of Interactive Mobile Technologies.

[30] T. M. H. Alanzi, "A review of mobile applications available in the app and google play stores used during the COVID-19 outbreak," Journal of Multidisciplinary Healthcare, vol. 14, p. 45, 2021.

[31] tabaud, about the application url: https://tabaud.sdaia.gov.sa/IndexEn

[32] Michie, S., West, R., Pidgeon, N., Reicher, S., Amlôt, R., & Bear, L. (2021). Staying 'Covid-safe': Proposals for embedding behaviours that protect against Covid-19 transmission in the UK. British Journal of Health Psychology, 26(4), 1238-1257.

[33] Sudre, C. H., Lee, K. A., Lochlainn, M. N., Varsavsky, T., Murray, B., Graham, M. S., ... & Ourselin, S. (2021). Symptom clusters in COVID-19: A potential clinical prediction tool from the COVID Symptom Study app. Science Advances, 7(12), eabd4177.

[34] Morgan, A. U., Balachandran, M., Do, D., Lam, D., Parambath, A., Chaiyachati, K. H., ... & Asch, D. A. (2020). Remote Monitoring of Patients with Covid-19: Design, implementation, and outcomes of the first 3,000 patients in COVID Watch. NEJM Catalyst Innovations in Care Delivery, 1(4).

[35] Wymant, C., Ferretti, L., Tsallis, D., Charalambides, M., Abeler-Dörner, L., Bonsall, D., ... & Fraser, C. (2021). The epidemiological impact of the NHS COVID-19 App. Nature, 594(7863), 408-412.

[36] Abdool Karim, S. S., de Oliveira, T., & Loots, G. (2021). Appropriate names for COVID-19 variants. Science, 371(6535), 1215-1215.

[37] Grundy, Q. (2021). A Review of the Quality and Impact of Mobile Health Apps. Annual review of public health, 43.

[38] Alkodaymi, M. S., Omrani, O. A., Fawzy, N. A., Abou Shaar, B., Almamlouk, R., Riaz, M., ... & Tleyjeh, I. M. (2022). Prevalence of post-acute COVID-19 syndrome symptoms at different follow-up periods: A systematic review and meta-analysis. Clinical Microbiology and Infection.

[39] Shailaja, K., Seetharamulu, B., & Jabbar, M. A. (2018, March). Machine learning in healthcare: A review. In 2018 Second international conference on electronics, communication and aerospace technology (ICECA) (pp. 910-914). IEEE.

[40] Kaul, D., Raju, H., & Tripathy, B. K. (2022). Deep Learning in Healthcare. In Deep Learning in Data Analytics (pp. 97-115). Springer, Cham.

[41] Amin, R., Al Ghamdi, M. A., Almotiri, S. H., & Alruily, M. (2021). Healthcare techniques through deep learning: issues, challenges and opportunities. IEEE Access, 9, 98523-98541.

[42] Studio, A. (2017). Android studio. The Official IDE for Android, 9

[43] Peleg, D. (2017). Mastering Sublime Text. Packt Publishing Ltd.

[44] Friends, A. (2017). XAMPP Apache+ MariaDB+ PHP+ Perl. Apache Friends.

[45] Son, S., & Shmatikov, V. (2013, February). The Postman Always Rings Twice: Attacking and Defending postMessage in HTML5 Websites. In NDSS.

[46] Sutanto, E. (2020). Pemrograman Android Dengan Menggunakan Eclipse & StarUML. Airlangga University Press.

[47] Arnold, K., Gosling, J., & Holmes, D. (2005). The Java programming language. Addison Wesley Professional.

[48] World Wide Web Consortium. (2006). Extensible markup language (XML) 1.1.

[49] Lerdorf, R., Tatroe, K., & MacIntyre, P. (2006). Programming Php. " O'Reilly Media, Inc.".

[50] He, R. Y. (2015, January). Design and implementation of web based on Laravel framework. In 2014 International Conference on Computer Science and Electronic Technology (ICCSET 2014) (pp. 301-304). Atlantis Press.

[51] Enterprise, J. (2015). HTML 5 Manual Book. Elex Media Komputindo.

[52] Gaikwad, S. S., & Adkar, P. R. A. T. I. B. H. A. (2019). A review paper on bootstrap framework. IRE Journals, 2(10), 349-351.

[53] Islam, Q. N. (2015). Mastering PyCharm. Packt Publishing Ltd.

[54] Python, W. (2021). Python. Python Releases for Windows, 24.