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Intelligent System for Telemonitoring Healthcare. Case study : COVID-19.

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Dedication

I dedicate this work first and foremost To my dear parents, for all their sacrifices, love, tenderness, support and prayers throughout my studies, To my sisters Belkiss and Maram for their permanent encouragement, and moral support , To my dear brother, Kheyreddine, for his support and encouragement, To my fiancee, Malak for her support throughout my master's studies. Thank you for always being there for me.

Seyf-Eddine

Abstract

The COVID-19 pandemic has overwhelmed the existing healthcare infrastructure in many parts of the world. Healthcare professionals are not only over-burdened but also at a high risk of nosocomial transmission from COVID-19 patients. Screening and monitoring the health of a large number of susceptible or infected individuals is a challenging task. Although professional medical attention and hospitalization are necessary for high-risk COVID-19 patients, home isolation is an effective strategy for low and medium risk patients as well as for those who are at risk of infection and have been quarantined. However, this necessitates effective techniques for remotely monitoring the patients' symptoms. Recent advances in AI have strengthened the power of analyzing techniques and can be used remotely to analyze and monitor the vital signs of a patient and take actions instantly. In this thesis we propose My Health intelligent system, wich is an Electronic Health Record and a Remote Patient Monitoring system based on intelligent agents that collects vital signs of a patient and analyze it, store it and make a call to a favorite number phone, launch phone alarm to alert the nearby persons, sends an sms to the patient‘s responsible doctor and emergency operating services if there is a critical case.

لقد طغت جائحة كورونا على البنية التحتية للرعاية الصحية الحالية في أجزاء كثيرة من العالم. لا يتحمل أخصائيو الرعاية الصحية أعباء زائدة عن الحد فحسب، بل يتعرضون أيضاًا لخطر انتقال العدوى من مرضى كورونا. يعد فحص ومراقبة صحة عدد كبير من الأفراد المعرضين للإصابة أو المصابين مهمة صعبة. على الرغم من أن العناية الطبية المهنية والاستشفاء ضروريان لمرضى كورونا المعرضين لمخاطر عالية، إلا أن العزل المنزلي هو استراتيجية فعالة للمرضى منخفضي ومتوسطي الخطورة وكذلك لأولئك المعرضين لخطر العدوى والذين تم عزلهم. ومع ذلك، فإن هذا يتطلب تقنيات فعالة لمراقبة أعراض المرضى عن بعد. عززت التطورات الحديثة في الذكاء الاصطناعي قوة تقنيات التحليل ويمكن استخدامها لتحليل ومراقبة العلامات الحيوية للمريض عن بعد واتخاذ الإجراءات على الفور. في هذا البحث، نقترح نظام My Health (صحتي) الذكي، وهو عبارة عن سجل صحي إلكتروني و نظام لمراقبة المرضى عن بعد يعتمد على عملاء أذكياء تجمع العلامات الحيوية للمريض وتقوم بتحليلها وتخزينها وإجراء مكالمة إلى رقم هاتف مفضل، وإطلاق إنذار الهاتف لتنبيه الأشخاص القريبون ، إرسال رسالة نصية قصيرة إلى الطبيب المسؤول عن المريض ومصلحة الطوارئ إذا ما كانت هناك حالة حرجة.

La pandémie de COVID-19 a submergé les infrastructures de santé existantes dans de nombreuses régions du monde. Les professionnels de la santé sont non seulement surchargés, mais également exposés à un risque élevé de transmission nosocomiale des patients COVID-19. Le dépistage et la surveillance de la santé d'un grand nombre d'individus sensibles ou infectés est une tâche difficile. Bien que des soins médicaux professionnels et une hospitalisation soient nécessaires pour les patients COVID-19 à haut risque, l'isolement à domicile est une stratégie efficace pour les patients à risque faible et

moyen ainsi que pour ceux qui sont à risque d'infection et ont été mis en quarantaine. Cependant, cela nécessite des techniques efficaces pour surveiller à distance les symptômes des patients. Les progrès récents de l'IA ont renforcé la puissance des techniques d'analyse et peuvent être utilisés pour analyser et surveiller à distance les signes vitaux d'un patient et prendre des mesures instantanément. Dans cet article, nous proposons le système intelligent My Health, qui est un système EHR et RPM basé sur des agents intelligents qui collectent les signes vitaux d'un patient et les analysent, les stockent et appellent un numéro de téléphone préféré, lancent une alarme téléphonique pour alerter les personnes à proximité, envoyer un sms au médecin responsable du patient et aux services d'urgence en cas de cas critique.

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Introduction

In recent decades, mobile devices and Internet have seen great developments, which have facilitated a human's lives and made their livelihoods easier, so the difficult thing became easy and the distant became close, people today look like they live in one small village, they do what was —before— a dream or impossible. But this is not at all, dealing with modern technology differs from one country to another and from one person to another. Some of them took advantage of it in good ways and made it a reason for their development and prosperity, and some of them did the opposite. Among the greatest uses of modern technology, there are mobile devices and applications related to human's health, whether those that remind him to time of taking medications, such as "Medisafe Pill Reminder", or those that allows him to consult doctors by messaging such as "Docttocare", or those that monitor patients in clinical cases or at home such as "Dexcom", in addition to other useful applications that help during health emergencies.

It is noticeable that Algerian authorities don't have a system that can manage patients records or monitor patients remotely. We strive to be one of the contributors to enrich the technological community in a beneficial way. For that, we proposed a solution called "My Health".

My Health is composed of two parts: A Smartphone Intelligent application installed on patient's phone and a web application hosted on a server which is easy to access from anyplace has internet and on any device.

The smartphone application based on collecting the vital signs of the patient and this is in two ways, either manually entered by the patient or his companion by writing or by voice, or the system collects them automatically through sensors, the system contains a smart agent that analyzes this information and sends it to the main system to be saved and In order to be monitored by the responsible doctor, in the event that the result of the analysis is negative, this smart agent will perform several warning operations, such as sending a text message to the responsible doctor, as well as sending a text message containing the coordinates of his whereabouts to the Civil Protection, activating the phone alarm to notify people close to him in addition to this Possibility to call a favourite phone number.

The web application is an Electronic Health Record System which will contain all the patients information which can be previewed by patients or health workers an updated by doctors, and it also provides remote patient monitoring service. It based also on a smart agent that receives data from the smartphone application and store it on database.

Our thesis consists of four chapters organized as follows:

- Health and E-Healthcare.
- Intelligent systems for health
- Analysis and design
- Implementation

Chapter I

Health and E-Healthcare

I.1 Introduction

In this chapter we will present in a general way the basic notions on health, E-healthcare and it concepts More specifically, this chapter aims to answer the following questions:

- What is "Health"?

- What is "E-healthcare"?

I.2 Health

I.2.1 Definition

The World Health Organisation (WHO) Constitution of 1948 defines health as a state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity. In addition, the Ottawa Declaration states an "individual or group must be able to identify and realize aspirations, to satisfy needs, and to change or cope with the environment. Health is, therefore, seen as a resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources, as well as physical capacities"[21].

I.2.2 Historical reminder

- **Mid-nineteenth century:** neither hygiene nor the modes of propagation of infections.
- **1776:** Royal Society of Medicine realized the first collection of medical topographic data medical topography, laws, fight against livestock diseases...
- **1902 (France):** organization and sanitary regulation at the departmental and communal level and communal level, the obligation of vaccinations, declarations of diseases, disinfections
- **Beginning of XXth century:** tuberculosis and food hygiene, hygiene of workplaces, prisons, schooling, psychological problems, prophylaxis of infectious diseases...

I.2.3 Health concepts

Health is perceived in different ways giving rise to various concepts of health. Health was involved over the centuries as a concept from an individual concern to a worldwide social goal.

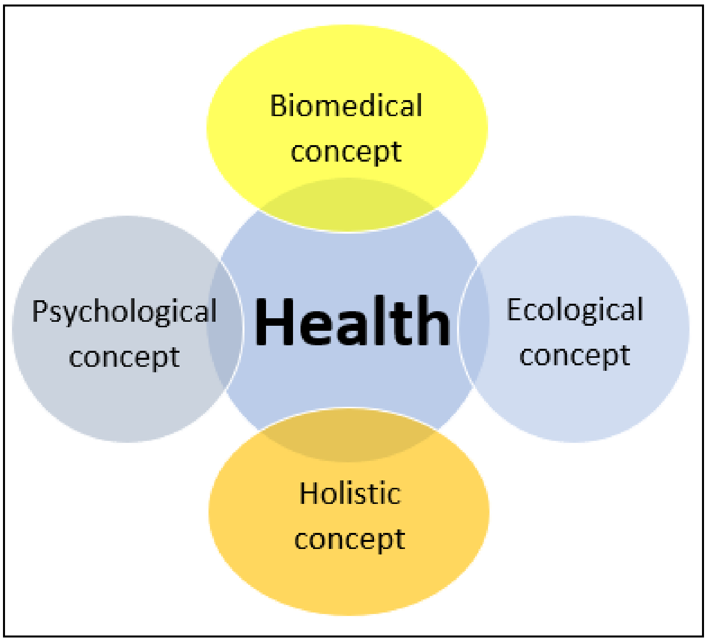

Figure 1.1: Health Concepts

I.2.3.1 Biomedical concept

Health is defined as the absence of disease, and if a person is disease-free, he is termed healthy. The germ theory of disease underpins this hypothesis.

I.2.3.2 Ecological concept

Health is a dynamic equilibrium between human being and his surroundings environment and disease is a maladjustment of man to environment. The ecological concept raises two issues :

- Imperfect man.
- Imperfect environment like air pollution, lack of safe water and bad sanitation.

I.2.3.3 Psychosocial concept

Health is not merely a biomedical phenomenon; it is also influenced by social, mental-cultural, economic, and political variables.

I.2.3.4 Holistic concept

This is the result of combining all of the above concepts. A sound mind, in a sound body, in a sound family, in a sound surroundings, is what health entails.

I.2.4 Dimensions of Health

There are five dimensions of health: physical, mental, emotional, spiritual, and social. These five dimensions of health provide a full picture of health as a change in any dimension affects the others.

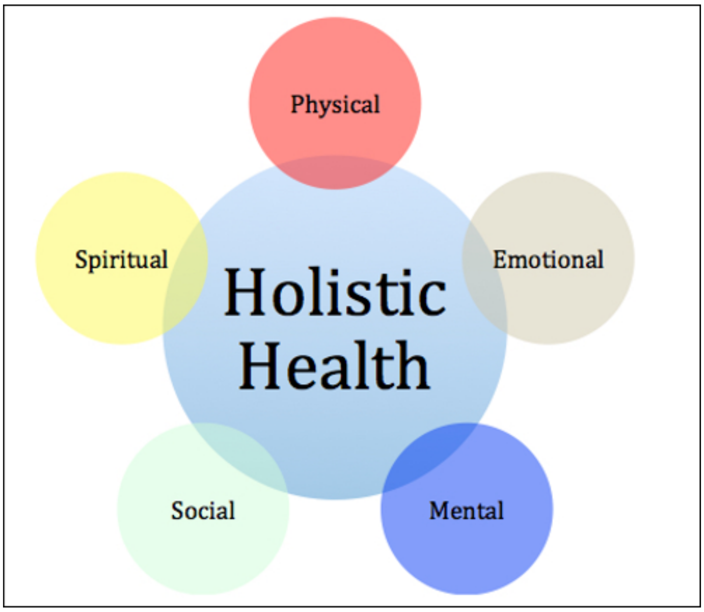

Figure 1.2: Dimensions of Health

I.2.4.1 Physical Health

Physical health can be defined as normal functioning of the body at all levels; a normal course of biological processes that ensures individual survival and reproduction; a dynamic balance between the body's functions and the environment; participation in social activities and socially useful work; performance of basic social functions; the absence of diseases, painful conditions, and changes; and the body's ability to adjust to the constantly changing conditions of the external environment [8](p.603).

I.2.4.2 Mental Health

Mental health can be defined as "a state of well-being in which the individual realizes his or her own abilities and is able to cope with the normal stresses of life, work productively and fruitfully, and make a contribution to his or her community" [23].

I.2.4.3 Social Health

Social health is a positive dimension of health which is included in the constitutional definition of health of WHO. It is an individual's ability to handle and act based on different social conditions.

I.2.4.4 Emotional Health

Emotional health is about the persons mood or general emotional state. It is our ability to recognise and express feelings adequately. It relates to your self esteem as well as your ability control your emotions to maintain a realistic perspective on situations.

The relationship between emotional and mental health is clear and as such some illnesses relate to both, such as: depression and anxiety.

Emotional health affects the other dimensions of health as a person with a good self esteem is more confident in social settings, makes friends quickly and often performs better in physical activity.

I.2.4.5 Spiritual Health

Spiritual health relates to our sense of overall purpose in life. People often find this purpose from a belief or faith system, while others create their own purpose. A person who has purpose to life is said to be healthier than those who don't see a purpose to life.

Spiritual health will very easily affect emotional and mental health as having a purpose in life can help you to apply yourself to achieving goals. Having a purpose to life can also help people to maintain a proper perspective on life and overcome adversity. Often people who are spiritual meet together regularly around their spiritual purpose, which helps to improve their social health.

I.2.5 Public Health

Public Health according to **Charles-E.A Winslow** is: "The science and art of preventing diseases, prolonging life, and improving the mental and physical health and vitality of individuals by means of concerted collective action to sanitize the environment, to control diseases of social importance, to teach the rules of personal hygiene, to organize medical and nursing services for the early diagnosis and preventive treatment of disease, and to implement social measures to ensure for each member of the community a standard of living consistent with the maintenance of health, the ultimate purpose being to enable each individual to enjoy his or her right to health and longevity. " Public health is therefore interested in the collective dimension, and integrates the concept of health with society, thus giving it a new dimension, which cannot be limited to the sum of individual health. There are also two important dimensions in the understanding of this concept: the method and the spirit. The method borrows from various sciences: information and education, economics, humanities, morals... [19].

I.2.5.1 Public Health Actions

I.2.5.1.1 Objectives : The public health objectives are set by the WHO and lead to actions according to the social, economic and cultural social, economic and cultural possibilities [6]. These actions are articulated in 4 phases:

- health planning, which determines needs based on epidemiology. This planning establishes objectives, defines a plan of action, implements a program and evaluates the results.
- prevention.
- health promotion.
- health education (national laws go down to the individual, their goal is to bring about change in people).

Public health actions focus on the following topics:

- alcohol.
- tobacco.
- road violence.
- drugs (etc...).

I.2.5.1.2 Levels : It is the public authorities that regulate these actions at different levels:

- **The state :** allocates its budget and draws up laws specifying the priority orientations in public health public health (e.g.: anti-cancer plan). The State organizes prevention against alcoholism, drug addiction and AIDS.
- **The department :** It finances certain actions with its own funds and draws up regulations concerning health and living conditions: drinking water, foodstuffs, waste disposal.
- **The municipality :** has a mission of control and disinfection
- **Health cooperation :** it is essential at the cross-sectoral level and is dependent on social and economic policy [6].

I.2.6 Health promotion and disease prevention [22]

I.2.6.1 Disease prevention

Disease prevention, understood as specific, population-based and individual-based interventions for primary and secondary (early detection) prevention, aiming to minimize the burden of diseases and associated risk factors.

Primary prevention: refers to actions aimed at avoiding the manifestation of a disease (this may include actions to improve health through changing the impact of social and economic determinants on health; the provision of information on behavioral and medical health risks, alongside consultation and measures to decrease them at the personal and community level; nutritional and food supplementation; oral and dental hygiene education; and clinical preventive services such as immunization and vaccination of children, adults and the elderly, as well as vaccination or post-exposure prophylaxis for people exposed to a communicable disease).

Secondary prevention: deals with early detection when this improves the chances for positive health outcomes (this comprises activities such as evidence-based screening programs for early detection of diseases or for prevention of congenital malformations; and preventive drug therapies of proven effectiveness when administered at an early stage of the disease).

It should be noted that while primary prevention activities may be implemented independently of capacity-building in other health care services, this is not the case for secondary prevention. Screening and early detection is of limited value (and may even be detrimental to the patient) if abnormalities cannot be promptly corrected or treated through services from other parts of the health care system. Moreover, a good system of primary health care with a registered population facilitates the optimal organization and delivery of accessible population based screening programs and should be vigorously promoted.

I.2.6.2 Health promotion

Health promotion is the process of empowering people to increase control over their health and its determinants through health literacy efforts and multisectoral action to increase healthy behaviors. This process includes activities for the community-at-large or for populations at increased risk of negative health outcomes. Health promotion usually addresses behavioral risk factors such as tobacco use, obesity, diet and physical inactivity, as well as the areas of mental health, injury prevention, drug abuse control, alcohol control, health behavior related to HIV, and sexual health.

Disease prevention and health promotion share many goals, and there is considerable overlap between functions. On a conceptual level, it is useful to characterize disease prevention services as those primarily concentrated within the health care sector, and health promotion services as those that depend on intersectoral actions and/or are concerned with the social determinants of health [22].

I.3 E-HealthCare

The first use of the term "E-Health" probably dates back to 1999. In a presentation at the 7th International Congress of Telemedicine - or remote medicine - John Mitchell, an Australian health consultant, defined it as "the combined use of the Internet and information technology for clinical, educational and administrative purposes, both locally and remotely [26].

I.3.1 Definitions

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. communication technologies (ICT) to the field of health and well-being. Telemedicine is a professional activity professional activity that uses digital telecommunications to enable physicians and other health professionals to and other members of the medical profession to carry out medical procedures at a distance, while telehealth is the use of communication systems to protect and promote health [26].

Application of the Internet and other related technologies in the healthcare industry to improve the :

- Access
- Efficiency
- Effectiveness
- Quality of treatment
- Business

I.3.2 Electronic Medical Record (EMR)

The widely deployed and popular computer applications such as electronic medical record (EMR), sometimes also called as electronic patient record, is in basic version, a digitalized version of the regular traditional paper-based medical chart for each individual. It contains all of the patient's medical and clinical data history created in a single facility, such as a hospital, clinic, or general practitioner (GP) office. EMR includes patient demographics, medical and treatment histories, vital signs, progress and problems notes, laboratory and test results, medications, treatment plans, immunization and allergies information, radiology images, and behavioral and environmental data. Health care providers use it to monitor and manage care delivery within the facility. EMRs have developed a lot over time and nowadays EMR itself comprises a lot of different modules [29].

I.3.3 Electronic Health Records (EHRs) [4]

I.3.3.1 Definitions

An Electronic Health Record or EHR is defined as "a repository of information regarding the health status of a subject of care in computer processable form, stored and transmitted securely, and accessible by multiple authorized users. It has a standardized or commonly agreed logical information model which is independent of EHR systems. Its primary purpose is the support of continuing, efficient and quality integrated healthcare and it contains information which is retrospective, concurrent, and prospective".

Electronic health records are considered to be a summary of various electronic medical records which are generated during clinical encounters. Thus, an electronic health record of a person is defined as an aggregation of all electronic medical records of the person from his or her very first entry into the healthcare system until today. It is recommended that all records be preserved during the lifetime of the individual. EHRs can contain a patient's medical history, diagnoses, medications, treatment plans, immunisation dates, allergies, radiology images, and laboratory and test results. Effectively, EHRs allow access to evidence-based tools that providers can use to make decisions about a patient's care and automate and streamline provider workflow.

I.3.3.2 Difference between EHR and EMR

Electronic Health Records (EHR) and Electronic Medical Records (EMR) are often used interchangeably. In fact, some confusion arises regarding whether an EHR differs from an EMR or not. However, in the present circumstances, the term EHR is referenced more frequently and considered to encompass more information compared to an EMR. Electronic medical records contain only clinical data of a patient, whereas electronic health records go beyond that to focus on the broader, total health of each patient.

Thus, an EMR contains the medical and treatment history of the patients generated in one single clinic/hospital. The information in EMRs therefore is normally used only within the boundary of the clinic/hospital and does not move beyond that.

On the other hand, EHRs are designed for use within a wider boundary, i.e., beyond the health organisation where such data is originally collected and compiled. EHRs are generated to share information between several healthcare providers, such as clinics, hospitals, laboratories, and specialists, so that they are updated by all such organisations involved in the patient's care and store information from all of them. The EHR data "can be created, managed, and consulted by authorised clinicians and staff across more than one healthcare organization." (as stated by The National Alliance for Health Information Technology (NAHIT) in the United States of America). It is therefore possible to move the information simultaneously with a patient across hospitals, states, and countries.

I.3.3.3 EHR System

While an EHR contains the medical and treatment histories of patients, an EHR system (EHR-S) may be built to contain information beyond standard clinical data and can be inclusive of a broader view of the information related to the healthcare facilities for the patients.

The EHR-S can be considered as an integration of patient information systems. It generates a data stream and provides support for health data analysis, policymaking, controlling the overall disease burden of the country, and performing research in social perspective. The EHR-S includes the network that links databases, interfaces, order entry, electronic communication systems, and the clinical servers (ISO TC 215, ISO/TR 20514:2005). An EHR system also contains security, privacy, and legal data.

The EHR System or EHR-S is defined to include [4]:

- Longitudinal collection of electronic health information for and about persons, where health information is defined as information pertaining to the health of an individual or healthcare provided to an individual.
- Immediate electronic access to individual-level and population-level information by authorised, and only authorised, users.
- Provision of knowledge and decision-support that enhance the quality, safety, and efficiency of patient care.
- Support of efficient processes for healthcare delivery.

I.3.3.4 Benefits of EHR

A personal health record is implemented as a documentation of any form of patient information, which includes medical history, medicines, allergies, visits to the doctors, and vaccinations.

With fully functional EHRs, all caregivers (doctors, nurses, management personnel) have ready access to the latest information, allowing more coordinated care for the patients. Patients themselves should be able to view, carry, amend, annotate, or maintain the data. Thus, the information gathered by the primary care provider can inform the emergency department clinician about the patient's life threatening allergy, so that care can be taken even if the patient is unable to share such information. A patient can view his or her own record and observe the trend of the lab results over the last year. A specialist can view the recent pathological or other tests to avoid any duplication. The notes regarding the patient's treatment in a hospital can help to inform the follow-up care and enable the patient to move smoothly from one care provider to another.

I.3.4 TeleMedicine & TeleHealth (TeleCare) [10]

I.3.4.1 Definitions

Tele distance **medicine** or **health** is the use of information and communication technologies (ICTs) to deliver health services where there is physical separation between care providers and/or the recipients over both long and short distances. It is about transmitting voice, data, images, and information rather than moving care recipients, health professionals, or educators. It encompasses preventive as well as curative aspects of healthcare services for recipients. The interactions can be between care recipient(s), care providers or educators, and lately also computerized devices standalone, as well as working though a mobile.

Telemedicine describes remote clinical services in the form of patient and clinician contact. It includes diagnosis, monitoring, advice, reminders, education, intervention, and remote admissions. Variations include clinicians discussing a case over video conference; telementoring, which means overseeing a procedure being done by a less trained person; digital monitoring with live feed or application combinations; and forwarding of test reports for interpretation by a specialist. Other examples are home monitoring of the aged or infirm through continuous feeding of patient health data, client to practitioner online conference, videophone interpretation during a consult, and also robotic surgery. In emergent situations, such support can save vital seconds and, in chronic care, cut down frequent travel, saving travel cost and time.

In **Telehealth** the scope expands beyond telemedicine to administrative meetings and other nonclinical services too, like inclusion of preventative and promotive components. Also included is tele-education, for patients or care providers, through distance learning, meetings, supervision, and presentations.

Besides saving in physical transportation, which could be by the care recipient, the provider, or both, all variants support achievement of quality aims, addressing barriers to care through innovative means and leveraging the proliferation of technology in an increasingly mobile-friendly and technology-centric population.

The information collected can be further processed and analyzed to plan a long-term health strategy of an increasing aged population, many living alone in diverse locations, with a rising number of chronic conditions.

I.3.4.2 Why TeleHealth?

Telehealth systems and processes provide benefits for a range of stakeholders, although many may not be aware of it. There are issues also, that constitute a Why not.

- **For the patient:** Faster, efficient, and cheaper care delivery without the constraints of time and distance. Travel costs are decreased. One must remember that this is required both for the patient and the accompanying relatives, who not only have to take the day off from work but also pay for the stay in hotels. Much of such stay before the procedure can be wasteful, for example, delay in appointment for a particular test or simple issues like specialist is on leave or you have to come fasting. Since the workup is done jointly over time with the help of the referring doctor, there is less chance of preprocedure tests being missed. Postprocedure care is also done locally. Outcomes improve—no wonder 76% of U.S. citizens elect telecare over a physical visit.

- **For nurse practitioners and GPs:** Medical knowledge today is not humanly manageable. Being a GP is one of the most difficult jobs as one never knows what the next patient will have. ICT not only provides access to written knowledge but also creates instant referral to a particular specialist. Hence, GPs and nurse practitioners can cater to a wider range of problems and better satisfy health needs within their local community leading to an expansion of clientele, who are more confident about the GPs capability. Results improve as one learns, even while the patients are jointly managed.

- **Specialists:** One neurologist for around 200,000 population in the United Kingdom is considered less than ideal. However, many specialists do not manage to find adequate work because patients are unable to reach them because of time or distance. Many specialists cover different hospitals on different days with much time wasted in traveling. Referrals done through the ePlatform are faster and easier with a high patient satisfaction rate. Cardiologists and neurologists can cover a range of hospital CCUs and ICUs and control administration zspecialists do not manage to find adequate work because patients are unable to reach them because of time or distance. Many specialists cover different hospitals on different days with much time wasted in traveling. Referrals done through the ePlatform are faster and easier with a high patient satisfaction rate. Cardiologists and neurologists can cover a range of hospital CCUs and ICUs and control administration of streptokinase for MI and stroke,1 respectively, even while staying at home. Patients do go window shopping for specialists, but they are more likely to freeze the decision after contact is established in any way. Specialists also need to refer their patients to other specialists, for example, a diabetic person with a stroke would need an endocrinologist and many a times an eye surgeon, a nephrologist, a vascular surgeon for diabetic foot, etc.

Telemedicine can be further classified according to the care process whether it is for consultation/monitoring/appointment provision or simple data collection.

In summary, the advantages of telehealth can be listed as per the U.S. Government Accountability Office, 2017:

- increases access to specialized and timely urgent care.
- increases the capacity and efficiency of specialists.
- reduces wait times for appointments and follow-up visits.
- reduces emergency department visits and the time patients spend in hospitals.
- reduces the discomfort and anxiety associated with patients traveling to receive services.
- reduces the costs and carbon emissions associated with patient travel.
- connects care teams to provide greater continuity of care.
- connects remote family members with long-stay patients.
- connects healthcare professionals for knowledge sharing.
- integrates with conventional care delivery models.
- keeps patients in their homes and communities longer.

I.3.4.3 Types

- **Real time (or synchronous):** Information or data is transferred live. Video conferencing between a patient and the healthcare provider is the prime example. Others include live viewing of ultrasounds or angiograms as they are taking place, streaming of procedures from the OR, or of heart sounds using a tele-stethoscope.

This is a convenient and easy form of telemedicine but requires high bandwidth, constant connectivity, and investment in related hardware [10].

Real time telecare is relatively easy to do but has a high dependence on technology and connectivity. Since it is visual and also easy to understand with a certain wow factor, that made it the major form to be advertised, as well as sold. However, getting outcomes remains a challenge, with pitfalls in the form of the need of constant connectivity, an inability to garner the entire information in one go, call drops, and a high dependence on training to get the best value. Most failures were because this type of telecare was oversold. However, real time remains to be the most popular type aided by cheaper connectivity and hardware. It is a major component of mHealth. Most cameras, standalone as well as within microscopes and endoscopes, X-rays, MRIs, etc. use digital formats; hence, sharing or transmitting on a real-time basis is easy [10].

- **Store and forward (S&F) or asynchronous:** Information is recorded and transferred. It can be stored locally or in a server depending on when connectivity becomes available. Viewing, comments, and even incorporation of the data into a different server can occur at the convenience of the other participants of the telehealth stream. It is less dependent on constant connectivity but more complicated to administer. Choice of software and interconnectivity standards has a greater role as interpretations may differ [10].

  S&F essentially depends on gathering patient information and sharing the same after processing. While sharing photos, there is need to create a relevant case of whose photo? and why an opinion is required. This required typing not only by the referring person, but also by the expert who may have some further questions or is providing the opinion in the form of a written prescription or advice. Sending scanned copies or photographs of prescriptions and reports is also extremely time-consuming besides being inefficient as the specialist might be just wanting to know the ESR and CRP, but will have to one by scroll through the entire set of 9 or 10 pages of the sent reports. The doctors' scrawl is famous for unreadability, photographs of such handwritten text, one can imagine would be even more difficult to interpret. Simple typing of the relevant information is also inefficient, slow and a reason for mistakes which may get accentuated, if anything, by autocorrect. This has been another rea son for failure of telemedicine systems of the past. We now describe a better way [10].

- **Telemonitoring:** Medical devices record and process personal information and transmit continuously (real time) or in a processed summary form (asynchronously) to the clinician. Examples are home care devices for old age and infirm as well as tele-ICU [10]. Because of the importance of this type in our thesis.

- **Mobile health or mHealth :**This is a special form of Digital Health. Smart mobiles have computing power and connectivity access better than specialized telemedicine systems of the past. They are inexpensive, have inbuilt audio and video, are flexible to allow both real time, and store and forward transmission as well as viewing from almost anywhere. Telemonitoring through inbuilt or even add-on sensors allows a single device to be a complete telehealth solution for a range of different problems. Many specialized applications or apps can directly inform the patient about their health status [10].

Another method of classifying telehealth is by defining the partners and the direction of the flow of information. These Telehealth Streams are hereby listed as follows:

- **Between patient and provider:** Phone calls, emails along with text, or multimedia messaging services are used to explain the problem at hand and request for an appointment at the first instance and later to review investigation reports, assess progress, and provide online prescriptions. Social media and commercial tools like Skype as well as a range of ready-to-use apps have made this stream very diverse [10].

- **Between providers of different levels:** If patients are considered as tier 0, healthcare delivery is classified under primary care (GP, tier 1), secondary (specialist, tier 2), or tertiary (super specialist, tier 3) with costs escalating with each rise in level. Tier 1 may even be provided at the subprimary level, meaning the nurse practitioner. In this stream, interactions take place between tiers for assistance in diagnosis and for management of emergencies. Information flow is more focused and better directed as compared with the previous stream. A complete history may be provided, and also a more detailed examination conducted by the remote practitioners. While procedures and advanced care is done at higher centers, follow-up like stitch removal, dressings, or prescriptions for pain is again relegated to the remote caregivers. This is the most important form of telehealth [10].

- **Between providers of the same level:** Formal tele-education is through online CMEs, meetings and webinars. Medical schools with less than ideal number of faculty can benefit from classes held elsewhere.17 Most conferences these days have a remote speaker and remote delegate component. Many a time, one may be confronted with an atypical case or need help for a complication from a more experienced colleague. Online discussion forums and bulletin boards are a more informal set. There has been a recent flood of groups operating on WhatsApp, Telegram, and other mobile platforms [10].

- **Within an enterprise:** An example is cardiac hospital chains, wherein angiograms are done in a set of peripheral franchises, and then patients are referred for surgery to the higher center. Follow-up care is again local with unified billing and care administration [10].

- **For public health purposes:** Data collection and analytics; discussions within the team for health administration; online meetings; healthcare system integration; assessment of need for support in emergencies; inventory management to ensure the flow of essential supplies; etc [10].

- **Home healthcare:** The patient stays at home mostly with ICT-based monitoring with or without involvement of medical personnel. Home Healthcare is being used extensively in developed countries for care of the aged and infirm [10].

Telehealth allows multiple, different disciplines to merge and deliver a much more uniform level of care using the efficiency and accessibility of everyday technology. Increasing usage of telehealth challenges the notions of traditional healthcare delivery, and different populations are starting to experience better quality, access, and personalized care in their lives [10].

- **Classification based on connectivity:** It is mentioned only in passing. During the early days the connectivity option used to be a major decider of projects, for example, the data sent by phone, SMS, or satellite link. Omnipresence of the broadband Internet as well as 4G and 5G has overcome these barriers. Such issues still predominate in some areas of the developing world [10].

- **Classification based on specialty:** Specialities that use images as an important component were among the earlier ones to adapt to telecare. An abbreviated list of the top departments or services, which have benefited from telehealth [10], is provided in **Table I.1**.

Table 1.1: Departments which can benefit from telecare

Service	Important Components	Role
Wound care	Unless very serious, wounds should be managed at the subprimary level. Requires transfer of images mostly. Sometimes telementoring and VC.	Very high
Radiology	Images and video. Preexisting digitization and PACS make it easy. DICOM a specific standard.	Very high
Dermatology	Images. Most problems are chronic, so decrease in frequency of visits is important.	Very high
Cardiology	Tele-ECG, telestethoscope, and emergency support for MI.	High
Ophthalmology	Images, which used to be taken through a slit lamp, an ophthalmoscope, and a fundoscope, can now be replaced by smart mobiles with special attachments.	High
Psychiatry	Video conference and face-to-face contact for counseling.	High
Pathology	Images and opinion. Special microscopes allow remote manipulation of the slide.	Moderately high
Intensive care	Monitoring devices and emergency support.	Moderately high
Emergency care	Allows care to begin as soon as an emergency call is made.	Moderately high
Rehabilitation	Immobility of patients is a constant concern.	Moderately low
Pediatrics	Emergency support and telemonitoring home-based care. A comfortable environment and access to parents is helpful for child development.	Moderately low
Orthopedics	X-ray films. Home monitoring of splints and dressings. Emergency support.	Low
Neurology	Tele-ICUs with robotic assistants and home care.	Low
Plastic surgery	For preop assessment, planning, and also follow-up care.	Low

I.3.5 Remote Patient Monitoring (RPM)

Remote patient monitoring (RPM) uses technological solutions to enable providing care outside of traditional clinical settings. It connects the patient with health care providers that are located at different locations by collecting medical and other health data from the patient in one location and transferring this data to the health care provider. Then the health care providers can assess this data and give out medical recommendations. RPM features such as physical parameter monitoring and trend analysis give out timely information to the caregivers about the changing conditions of the patient. Then it is possible to take actions before it requires going to the emergency center and stay in the hospital. Chronic disease management is an important part of RPM as people can manage their conditions independently from their own homes with minimal costs without complications and disruptions of visiting a care facility. RPM gives comfort to patients and their families because they know that they are constantly monitored and supported if needed, especially if care involves difficult self-care processes. RPM might have a positive effect by saving time, decreasing costs, and increasing patient satisfaction, quality of life, and access to better care [29].

One of the best definitions is still provided by the good old "Telemedicine Glossary of the EU" by Luciano Beolchi from 2003, in which the Italian sums it up in inimitable brevity: "The use of audio, video, and other telecommunications and electronic processing technologies to monitor patient status at a distance." [11].

I.3.6 Remote Patient Consultation (RPC)

Remote patient consultation (RPC) or e-visits are secure, documented, and direct consultative communications between health care providers and a patient. RPC can include phone calls, video conferencing, emails, text messages, and so on. This enables new ways of interaction for the patient to conveniently connect with his or her health care providers from wherever the patient or the providers are. RPCs are needed when a patient has a quick question, needs a simple service that usually would not need a physical encounter, or there are issues with distance, mobility, or transportation of the patient if for example they live in remote rural areas far away from health care providers. If systems for RPCs are connected to EMR, EHR, or HIE, the information for the consultation, if needed, can be gathered from these official systems and also entered into the patient record after the consultation. RPCs with greater functionality make possible for the patient to update their vital signs, allergies, and other information. RPCs can increase patient satisfaction by decreasing avoidable physical encounters and reducing time and costs of visiting a doctor. Also it might free up health care providers time [29].

I.3.7 Electronic Booking

Electronic booking or e-booking is the digital version of regular phone or in person appointment scheduling with a health care provider. E-booking has benefits for patients and providers. For the patient, it is more convenient, easier to use, and might include digital reminders, which reduce missing the appointments. Appointments can be made 24/7. For providers, it saves substantial time, improves staff satisfaction, and decreases the number of people who do not show up or cancel in the last minute. As staff spends less time scheduling appointments on phone, it opens up time for more valuable work.

I.3.8 Patient Portals

Patient portals (eHealth portals) are online access points that enable patients to use different services, communicate, and interact with health care providers and share medical and health information with each other remotely. Patient portals can be used 24/7. There are different types of patient portals. Some applications are standalone websites, others are integrated into health care providers existing websites, and some are modules added on top of EMR systems. There could be several different patient portals in use for the patient at the same time from different service providers. These patient portals can include and show different information and have different services. This is a real shortcoming, as the information is fragmented and inconvenient to access. The aim of patient portals is to increase efficiency and productivity for patients and health care providers.

Patient portals offer different services. The core functionality of every patient portal is the ability for the patient to securely access health information that has been collected about them by the health care providers. This makes it possible for the patients to understand their health better and take more active stance for improving it. On the other hand, people might want to check that their health information is correct. Next functionality that many patient portals have is RPCs. Patients can communicate with their caregivers by sending messages, commenting, or asking questions. Patient portals might also enable patients to fill some registration forms that reduce visitation time in a health care facility. Electronic booking might be also part of patient portals. In patient portals, people can give permissions such as organ donation permission and prohibition of resuscitation or blood transfusion. People can also designate trustees and close their own health data. Some patient portals also allow to order eyeglasses and contact lenses. Patient portals might also enable online requests for prescription renewals and refills. This way patients do not have to physically visit their health care providers or call them. eHealth portal services can be quite useful for the patients and help patients do better informed decisions and reduce inefficiencies. As can be seen, there are different services available and new ones being constantly developed [29].

I.4 ICT Technologies for E-Healthcare

I.4.1 Artificial Intelligence & Machine Learning

I.4.1.1 Definitions

Artificial Intelligence (AI) is the science and engineering of making intelligent machines, especially intelligent computer programs, or more concrete: "...is the capacity of a computer program to perform tasks or reasoning processes that we usually associate to intelligence in a human being" [28].

Machine learning (ML) is a subset of AI. ML provides software, machines, devices, and robots with the ability to learn without human intervention or assistance or static program instructions [17].

Machine learning evolved from the study of pattern recognition and computational learning theory. The term was coined by AI pioneer J.A.N. Lee in 1959, who defined it as a "field of study that gives computers the ability to learn without being explicitly programmed."

The implementation of it depends on having sufficient computing resources housed at the required level, and this together with the availability of the necessary data to apply the associated algorithmic techniques (machine learning, pattern recognition...). Very often, sharing distributed computation resources among the different levels is a convenient strategy to be applied.

The main objective of an eHealth initiative supported by AI is to have a healthcare system reinforced by a series of strategies based on the extraction of knowledge accumulated in the large amount of data that the system generates about the patients.

Data captured by certain wearable devices can be conveniently treated to be sent and integrated to a higher level, in the patient's medical history (EHR)ss, existing in the server system or computing cloud of the reference hospital. Other existing information in this level of the architecture is the set of data associated with the electronic prescription, which allows the professionals to have a privileged information and knowledge about the condition and evolution of the patient.

The methods used in artificial intelligence are aimed at integrating knowledge about a given problem (healthcare in our case) into an algorithmic set, with the purpose that after a learning process, the AI system will be able to generalize a solution of those cases that it has never analysed before. This knowledge is extracted from the analysis of the corresponding data and is accumulated during a learning process.

Depending on the type and number of treated data , the level of the IoT architecture that we are considering, and the problem to be solved, it will be appropriate to decide between the different techniques and applicable machine learning methods [28].

I.4.1.2 Machine Learning Methods [28]

- **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 labelled 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.

- **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 labelling 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).

- **Semi-supervised learning methods:** in this methodology, the two previous methods are combined according to a defined strategy. We can mention Co-training as a classic semi-supervised setting.

Another automatic learning typology called **Knowledge based method** can be implemented. This approach represents and transfers knowledge from a human expert (healthcare personnel, medical experts...) to the computer algorithms in order to stablish a computer-aided decision support system. For example, this type of method can deliver tailored information and advice to patients, taking decisions that are described in the treatment plan.

As mentioned above, the type of learning algorithm to be used is largely dependent of the problem to be solved and the boundary conditions that must be respected. These constraints establish, among other characteristics, the necessary computing capacity, the necessary number of data and parameters of the model (this largely determines the requirements of the hardware that must process the information). For example, if an algorithm should be run on the sensor layer (for instance, in a wearable), the method must be chosen carefully and will probably consider a compatibility with a reduced need of memory and computing resources. Power consumption is of paramount important and largely related with the intensive use of resources.

If we consider the management and analysis of large amounts of data, probably the server or cloud layer levels should the most appropriate, using a combination of supervised and non-supervised methods. At that level, some new strategies of Deep Learning (DL) should be possible. In fact, a DL strategy is based on a combination of conventional ANN structures with the corresponding learning algorithms, requiring a considerable computational capability.

I.4.1.3 Benefits

The following are some of the advantages that can be seen in the application of AI techniques to eHealth:

- Sensing interoperability: multiple sensors with different features coexisting in a system.
- Lifelogging mode: continuous monitoring and access to the personal data in a life-long term.
- Uncontrolled environment: The new evolving scenario is uncontrolled, with many aging people, transformation of the traditional healthcare services...
- High volume of data.
- Security and privacy.

I.4.2 BigData

I.4.2.1 Definition

Big data is data that contains greater variety, arriving in increasing volumes and with more velocity. This is also known as the 3Vs [20]. Put simply, big data is larger, more complex data sets, especially from new data sources. These data sets are so voluminous that traditional data processing software just can't manage them. But these massive volumes of data can be used to address business problems you wouldn't have been able to tackle before [20].

In healthcare big data is the abundant health data amassed from numerous sources including electronic health records (EHRs), medical imaging, genomic sequencing, payor records, pharmaceutical research, wearables, and medical devices, to name a few. Three characteristics distinguish it from traditional electronic medical and human health data used for decision-making: It is available in extraordinarily high volume; it moves at high velocity and spans the health industry's massive digital universe; and, because it derives from many sources, it is highly variable in structure and nature.

With its diversity in format, type, and context, it is difficult to merge big healthcare data into conventional databases, making it enormously challenging to process, and hard for industry leaders to harness its significant promise to transform the industry [18].

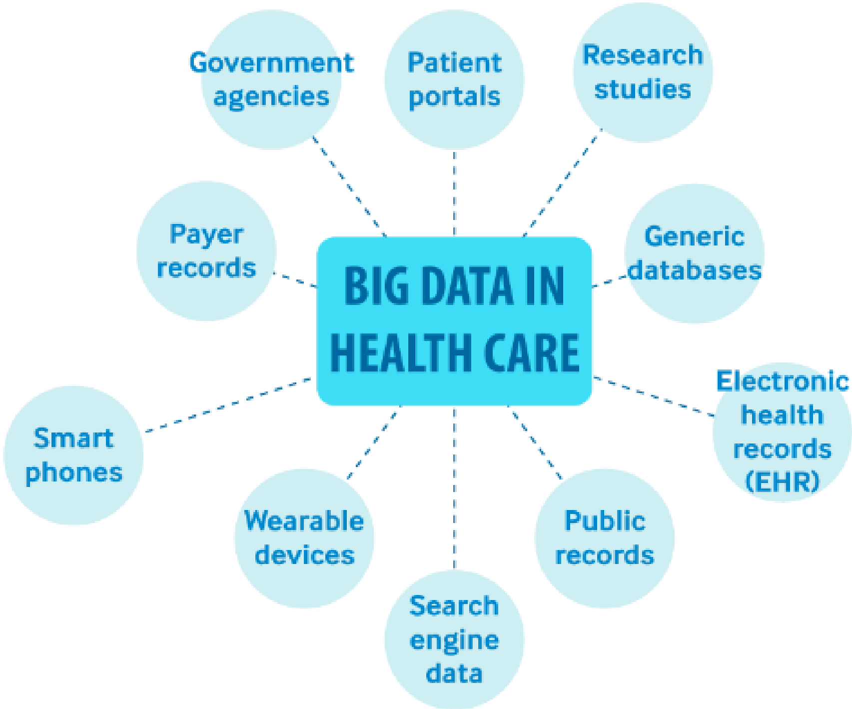

Figure 1.3: Big Data Sources in Healthcare

I.4.2.2 Applications for Big Data in Healthcare [18]

- **Keeping patients healthy and avoiding illness and disease:** stands at the front of any priority list. Consumer products like the Fitbit activity tracker and the Apple Watch keep tabs on the physical activity levels of individuals and can also report on specific health-related trends. The resulting data is already being sent to cloud servers, providing information to physicians who use it as part of their overall health and wellness programs.

- **Expanding diagnostic service:** gives patients greater access to professional care. Apps for mobile devices, such as Aetna's Triage, advise patients on their medical condition using aggregated data and can recommend patients seek medical care based on input to the app.

- **Reducing prescription errors:** improves outcomes and saves lives.

- **Reducing costs:** The greater insight that medical data gives physicians translates to better patient care, shorter hospital stays, and fewer admissions and re-admissions.

I.4.2.3 Challenges [18]

- **Data Aggregation Challenges:** first, patient and financial data are often spread across many payors, hospitals, administrative offices, government agencies, servers and file cabinets. Pulling it together and arranging for all data producers to collaborate in the future as new data is produced requires a lot of planning. In addition, every participating organization must understand and agree upon the types and formats of big data they intend to analyze. Looking beyond issues of the format in which it is stored (paper, film, traditional databases, EHR, etc.), the accuracy and quality of such data need to be established. This requires not only data cleansing (usually a largely manual process), but also a review of data governance: Was the data recorded accurately, or have errors crept in, perhaps over a period of many years?

- **Policy and Process Challenges:** once data is validated and aggregated, various process- and policy-related issues need to be addressed. The HIPAA regulations demand that policies and procedures protect health information. Access control, authentication, security during transmission, and other rules complicate the task. This multifaceted issue has been solved to some extent by cloud service providers, perhaps most notably Amazon AWS, which offers cloud services that comply with HIPAA and Protected Health Information (PHI).

- **Management Challenges:** finally, realizing the promises of big data analytics in healthcare requires organizations to adjust their ways of doing business. Data scientists will likely be needed along with IT staff that have the required skills to run the analytics. Some organizations may struggle with the thought of having to "rip and replace" much of their IT infrastructure, although cloud service providers mitigate some of those concerns. Physicians and administrators may need time before they trust the heretofore unseen advice big data can provide.

I.4.2.4 The Future for Big Data in Healthcare

- **Precision medicine**.

- **Wearables and IoT sensors:** have the potential to revolutionize healthcare for many patient populations—and to help people remain healthy. A wearable device or sensor may one day provide a direct, real-time feed to a patient's electronic health records, which allows medical staff to monitor and then consult with the patient, either face-to-face or remotely.

- **Machine learning:** a component of artificial intelligence as already mentioned above, and one that depends on big data is already helping physicians improve patient care. Machine learning, together with healthcare big data analytics, multiply caregivers' ability to enhance patient care.

I.4.3 Cloud Computing [5]

I.4.3.1 Definition

Cloud computing is an innovative system that aids the delivery of digital services over the internet. It allows its user access to servers, database, infrastructure, storage and many more services at a reduced cost and a faster and convenient way.

In the 21st century, cloud computing is one of the most brilliant and efficient inventions and a lot of industries are taking advantage of it. Healthcare however leads the way in the adoption of cloud computing which is quite surprising for an industry that lags in technological adoption. Research shows that more than 35% of healthcare organizations hold more than 50 per cent of information and infrastructure in the cloud, and the global market for cloud technology in healthcare has a growth expectation of $25 billion by 2023. The pandemic (COVID-19) has also helped to boost the adoption of cloud computing by the healthcare industry which is also good as the advantages of cloud computing are wide, and a lot of patients could benefit from this.

I.4.3.2 Benefits

There are numerous advantages to cloud adoption in healthcare, and these are just a few of the reasons why the trend is still gaining traction :

- **Security:** one of the major benefits of the cloud is the security it provides. A lot of concerns have been raised over the years as to the safety of leaving patient's data and information on a third-party server, and also adhering to privacy laws like GDPR and HIPAA. But storing information in the cloud also helps to protect these data and information from being lost. Data stored in hospitals and their servers could easily be lost in the case of a system failure or breach information, but storing this information in the cloud increases the level of security and protects these data from those losses while also serving as a backup.

- **Service at Reduced Cost:** cloud computing also allows healthcare companies to cut cost drastically. The cloud provides a platform that allows hospitals and healthcare centres to store patient data and information online and also access them easily. This service saves the companies cost because they no longer have to purchase really expensive hardware, software, servers and hire personnel to maintain these infrastructures.

- **Allows Patients to Own their Data:** an advantage of cloud computing is that it gives patients and healthcare consumers control and power over their own information. Patients have been granted access to the cloud in order to access their own information. This helps to improve trust and allows for easy personalization of healthcare.

I.4.4 Internet Of Things & Sensors

I.4.4.1 Overview:

The Internet of Things (IoT) is a physical device along with other items network that embedded with software, electronics, network connectivity, and sensors to collect objects in order to exchange data. The IoT impact in healthcare is still in its initial development phases. The IoT system has several layers that lead to implementation challenges where many engaged devices have sensors to collect data. Each has its manufacturer own exclusive protocols. These protocols using software environment associated with privacy and security raise new challenges in the IoT technology. This current chapter attempts to understand and review the IoT concept and healthcare applications to realize superior healthcare with affordable costs [2].

The IoT is a novel Internet revolution, where objects/devices are organized to realize intelligence system for enabling context related decisions. The information is accessible by other things, or components of complex services. This IoT system is associated with the cloud computing capabilities and the unlimited addressing capacity of the Internet transition towards IPv6. The communications and infor mation rapid technology convergence occurs at technology innovation layers, namely the data, cloud, devices, and communication networks. The healthcare reliance on IoT is aggregating to develop access to care, to increase the care quality and to reduce the care cost.

The foremost IoT system must provide powerful, simple application access to IoT data and devices to aid designers for visualization dashboards, analytics applications, and healthcare-IoT applications. The major key abilities that leading platforms have to include:

- **Easy device management:** easy device management empowers enhanced asset availability, minimized unintended outages, increased throughput, and reduced maintenance costs.
- **Simple connectivity:** a noble IoT platform makes it easy to perform device management functions and to connect devices. Scaled cloud-based services can be performed easily with applying analytics to achieve insight organizational transformatio.
- **Informative analytics:** with massive IoT data volumes, analysis is necessary for superior decisions. Real-time analytics are essential to monitor the existing conditions and respond consequently [2].
- **Intelligently transform:** information ingestion and store the IoT data to merge data and cloud in an integrating way. Data is consumed from platforms and diverse data sources, and then the indispensable values are extracted using valuable analytics.

I.4.4.2 Sensors [24]

Basically, a sensor is equipment which can detect environmental changes. A sensor has no use unless it is attached to an electric system. Once that is done, it becomes the key component. Sensors are capable of measuring physical singularity, e.g., temperature, humidity, etc., and converting it into a digital signal. Base of a good sensor consists the below attributes:

- It must be delicate to the singularity under measurement.
- It must not be affected by other environmental singularitie.
- While converting to digital signal or gathering the environmental data, sensor should not alter it anyhow.

A vast number of sensors are offered with us nowadays to quantify almost every physical phenomenon around us. Knowingly or unknowingly we all have come across the following sensors at some point of Life: thermometer, light sensor, pressure sensor, motion sensors, gyroscope, gas sensors, and accelerometer. Figure 1.4 shows different types of sensors available.

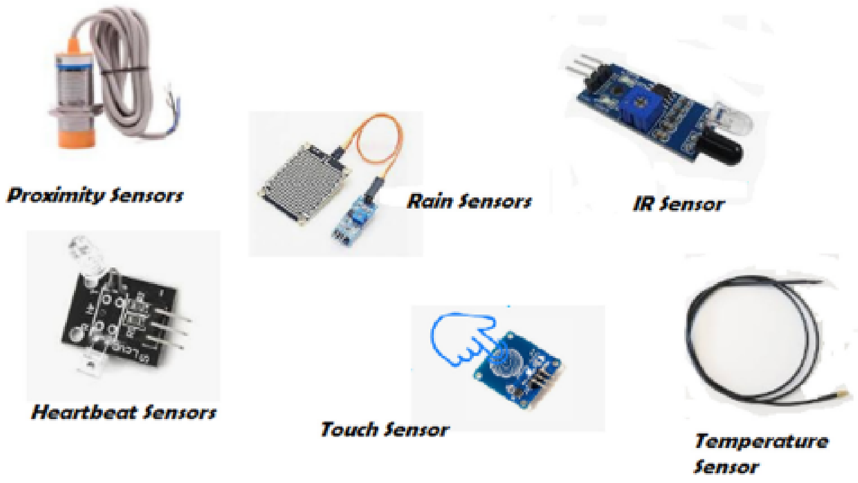

Figure 1.4: Different types of sensors

Key points for a sensor:

- **Range:** The upper limit and lower limit of the values of the parameter that the sensor is measuring.
- **Sensitivity:** The minimum variance of the measurement that causes a distinct change in the output signal.
- **Resolution:** The smallest alteration in the phenomenon that the sensor is able to sense.

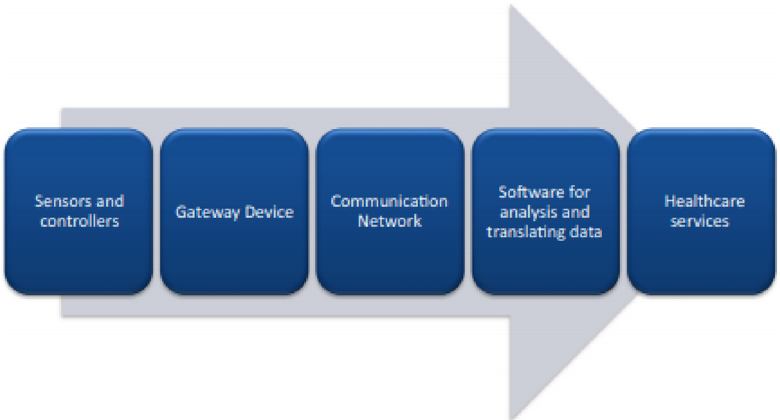

Figure 1.5: IoT Architecture

I.4.4.3 Sensors Classification

Sensors can be clustered by numerous standards:

- **Passive/Active:** Passive sensors are the ones which don't require an external power source, while active sensors require an external power source to perform its job.
- One type of cataloging is done based upon the technique used for measuring and sensing. Examples are electrical, chemical, etc.
- **Analog/Digital:** Sensors which generate an analog signal, i.e., continuous signal, are called analog sensors. The sensors that transmit discrete signals are termed as digital signal.

A huge variety of classifications are available to cluster sensors. We just discussed most basic ones here.

I.4.4.4 History of IoT in healthcare

For the last 10 years or more, patients are being introduced to IoT devices in different forms. For some patients, following up for different parameters, e.g., temperature monitors, fetal monitors, ECG, blood glucose monitor, etc., is very important but it needs to be done by medical professionals. Introduction of IoT devices has changed this scenario up to a great extent by reducing the need of direct patientephysician communication. IoT has opened the gateway for real-time and more valuable data for medical professionals.

Primitive IoT applications in healthcare had smart beds which could detect whether vacant or not or if a patient was trying to get up, without manual intervention.

Another application was home medication dispenser which could notify when medication wasn't taken or any other alerts and could upload the data to cloud for proper actions [24].

I.4.4.5 Challenges in current healthcare system

The problem areas in healthcare system where IoT can have the biggest impact are the aging population, increased number of patients with a chronic disease (e.g., diabetes, asthma, etc.), and the general inefficiency of the healthcare systems shown in Figure 1.6.

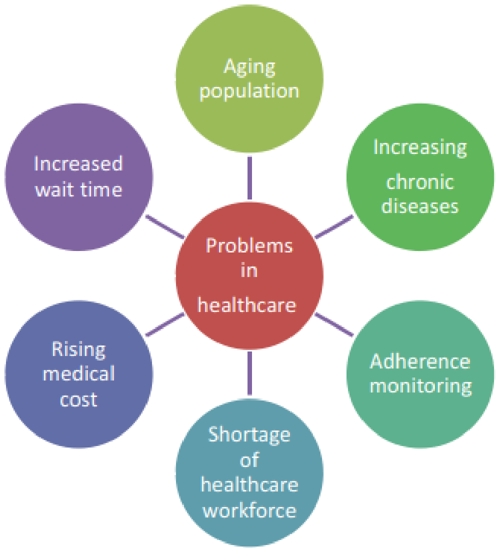

Figure 1.6: Challenges of current healthcare system

- **Aging population:** IoMT or Internet of Medical Things could be a very powerful tool for an aging population. Studies suggest, by 2025, 1.2 billion of the 8 billion people on the earth will be elderly. Elderly people are likely to have more health-related issues. As a result the cost of healthcare will increase as our population continues to age. Elderly people require more routine checkups and more monitored environment [24].

- **Chronic diseases:** Patients with chronic diseases require frequent visits to the doctor's office to monitor their condition. By the use of IoT the need for face-to-face visit can be reduced which in turn will reduce the medical costs. IoT devices can collect and send patients' health information and vital data to the doctor through network and the doctor can use those information to provide remote healthcare support [24].

- **Failing to adhere to doctor's orders:** In the traditional healthcare system, doctors have no way to track if the patient is following his or her orders or not. Many a times patients don't adhere to the medication or lifestyle prescribed by the doctor once they leave the healthcare facility. This lack of cooperation increases the risk of falling ill again as the disease cannot be fully cured [24].

- **Lack of healthcare personnel:** The rate at which requirements are increasing for healthcare services demands increased number of staff to provide services. Workforce includes doctors, nurse, nutritionists, caretakers, assistants, etc [24].

- **Rising medical cost:** Increase in chronic diseases and increased aging population rise the expenditure for medical services. One of the key problem areas in healthcare services today is the increased cost [24].

- **Increased wait time:** Minor checkups at the clinic have become as tedious as a trip to the emergency room. Apart from the medical expenses, emergency room waiting times are sometimes too long [24].

I.4.4.6 The impact of the Internet of things on health care

Internet of Things will be the phase changer of healthcare industry. From taking care of patient's health by taking care of comfort zone of both the parties at very low cost. Interconnected devices in the Internet provides more feasibility to the patients to connect them via specialist all over the world. In a single sentence we can say IoT as "It provides seamlessly healthcare system to the patients." The IoT in healthcare provides the observation of heartbeats, glucose level as well as the routine water level measurement of the body etc [2].

Mainly IoT in Healthcare focuses on:

- Critical treatments which have high risk of life.
- The routine medicine/check-up of the patient.
- Critical treatments by standard way and connect machine, people, data that can be deployed on machine or in the cloud.

The main idea of applying IoT in healthcare is move out from traditional area to visit hospitals and waiting will come to an end. The concept here is that it can be able to sense, process moreover communicate with biomedical and physical parameters so that they can work on it [2].

The view is to connect the doctors, patients via smart device and each entity can roam without any restrictions. The idea is constant monitoring of patient take some important information and upload it to doctor's side then he can suggest further steps to be followed. Here to upload the data patient can take the use of cloud services, the big data then the analysis of the data will do. The smart devices are the necessity of user's life. A user needs to access available wide area network with highly facilities applications which will solve the maximum problem of the user [2].

While designing something for health some criteria that need to be take care is:

- IoT for healthcare should be in centre not the technology which is implemented [2].
- We think IoT as wireless sensor network (M2M) communication will happen. Here reliability is most important criteria for it [2].
- The flexibility that is provided should be mobile. One should be able to roam even after having it [2].

Healthcare with IoT they are mainly based on the network connected devices that can directly communicate with each other to capture the data, process the data, through the secure service layer. Other useful healthcare devices can be independent living services, telehealth, wearable devices. Specifically in the field of telecare, remote monitoring of the users allow more self management of chronic disorders and cost reductions [2].

Figure 1.7 presents the planned architecture for HealthCare in Internet of things. With the help of figure we can say that basically it is made up of four layers. The first layer which is the Medical devices layer shows that it is made up of various device e.g. cylindrical magnetic resonance machine (MRI machine) which is with the help of Ethernet connected with the second layer which is M2M Multi-Service Gateway which consist of Remote Gateway Routers. The routers are responsible for uploading the data to central data repository. Third layer is M2M Integration Platform which is of central data repository which could be public/private cloud. The fourth layer of proposed architecture M2M Integration Platform which uses the data presented at the cloud for notifications regarding regular check-ups and reminder of medicines are sent as a notification to the patients, reports are generated. The cloud system might as well connected to the IT database for the live data purpose [2].

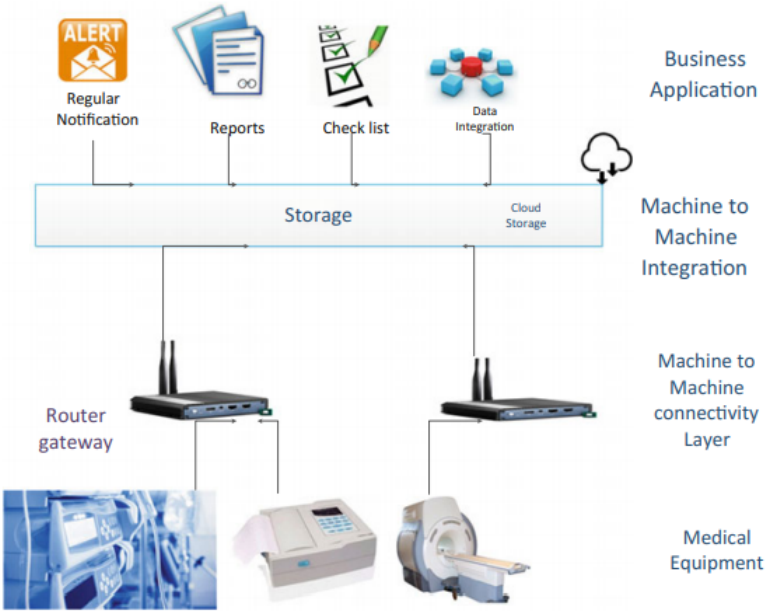

Figure 1.7: Proposed HealthCare architecture in IoT

The future of Internet of Things mainstream will be based on efficient wireless protocols, cheap and low-power microprocessor, right standardization, support of communities etc. The medical care should provide the wearable devices, physician and associate system must facilitate the information and rigorously should protect the patient's privacy. To achieve this healthcare part in Internet of Things must be as flexible and rapidly scalable as they are highly secure [2].

The working of monitoring patients remotely when they are at their home known as telemonitoring system has one between operation that passes the sensed data to remote server which is responsible for critical event detection, analysis of collected data moreover for consolidation too. By this way associated with smart sensor which is responsible for smarter environment which pushes the information to medical teams to communicate, to technologies for citizen (especially for elders) to find best suitable condition to proceed with proper local treatments [2].

Few facilities that will be added when we talk about Internet of Things in HealthCare are:

- **Flexible patient Monitoring:** While most of the patient needs to move from very places, Internet of Things will allow patient to choose their comfort zone and then they can perform any treatment remotely without moving from their place [2].
- **Improved Quality of Drug:** One of the biggest problem for today's drug industry is to maintain and produce the drug. One solution for the drug management came into the picture is to tag each and every drug with one RFID tag which will enter inside the body and it will provide the medicine as well as it will also monitor the inside body structure. It will help to take advance step for any dieses like Cancer [2].

Personalized healthcare is based on an individual's exclusive behavioral, biological, social characteristics. This leads to superior outcomes with making healthcare cost-effective. A supportable service focuses on the early disease detection, and homecare rather than the exclusive clinical one. IoT can handle the care personalization services and can preserve a digital identification for every individual. Various equipments are used in healthcare, to communicate and to make the omnipresent system-of-system. Thus, a categorization of the IoT based on personalized health care systems includes remote monitoring and clinical care [2], where:

- Remote monitoring allows the ready access to actual health monitoring through using dominant wireless solutions connected through the IoT to monitor the patients using the secured captured patient health data. Several complex algorithms and sensors are employed for data analysis, and then share this data via wireless connectivity to attain medical the professionals' health recommendations remotely [2].
- Clinical care employs noninvasive monitoring IoT systems for hospitalized. This clinical care system uses sensors for collecting physiological information that to be stored and analyzed using cloud. It delivers a continuous automated information flow, which improves the care quality with lower cost [2].

The general framework for the IoT's system consists of several architectures for health monitoring devices [2]. The common features/uses of the IoT health monitoring are as follows:

- It gathers data from sensors using wireless sensor networks (WSNs).
- It supports user displays and interfaces.
- It allows network connectivity to access infrastructure services.
- It provides robustness, accuracy, reliability and durability.

I.4.4.7 Requirements in healthcare

The main components/requirements for the IoT system in healthcare applications are:

- **Wireless Sensor Networks (WSNs):** connects a number of sensor and nodes in a network via wireless communication. This incorporates the network into a higher level system using a network gateway [2].

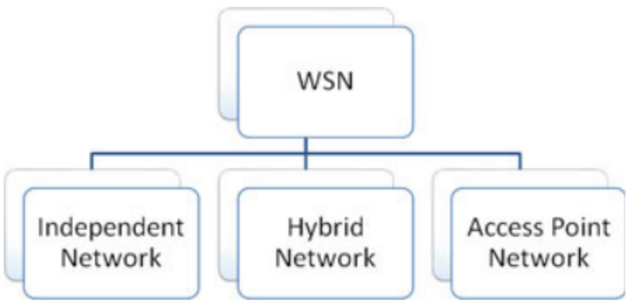

Figure 1.8: Classification for the WSN

- **Ubiquitous Sensor Network (USN):** is an extension of WSN combined with an IoT application system. It uses gateways which are information hubs that assemble sensor data, analyses data for further transmission to the cloud via wide area network (WAN). Physical data for the monitored parameters are measured using sensors. There are three approaches to connect the WSNs to the Internet as illustrated in Figure 1.8 [2].

  Figure 1.8 depicted that the WSN has three approaches, namely independent network, hybrid network, and access point network.

- **User interface equirements:** includes the (i) interoperability which is realized by the device manufacturers, (ii) usability which is developed by empowering display devices to carry information using graphics user interfaces (GUIs), (iii) reliability represents the IoT adoption to provide correct information, (iv) mobility support by tolerating the association with the user even if the network scheme changes, and (v) extensibility and flexibility that allow changes in the devices to location mapping [2].

I.4.4.8 Services and Applications

- **Mobile Health/mHealth:** We have explained this term before in e-healthcare types.

- **IoT for ambient assisted living:** The incapacitated and aging population can benefit a lot from the use of IoT technologies. IoT-enabled devices can help monitor vitals (e.g., heart rate, diabetes) and perform real-time monitoring using location-aware devices. Here IoT can play a huge role. IoT devices can monitor glucose and track vitals. These devices can also track activities and sleep patterns of the patient. One major problem with senior patients is that they often not remember to take their medicines at the right time. IoT devices can help remind people to take medicines on time and note down exact timings of medication which will later help healthcare providers diagnose the patient. Portable IoT devices which can perform routine health checks like blood and urine test, blood pressure levels, etc., are a boon to loved ones of the patients who are not able to stay and supervise the patient. These devices can perform routine checks and send reports to the doctor as well as any family member or caregiver. In this way family members can remotely monitor the health of their elderly living away from them. These devices can also send warnings in case a memory care patient breaches their boundary[24]. Figure 1.9 shows the process of remote monitoring.

- **IoT in medication:** Not only treatment and diagnosis, IoT also enables users to maintain adherence to medication. It is often noticed that patients forget to take medications on time and doctors do not receive that information correctly. Studies suggest smart pill bottle technologies in combination with wearable audio sensors and classification techniques are competent to assess adherence to medication with high accuracy [24]. IoT devices can prevent adverse drug reaction (ADR). NFC-enabled smart pill bottle, knowledge-based system, and electronic health record can considerably prevent the undesirable consequences of wrong medications [24]. Figure 1.10 shows how digital medication monitoring can help track adherence to medication and enable doctors to design a better treatment for the patient.

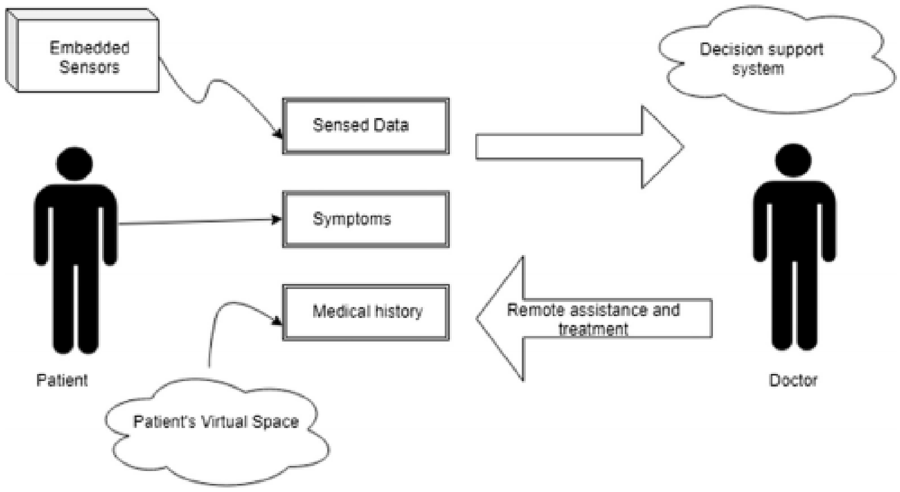

Figure 1.9: Remote patient monitoring with IoT.

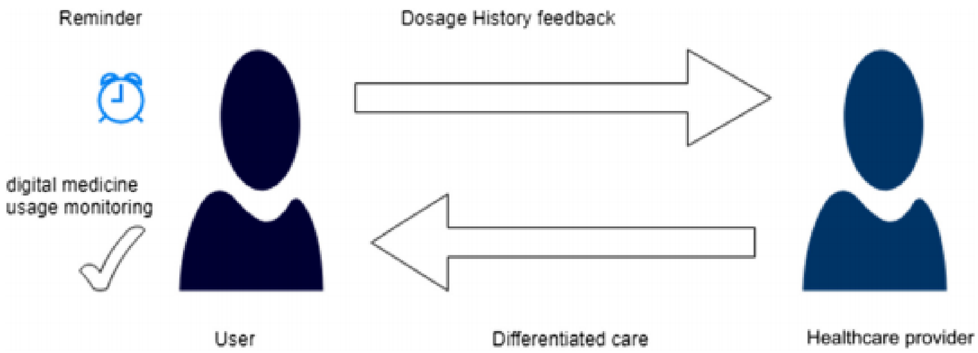

Figure 1.10: Adherence monitoring with smart medicine.

- **IoT for specially abled people:** According to a survey conducted by WHO, it shows that almost a billion people live with some or the other kind of disability. Lives of these disabled individuals can significantly be improved by the use of smart gloves, smart watch, and other IoT-aware devices. Smart gloves are devices consisting of low-cost inertia sensors that help people with hearing loss to communicate with individuals not having knowledge of sign language [24].

- **IoT-enabled medical implants:** Apart from wearables, IoT is also helping us with a lot of medical devices that are implantable. These are highly sophisticated devices and they are mostly available in miniaturized, dependable form inserted within the body to improve the individual's body functions [24].

- **Data analysis and research to improve healthcare:** By using Big Data analytics, the vast amount of medical data that is stored from various IoT devices are processed and deep insights are being drawn upon that data. Data for DNA sequences are being used to analyze different types of genes and their association to a disease [24].

- **Tracking staff, patients, and inventory:** Hospitals need to track their patients, equipment, staff member, etc., throughout the building. Without the ability to track, hospitals will not be able to maintain maximum security for their staff and patients. The activity of tracking is quite easy for small institutions, but becomes a huge problem when dealing with multiple facilities, housing large number of patients, staff, and thousands of equipment. Many hospitals are looking into IoT and real-time location trackers to help their asset management. With the help of IoT devices, the day-to-day monitoring of hospital activities is inexpensive, effective and also provides the hospital with technological boost [24].

- **Enhanced drug management:** One of the magical inventions of modern technology in the healthcare domain is the new form of prescription medication. Along with regular medication doctors can now prescribe sensor-enabled medicines. These pills contain microscopic sensors that can transmit signal to external device, a kind of patch attached to patient's body. These pills are used to ensure proper usage and dosage of prescribed medication. The data sent by these sensor-based pills are invaluable when it comes to reevaluating patient's diagnosis, tracking usage of medication, and reminding the patient to take medicines [24].

- **Reducing the wait time in emergency room :**Emergency room wait time can take hours to complete. Thanks to IoT, now we have solutions to manage emergency room care more effectively. One hospital in New York in partnership with GE Healthcare is using new IoT-based software, Auto Bed. Auto Bed tracks occupancy among 1200 units and factor 15 different metrics to measure the needs of patients. This way system can effectively assign emergency care beds to patients who are in need of inpatient care [24].

I.4.5 Agents And Healthcare

- De Paz et al. presented a project: Autonomous aGent for monitoring Alzheimer's patients (AGALZ), which facilitates the monitoring and tracking of patients with Alzheimer's [27].

- [25] is a Tele-monitoring system aimed at enhancing remote healthcare of dependent people at their homes has also been developed. The main contribution is the use of an experimental architecture that allows the interconnection of heterogeneous Wireless Sensor Networks.

- De Meo et al. presented multi-agent system that supports personalized patient access to health care services. The proposed system combines submitted queries with the corresponding patient profiles to identify services likely to satisfy patient needs and desires [7].

- Vaidehi et al. presented a design for a health care monitoring system based on multi-agent and wireless sensor networks, which can collect,retrieve, store and analyze patient vital signs [30].

I.5 Conclusion

In this chapter we presented generals on health an E-healthcare and it concepts and we mentioned also works on intelligent agents that are related to E-health.

Chapter II

Intelligent systems for health and Telemonitoring

II.1 Introduction

In this chapter, we will give a brief overview of Intelligent Systems, and give examples of applications for remote patient monitoring and will discuss the challenges of RPM systems.

II.2 Intelligent Systems [1]

II.2.1 Definitions

An intelligent system is a tool that operates in a complex world with limited resources possesses primary cognitive abilities such as perception, action control, reasoning, or language use, and exhibits complex intelligent behavior supported by abilities such as rationality, adaptation through learning, or the ability to explain the use of its knowledge by introspection .

Intelligent systems have been characterized in the literature of AI using the concept of intelligent agent. This concept provides an adequate degree of abstraction that helps to identify general properties. Table 2.1 shows a sample of definitions of intelligent system considered as an agent. These definitions highlight that the system works in an environment, has a set of capabilities (perception, learning, etc.), and makes decisions about how to act.

The word system (instead of agent) is used by some authors (e.g., Meystel and Albus (Meystel and Albus 2002)) and in academic areas of information technology such as the names of university courses or academic journals (e.g., IEEE Intelligent Systems and International Journal of Intelligent and Robotic Systems). In this case, the word system emphasizes the presence of multiple components that must be adequately combined to create intelligence. Knowing how to do this combination efficiently is one of the key aspects in the development of such type of systems.

Table 2.1: Sample of definitions of intelligent agent.

Definition 1: Intelligent agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed (Maes 1995).
Definition 2: Intelligent agents continuously perform three functions: perception of dynamic conditions in the environment; action to affect conditions in the environment; and reasoning to interpret perceptions, solve problems, draw inferences, and determine actions (Hayes-Roth 1995).
Definition 3: Intelligent agents operate autonomously, perceive their environment, persist over a prolonged time period, adapt to change, and create and pursue goals (Russell and Norvig 2014).
Definition 4: Intelligent agents are autonomous or semi-autonomous hardware or software systems that perform tasks in complex, dynamically changing environments. Agents communicate with their environment and effect changes in their environment by executing actions (Muller 1996).

II.2.2 Intelligent Systems Properties:

II.2.2.1 Working in a complex world

As mentioned in definitions, one of the properties of an intelligent system is that it is a tool designed to perform tasks in a complex world using limited resources. For example, this means that the complexity of the world is significantly higher than the information processing capacity of the system. The amount of components of the environment, their interactions or the anticipated effect of potential actions in the environment cannot usually be completely represented in the memory of the intelligent system. For example, in the chess game, it is not possible to anticipate the exact effect of all potential movements, because the amount of combinations is too high .

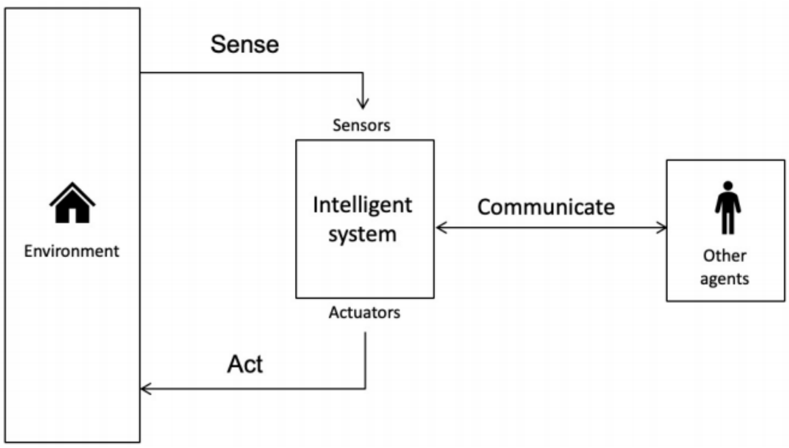

Figure 2.1: World interaction of an intelligent system

We can distinguish two types of components in the world: the environment and other agents (human agents or artificial computer-based agents) (Figure 2.1). The system observes features from the environment through sensors and performs actions using actuators .

Example: A thermostat is a simple example that illustrates the concept of a system that operates in an environment (e.g. house rooms). The thermostat uses a thermometer to sense the temperature of the room, and actuates by starting or stopping a heater. The thermostat also communicates with a human user who starts and stops the thermostat, or establishes the desired temperature.

The use of sensors and actuators (real or virtual) separates clearly the body of the intelligent system from the rest of the environment. This characteristic is called embodiment. It it also said that the agent is situated in an environment when the agent operates in a close-coupled continuous interaction with environment in a continuous sequence of sense-act .

The degree of complexity of the environment with respect to the agent can be described with the following features (Wooldridge 2009; Russell and Norvig 2014) :

- **Static (or dynamic):** the environment does not change (or changes) while an agent is deliberating.
- **Discrete (or continuous):** the state of the environment, time, percepts or actions are discrete (or continuous).
- **Fully-observable (or partial-observable):** sensors detect (or do not detect) all aspects that are relevant to the choice of action.
- **Deterministic (or stochastic):** the next state of the environment is (or it is not) completely determined by the current state and the action.
- **Episodic (or sequential):** actions do not influence (or they influence) future actions.
- **Known (or unknown):** the outcomes for all actions are known (or they are not known) by the agent in advance.

Example: The environment for a chess player is static, discrete, fully observable, deterministic, sequential and known. In the case of a self-driving car, the environment is continuous, partial observable, stochastic, sequential and known.

II.2.2.2 Primary cognitive abilities

We distinguish four primary cognitive abilities of an intelligent system (Figure 2.2): (1) perception, ability to extract relevant information from the environment , (2) deliberation, ability to reason about the world and make decisions about what to do, (3) interaction, ability to communicate with other agents using language, and (4) action control, i.e., ability to control the execution of the own actions. Perception and actuation may be divided in multiple separate components that operate in parallel at a high frequency. However, deliberation and communication should operate sequentially which is necessary for coherent reasoning (Laird, Lebiere, and Rosenbloom 2017) and consistent communication .

- **Deliberative and reactive:** Deliberative behavior contrasts with reactive behavior. In general, deliberation (Ingrand and Ghallab 2017) includes multiple functions such as planning or goal reasoning. It is assumed that the fundamental characteristic of deliberation is the ability to reason about the world and reach justifiable conclusions. On the other hand, reactive behavior generates instantaneous actions in response to a stimulus. This reactive behavior is present, for example, in animal reflexes or in behaviors based on human intuitions, which reach conclusions based on feelings rather than on facts or evidence .

  Reactive behavior is useful because it allows an intelligent agent to react efficiently to dynamic events of the environment. A situated agent may work with reactive behaviors with a limited or nonexistent memory about the world. The immediate feedback of the state of the world through sensors can be used to make quick decisions and, consequently, react quickly to events .

  Deliberative behavior is related to rational thinking. An agent that thinks rationally makes decisions that are consistent with its own knowledge (with its own beliefs and goals) and, therefore, the agent is able to find reasons (i.e., a logical justification) for the decisions taken. In contrast to reactive agents, deliberative agents with rational thinking can explain the reasons that support a decision. Deliberation may be also useful to inhibit reactive behaviors in some cases, when it is necessary to postpone immediate answers in order to reach more useful long-term goals .

  The separation in this two ways of thinking is related to the human mind as it is described, for example, by Daniel Kahneman (Kahneman 2011) with the names System 1 and System 2. System 1 is slow, logical, effortful, conscious, linguistic (can be described verbally) and makes complex decisions. On the contrary, system 2 is fast, intuitive, automatic, unconscious, non-linguistic (difficult to verbalize) and corresponds to everyday decisions. In the development of computer-based intelligent systems, bridging the gap between these two parts is in general a non trivial problem that require specialized functions (e.g., attention mechanisms, symbol grounding, cognizant failure and action meta-control) .

- **Interaction with other agents:** The type of interaction with other agents is an important characteristic that distinguish different types of intelligent systems. The interaction may be established with only one single agent (e.g., an end user that delegates tasks or asks for advice) or with multiple agents organizing several intelligent systems in complex structures in the form of multi-agent systems that may cooperate using social coordination mechanisms to achieve common goals .

  During the interaction, an intelligent system may be proactive. This means that the system do not need to wait until a user asks to do a task, but it takes the initiative to perform tasks based on what the system perceives from the world and its own goals .

  Autonomy is a relevant characteristic that an intelligent system may exhibit during the interaction with other agents. In general, an autonomous system makes its own decisions about how to act in the environment to complete a task delegated by another agent. As figure **??** illustrates, autonomous systems can be contrasted with systems that are designed to give advice. An autonomous system acts in the world to help the user. This means that the user delegates in the system a task and the system decides and performs autonomously specific actions in the environment that allow the task to be completed .

In contrast to this, an intelligent advisor system helps the user act in the world. In this case, the user is the one who makes the decisions about what actions to do and the role of the system is to give advice by providing useful information to facilitate decisions. This information can be generated using descriptive or predictive analytical methods (e.g., pattern recognition, methods for diagnosis or temporal projection). In addition, the system can use prescriptive methods (e.g., resource assignment, scheduling or planning) to recommend what actions should be done .

An autonomous system can also accept or reject proposed tasks from the user according to certain reasons, such as the current situation of the environment or its own goals (e.g., safety goals). For this purpose, the system can verify the correctness and feasibility of a requested task before it is performed and explain to the user the reasons that justify why a requested task is rejected .

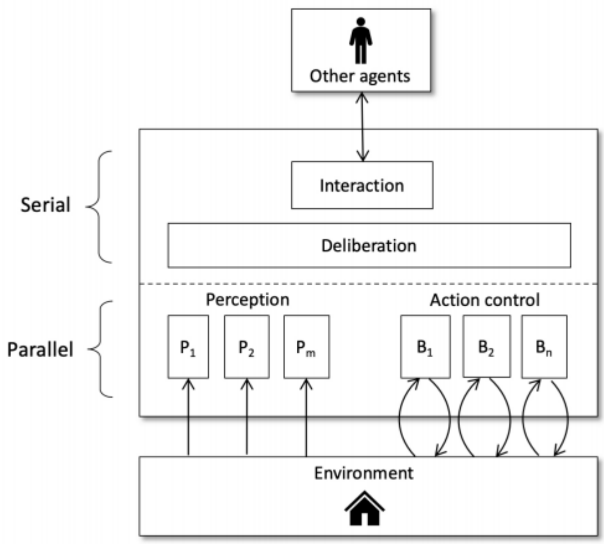

Figure 2.2: World interaction of an intelligent system

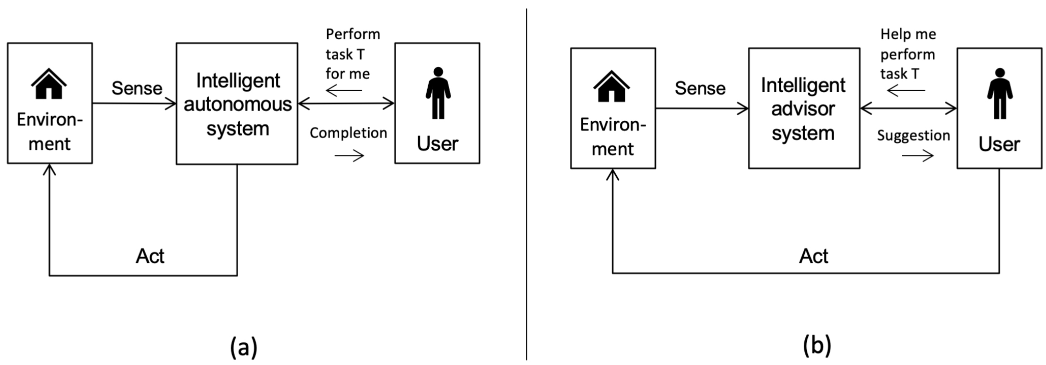

Figure 2.3: Comparison between (a) autonomous system and (b) advisor system.

II.2.2.3 Complex intelligent behavior

A system can exhibit complex intelligent behavior with certain abilities such as acting rationally, adaptation through learning, or introspection . The following points describe these abilities in more detail:

- **Acting rationally:** An intelligent system that acts rationally uses its cognitive abilities in the best possible way to obtain the maximum performance. In the chess game, for example, a performance measure can be the number of tournaments won by the chess player. In a medical diagnostic system, a performance measure can be the number of times that diseases are correctly diagnosed. The performance measure of the recommendations of an investment advisor may be the economic profit obtained .

  Since the environment is usually complex, an intelligent system is not able to determine in advance the exact performance measure that will be obtained, but estimations based on expected performance with uncertainty. This can be explicitly programmed using algorithms that make decisions based on the expected performance using for example decision theory. In other cases, rationality may be implicit in the algorithms because it is imposed by the design decisions made by the developers when they build the intelligent system .

  Rational decisions may affect different cognitive abilities. For example, a rational agent may decide what parts of the observed environment require more attention (perception) or what is the next question to ask to a user during information gathering (interaction). The rational agent may also decide what is the most appropriate method for solving a task or what is the best next action to do (deliberation) or the best way to control actions (actuation) .

- **Adaptation through learning:** An agent with the capacity of learning is able to improve its performance in the course of multiple interactions with the world. For example, a chess player can learn more effective strategies after playing multiple games. This capacity allows the intelligent system to adapt to the world and its changes .

  Learning can improve different cognitive abilities. For example, an aerial robot can learn to land more precisely on a marked surface after multiple trials (action control). A personal assistant can improve its speech recognition after listening to multiple sentences from the same voice of a user (perception) .

  An intelligent system that is able to learn needs a value judgement method that evaluates its behavior. The result of such evaluation is used by the intelligent system to change its internal model to modify its future behavior in order to obtain more positive evaluation. The value judgement method can be an external agent who works as a instructor (or trainer or supervisor) observing and assessing the behavior of the intelligent system to provide positive and negative feedback (e.g., in the form of reward or punishment). The intelligent system can also use an internal method that judges its own actions based, for example, on simulated feelings (e.g., pain or pleasure etc,) .

- **Introspection:** An intelligent system with the capacity of introspection can analyze how operate its own cognitive abilities. This means that the system has a self-reflective ability supported by an observable model that represents dynamically how its own cognitive abilities work. Such a model can be used as input data of algorithms to simulate self-awareness processes .

  One of the important practical utilities of introspection is that it allows the system to generate explanations to an external agent (e.g., a human end-user) to give credibility in the system's conclusions. For example, in the case of an intelligent advisor system that recommends decisions to an end-user, the system can generate convincing logical justifications connected with evidences that allow end-users to assume the responsibility of the decisions .

II.2.3 A taxonomy of intelligent systems

The definition of an intelligent system enumerates a set of cognitive abilities such as perception, action control, interaction, or deliberation. The presence or absence of such abilities may be used to identify different types of systems. Figure 1.5 organizes in a hierarchical structure some of the main types of intelligent systems. This taxonomy is not intended to be accurate and exhaustive but to introduce existing systems highlighting their main differences. The presented structure should be considered approximate because it includes certain simplifications to present the categories in a tree structure.

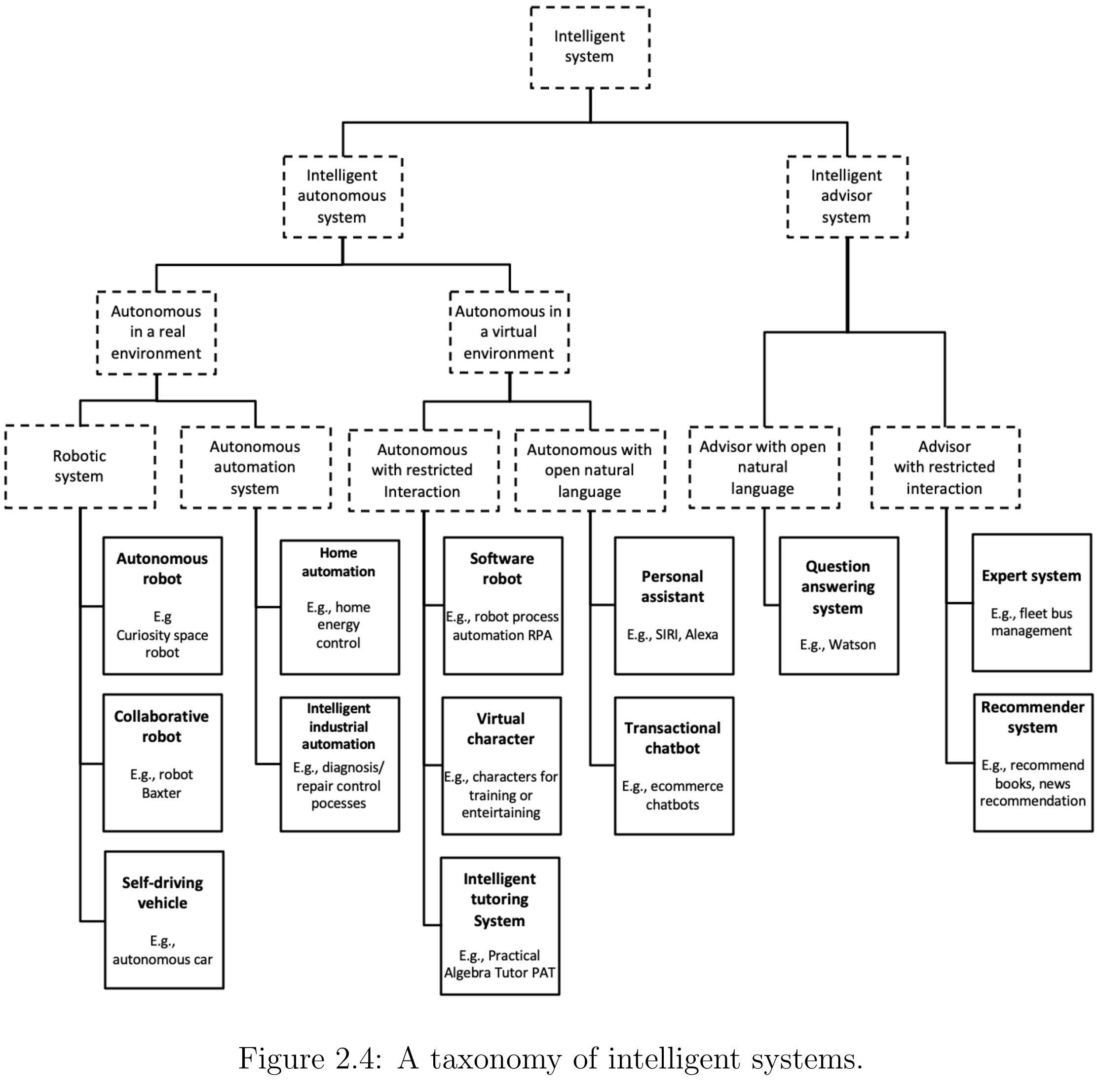

Figure 2.4: A taxonomy of intelligent systems.

We will go through some of these intelligent systems in greater detail in the following sections and illustrate them using real-world examples to show how they may be defined using the characterisation offered in our thesis.

II.2.3.1 Expert systems (ES)

The development of expert systems contributed to the practical success of AI in the 1980s with many commercial systems in multiple domains. They were applied to perform automatically tasks such as the following :

- **Classification:** Find the category of an object using observations (e.g., determine the presence of a mineral, recommend a type of investment, detect abnormal behaviors).
- **Diagnosis:** Find the causes of symptoms (e.g., medical diagnosis, mechanical diagnosis).
- **Temporal projection:** Estimate the future behavior of a dynamic system (e.g., economic market prediction).
- **Assignment/Scheduling:** Assign a set of resources to a set of needs (e.g., assign airplanes to gates in a airport).
- **Configuration:** Create a design that satisfy some requirements (e.g., design the machinery of an elevator).
- **Planning:** Find a set of actions to reach a desired state (e.g., emergency evacuation planner)

II.2.3.1.1 First generation Expert Systems

The first generation of expert systems used mainly heuristic reasoning with symbolic knowledge representations such as rules. For example, Mycin was one of the first expert systems that was used sucessfully as a model in other types of problems. Mycin was developed at the Stanford university in the 1970s (Buchanan and Shortliffe 1984) and it was able to diagnose infectious diseases and propose therapies. This system has the following two main functional components :

- **Interaction:** The information about patients is obtained through the communication with the user. Dialogue with the user is done in a question-answering process with prefixed questions and answers. Mycin asks questions about the patient and cultures. The questions are adapted to the previous answers (questions have context). The user may answer with uncertainty and may ask for explanations. Mycin presents diagnosis and therapy recommendation.
- **Deliberation:** Mycin diagnoses the causes of the symptoms finding the possible infectious organisms. Mycin uses a heuristic classification method with a knowledge base with 450 rules and backward chaining. Mycin includes an original method for approximate reasoning (certainty factors as values in [-1, +1]). In addition, Mycin recommends therapies using a method based on a generate and test procedure.

The methods used for building expert systems demonstrated that they are valid in many problems, but they present limitations to be used in certain cases. One of the most important limitation is what is called the knowledge acquisition bottleneck. Expert systems use heuristic knowledge formalized with declarative representations (e.g., rules and frames) that is stored in a knowledge base. The creation and maintenance of a knowledge base usually requires significant effort. Therefore, this approach is limited for the development of knowledge bases that are not too large .

Expert systems may be able to solve difficult problems, but they operate in very specialized domains, without general knowledge about the rest of the world . Therefore, compared to human experts, who have also common sense knowledge, expert systems are brittle and unable to react correctly in unexpected situations .

Another problem is related to the way these systems obtain information about the environment. For example, Mycin gets information about the patient using a prefixed set of questions and answers. This communication mechanism may be too narrow and rigid to be used in situations when the format of available data is more diverse (e.g., unstructured texts). This limitation makes difficult to integrate the expert system into day-to-day operations .

II.2.3.1.2 Expert Systems for the management of sensorized environments

The behavior of dynamic environments can be monitored with the help of sensor networks and information systems. This is the case, for example, of modern information infrastructures that have been developed in the last decades applied for example to strategic areas such a smart cities (transportation, climate, pollution surveillance) or industry 4.0 (with sensorized industrial installations) .

In this context, it has emerged the need of using intelligent systems that advise operators to make decisions for the management of such environments. There are multiple examples of expert systems that belong to this category. For instance, there are systems for public transportation management (Molina 2005), scheduling and coordination at an airport (Jo et al. 2000), emergency decision support in floods (Molina and Blasco 2003) or electric power operation (Filho et al. 2012) .

In general, this type of systems include a perception component to observe and interpret characteristics of the environment behavior using a sensor network or an information system. In addition, the system includes a deliberation component to derive conclusions from data, such as :

- what happens in the environment (detection).
- why it happens (diagnosis).
- what may happen in the future (temporal projection, what-if analysis).
- what should be done (planning).

The system also includes an interaction component to present this information to the human operator. This type of intelligent system does not have an actuation component to modify the environment. The operator is responsible of making management decisions and implementing the actions in the environment. Therefore, it is important that the interaction component presents the system suggestions with sufficient justification in such a way that the operator can take responsibility for the decisions .

II.2.3.2 Question-answering systems based on cognitive computing

The company IBM developed a system called Watson (Ferrucci et al. 2010) that marked a significant milestone in the history of artificial intelligence when it won the first prize of the quiz TV show "Jeopardy" in 2011 competing against human opponents. The system was able to respond better than humans to open domain questions written in natural language about general culture .

In the quiz game, Watson had to guess an answer based on a given clue provided by the user. For example, Watson receives a clue such as "this drug has been shown to relieve the symptoms of ADD with relatively few side effects". In less than 5 seconds, Watson had to generate the answer expressed as: "what is Ritalin?" (according to the rules of the game, the answer "Ritalin" is presented as a question) .

Watson used a selected large corpus of text documents of about 2 million pages as a source of information (e.g., news, encyclopedias and literary works). Watson searches candidate answers in such a corpus that can be possible responses to questions formulated by the end user in natural language. Watson uses a sophisticated structure of algorithms to (1) select relevant search keywords that may be used to find out (partial) candidate partial answers and (2) rank and integrate partial answers to generate the final answer in natural language .

The components mentioned in our thesis can be used to explain Watson's general qualities. The corpus of documents can be thought of as the environment in which the algorithm performs its searching activity. Watson's components, according to this, are as follows:

- **Interaction:** The interaction component of Watson uses natural language processing to extract the linguistic structure of the given clue. The interaction component also generates the final answer in natural language (in form of a question).

- **Deliberation:** Deliberation in Watson included two parts. A first part generates a number of search keys from the linguistic structure of the given clue. Each search key is generated to be used later (by the perception component) to retrieve information from text documents.

  The second part of deliberation ranks and combines retrieved candidate answers. For this purpose, Watson was is able to merge answers (Kalyanpur et al. 2012) doing temporal reasoning, geospatial reasoning and taxonomic reasoning (subsumption, disjointness, etc.) using ontologies and databases (e.g., Yago, DBPedia, Freebase). In order to score answers, Watson uses models generated by machine learning.

- **Perception:** To obtain candidate answers from the corpus of documents, Watson used dozens of specialized algorithms for information extraction using natural language processing.

Watson is a successful representative case of a question-answering system that uses a computing approach called cognitive computing. The idea of this approach is that the system uses as a source of information large amounts of structured and non-structured data (text, images, etc.). The system performs automatically cognitive tasks that include feature extraction (e.g., using natural language processing or computer vision), answer aggregation (reasoning with ontologies or knowledge bases), natural language communication (using natural language understanding and generation) and evidence assignment of hypotheses using models learned by machine learning .

II.2.3.3 Autonomous robots

An autonomous robot may be also considered as a representative case of intelligent system. An example of this system is an aerial robot for airplane inspection developed as a demonstrative prototype in 2019 for the company Airbus (Bavle 2019). This system performs the following functions :

- **Perception:** The aerial robot is equipped with multiple sensors such as (1) inertial measurement unit (IMU) to provide information about orientation, angular velocities, and linear accelerations, (2) cameras to calculate velocity using visual odometry, (3) a lidar sensor that generates a 3D point cloud, and (4) a high resolution frontal camera. The perception system performs data fusion from multiple sensors for a precise localization. The high resolution camera is used to detect anomalies on the surface of the airplane using computer vision.

- **Deliberation:** In this system, the main deliberative function is path planning. The system may generate an inspection plan to cover the surface of the airplane. In addition, the system stores images to be analyzed later.

- **Action control:** Action control corresponds to plan execution and motion control to complete the navigation plan. Action control also includes a reactive mechanism to avoid unexpected obstacles detected with the help of the lidar sensor.

- **Interaction:** The operator provides the geometry of the airplane and initiates the mission. The operator can stop the mission execution if an emergency happens.

In general, an intelligent robotic system is one of the most complex types of intelligent system since it typically contains the bulk of the components discussed in this thesis and functions in real-world contexts with physical constraints. There are a variety of systems in this category, each with a distinct level of sophistication, such as industrial collaborative robots, autonomous vehicles, assistive robots, domestic robots, entertaining robots, etc.

II.2.4 Building intelligent systems

This section outlines two critical components of building an intelligent system: (1) selecting artificial intelligence methods and (2) the acquisition of the domain knowledge used by the system to perform the desired tasks.

Table 2.2: Functionalities related to cognitive abilities together with examples of computational methods used for building intelligent systems.

General cognitive ability	**Example function**	**Examples of detailed functions**	**Examples of computational methods**
Perception	Feature extraction	Image recognition, information extraction, signal processing, natural language understanding, attention mechanisms.	Convolutional neural networks, natural language processing (rules, statistics models, LSTM neural networks), statistical data analysis.
	Data aggregation	Data abstraction, data fusion.	Statistical data analysis.
Deliberation	Semantic memory	Knowledge retrieval, knowledge integration, belief revision, symbol grounding.	Ontologies, truth maintenance systems, perceptual anchoring.
	Reasoning	Analytic reasoning (diagnosis, classification, etc.), synthetic reasoning (planning, assignment, etc.), goal reasoning.	Probabilistic reasoning, automated deduction, taxonomic reasoning, automated planning, constraint satisfaction, heuristic search.
Interaction	Language use	Natural language understanding, natural language generation, speech recognition.	Natural language processing (rules, statistic models, LSTM neural networks).
	Coordination	Dialog management, social coordination.	Multi-agent coordination algorithms.
Action control	Action selection	Goal-driven action selection, event-driven action selection, action conflict management.	Behavior trees, Petri nets, finite-state machines.
	Action execution control	Motion control, manipulation control.	Reinforcement learning, neural networks, fuzzy control, control theory.

II.2.4.1 Artificial intelligence methods

The development of a complex intelligent system can require using several artificial intelligence methods. Table 2.2 shows functionalities related to cognitive abilities together with examples of some of common methods used for building intelligent systems .

These methods can be divided according to two distinguished approaches. One approach uses symbolic methods such as logic-based representations, taxonomic representations or constraints based representations. The other approach uses non-symbolic methods such as connectionist representations (e.g., artificial neural networks) .

Symbolic and connectionist methods correspond to alternative approaches that have complementary strengths and weaknesses. In fact, there is a lack of understanding of how information processing performed by symbolic approaches can be mapped onto computations performed by connectionist methods. The term computational explanatory gap has been used to express that it is unclear how the two approaches are related .

Cognitive abilities that are consciously accessible (such as processes related to deliberation or interaction) may be implemented using symbolic methods. These methods can describe the symbols that represent knowledge to justify how to reach a certain conclusion .

On the other hand, perception and action control are usually carried out in an unconscious way and they are better implemented with non-symbolic approaches such as connectionist methods. In practice, it is interesting to note that the implementation of unconscious sensorimotor skills require much more computation compared to deliberative reasoning. This has been stated as the Moravec's paradox .

One of the difficulties in the development of complex intelligent systems is the combination of deliberation (with symbolic approaches) and reaction (with connectionist approaches). This may require additional mechanisms such as perceptual anchoring for symbol grounding or action execution control with cognizant failure .

II.2.4.2 Knowledge acquisition

Intelligent systems normally use knowledge models that represent knowledge that is difficult to be formalized using procedural representations of computer languages such as Java, Python or C++ .

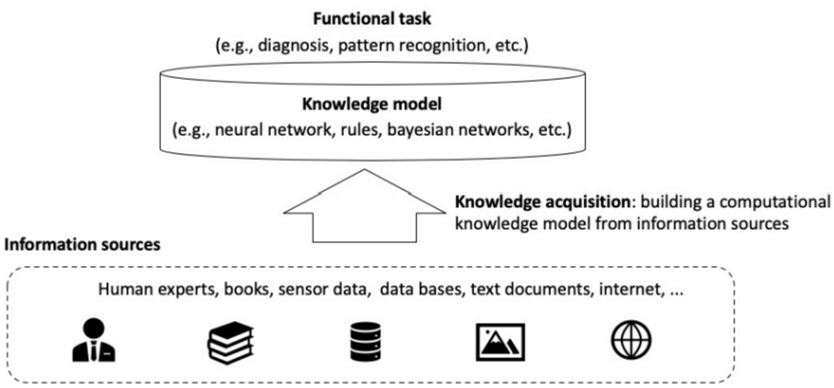

Figure 2.5: Overview of the knowledge acquisition process.

These models are used by general inference algorithms to generate conclusions from given premises .

Example: Consider an example of a medical expert system that uses a model that relates symptoms and diseases. This model, which is called knowledge base, is represented using symbolic rules. An inference algorithm processes such rules to diagnose the disease of a given patient. The inference algorithm is general and, therefore, it may be implemented using generic software tools. However, the rules of the knowledge model are specific and must be written for the particular expert system.

The construction of a knowledge model by developers is called knowledge acquisition (figure 2.5) and can be done either manually or automatically. Many of the knowledge bases of classical expert systems (like the Mycin medical system) represent heuristic knowledge that was acquired manually from domain experts and formalized using declarative representations (e.g., rules or first order logic) .

The creation and maintenance of such knowledge bases usually requires significant effort. This has been called knowledge acquisition bottleneck because it is one of the most difficult tasks of the development of the intelligent system. To facilitate this work, ontological engineering can be applied to reuse part of the content of knowledge bases across different intelligent systems .

In contrast to manual acquisition, it is possible to apply automatic methods for knowledge acquisition which has gained popularity in the last decades due to the increasing availability of large amounts of data. Automatic acquisition methods can use information sources with different formats such as images (or videos), structured data (e.g., data bases with alphanumeric data, temporal series) or non-structured text (e.g., written in natural language) [9].

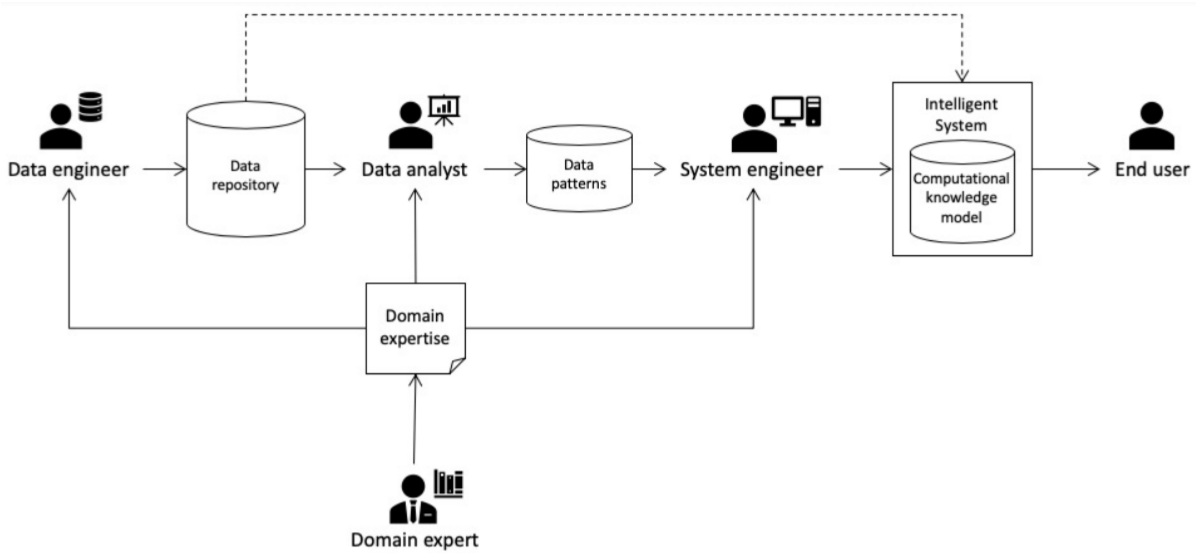

Figure 2.6: Summary of the participants in the development of an intelligent system.

In order to acquire knowledge automatically, it is possible to use machine learning or natural language processing. Machine learning methods can be used, for example, to generate knowledge models from examples. For instance, a neural network can be trained to recognize defects in images of a surface of an airplane. Natural language processing methods can be used to extract knowledge from text documents written in natural language .

The construction of intelligent systems may involve multiple participants that can be summarized in the following main roles :

- **System engineer:** The goal of the system engineer is building the final computational implementation of the intelligent system. The main specialization area of system engineers is computer science (knowledge representation, machine learning, natural language processing, software engineering, computer programming) and they may be familiar with tools and computer language such as TensorFlow, Python, Prolog, Drools, ROS and C++.
- **Data analyst:** The goal of the data analyst is discovering and describing patterns in data (statistical analysis, predictive analysis, etc.) that will be par of the intelligent system. Data analysts are mainly specialized in Mathematics (statistics, data visualization, machine learning algorithms) and related software tools such as R, Python, SAS, Matlab and Weka.

- **Data engineer:** The goal of the data engineer is building efficient and accessible data repositories to be used for data analysis or as information source of the intelligent system. Data engineers are specialized in data base management (conventional data bases, distributed data bases, big data architectures) and software tools and languages such as SQL, Hadoop, MongoDB.

- **Domain expert:** In the development of an intelligent system helps, the presence of domain experts are important to help the rest of participants providing the required support about domain knowledge (e.g., biology, medicine, finance, economy, etc.).

II.3 Applications for Remote Patient Monitoring

Many of companies around the world had developed RPM applications we present bellow few of them:

- **A&D Medical, Wellness Connected:** The suite of remote monitoring apps and devices allow patients to connect their health data with providers and keep family, caregivers, and medical professionals constantly updated on patient health. Devices such as a connected scale, wearable fitness tracker, connected blood pressure monitor, and a sleep tracker send data to providers and allows patients to graph and see how their health changes [15].

- **Biotronik Home Monitoring:** The cardiac home monitoring tools offered by Biotronik aim to replace unnecessary doctor's visits through early detection of cardiac health risks. Devices are equipped with an antenna and extra storage capacity that connects to a patient device called CardioMessenger. Through CardioMessenger, clinical data (e.g., vitals, health information) is collected, encrypted, and sent to a patient's provider and categorized by importance based on a patient's most pressing health needs [15].

- **Latitude NXT:** The Latitude NXT in-home patient monitoring system allows a healthcare team to monitor connected devices in-between primary care visits. Devices send data to providers at regularly scheduled times from blood pressure monitors, pacemakers, cardiac monitors, weight scales, and other connected health devices. The NXT connector is hands-free, meaning that patients do not have to intervene to send health data [15].

- **Medtronic, Vital Sync:** Through the Vital Sync monitoring platform from Medtronic, providers can integrate physiological information from bedside monitors and wearable devices to a hospital server. Providers are able to set clinical protocols through mobile apps and devices, view patient information remotely, and receive alerts and updates to a mobile device. Vital Sync also offers the ability to remotely monitor spontaneous breathing trials, identify patient deterioration in the ICU, and transition from telemetry to surveillance monitoring [15].

- **Spacelabs Healthcare, Xhibit:** The Xhibit remote monitoring platform allows providers to customize monitoring for specific patient needs through connected monitors, wearable health devices, and dashboards. With instant access to patient data, a provider is able to use a clinical suite to make data-informed decisions via monitoring-generated vitals, and determine if new care solutions are needed for said patient [15].

II.4 Intelligent systems for covid-19 management

When the COVID-19 pandemic hit, the necessity of a smart apps model became even more apparent. So many companies have started developing smart apps to try to control the spread of this virus. We present few of these applications bellow

- **VIVID:** With the support of a new $654,000 supplement grant, a team of engineers at Rensselaer Polytechnic Institute will develop an artificially intelligent agent called the Virtual Intelligent preceptor for COVID (VIVID), which will prepare teams for surgeries, to intubate patients, and to properly use personal protective gear, without increasing anyone's risk of exposure. Design of the VORTeX simulation system was initially intended to allow clinicians to train as a team in virtual reality environments, allowing doctors and nurses to practice life-saving and team-building skills in a risk-free setting [13].

- **ZOE COVID Study:** The COVID Symptom Study, formerly the COVID Symptom Tracker, is a COVID-19 epidemiological 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. The COVID Symptom Study requires users to give their location. Users give personal information including age, gender and location, and report if they have any underlying chronic conditions. They also answer questions related to common COVID-19 symptoms, and input any illness or symptoms that they have, as well as stating whether they have been tested for COVID-19. Beginning in May 2020, a random sample of users is selected (on the first day they report symptoms) for a swab test. Researchers then use statistical analysis to determine which symptoms are likely to indicate COVID-19, rather than the common cold or seasonal influenza. The app does not have any contact tracing functionality [12].

- **COVID Tracker Ireland:** is a digital contact tracing app released by the Irish Government and the Health Service Executive on 7 July 2020 to prevent the spread of COVID-19 in Ireland. The app uses ENS and Bluetooth technology to determine whether a user have been a close contact of someone for more than 15 minutes who tested positive for COVID-19.On 8 July, the app reached one million registered users within 36 hours after its launch, representing more than 30% of the population of Ireland and over a quarter of all smartphone users in the country.As of August 2021, over 3,030,000 people have downloaded the app [16].

- **TraceTogether:** is a digital system the Government of Singapore implemented to facilitate contact tracing efforts in response to the COVID-19 pandemic in Singapore. The main goal is quick identification of persons who may have come into close contact with anyone who has tested positive for COVID-19. The system helps in identifying contacts such as strangers encountered in public one would not otherwise be able to identify or remember. Together with SafeEntry, it allows the identification of specific locations where a spread between close contacts may occur [3]. Released on 20 March 2020, the system initially consisted only of an app by the same name. However, this was later supplemented by a physical token mainly intended for elderly and children who may not own a smartphone, or those who prefer not to use the app. The app was the first main COVID-19 tracking app released in the world and its development encouraged the development of similar apps in other countries [3]. The app has raised significant concerns about the privacy of those who use the app, although the app states that it uses several features to protect users' privacy, especially due to a lack of decentralised report processing and access to the data by police. However, the app states it has several features to ensure users' privacy, such as regularly rotating users' IDs and storing limited data. Despite the concerns over privacy, the app was slowly adopted by the population of the Singapore, eventually reaching a 92% adoption rate in May 2021. The app is now also mandated for specific groups of people and those attempting to enter certain venues and events [3].

II.5 A Discussion

Intelligent and remote patient monitoring systems have some characteristics making them difficult to apply specially in middle and low SDI countries, where infrastructures are also poor. We present bellow some of these characteristics:

- **Data Security:** For the data transmitted over any RPM platform to be secure enough to meet the standards required of healthcare, it will need robust data management practices, clear boundaries of ownership and ironclad security protocols. Large sections of the data management process could be handled by third parties, which creates risk for patients potentially having their data stolen. The challenges are no less acute for hospitals, who risk integrating a third-party system that could be hacked, putting their patients' safety and privacy at risk [14].
- **Data Accuracy:** Arguably the most complex challenge facing RPM adoption concerns data accuracy. A lot of this comes down to perceptions, both amongst patients and medical staff [14]. Can we really expect patients more accustomed to traditional healthcare methods, to trust that a small device will provide more accurate data about their health than what they could provide to their doctor themselves? Frontline medical professionals will be expected to diagnose and treat patients on the strength of the data provided. They, too, need to trust that it is of the highest possible accuracy if they are to take the kind of swift and decisive action needed - particularly in the treatment of chronic and potentially fatal conditions [14]. Another thing to consider here is the sheer amount of patient data that could be collected and presented to doctors and nurses. This has the potential to be overwhelming. How successfully they are able to quickly assess which data points are most relevant will depend on how much data is presented, as well as the format in which it is presented. This makes the margin for error, and the accuracy of decisions made on the basis of this data, very hard to predict [14].
- **Real-time Access to Data:** The transfer of information required for RPM to work is potentially a long and complicated process and consists of a multiple transfers. Firstly, data must be collected and uploaded from the patient's device. If this device is on a mobile network, the data must then travel through that network provider's infrastructure and out on to the internet before ending up in the service providers network, probably via multiple data centres and the RPM platform network [14]. If any of these hops is interrupted, or an outage occurs at any of the stops on this journey, the data might be delayed in getting to its destination. Mobile networks

are not guaranteed to be always available. This is seen as a big enough problem in cases where mobile users cannot access Instagram for an hour or two, but when it is genuinely a matter of life and death, as it could be for a patient, it is critical that data is delivered reliably and in a timely manner [14].

- **Systems integration:** If it were the case that all healthcare providers around the world used exactly the same systems on the same network, then systems integration would not be so much of an issue. Unfortunately, that couldn't be further from the truth [14]. For example, in Algeria, the healthcare sector tends to use outdated software stacks and a labyrinth of different systems for different things. Introducing a remote monitoring platform to the mix would, therefore, have to be managed extremely carefully to avoid corrupting existing patient records and ensure that any future systems migrations would not interfere with the RPM platform.

- **Cost of Devices:** A review conducted in the US in 2016 came up with a range of costs for rolling out RPM. Across 13 separate studies, the "combined intervention cost" (the total cost of the device, plus servicing and monitoring) was between $275 and $7,963 per patient. That's roughly anything from 37,600.00 DZD to 1,087,900.00 DZD. Again, that's per patient. For struggling institutions this kind of cost is simply not possible as a nationwide solution.

II.6 Motivation

We propose to develop an intelligent system based on agent which make Patients Tele-Monitoring easy to doctors because they can monitor their patients from anyplace they are. This system contains all the information about patients health state so it make taking the decision very fast and easy to doctors. A Mobile phone agent that collects data and analyze it then make alerts according to results.

II.7 Conclusion

In this chapter we presented the principles of intelligent systems and we mentioned few applications of Remote patient monitoring in the end we discussed some of the difficulties that faces RPM. In the next chapter we will analyze and identify the needs of the system to be realized.

Chapter III

Analysis and design

III.1 Introduction

In the first section of this chapter, devoted to the analysis and design of our platform, we will give a functional description of the system as well as the development methodology followed. Next, we will present the vowel method and the AUML (Agent Unied Modeling Language) modeling language that we used for the modeling of our system. In the third section, we will end with the design part where we will present the different diagrams of our application.

III.2 Realised system description

The system that we want to create is a digital platform that enable's doctors to create, update and preview patient's EHRs and thus enable them to make quick decisions in the futur, and also provides doctors with patient remote monitoring option in clinical cases or cases that requires monitoring. The system contains smart agents that collects analyzes the state of patients who are in the process of monitoring and make actions according to results. The system provides also a remote doctor's consultation service.

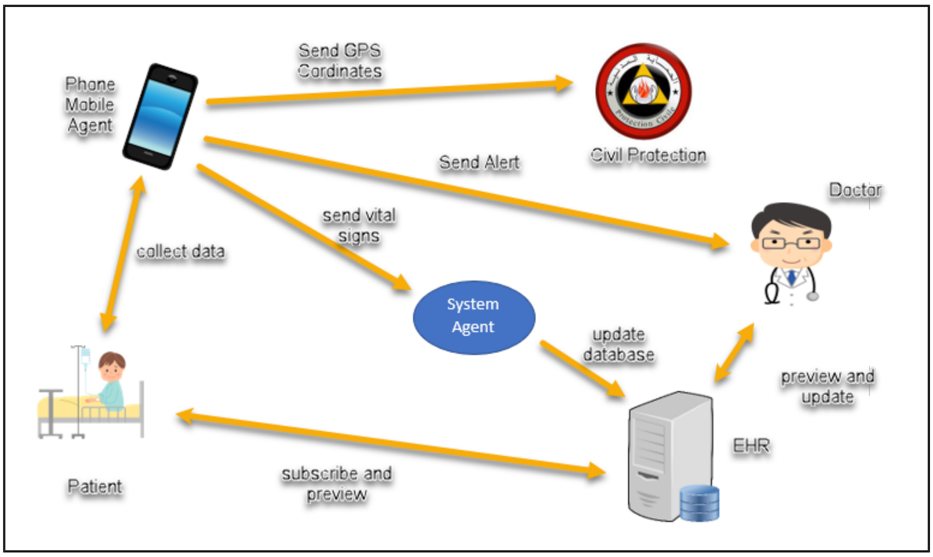

Figure 3.1: System Architecture

III.3 Methodological choice

III.3.1 Vowel Method

Among the methods that better cover the development cycle of a multi-agent system, we have chosen the Vowel methodology to model our system. It's a approach that encourages thinking about the design of the system simultaneously in terms of four dimensions (Figure 3.2): agent, environment, interaction and organization In other words allows us to use all the power of multi-agent systems without restricting the methodological design possibilities unlike MADKIT.

- Agents: it concerns the models (or architectures) used for the active part of the agent, from a simple automaton to more complex cases, such as knowledge-based systems.
- The environments: it is the environments in which the agents are immersed. It is spatial in most of the applications offered.
- Interactions: it concern the infrastructures, languages and interaction protocols between agents, from simple physical interactions to interactions by speech acts.
- Organizations: which structure agents into groups, hierarchies, relationships ...

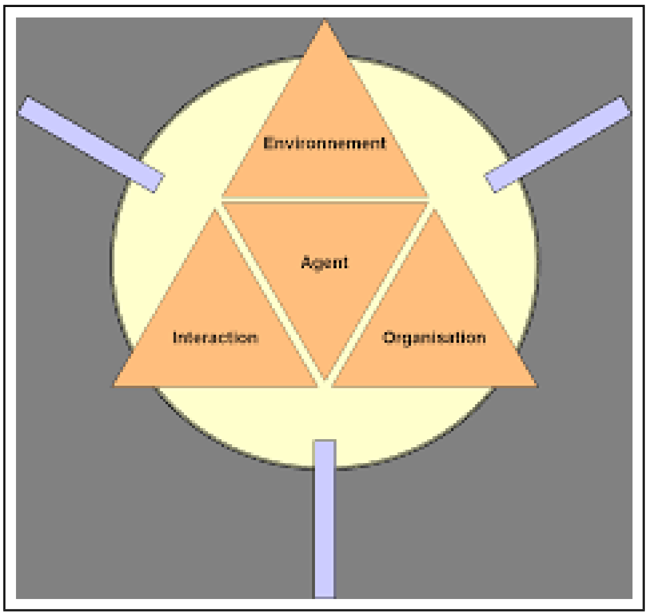

Figure 3.2: Multi Agent systems representation with Vowel method

III.3.2 AUML

AUML is a graphical modeling language that has been standardized by FIPA (Foundation for Intelligent Physical Agents) technical modeling committee. It has been proposed as an extension of the Unified Modeling Language (UML). Until now there is no recognized standard for multi-agent system modeling and AUML has emerged as a candidate to assume such a position.

It uses the characteristics of "decomposition", "abstraction", and "organization", which reduce the complexity of software development. AUML decomposes the system into small parts of objects, models, use cases or classes, and operational actions. Concerning "abstraction", it offers a specialized abstract view of the modeling (class, use case, diagram, interface, etc.).

Agent UML is a support notation for agent-oriented development It consists in using the UML modeling language and its extension to represent agents, their behaviors and their interactions between them. It generally offers some frameworks (class, diagram, interface, etc.) to see how agents can be built in a system.

The main part of AUML is the modeling mechanisms of the interaction protocols of multi-agent systems. This is achieved by introducing a new class of diagrams to UML : "Protocol diagram". These diagrams extend the sequence diagrams by including: 'agent roles', 'agent behaviors', 'agent interactions', 'protocol Template', etc.

III.3.3 AUML Diagrams

Since Agent UML is an extension, it inherits the representations proposed by UML.

III.3.3.1 Structure diagrams

Structure diagrams show the static structure of the system and its parts on different abstraction and implementation levels and how they are related to each other. The elements in a structure diagram represent the meaningful concepts of a system, and may include abstract, real world and implementation concepts, there are seven types of structure diagram as follows:

- Class Diagram.
- Component Diagram.
- Deployment Diagram.
- Object Diagram.
- Package Diagram.
- Composite Structure Diagram.
- Profile Diagram.

III.3.3.2 Behaviour diagrams

Behavior diagrams show the dynamic behavior of the objects in a system, which can be described as a series of changes to the system over time, there are seven types of behavior diagrams as follows:

- Use Case Diagram.
- Activity Diagram.
- State Machine Diagram.
- Sequence Diagram.

- Communication Diagram.
- Interaction Overview Diagram.
- Timing Diagram.

III.4 Analyze

This step consists of identifying the components of our system.

III.4.1 User identification

In the developed system, we identify four types of users: patients, doctors, operators, administrator.

Patients: these are persons who access the platform to preview their EHRs and submit symptoms in monitoring cases. The main activities of Patients in the system include:

- Previewing EHR.
- Updating profile.
- Previewing appointments.
- Submitting Symptoms
- Consulting doctors by messaging.

Doctors: they access the platform to search and preview patients EHRs, manage consultations and monitor patients. The main activities of doctors in the system include:

- Previewing EHRs.
- Managing consultations.
- Previewing appointments.
- Monitoring Patients.
- Adding treatments.
- Recruiting operators

Operators: they help doctors by managing patients appointments and updating EHRs. The main activities of operators in the system include:

- Previewing EHRs.
- Managing appointments.
- Updating EHRs.

Administrator: is responsible for the management of the electronic platform. The main activities of the of the administrator in the system are:

- Managing users accounts.
- Updating diseases list.
- Approving role changes.

III.4.2 Agent identification

Mobile Phone Agent: This agent is located in patient mobile phone or tablet it collects data and analyze it then take actions (launch phone alarm, make phone calls, send phone messages) according to results. It also sends collected data and analyzing results to System Agent.

System Agent: This agent is located in the main system it receives collected data from Mobile Phone Agent and updates patient state.

Interrunction

- **Mobile Phone Agent / System Agent:** Mobile Phone Agent collects data and analyzes it then sends it to System Agent. The latter updates patient's state in database and doctors interface and notifies doctor.

III.4.3 Environment

In MAS, the environment of an agent consists of the agents of the system and the other physical or logical entities with which it interacts. The table below 3.1 shows the environment of each agent of our system.

Table 3.1: Agents Environements

Agent	**Environement**
Mobile Phone Agent	Patient Mobile, System, Database, Doctor's interface.
System Agent	System, Database, Doctor's interface.

III.4.4 Organisation

Organization is a structure describing how agents in the environment relate and interact to achieve interact and relate to each other in order to achieve goals. The structural organization is:

- Patient side on mobile we find Mobile Phone Agent which intercepts with sensors that are on patients body. this agent is directly related to System Agent and the GUI System represents it interaction points with patient. The subscription phase register this agent on XMPP server and the patient can starts it selecting automatic collecting mode.

- System side we find System Agent which created and registered on XMPP server by the system this agent receives analyze results and collected data from Mobile Phone Agent and it interacts directly with database.

III.5 Conception

III.5.1 Use case identification and description

III.5.1.1 Use case diagram

Figure 3.4 illustrates the global use case diagram of our system. In this diagram we have three main actors:

- The patient who enters the platform to preview EHR and appointments, submit symptoms, send messages.
- The doctor who enters the platform to preview EHRs, manage consultations and monitor patients.
- The operator who enters the platform to preview EHRs, manage appointments.
- The administrator who is responsible of managing accounts and updating diseases list.

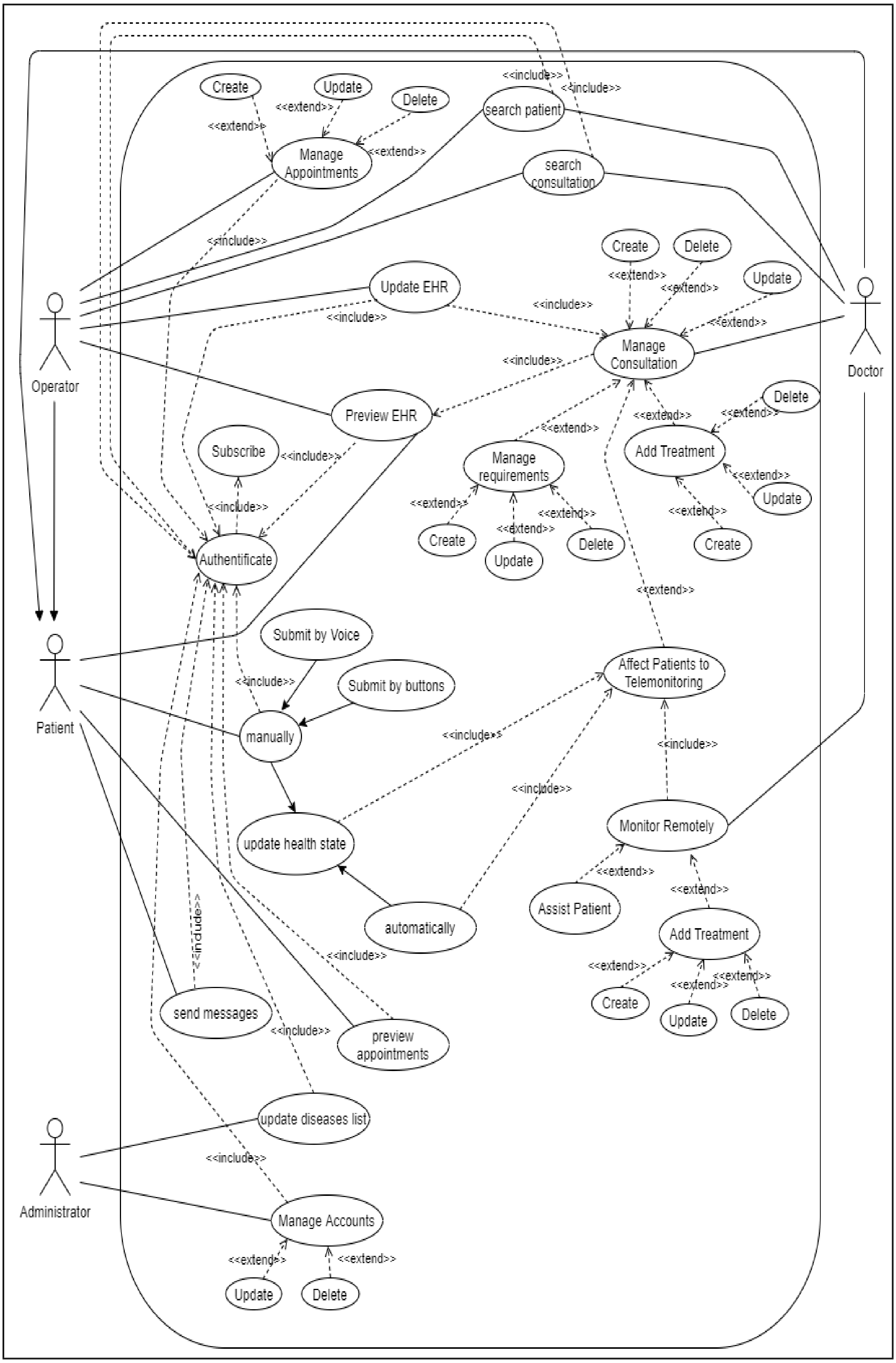

Figure 3.3: Use case diagram.

III.5.1.2 Use case diagram description (by sequence diagrams)

Patient's subscription sequence diagram

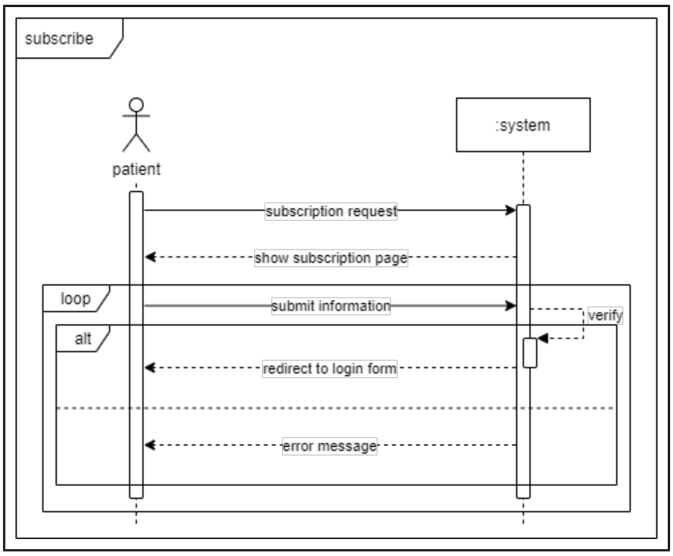

Figure 3.4: Patient's subscription sequence diagram.

Create consultation sequence diagram

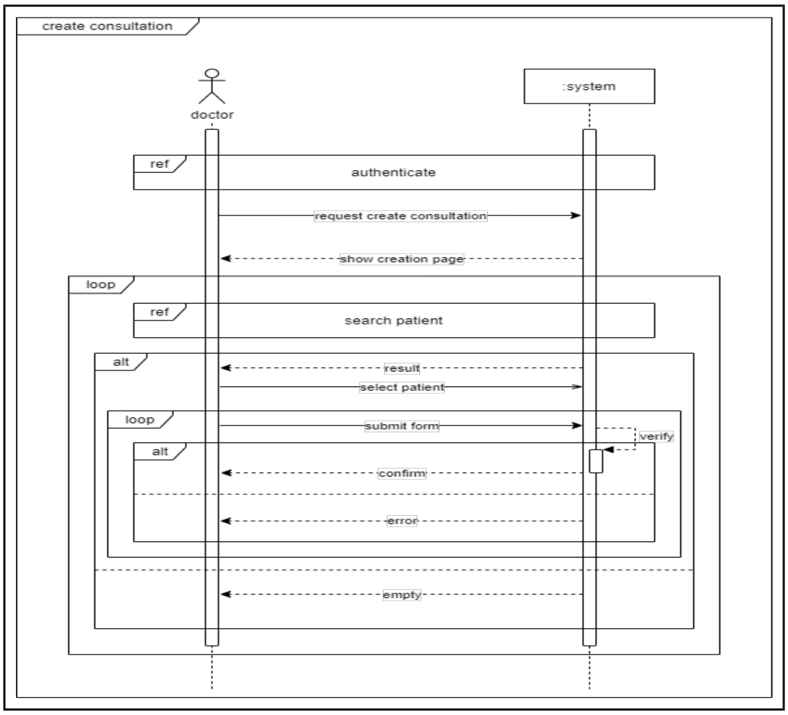

Figure 3.5: Create consultation sequence diagram.

Manage consultation sequence diagram

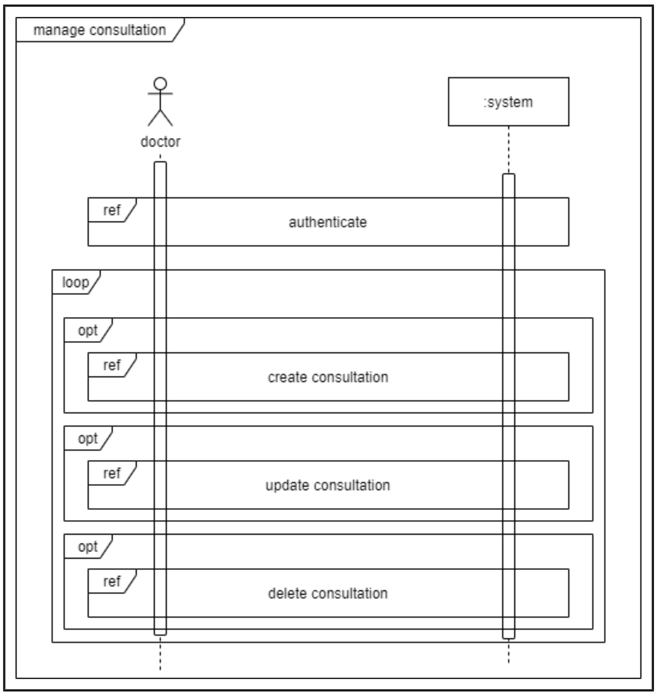

Figure 3.6: Manage consultation sequence diagram.

Update Health state sequence diagram

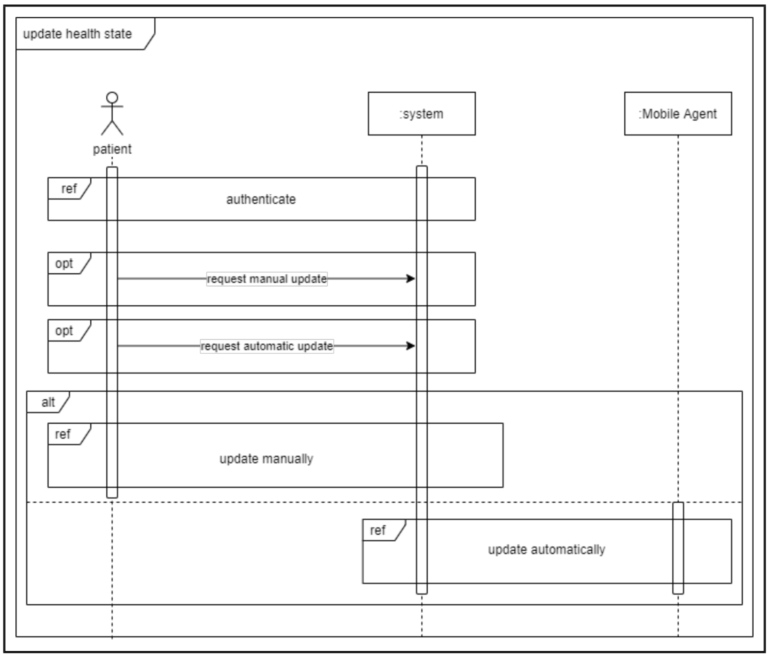

Figure 3.7: Update Health state sequence diagram

Update automatically health state sequence diagram (Agents Interaction)

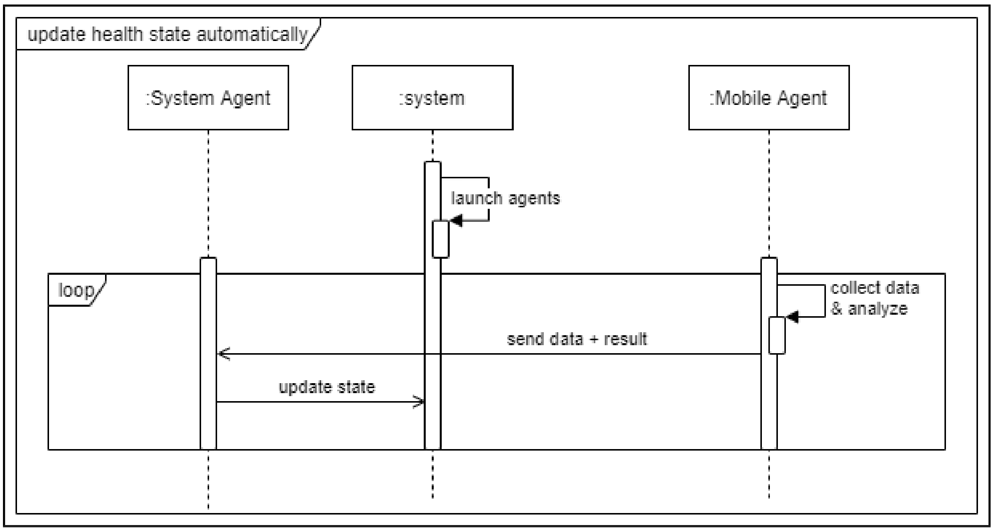

Figure 3.8: Update automatically health state sequence diagram (Agents Interaction)

Search appointment sequence diagram

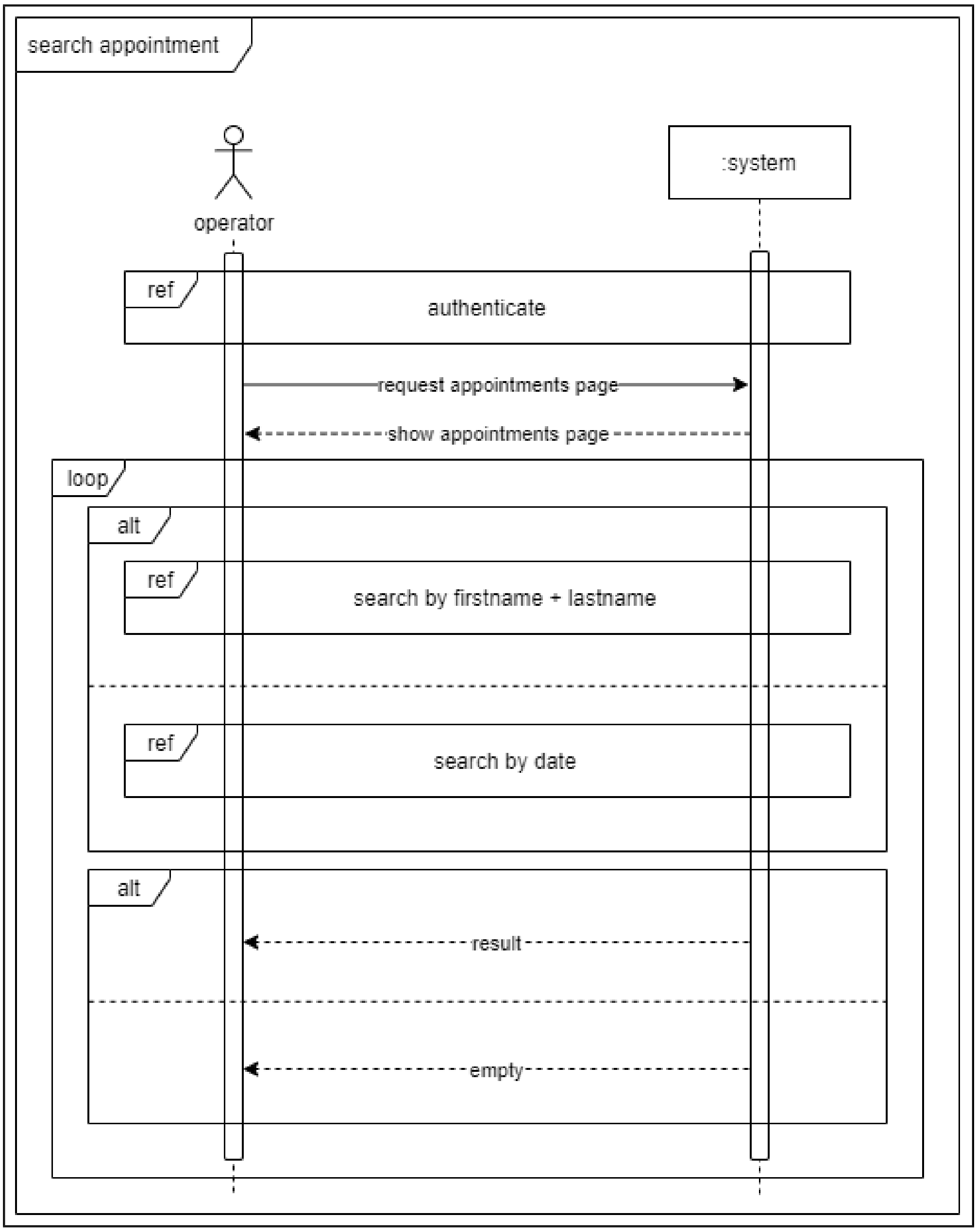

Figure 3.9: Search appointment sequence diagram

III.5.1.3 Activity diagrams

Create consultation activity diagram

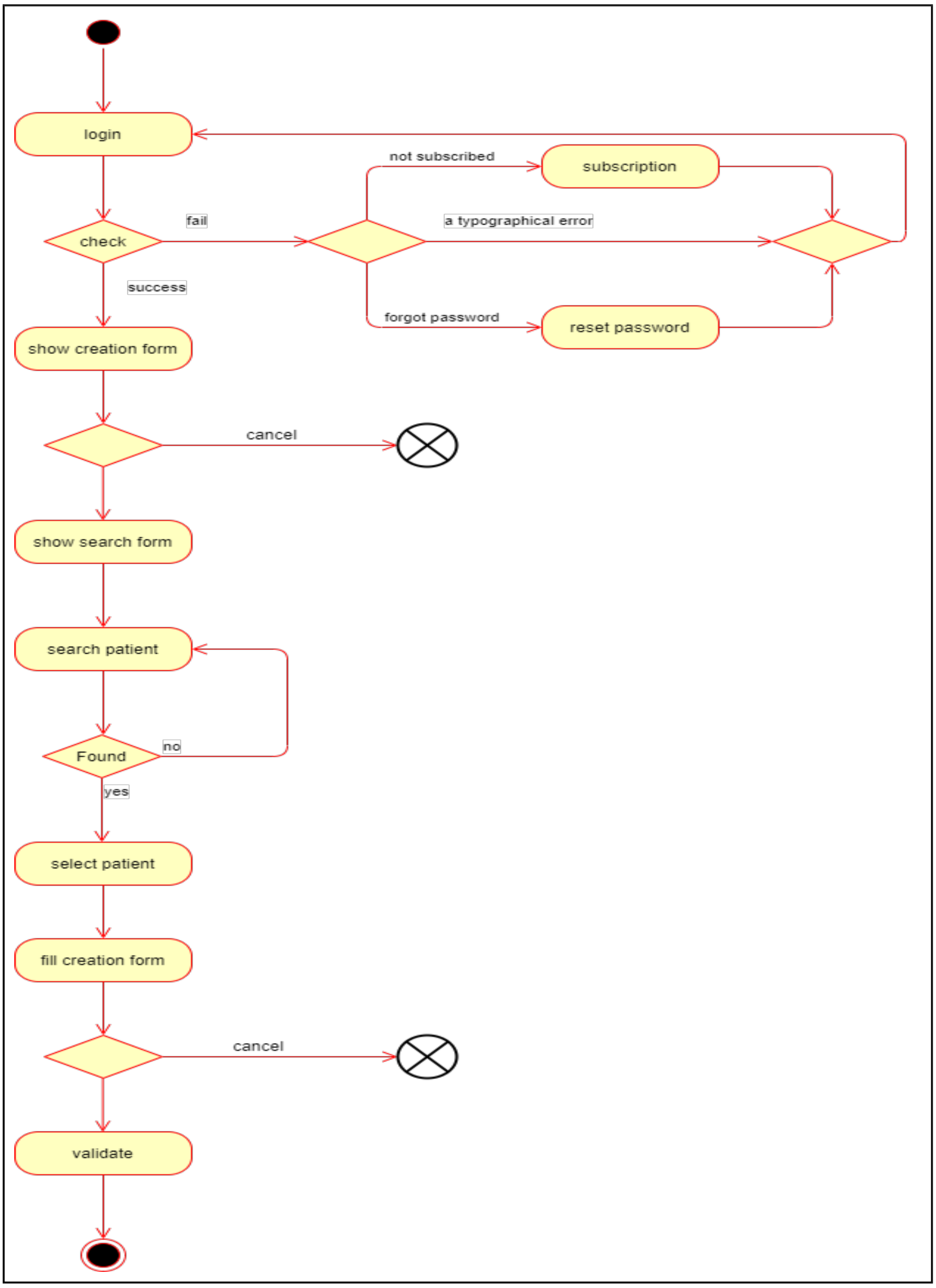

Figure 3.10: Create consultation activity diagram

Update state activity diagram

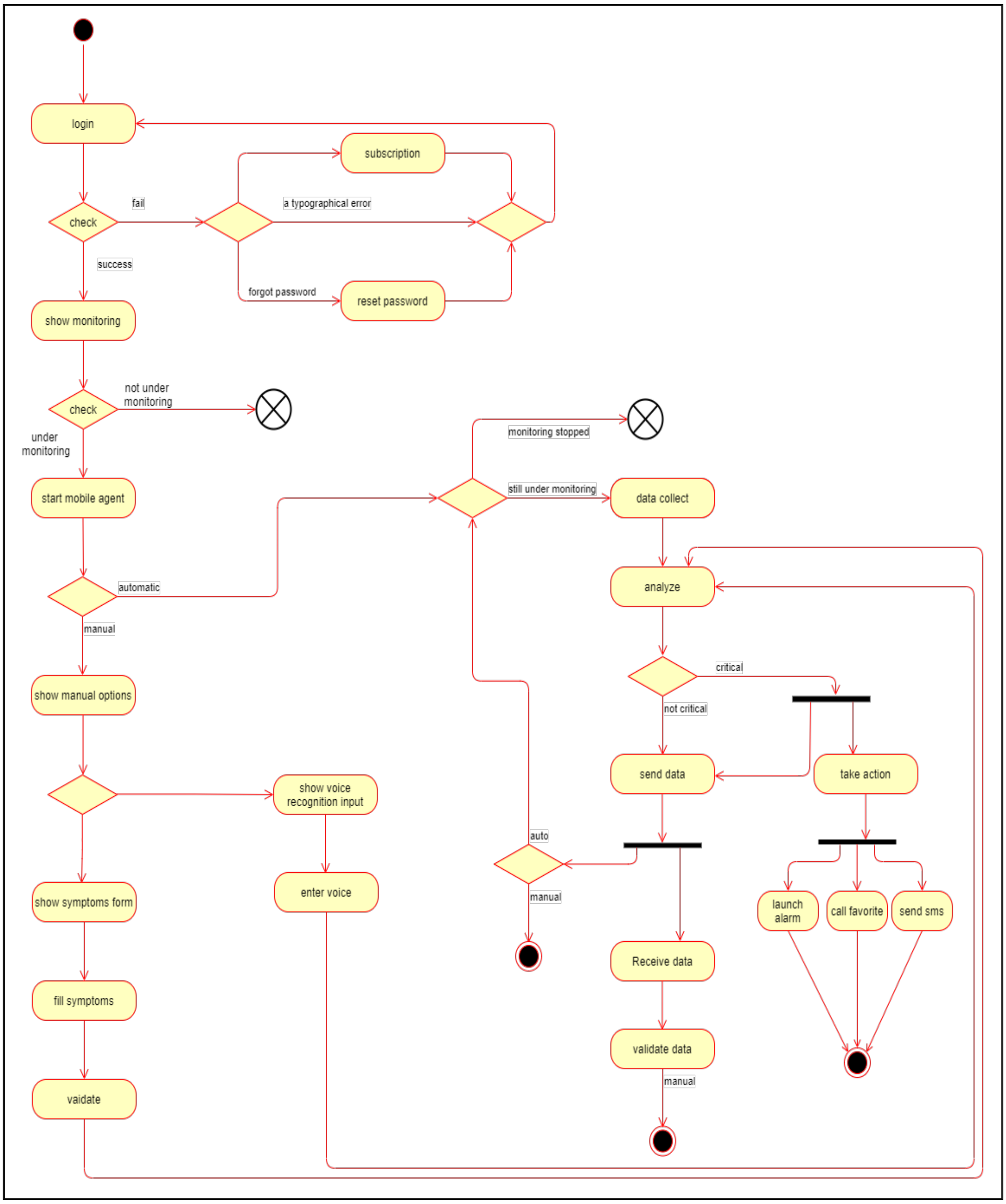

Figure 3.11: Update state activity diagram

III.5.2 Class diagram

In this section we move on to designing the static aspect of our system. We start by building a class diagram representing our system. Then we will present in a separate diagram the different classes of agent used in our system

III.5.2.1 System class diagram

Figure 3.12 presents the class diagram of our system.

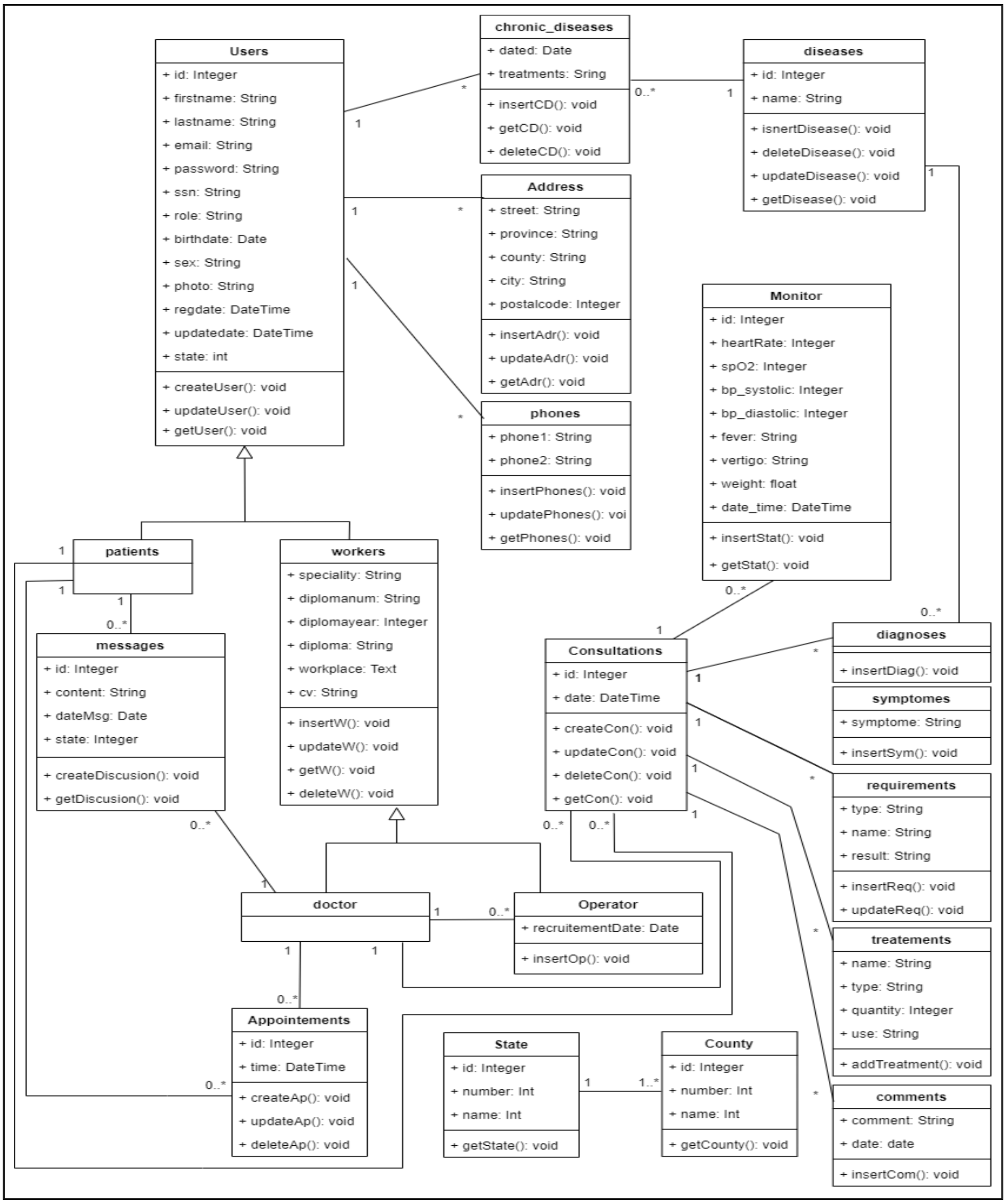

Figure 3.12: Class diagram

III.5.2.2 Agents class diagram

Figure 3.13 presents the class diagram of the agents in our system. In this diagram we have two agent classes which inherit from the agent class

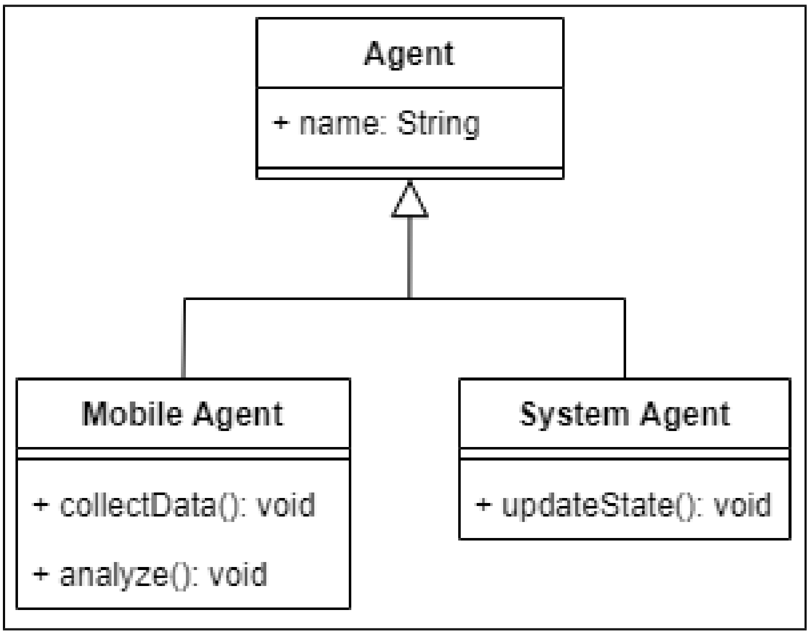

Figure 3.13: Agents class diagram

III.5.3 Conclusion

In this chapter, we have presented the analysis and design phase of our system, based on the AUML language after the identification of different components of the system, we have developed the necessary AUML diagrams for its modeling, namely the use case diagram, the Activity diagrams, and the class diagram. The following chapter will be devoted to the implementation of this system.

Chapter IV

Implementation

IV.1 Introduction

In the previous chapter of this thesis, we proposed an agent-based architecture for the creation of a platform for managing EHRs and patient‘s remote monitoring. In this chapter, we will move on to the last step which is realization. This step is crucial for the implementation of what we have done before. We will begin this chapter by presenting the different languages and tools used to develop our system. Next, we will briefly explain how to implement our system with Spade. We will end this chapter by presenting some interfaces and the different agents of the system using Spade tools.

IV.2 Development languages and tools

In this section, we present the different languages and tools to use for the development of our application.

IV.2.1 Python Language

Python[9] is an interpreted, object-oriented, high-level programming language with dynamic semantics. Its high-level built in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components together. Python's simple, easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance. Python supports modules and packages, which encourages program modularity and code reuse. The Python interpreter and the extensive standard library are available in source or binary form without charge for all major platforms, and can be freely distributed.

IV.2.2 HTML

HyperText Markup Language, HTML[35], is the language for describing the structure of Web pages. HTML gives authors the means to:

- Publish online documents with headings, text, tables, lists, photos, etc
- Retrieve online information via hypertext links, at the click of a button.

- Design forms for conducting transactions with remote services, for use in searching for information, making reservations, ordering products, etc.
- Include spread-sheets, video clips, sound clips, and other applications directly in their documents.

With HTML, authors describe the structure of pages using markup. The elements of the language label pieces of content such as "paragraph," "list," "table," and so on.

IV.2.3 Css

Cascading Style Sheet CSS[35] is the language for describing the presentation of Web pages, including colors, layout, and fonts. It allows one to adapt the presentation to different types of devices, such as large screens, small screens, or printers. CSS is independent of HTML and can be used with any XML-based markup language. The separation of HTML from CSS makes it easier to maintain sites, share style sheets across pages, and tailor pages to different environments. This is referred to as the separation of structure (or: content) from presentation.

IV.2.4 JavaScript

JavaScript[32] is a scripting or programming language that allows you to implement complex features on web pages — every time a web page does more than just sit there and display static information for you to look at — displaying timely content updates, interactive maps, animated 2D/3D graphics, scrolling video jukeboxes, etc.

IV.2.5 JQuery

JQuery[31] is a fast, small, and feature-rich JavaScript library. It makes things like HTML document traversal and manipulation, event handling, animation, and Ajax much simpler with an easy-to-use API that works across a multitude of browsers. With a combination of versatility and extensibility, jQuery has changed the way that millions of people write JavaScript.

IV.2.6 Spade

Smart Python Agent Development Environment, Spade[34] is a multi-agent systems platform written in Python and based on instant messaging (XMPP).
It is for Develop agents that can chat both with other agents and humans. It Featres are:

- Multi-agent platform based on XMPP.
- Presence notification allows the system to know the current state of the agents in real-time.
- Python $\geq$ 3.6.
- Asyncio-based.
- Agent model based on behaviours.
- Supports FIPA metadata using XMPP Data Forms (XEP-0004: Data Forms).

- Web-based interface.
- Use any XMPP server.

IV.2.7 Flask Framework

Flask[33] is a web framework, it's a Python module that lets you develop web applications easily. It's has a small and easy-to-extend core: it's a microframework that doesn't include an ORM (Object Relational Manager) or such features.

It does have many cool features like url routing, template engine. It is a WSGI web app framework.

IV.2.8 XMPP

XMPP[13] is the Extensible Messaging and Presence Protocol, a set of open technologies for instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalized routing of XML data.

XMPP was originally developed in the Jabber open-source community to provide an open, decentralized alternative to the closed instant messaging services at that time. XMPP offers several key advantages over such services:

- **Open:** the XMPP protocols are free, open, public, and easily understandable; in addition, multiple implementations exist in the form clients, servers, server components, and code libraries.
- **Standard:** the Internet Engineering Task Force (IETF) has formalized the core XML streaming protocols as an approved instant messaging and presence technology. The XMPP specifications were published as RFC 3920 and RFC 3921 in 2004, and the XMPP Standards Foundation continues to publish many XMPP Extension Protocols. In 2011 the core RFCs were revised, resulting in the most up-to-date specifications (RFC 6120, RFC 6121, and RFC 7622).
- **Proven:** the first Jabber/XMPP technologies were developed by Jeremie Miller in 1998 and are now quite stable; hundreds of developers are working on these technologies, there are tens of thousands of XMPP servers running on the Internet today, and millions of people use XMPP for instant messaging through public services such as Google Talk and XMPP deployments at organizations worldwide.
- **Decentralized:** the architecture of the XMPP network is similar to email; as a result, anyone can run their own XMPP server, enabling individuals and organizations to take control of their communications experience.
- **Secure:** any XMPP server may be isolated from the public network (e.g., on a company intranet) and robust security using SASL and TLS has been built into the core XMPP specifications. In addition, the XMPP developer community is actively working on end-to-end encryption to raise the security bar even further.
- **Extensible:** using the power of XML, anyone can build custom functionality on top of the core protocols; to maintain interoperability, common extensions are published in the XEP series, but such publication is not required and organizations can maintain their own private extensions if so desired.

- **Flexible:** XMPP applications beyond IM include network management, content syndication, collaboration tools, file sharing, gaming, remote systems monitoring, web services, lightweight middleware, cloud computing, and much more.
- **Diverse:** a wide range of companies and open-source projects use XMPP to build and deploy real-time applications and services; you will never get "locked in" when you use XMPP technologies.

IV.2.9 Pycharm

PyCharm is an integrated development environment (IDE) used in computer programming, specifically for the Python language. It is developed by the Czech company JetBrains (formerly known as IntelliJ). It provides code analysis, a graphical debugger, an integrated unit tester, integration with version control systems (VCSes), and supports web development with Django as well as data science with Anaconda.

IV.2.10 Oracle Database

Oracle Database (commonly referred to as Oracle DBMS or simply as Oracle) is a multi-model database management system produced and marketed by Oracle Corporation.

It is a database commonly used for running online transaction processing (OLTP), data warehousing (DW) and mixed (OLTP and DW) database workloads. Oracle Database is available by several service providers on-prem, on-cloud, or as hybrid cloud installation. It may be run on third party servers as well as on Oracle hardware (Exadata on-prem, on Oracle Cloud or at Cloud at Customer).

IV.3 My Health ScreenShots

Login Page

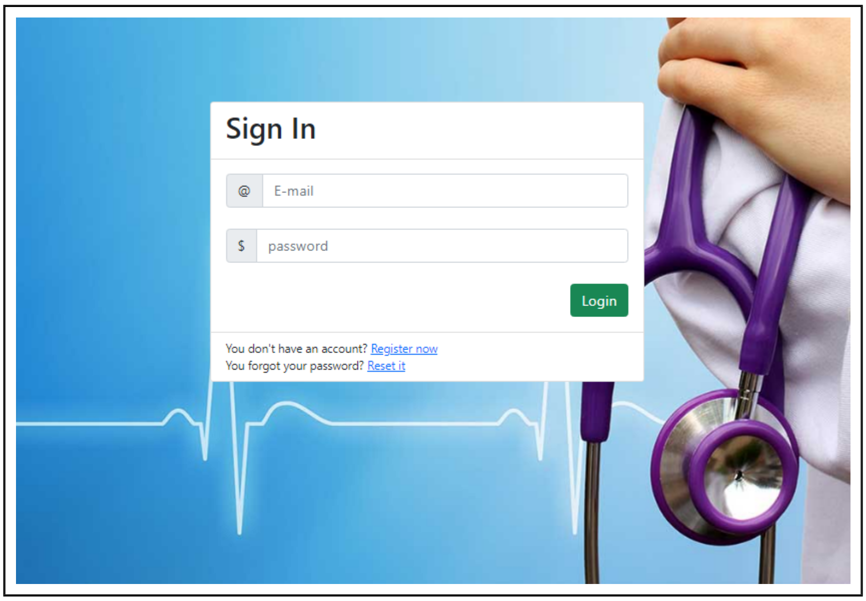

Figure 4.1: Login Page

Registration Page

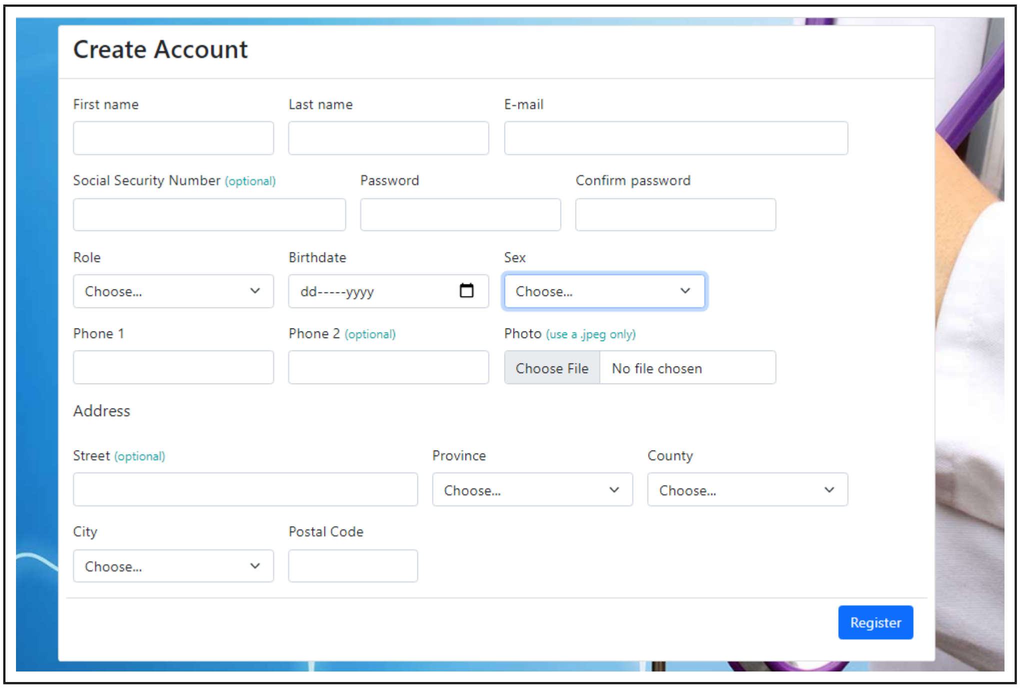

Figure 4.2: Registration Page

Profile Page

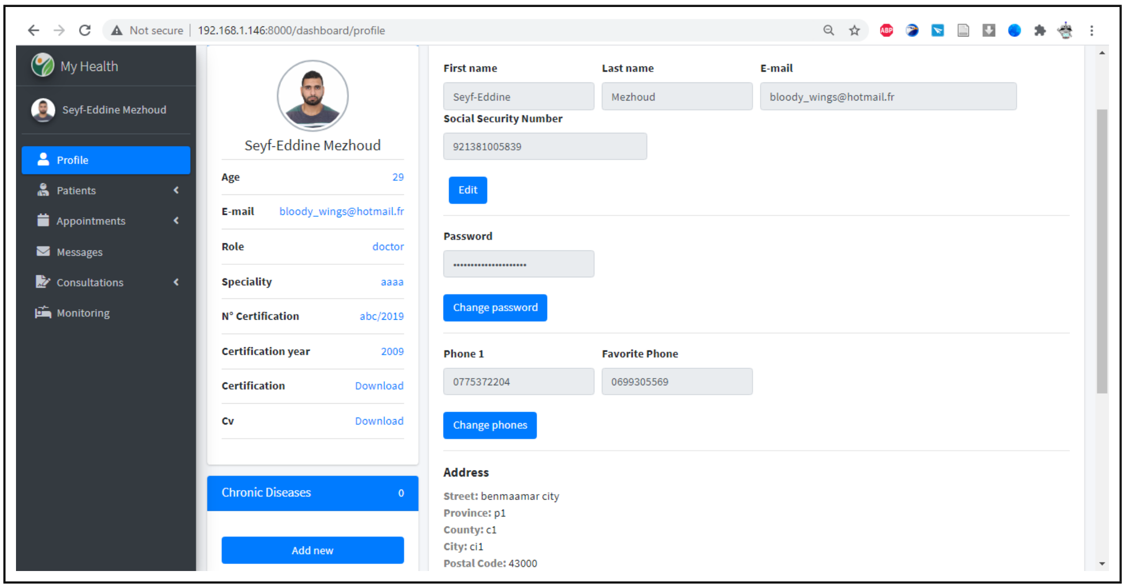

Figure 4.3: Profile Page

Search Patient Page

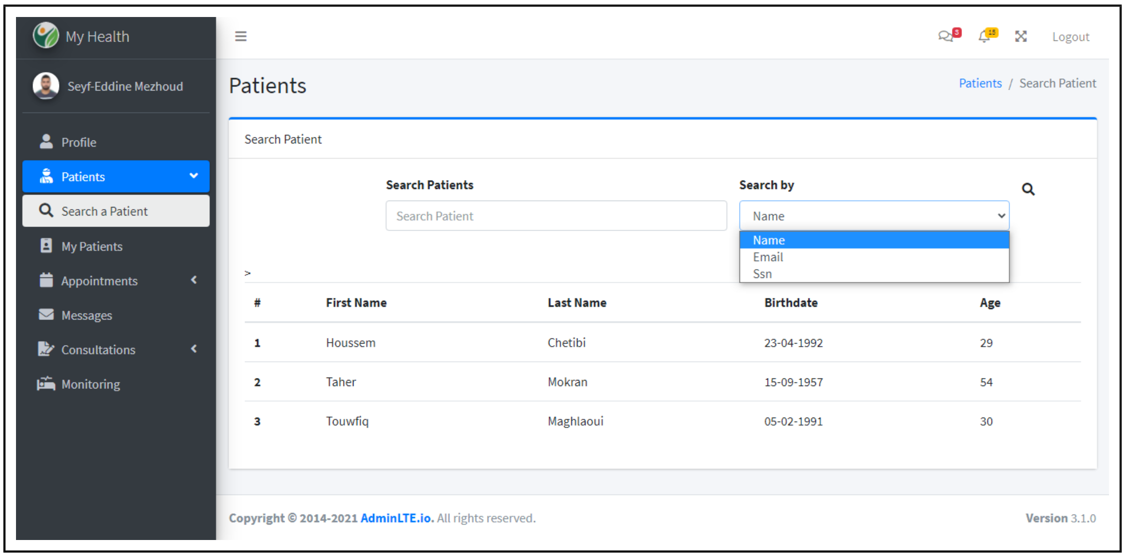

Figure 4.4: Search patient Page

My Patients Page

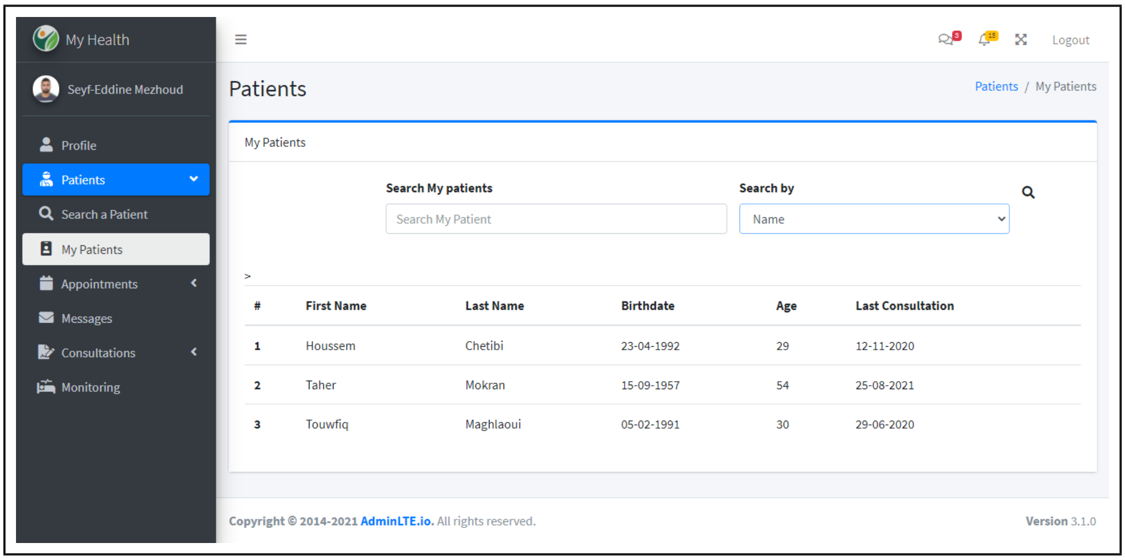

Figure 4.5: My Patient Page

Add New Appointment Page

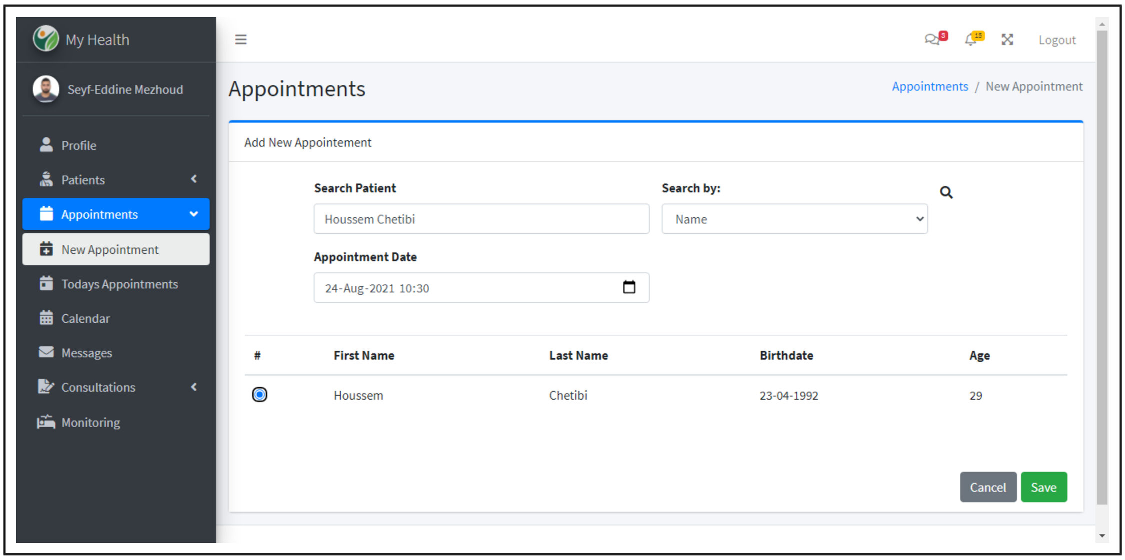

Figure 4.6: Add New Appointment Page

Todays Appointments Page

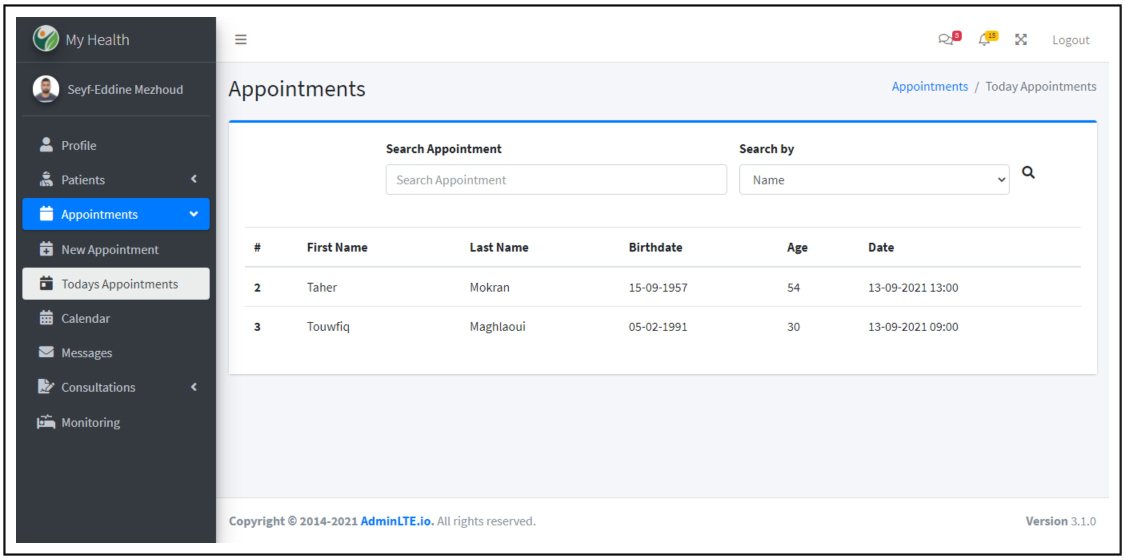

Figure 4.7: Todays Appointments Page

Calendar Page

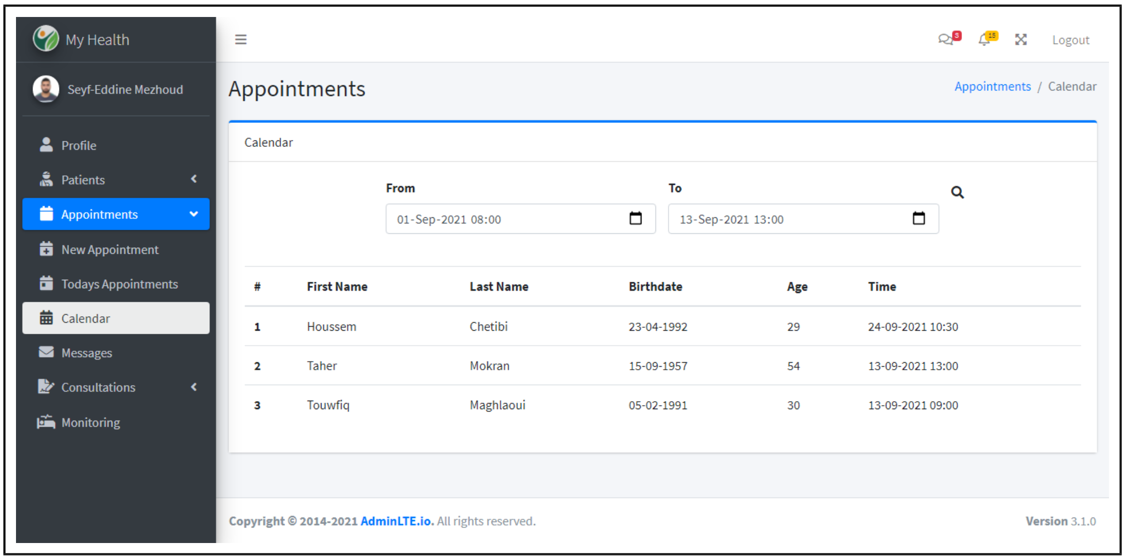

Figure 4.8: Calendar Page

Create new consultation Page

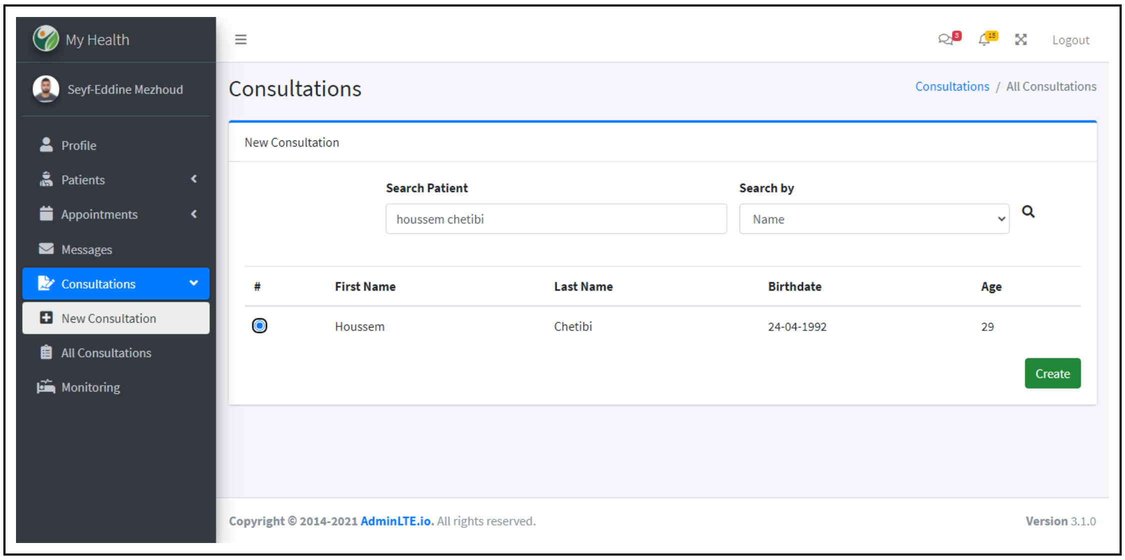

Figure 4.9: Create new consultation Page

All Consulations Page

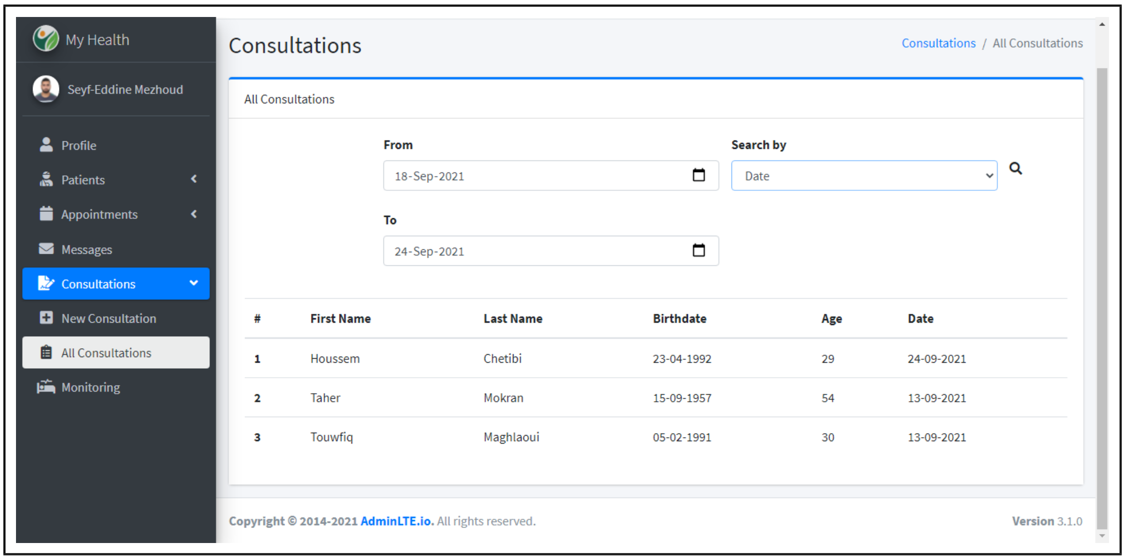

Figure 4.10: All Consulations Page

Edit Consltation Page

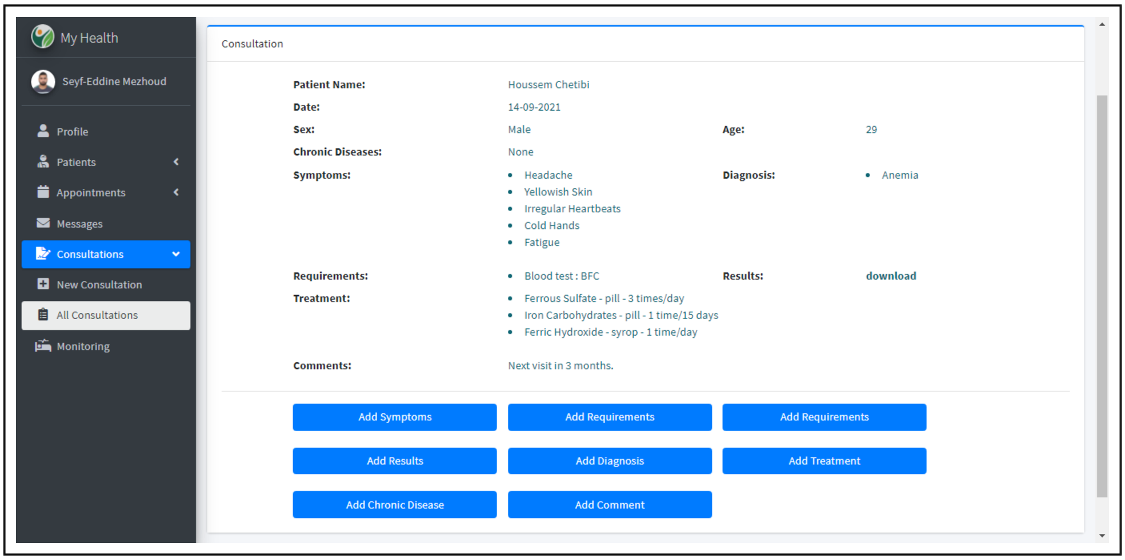

Figure 4.11: Create new consultation Page

Conclusion

The aim of this thesis is to develop an intelligent system to follow up the condition of patients remotely and also to keep their health records, in order to raise the pressure on doctors and to eliminate the need to stay under observation in the hospital, except in very critical cases. To realize this project, we studied several remote patient monitoring systems and consulted doctors about it. We noticed that the health system does not have an Electronic Health Record system and does not have a remote patient monitoring system at all, but rather relies on old systems that require hospitalization. In this thesis, we proposed an Intelligent System called My Health, which composed of two mobile phone application and a web application, the first is for patients to collect their vital signs, and the second to preview patients' records, as well as monitor their cases remotely and update their health record, and also to enable patients to preview their EHR. The main feature of this system is to monitor the health status of the patient by collecting and analyzing his vital signs and sending alerts to the doctor and people close to the patient, as well as civil protection, depending on the result of the analysis Finally, we would like to mention that there are a lot of ideas that we want to achieve in the future, for example increasing the number of sensors, for example: brain sensors. We can also develop our system to accommodate all the interests that have to do with the health of our country.

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