# MyHealth Clinic: An Example of Technology-Driven Health-Care

Enterprise ICT Architectures

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# Introduction

The growing relevance of the digital process has impacted the medical field with new solutions, while leading towards a technology-driven business model. For this reason, the health-care sector should adopt a solution where a solid ICT architecture is implemented, in order to improve data management and communication between the various stakeholders including patients, doctors and investors. With this paper, we want to present a possible solution for technology management in health-care that can be summarized in the following phases. Firstly, we highlighted the business model of a hypothetical private clinic, called MyHealth Clinic. Secondly, we described the customer relationship management system and used a BOAT framework to provide a structured view of the organizational aspects. Then, we focused on data and how they should be gathered, stored and used. The study revealed that the health-care industry still does not have a predefined standard model for the management of clinical data and processes. The use of a technological perspective in healthcare companies has a major potential that has yet to be exploited.

# 1. Enterprise Background

MyHealthClinic is a network of multi-specialty clinics providing a wide range of outpatient healthcare assistance. From medical checkups, doctor consultations, health screening to other medical practices. MyHealthClinic is specialized in long-term diseases and follows its patients during their entire life. The main problem that this institution is facing at the moment is to build an information system that keeps track of the patient's progress data securely and prepares ad hoc digital services to support the patients. To improve the relationship with its clients, the hospital decided to implement its information system.

| **Relationship with the clients** | |
|---|---|
| **Parties** | B2C |
| **Objects** | Digital and physical products |
| **Time Scope** | Dynamic<br>Semi-Dynamic |

| | |
|---|---|
| **Drivers** | More interconnected relationship between the hospital and the patients. Advanced data analysis and security. Time efficiency. |

The main tools that this information system should provide to the patient are:

1. A registration system thanks to which the non-register users won't be allowed to enter in this system.
2. The possibility of booking exams and visits 24/7. In particular, the system should notify if the booking procedure was successful or not and, in addition, right after the booking process, the system should provide feedback about the reservation in a few seconds.
3. The possibility to plan collateral activities and prevention activity to advice for behaviors that may help the patient's health.

Summing up, the information system should give constant support to the patients during their diseases and should give to the doctor a 360 degrees perspective over the changes in patients' health.

# 2. Business Process

## 2.1 Hospital Offers

Due to its private nature, the clinic needs to be profitable. In order to make the best out of its resources, it has identified three deals for the patients. Based on the patient's needs, the deals offer various methods to get in touch with the clinic.

1. **Basic**: The entry-level offer gives patients the possibility to get in contact with the clinic through calls.
2. **Premium**: The second deal, in addition to the first one, gives the patient the opportunity to sign up for a fidelity card and receive a free eye or derma check. It also upgrades the communication channels between the clinic and the patient, which

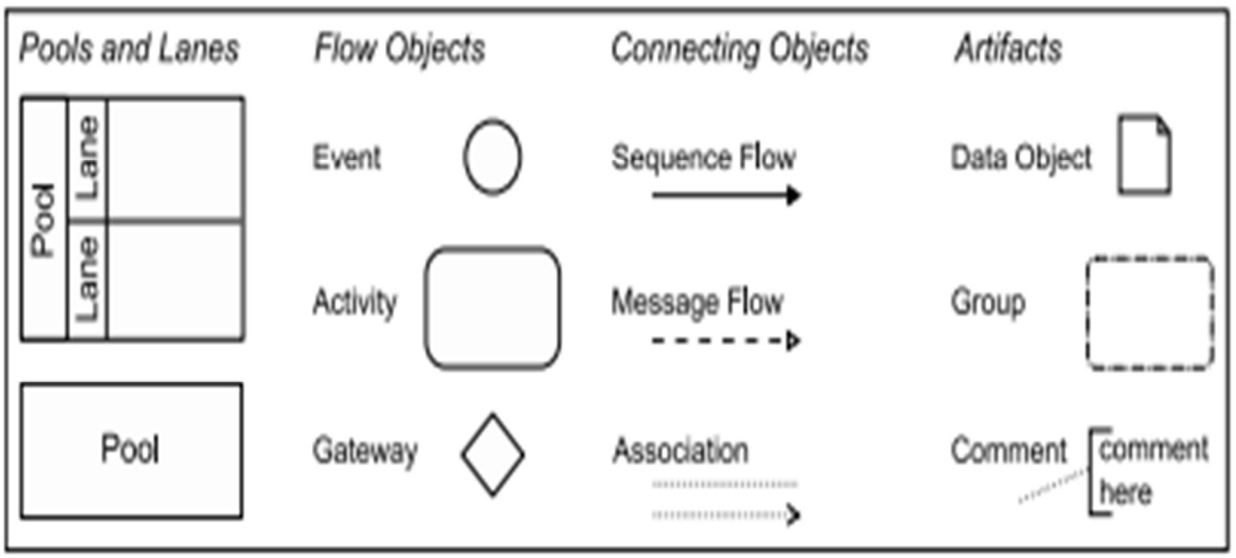
has the chance to receive a first diagnosis through a bot (which will be described later). The patient can also receive psychological support though-out its therapy.
3. **Luxury**: The last deal includes everything that was already part of the other two, and in addition, the clinic provides a wearable device that will help keep track of the patient parameters on a daily basis.

It is important to specify that these deals are just a way to properly manage the clinic communications, their objective is not to prioritize or differentiate the patient. The aim is not to create status A and status B patients, but it is just to give a structure to the interactions between the clinic and the patients.

## 2.2 Registration (BPMN)

The relationship between a hospital and its patient starts with the registration of the latter. This entails a whole series of problems on the part of the hospital, such as: Which data should the patient provide? How could the patient register? Where should the data be stored?

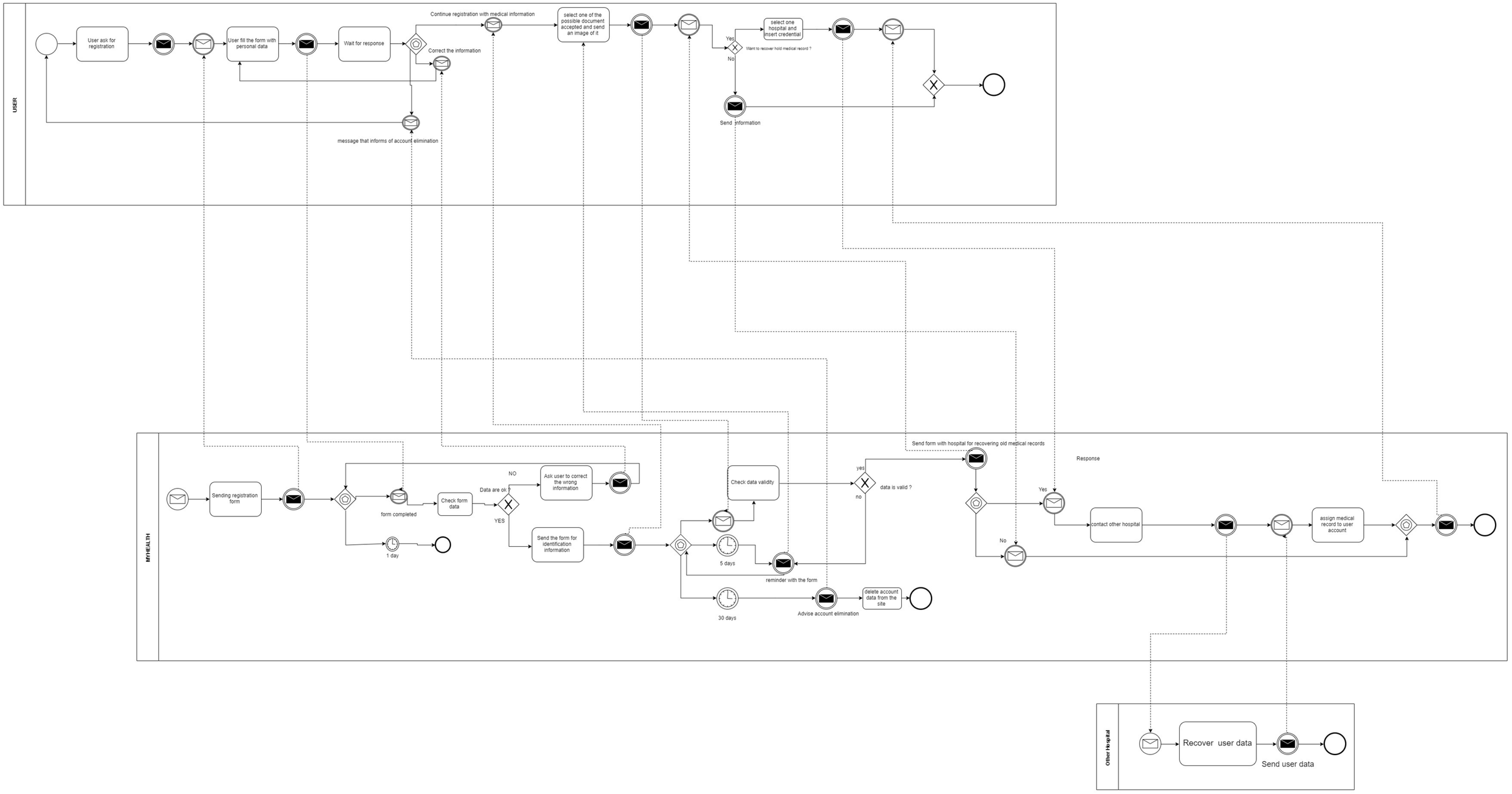
To answer all these questions and build an effective registration system, all the Clinic stakeholders and processes should be appropriately mapped. An effective way to do it is by using the **Business Process Model and Notation (BPMN)**, which is a graphical representation for specifying business processes in a business process model. Throughout graphical notation, the model will give organizations the ability to communicate these procedures in a standard manner. Furthermore, the graphical notation will facilitate the understanding of the performance collaborations and business transactions between the organizations. This will ensure that businesses will understand themselves and participants in their business and will enable organizations to adjust to new internal and B2B business circumstances quickly.




### 2.2.1 Entry Level Patient

The first BPMN is used to display all the steps that take the registration of a new user. The process begins when the user asks for registration to MyHealth, which replies by sending a registration form to the user: if the user does not fill the form within 1 day, the process ends. Alternatively, once the user has completed the form with personal data, the application checks for data consistency. If data are not correct, the system asks the user to correct for wrong information until the problem is solved. At this point, the system sends the form for identification information to the user, who continues the registration process by inserting his medical information. Unless the user sends back the form with its medical information within the first 5 days, MyHealth sends a reminder message with the form attached; after 30 days, if the user has not answered yet, upon his confirmation, the app closes the account from the site.

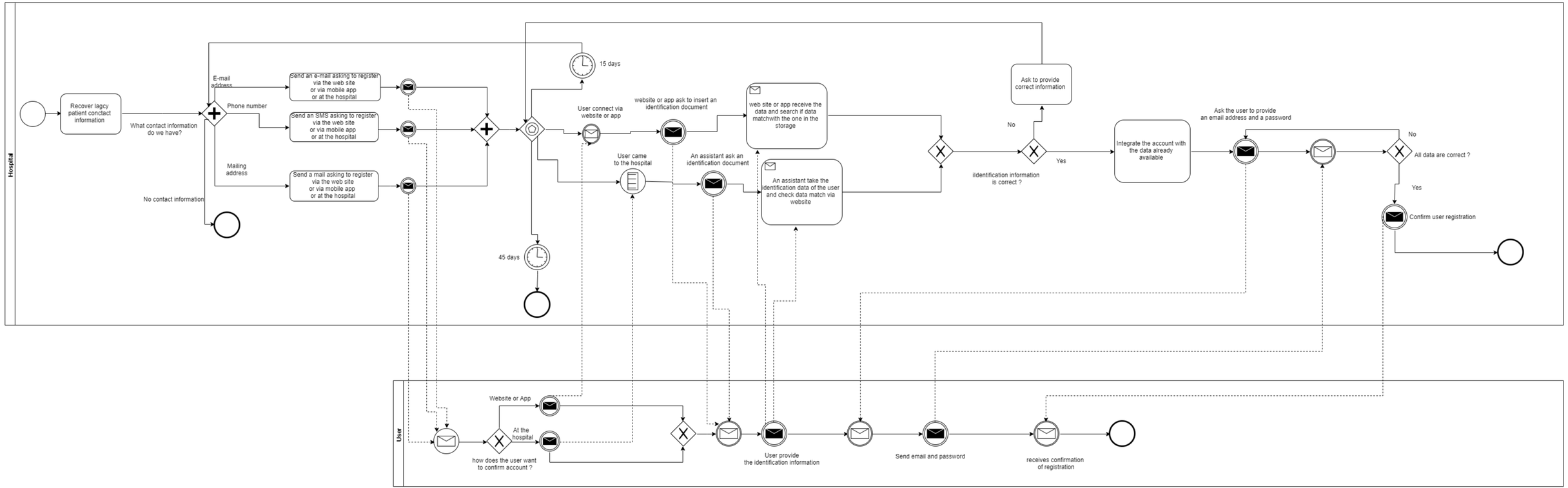
Once MyHealth has received the user form and has checked for data validity, the user has to decide whether he wants to recover past medical information by selecting the hospital; if he does not want to, the process ends. Alternatively, in order to past data, the system contacts the old hospital and assigns the medical records to the user account, which is the last phase of the project.


USER
User ask for registration
User fill the form with personal data
Wait for response
Correct the information
Continue registration with medical information
select one of the possible document accepted and send an image of it
Yes
No
Want to recover hold medical record ?
select one hospital and insert credential
Send information
message that informs of account elimination
MYHEALTH
Sending registration form
form completed
Check form data
Data are ok ?
NO
YES
Ask user to correct the wrong information
Send the form for identification information
1 day
5 days
30 days
reminder with the form
Advise account elimination
delete account data from the site
Check data validity
data is valid ?
yes
no
Send form with hospital for recovering old medical records
Response
Yes
No
contact other hospital
assign medical record to user account
Other Hospital
Recover user data
Send user data

### 2.2.2 Legacy Patients Register

Let us now analyze the second BPMN which concerns the process for users that are already registered but whose accounts need to be updated. In order to recover legacy patient contact information, depending on the available contact type (e-mail address, telephone number, mailing address), the system asks to register via the web site, via app mobile or at the hospital. If the user does not fulfill the request within 15 days, the system sends a reminder message and, after 45 days with no response, the process is closed; it goes without saying that the process ends right away if we do not have any contact information.

Once the user has received the request, he decides how to fulfill it, but, in both cases, he is asked to insert an identification document, digitally or personally. Once the user has provided the identification information, the system checks that it matches the one already stored in the database and, if not, the user is asked to provide correct information. Finally, the system integrates the account with the data that are already available in the database, asks the user to provide an email address and password and, eventually, gives confirmation of registration.


Hospital
Recover lagcy patient conctact information
What contact information do we have?
E-mail address
Phone number
Mailing address
No contact information
Send an e-mail asking to register via the web site or via mobile app or at the hospital
Send an SMS asking to register via the web site or via mobile app or at the hospital
Send a mail asking to register via the web site or via mobile app or at the hospital
15 days
45 days
User connect via website or app
website or app ask to insert an identification document
User came to the hospital
An assistant ask an identification document
web site or app receive the data and search if data matchwith the one in the storage
An assistant take the identification data of the user and check data match via website
Ask to provide correct information
No
Yes
iIdentification information is correct ?
Integrate the account with the data already available
Ask the user to provide an email address and a password
No
All data are correct ?
Yes
Confirm user registration
User
Website or App
At the hospital
how does the user want to confirm account ?
User provide the identification information
Send email and password
receives confirmation of registration

## 2.3 To Outsource or Not? BPM vs. BPO

Business Process Outsourcing is an alternative to Business Process Management that is handled internally by the organization. Outsourcing is the usage of an external third-party company instead of an internal source which may include the production of a single operation, a product or an entire line, shipping and order fulfillment, product design, network infrastructure support or many other functions. The outsourced functions are generally outside of an organization's core competencies and they are done in order to reduce the cost, reduce lead time, improve the focus and quality of a stated goal. Business Process Outsourcing (BPO) is the outsourcing of Business Process Management (BPM). Currently, many organizations outsource business processes to other companies to manage and execute their non-core business processes. Companies in competitive markets are looking for ways to focus their efforts on the core activities in order to increase their productivity, cost-cutting, and profitability. The concept of Business Process Outsourcing comes out as a possible solution to this problem.

Organizations engage in Business Process Outsourcing for two main areas of work: back-office functions and front-office functions. Organizations can outsource a range of back-office functions (also referred to as internal business functions) including accounting, IT services, human resources (HR), quality assurance (QA) and payment processing. Similarly, they can outsource various front-office functions, such as customer relations services, marketing, and sales. Organizations can also outsource specific functions (i.e., payroll) in those areas in addition to outsourcing an entire functional area (i.e., human resources).

Organizations prefer engaging in Business Process Outsourcing than internal Business Process Management as they expect to benefit from the arrangement in various ways. The benefits that are generally cited by proponents of BPO include:

- Financial Benefits: Organizations realize that an outsourced third-party provider can perform a business process at much lower costs or they often

find that by contracting with an outsourced provider they can save money as a result of the relationship in other ways, such as in tax savings.

- Flexibility: BPO contracts allow organizations to be more flexible to adjust how it completes the outsourced business process, allowing them to react better and faster to changing market dynamics.

- Competitive advantage: Engaging in BPO allows organizations to outsource those processes that aren't core to their businesses or missions. The non-core business processes are typically not their areas of expertise and therefore BPO contracts allow organizations to focus more of its resources on the operations that distinguish them in the marketplace.

- Higher quality and better performance: Because the core business of BPO providers is performing the specific processes they're hired to do, they are, in theory, able to focus on providing those processes at the highest levels, often with greater accuracy, efficiency, and speed. In addition to the anticipated benefits, there are also several risks of Business Process Outsourcing. The potential risks and drawbacks include:

- Security breaches: In the case of a BPO, organizations must create technology connections between themselves and third-party providers. The formation of such a connection creates another potential vulnerability that could be exploited by bad actors. Besides, organizations often need to share sensitive or regulated data with their service providers, which is another potential security risk.

- Unanticipated costs: Organizations can underestimate the price they'll be charged for the work that they're outsourcing, either because they underestimate the amount of work or they did not calculate or anticipate the full costs of their contracts with their providers.

- Communication challenges: Organizations may experience communication problems with their outsourced providers. Moreover, in case of offshore

outsourcing, organizations may find that there are cultural barriers that can hinder a strong business partnership between them and their service providers. Such problems can prevent hiring organizations to experience the full benefits of their BPO contracts.

MyHealth Clinic will benefit from an onshore Information Technology Enabled Service (ITES-BPO) instead of an internal Business Process Management for their front-end operations due to various reasons such as lower costs and concentration on core functions. Outsourcing helps businesses to use variable-cost models, such as fee-for-service plans, instead of fixed-cost models that are required when hiring local employees. In addition, MyHealth Clinic is located in the Philippines which stands out as a popular and dynamic country for Information Technology Enabled Service-Business Process Outsourcing. A possible onshore BPO in the Philippines would eliminate the concerns regarding communication challenges and cultural barriers. Another reason for the adoption of BPO is that it would allow MyHealth Clinic to focus on the main offering. MyHealth Clinic is a healthcare provider organization and information technology is not their field of expertise. With an ITES-BPO for their front-end operations, MyHealth Clinic will be able to focus its energy on healthcare and improve their patients' health and satisfaction.

Even though lower costs and concentration on core functions are significant benefits of BPO, data security remains to be the biggest reason for MyHealth Clinic to engage in Information Technology Enabled Service-Business Process Outsourcing. As data breaches are an inevitable part of the modern-day, it is more essential than ever to keep the data of the clients and customers safe and secure. As MyHealth Clinic is operating in healthcare, data security is essential and legally required. The clinic has to ensure that all sensitive patient information and protected health information is being kept as safe as possible. A complicated and sensitive matter like data security has to be managed externally by specialists, as information security is not a core function and expertise of MyHealth Clinic. With the help of a reliable ITES-BPO provider, MyHealth Clinic will build up its healthcare data security infrastructure with best practices according to the local regulations and make sure that they’re continuously up to date. NEXT BPO is a third-party service provider that specializes in Data and Information Security. The company implements stringent

security safeguards and processes for every information touchpoint. Their security processes include planning, protection, detection, and response.

## 3. Customer Relationship Management

A Customer Relationship Management approach might be effective to track constantly the patients' progress, and the change in the disease in relation to healthcare. CRM (Customer Relationship Management) can be described as a strategy that helps organizations to build long-term relationships with current and future customers and increase profit through a proper management system and the application of customer customized approaches. A successful CRM is a combination of technology, people and process that intends to understand the customers. From a technological perspective, this approach is defined as an information system (IS) that allows organizations to focus more on their customers.

Over the last 10 years, many studies have tried to review CRM from different industries, evaluating it not just from the sales or marketing point of view. In particular, from the healthcare sector, where patients are the key customers, the term patient relationship management (PRM) is frequently used nowadays. CRM for healthcare is a way of learning about patients, relevant communication, building good relationships, providing the right data on time, and tracking patient's results to make the necessary adjustments. Building a good relationship that links hospitals and patients will not only increase the satisfaction rate rather than it helps to initiate a successful way of communication among medical staff, physicians, and patients, as it also improves the overall quality of healthcare with the ability to manage chronic disease. An effective CRM system integrates individual health records, patient records, along with hospital data to offer a solution for managing healthcare-related issues, benefits, and costs. However, a failure in building such kind of relationship with patients will lead to dissatisfaction and distrust, resulting in a loss of patients.

As well as for sale, Healthcare CRM includes 3 different modules:

**Communication module**. This module has features to schedule, initiate, and track interactions with patients. It also includes functionality to set reminders and schedule and confirm appointments.

**Task management module**. This module allows staff to add tasks, assign them to people, view and update them, and track their progress, deadlines, priorities, and completion.

**Report module**. This module allows you to generate and customize various reports, such as reports that track ROI for campaigns or reports on the average number of patient no-shows.

Apart from other industries, Healthcare CRM embraces a specific feature, and so a fourth model:

**Patient management module**. This module allows staff to add or update patient records, segment patients to target groups based on conditions, and effectively communicate with patients.

Of course, as any CRM strategy, these four modules can be customized according to the peculiar needs of each medical establishment. CRM, if properly designed and implemented, can be very useful for all the typical services provided by hospitals. In fact, it automates the majority of administrative processes and minimizes human interactions, the main causes of errors. Similarly, allows storing all the possible information about each patient, including their medical records. This overcomes the huge problem of lost charts (patient charts can't be found at almost 30 percent of visits).

With CRM, you can track patients' satisfaction, moods, and the likelihood of referring to their doctor or clinic to friends and family, using, for example, an automated survey. The results of surveys can then be used to generate automatic reports and provide valuable insights for the decision support system and then the executive information system.

Security, as well, is one of the main concerns in the healthcare industry. On average, 17,000 patient records are breached every day. Even today, a lot of clinics, hospitals, and individual practitioners store and transfer patient health information ways that aren’t HIPAA compliant (HIPAA, the Health Insurance Portability and Accountability Act, is an American legislation which aims to protect health insurance coverage for workers and their families when they change or lose their jobs

(Portability) and to protect health data integrity, confidentiality, and availability (Accountability)). For example, it’s estimated that 74 percent of healthcare practices are not encrypting data on their mobile devices.

When building a custom CRM, there are many security mechanisms to protect clinics and the patients’ personal data from hacker attacks. These security measures include:

- Multiple-factor authentication
- Biometric identification
- Data encryption
- Digital signature
- Multi-level user access to databases
- HIPAA compliant data storage

A CRM system allows clinics and hospitals to follow federal and state legislation and helps avoid financial penalties for unlawful data storage and mishandling of patient information. A practical application of CRM, from the client's point of view, is in the possibility for patients-customers of booking their exams and consulting results directly from the Hospital Website or from the specific App with dedicated "Reservation" and "Consult your Results" services. Once the software has checked the availability of the doctors and the ID of the registered patient, this one can successfully be booked a visit and then, after a while, with an authentication procedure, he/she can view the results.

The problem here may be the complexity of using such a well-designed software since the patients need to learn how to use it continuously if they want to take advantage of this technology and mostly the elders might be excluded. However, a customer relationship management system in the healthcare industry is not just a trend that will disappear soon. Real-world results from various clinics show that CRM software helps solve some of the biggest problems in the healthcare sphere, improve customer satisfaction, and boost revenue. CRMs are no longer seen as just additional software to improve services, in fact, nowadays they are a necessary tool to survive in a highly competitive market.

So, there are a lot of Healthcare CRM solutions on the market among which hospitals can choose in order to select the best software for their needs. Obviously, it's about a make or choice decision, but, since clinics have as a primary focus the customers and the health of the customers, the better decision is to delegate to professional providers the management of CRM technology. Here are listed some of the best CRM solutions for Healthcare:

- **ScienceSoft**, thanks to their 14 years of experience in Healthcare IT, delivers Healthcare CRM solutions based on Microsoft Dynamics 365 and Salesforce Health Cloud to help improve the quality of care and raise patient satisfaction through personalized, better-informed services.

- **LeadSquared** is a Patient Relationship Management platform for healthcare businesses, such as hospitals, clinics or diagnostic centers. Increases new patient acquisition & retention ratios with appointment booking automation, physician onboarding, patient experience management, healthcare analytics features and more.

- **Evariant** is the leading company to provide Healthcare CRM program. It manages all the features of documentation, business intelligence tool, multi-channel marketing, email marketing campaigns, improving the relationship with patients with effective communication.

- **Deskra CRM** is the unbeatable solution for CRM for Healthcare, increasing the patients' driven healthcare and resolving patients' queries with precisely customer services. Furthermore, it provides healthcare associations to concentrate on Customer Relationship Management for streamline procedures and increase customer satisfaction.

## 4. BOAT framework

We will use the BOAT (Business, Organization, Architecture, Technology) framework that defines methods and tools in order to describe an enterprise

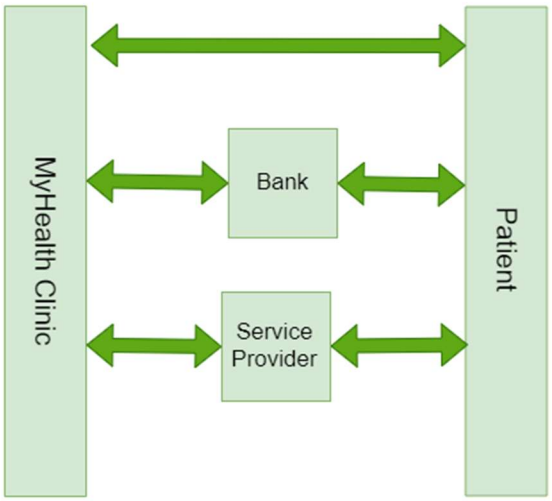
information system from multiple views. We will focus on the organizational perspective with the aim of providing a structured view of the organizational aspects to be considered in the development of information systems.

In the end, we will provide a description of the functional architecture through the architectural abstraction perspective, there are three levels of abstraction:

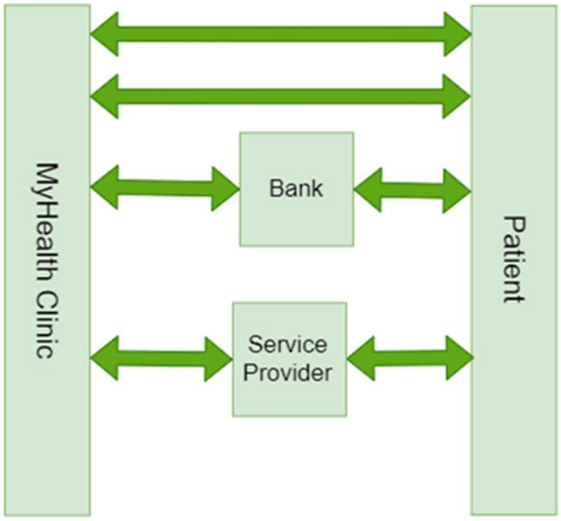
1. Market level Architecture
   • Inter-organization focus
   • Messages sent between parties and intermediaries
2. Parties level Architecture
   • Refinement of market level architecture
   • Intra-organization focus
   • Detail of messages between backend systems and interfaces
3. System level Architectures
   • Focus on subsystems

## 4.1 Market level architecture

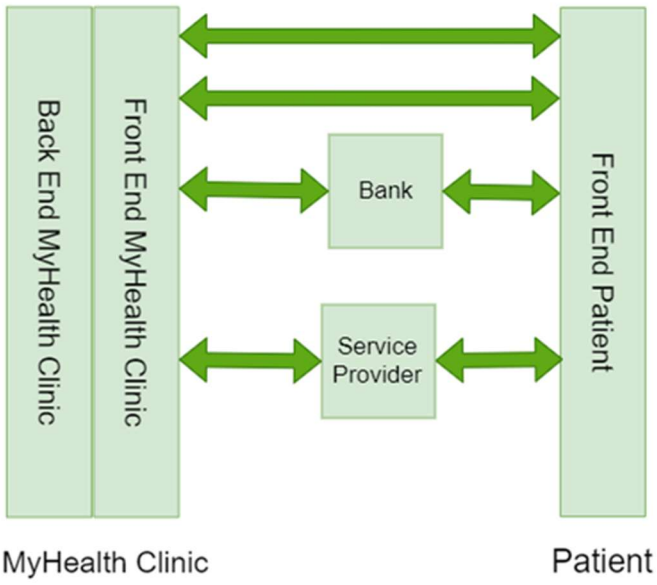

organizational structure - level 0




organizational structure - level 1

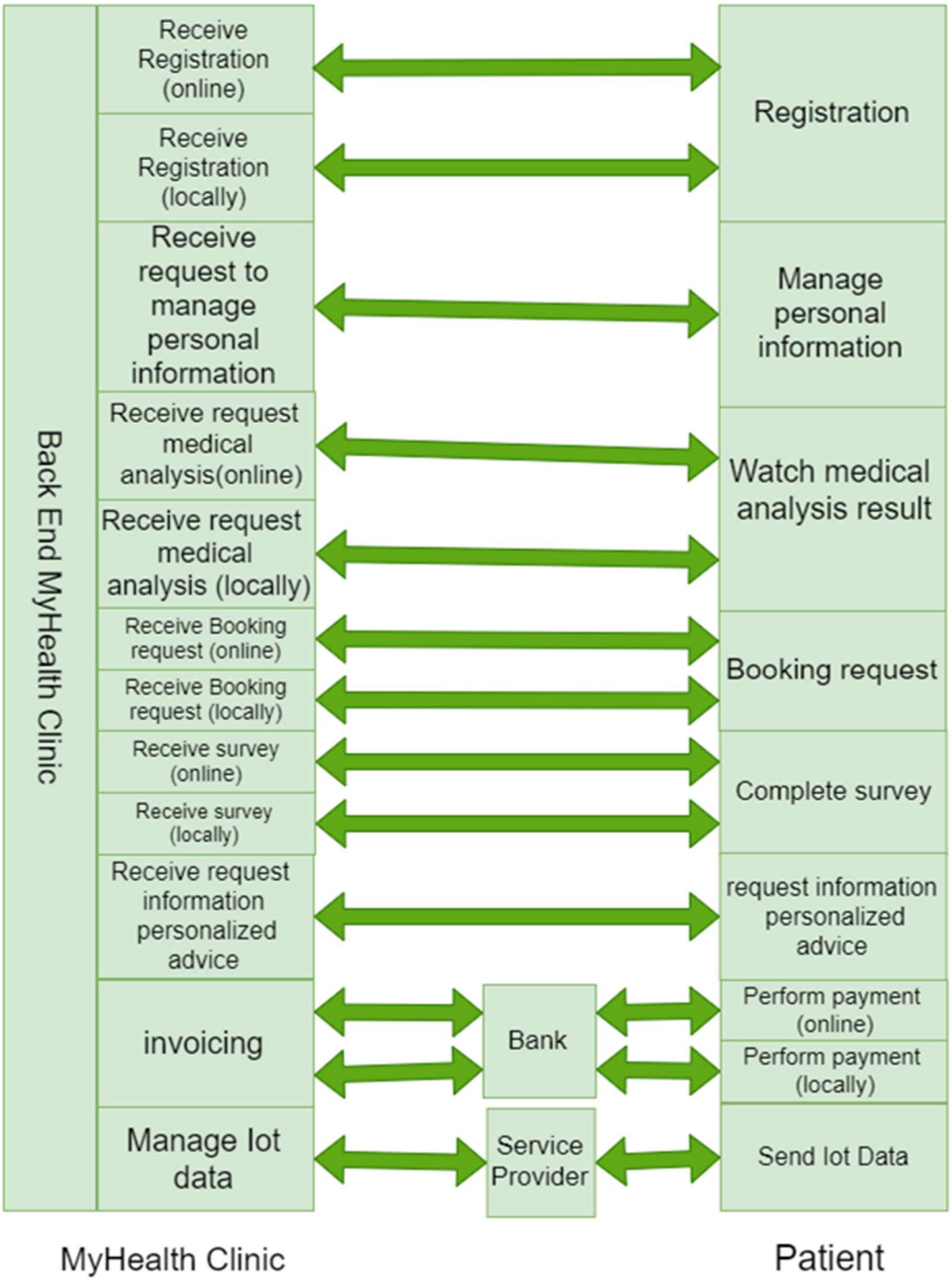



organizational structure - level 2

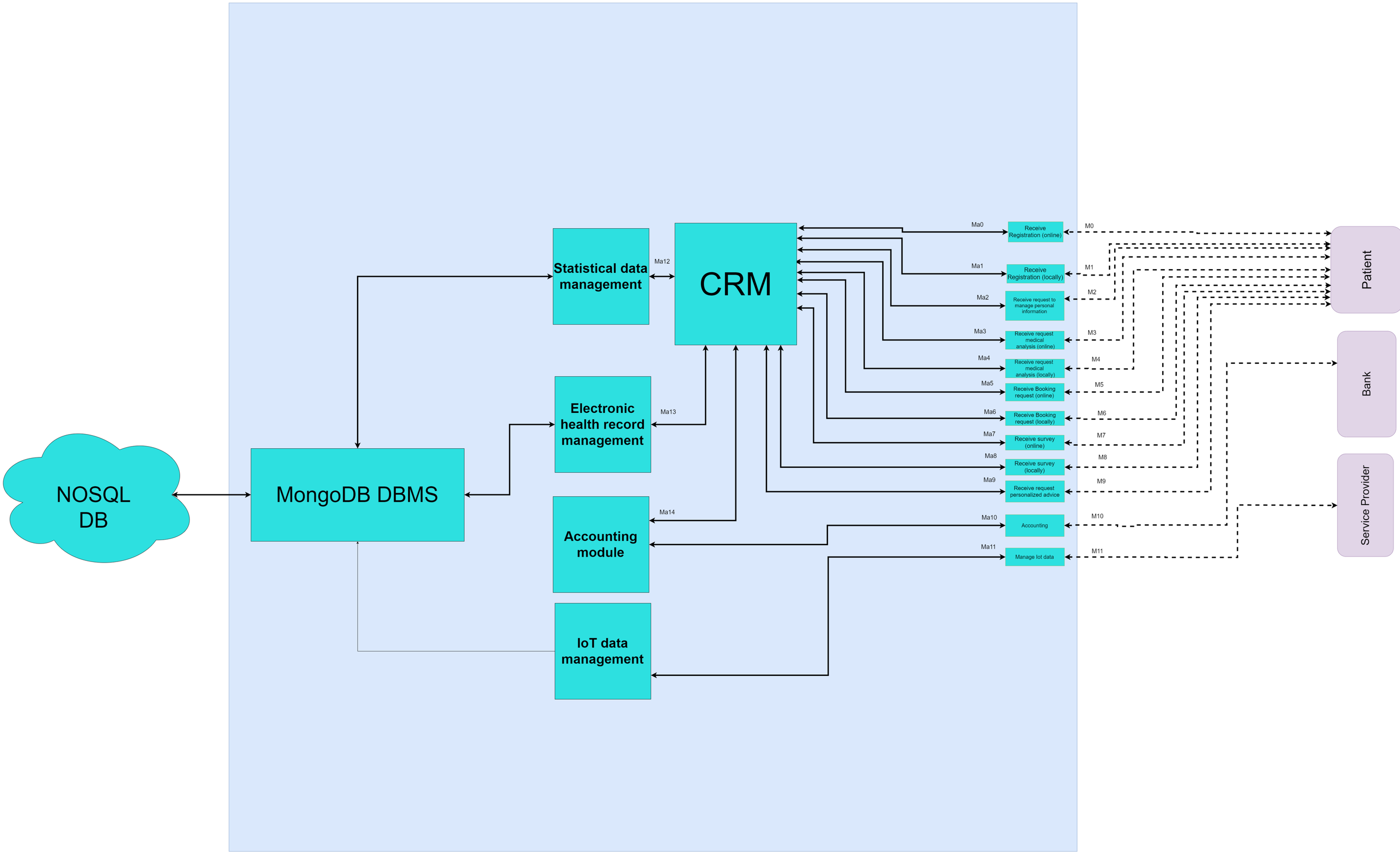



organizational structure - level 3

# Organizational structure - level 4



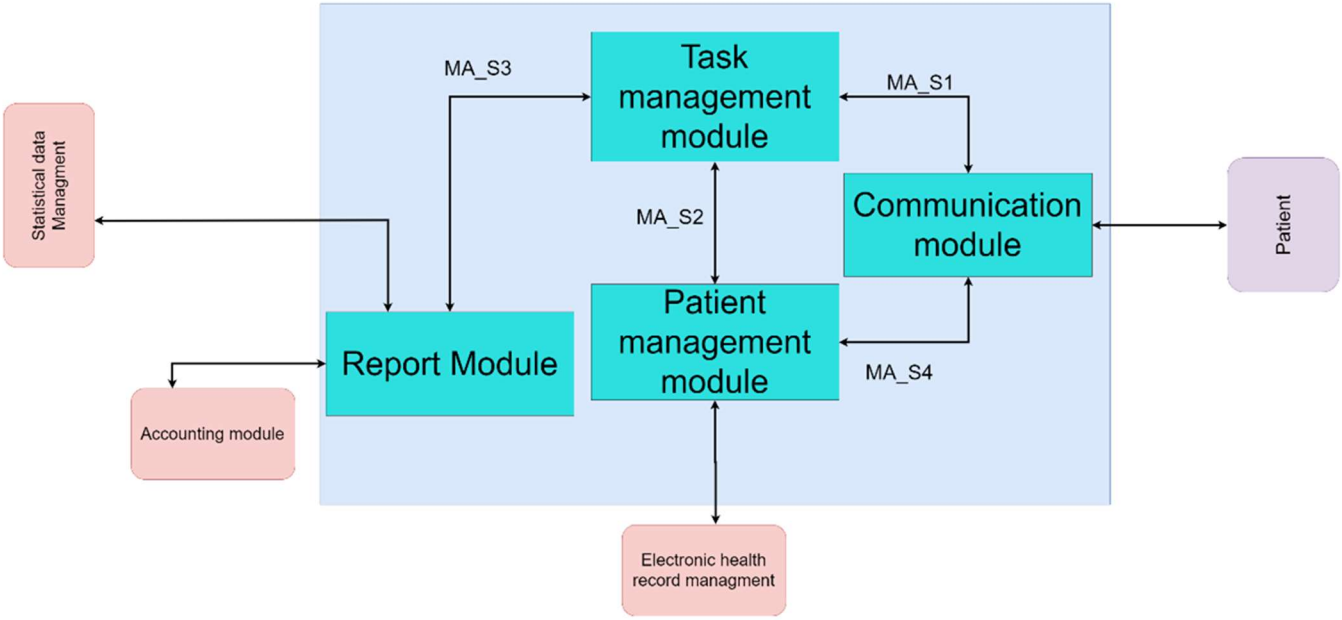
# Party level architecture



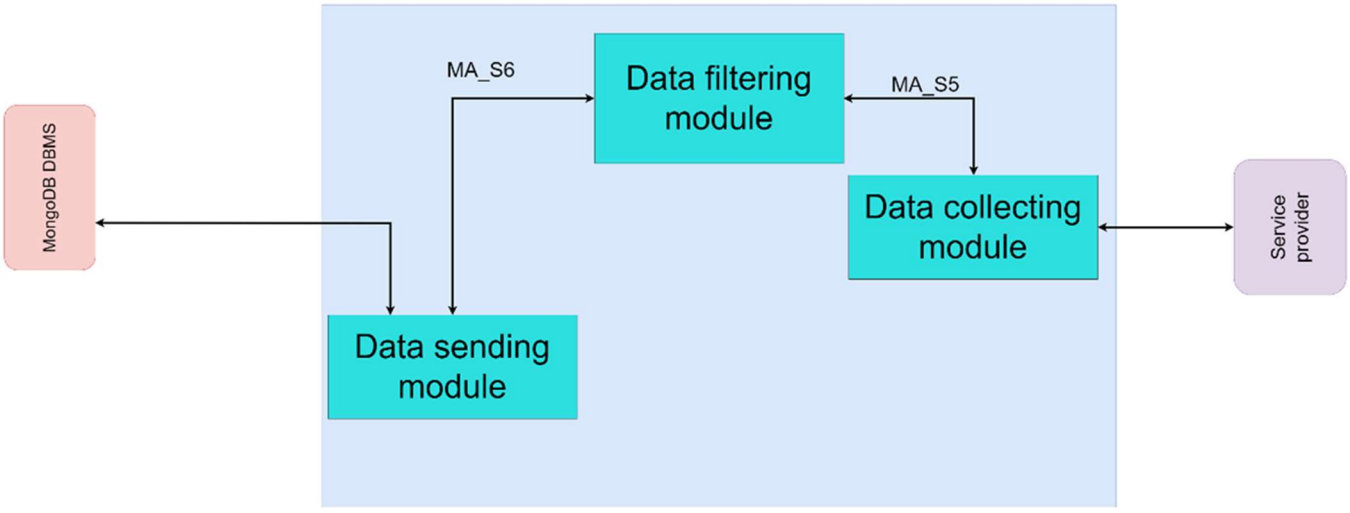
| Messages | exchanged content |
| --- | --- |
| M0 | Personal information, registration confirm |
| M1 | Personal information, registration confirm |
| M2 | Account information and new information, Data modification confirm |
| M3 | Medical analysis Request, Analysis results |
| M4 | Medical analysis Request, Analysis results |
| M5 | Medical examination Request, Date of examination |
| M6 | Medical examination Request, Date of examination |
| M7 | Survey data, Survey completion confirm |
| M8 | Survey data, Survey completion confirm |
| M9 | Medical advice request, Medical advice reply |
| M10 | payment receipt, payment confirmation |
| M11 | IoT data |
| | |

| Messages | exchanged content |
|---|---|
| Ma0 | registration form, Personal information |
| Ma1 | registration form,<br>Personal information |
| Ma2 | User information,<br>Account information and new information |
| Ma3 | Medical analysis Request,<br>Analysis results |
| Ma4 | Medical analysis Request,<br>Analysis results |
| Ma5 | Medical examination Request, Date of examination |
| Ma6 | Medical examination Request, Date of examination |
| Ma7 | Survey form, Survey data |
| Ma8 | Survey form, Survey data |
| Ma9 | Medical advice request,<br>Personalized Medical advise |
| Ma10 | User payment data, Service charge |
| Ma11 | IoT data, No response |
| Ma12 | Patient data, Statistical information |
| Ma13 | User data, Electronic health record |
| Ma14 | User payment data |

## 4.3 System level architecture for CRM




## 4.4 System level architecture for IOT data management



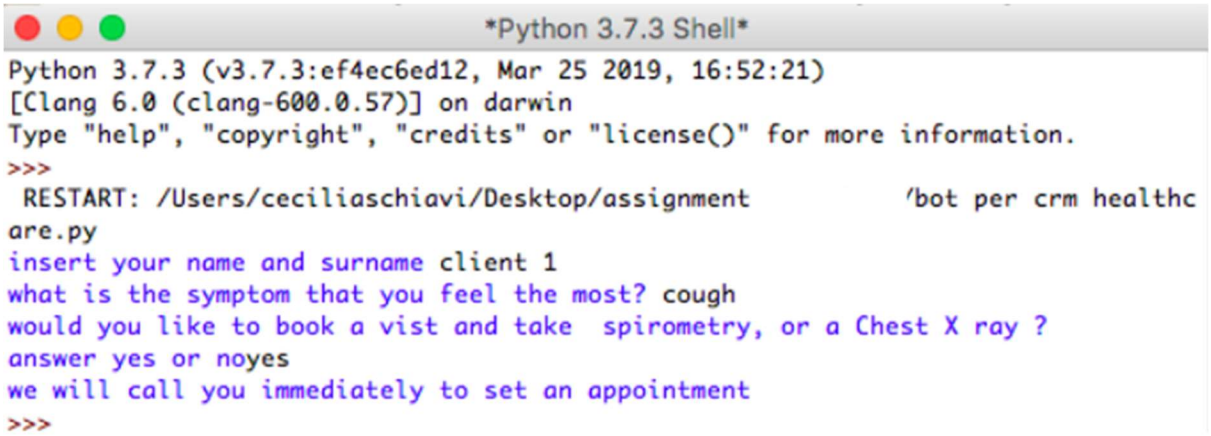
| Messages | exchanged content |
|---|---|
| MA_S1 | Communication tasks |
| MA_S2 | Medical expert tasks |
| MA_S3 | Reports tasks, reports |
| MA_S4 | Patient Communication, medical expert answers |
| MA_S5 | Data |
| MA_S6 | Filtered data |

## 4.5 A Demo Program to improve the CRM

In order to improve the relationship with premium and luxury clients, MyHealthClinic could offer a sort of BOT. A little and simple program that allows the clients to insert their symptoms and suggests them the better exams to book. If they agree to take a certain exam, the office will receive a notification so the secretary will call the client in order to book a visit.

Moreover, the secretary will also store the data that the patient has insert in our MongoDB.

Since this application is just a test, the font is really essential and not well designed, although it is really simple to understand.




When this program is opened it will ask for name and surname so that the staff can understand who to call in case of a visit reservation. After that, the bot will ask which symptoms are affecting the patient. With these informations, the bot will ask the client to take an exam that will help to diagonalize the most probable diseases with a certain kind of symptoms and if the answer is yes, it will be communicated to the secretary which will call the client and set an appointment immediately.

The exam recommendations are based on some medical researches that have been carried in order to define the variables of the bot.

bot per crm healthcare.py - /Users/ceciliaschiavi/Desktop/assignment ..., bot per crm healthcare.py (3.7.3)

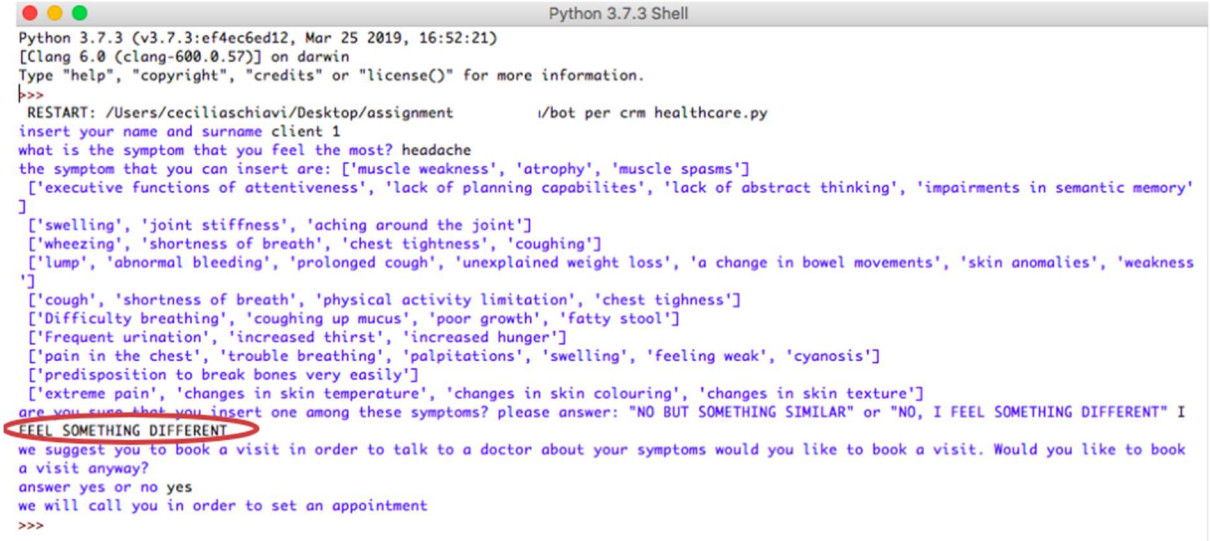
```
ALS_meaning = 'Amyotrophic lateral sclerosis'
ALS_symptoms = ['muscle weakness' , 'atrophy','muscle spasms']
ALS_diagnosis = 'electromyography'
ALS_cure = 'Riluzole'
ALS_possible_evolution = 'lose the ability to initiate and control all voluntary movement'
ALS_additional_therapy = 'aerobic exercise', 'psychological support'
ALS = [ALS_meaning, ALS_symptoms, ALS_diagnosis, ALS_cure, ALS_possible_evolution, ALS_additional_therapy]

Dementias_symptoms = ['executive functions of attentiveness', 'lack of planning capabilites', 'lack of abstract thinking', 'impairments in semantic memory']
Demetias_diagnosis = 'neuropsychological tests or an analysis of the historical evolution of the patient'
Demetias_cure = 'Five medications are currently used four are acetylcholinesterase inhibitors (tacrine, rivastigmine, galantamine and donepezil) and the other (memantine) is a
Demetias_possible_evolution = 'extreme apathy'
Demetias_additional_therapy = 'cognitive and language exercise'
Demetias_prevention = 'follow Mediterranean diet and try to preserve cognitive functions with exercises'
Alzheimers_Disease_and_other_Dementias = [Dementias_symptoms, Demetias_diagnosis, Demetias_cure, Demetias_possible_evolution, Demetias_additional_therapy, Demetias_prevention]

Arthritis_symptoms = ['swelling', 'joint stiffness', 'aching around the joint']
Arthritis_diagnosis = 'radiology or a blood tests'
Arthritis_cure = 'acetaminophen, surgery, electrical nerve stimulation'
Arthritis_additional_therapy = 'physical activity'
Arthritis = [Arthritis_symptoms, Arthritis_diagnosis, Arthritis_cure, Arthritis_additional_therapy]


Asthma_symptoms = ['wheezing', 'shortness of breath', 'chest tightness','coughing']
Asthma_diagnosis = 'spirometry'
Asthma_prevention = 'reduce tobacco smoke, air pollution, chemical irritants including perfume'
Asthma = [Asthma_symptoms, Asthma_diagnosis, Asthma_prevention]

Cancer_symptoms = ['lump', 'abnormal bleeding', 'prolonged cough', 'unexplained weight loss', 'a change in bowel movements', 'skin anomalies', 'weakness']
Cancer_diagnosis = 'blood tests, X-rays, and endoscopy'
Cancer_cure = 'chemotherapy, radiation and surgery'
Cancer_additional_therapy = 'follow a specific diet, have a well-balanced lifestyle, follow a group therapy or have a psychological support'
Cancer = [Cancer_symptoms, Cancer_diagnosis, Cancer_cure, Cancer_additional_therapy]

COPD_meaning = 'Chronic obstructive pulmonary disease'
COPD_symptoms = ['cough', 'shortness of breath', 'physical activity limitation', 'chest tighness']
COPD_diagnosis = 'spirometry, or a Chest X ray'
COPD_cure = 'follow a program of pulmonary rehabilitation'
COPD_additional_therapy = 'tai chi'
COPD_prevention = 'avoid polluted environment and smoking'
COPD = [COPD_meaning, COPD_symptoms, COPD_diagnosis, COPD_cure, COPD_additional_therapy, COPD_prevention]

Cystic_Fibrosis_symptoms = ['Difficulty breathing', 'coughing up mucus', 'poor growth', 'fatty stool']
Cystic_Fibrosis_diagnosis = 'sweat test'
Cystic_Fibrosis_cure = 'Antibiotics, pancreatic enzyme replacement, lung transplantation'
Cystic_Fibrosis = [Cystic_Fibrosis_symptoms, Cystic_Fibrosis_diagnosis, Cystic_Fibrosis_cure]

Diabetes_symptoms = ['Frequent urination','increased thirst', 'increased hunger']
Diabetes_diagnosis = 'Glycated haemoglobin, Glucose tolerance test'
Diabetes_cure = 'glucose control'
Diabetes_additional_therapy = 'follow a specific diet'
Diabetes = [Diabetes_symptoms, Diabetes_diagnosis, Diabetes_cure, Diabetes_additional_therapy]
```

The main technical problem with this bot is that the client can only insert a symptom which is stored in the variables, with the exact words of the bot. As said, this is a prototype and a better use of this program in order to interact with the client is still under evaluation.

Python 3.7.3 Shell

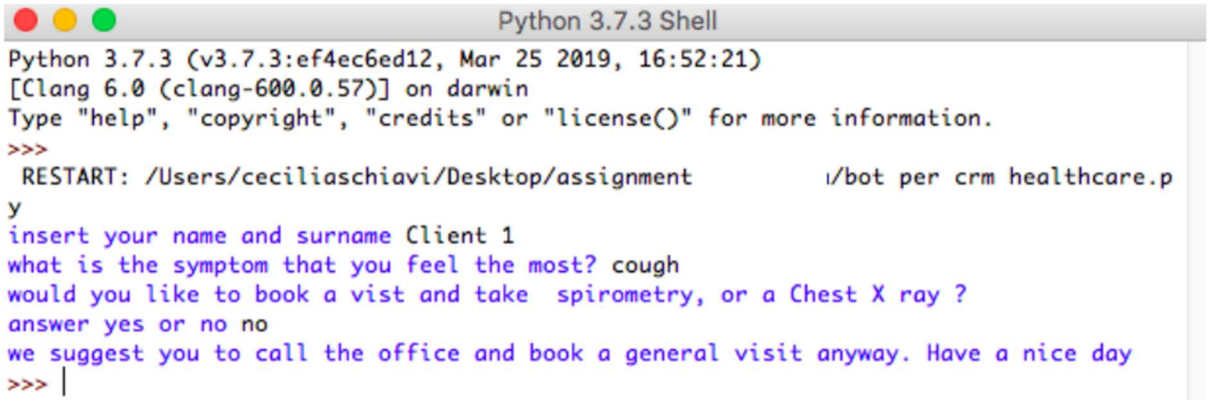
```
Python 3.7.3 (v3.7.3:ef4ec6ed12, Mar 25 2019, 16:52:21)
[Clang 6.0 (clang-600.0.57)] on darwin
Type "help", "copyright", "credits" or "license()" for more information.
>>>
 RESTART: /Users/ceciliaschiavi/Desktop/assignment         ı/bot per crm healthcare.py
insert your name and surname client 1
what is the symptom that you feel the most? urination
the symptom that you can insert are: ['muscle weakness', 'atrophy', 'muscle spasms']
 ['executive functions of attentiveness', 'lack of planning capabilites', 'lack of abstract thinking', 'impairments in
semantic memory']
 ['swelling', 'joint stiffness', 'aching around the joint']
 ['wheezing', 'shortness of breath', 'chest tightness', 'coughing']
 ['lump', 'abnormal bleeding', 'prolonged cough', 'unexplained weight loss', 'a change in bowel movements', 'skin anoma
lies', 'weakness']
 ['cough', 'shortness of breath', 'physical activity limitation', 'chest tighness']
 ['Difficulty breathing', 'coughing up mucus', 'poor growth', 'fatty stool']
 ['Frequent urination', 'increased thirst', 'increased hunger']
 ['pain in the chest', 'trouble breathing', 'palpitations', 'swelling', 'feeling weak', 'cyanosis']
 ['predisposition to break bones very easily']
 ['extreme pain', 'changes in skin temperature', 'changes in skin colouring', 'changes in skin texture']
are you sure that you insert one among these symptoms? please answer: "NO BUT SOMETHING SIMILAR" or "NO, I FEEL SOMETHI
NG DIFFERENT" NO BUT SOMETHING SIMILAR
close this application and restart it.
 please insert symptoms among the previous list
>>>
```

So if the client inserts symptoms similar to one in the bot he should check in the list which is the most similar symptoms and close and restart the application.
If the client feels something that it is not present in the variables, the programs asks him to book a visit in order to see a doctor.




The pros and cons of using this kind of application are various. For example, some advantages could be that: it can help the organization to collect the data of the clients, reduce the booking time and also speed-up diagnosis and medical interventions.
One con of this method is that a doctor has surely a more complex vision on the patient's history and so it could be harder to determin exam should the patient take in order to make a diagnosis.
Moreover, some medical exams might be invasive to take in fact the client can decide not to take them and to book a visit instead.

So the clinic decided to keep this application as a demo version for the first 6 months and after that period evaluate if it really improves the relationship with patients.
If the relationship is improved the application will developed with some improvements in order to make it more usable.




## 5. Which data are important?

The digitization of many processes in healthcare has generated a lot of new information that a few years ago was not available. This has led healthcare to use big data for its processes. The application of big data has a lot of positive aspects like for example to prevent epidemics, cure diseases and cut down costs. Moreover, a large amount of data comes from different sources and can help doctors to have a 360-degree vision over the patients. In addition, with the constant improvement of technology it is really easy to compute and visualize the data that has been extracted. Here is a list of the possible application of data-driven analysis in healthcare.

1. Improving the staff management
2. Electronic health records which trigger warning and reminders when a patient should get a new lab test
3. Prevent overdose
4. Suggest some additional therapy or complementary behavior that can help to treat a particular disease
5. Data can have a predictive function
6. Our data architecture will be built using:
7. Clinical data
    a. Symptoms
    b. analysis that a patient has taken and results
    c. diagnosis
    d. number of medical visits for each specialist that has seen the patient
    e. medicines that the patient has taken
8. Demographic patient data
    a. Home setting

b. Job
c. Lifestyle

9. Electronic health records:  This kind of devices provide data about the patient's lifestyle and data that come from the constant tracking of its such as:
    a. The nutrition habitudes
    b. The sleep habitudes
    c. The heartbeat
    d. Glycemic index

## 5.1 How we plan to collect these data

These data can be collected in several ways. Firstly, each of our patients will have to register to our server, so he/she will have to provide his/her anagraphical data. Subsequently, all the visits that the patient books, all the medicines and therapies, the diagnosis and the patient conditions are recorded and analysed in a MongoDb database as soon as the IT staff of the hospital is informed by medicines and nurses. Another important source of data is "Patient-Reported Outcome Measures (PROM)" which are standardized, and validated questionnaires completed by patients in order to measure their perceptions of their own disease severity and wellbeing.
The last source of information that we plan to use is the data are the fit-bit and other specific IoT devices.

## 5.2 IoT in Healthcare

Internet of Things or IoT is a network of computing devices, where billions of objects, things, sensors, and devices are connected through communications and information structures in order to collect and share data for many different applications. One of the major areas where IoT is being used is healthcare and smart health services. IoT makes remote patient monitoring possible through the use of IoT and wearable devices with embedded sensors that collect the patients' data. As MyHealth Clinic is a hospital with long term patients, remote patient monitoring is crucial to track patients' health outside the hospital. The constant observance of patients' health also tackles emergency situations. MyHealth Clinic uses several IoT wearables and devices in order to monitor the patients and their attention-required specific health conditions. IoT devices and their functionalities are explained below.

## 5.3 IoT Devices at MyHealth Clinic

### 5.3.1 Wearable Trackers for General Monitoring (Fitbit Charge 3)

Fitbit is a fitness tracker that monitors the user's heart rate and insights of their body including daily activities and exercises. Fitbit provides continuous heart rate monitoring, which is used for calculating different variables. With the help of the heart rate, the tracker is able to calculate the estimated number of calories burned during the day, including exercises. Besides, Fitbit also offers a sleep tracking system, where the users can see how long they have been in light, deep and REM sleep. The analysis of the quality of sleep and other insights can be significant indicators of an underlying serious condition. The tracker gathers the data from the wrist of the user and shares it via Bluetooth connection. The tracker is connected to a smartphone by Bluetooth and it transfers the data to the phone. Then, the phone delivers the collected data to the Fitbit app, which is also provided by Fitbit itself. After that, the data is uploaded to the server of the service provider through the internet. The data that is uploaded is stored in the IoT Data Management System. In the case of MyHealth Clinic, MongoDB is used as the main database. In order to be used by the hospital, the data is filtered and reorganized. Right after it is processed, the data becomes available to the hospital and to the doctors for monitoring their patients.

### 5.3.2 High-Tech Pacemakers for Heart Disease Treatments

High-tech pacemakers have a ton of benefits for patients that suffer cardiac diseases. A pacemaker is an electronic device that is surgically implanted into the patient's body to prevent the heart rate from becoming too low. When the heart rate gets too low, the pacemaker will provide an electronic impulse that will increase the heart rate and prevent the heart rate from getting too low. The high-tech pacemakers differ from the ordinary ones as they provide constant monitoring of the patient's heart health. These little IoT devices have connections and it allows them to share the information that they gather with the hospital staff and doctors. With the exchange of critical information, the doctors are able to monitor their patients constantly and are able to diagnose before an emergency happening.

### 5.3.3 Propeller’s Breezhaler for Asthma and COPD

Asthma and Chronic Obstructive Pulmonary Disease (COPD) are types of lung diseases that are defined by long-term breathing problems and poor airflow. Propeller is an IoT device that includes a sensor, and it is attached to a regular inhaler that is sold in pharmacies. The inhaler medication is used as it is prescribed and meanwhile the medication is used, Propeller collects its data. The data that is collected by Propeller provides the patient with insights about their triggers (air pollen, temperature) in order to prevent an attack. The use of a mobile app makes it easier to fight with these respiratory diseases. The device also shares critical information with the patient's contacts and their healthcare providers. Doctors are able to monitor the patient's status of illness constantly, and they can notify the patients whether the use of inhaler is necessary or not.

### 5.3.4 Glucose Monitoring (Eversense Continuous Glucose Monitoring System)

Diabetes is a chronic disease that occurs due to an abnormal functionality of the pancreas gland. The pancreas of the patient that is diagnosed with diabetes produces less insulin than the health levels and as a result, the blood sugar goes up or down which may lead to internal organ damage or even death. The Eversense Continuous Glucose Monitoring IoT device continuously monitors the patient's blood sugar levels and minimizes the risks by preventative methods. The CGM consists of three elements. First of all, a sensor is professionally placed by a healthcare provider. Then, the sensor collects the data and sends the data to the transmitter. Lastly, the transmitter delivers the data to a mobile device. Within the mobile app, the patient receives real-time glucose measurements and can share their data with friends, family, and doctors. The data is also can be analyzed by the patient or their doctor easily from the app. As the device provides a continuous sugar level monitoring, patients are notified in case of low or high blood sugar levels. This prevention method allows patients and their healthcare providers to act up before the disease gets worse.

## 5.4 The Patient-Reported Outcome Measures (PROM)

These PROMs examine the impact of a disease state of a patient’s emotional physical, social and functional well-being. These questionnaires were originally developed for research used but nowadays are used for routine clinical practice and they are considered relevant to improve the quality and effectiveness of health care.

Patients rate their health in response to an individual question which is scored (from 0 to 4, for example) according to the level of difficulty or severity reported by the patient. When these PROMS are analyzed the individual rating is combined to produce an overall score, and the analysis focuses on two main aspects: the amount of change that occurred in the patients’ condition and on their overall quality of life. These questionnaires are used to measure patient perspectives of care. Their distinctive characteristic is that PROMs are meant to be independent of the view of the clinical staff so also the method of data collection is built in order to avoid external influences on the patient's opinion. For example, it is unsuitable to present these questionnaires when patients attend outpatient appointments because of the risk of introducing biases.

PROMs sent periodically (usually after surgery, of with the prescription of new therapy) using the web application to each patient which is registered, if a client doesn't answer within two weeks the server sends a reminder email, within three weeks the client will be contacted on the telephone. There are different types of PROM that can be chosen, and the choice of the PROM is a really critical aspect. Our institution has created a range of different PROMs that relies on articles and empirical evidence that demonstrate that these measures are acceptable to patients, reliable, valid and responsive (sensitive to change). We will present different types of PROMs according to the type of patient (age, sex, and disease), in order to make more accurate statistics. Also, these data are going to be stored in our MongoDB architecture in order to allow immediate statistical analysis, minimizing complexity. These questionnaires are important to understand how patients perceive their symptoms but, the negative aspect is that these PROMs are long and require a long time to be understood (sometimes terms are difficult to understand) and completed.

## 6. NoSQL

NoSQL databases are more suitable for patient data because of the scheme-less attribute, support array data type, and many null values in the healthcare data. Using NoSQL has many advantages in terms of:

- Performance: Better patient satisfaction and quickly request processing
- Flexibility: Lower costs and faster time to market
- Security: Meets the medical industry privacy regulations
- Scalability: Very high request rates at very low latency

Similarly, these databases consume data coming in any of digital forms, load real-time data, process huge volumes of data (Distributed storage and processing based on Map-Reduce paradigm) and allow for efficient retrieval of features (Key-value databases). In our analysis, many different NoSQL databases had been evaluated, such as Key-value Databases, Document Databases, Graph Databases, and Wide Column Store, in order to cope in the most efficient way with the huge amount of big data in the healthcare environment. Here, Big Data has increased over the years in complexity, variety, and volume.

Healthcare Big Data can be defined as:

1. Graph structures Big Data, where entities are related to each other in complex relationships like trees, networks or graphs. This type of data is typically neither large, nor unstructured, but graph structures of undetermined depth are very complex to store in relational or key-value pair structures. For this reason, the graph-oriented NoSQL database, such as Neo4J, is more suitable. An example of graph structures in healthcare is the network of providers linked to a group of practices or a hospital group. Another useful graph-based analysis is the spread of a highly contagious disease through groups of people who were in contact with each other. An infectious disease clinic, for instance, should strive to have higher infection caseloads across such a network, but with lower actual infection rates. A more deep-dive application of graph-based analytics is to study network models of genetic inheritance.

2. Sensor Data, often normally quite structured, whose complexity comes in that for each patient or each blood sample test you often have a variable record structure with widely different aspects being measured and recorded. This kind of data, produced in high volume and high rate, is often stored in key-value databases, such as Riak, DynamoDB, Redis Voldemort and Hadoop. Biosensors are now used to enable better and more efficient patient care across a wide range of healthcare operations, including telemedicine, telehealth, and mobile health. Typical analyses compare related sets of measurements for cause and effect, reaction predictions, antagonistic interactions, dependencies, and correlations. For example, biometric data, which includes data such as diet, sleep, weight, exercise, and blood sugar levels, can be collected from mobile apps and sensors. Outcome-oriented analytics applied to this biometric data when combined with other healthcare data, can help patients with controllable conditions improve their health, by providing them with insights on their behaviors leading to increases or decreases in the occurrences of diseases.

3. Unstructured text data, 80% of medical data remains unstructured and untapped after it is created (e.g., text, image, signal, etc.). Since it is hard to handle this type of data, it tends to be ignored, unsaved, or abandoned in most medical centers for a long time. However, we need to manage those unmanaged unstructured big data in healthcare systems before mentioning the development of medical artificial intelligence which is currently based on machine learning technology.The NoSQL document databases, particularly Mongo DB, are very good for storing, processing and analyzing documents consisting of unstructured text of varying complexity, typically contained in XML, JSON or even Microsoft Word or Adobe format files.

The document databases are good for storing and analyzing prescriptions, drug schedules, patient records, and the contracts written up between healthcare insurers and providers.The primary goal is, basically, to turn unstructured text into structured data, by applying natural language processing (NLP) and analytical methods. For example, if a co-occurrence analysis found that BRCA1 and breast

cancer regularly occurred in the same sentence, it might assume a relationship between breast cancer and the BRCA1 gene. Nowadays co-occurrence in the text is often used as a simple baseline when evaluating more sophisticated systems. Nevertheless, it's important to keep in mind that textual data brings ambiguity, such as multiple relationships between language and meanings or categories, that makes analysis and interpretation of this data very difficult. Consequently, is necessary to eliminate this ambiguity before processing, making sense of, and applying analytics to it. Establishing and capturing context is also crucial for unstructured text analytics – the same text can have radically different meanings and interpretations, depending on the context where it is used.

In all this analysis, the NoSQL databases that most fit with our purpose is Mongo DB. With this efficient and very fast recording database, clinical data, demographic patient data, electronic health records, and The Patient-Reported Outcome Measures (PROM) as well, will be stored in the document database. Furthermore, Mongo DB has great and not negligible advantages, the possibility of retrieving data in a fast way and incremental changes and transformation of data in the database are some.

More precisely, Mongo DB provides a **360-Degree Patient View**, aggregating patient, doctor, procedure and other types of information in a single data store. This solves the problem of the lack of centralization needed to allow professionals and patients to access the right information at the right time. Healthcare provider networks have massive amounts of patient data and metadata, which often comprise a patchwork of siloed systems and technologies. It is increasingly challenging to store the variety of structured and unstructured data required, from basic patient information and medical histories to lab results and MRI images.

Furthermore, hospitals need **flexibility** in order to cope with the rise in both the number of tests conducted and the variety of data collected and so with the demand of analysis achievable with this data, like real-time analytics and visualizations. With MongoDB, dispensing great flexibility, providers of lab testing, genomics, and clinical pathology can ingest, store and analyze a variety of data types from numerous sources all in a single data store. Doing so not only drives significant savings on infrastructure and licensing costs but also enables these companies to generate new insights and revenue streams.

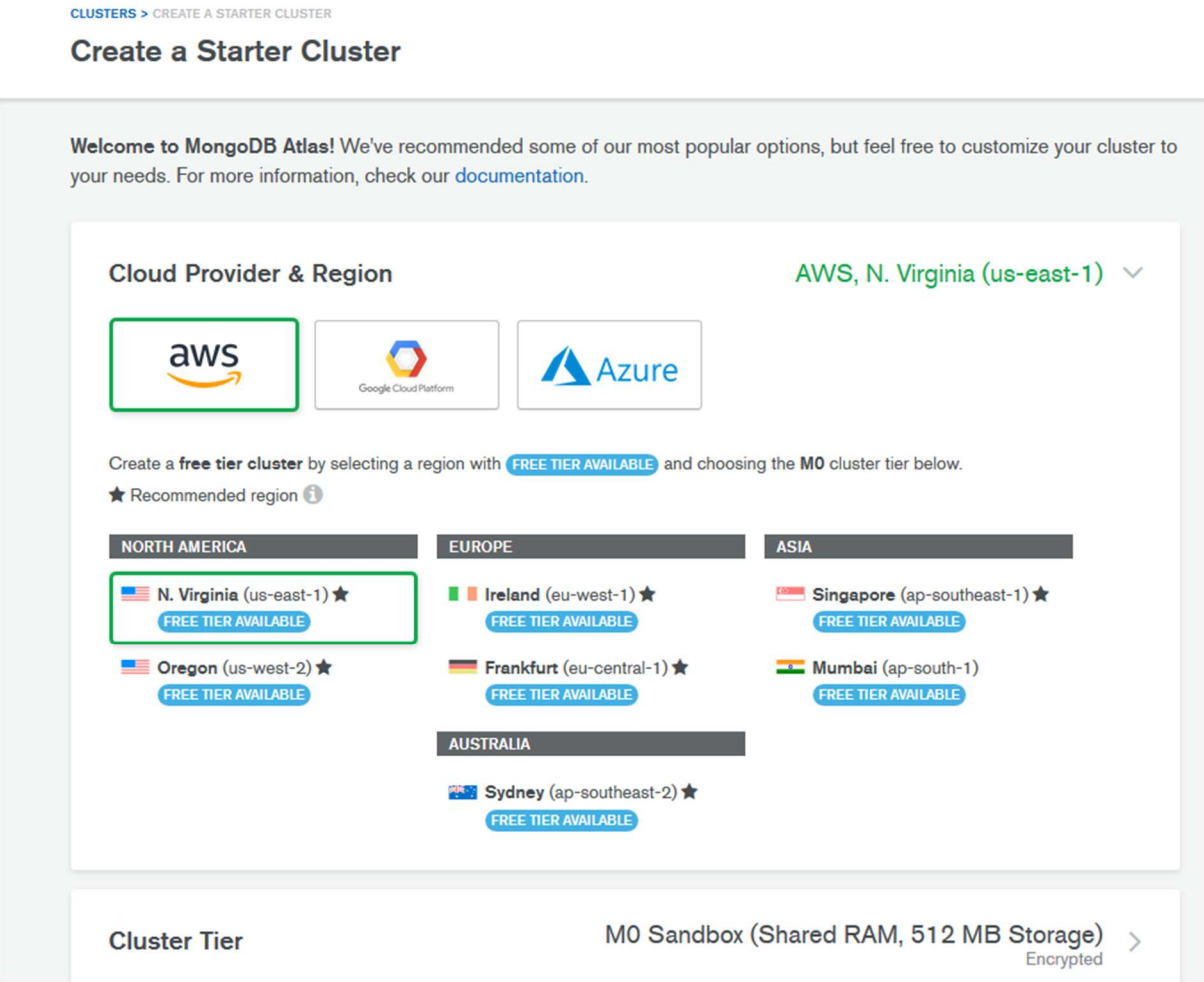
## 6.1 Our Database

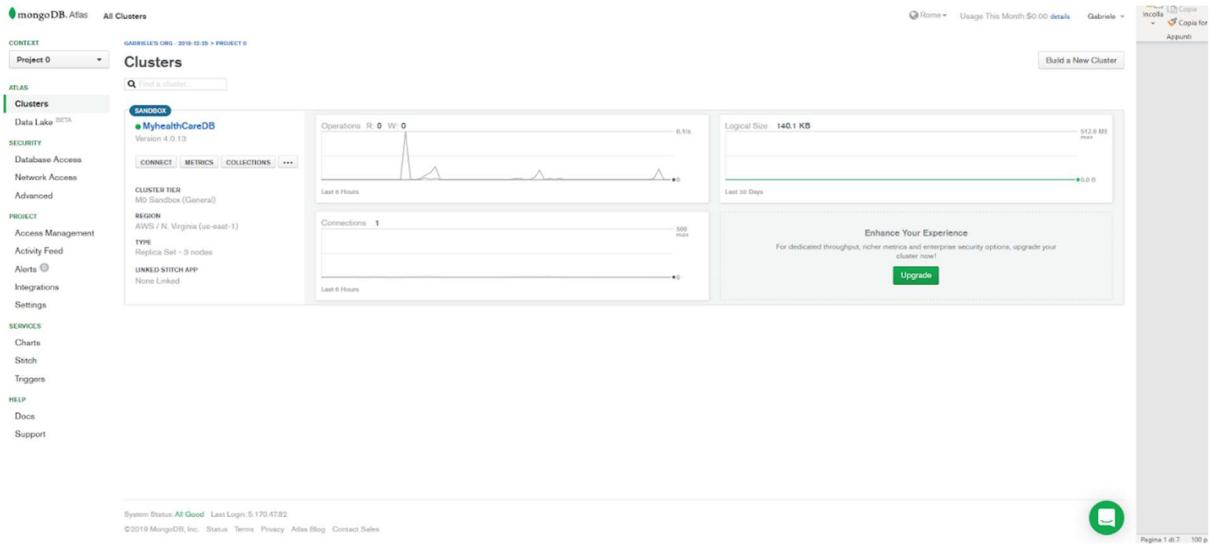
Here we present a NoSQL API Prototype which is accessible from these following links.

GitHub repository: https://github.com/karroot/myhealthcaredb

API prototype: https://myhealthcaredb.herokuapp.com/

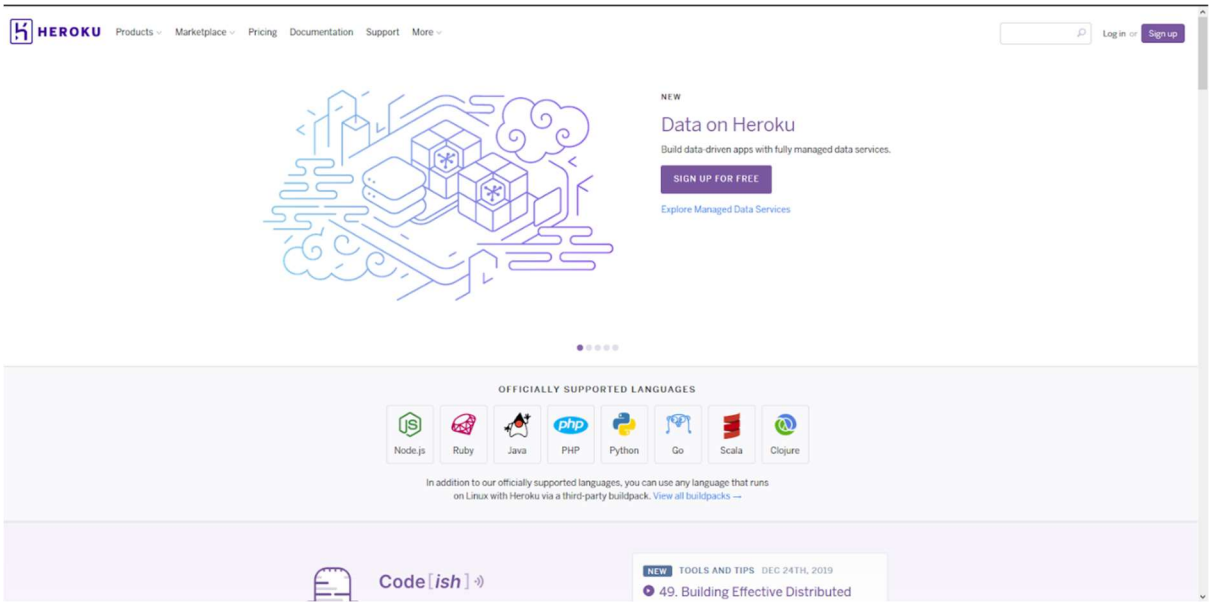
We decide to host our MongoDB database using the cloud platform MongoDB Atlas (https://www.mongodb.com/) that provide an easy to manage cluster through Amazon web service or another cloud provider:






In order to interact with our database, we decided to use REST API, in this way when a user decides to perform a query, he just needs to call an HTTP(s) endpoint. The API query language fits really well our needs because it allows querying according to content.

The REST API is easier and more intuitive to use than usual API, so the staff can learn faster how to perform a query. In fact, the query using the rest method is performed simply by adding a slash and writing the category for which we are looking. In order to realize the API, we choose Heroku as a cloud application platform, so as a platform as a service (PaaS), that help us to run our application. (https://www.heroku.com/ )



Finally, we choose NodeJS in order to realize the backend of our application because of the numerous code libraries such as *express* and *MongoDb* which are very convenient for connecting with the database and defining the various queries.
These libraries fit well our data because they are really dynamics and they are based on documents which are less rigid than relational Database.

### 6.2 The structure of the Database

Each patient is identified by an ID code and for each patient, we store some personal/demographic data such as:

- ***First name***
- ***Middle name***
- ***Last name***
- ***Email***
- ***Job***
- ***Postal address***
- ***Phone number***
- ***Date of birth***

We register also some data in order to better understand the relationship that patients have with this Healthcare institution such as:

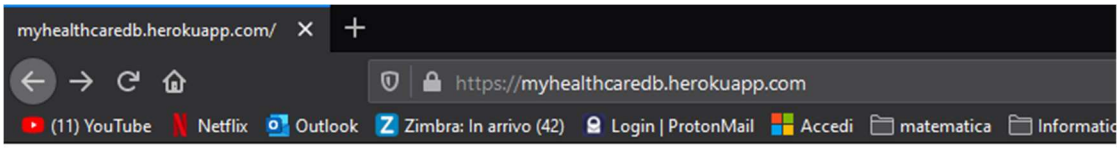
- ***Date of creation of the account***
- ***Date of the update of the account***
- ***Profile:*** which can be basic, premium or luxury and it depends on the rate

In the end, there are obviously also some clinical data such as:

- ***The illness*** that has been diagnosed
- ***The condition*** which consists of the symptoms which are constantly updated with the evolution of the disease
- ***Activities*** which are sports or physical activities that a patient take
- ***Current medication:*** the medicines that a patient is currently taking
- ***Medication taken:*** the medicines that have been taken previously
- ***Treatment:*** consists of specific medical treatment like chemotherapy or radiotherapy…
- ***Blood type:*** it is an important feature because some long-term disease may need a blood transfusion

- ***Current Diet*** because for some diseases a specific diet might be considered as an additional therapy that helps to increase the improvements of the patients
- ***Analysis*** that are the medical examinations taken in order to diagnose a certain disease

Starting from this information we decided to define this set of queries because in our opinion these might be the most probable query in this situation.




# Welcome to MyhealthCare database

## How to quey the database:

use the REST way:

https://myhealthcaredb.herokuapp.com/patients for a list of all patients

https://myhealthcaredb.herokuapp.com/patient/{insertID} to search for a particular patient

https://myhealthcaredb.herokuapp.com/patient/blood/{insertID} to search for a patient with a particular blood type

https://myhealthcaredb.herokuapp.com/patient/profile/{insertID} to search for a patient with a particular profile

https://myhealthcaredb.herokuapp.com/patient/job/{insertID} to search for a patient with a particular job

https://myhealthcaredb.herokuapp.com/workers for a list of all workers

https://myhealthcaredb.herokuapp.com/worker/{insertID} to search for a particular worker

https://myhealthcaredb.herokuapp.com/iot for a list of all iot data

https://myhealthcaredb.herokuapp.com/iot/{insertID} to search for a iot data

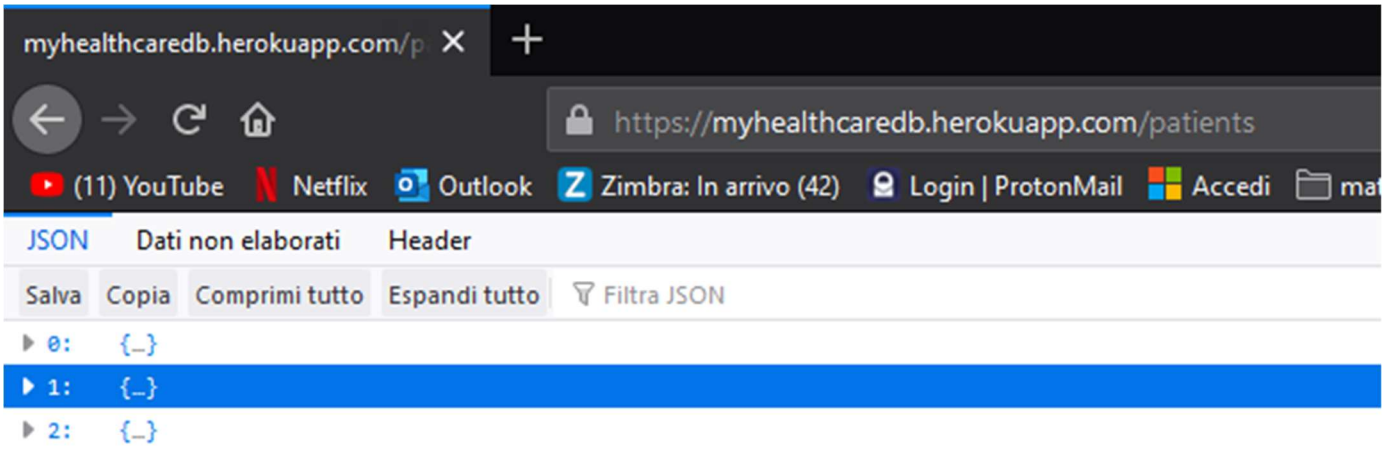
https://myhealthcaredb.herokuapp.com/iot/device/{insertID} to search for a iot device

https://myhealthcaredb.herokuapp.com/iot/patient/{insertID} to search for a iot data by user

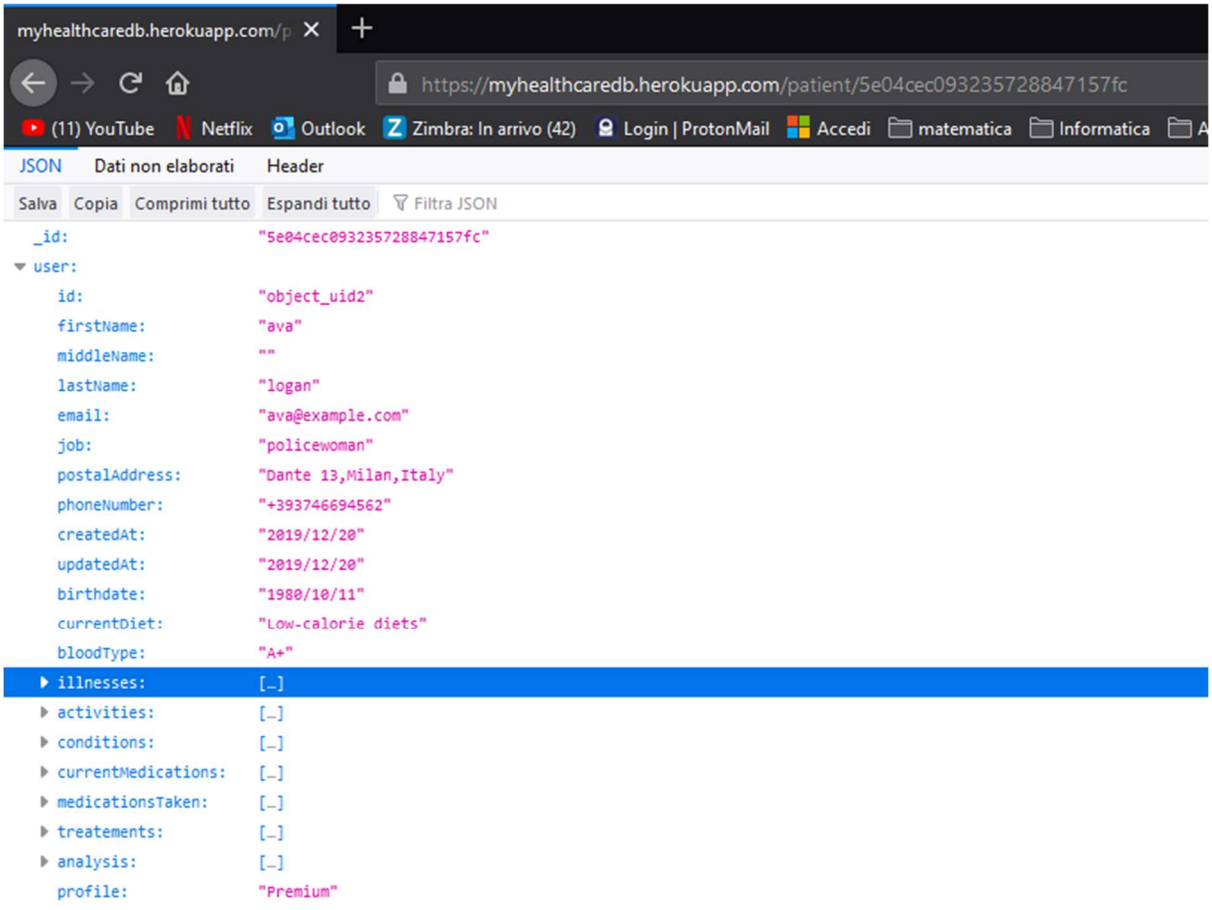
https://myhealthcaredb.herokuapp.com/iotDevices for a list of all iot ddevices

https://myhealthcaredb.herokuapp.com/iotDevice/{insertID} to search for a iot device

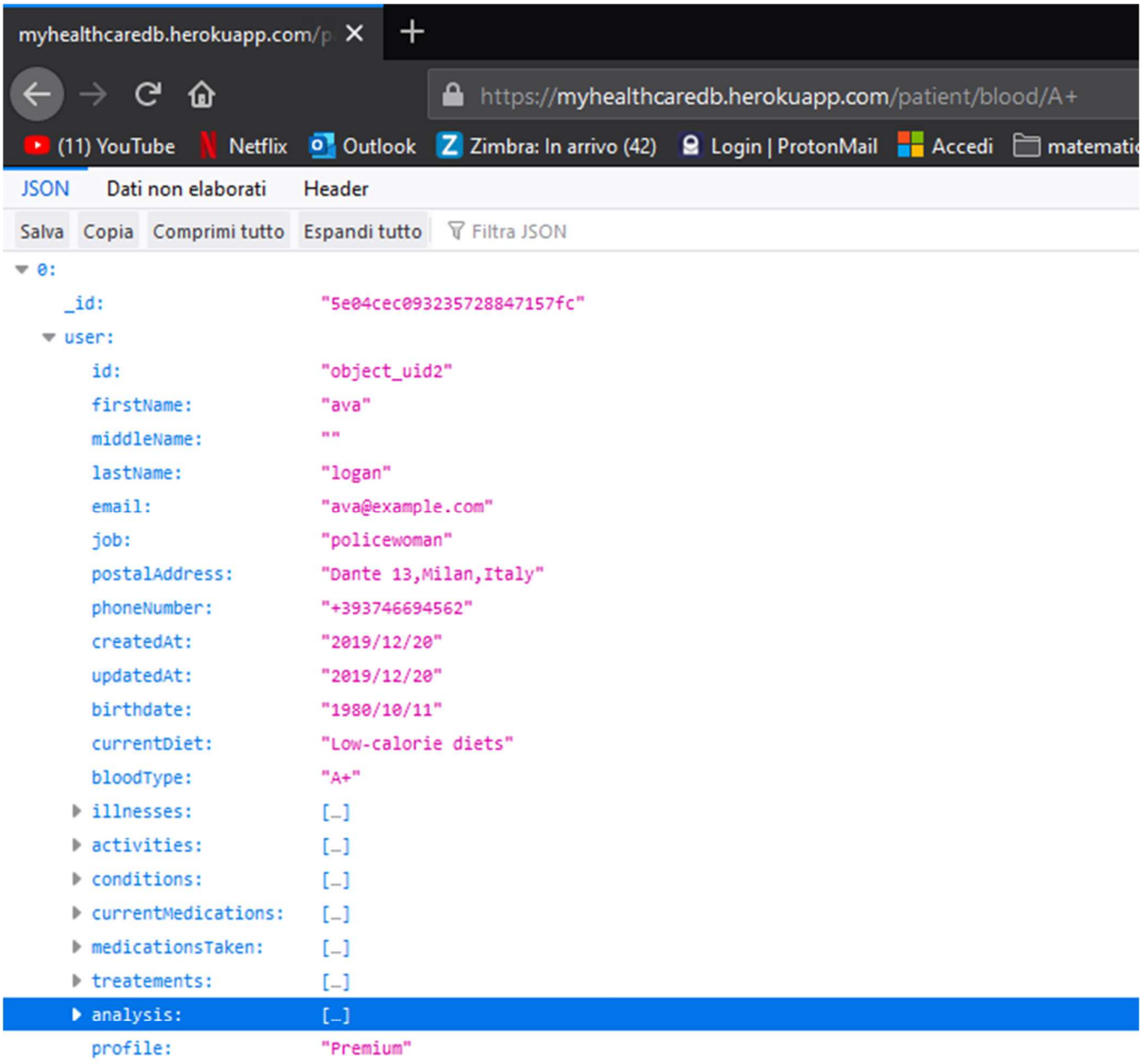
Here we can search for all the patients:



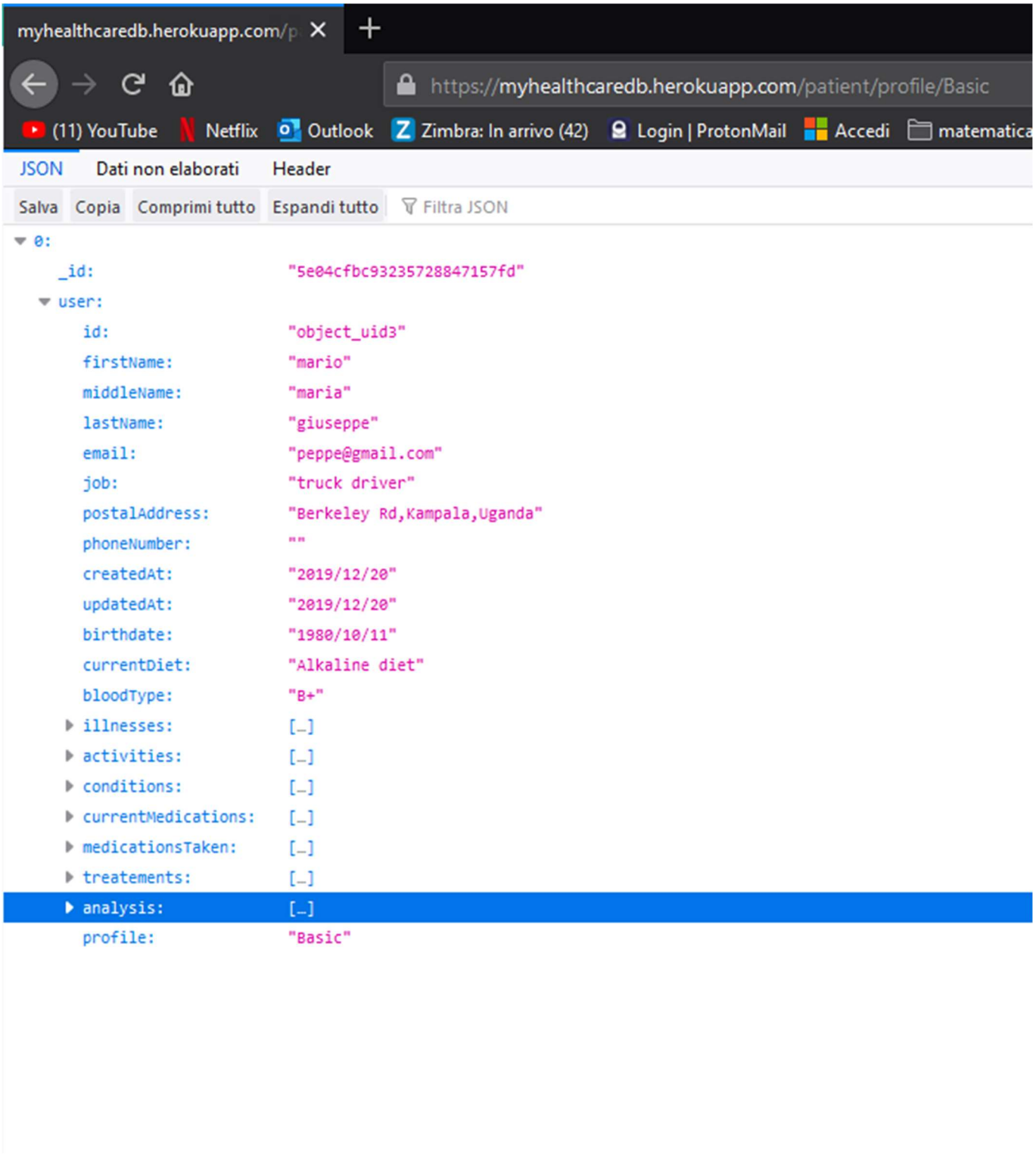

Or just for a particular one:



It is also possible to filter all patients with a particular characteristic, like blood type:

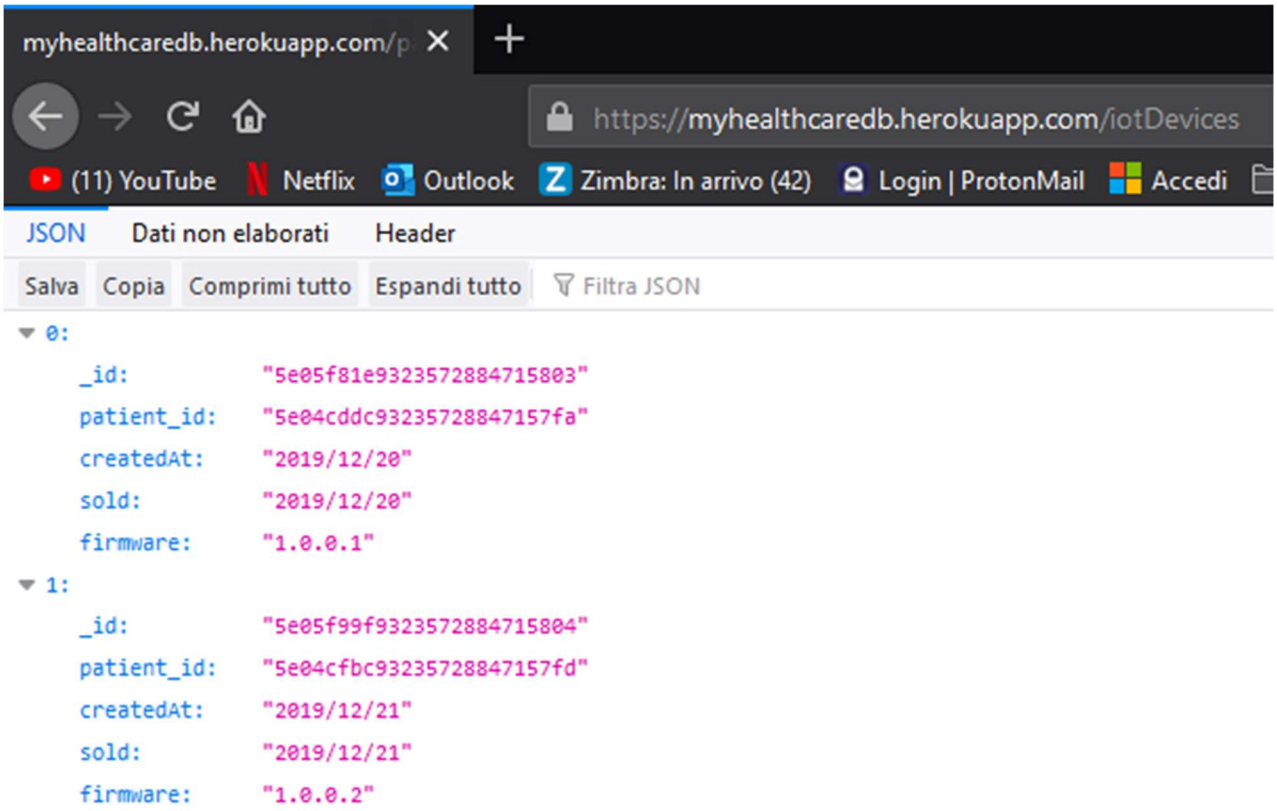


or profile:

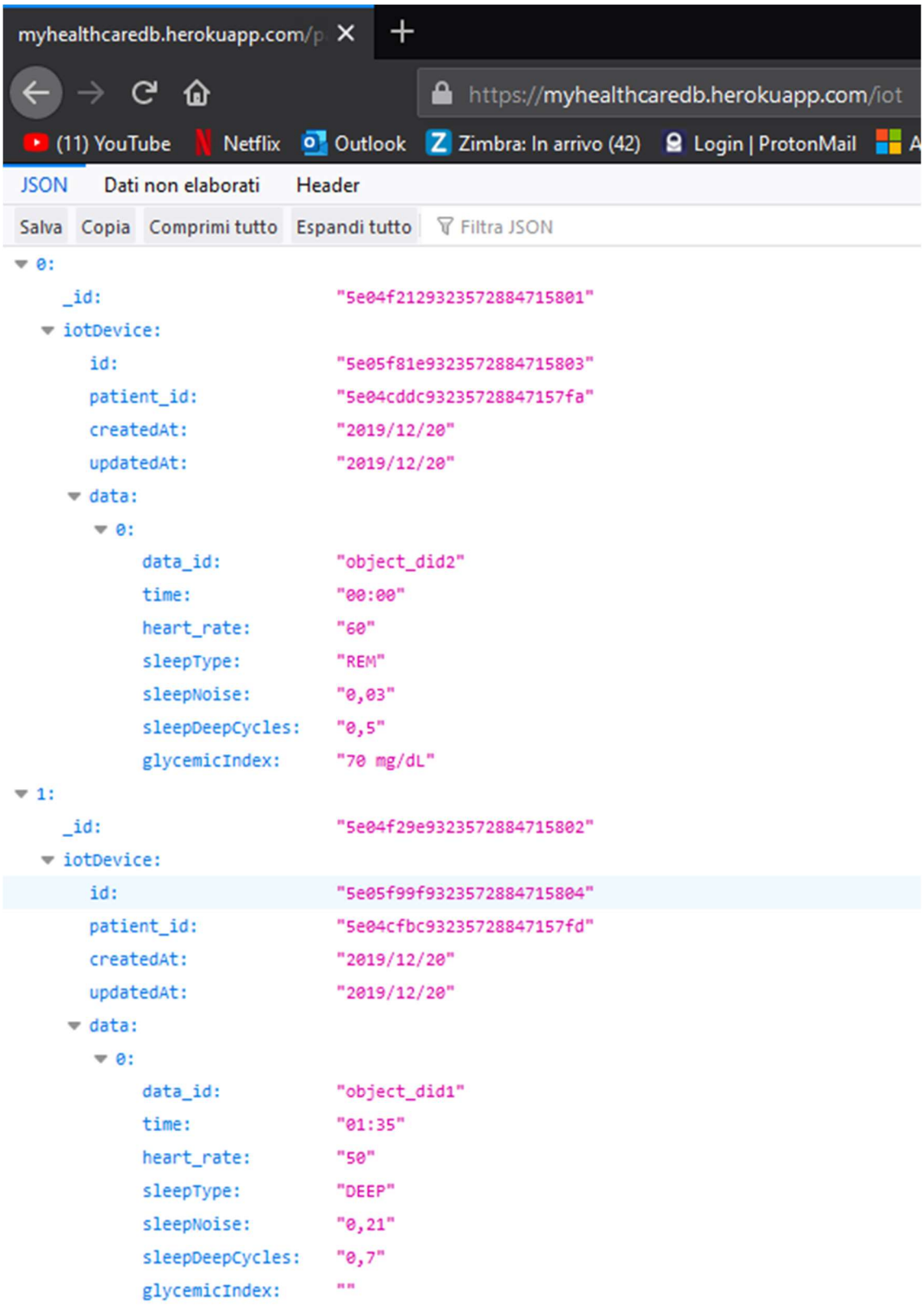



As we said before, this institution provides IoT devices in order to constantly track the progress of some patient. Here we have also a list of all IoT devices that we have

sold:




So here it is possible to see the information that comes from the IoT devices.




### 6.3 How these data will be used?

This Data are really useful for a different reason: the usage of Data in Healthcare is generally divided into primary use and secondary use.

Primary use is when health data is used to deliver health care to the individual from whom it was collected: here individual Data are used by the doctor in order to analyze deeply the clinical history of patients and data can help to make a more accurate diagnosis.
The secondary use is when health data is used outside of health care delivery for individuals, so these data are analyzed also at an aggregate.
The aggregate analysis of data may have different aims:

- Clinical research: a branch of healthcare science that determines the efficacy (safety and effectiveness) of medications, devices, diagnostic products, and treatments.

Clinical research collect statistical evidence in order to choose the most effective treatment for a particular disease.

- Support campaign of public health which is defined as the science of preventing disease: this subject is based on the study and the analysis of the distribution of disease.

But how these data will support clinical research?

From the PROMs, it is possible to see if patients' conditions have changed after a new therapy, medicine or after surgery, so it is possible to analyze how much drugs and therapy are effective on patients' diseases according to their age. A logistic regression would suite this kind of analysis: the improvements in patients' condition would be the dependent variable and, the possible therapies, sex, and age can be the independent variables used for the analysis. This process should be iterated for the long-term disease that this hospital follows in order to identify the most effective treatment for each disease given age and sex of the patient. This process can lead the doctor to choose the most effective treatment in a short amount of time, without trying too many cures on patients.
Moreover, in the database also data concerning lifestyle are store, so there's the possibility to see patients' improvements are also related to diet and physical activities. Also, this statistical analysis could require logistic regression. This work can help the doctor to advise patients about some diets or physical activities that may improve their health.

In the end, this data can help to predict the probability of a certain disease starting from personal details: for example, it is empirically proved that heart diseases are connected to some kind of occupations such as financial trader or truck driver. In addition also respiratory diseases are correlated to pollution so, if there is a concentration of pulmonary illnesses in a big city, it is possible that pollution caused it. These studies may be used from political institutions in order to decide some policies that might influence variables that are correlated to this disease for example governments can put in place some policies related to traffic regulation or can set a minimum of holidays that should be compulsorily taken by workers. So, these statistical analyses have lots of positive aspects: they can help doctors in order to have a more complete vision on patients' situations, can increase the effectiveness of cures and can also help institutions in taking a decision.
Anyway, doctors shouldn’t take decisions only relying on statistics because statistics are not always corrected: data can be disturbed or sometimes the used model might not suit the data well. In addition, each human being can react differently to therapy so a therapy that seems ineffective on the 99% of the population might cause amazing improvements in just one patient. Consequently, doctors should study and analyze properly not only statistics but also the patients' features and clinical history in order to make informed and effective decisions.

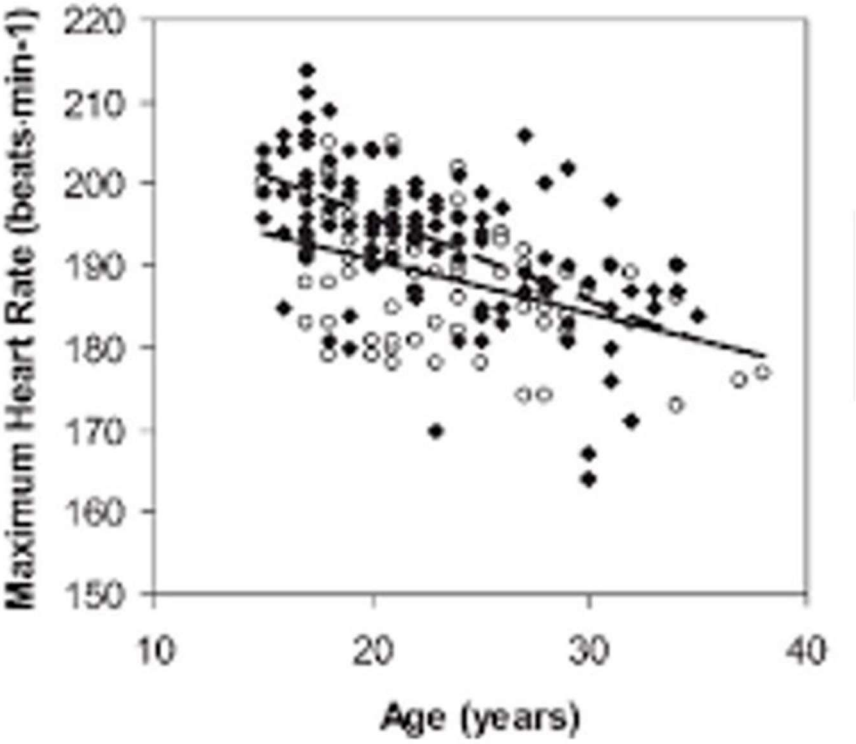
## 7. Anomaly Detection for Diagnosis

Anomaly detection can be generally defined as any method for finding events that do not conform to an expectation; from this definition, we can infer that some applications can be useful also in the medical field. Before going into details, it is important to add that the study of anomaly detection is closely coupled with the concept of time series analysis: an anomaly is often defined as a deviation from what is normal or expected, given what had been observed in the past. Concretely, our objective is to develop a computational tool that uses previously gathered patient data to detect unusual patterns for the patients.

In our specific case, for example, it is worth to look at the electronic health records (heartbeat, Glycemic index) and build an ARIMA model to identify deviations

from the mean for a specific age group. Once the model has been built, we compare observed data with the ones predicted by the model: if the observation falls outside the threshold of a confidence band, then an anomaly alert must be raised. The big advantage of this process is that is not labor-intensive since relies on machine-learning algorithms.

As it is possible to see in the graph below, on the x-axis we have three age intervals whereas on the y-interval the maximum heart rate measured in beats/minutes. The downward sloping line shows the average of the observations from which we construct the model. From this, we can deduce that large outliers (anomalies) will be classified as anomalies by ARIMA.



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