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IBD Tool: Enabling Continuous Data Export and Improvement of User Experience

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Abstract

IBD Tool is a web application born in 2020 from the collaboration between the research Center LINKS Foundation and the Mauriziano Hospital of Turin. The platform fits in the context of telemedicine: it allows the remote monitoring and treatment of patients suffering from inflammatory bowel diseases (IBDs), such as Ulcerative Colitis and Chron's disease. These pathologies are slightly different from each other, but a common element is the fact they all present an alternation of phases of remission, where there are very few symptoms, and relapse, where the illness has a considerably hight impact on patients' standard of life. In these conditions, a constant monitoring of the symptoms is crucial in order to prevent complications and telemedicine can surely offer a great support without forcing the patient to visit the hospital constantly: that's where IBD Tool finds its goals.

The web application allows the delivery of remote care, a type of health service that revealed itself to be necessary during Covid-19 era and that can make life easier for people with different needs that are not able to leave the house or to go visit physician frequently.

Patients enrolled in this platform periodically receive questionnaires with specific and well-structured questions about their current state of health. The answers are then sent to the physicians that can evaluate the results and, if needed, act accordingly changing patient therapy or planning future face-to-face visits. This system creates a direct link between physicians and patients, who can also communicate through a chat system that is integrated in the web application. Furthermore, the platform offers to the physicians a section where all the data about the patients are available, this tool is useful to study incidence and evolution of the diseases. This thesis work is focused on the management of the web application and on the development of new functionalities needed by the physicians, they have guided the changes to be made.

Technologies used are Angular for the Front-end and Java Spring Boot for the Back-end, while the data are stored in a MongoDB database. For the development and the deployment are utilized different tools such as Visual Studio Code, Heroku and Firebase.

The objectives set in the definition of the work have been achieved and have led

to the following results:

- Resolution of problems concerning the sending of emails.
- Insertion of a new export data function, that allows the physicians to collect data in order to analyse and extract information from them to better study the evolution of the disease.
- Improvement of the user experience, for the physician side, thanks to the introduction of several visual elements that enhance the usability of the platform.

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Acronyms

ACID	Atomicity, Consistency, Isolation, Durability
API	Application Programming Interface
BE	Back-End
CD	Chron's Disease
CLI	Command Line Interface
CRUD	Create Read Update and Delete
CSS	Cascading Style Sheet
DB	Database
EU	European Union
EQ5D5L	European Quality version 5D - 5 Levels
FE	Front-End
GDPR	General Data Protection Regulation
GUI	Graphic User Interface
HBI	Harvey Bradshaw Index
HTML	Hypertext Markup Language
IaaS	Infrastructure as A Service
IBD	Inflammatory bowel diseases
IBD-DISK	inflammatory Bowel Disease - Disability Index Disk Form
IBDQ	Inflammatory Bowel Disease Questionnaire
ICTs	Information and Communication Technologies

IPAQ-SF	International Physical Activity Questionnaire - Short Form
MIAH	Monitor IBD at Home
MMAS8	Morisky Medication Scale 8 items
PaaS	Platform as A Service
PHQ9	Patient Health Questionnaire 9 items
PRISM	Pictorial Representation of Illness and Self Measure
PSQI	Pittsburgh Sleep Quality Index
REST	Representational State Transfer
RDMS	Relational Database Management System
SaaS	Software as A Service
SCCAI	Simple Clinical Colitis Activity Index
SQL	Structured Query Language
SSN	Social Security Number
SMTP	Simple Mail Transfer Protocol
TSQM	Treatment Satisfaction Questionnaire for Medication
UC	Ulcerative Colitis
UX	User Experience
VSC	Visual Studio Code
WPAI	Work Productivity and Activity Index

Chapter 1

Introduction

1.1 IBD: Inflammatory bowel disease

Inflammatory bowel disease (IBD) is a term used to indicate different medical conditions characterized by chronic inflammation of the gastrointestinal tract, the most common among patients are Chron's Disease (CD) and Ulcerative Colitis (UC) [1].

The two diseases differ slightly in some aspects but have the majority of symptoms in common, such as: persistent diarrhea, abdominal pain, weight loss, fatigue [2]. Both the pathologies persist throughout all the life of the patient and are characterized by a discontinuous trend, indeed they present an alternation of phases of remission, where there are very few symptoms, and relapse, where the illness has a considerably hight impact on patients' standard of life.

The etiology of IBDs is still unknow but it seems that the genesis may be multifactorial: the interaction of environmental and genetic factors leading to immunological responses and inflammation in the intestine may be the cause.

Furthermore, although IBDs are not properly hereditary diseases, they are characterized by a tendency to occur in relatives of affected people. Situations of mental distress (such as anxiety and depression) can also be involved. IBDs affect people of any age, but it is usually diagnosed between the age of 15 and 40.

1.1.1 Chron's Disease

Chron's disease is a Chronic Inflammatory Bowel Disease that can affect any part of the gastrointestal tract, but most often it regards the portion of the small intestine before the colon. It is characterized by intestinal ulcers, which if not treated properly can lead to complications, such as strictures, fistulas or abscesses. Usually the lesion are not continuous, damaged areas can appear in patches that are next to areas of healthy tissue [2].

This pathology is defined as chronic because the course of the disease is characterized by periods of remission, where the patient experiences a time of relative well-being, and periods of relapse, in which symptoms manifest themselves.

As for the frequency, it seems that the disease has a higher incidence rate in Western countries and is almost absent in developing countries. In the last 30 years the number of IBD patients has increased considerably, currently in Italy there are about 250,000 patients affected and of these about the 40% suffer from Chron's disease [3].

Symptoms depend on the part of the intestine that is inflamed and on the current state of activity of the disease, typically a patient could suffer from:

- chronic diarrhea.
- fever.
- blood in the stool.
- reduced appetite and weight loss.
- perianal disease.

The medical therapy of CD must be differentiated considering the actual phase of the disease: an attack therapy is used in an acute phase while in a remission period a maintenance therapy is needed. In cases of severe disease, surgery to remove damaged portions of the gastrointestinal tract may also be necessary. [3]

1.1.2 Ulcerative Colitis

Ulcerative Colitis is a Chronic Inflammatory Bowel Disease that affects the large intestine (colon) and the rectum of the patients [2]. It's characterized by a chronic inflammation that causes ulcerative lesions. As for CD, its course is characterized by an alternation of acute episodes followed by periods of clinical remission.

The frequency of UC varies from one country to another: the highest incidence rate is found in industrialized countries. In Italy there are between 60 and 100,000 cases of CU, with an equal distribution between the sexes. The disease can occur at any age but mostly it appears in young adults. The causes of the disease are unknown, but could be influenced by various factors: genetic, environmental, infectious.

Ulcerative colitis is classified according to the severity of the mucosal lesions (mild, moderate and severe) and extensions (proctitis, left colitis, pancolitis). Here's a list of the most recurrent symptoms:

- diarrhea.

- abdominal pain.
- rectal tenesmus (frequent urge to evacuate).
- rectal bleeding.
- inability to defecate despite urgency.
- weight loss and fatigue.
- recurrent fever (with T <38 ° C).

Medicines used to treat ulcerative colitis or Crohn's disease include: aminosalicylates, which can reduce inflammation in the gut; immunosuppressants (steroids or azathioprine), to limit the activity of the immune system; biological and biosimilar medicines [4].

1.2 Telemedicine

Telemedicine is the practice of medicine using ICTs (Information and Communication Technologies), it allows the remote diagnosis, treatment and monitoring of patients and plays a key role in situations where the distance is a critical factor.

1.2.1 Telemedicine: Introduction

The term "telemedicine" was coined in the 1970s by Thomas Bird with the meanining of "healing at a distance" (from "medicus" in Latin and "tele" in Greek). After that, the idea of telemedicine spread rapidly until it arrived in Italy with the transmission of remote electrocardiograms and then was extended to other areas of medicine, such as those of nephrology, hematology and other specialized branches [5].

Telemedicine is a sector in continuous evolution, increasingly complex and multidisciplinary, thanks mainly to the new digital technologies developed during the last decade: for these reasons has been difficult to give a precise and unique definition, since it is often used indiscriminately with terms such as telecare and telehealth, or more general, ehealth (Figure 1.1) [5]. All these are facets of the same term that tend to take on a more precise and specialized meaning, although still based on the concept of a remote medical service. The main cathegories are:

- Telecare: solutions that allow home monitoring of the psycho-physical and behavioral conditions of non self-sufficient people (e.g. elderly or disabled), and which may include the use of sensors and environmental support devices for carrying out daily activities (rescue, surveillance, companionship, etc.) [5, 6].

- Telediscipline: support in relations between professional figures, in the case of consultations or reports a distance, whether or not the patient is present [5].
- Telehealth: allows the general practitioner to remotely interpress the data necessary for the telemonitoring of a patient. The recording and transmission of data can be automated [6].
- Specialist telemedicine: context in which the various phases of medical assistance from a physician specialist take place electronically, consisting of: televisit, teleconsult and tele-health cooperation [6].

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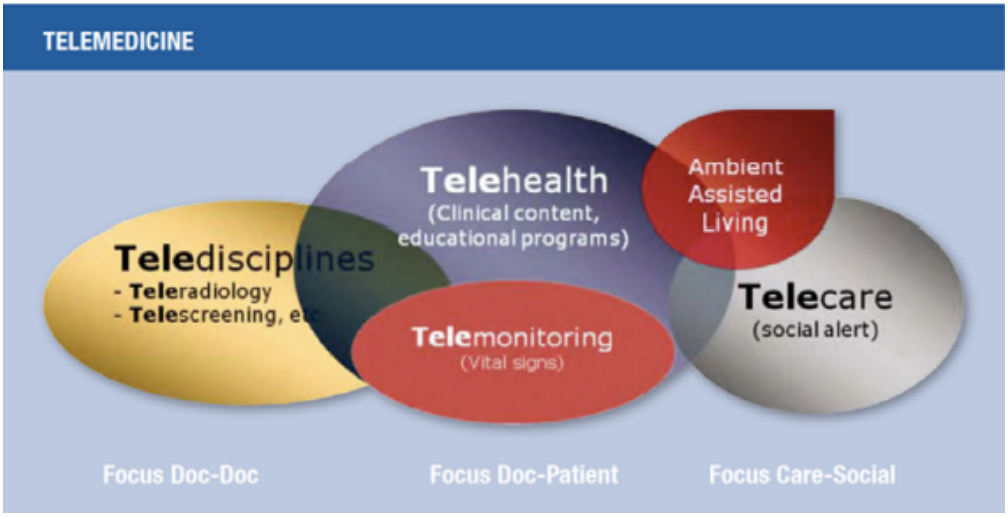

Figure 1.1: Possible representation of the components of Telemedicine [5].

In all these cases, the technologies used to implement the services can be various, but the mainly used are web applications, video calls, medical sensors and more specific tools to support clinical decisions and manage the disease (e.g. Diabetes Management tools, Mobile CardioVascular tools).

1.2.2 Telemedicine during COVID-19 era

During 2020, COVID-19 pandemic has had a significant global impact on the provision of healthcare and the need of digital services, such as telemedicine, has never been more relevant. Due to the social restrictions and the necessity to maintain the continuity of medical care, telemedicine has been the most practical solution to keep providing care without exposing patients or doctors to the virus. While in the past the growth of this type of care was slow and subject to several

limitations (e.g.limited economic investment in technological resources for hospitals), the pandemic era marks a turning point for telemedicine history. Various medical fields have been affected by the introduction of these services and they realized to have a great benefit for healthcare organizations and most of all for patients, which often take benefits from receiving care without the need to travel to reach medical structures [7].

In any case, it is necessary to consider telemedicine as a support to medical assistance in presence and not as a substitute. Visits in presence remain an irreplaceable point of medicine because they allow the physician to identify with greater precision the details that may be fundamental for a correct diagnosis. Despite telemedicine can't completely replace traditional visits, the provision of medical services has been transformed and the potential of telemedicine platforms is various and still all to explore.

1.2.3 Telemedicine in Inflammatory Bowel Disease

Given the nature of the disease and the alternation of phases of remission and recovery, continuous monitoring plays a crucial role for the IBD patient, whose medical care must be specialist and focused on preventing relapse.

Different works [8, 9] have investigated on how telemedicine can be applied on IBDs, concerning the delivery of care, the patient acceptance and the improvement of quality of life. The main use of telemedicine in the care of IBDs regards the monitoring of patients with devices/applications to keep track of changing symptoms (telemonitoring), followed by teleconsulting, and tele-surgery.

Telemonitoring consists in the remote monitoring, treatment and diagnosis of patients. To apply this kind of medical care different infrastructure and technological innovation are required: it is necessary to build an easy and effective communication system.

George LA and Cross RK [9] studied and presented in their work the multitude of apps developed for IBDs patients, such as *myIBDcoach* or *eHealth*. A mention to be made is also to the University of Maryland, where it has been created *The Home Unit (HAT)*, an unit made up of a portable computer that collects patient information (symptoms diary, adverse effects, medication, etc).

Teleconsulting is based on the search of medical information through ICTs. It's used between both patients and physicians and between local or external medical staff when consultations are needed. The most common tool used is the one of video-conferences [8].

Tele-surgery (tele-endoscopy for IBDs) is the carrying out surgical procedures at a distance by a surgeon [8].

In experts' opinion [10] patients have been receptive and have embraced telemedicine. People are always busy nowadays and the opportunity to receive remote medical care when they are not able to take time to reach the physician is appreciated. One of the main challenges is to maintain the quality of care even if it is delivered through ITCs and in order to do that it is necessary to deal with the costs of the technologies needed to create a service not only working but also safe and effective.

Chapter 2

IBD Tool

2.1 Treatment of IBDs with ICT tools: IBD Tool

IBD Tool is a web-application launched in 2020 thanks to the collaboration between the department of Gastroenterology of the Mauriziano Hospital and the research Center LINKS Foundation, with the aim of providing a telemedicine service to the patients of the aforementioned hospital.
IBD tool is used in the treatment of chronic diseases such as UC and CD, allowing the monitoring of the patients' symptoms through the periodic administration of several questionnaires.

In the following sections the functionalities of the platform and its structure will be described in detail.

2.1.1 How IBD Tool works

IBD Tool is reserved to the patients of the Mauriziano Hospital, which have the possibility to utilise the offered services upon physician's invitation. As soon as they are registered into the system, they receive an email containing all the information about how to log into the platform and how to change their password, along with an application user manual. From this moment on, patients have access to a direct communication with physicians, thanks to the chat system integrated on the web-app that makes conversations easier and faster from both sides.

The main element is the system of questionnaires offered by the platform, that allows remote monitoring and treatment of the pathologies. Once a questionnaire is filled by a patient, the physician receives a notification and he can read the results and evaluate whenever or not there's an evolution of the symptoms. In the treatment of diseases like CD or UC the timing with which the deterioration of the state of health is noticed is crucial to prevent relapses. Based on the results, physicians can decide if a change in the therapy is needed.

The questionnaires can be sent periodically: monthly, quarterly, semi-annually, annually or at discretion of the physician, who can set any time frame. Whenever a new questionnaire is available, the user is notified by email, with this mechanism the possibility that a patient misses the compilation of a questionnaire is reduced.

2.1.2 Privacy and data management

The web-app deals with sensitive and personal data, needed to offer a remote medical service. For this reason, the first element that appears to the user after the first login is an informed consent form (Figure 2.1).

Figure 2.1: IBD Tool: informed consent form.

The General Data Protection Regulation (GDPR) is the legal framework for data protection in the European Union (EU) and sets the rules for the processing of personal data, in accordance with its regulations the patient must give the consent in order to use the application.

2.2 Platform structure

The platform presents two different views, one for the patient and one for the physician. The distinction is due to the fact that the two types of user perform

different actions and have different privileges.
On the initial page (Figure 2.2) the difference is already visible, since the physicians are the only ones who can directly sign up to the application, while the patients can only login if they have been previously registered by their physician.

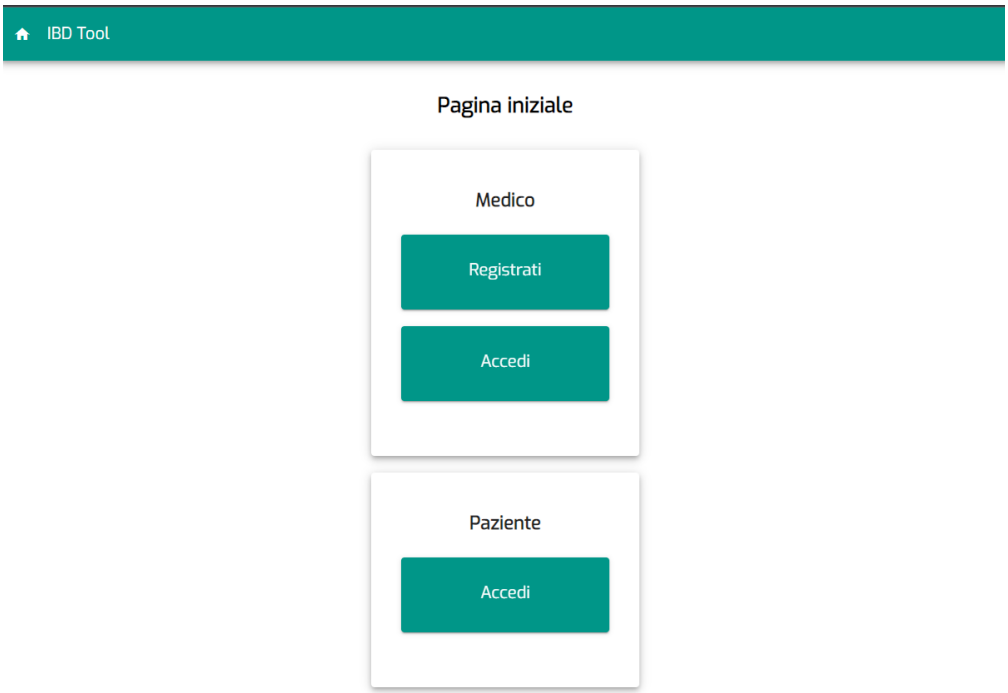

Figure 2.2: IBD Tool: initial Page.

Both patients and physicians have access to the chat system and to the notifications section, while other aspects of the platform, like the dashboard, are different. In the following sections the structures of the application for both sides will be illustrated.

2.2.1 Physician view

Physicians' homepage (Figure 2.3) presents the list of all the sections that can be accessed for IBDs management:

- Personal patients.
- Global patients.
- News.

- Application status.
- Export data.

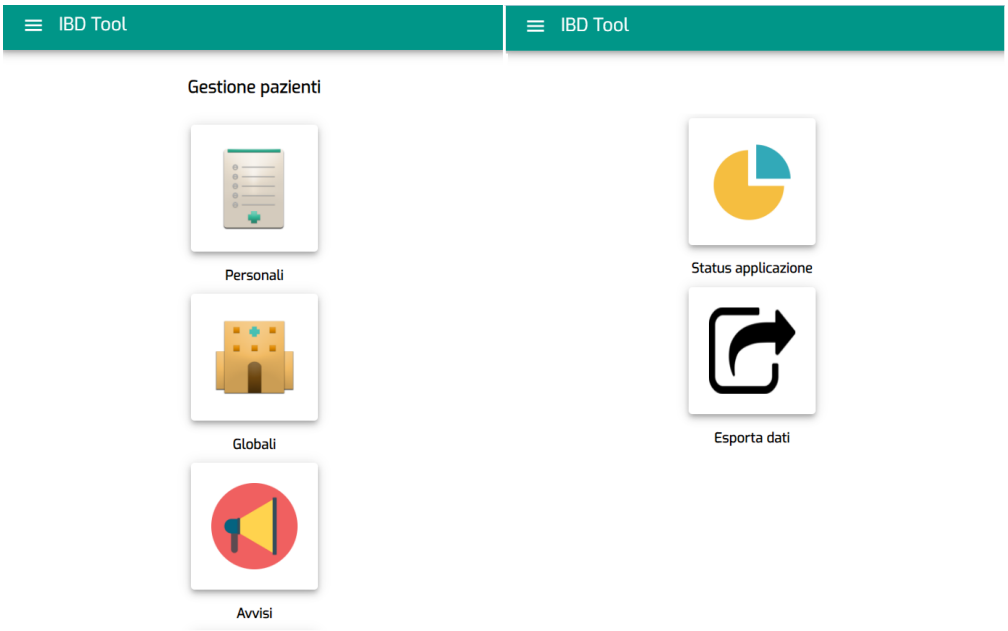

Figure 2.3: IBD Tool: physicians' dashboard.

Patients management

The sections "Personali" and "Globali" of the dashboard allow the physician to have a complete view of, respectively, his personal patients and all the patients enrolled in the platform.

Figure 2.4 illustrates the main component of the pages, a table in which the principal information about each patient are shown: surname, name, social security number (SSN) and group. This last column indicates the type of user profile, whether *standard* or *telemedicine* (the two differ on the frequency with which the questionnaires are sent).
Using the buttons in the rows, for each patient, a physician can:

- access to medical records;
- check the questionnaires page;
- send an email;
- delete the user from the platform.

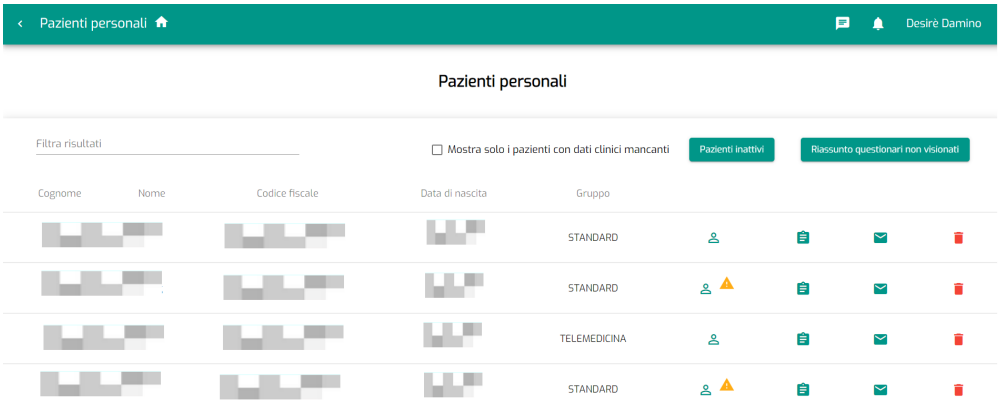

Figure 2.4: IBD Tool: section "Personali".

Medical Records pages show personal and clinical data (Figure 2.5). From these sections it is possible to update the information and to see all the details about surgical interventions and past/ongoing therapies.

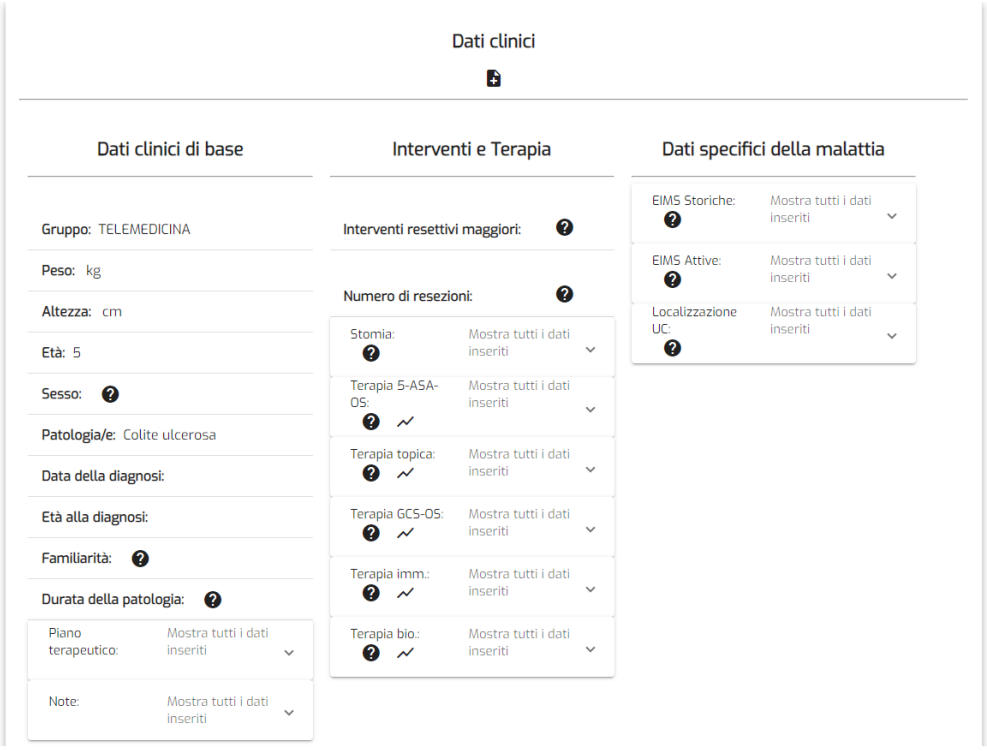

Figure 2.5: IBD Tool: clinical data of patient's medical record.

Questionnaires management

Questionnaires are the principal tool used by physicians to monitor the symptoms of IBDs patients. The physician has access to all the questionnaires compiled from a medical point of view (*CLINICAL*) (Figure 2.6) and to those filled directly by the patient (Figure 2.7). It is possible to check the various results and evaluate them in order to understand if an intervention is necessary or not. Other additional features are the possibility to set the time interval with each type of questionnaire must be sent and the one to add a new one whenever if needed.

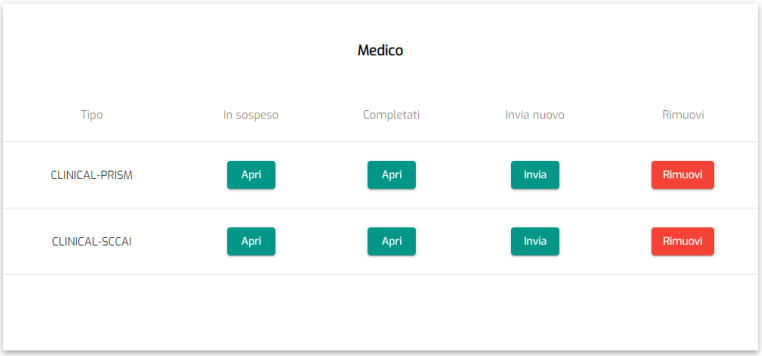

Figure 2.6: IBD Tool: clinical questionnaires.

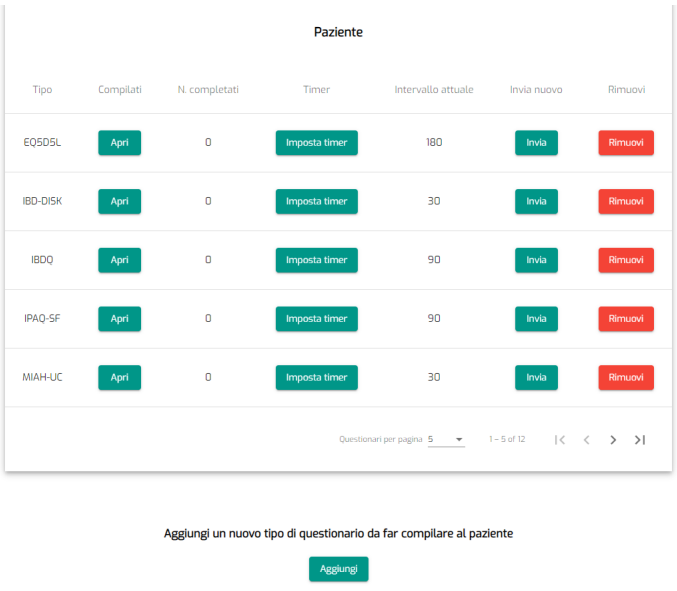

Figure 2.7: IBD Tool: patient questionnaires.

News

The platform offers doctors an effective and practical way to communicate news of common interest. From this section it is possible to write and send a notice, which will be shown to all physicians and to Telemedicine patients once they login (Figura 2.8).

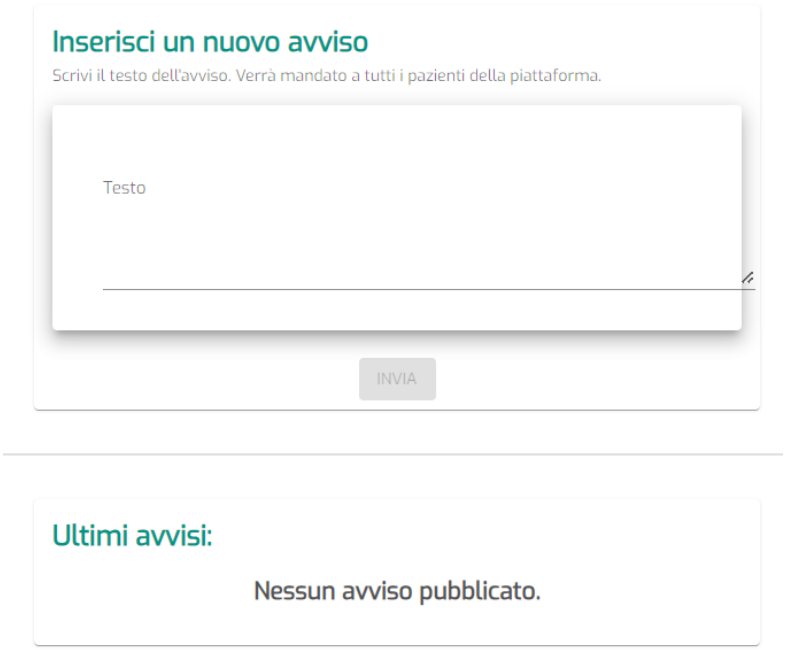

Figure 2.8: IBD Tool: news section.

Application Status

IBD Tool is also used by physicians and researchers to study incidence and evolution of diseases thanks to the statistics obtained from patients and questionnaires. The platform presents an entire section dedicated to the analysis of the data collected, divided into different areas (Figure 2.9). This tool gives also an idea of patients acceptance of telemedicine, since some descriptions evaluate the utilisation of the web-app.

Figure 2.9: IBD Tool: application status overview.

The analysis presented are numerous and various, they mainly regard:

- active/inactive patients;
- stable/unstable patients;
- global/personal patients;
- global questionnaires.

All the above are categorized by age, therapy, disease, interventions, etc.

Figure 2.10 shows an example: a chart of the total number of users, divided by pathology.

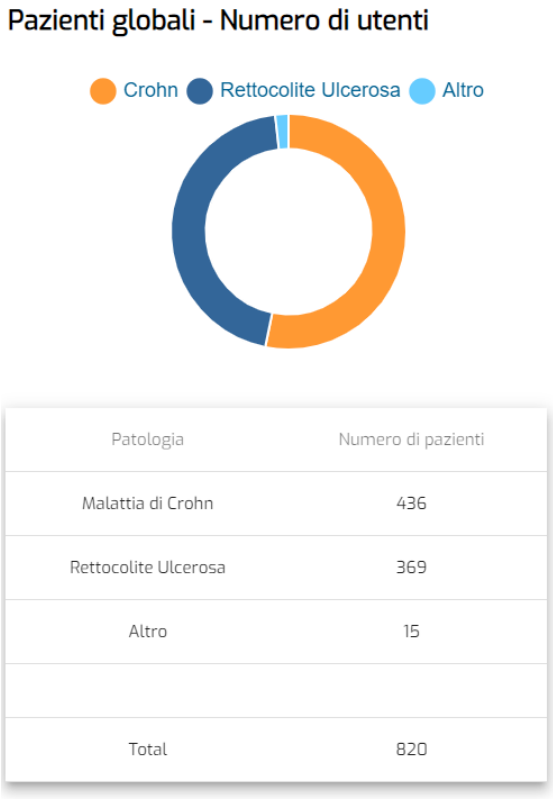

Figure 2.10: IBD Tool: chart of the total number of users, divided by pathology (updated on 20/10/22).

Export data

A data export section available to users provides to extract collections needed to perform more in-depth researches on IBDs. Data analysis plays an important role in IBD Tool and thanks to it several publications have been made. For this reason, the topic will be discussed more in detail in Section 2.3.

2.2.2 Patient view

Patients logged into the platform have access to different modules, as shown in Figure 2.11, useful for:

- manage their own questionnaires, new and old ones;

- interact with the physician;
- give a feedback on the web-app, through a satisfaction questionnaire.

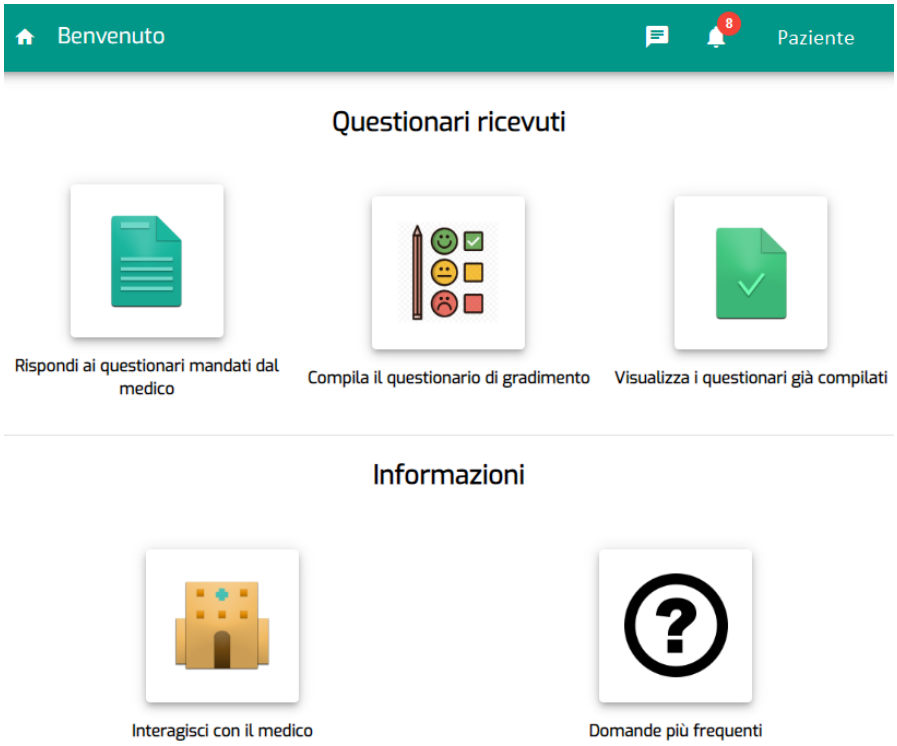

Figure 2.11: IBD Tool: patients' homepage.

Received questionnaires

When a new questionnaire is ready to be filled, a notice is visible on the navbar of the homepage (Figure 2.11). The patients can enter into the Notification Center (Figure 2.12) and check what needs to be compiled.
It's also possible to access to the questionnaires sent by physicians directly from the homepage by going on *"Rispondi ai questionari mandati dal medico"*. This section is shown on Figure 2.13 : all the pending questionnaires are listed, within the date in which they have been sent by the physician and their type.

Questionnaires already filled are also available in a further component, where the user can check how many for type he has compiled so far.

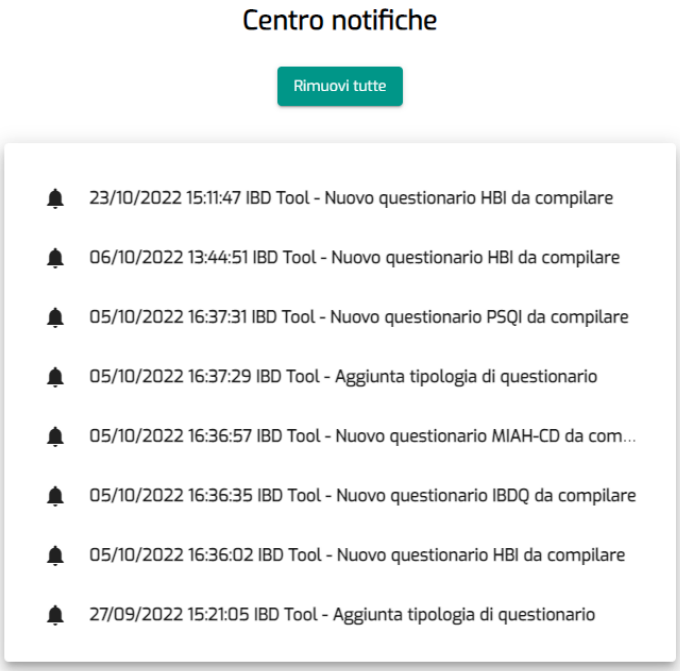

Figure 2.12: IBD Tool: notification center.

Figure 2.13: IBD Tool: user's pending questionnaires.

Interaction with the physician

IBD Tool permits a fast and easy communication between patients and doctors through a module (Figure 2.14) from which the user can :

- send a new questionnaire;
- start a chat.

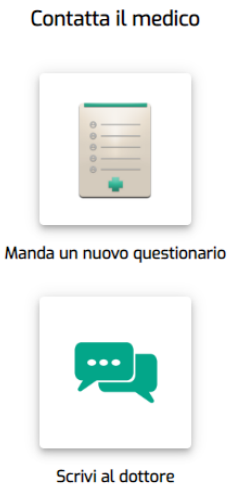

Figure 2.14: IBD Tool: interaction with the physician.

If the user decides to send a questionnaire, he is taken to a page where the various possible types are present, along with their description, so he can choose which aspect of the disease he wants to be monitored (Figure 2.15). Otherwise, if he just wants to have a dialogue with the physician without sending anything, he simply can start a chat.

2.2.3 Questionnaires

The questionnaires used to monitor IBDs are specific and structured in such a way that results can be easily evaluated by physicians. Each of these, indeed, scores and covers a specific area of the patient's health. The web-app presents in total 16 questionnaires, characterized by a certain periodicity.

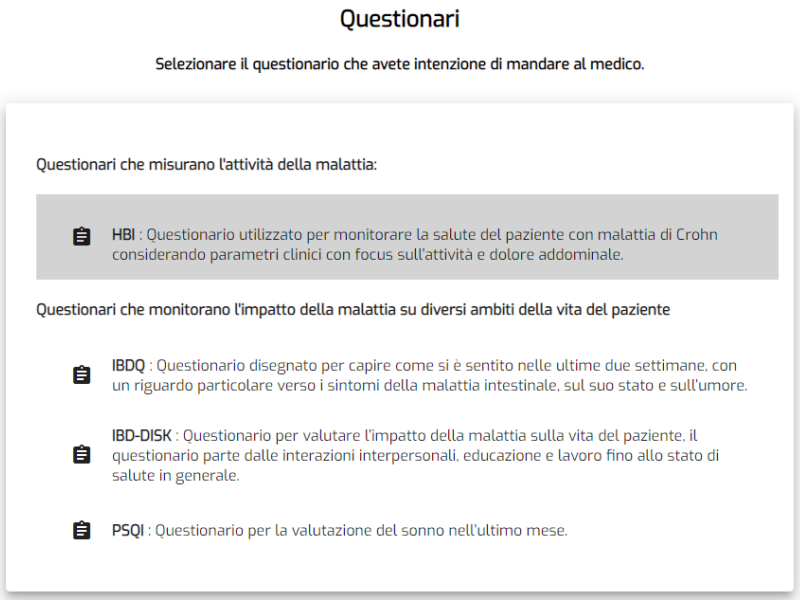

Figure 2.15: IBD Tool: list of questionnaire sendable to the physician.

Monthly questionnaires are:

- HBI (Harvey Bradshaw Index): it is, by default, only aimed for CD patients. It's composed by 5 items that evaluate patient's well-being, abdominal pain, number of liquid or soft bowel movements, presence of abdominal mass and complications.
- CLINICAL-HBI, it is a HBI filled out by clinicians to compare the results with patient scores.
- SCCAI (Simple Clinical Colitis Activity Index): addressed to UC patients. It's composed by 13 questions that evaluate last week's symptoms, such as bowel movements, urgency of defecation, blood in the stool and general well-being.
- CLINICAL-SCCAI, it is a SCCAI filled out by clinicians to compare the results with patient scores.
- IBD-DISK (Inflammatory Bowel Disease - Disability Index disk form): it is based on 10 items, aimed to assess the impact of the disease on the patient's life. They questions about abdominal pain, regulating defecation, education and work, sleep, energy, emotions, body image, sexual functions, and joint pain.

- MIAH (Monitor IBD at Home): it is available in two versions, one for patients with Crohn's disease (MIAH-CD) and one for patients with ulcerative colitis (MIAH-UC), with respectively 6 and 5 questions.
  MIAH-CD questions about rectal bleeding, mucus, stool frequency, urgency and fatigue. MIAH-UC questions about rectal bleeding, stool frequency, urgency and abdominal pain.

Three-monthly questionnaires are:

- PRISM (Pictorial Representation of Illness and Self Measure): it is not composed of questions but of a graphic representation to measure the impact of the disease on the patient's life. It is made up of two circles representing the disease and the patient; the user indicates, by moving the circles, how much he suffers due to his illness.
- CLINICAL-PRISM, it is a PRISM filled out by clinicians to compare the results with patient scores.
- PHQ9 (Patient Health Questionnaire 9 items): used for diagnosis and monitoring of depression.
- WPAI (Work Productivity and Activity Index): used to assess the effects of IBDs on the ability to work and carry out normal daily activities
- IPAQ-SF (International Physical Activity Questionnaire - Short Form): it is composed by questions regarding the physical activities that the patient has done in the last 7 days.
- IBDQ (Inflammatory Bowel Disease Questionnaire): it consists of 32 questions, which take into consideration different fields of patients life and are aimed to assess the quality of life related to IBDs.
- MMAS8 (Morisky Medication Scale 8 items): it is based on 8 questions that assess adherence to therapy. The questions relate to the patient's personal experience with therapy.
- TSQM (Treatment Satisfaction Questionnaire for Medication): it is used to assess the level of satisfaction or dissatisfaction with the ongoing therapy.

Six-monthly questionnaires are:

- EQ5D5L (European Quality version 5D - 5 Levels): it is about measurement and monitoring of the patient's physical and psychological health. It's composed of questions about work, personal care, usual activities, pain and discomfort.

- PSQI (Pittsburgh Sleep Quality Index): 9 questions used for the evaluation of sleep in the last month.

As previously mentioned in section 2.2.1, users are divided into two groups: *standard* and *telemedicine*, which differ in the frequency with which questionnaires are sent/received. Telemedicine patients compile all the questionnaires with their regular administration frequency, while Standard patients only compile HBI, IBD-DISK, MIAH, SCCAI, IBD-DISK with a frequency of three months.

Table 2.1 recaps, for each questionnaire, the typology of patient it is addressed to, the frequency for each group and the object of the analysis.

Questionnaire	Patients	Telemedicine Frequency	Standard Frequency	Object
HBI	CD	Monthly	3-Monthly	Symptoms and activity
SCCAI	UC	Monthly	3-Monthly	Symptoms and activity
MIAH-CD	CD	Monthly	3-Monthly	Home monitoring
MIAH-UC	UC	Monthly	3-Monthly	Home monitoring
IBD-DISK	CD,UC	Monthly	3-Monthly	Impact on the patient's life
PRISM	CD,UC	3-Monthly		Impact on the patient's life
PHQ9	CD,UC	3-Monthly		Depression
WPAI	CD,UC	3-Monthly		Influence in daily activities
IPAQ-SF	CD,UC	3-Monthly		Physical activities
IBDQ	CD,UC	3-Monthly		Quality of life
MMAS8	CD,UC	3-Monthly		Adherence to therapy
TSQM8	CD,UC	3-Monthly		Therapy satisfaction
EQ5D5L	CD,UC	6-Monthly		Physical and psychological health
PSQI	CD,UC	6-Monthly		Sleep

Table 2.1: IBDs questionnaires with patients, frequency and analysis object.

2.3 Data analysis

The data analysis obtained from the web-app has proved to be relevant in the study of IBDs. Beside graphs and statistics accessible to doctors from the homepage, which have already been discussed in section 2.2.1, the platform offers an Export section which allows the download of a specific combination of data in an Excel file.

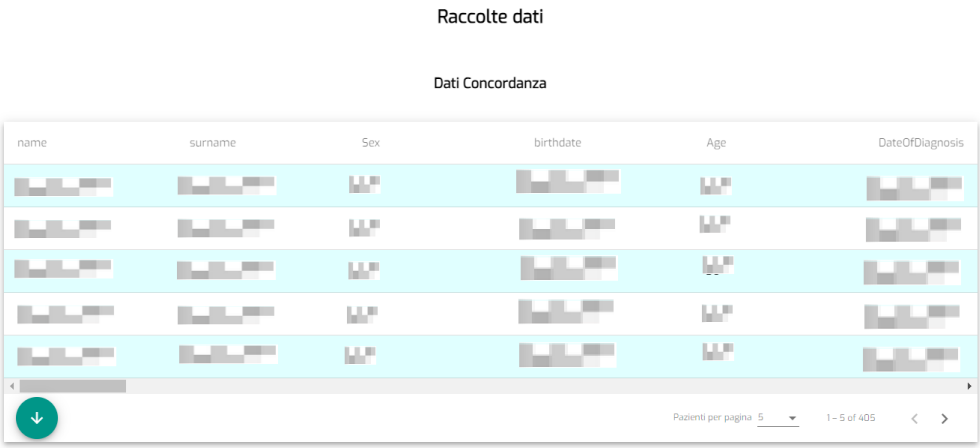

Figure 2.16: IBD Tool: Data collection export.

Data collection in Figure 2.16 shows a table that permits to evaluate the degree of agreement between patients, junior and senor physicians. The user can easily download it in the form of an Excel sheet, that will present for each row:

- personal and clinical information about the patient (including therapies, surgical interventions, etc.);
- date and score of HBI/SCCAI, PRISM from the patient's point of view;
- date and score of CLINICAL questionnaires filled out by both a junior and a senior figure.

These elements' combination has been used to perform studies on the *Agreement between patients and physicians on scores of inflammatory bowel disease activity* [11].

The degree of agreement was assessed for HBI, SCCAI and PRISM in a group of 289 patients with CD and 271 with UC. It emerged how the concordance was substantial for disease activity and moderate for disease impact.

The results showed that differences were present also between senior and junior physicians' scores: the last ones, indeed, seemed to be more strongly correlated with patients' scores. Generally, however, there's also a correspondence between

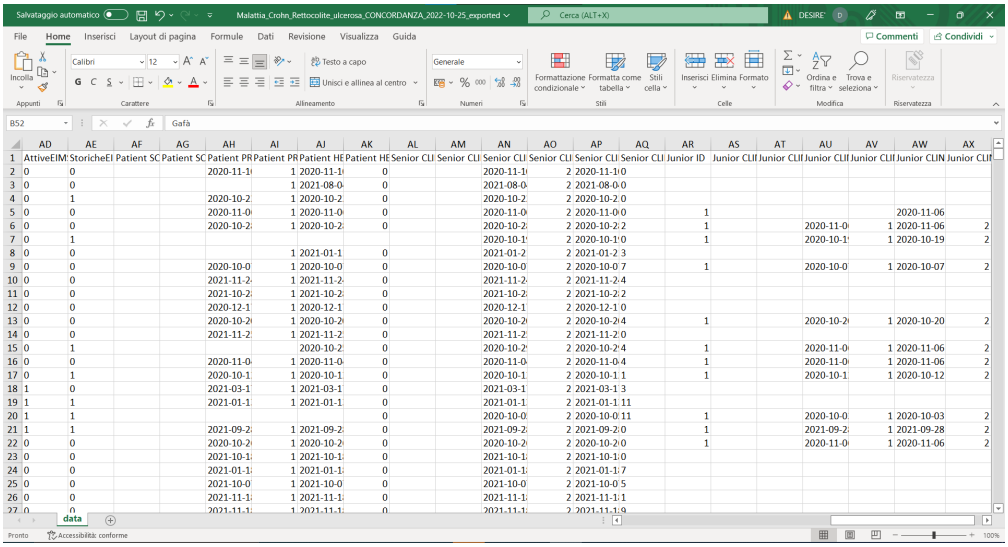

Figure 2.17: Example of Excel file with data aggregations.

doctors' scores than between patients' and doctors'. Physicians tend to agree more with themselves than with patients about disease activity and especially about disease's impact on life.

Chapter 3

Method and Materials

The work done on IBD Tool aims to fix existing problems that interfered with the functioning of the web-app, add new functionalities and enhance the ones already present.

To achieve the goal, the work done proceeded in accordance with the following steps:

1. Study of technologies and development tools previously used.
2. Analysis of platform structure, Back-end and Front-end.
3. Examination of the database design.
4. Evaluation of a suitable strategy to complete each task, using the appropriate technologies.

3.1 Technologies

IBD Tool has been designed and created by using different technologies among the most utilised in the panorama of web application development.

From an architectural point of view, the web-app is a REST-type (Representational State Transfer) application and provides a *Client/Server* structure: the server receives requests from the client and makes the needed resources/data available. It is possible to make a clear division between platform's Front-end and Back-end, which have been developed using different tools and languages.

3.1.1 Front-end

The Front-end of an application (FE) is the interface with which the user can interact, it is the part that allows the effective reactivity of a platform.

The visual elements of a web-page permit the functioning of the product and play a key role for UX (User Experience), that can be defined as the easiness and the fulfillment with which a person interacts with the system.

Angular

The development platform used is Angular, built on TypeScript [12]. It includes:

- A component-based framework for building scalable web applications.
- A collection of libraries that cover a wide variety of features (routing, forms management, client-server communication, etc.).
- A suite of developer tools.

Angular is used to create modern products that follow the concept of SPA (Single Page Applications): web applications where the whole data is sent to the client from the server at the beginning and as the client clicks certain parts of the web-page, only the required elements are fetched from the server so the page is rewritten dynamically. This leads to a lesser load on the server and ensures high performances [13].

Applications are composed of building blocks called *Components*. A component is a single element of the interface, it usually consists of three files: an HTML (Hypertext Markup Language), a CSS (Cascading Style Sheet) and a TypeScript class.

HTLM allows to define the elements within the page, while the CSS sheet defines their location and properties (style). TypeScript is an open source Object-Oriented programming language that extends JavaScript and it is used for building the logical part of the component.

The *@Component()* decorator specifies the following Angular-specific information:

- A selector that defines how the component is used in a template. HTML elements that match this selector become instances of the component.
- An HTML template that instructs Angular on how to render the component. It can be written directly as *"template"* or it can address an HTML file through *"templateUrl"*.
- A set of CSS styles that define the appearance of the template's elements.

Implementation of a component is showed in the following example:

```
import { Component } from '@angular/core';

@Component({
  selector: 'test-component',
  template: `
    <h2>Test</h2>
    <p>This is my first component!</p>,
    styles: ['h2 { font-weight: normal; }']
  `
})

export class TestComponent {
  // The code in this class drives the component's behavior.
}
```

Among the many libraries offered by Angular, the toolkit *Angular Material* has been used for the implementation of IBD Tool's theme and graphic elements (table, forms, icons, lists, etc.).

Beside Components, other key elements of the application are *Services*. Services are designed to provide support for handling HTTP requests to the server.

In the following example there's the implementation of a new service, it must import the Angular Injectable symbol and annotate the class with the @Injectable() decorator;

```
import { Injectable } from '@angular/core';

@Injectable({
  providedIn: 'root'
})

export class TestService {

// The code is this class provides the services.

}
```

The decorator marks the class as part of the *dependency injection* system.

Dependency Injection (DI) is a design pattern for delivering some parts (in this case, a service) of an application to other parts that need them. When a service is

provided at the root level, as in the example (*providedIn : 'root'*), Angular creates a single, shared instance and injects into any class that asks for it.

IBD Tool's FE structure is characterized by a series of Components, grouped in category by sub-folders (e.g. components related to doctor/user actions, page compositions etc.), that can call the related Services to interact with the server.

The diagram in Figure [12] shows how the basic pieces of the web-app are related.

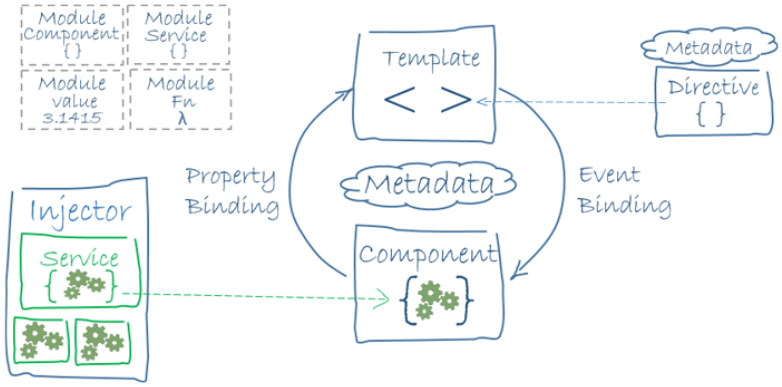

Figure 3.1: Angular applications' structure [12].

3.1.2 Back-end

The Back-end of an application (BE), also known as server-side, is the mechanism that processes data and performs actions on websites. The back-end is the code that runs on the server, it deals with client's requests and contains the logic to prepare and send the appropriate data back and handle the ones received [14].

The programming language used to implement IBD Tool's server-side is Java, along with the framework Spring Boot.

Java Spring Boot

Spring Boot is a simplified and automated version of the Spring framework, an applications' development solution that uses techniques such as Aspect-Oriented Programming (AOP), Plain Old Java Object (POJO), and Dependency Injection (DI) (mentioned in Section 3.1.1) [15, 16].

Spring boot presents the following architecture, made up by four layers [15] :

- **Presentation Layer**. It is the top layer. It handles the HTTP requests received by the client and passes them to the Service Layer. This layer is composed of classes defined as @Controller, that manage also the responses

received by the server through the Service Layer and send them back to the client.

- **Service Layer**. It performs the business logic: inside we find @Service classes. They receive the data from the top level and validate it.
- **Persistence Layer**. It is the layer that takes care of the abstraction of objects to the database row and viceversa. The classes inside this layer are labeled with @Document.
- **Database Layer**. It contains the databases (in this case, MongoDB) and the methods used to interact with them and perform the CRUD (Create, Read, Update and Delete) operations.

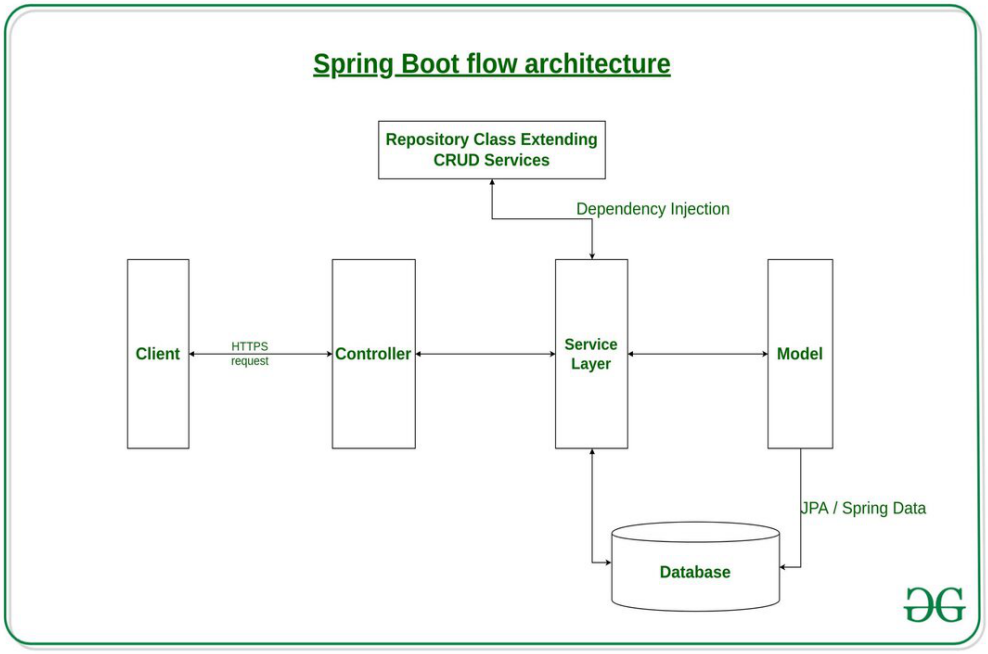

Figure 3.2: Spring boot architecture [15].

IBD Tool's BE follows this architecture, here's an example of handling an HTTP request for the retrieving of some data:

```
//Presentation Layer,
//in DoctorController.java the request is hanlded:

@GetMapping("private/doctor/get-data/{doctorID}")
public ResponseEntity<Entity> getData(@PathVariable String doctorID)
 throws Exceptions {

        // it passes request to the Service Layer
        Entity data = userService.getData(doctorID);

        ...
 }

// Service Layer,
// in class userService the business logic is performed:

public Data getData(String doctorID) throws Exceptions {

     Optional<UserEntity> optionalDoctor =
     userRepository.findByDoctorID(doctorID);

    // Class UserEntity belongs to the Persistance Layer,
    // which takes care of abstraction of objects to the database
    // row and viceversa
    // Class UserRepository belongs to the Database layer and its methods
    // such as findByDoctorID(doctor ID) perform CRUD operations.

   ..
 }
```

3.1.3 MongoDB

MongoDB is the database chosen for the storage of IBD Tool data, it is an open-source document-oriented database. This database is defined as NoSql (Not only SQL) because data is not stored under the form of traditional tables, while collections and documents are used [17].

Collections are equivalent to tables in MySQL, within these we find one or more documents that represent our data (Figure 3.3).

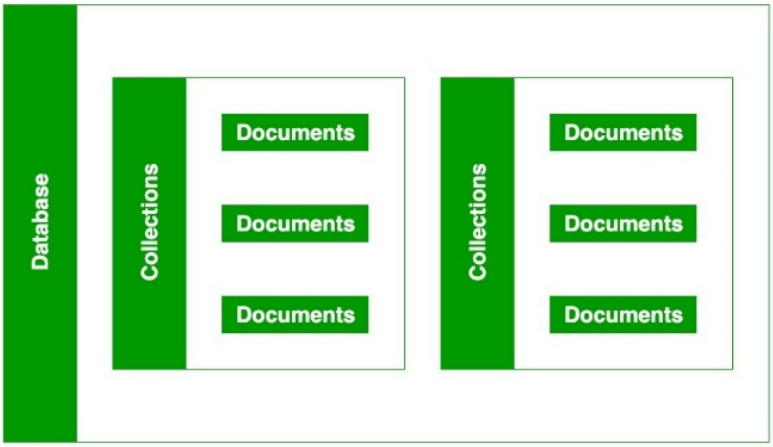

Figure 3.3: MongoDB database structure [17].

The documents in MongoDB are in a BSON format, that is a Binary representation of JSON.

There are different advantages in choosing a document-oriented database over a relational one for the storage of IBD Tool data: it provides great flexibility, high performance, availability, scalability. However, disadvantages like the use of high memory for data storage are not excluded. Table 3.1 illustrates the main difference between Relational Database Management Systems (RDBMS) as MySQl and NoSql database as MongoDB.

In IBD Tool case we have a web-app where data structure is growing rapidly and may change, so using a database that allows flexibility may result to be a better choice than using a database with a strict schema such a SQL one.

Figure 3.4 shows the structure of IBD Tool data storage: we have one database with different collections that contain multiple documents where data are stored.

	RDBMS	NoSQL
Type	Relational	Not Relational
Data	Stored in tables	Stored in documents
Schema	Strict and rigid	Dynamic and flexible
Language	Structured Query Language	No declarative query language
Scaling	Vertically scalable	Horizontally scalable
Pros	Data consistency, integrity, security	Flexibility, agility, low cost

Table 3.1: Comparison between RDMBS and NoSql Databases.

The collections are:

- Users: it contains the data about all the user registered on the platform, both patients and doctors. The two profiles differ for the values of the key "role" that are, respectively, "PAZIENTE" and "DOTTORE". Besides this, the user profile contains additional information in fields "doctor" (object with the data of the physician who registered him on the platform), "questionnaires" (type of questionnaires compiled), "checkClinicalData" (flag that informs about the status of patient clinical data - if completed or not) and "category" (whatever "TELEMEDICINA" or "STANDARD"). The addition info in the doctor profile, instead, is just "doctorId" and "doctorRole" ("JUNIOR" or "SENIOR") (Figure 3.5);
- Questionnaires: data of all filled questionnaires, with type, date, results, lecture flag and e warning ("true" or "false" depending on the scores).
- Announcement: collection of all the new published on the platform by doctors.
- ChatMessages: it stores all the chat messages between physicians and patients.
- AssignedPatients: for each clinician, it contains all the assigned patients.
- ClinicalDataPatients: among with some personal data, it stores medical records of the patients as an object inside a "bodyStat" field. .
- Pending: information about questionnaires waiting for lecture/filling.

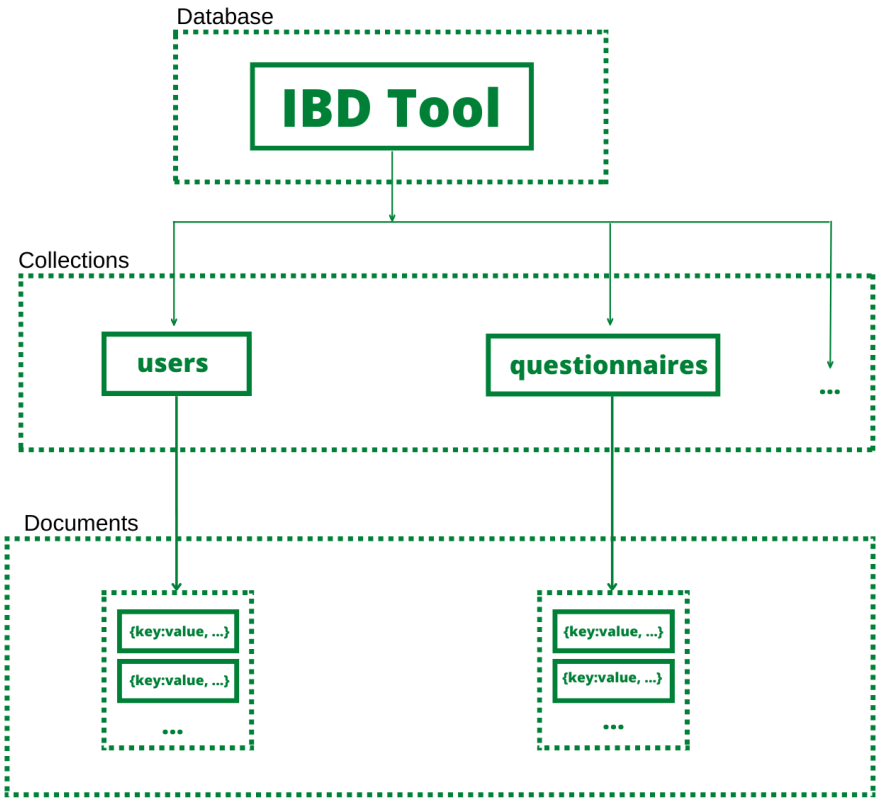

Figure 3.4: IBD Tool database structure.

- QuestionnairesToNotify.
- userNotifications: for each user enrolled in the platform, documents contains an array of all notifications.

```
_id: "desiredamino@gmail.com"
name: "Desire"
surname: "Damino"
SSN:
phoneNumber:
password:
role: Object
  userRole: "DOTTORE"
uuid:
enabled: true
emailValid: true
registrationTime:
doctorID:
chatNotificationEnabled: false
birthDate
birthPlace: ""
deadlineQuestionnaireModified: false
timestampLastMonthlyQuestionnaire: 0
timestampLastThreeMonthlyQuestionnaire: 0
timestampLastBiannualQuestionnaire: 0
doctorRole: "JUNIOR"
lastLogin: 2022-10-26T19:26:45.292+00:00
usageTime: 842542
_class: "com.backend.web.ibdtool.entity.UserEntity"
```


Figure 3.5: Example of document inside the "user" collection.

3.2 Development (Tools and Platforms)

Various tools were used to develop IBD Tool. Each of them assumed a key role for writing, hosting, executing the code and supporting the features.

The following sub-sections show an overview of the different instruments used to support the work.

3.2.1 Visual Studio Code and Github

Visual Studio Code (VSC) is the IDE (Integrated Development Environment) used to actively write the code. It is a code editor that supports development operations like debugging and version control thanks to different extensions and allows to interact and collaborate with Github through *Git*, a source software for distributed version control. From VSC terminal is possible to use Git and clone/share/update the code.

Github is the cloud-based service for storing and sharing source code under the form of Repository. On Github there are two private repositories that host IBDTool code, one for the front-end (*IBDTool-fe*) and one for the back-end (*IBDTool-be*), to which only IBD Tool staff has access. The use of this platform is essential to

update the code in a structured and consistent way. Various branches are used to make the appropriate changes or carry on new features without modifying the main version and interfering with others' work.

In particular, besides the *main* branch, that is directly connected to the remote server, there's a *dev* branch both for FE and BE:

- in *IBD-Tool-fe's dev branch,* the client (hosted on `localhost:4200` reaches the local server (if in execution) on the address `localhost:8080`;
- in *IBD-Tool-be's dev branch* server's code is set to run on `localhost:8080`.

Once a feature or some development are ready, the *dev* branch is "merged" into the main one. All operations are possible thanks to git commands, here's a list of the most common used:

- Commit: operation that records changes to the code, a description can be added to specify the object of the commit.
- Push: update of the remote repository (it is possible only if a commit has been previously made).
- Pull: it is used when the remote branch has been changed, it allows to "download" the changes.
- Merge: combine different branches.

Github Desktop

For this thesis work, in addition to regular git commands written directly on the VSC terminal, a support tool called *Github Desktop* has been used. It is an application that presents a Graphic User Interface to interact with Github repositories without the command line, it simplifies the workflow by showing changes in the code (with the opportunity to make a direct comparison with the older code) and history of commits (Figure 3.6).

3.2.2 Gmail

Gmail is the free mail service provided by Google and it is used as support in the sending of emails for IBD Tool.

The sending of emails is an important feature for the web-app, since patients and physicians must receive periodic updates about questionnaires and any re-configuration of the user profile (such as, for example, the request of a new password) is handled thanks to it.

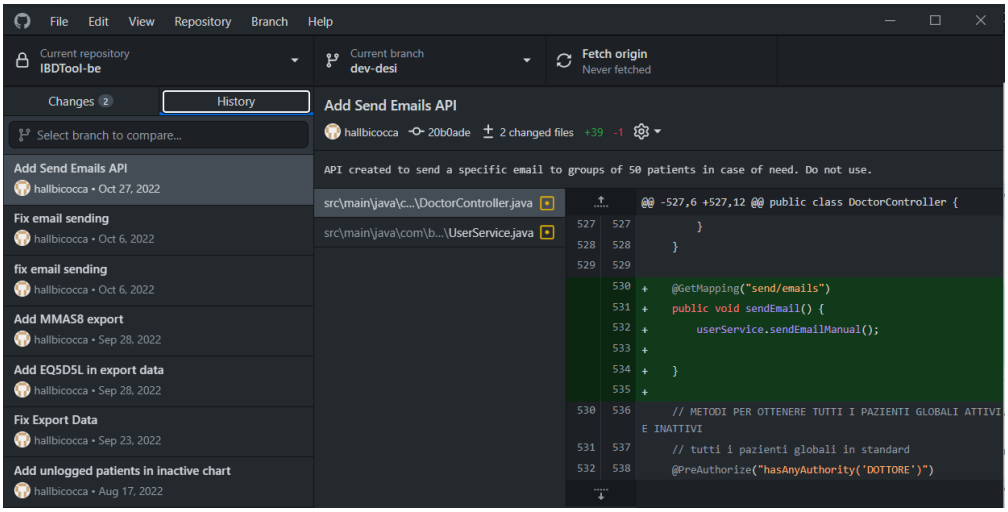

Figure 3.6: Github Desktop interface.

The application relies on a Gmail Account specifically created for IBD Tool (*ibd.app.mauriziano@gmail.com*), to which any user can also write for any problem concerning the platform. The account is managed directly by IBD Tool developers, who keep track of the correct functioning of the service.

Mail Service

The Mail Service is configured in the back-end of the web-app trough the SMTP (Simple Mail Transfer Protocol) server. Spring supports JavaMail messaging with the Spring Mail module. The *MailService* class internally implements various methods for sending emails, the main one is SendMail().

In the following code an example of implementation of the method inside the class is shown:

```
public void sendMail(String email, String subject, String message)
throws MailException {

            SimpleMailMessage mail = new SimpleMailMessage();
            mail.setTo(email);
            mail.setFrom(emailFrom);
            mail.setSubject(subject);
            mail.setText(message);
            javaMailSender.send(mail);
}
```

where:

- *SimpleMailMessage* is the class used to create the mail message specifying the to and from emails, the subject and the content;
- *javaMailSender* is the interface previously configured by setting all the properties for the sending of emails, such as the host *"smtp.gmail.com"*, the port, username, password, etc.

3.2.3 Google Drive

Google Drive is a Cloud Storage tool to share and archive multimedia files. It is one of the most popular services offered by Google and it is partially free, each account provides 15 GB of storage space. This platform has been used as support of IBD Tool for the sharing of files and pdf, such as the *User manuals* for Patients and Physicians. It provided a practical way to share in the emails reserved to new users the information needed.

3.2.4 MongoDBCompass

MongoDB Compass is a GUI for querying, aggregating, and analyzing MongoDB data [18]. It has been used to connect to the MongoDB remote deployment, where IBD Tool data are stored, to check the status of the database and to access to the local MongoDB, by setting Hostname to localhost and Port to 27017. The interface allows to have a clear view of the database, collections and documents and permits different actions like, for example, the querying of the database, that results to be very useful while testing new functions that perfom CRUD operations.

3.3 Deployment

Back-end and Front-end Deployments are managed differently by using, respectively, *Heroku* and *Firebase*. In the following sections a brief description of these platforms and their use for this project is provided.

3.3.1 Heroku

Heroku is a container-based cloud Platform as a Service (PaaS) [19], that means a type of computing model where a third-party provider supplies hardware and software tools needed for application development [20]. PaaS is just one of the main categories of cloud computing services, there are also IaaS (infrastructure as a service) ans Saas (software as a service): the three differ for the type of services provided to the users. In SaaS, for example, a provider offers an entire application stack while in IaaS a provider supplies the basic compute, storage and networking infrastructure are supplied. Figure 3.7 shows a comparison between the different categories of Cloud Computing services.

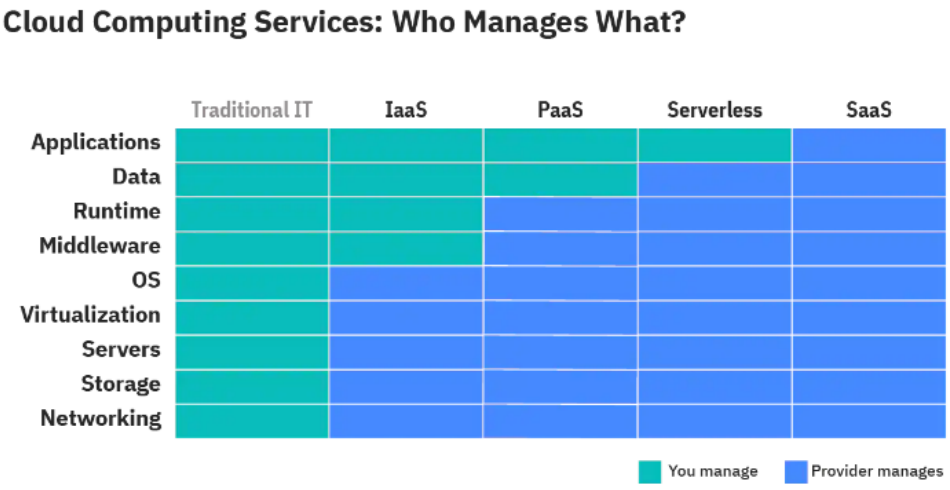

Figure 3.7: Comparison between Cloud Computing Services [21].

As a PaaS Heroku hosts the development platform on its own infrastructure and makes IBD Tool Server available on the internet.

The deployment on Heroku is easy and practical thanks to an integration with Github, that allows the automatic import of a branch of the application: in our case the branch *main* of repository *IBDTool-be*. Each time an update is made to the selected branch (*push operation on git*), Heroku starts the build and the deployment of the platform.

3.3.2 Firebase

Firebase is a Google platform used for the development and the design of high-quality apps. It provides several services, one of them is the hosting. To use Firebase functionality a Google Account is needed: in our case, it is the same used for Gmail Services. Project is easily configurable through the Console Firebase Google.

IBD Tool front-end is hosted at `https://ibd-tool-mauriziano.web.app/`.

While with Heroku the update of the server is automatic and integrated with the push made on Github main branch, with Firebase some additional steps are needed when a change of *IBD Tool-fe* code is made. To deploy a new release , it is necessary to act in accordance with the following procedure:

1. Install the Firebase Command Line Interface (CLI).
2. Login on Firebase.
3. Build the code.
4. Execute the deployment.

Here's an example of the flow to follow when a new release is ready to be deployed:

```
npm install -g firebase-tools
firebase login
ng build -prod
firebase deploy -m "generic comment - new release"
```

Chapter 4

Results

The results obtained during this thesis have led to changes in both the Back-end and the Front-end of IBD Tool. The workflow followed the needs gradually manifested by physicians over the months and was organized in tasks, each of them with a clear goal. The objectives set at the beginning of the work and the ones introduced during the months have been reached, they regarded:

- the resolution of pre-existing problems that interfered with the correct functioning of the web-app;
- the implementation of a new function for Data Aggregation in response to physicians' need;
- enhancement of the User Experiences, by adding new visual elements to the User Interface.

4.1 Management of the web-app

To approach the application and solve the problems noticed by physicians and patients, the first step has been to verify its correct functioning and check the status of the current configurations of the support tools (such as Gmail, Heroku and Firebase). Specifically, issues regarding the sending of emails and the deployment on Heroku have been solved.

A detailed overview of both of them will be provided in the next paragraphs.

4.1.1 Gmail Auth on third-party email applications

In the initial phase of the work, after studying IBD Tool's execution flow, the goal was to solve a problem detected by physicians and patients: the non-functioning of

the mail service. Although this service is a crucial point for the web-app, users had not received emails for months. By testing the app, it was noticeable that emails were not sent in any case, so it was not even possible to register a new user to the app (since confirmation emails are required) or to change the password if needed. Besides the actual sending of messages, every other feature of IBD Tool worked correctly.

Figure 4.1: Server logs: Gmail authentication error.

As shown in Figure 4.1, the Heroku console reporting Server logs indicated that the problem was the authentication (*AUTH LOGIN failed*), despite *Username* and *Password* of the Gmail account had not changed.

The problem found was that in May 2022 Google updated his terms and decided to no longer allow username and passwords on third-party email applications (like IBD Tool) [22] and that was the reason why any try to login and send emails using the Google mail service from the platform failed.

To allow authentication and the use of Gmail on the web-app, it was first necessary to enable two-factor authentication on the Google IBD Tool account and then generate a password for the use of third-party application.

After configuring username and password on the server like in the following example, the service re-started to work correctly (Figure 4.2).

```
spring.mail.host=smtp.gmail.com
spring.mail.port=587
spring.mail.username=ibd.app.mauriziano@gmail.com
spring.mail.password=*********
spring.mail.properties.mail.smtp.auth=true
spring.mail.properties.mail.smtp.starttls.enable=true
spring.servlet.multipart.maxFileSize=15MB
spring.servlet.multipart.maxRequestSize=15MB
```

```
DEBUG SMTP: protocolConnect login, host=smtp.gmail.com, user=ibd.app.mauriziano@gmail.com, password=<non-null>
DEBUG SMTP: Attempt to authenticate using mechanisms: LOGIN PLAIN DIGEST-MD5 NTLM XOAUTH2
DEBUG SMTP: Using mechanism LOGIN
DEBUG SMTP: AUTH LOGIN command trace suppressed
DEBUG SMTP: AUTH LOGIN succeeded
```

Figure 4.2: Server logs: Gmail authentication succeeded.

4.1.2 Heroku Re-Configuration

The deployment on Heroku has been an issue that didn't interfere with the correct functioning of the web-app, but with its development. After making the necessary changes to the code and updating the Github repository *IBDTool-be*, it was noticed that the Build and the Deployment of the code did not happen automatically after updates, as they should along with Heroku settings. Apparently, Heroku's GitHub private repositories were downloaded by a threat actor on April 9 2022 thanks to a compromised OAuth token [23]. During investigations about the incident Heroku decided to remove of the Heroku-GitHub integration and that led to some features (including the automatic build and deployment) becoming not operative.

GitHub integration was restored by the platform on May 25 2022 since there was no evidence of customer impact. After that date, a re-configuration of Heroku deployment for the server of IBD Tool has been carried out and allowed to return to the correct functioning of automatic deployment after a *push* on the Github repository.

4.2 Data Export

The main part of this work is the introduction of a function for the continuous export of Patients Data (that include clinical and questionnaires data).

This feature has been directly requested by physicians: the goal is to obtain a specific data aggregation in order to carry out further data analysis. As mentioned in Chapter 2 while describing the IBD Tool platform, physicians' homepage provides a section called "Export data", that allows the visualization and the download in an Excel file of some information about the collected data.

At the beginning of this work the section included only a table, previously used by physicians and researchers to conduct an analysis about the agreement between patients and clinicians (*senior* and *junior*) [11].

The introduction of a new Data Aggregation Export arises from a specific request of the physicians to have a data extraction that could allow the evaluation of the entire database, by combining information about the number of questionnaires filled out for each type, their scores, the subgroups of patients (that can be sex, age, pathology, etc.) and the satisfaction about the program (that is measured through the Satisfaction Questionnaire). To fully understand the physicians' requests and complete the Task, a direct communication with them was required. Given the amount of data needed the two main challenges have been:

- decide how to structure the extraction required;
- find a solution to display all the data in a practical way.

The initial solution proposed was a table where, for each questionnaire type (*HBI, SCCAI, etc.*), it was reported the number of questionnaires filled out, the number of questionnaires sent, the average scores, the number of users for each subcategory who had answered the questionnaires. However, this solution was not functional to the ultimate purpose of data analysis because it wouldn't have allowed to make all the appropriate and detailed inferences.

The final solution was to structure a table that for each row could contain all the data of a single patient, in combination with the clinical variables and all the information about each type of questionnaire (including the satisfaction one). In order to be able to make a comparison between the various patients and the progress of the diseases, depending on the case, it was necessary to design a system to state a difference between patients who had filled only one questionnaires and patients who instead had compiled multiple ones of the same type.

Another aspect to take into consideration was the need to extract more results of questionnaires of the same type for the each patient, in order to see the trend of the scores. Initially, the proposal was to include for each type a number of columns equal to the maximum number of questionnaires of that type filled out by a single

patient. However, by analysing the DB through MongoDB Compass it was seen that some patients had more than 50 entries for some types of questionnaire and that would have made the table unreadable and unpractical. To overcome this problem it was decided to organize the questionnaires part as follow, for each type is introduced:

- Total number;
- Date of the first questionnaire;
- First Result;
- Date of a compilation at +3 (where +3 means that the questionnaire we are considering has been filled between 2 and 4 months from the first one and we're considering the closest one to 90 days later);
- Score at +3;
- Date of a compilation at +6 (where +6 means that the questionnaire we are considering has been filled between 5 and 7 months from the first one and we're considering the closest one to 180 days later);
- Score at +6;
- Date of a compilation at +12 (where +3 means that the questionnaire we are considering has been filled between 2 and 4 months from the first one and we're considering the closest one to one year later);
- Score at +12.

If a patient didn't compile a questionnaire of that type after 3, 6, 12 months the fields remain empty. Furthermore, the satisfaction questionnaire has also been included, dividing it in 8 columns, each of them referring to a question.

The Data Export can be considered continuous because whenever physicians decides to export those information, they can go to the Export data section and wait for the analysis and extraction, that will be done on the data present in that moment on the database.

Since this is a relatively large data export that involved practically almost the entire database, it was necessary to find a solution that would not make the data loading excessively long. Two different APIs have been developed for the collection of data, one retrieves and deals with personal and clinical data, while the other one is specific for the aggregation of data concerning the questionnaires. The first is useful to be reused in possible future extractions, in combination with additional data aggregation when patient's variables are needed.

The client calls the first API, mapped at *host + "private/doctor/get-all-patients-data"*, on entering on the Data Export section, that retrieves the needed source related to the patients.

Figure 4.3 shows the actions performed in organizing the resources sent to the Client.

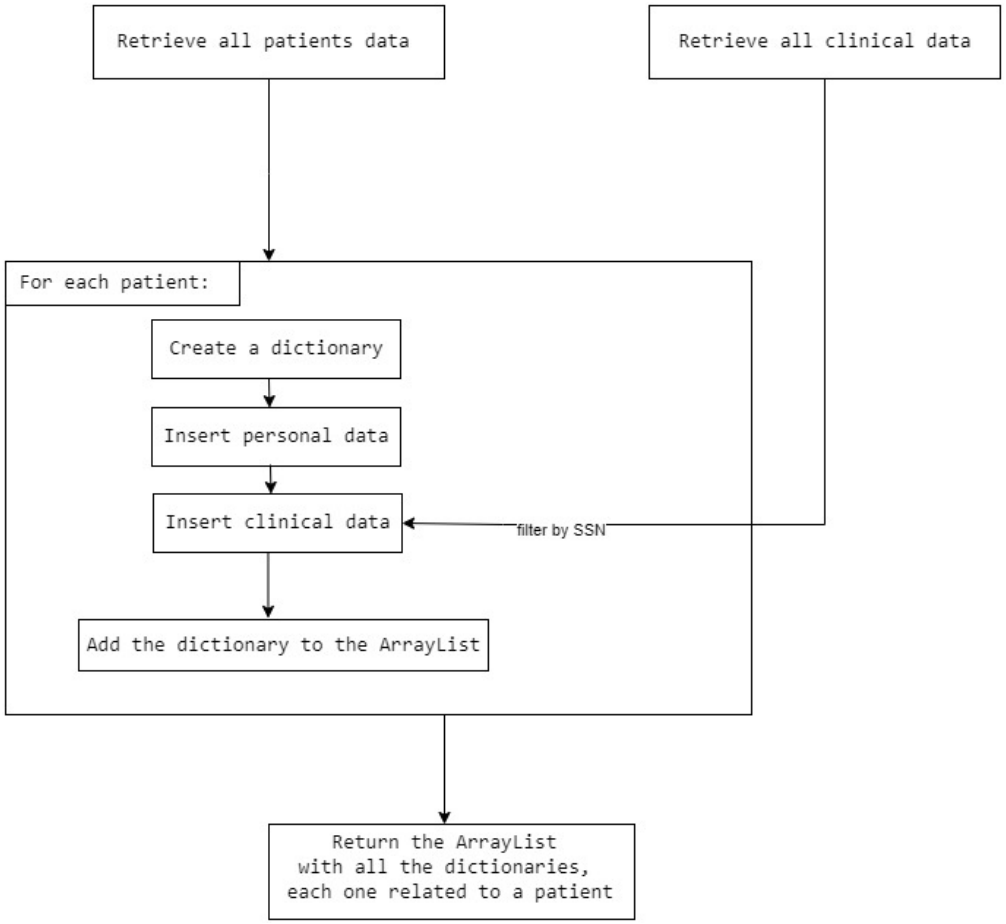

Figure 4.3: Execution flow of Patient Data extraction.

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The second API is mapped at *host + "private/doctor/get-data-analyses"*, its flow is described in Figure 4.4.

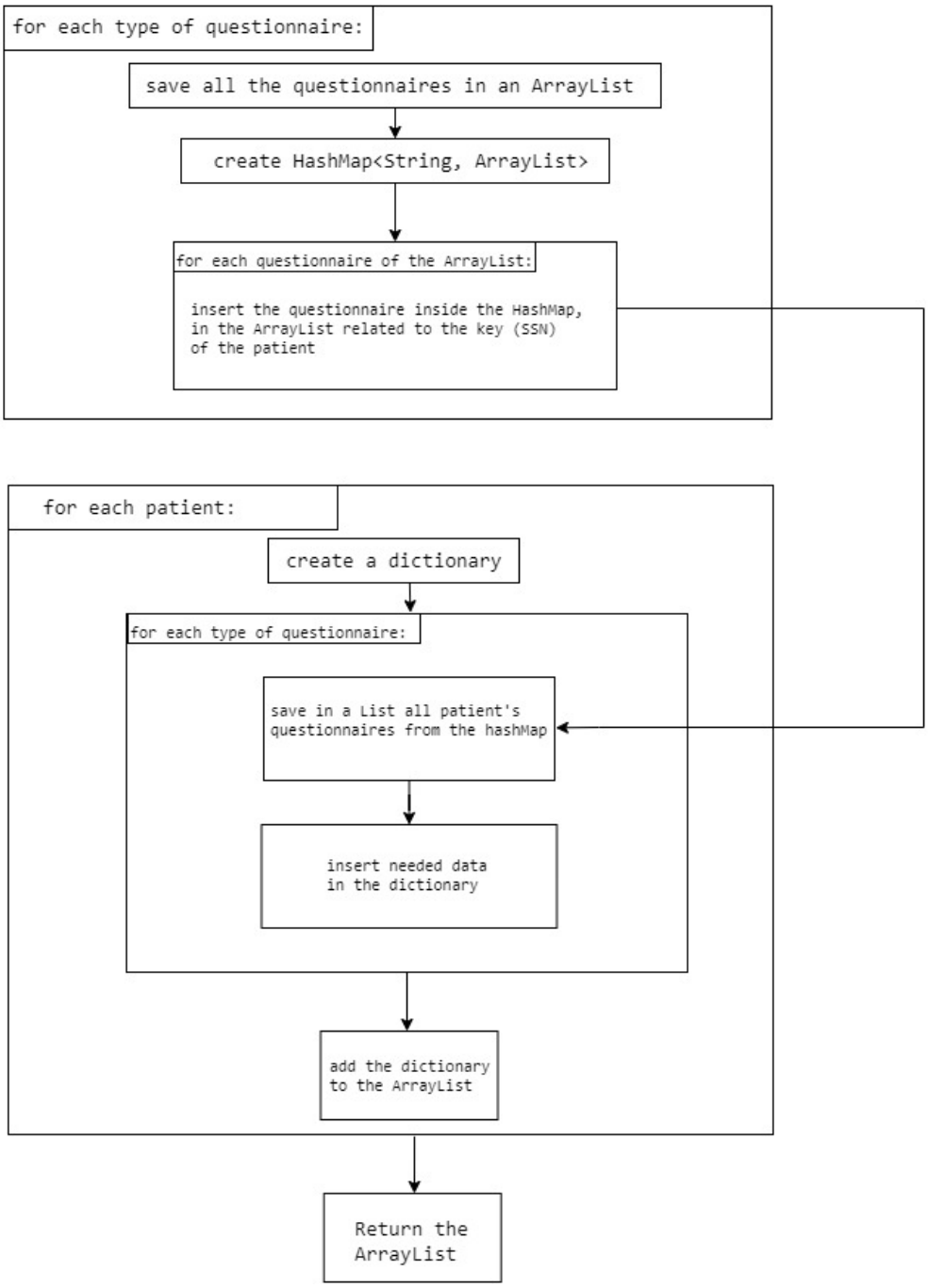

Figure 4.4: Execution flow of Questionnaires Data extraction.

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In the Front-end, to display the data a new component *AnalysesDataComponent*

has been created. It is similar to the other component in the Export Data to maintain theme, consistency and standards in the page, that means a table where each fields of the dictionary is a column and that displays 5 patients at a the time. Under the table there's a button to download the data in a csv format and open it with Excel (Figure 4.5).

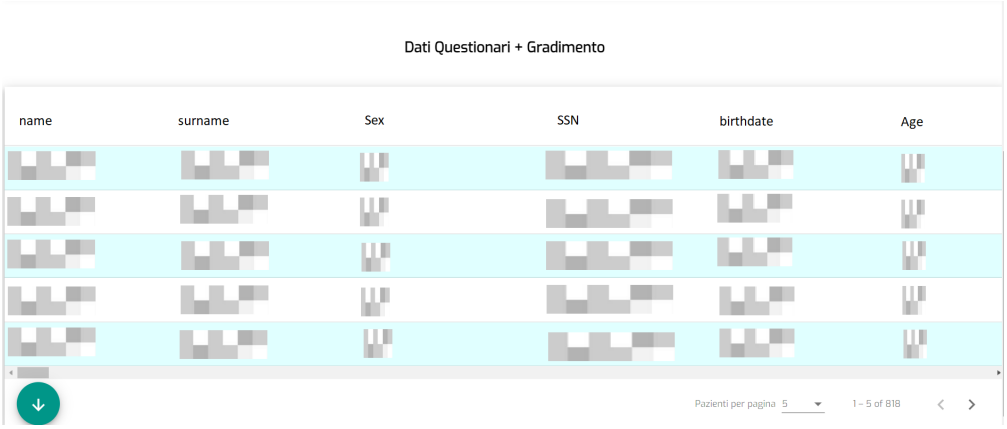

Figure 4.5: Analyses Data Component: new Data Export table.

Figure 4.6 shows a close-up of the columns of the downloaded file that contain information about a type of questionnaires (in this case IBD-Disk).

Num IBD-Disk	data IBD-Disk	IBD-Disk basale	data IBD-Disk +3	IBD-Disk +3	data IBD-Disk +6	IBD-Disk +6
10	2020-08-14	10	2020-12-12	0		
10	2020-08-14	10	2020-12-12	0	2021-03-13	0
10	2020-08-14	50	2020-12-12	10	2021-03-13	60
10	2020-08-14	80	2020-12-12	50	2021-03-13	65
10	2020-08-14	50	2020-12-12	10	2021-03-13	40
10	2020-08-14	50	2020-12-12	25	2021-03-13	13
10	2020-08-14	50	2020-12-12	40	2021-03-13	30
10	2020-08-14	90	2020-12-12	50	2021-03-13	80
10	2020-08-14	50	2020-12-12	15	2021-03-13	15
10	2020-08-14	30				
10	2020-08-14	5				
10	2020-08-14	15	2020-12-12	5	2021-03-13	0
10	2020-08-14	60	2020-12-12	70		
10	2020-08-14	30	2020-12-12	20	2021-03-13	20
10	2020-08-14	20	2020-12-12	5		

Figure 4.6: Example of IBD-Disk questionnaires info in a csv file.

At the end of this work the Data Export is functional and it is possible to obtain the analysis of the data of 825 patients.

4.3 Improvement of the User Experience

User experience is a crucial element for any application. Interfaces should have some characteristics in order to maintain usability and accessibility criteria. One of the results of this thesis work has been the improvement of the user experience and it was done thanks to the addition of visual elements that could give the user a clear idea of what was actually happening inside the application.

Specifically, in order to accomplish this goal some of the *Ten Usability Heuristics* of Nielsen [24] have been considered. These heuristics are ten general principles for user interface design that describe some of the main elements a system should have. In particular, the work done makes the platform more pertinent with principles 1 and 10 : *Visibility of system status* and *Help and documentation.*

4.3.1 Visibility of System Status

This heuristic is about the way an application informs the users about what's happening, since *"the system should always keep users informed about what is going on, through appropriate feedback within reasonable time"* [24].

IBD Tool retrieves a large amount of data from the server and these data are often displayed on the interface of the application, for example in *Application Status* Section, where physicians can access to different charts that show information and comparisons of any kind. In this part of the platform, elements to keep the user informed of what is happening were missing at the beginning of this work: while the graphs were loading, the pages were simply left empty.

The visibility of system status is now improved with various loading spinners (Figure 4.7); in the front-end code related to General Status, for each components different flags are set to *true* or *false* whenever the resources requested to the server are ready or not. The graphs are shown just when data is ready while the user can see the spinners while they are still loading.

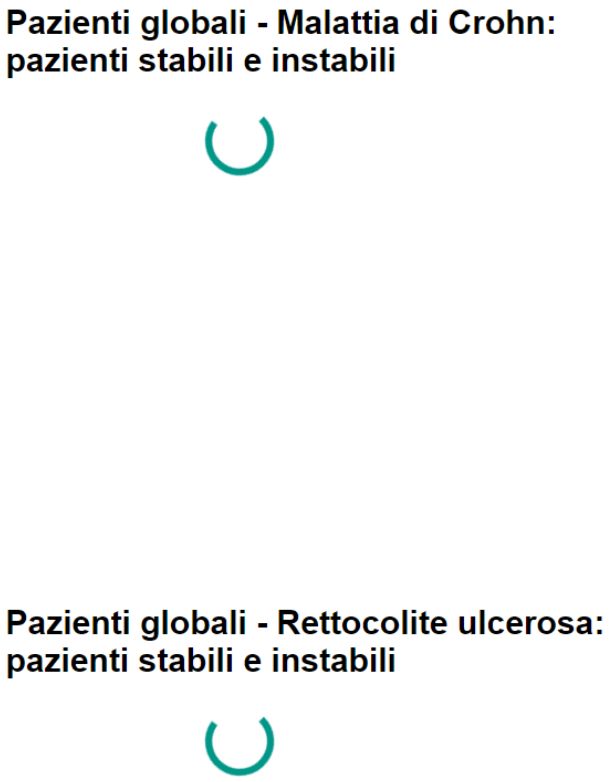

Figure 4.7: IBD Tool: loading spinners before the charts are ready.

4.3.2 Help and documentation

Another element that was considered regarding Nielsen's heuristics is the addition of some details and information in components that could be unclear to the user. Since *"information should be easy to search, focused on the users task"* [24], improvements to the platform to helps users in not-clear situations have been made. Among the charts of the application status, some of them are very specific and the meaning of the fields is system-oriented: for example, the classification of inactive users is made in the following way:

- an user is considered *inactive* if and only if he hasn't logged in 4-6 months (according to his category, *TELEMEDICINA* or *STANDARD*).
- an user that never logged into the system within two weeks from the sign up

date, despite not having any activity on the web-app, doesn't fit in *"inactive"* users but in *"never logged"*.

In the initial state of the application, in the comparison page for active and non-active users, the sum of the two was not equal to the total sum of users actually registered on the platform (Figure 4.8).

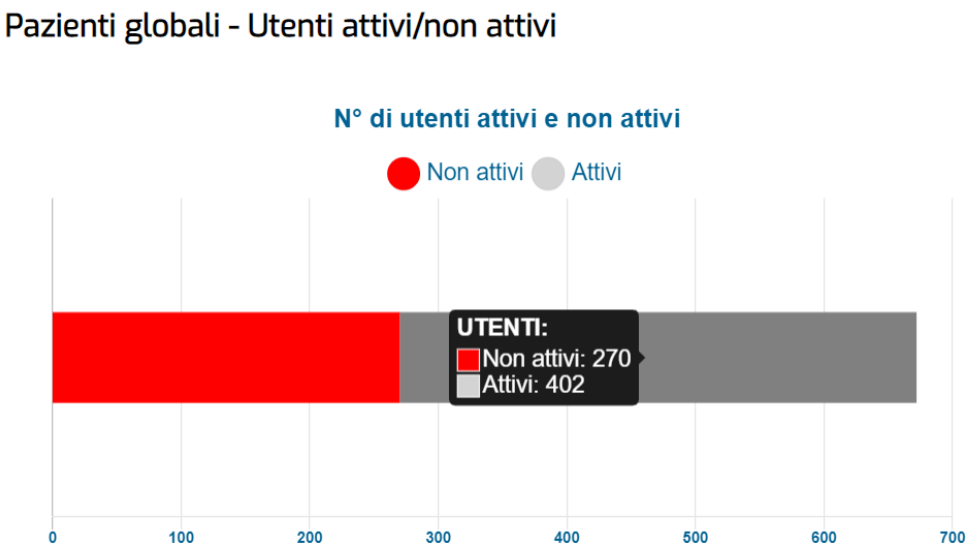

Figure 4.8: Global patients - Active/Inactive users (updated on 30/11/22).

Since the non-specification could lead to confusion even physicians while taking note of IBD Tool statistics, by following the Nelsen's heuristic for which the user must always have everything clear, it was decided to add an info button. While looking the charts, the user could have doubts about the meaning of something and at the click on the button all the relevant information appear.

The click sets a state *"isInfoShowed"* to *true* or *false* and according to it a with the needed info is shown. Figure 4.9 illustrates the update of the component after the click on the button.

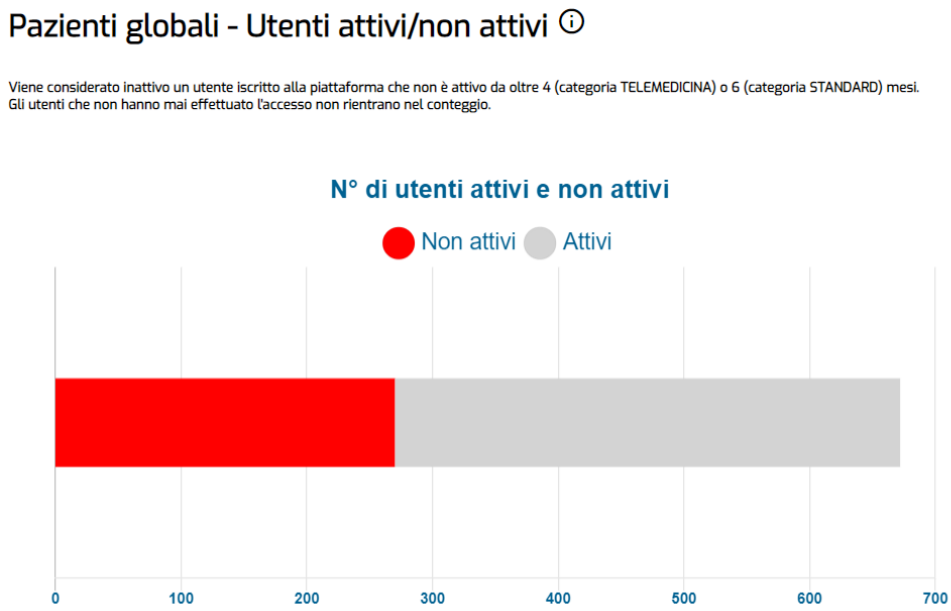

Figure 4.9: Active/Inactive users with info button functionality.

4.4 Further tasks

4.4.1 Increased awareness for patients

Further work was done in response to physicians' request of sending a message to all the patients through emails. The goal was to spread knowledge between patients about the progress made by IBD Tool team in research about the evaluation of the disease and, consequentially, increase awareness towards the web-app. Specifically, physicians requested to inform platform's user about the results of the study on the degree of agreement between patients and doctors, previously mentioned in Section 2.3 (Figure 4.10).

At the current state of the application sending more than 500 emails in a day is not possible from the Gmail Account. For this reason, in order to send the message to each individual patient through email, it was necessary to proceed by writing a specific API, called manually in a local environment, that sent the set message to 50-100 patients at a time. It was decided to send the individual emails and not to include the patient groups in cc, despite the message being the same, because it would have threaten the privacy of individual patients.

This solution wasn't deployed on the remote server, the code used is stored on the *dev* branch of *IBD-Tool-be* and the API must be fetched at *host + "send/emails"*

Although the request has been met, it is not excluded that similar situations

Figure 4.10: Message to patients about IBD Tool's work.

can occur again in the future. It will be necessary to develop a new service focused on sending 50 emails for day to a sub-group of patients or to upgrade the Gmail Account in order to send more than 500 emails daily.

4.4.2 News Section extended

The News Section, previously available only for patients in Telemedicine category and for physicians, is now added for Standard patients too. Doctors' need to be able to send news (such as the publication of research results), combined with the impossibility to send emails to all 825 patients, led to the decision to extend the alerts section to all patients.

While at the initial state of the work the homepage of standard and telemedicine patients' differ from the presence of this feature, now they are equal, as illustrated on Figure 4.11.

This introduction meets halfway the need to alert all the users of the platform at the same time, even if for the moment it is not possible to send 825 emails on the same day.

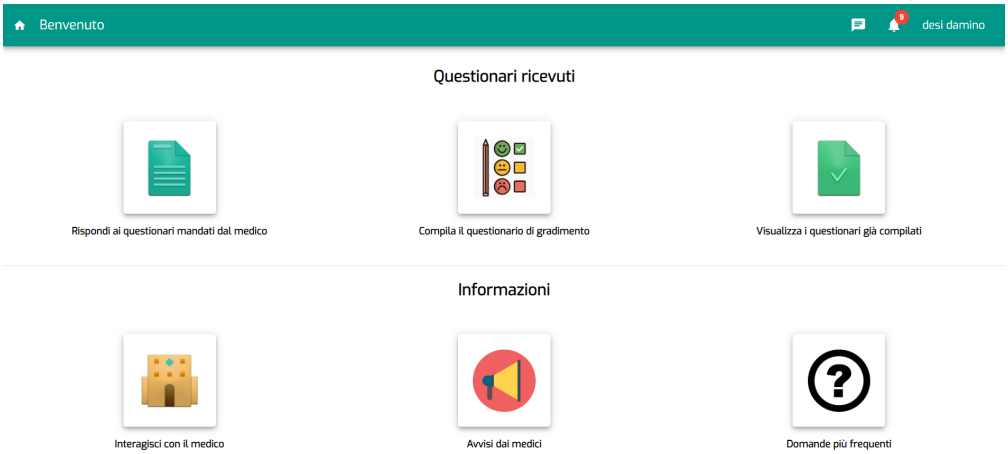

Figure 4.11: IBD Tool: patients' homepage with News Section.

Figure 4.12: IBD Tool: patients News Section.

Chapter 5

Conclusions

IBD Tool is a stable platform actively used by physicians to interact with IBDs patients of the Mauriziano Hospital of Turin. In the current state there are 838 users, of which 825 are patients (Figure 5.1), with the following division:

- 53% suffering from CD;
- 45% suffering from UC;
- 2% others.

Patologia	Numero di pazienti
Malattia di Crohn	437
Rettocolite Ulcerosa	373
Altro	15
Total	825

Figure 5.1: IBD Tool: global patients (updated on 12/11/22).

The 67.4% of the patient is active on the platform.

This work restored the Mail Service successfully: the Gmail Account sends about 200 emails daily to notify patients that new questionnaires are available and physicians are advised with updates of compiled questionnaires, with a total of more than 40.000 emails sent from the beginning of the project.

Thanks to the Satisfaction Questionnaire inserted in previous releases, it's possible to state that the application is accepted, appreciated by users and easy to use.

The results of this work allow an additional direct communication between clinicians and patients, since news of known importance can be communicated to all users easily at the same time.

The data analysis sections, as demonstrated by the research made by the *IBD Tool* team on the agreement study, can give a meaningful support to understand the evolution and the perception of the disease: the data export function included in this work will allow researchers and physicians to analyze all the possible inferences and to study the development of the pathologies. The intersection with the scores of the Satisfaction Questionnaire will also permit to understand further correlations with the appreciation of the web-app. The improvement of User Experience for the physicians will also help to better enhance the usability while collecting the data.

The results obtained since the beginning of the project prove the use of Telemedicine is functional: although it is not possible to replace face-to-face care, *IBD Tool* has shown on how it is useful for patients to be followed remotely.

As for future developments, it is certain that the application will integrate new features that may emerge from the needs of physicians and patients. First of all, the implementation of a service that will allow to notify at the same time all the users (maybe through emails with an upgrade of the Gmail Account or through the development of a Telegram channel). By continuing to invest in projects of this type, there will certainly be further developments for Telemedicine in Italy.

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