University of Reading

Department of Computer Science

An AI-assisted decision making system for thyroid nodule classification

Stefanos Stefanou

Supervisor: Huizhi Liang

A report submitted in partial fulfilment of the requirements of
the University of Reading for the degree of
Bachelor of Science in *Computer Science*

April, 2021

Declaration

I, Stefanos Stefanou, of the Department of Computer Science, University of Reading, confirm that all the sentences, figures, tables, equations, code snippets, artworks, and illustrations in this report are original and have not been taken from any other person's work, except where the works of others have been explicitly acknowledged, quoted, and referenced. I understand that if failing to do so will be considered a case of plagiarism. Plagiarism is a form of academic misconduct and will be penalised accordingly.

Stefanos Stefanou
April, 2021

Abstract

Deep learning has found numerous applications in the health care community. Recently, a massive explosion of research on the relevant field, driven by large amounts of available data, has generated important disease prevention and identification results. Fine Needle Aspiration (FNA) is the dominant procedure for thyroid nodule classification. FNA has associated risks and expenses, and in this project, we will try to reduce both using the recent advancements in Artificial Intelligence and Deep Learning. Our primary goal is to bring closer the radiologists 'on the field' with those complex algorithms and provide value to real patients by providing an interface, in the form of a web application, for probabilistically predicting the severity and the category of a given module.

Contents

Acknowledgments

Acknowledgments section is optional. You may like to acknowledge the support and help of your supervisor(s), friend(s), or any other person(s), department(s), institute(s).

Chapter 1

Introduction

Deep learning has found numerous applications in the health care community. Recently, a massive explosion of research on the relevant field, driven by large amounts of available data, has generated important disease prevention and identification results.[Eun Ju Ha (2021)]

The Dominant process for thyroid nodule identification and classification is called FNA (or Fine Needle Aspiration/Biopsy). FNA is an expensive process requiring expensive lab equipment and specialized personnel.[*Fine Needle Aspiration Biopsy of Thyroid Nodules* (2019)]

There is no way to determine the category of a thyroid nodule apart from performing FNA on a sample. Our vision is to create an application to act as a bridge between the academic community working on theoretical Deep Learning models to predict a nodule's category and the radiologists working with actual patients and accurate data. Our hope is that by establishing a common language(the application) we will improve the research process as experimental models will work on accurate nodule scans, providing instant feedback to the researchers for further analysis.

Our system needs to be as generic as possible to support any prediction model, reliable, easy to maintain, and expand. It needs to be optimized to handle the Deep Learning models and finally needs to be as secure as possible because it will eventually work with actual patients on sensitive data.

Abbreviations

FNA(Fine Needle Aspiration), AI(Artificial Intelligence), DP(Deep Learning)

Keywords

FNA, AI, DP

Chapter 2

Literature Review

2.1 Introduction

This section will note the essential sources needed to be studied and to be revised to complete this project. The sources are carefully selected to include theoretical, practical, and best practices knowledge in order to cover the wide variety of topics needed to fulfill the requirements of this project.

2.2 Brief Table of books

ISBN	Name	Type
N/A	ST1PS-18-9A: Probability and Statistics (2018/19)	Module Lectures
9780030105678	Linear Algebra and Its Applications	Book
9780131687288	Digital Image Processing	Book
9780262035613	Deep Learning	Book
9780128104088	Deep Learning for Medical Image Analysis	Book
9781491962244	Hands-on machine learning with scikit-learn and tensorflow	Book

2.3 Brief Table of papers

- Ye, H., Hang, J., Chen, X. et al. An intelligent platform for ultrasound diagnosis of thyroid nodules. Sci Rep 10, 13223 (2020). https://doi.org/10.1038/s41598-020-70159-y

- Nguyen DT, Pham TD, Batchuluun G, Yoon HS, Park KR. Artificial Intelligence-Based Thyroid Nodule Classification Using Information from Spatial and Frequency Domains. J Clin Med. 2019;8(11):1976. Published 2019 Nov 14. doi:10.3390/jcm8111976

- Manivannan T, Ayyappan N. Classification of thyroid nodules using ultrasound images. Bioinformation. 2020;16(2):145-148. Published 2020 Feb 29. doi:10.6026/97320630016145

- Nguyen DT, Kang JK, Pham TD, Batchuluun G, Park KR. Ultrasound Image-Based Diagnosis of Malignant Thyroid Nodule Using Artificial Intelligence. Sensors (Basel). 2020;20(7):1822. Published 2020 Mar 25. doi:10.3390/s20071822

- Chen J, You H, Li K. A review of thyroid gland segmentation and thyroid nodule segmentation methods for medical ultrasound images. Comput Methods Programs

Biomed. 2020 Mar;185:105329. doi: 10.1016/j.cmpb.2020.105329. Epub 2020 Jan 9. PMID: 31955006.

- Ha EJ, Baek JH. Applications of machine learning and deep learning to thyroid imaging: where do we stand? Ultrasonography. 2021 Jan;40(1):23-29. doi: 10.14366/usg.20068. Epub 2020 Jul 3. PMID: 32660203; PMCID: PMC7758100.

Chapter 3

Requirement Analysis

3.1 Introduction

Before we even start exploring this project and its features, it is essential to define the requirements that need to be fulfilled strictly and this project's scope. Failing to perform a requirement analysis beforehand puts additional and unnecessary risks to the project due to the project's unspecified and volatile scope and target set.

3.2 Functional Requirements

Functional requirements define the basic system behavior. We define the functional requirements as follows.

- User needs to log in with a personal password.

- User needs to be able to create a new patient record

- User needs to be able to upload a new ultrasound scan image associated with a given patient

- User needs to be able to see its associated patients

- User needs to be able to see its uploaded ultrasound images

- User needs to be able to search for a specific patient

- User needs to be able to see a list of all ultrasound images for a specific patient

- User needs to be able to see the details of a specific patient

- User needs to be able to see the details of a specific submitted scan, as well as the prediction results if available.

- User should be notified if the prediction results are ready

Those requirements can be easily visualized in a Use Case Diagram, given below.

Figure 3.1: Use Case Diagram
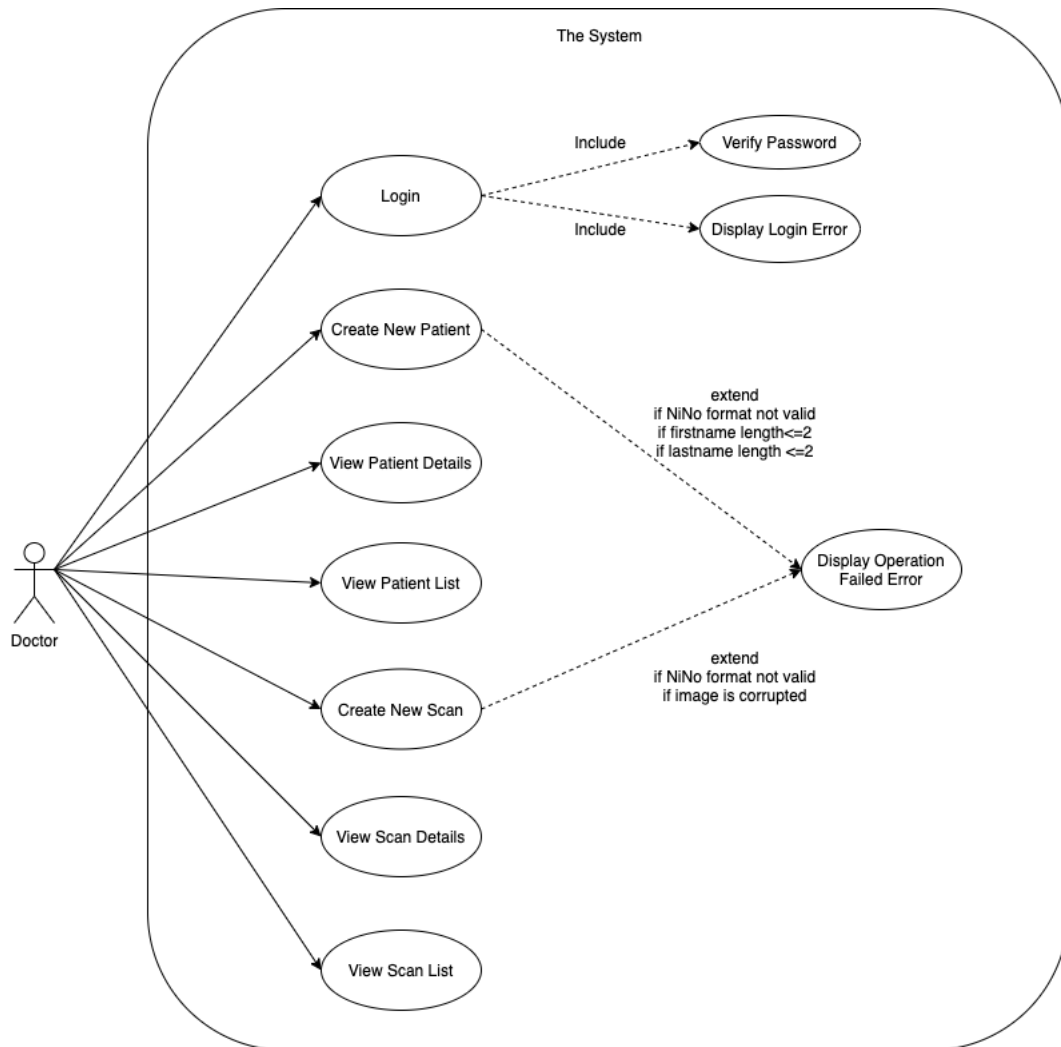
3.3   Non Functional Requirements

Nonfunctional requirements are the properties of the system; an comprehensive list of the agreed nonfuctional requirements is given below

- The system must be secure, as it handles the personal information of the patients

- The system should be reliable, as downtimes are affecting the hospital's performance

- The system should be able to complete a prediction scan in a reasonable amount of time(1-10 mins)

Chapter 4

Entity Relation Analysis

4.1 Introduction

After the requirements have been set. We need to translate them into workable relational entities in order to be able to modeled through a classical relational database system (RDBMS).

4.2 Entities

We will start our exploration by defining our entities for this project.

4.2.1 Scan

A scan is the result of an ultrasound scan performed in a specific patient(see [4.2.2)]. A scan entity has certain attributes

Image	The image produced by the ultrasound scan. 360x560 pixels
Prediction	The result of the prediction algorithm. Acceptable Values = Maligrant, Benign
Results	The logs of the algorithm performed the prediction, Optional
Algorithm	The algorithm used to perform the prediction. Acceptable Values = SVC,RES
Token	The scan identifier across the application services. token type is UUID [Leach (2005)]

4.2.2 Patient

A patient is a physical person that is suspected to have a thuroid nodule. A person may have 0 up to n scans, where n is the theoretical maximum number of records(no limit is enforced by the database or the application). A patient has characteristics explained below

First Name	The first name of the patient.
Last Name	The last name of the patient
NiNo	The National Insurance Number(NiNo) of the patient
Enrolled Date	The Date that the patient was registered in the system
Ascosiate Doctor	The Doctor identification number, handling the case of the patient(see 4.2.3)
Comments	The Doctors(see 4.2.3) comments for the particular patient

4.2.3   Doctor

A doctor is a physical person with access on the system. Is the end-user of the system and has rights of uploading ultrasound image scans and retrieve predictions for those scans. It can also provide feedback to the system for a given prediction to be used for further research and develepoment. A doctor has specific characteristics presented below.

Username	Plain-text username
Password	MD5 Hashed[Rivest (1992)] and salted[Manber (1996)] password
First Name	National Insurance Number[*National Insurance Manual* (2021)]
Last Name	The date that the patient was registered in the system
Title	The title of the doctor.
Enrolled Date	The date and time of the user enrolled to the system
Last Seen	The date and time of last login of the user
Online Status	The status of the user, acceptable values are Connected,Not Connected
Tasks	The number of scans uploaded by the user

4.2.4   Notification

A notification is a short message from the system to the end-user(The doctor). Its sole purpose is to inform the user about various events that may interest the end-user. An example of this may be that the scan results for a given scan task are ready to view. A notification has specific characteristics witch are displayed and explained below.

|	
Message	The message in question
Ascosiated Doctor	The receipient doctor identification number
Created Date	The Date and Time where the event in question where happened

4.3   Entity Relations

The aforementioned entities have well defined relations. An exhaustive list is given below

- A doctor has many patients (1 - ∞)

- A doctor has many notifications(1 - ∞)

- A Patient has many Scans(1 - ∞)

A above relations can be summarized in the following E-R[1] Diagram

Figure 4.1: Entity-Relation Diagram
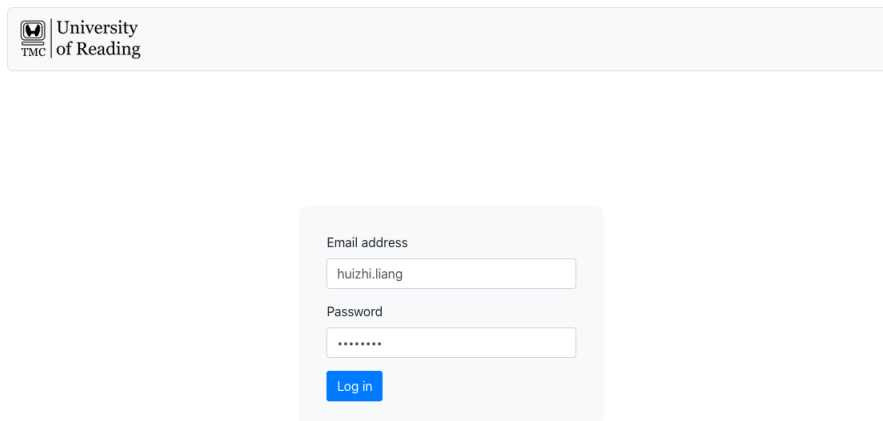

---
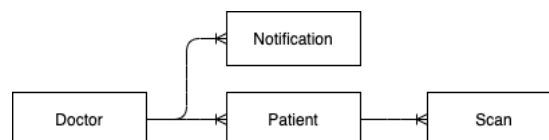
[1]Entity-Relation

Chapter 5

Users Perspective

5.1 Introduction

In this section, we will start our exploration of the application and its features. As the nature of the requirements of this the system is complicated. Unavoidably the system will be complex as well. Taking this into consideration, we will follow a natural top-to-bottom approach explaining its internals, starting as end-users and seeing the system as a black box. In this section, we will analyze its functionality from the user's perspective. This section may also serve as an instruction manual for the end-user as it contains everything needed for an inexperienced user to start working with the software.

## 5.2 Login and Authentication

Figure 5.1: Login Screen

The login screen is the first screen that our end-users will encounter. Here a username and a password is required to be given by the user to log in. The Credentials of the user remain encrypted during the process of login, as the system utilizes an HTTPS[Rescorla (2000)] protocol for its connection, this is essential for the first non-functional requirement about security (see 3.3). The username and the password may be requested by the system administrator or the NOC[1] of the hospital.

---

[1]Network Operations Center

5.3   Home

Figure 5.2: Home Screen
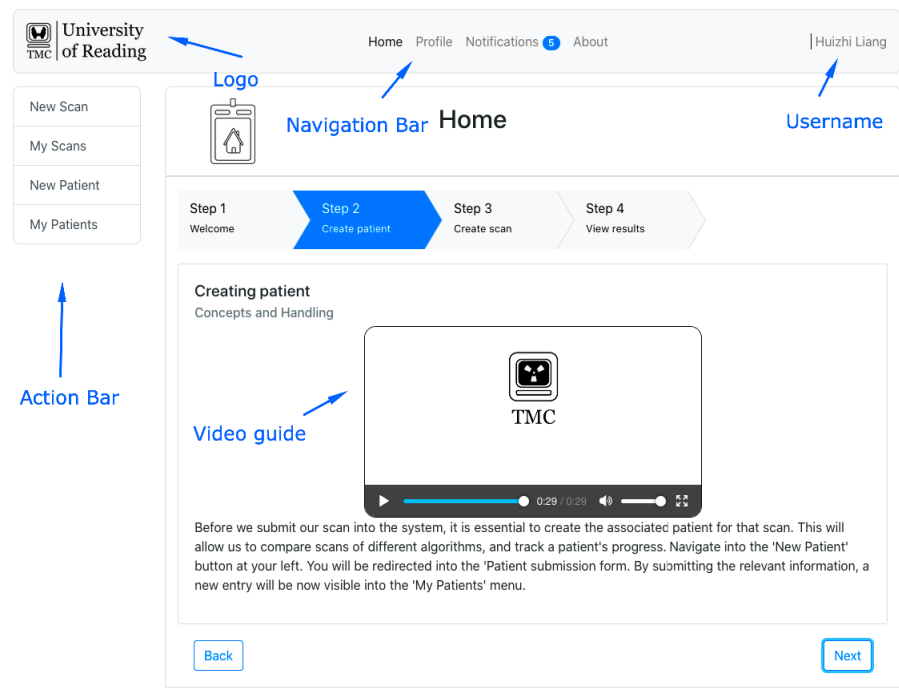
After the login process is completed. The user encounters the 'home screen. From here, it is possible to navigate to the features of the software as well as learn about how the software can be utilized through detailed guides and videos. The UI/UX[2] has been designed to be as user-friendly as possible. Some areas of interest are given below.

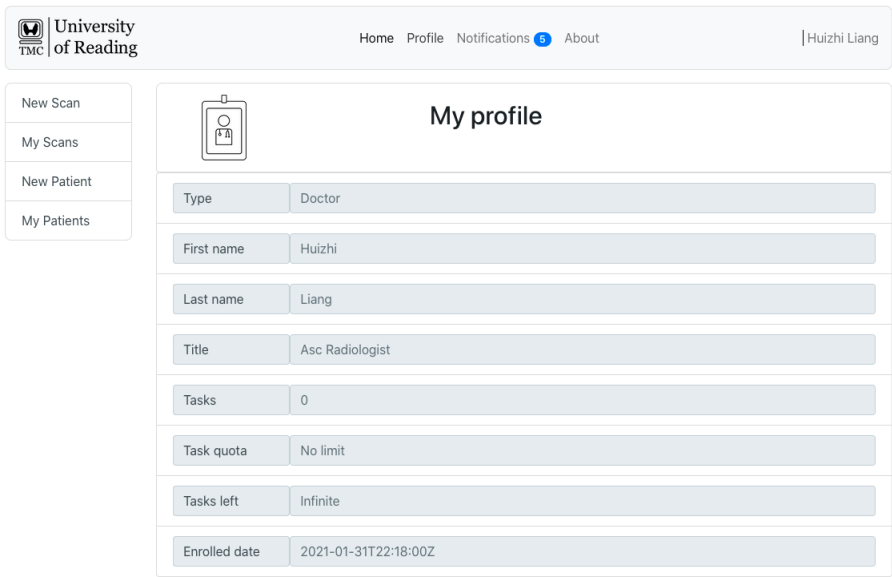| Action bar	The Actions that can be performed using the software can be accesed from here.
Navigation bar	General information and notification bar.

5.4   Navigation bar

In this section, we will briefly look at the options under the Navigation bar.

---

[2]User Interface-User Expieriance

5.4.1 Profile

Figure 5.3: Profile

In the profile section, the user can see its associated information, saved on the registration date. The information for security reasons cannot be altered by the user itself, but only after a request to the system administrator or NOC[3].

5.4.2 Notifications

Figure 5.4: Notifications
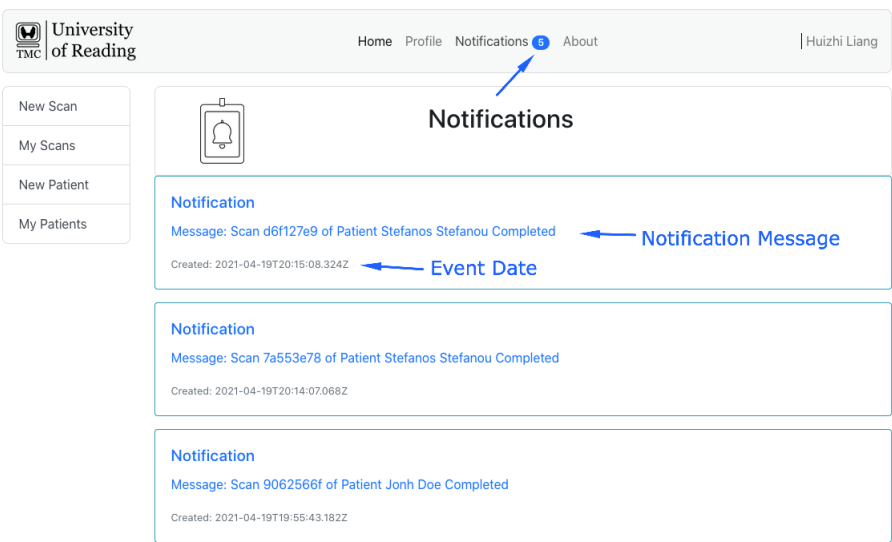
In the notification section, helpful information about events that may interest the end-user can be found, such as the fact that uploaded scan results are ready to view.

---

[3]Network Operations Center

5.4.3 About

Figure 5.5: About

From here, a user may found helpful information about the software, such as the current version.

5.5 Action Bar

In this section, we will briefly look at the options under the Action Bar.

5.5.1 My Patients

Figure 5.6: Patients List

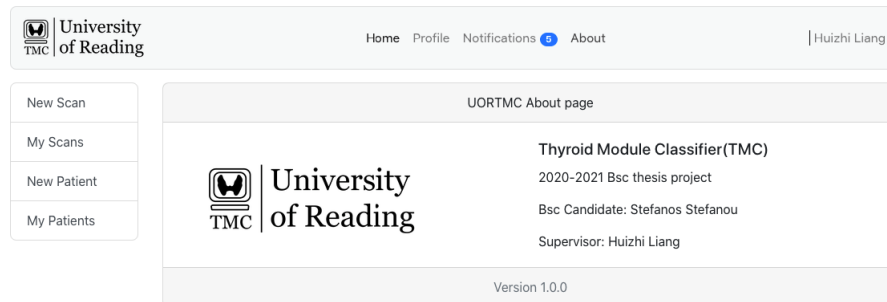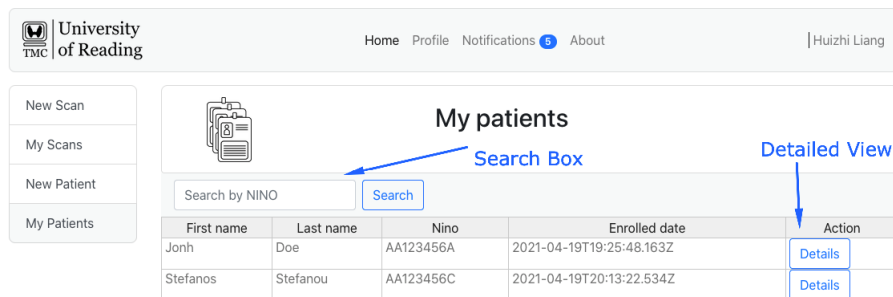This page will show us a list of the currently registered patients. Each end-user(doctor) may only see its patients and not others. The end-user can search the list based on NiNo[*National Insurance Manual* (2021)] of the given patient for convenience. The end-user can also view the details of a given patient and record various notes/comments for that patient by clicking the 'Details' button on his selected patient, as seen below. Finally, clicking the button 'View Scans' can see the specific patient history of uploaded scans.

Figure 5.7: Patient Details

5.5.2   New Patient

Figure 5.8: New Patient

By clicking the 'New Patient' action on Action Bar, the user can register a new patient on the system. The following conditions need to be met for the operation to be successful.

- First name length should be more than 2 characters, encoded as UTF-8[Yergeau (2003)]

- Last name length should be more than 2 characters, encoded as UTF-8[Yergeau (2003)]

- NiNo should be at standard format [*National Insurance Manual* (2021)], encoded as UTF-8[Yergeau (2003)]

Failing to fulfill these constraints should lead to an error, as shown below.

Figure 5.9: New Patient Error

5.5.3   My Scans

Figure 5.10: My Scans

'MyScans' are a complete list with all submitted scans for a given end-user. The user can search for the scans of a specific patient by using the search box and viewing the scan results (if a given scan is complete) by clicking the 'Details' button of the scan in question.

Figure 5.11: Scan results

5.5.4 New Scan

Figure 5.12: New Scan

By clicking the 'New Scan' action, the user is redirected into the scan submission form. Here it is possible to submit a new ultrasound image for a given patient. The user can also select the algorithm for performing the classification (see 12). The operation to be completed should meet the following criteria.

- Patients Nino should be in standard format[*National Insurance Manual* (2021)] and encoded as UTF-8[Yergeau (2003)]

- Scan Image should be a ISO/IEC 10918-1/JPEG[International Organization for Standardization (1994)] format with 360x560 resolution. The image name should be encoded as UTF-8[Yergeau (2003)]

Failing to fulfill these constraints should lead to an error, as shown below.

Figure 5.13: Invalig image format (PNG) error

Chapter 6

System Architecture

In this chapter, we will introduce the architecture of our system, explaining the essential elements that it is composed of and their interactions.

6.1 Overview

In the section 3.3 we discussed the non-functional requirements of this application. Two of the most important ones were security and performance. These requirements heavily influenced the design decisions of this project, leading to the microservice-inspired architecture [Newman (2020)]shown below.

Figure 6.1: Simplified Architectural Diagram
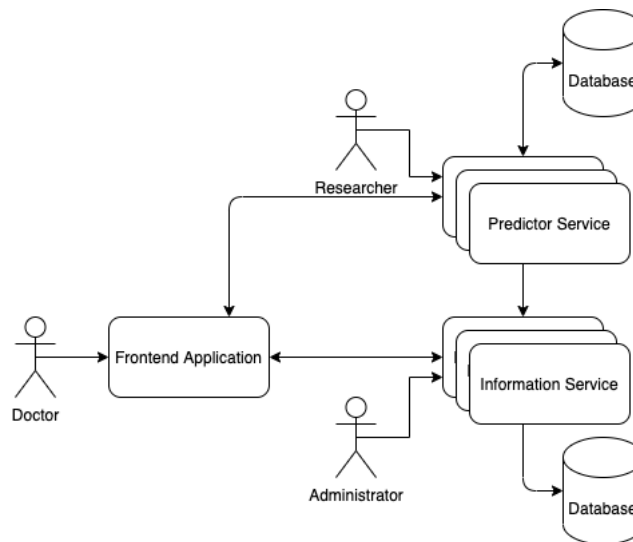
Microservice pattern[Newman (2020)] tries to decrease complexity and increase safety by splitting the internal logic of a system into several components called 'Microservices'. Each microservice is essentially a server that handles a small portion of the systems logic. As opposed to the monolithic services, microservices have a number of advantages that made them ideal for the requirements of this project such as.

- Highly maintainable and testable code

- Loosely coupled logic

- Independently deployable services

- No single point of failure

- Flexible scaleability factor

- Enchanced security

6.1.1   Maintainability

By implementing our system using microservices[Newman (2020)], we effectively separate the complex logic of our system into different services. This separation of complexity leads to several elementary and easily testable and maintainable entities. This brings down the maintenance costs.

6.1.2   Loosely coupled logic

Microservices ideally are loosely coupled. That means that changes tend to remain local to one microservice and do not span multiple ones. In case that the requirements change and new features are needed, the features will not affect a significant part of the code. This translates more negligible probability of occurring bugs and errors.

6.1.3   Indepedently deployable services

Using microservices gives us the advantage of deploying changes independently on the system, only on services that we need. This translates to fewer downtimes due to maintenance. An example of this will be a potential deployment of a new algorithm on the Prediction service. During the deployment of the new version of the Prediction service the system will be unable to perform predictions, but the rest of the functionality will be unaffected as it lies under a different microservice. With a monolith approach(all functionality in a single service), this would not be possible.

6.1.4   No single point of failure

Using microservices, we ensure that it will not propagate to the whole system when a failure occurs. In the hypothetical scenario of a failure in the Prediction service, the rest of the system's functionality will remain intact during the incident. This scenario with a monolithic architecture will bring the whole application into an unusable state.

6.1.5   Flexible scaleability factor

This is not sorely a feature of microservices but a combined feature brought by some additional design choices from within the code itself. Both of the services are implemented using the actor model [Hewitt (2015)]. The actor model allows, in combination with the microservice model, our services to act as a distributed system with multiple nodes; this allows us to scale different services when demand changes dynamically and automatically, ensuring the performance non-functional requirement we set back in 3.3. An example of this can be when multiple users simultaneously use the most advanced and CPU-Intensive algorithm, the ResNet(see 12). If the system determines that the load is beyond some threshold, it can spin multiple instances of the same service. The instances will coordinate themselfs automatically and split the work that needs to be done into equal amounts, reducing the response time. This is implemented using the Heroku-autoscale feature and will be discussed in chapter 11

6.1.6 Enchanced security

Having multiple and distinct microservice enhances security, as the malicious compromise of one microservice does not imply the compromise of the whole system. In the hypothetical scenario of a malicious attacker may breach the Prediction Service, then the data of the Prediction Service will be at risk, but not the data from the Information System and vice versa.

6.2 Frontend Web App

The Frontend component has the responsibility of being the edge in our system.

Figure 6.2: Frontend Application
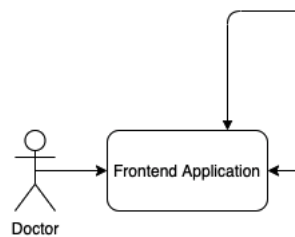
Every action from our end-users, will be channeled through the frontend application. Our frontend is a web-based application(for more information please see 9) and handles the application infastructure via a well designed stateful[Barth (2011)], Json-based[T. Bray (2014)] Https[Rescorla (2000)] RESTFull[R. Fielding (2014)] protocol (for more information please see chapter 10).

6.3 Backend

The backend services are the backbone of our application. They handle all the logic behind the application, from the saving and retrieval of patients, scans, images, and notifications, to the prediction and classification of the ultrasound images. There are two services with distinct areas of interest and different purposes, the Information Backend(also known as 'Information Service' to the simplified diagrams) and Task Backend(Also known as Predictor Service).

6.3.1 Information Backend

Figure 6.3: Information Service
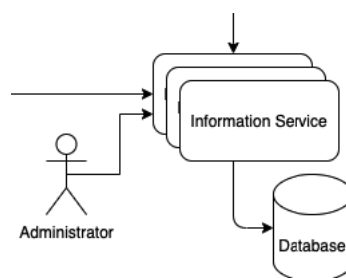
The Information Backend has the responsibility to perform all the logic apart from the prediction itself. It includes the functionality of keeping the associations of Patients, Scans, and the information composing those entities. It also includes the notification system and authentication services. Finally, it includes a small application for use by the NOC[1] for administrator purposes.

6.3.2   Task Backend

Figure 6.4: Predictor Service
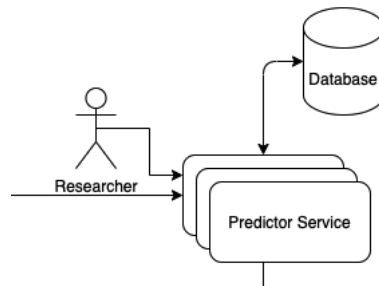
The Task Backend has the responsibility of performing the predictions based on the received ultrasound scan images. After completing a prediction, Task Backend should communicate with Information Backend to inform the user about the completion of the scan. Finally, it includes a small application for use by the researcher to gather the data and the feedback from the end-users.

---

[1]Network operations center

Chapter 7

The Administrators Perspective

7.1 Introduction

In this section, we will briefly go through the application interface for the administrator of the system. The administrator of the system has special rights and is assigned by the hospital that uses the software. It needs to belong to the NOC[1] of the hospital, and it is responsible for the maintenance of the software in the DevOps Level.

Figure 7.1: Information Service
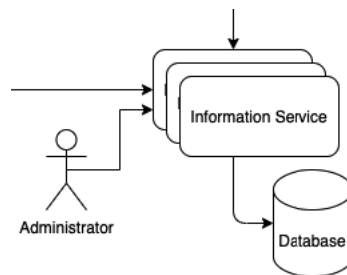
7.2 Administrator Panel

The administrator has special tools for maintaining the system and intervene in its internals, a special administrator panel that gives access to a plethora of features that needs to be handled with care.

> **Note 1.** *To connect to the administrator panel, we need to connect to the following addresses*
>
> *(if online) https://uortmc-infobe.herokuapp.com/admin/*
> *(local machine)http://127.0.0.1:3001/admin*
>
> *Please refer to the chapter 13 and chapter 14 for more details around how to connect.*

---

[1]Network Operations Center

7.2.1 Admin Panel Login

Figure 7.2: Administrator Panel
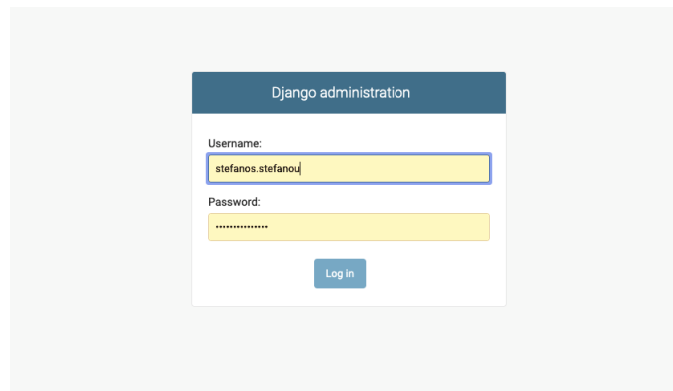
The login screen is the first screen that an admin should encounter. The information transmitted into the Information Service is encrypted using HHTPS[Rescorla (2000)] and transformed to an salted[Manber (1996)] MD5 Hash[Rivest (1992)] for maximum possible security.

7.2.2 Admin Panel Features

Figure 7.3: Administrator Panel-Home
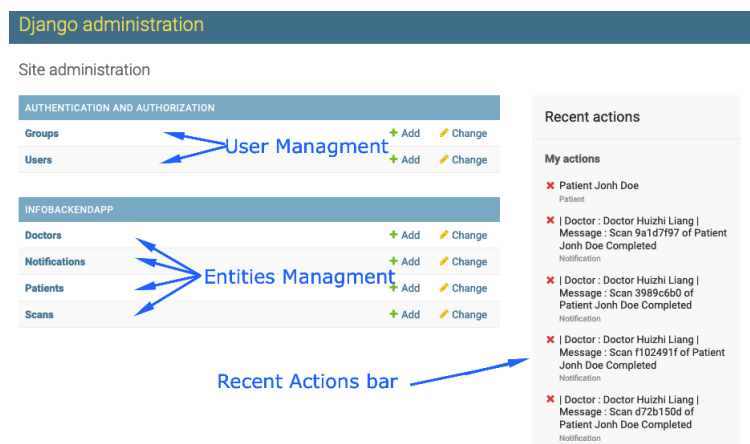
After the login sequence is completed, the administrator will be redirected to the panel's home page; there, it has available all the functionality needed to perform changes on the system. An administrator has the right to alter the system's properties as well as the entity's attributes. We can add, alter and delete entities at will, using the Entities Management.

Figure 7.4: Example deletion of a scan

Figure 7.5: Example alteration of a patient

Chapter 8

The Researchers Perspective

8.1 Introduction

In this section, we will briefly look at the available features for the researcher of the project. Every scientist working in prediction models for thyroid nodule classification may upload its algorithm on the platform and receive helpful feedback about its performance using the Researcher panel explained below. Visually the researcher's panel is nearly identical to the administrator panel explained in chapter 7 but offers access to the different data than the administrator panel. This is done to reduce costs and reuse the similar functionality developed for the administrator panel. The researcher panel is provided by the Predictor Service(Task Backend).

Figure 8.1: Predictor Service
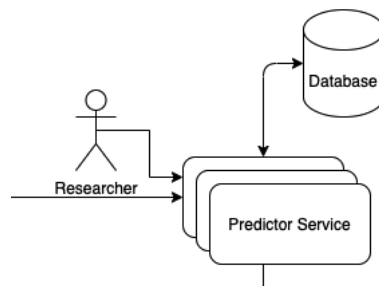
8.2 Researcher Panel

The researcher panel provides an interface to the researcher to view its algorithm outputs and performance in an easy and user-friendly manner.

Note 2. *To connect to the researcher panel, we need to connect to the following addresses*

(if online) https://uortmc-taskbe.herokuapp.com/admin/
(local machine)http://127.0.0.1:3002/admin

Please refer to the chapter 13 and chapter 14 for more details around how to connect.

8.2.1   Login screen

Figure 8.2: Researcher panel login screen
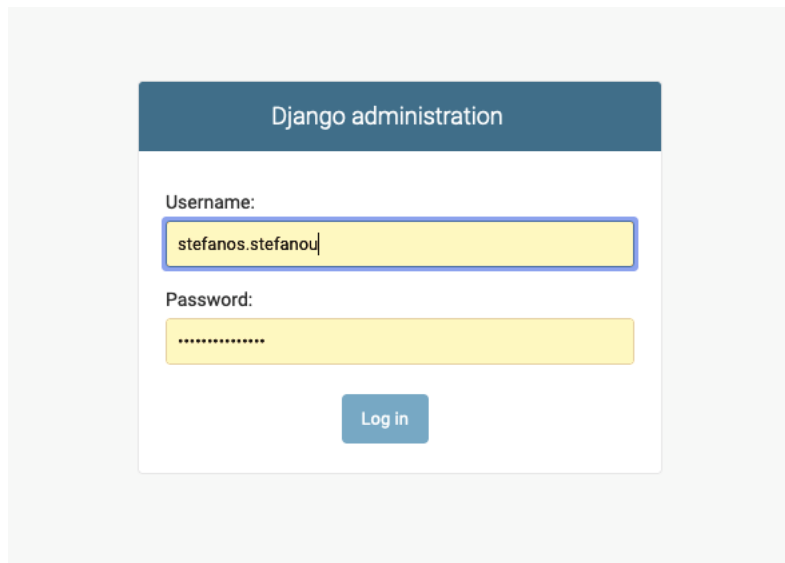
The login screen is the first screen that an researcher should encounter. The information transmitted into the Predictor Service is encrypted using HHTPS[Rescorla (2000)] and transformed to an salted[Manber (1996)] MD5 Hash[Rivest (1992)] for maximum possible security.

8.2.2   Researcher Panel Features

Figure 8.3: Researcher Panel-Home
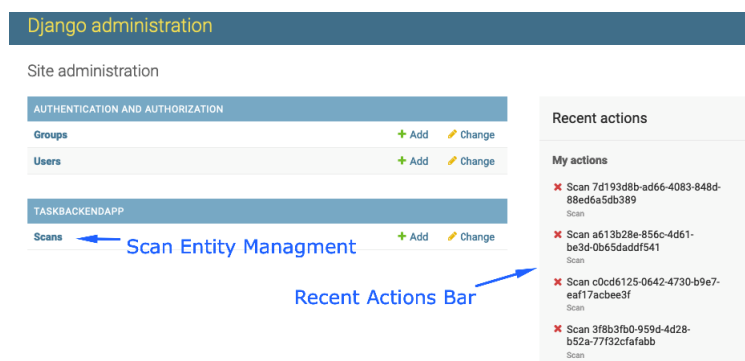
After the login sequence is completed, the researcher will be redirected to the panel's home page; there, it has available all the functionality needed to perform debbuging into the algorithm under develepoment, such as real-time logging capability. By selecting the scan in question can have access to the required information

Figure 8.4: Researcher Panel-List of scans
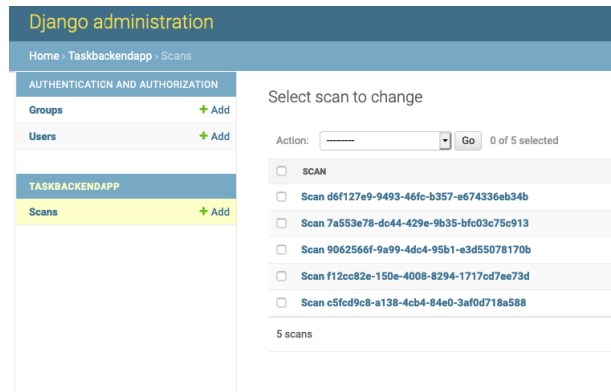
Figure 8.5: Researcher Panel-Scan Details Example
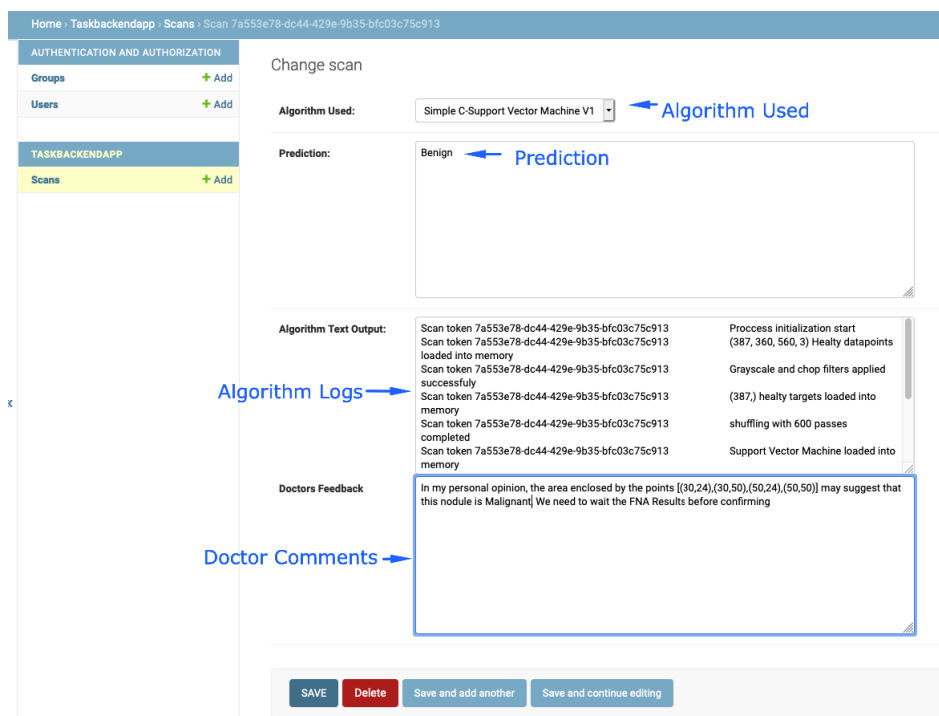
The researcher then can improve the algorithm based on the feedback provided from the doctors, as well as to troubleshoot possible errors using the real-time logging capability.

Chapter 9

The Frontend Application

9.1 Introduction

Figure 9.1: Frontend Application
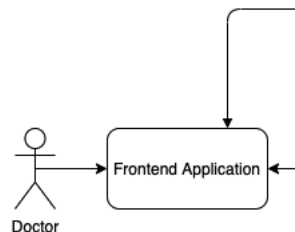
This chapter will look at the technology stack, internals, and points of interest of the frontend application. The frontend application's purpose is to serve as a visual middleware between the end-user (The Doctor) and the system itself. It propagates the actions of the user into the system by using plain HTTPS Requests, via a stateful[Barth (2011)], Json-based[T. Bray (2014)] Https[Rescorla (2000)] RESTFull[R. Fielding (2014)] protocol (for more information, please see chapter 10).

9.2 Technology Stack

The Frontend application uses the following frameworks and libraries

- React v18.0

- Boostrap v4

- Axios Requests

- Hansontable v8.3.2

9.2.1 React

React.js is an open-source javascript framework for developing frontend applications. It is created by Facebook and maintained by the open-source community as well as from some individual companies. It encourages the creation of applications with well-defined state and

state transitions by composing lightweight and reusable UI Elements called 'Components.' The system's behavior is modeled strictly by events generated due to a state transition, and the components should act accordingly. Our Frontend Application contains 16 independent components that communicate with each other by callbacks. An exhaustive list of the components is given below.

Body	The entry-point application-wide component
About	The About page
Home	The Home Page
Hints	The Instruction manual at home page
Login	The login form
MyPatients	The patients list
MyScans	The scan list
NewPatient	The new patient form
NewScan	The new scan form
Notifications	The notifications list
PatientView	The patiet's detailed view
ScanView	The scan's detailed view
Profile	The users profile page
Nav	The Navigation Bar
Alert	The Alert message box
Content	Main view and Action bar

An example screen with its respective components highlighted is shown below...

Figure 9.2: React Components on example screen
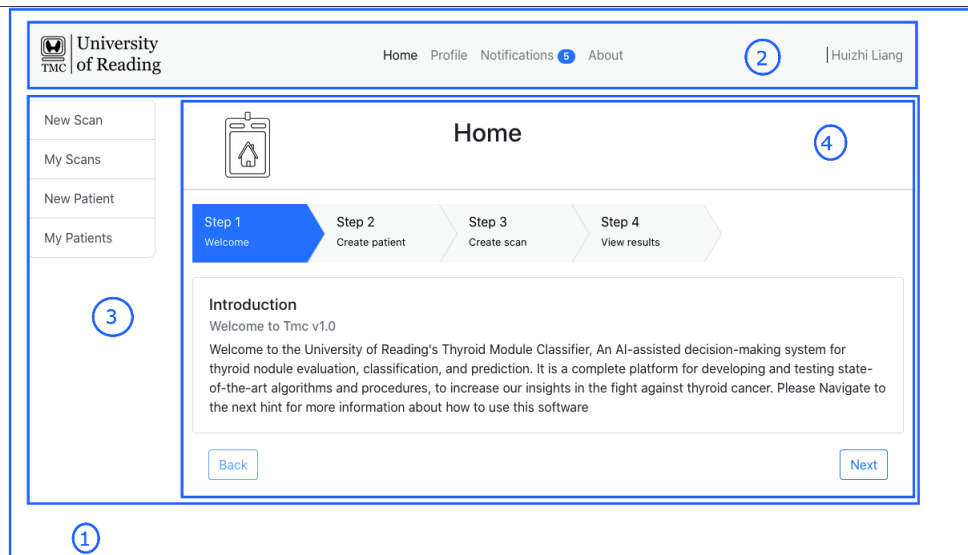
...where the marked areas are ascosiated on the respective components based on the mappings below.

1	Body
2	NavBar
3	Content
4	Hints

9.2.2   Boostrap

Bootstrap is an open-source CSS and Javascript web development network. It contains web templates, as well as forms, buttons, and navigation elements. Boostrap is used extensively throughout the frontend application to enable a user-friendly experience and cross-compatibility to various browsers and mobile devices.
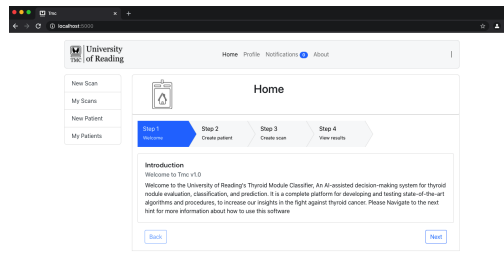
(a) System Works on Chrome
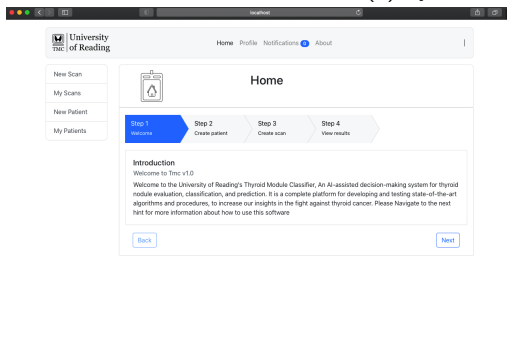
(b) System Works on Safari
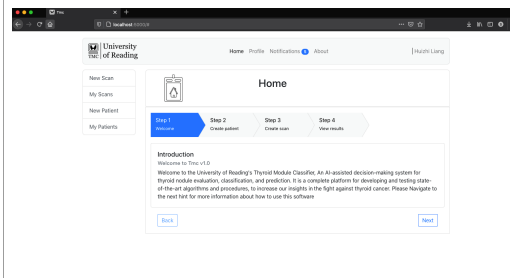
(c) System Works on Firefox

Figure 9.3: Boostrap runs consistetly everywhere

9.2.3   Axios Requests

'Axios is a popular, promise-based HTTP client that sports an easy-to-use API and can be used in both the browser and Node.js.'[Jacques (2018)]. Axios enables the communication of the Frontend Application with the Backend Services; it does this asynchronously, so it does not block the main thread of execution; this feature enables the application to be as smooth and responsive as possible, even under heavy loads(If the backend services are not responding fast enough, functionality non needed communication is not affected.)

9.2.4   Hansontable

Hansontable is a javascript library providing a fully functional MS Excel-style spreadsheet for generic use. We use this spreadsheet on two components, MyPatients and MyScans.

Figure 9.4: Hansontable example with the first two lines selected

Chapter 10

The Application Programming Interface

10.1   Introduction

In this section, we will briefly discuss the communication protocol used by the application to its internal components. As mentioned already in the previous chapters, the protocol used is a designed to be a stateful[Barth (2011)], JSON-based[T. Bray (2014)], Https[Rescorla (2000)], restful [R. Fielding (2014)]protocol. Let us explain briefly what those technical terms mean.

10.1.1   Stateful Protocol

A stateful protocol[Barth (2011)] is a protocol capable of recognizing and distinguishing between the different requests made by the same host machine. In our application, this is essential because the authentication functionality would be impossible otherwise. An authenticated user is always associated with a session. The session id[Kaplan (2014)] is a character string that is returned after the authentication is complete and should be attached to every subsequent request for user authentication to work. Our application protocol uses the cookie mechanism to attach the sessionID to every request, ensuring that the Services will recognize the sender. The following image provides an example.

Figure 10.1: Session ID Attached to Notifications Request, captured using Firefox-Tools
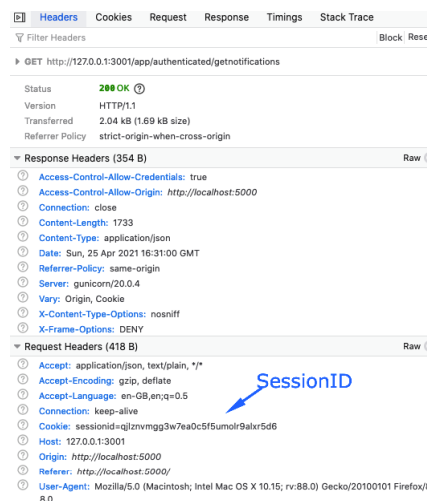
Here, the Session ID is attached to a request from the Frontend Application into the Information Service for the retrieval of new notifications.

10.1.2   Json

The JavaScript Object Notation (or JSON) Data Interchange Format[T. Bray (2014)] is a text-based, lightweight, human-readable language-independent data exchange format. We use JSON extensively to design our communication protocol, mainly because of its widely adopted use and availability of decoders. Additionally, both languages involved in the data transaction(javascript for the frontend, python for the backend services) support JSON natively.

Figure 10.2: Capturing the Information service's JSON-Based responce using Postman
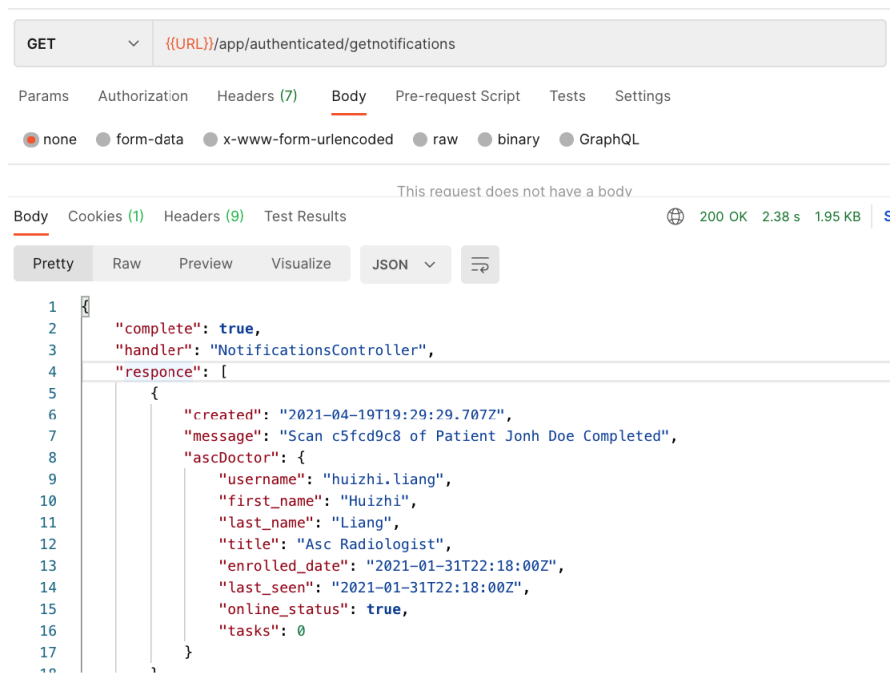
10.1.3   HTTPS

HTTPS[Rescorla (2000)] or HyperText Transfer Protocol Secure version is an updated version of the classic HTTP protocol, using TLS as an additional security layer. TLS encrypts all the underlying data to provide unparallel protection against various malicious attacks. The following images showed the login packages as they were sent from the Frontend Application to the Information Service using the WireShark packet analyzer.

Figure 10.3: Unecrupted Credentials (HTTPS disabled)
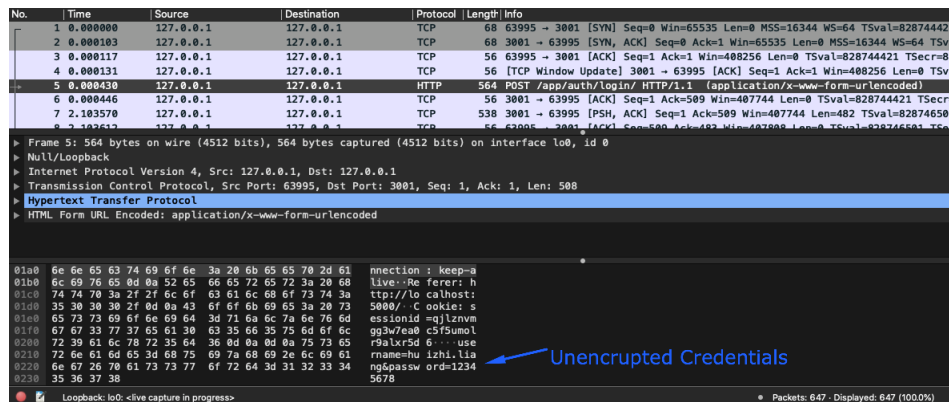
Figure 10.4: Ecrupted Credentials (HTTPS enabled)
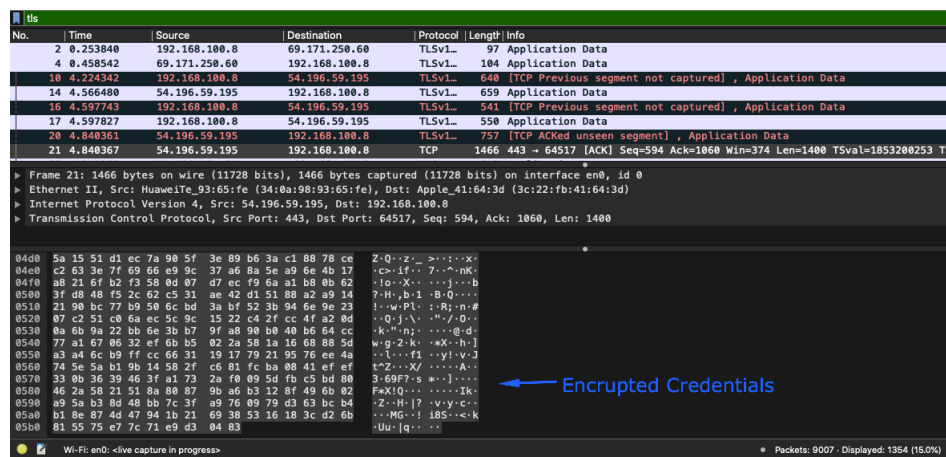
It becomes evident that, by using HTTPS, we increase our system security, as credentials and personal information are encrypted before sent over the internet.

10.1.4 RESTFull protocol

A protocol is REpresentational State Transfer (REST) Pautasso et al. (2008)Full when its design enables the following criteria to be fullfiled.

Resource identification through URI.

A protocol is RESTFul if it exposes several resources which identify the targets of the interaction with its clients. An example of this may be a contacts repository. The resources(contact repository) are identified via URIs[Berners-Lee (2005)].

10.1.5 Uniform Interface

A protocol is restFul if the exposed resources are manipulated through a fixed set of four operations. Those operations have been encoded to the HTTP/HTTPS protocols themselves, making the creation of RESTFul APIs easier. The operations are

- PUT

- GET

- POST

- DELETE

10.1.6   Self-descriptive messages

A protocol is RestFul if the underlying resource is decoupled of its representation, making the access of the resource possible using a variety of different formats, such as JSON, XML, plain text, PDF, and others.

10.1.7   Stateful interactions through hyperlinks

A protocol is Restful if every interaction between the server and a client is stateless i.e., the request messages are self-contained; hence any stateful interaction should be explicit and based on the contents of the message itself.

10.2   Protocol Specification

From now onwards, we will define and explain the various calls and responses that define our application protocol. This section may be referenced by future development as complete documentation.

10.2.1   Definitions

Before we proceed with the complete specification, we need to define some technical terms.

Session

A session[Barth (2011)] is a mechanism utilized by all the stateful protocols relying on a stateless protocol for application transmission. HTTP/HTTPS is the primary protocol for web communication, and our protocol relies on HTTP/HTTPS for data transmission. HTTP/HTTPS is a stateless protocol meaning that it does not have any explicit mechanism for maintaining state between requests. Our protocol needs to be stateful as it needs to support multiple users(doctors) and their actions. Knowing that a given request comes from an authorized source is essential to our application. A session in our application is implemented using session cookies. Session cookies keep a token; a unique identifier sent to our services with each request, then we can determine if an action is authorized based on that token. A request comes from an authenticated user if it contains a valid authenticated token.

10.2.2   Frontend application to Information Service Requests

In this section, we will list the interactions between the frontend application and the information service. The interactions as split into two main categories.

- **Authenticated Endpoints**: Endpoints that require a valid and authenticated session token(see 10.2.1).

- **Non-Authenticated Endpoints**: Endpoints that do not require a valid and authenticated session token(see 10.2.1).

Login endpoint

The first request that we will briefly discuss is the login endpoint. The login endpoint authenticates the user based on its username and password, and if those credentials are correct, it returns a session cookie to be used in the rest of the endpoints. The Login endpoint is a Non-Authenticated Endpoint.

Endpoint	URL/app/auth/login/
Parameter Type	www-form-urlencoded
Parameter 1	username
Parameter 2	password

Example

Endpoint	URL/app/auth/login/
Parameter Type	www-form-urlencoded
Parameter 1	stefanos.stefanou
Parameter 2	123456789

JSON Responce

```
1 {
2   "complete": true,
3   "handler": "SystemAuth"
4 }
5
```

It also returns a session cookie for subsequent requests.

```
1 sessionid=rlhr96oilrjvkt802dsw41zr6a2g6anp; expires=Wed, 12 May 2021
    15:42:03 GMT; HttpOnly; Max-Age=1209600; Path=/
2
```

If the request is not correctly formed, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "SystemAuth",
4   "reason": "Bad request: Request without the necessary fields has being
    raised."
5 }
6
```

Finally, if the credentials are not recognized, the following response should be expected.

```
1 {
2   "complete": false,
3   "handler": "SystemAuth",
4   "reason": "Invalid Credentials"
5 }
6
```

Signup endpoint

The Signup endpoint allows for the creation of an end-user(doctor). This endpoint is meant to be called only by the network operator application(see 7). The Signup Endpoint is a non-authenticated endpoint.

Endpoint	URL/app/auth/signup/
Parameter Type	www-form-urlencoded
Parameter 1	username
Parameter 2	password
Parameter 3	email
Parameter 4	first_name
Parameter 5	last_name

Example

Endpoint	URL/app/auth/signup/
Parameter Type	www-form-urlencoded
Parameter 1	stefanos.stefanou
Parameter 2	1233456789
Parameter 3	test@example.com
Parameter 4	Stefanos
Parameter 5	Stefanou

JSON Responce

```
{
  "complete": true,
  "handler": "SystemAuth",
  "responce": {
    "username": "stefanos.stefanou",
    "first_name": "Stefanos",
    "last_name": "Stefanou",
    "title": "Not Set",
    "enrolled_date": "2021-04-28T15:51:21.056Z",
    "last_seen": "2021-04-28T15:51:21.056Z",
    "online_status": true,
    "tasks": 0
}
}
```

Finally, if the request is not formed correctly, then the following response will be returned.

```
{
  "complete": false,
  "handler": "SystemAuth",
  "reason": "User already exists"
}
```

```
1 {
2   "complete": false,
3   "handler": "SystemAuth",
4   "reason": "Bad request: Request without the necessary fields has being
       raised."
5 }
6
```

Doctor profile endpoint

The Doctor profile endpoint informs the front end about the doctor's (end-users) details. It is called when the profile section is selected on the frontend application(see 5.4.1). The Doctor Profile endpoint is authenticated, needing a valid and authenticated session token belonging to an end-user(not root).

Endpoint	URL/app/authenticated/profile
Parameter Type	No Paremeters

Example

Endpoint	URL/app/authenticated/profile

JSON Responce

```
1 {
2   "complete": true,
3   "handler": "DoctorController",
4   "responce": {
5     "username": "stefanos.stefanou",
6     "first_name": "Stefanos",
7     "last_name": "Stefanou",
8     "title": "Bsc Candidate",
9     "enrolled_date": "2021-01-31T22:18:00Z",
10    "last_seen": "2021-01-31T22:18:00Z",
11    "online_status": true,
12    "tasks": 0
13   }
14 }
15
```

If the request contains an authenticated session-id but is belonging to a root user instead of an end-user, the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "DoctorController",
4   "reason": "Doctor-User association not found, this is probably because
       you own a session of a superuser(User that is not Doctor, etc root)"
5 }
6
```

Where if the incoming request is not authenticated, then the following request will be returned.

```
1 {
2   "complete": false,
3   "handler": "DoctorController",
4   "reason": "Authenticated endpoint without active session"
5 }
6
```

Finally, if a field is missing or the specification of the request is not met, then the following responce will be returned

```
1 {
2   "complete": false,
3   "handler": "PatientController",
4   "reason": "Bad request: Request without the necessary fields has being
       raised."
5 }
6
```

Doctor notifications endpoint

The doctor notifications endpoint informs the front end about the doctor's (end-users) available notifications. It is called when the notification section is selected on the frontend application(see 5.4.2). The Doctor Profile endpoint is authenticated, needing a valid and authenticated session token belonging to an end-user(not root).

Endpoint	URL/app/authenticated/getnotifications
Parameter Type	No Paremeters

Example

Endpoint	URL/app/authenticated/getnotifications

JSON Responce

```
1 {
2   "complete": true,
3   "handler": "NotificationsController",
4   "responce": [{
5     "created": "2021-04-19T19:29:29.707Z",
6     "message": "Scan c5fcd9c8 of Patient Jonh Doe Completed",
7     "ascDoctor": {
8       "username": "stefanos.stefanou",
9       "first_name": "Stefanos",
10      "last_name": "Stefanou",
11      "title": "Bsc Candidate",
12      "enrolled_date": "2021-01-31T22:18:00Z",
13      "last_seen": "2021-01-31T22:18:00Z",
14      "online_status": true,
15      "tasks": 0
16    }
17  }]
18 }
19
```

If the request contains an authenticated session-id but is belonging to a root user instead of an end-user, the following response will be returned.

```
1  {
2    "complete": false,
3    "handler": "DoctorController",
4    "reason": "Doctor-User association not found, this is probably because
         you own a session of a superuser(User that is not Doctor, etc root)"
5  }
6
```

Where if the incoming request is not authenticated, then the following request will be returned.

```
1  {
2    "complete": false,
3    "handler": "DoctorController",
4    "reason": "Authenticated endpoint without active session"
5  }
6
```

Finally, if a field is missing or the specification of the request is not met, then the following response will be returned.

```
1  {
2    "complete": false,
3    "handler": "PatientController",
4    "reason": "Bad request: Request without the necessary fields has being
         raised."
5  }
6
```

Add patient endpoint

The add patient endpoint makes possible the creation of new patient records through the frontend application. It is activated when we submit the patient submission form(see 5.5.2). Add Patient Endpoint is an authenticated endpoint, meaning that it requires a valid session token to proceed. The session token should belong to an end-user(doctor) and not root(administrator).

Endpoint	URL/app/authenticated/addpatient
Parameter Type	www-form-urlencoded
Parameter 1	first_name
Parameter 2	last_name
Parameter 3	nino

Example

Endpoint	URL/app/authenticated/addpatient
Parameter Type	www-form-urlencoded
Parameter 1	Test Patient
Parameter 2	Test Patient
Parameter 3	AA123456A

JSON Responce

```json
{
  "complete": true,
  "handler": "PatientController",
  "responce": {
    "first_name": "Test Patient",
    "last_name": "Test Patient",
    "nino": "AA123456A",
    "enrolled_date": "2021-04-28T16:17:43.595Z",
    "comments": "Not Set",
    "ascDoctor": {
      "username": "huizhi.liang",
      "first_name": "Huizhi",
      "last_name": "Liang",
      "title": "Asc Radiologist",
      "enrolled_date": "2021-01-31T22:18:00Z",
      "last_seen": "2021-01-31T22:18:00Z",
      "online_status": true,
      "tasks": 0
    }
  }
}

```

If the request contains an authenticated session-id but is belonging to a root user instead of an end-user, the following response will be returned.

```json
{
  "complete": false,
  "handler": "PatientController",
  "reason": "Doctor-User association not found, this is probably because
    you own a session of a superuser(User that is not Doctor, etc root)"
}

```

Where if the incoming request is not authenticated, then the following request will be returned.

```json
{
  "complete": false,
  "handler": "PatientController",
  "reason": "Authenticated endpoint without active session"
}

```

if the Nino[*National Insurance Manual* (2021)] already exists, the following response should be expected.

```
1  {
2    "complete": false,
3    "handler": "PatientController",
4    "reason": "Given NINO already exists"
5  }
6
```

Finally, if a field is missing or the specification of the request is not met, then the following response will be returned.

```
1  {
2    "complete": false,
3    "handler": "PatientController",
4    "reason": "Bad request: Request without the necessary fields has being
      raised."
5  }
6
```

Set patient comment endpoint

The set patient comment endpoint makes it possible for the end-user(doctor) to keep notes about a specific patient case. It is activated when we change the comments for a specific patient(see **??**). Set Patient Comment Endpoint is an authenticated endpoint, meaning that it requires a valid session token to proceed. The session token should belong to an end-user(doctor) and not root(administrator).

Endpoint	URL/app/authenticated/addpatient
Parameter Type	www-form-urlencoded
Parameter 1	nino
Parameter 2	comment

Example

Endpoint	URL/app/authenticated/addpatient
Parameter Type	www-form-urlencoded
Parameter 1	AA123456A
Parameter 2	Test Patient

JSON Responce

```
1  {
2    "complete": true,
3    "handler": "PatientController"
4  }
5
```

If the request contains an authenticated session-id, but as belonging to a root user instead of an end-user, the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "PatientController",
4   "reason": "Doctor-User association not found, this is probably because
      you own a session of a superuser(User that is not Doctor, etc root)"
5 }
6
```

Where if the incoming request is not authenticated, then the following request will be returned.

```
1 {
2   "complete": false,
3   "handler": "PatientController",
4   "reason": "Authenticated endpoint without active session"
5 }
6
```

If the given Nino is not associated with any patient, the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "PatientController",
4   "reason": "Given NINO not found or not permitted"
5 }
6
```

Finally, if a field is missing or the specification of the request is not met, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "PatientController",
4   "reason": "Bad request: Request without the necessary fields has being
      raised."
5 }
6
```

Get patients endpoint

The get patients endpoint makes it possible for the end-user(doctor) to retrieve its list of associated patients. It is activated when the end-user(Doctor) selects the MyPatients page(see 5.5.1). Get Patients Endpoint is an authenticaticated endpoint, meaning that it requires a valid session token to proceed. The session token should belong to an end-user(doctor) and not root(administrator).

Endpoint	URL/app/authenticated/getpatients
Parameter Type	No Parameters

Example

Endpoint	URL/app/authenticated/getpatients

JSON Responce with one patient

```
1  {
2    "complete": true,
3    "handler": "PatientController",
4    "responce": [{
5      "first_name": "Jonh",
6      "last_name": "Doe",
7      "nino": "AA123456A",
8      "enrolled_date": "2021-04-19T19:25:48.163Z",
9      "comments": "Not Set",
10     "ascDoctor": {
11       "username": "stefanos.stefanou",
12       "first_name": "Stefanos",
13       "last_name": "Stefanou",
14       "title": "Bsc Candidate",
15       "enrolled_date": "2021-01-31T22:18:00Z",
16       "last_seen": "2021-01-31T22:18:00Z",
17       "online_status": true,
18       "tasks": 0
19     }
20   }]
21  }
22
```

If the request contains an authenticated session-id but belongs to a root user instead of an end-user, the following response will be returned.

```
1  {
2    "complete": false,
3    "handler": "PatientController",
4    "reason": "Doctor-User association not found, this is probably because
     you own a session of a superuser(User that is not Doctor, etc root)"
5  }
6
```

Where if the incoming request is not authenticated, then the following request will be returned.

```
1  {
2    "complete": false,
3    "handler": "PatientController",
4    "reason": "Authenticated endpoint without active session"
5  }
6
```

If a field is missing or the specification of the request is not met, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "PatientController",
4   "reason": "Bad request: Request without the necessary fields has being
      raised."
5 }
6
```

Add scan endpoint

The add scan endpoint makes it possible for the end-user(doctor) to submit scans on its associated patients. It is activated when the end-user(Doctor) submits the scan submission form(see 5.5.4). Add Scan Endpoint is an authenticaticated endpoint, meaning that it requires a valid session token to proceed. The session token should belong to an end-user(doctor) and not root(administrator). Please note that this is the first request in a series of 2 needed to initiate a scan task correctly, the second one can be found in at paragraph10.2.3 , and more information about the procedure can be found in chapter11.

Endpoint	URL/app/authenticated/addscan
Parameter Type	www-form-urlencoded
Parameter 1	nino

Example

Endpoint	URL/app/authenticated/addscan
Parameter Type	www-form-urlencoded
Parameter 1	AA123456A

JSON Responce

```
1  {
2    "complete": true,
3    "handler": "ScanController",
4    "responce": {
5      "ascPatient": {
6        "first_name": "Jonh",
7        "last_name": "Doe",
8        "nino": "AA123456A",
9        "enrolled_date": "2021-04-19T19:25:48.163Z",
10       "comments": "Not Set",
11       "ascDoctor": {
12         "username": "huizhi.liang",
13         "first_name": "Huizhi",
14         "last_name": "Liang",
15         "title": "Asc Radiologist",
16         "enrolled_date": "2021-01-31T22:18:00Z",
17         "last_seen": "2021-01-31T22:18:00Z",
18         "online_status": true,
19         "tasks": 0
20       }
21     },
22     "token": "45dd6aff-929b-44d1-8e63-bbe7af707c8f",
23     "created": "2021-04-28T17:07:03.856Z",
24     "status": "SUBMITTED",
25     "comment": "Not Set"
26   }
27 }
28
```

If the request contains an authenticated session-id but as belonging to a root user instead of an end-user, the following response will be returned.

```
1  {
2    "complete": false,
3    "handler": "ScanController",
4    "reason": "Doctor-User association not found, this is probably because
        you own a session of a superuser(User that is not Doctor, etc root)"
5  }
6
```

Where if the incoming request is not authenticated, then the following request will be returned.

```
1  {
2    "complete": false,
3    "handler": "ScanController",
4    "reason": "Authenticated endpoint without active session"
5  }
6
```

If a field is missing or the specification of the request is not met, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Bad request: Request without the necessary fields has being
      raised."
5 }
6
```

Scan update comment endpoint

The scan update comment endpoint makes it possible for the end-user(doctor) to submit feedback on a specific scan for the researcher to use. It is activated when the end-user(Doctor) submit comments scan result(see 5.5.3). Scan Update Comment Endpoint is an authenticaticated endpoint, meaning that requires an valid session token, to procceed. The session token should belong to an end-user(doctor) and not root(administrator).

Endpoint	URL/app/authenticated/updatescancomment
Parameter Type	www-form-urlencoded
Parameter 1	token
Parameter 1	comment

Example

Endpoint	URL/app/authenticated/updatescancomment
Parameter Type	www-form-urlencoded
Parameter 1	9054afa6-8b03-4dad-8ab3-2180e34e94e1
Parameter 2	Test Comment

JSON Responce

```
1 {
2   "complete": true,
3   "handler": "ScanController"
4 }
5
```

If the request contains an authenticated session-id but is belonging to a root user instead of an end-user, the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Doctor-User association not found, this is probably because
      you own a session of a superuser(User that is not Doctor, etc root)"
5 }
6
```

Where if the incoming request is not authenticated, then the following request will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Authenticated endpoint without active session"
5 }
6
```

If a field is missing or the request specification is not met, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Bad request: Request without the necessary fields has being
       raised."
5 }
6
```

If the given token is not associated with a given scan, the following request should be expected.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Given scan token not found"
5 }
6
```

Get scans endpoint

The get scans endpoint makes it possible for the end-user(doctor) to view its associated scans. It is activated when the end-user(Doctor) selects the MyScans page(see 5.5.3). Get Scans Endpoint is an authenticaticated endpoint, meaning that it requires a valid session token to proceed. The session token should belong to an end-user(doctor) and not root(administrator).

Endpoint	URL/app/authenticated/getscans
Parameter Type	No Parameters

Example

Endpoint	URL/app/authenticated/getscans

JSON Responce example with 1 scan

```json
1  {
2    "complete": true,
3    "handler": "ScanController",
4    "responce": [{
5      "ascPatient": {
6        "first_name": "Jonh",
7        "last_name": "Doe",
8        "nino": "AA123456A",
9        "enrolled_date": "2021-04-19T19:25:48.163Z",
10       "comments": "Not Set",
11       "ascDoctor": {
12         "username": "huizhi.liang",
13         "first_name": "Huizhi",
14         "last_name": "Liang",
15         "title": "Asc Radiologist",
16         "enrolled_date": "2021-01-31T22:18:00Z",
17         "last_seen": "2021-01-31T22:18:00Z",
18         "online_status": true,
19         "tasks": 0
20       }
21     },
22     "token": "c5fcd9c8-a138-4cb4-84e0-3af0d718a588",
23     "created": "2021-04-19T19:29:28.607Z",
24     "status": "COMPLETED",
25     "comment": "Not Set"
26  },
27
```

If the request contains an authenticated session-id but as belonging to a root user instead of an end-user, the following response will be returned.

```json
1  {
2    "complete": false,
3    "handler": "ScanController",
4    "reason": "Doctor-User association not found, this is probably because
        you own a session of a superuser(User that is not Doctor, etc root)"
5  }
6
```

Where if the incoming request is not authenticated, then the following request will be returned.

```json
1  {
2    "complete": false,
3    "handler": "ScanController",
4    "reason": "Authenticated endpoint without active session"
5  }
6
```

If a field is missing or the request specification is not met, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Bad request: Request without the necessary fields has being
      raised."
5 }
6
```

10.2.3   Frontend application to Prediction Service Requests

In this section, we will list the interactions between the frontend application and the prediction service.

Add scan endpoint

The Add scan endpoint makes it the end-user(doctor) possible to submit a new scan task for its associated patients. Add Scan Endpoint is a non-authenticaticated endpoint.

Endpoint	URL/app/scan/addscan	
Parameter Type	www-form-urlencoded	
Parameter 1	token	Scan token taken from Information Service
Parameter 2	image	Encoded JPEG image as base64[Josefsson (2006)]
Parameter 3	algorithm	One of SVC,RESNet

Example

Endpoint	URL/app/scan/addscan
Parameter Type	www-form-urlencoded
Parameter 1	c1b75e1b-e2e1-89F2-93a7-cb19d37c2b6b
Parameter 2	[... too big to display ...]
Parameter 3	SVC

JSON Responce example with 1 scan

```
1 {
2   "complete": true,
3   "handler": "ScanController",
4   "responce": {
5     "algorithm": "SVC",
6     "token": "c1b75e1b-e2e1-89F2-93a7-cb19d37c2b6b",
7     "image": "[ ... too big to display ... ]",
8     "results": "Not Set",
9     "prediction": "Not Set"
10   }
11 }
12
```

If the request contains an invalid algorithm field, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Algorithm requested not supported. supported algorithm codes
      are ['SVC', 'RES']"
5 }
6
```

Where if the incoming request is not authenticated, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Authenticated endpoint without active session"
5 }
6
```

If the scan token already exists, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Given token already exists or invalid"
5 }
6
```

If the image given is corrupted or encoded in a wrong specification(example, PNG), the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Given image base64 string wasn't decoded successfully,
    possibly corrupt data or invalid data format? (Note that jpeg files are
      supported only in this version )"
5 }
6
```

Finally, if a field is missing or the specification of the request is not met, then the following response will be returned.

```
1 {
2   "complete": false,
3   "handler": "ScanController",
4   "reason": "Bad request: Request without the necessary fields has being
      raised."
5 }
6
```

Get scan endpoint

The get scan endpoint makes it possible for the end-user(doctor) to view the status and the prediction of the scan task. Add Scan Endpoint is a non-authenticaticated endpoint.

Endpoint	URL/app/scan/getscan	
Parameter Type	url-parameters	
Parameter 1	token	Scan token taken from Information Service

Example

Endpoint	URL/app/scan/getscan?token=c1b75e1b-e2e1-89F2-93a7-cb19d37c2b6b

JSON Responce example

```
1  {
2    "complete": true,
3    "handler": "ScanController",
4    "responce": {
5      "algorithm": "RES",
6      "token": "c1b75e1b-e2e1-89f2-93a7-cb19d37c2b6b",
7      "image": "[ ... too big to display ... ]",
8      "results": "Operation completed",
9      "prediction": "Malignant"
10   }
11 }
12
```

If a field is missing or the specification of the request is not met, then the following response will be returned.

```
1  {
2    "complete": false,
3    "handler": "ScanController",
4    "reason": "Bad request: Request without the necessary fields has being
      raised."
5  }
6
```

Where if the given token does not exist, the following response should be expected.

```
1  {
2    "complete": false,
3    "handler": "NotificationsController",
4    "reason": "Given scan token not found"
5  }
6
```

10.2.4   Prediction Service to Information Service requests

In this section, we will briefly look at the requests from the prediction to information services. The requests under this category are non-authenticated as they are exchanged sorely in the background between services; the internal network is assumed to be trusted in this version of the software.

Declare scan complete endpoint

The Declare scan complete endpoint is triggered when the Prediction Service finishes the prediction of a given scan, informing the Information service about the event and generating a notification for the end-user to see.

Endpoint	URL/app/scancomplete	
Parameter Type	www-form-urlencoded	
Parameter 1	token	Scan token taken from Information Service

Example

Endpoint	URL/app/scancomplete	
Parameter Type	www-form-urlencoded	
Parameter 1	token	Scan token taken from Information Service

JSON Responce

```
1  {
2    "complete": true,
3    "handler": "NotificationsController",
4    "responce": {
5      "created": "2021-04-28T18:13:46.562Z",
6      "message": "Scan 45dd6aff of Patient Jonh Doe Completed",
7      "ascDoctor": {
8        "username": "stefanos.stefanou",
9        "first_name": "Stefanos",
10       "last_name": "Stefanou",
11       "title": "Bsc Candidate",
12       "enrolled_date": "2021-01-31T22:18:00Z",
13       "last_seen": "2021-01-31T22:18:00Z",
14       "online_status": true,
15       "tasks": 0
16     }
17   }
18 }
19
```

If a field is missing or the specification of the request is not met, then the following responce will be returned.

```
1  {
2    "complete": false,
3    "handler": "ScanController",
4    "reason": "Bad request: Request without the necessary fields has being
       raised."
5  }
6
```

Where if the given token does not exist, the following response should be expected.

```
1  {
2    "complete": false,
3    "handler": "NotificationsController",
4    "reason": "Given scan token not found"
5  }
6
```

Chapter 11

The Backend

11.1 Introduction

Figure 11.1: Backend Services
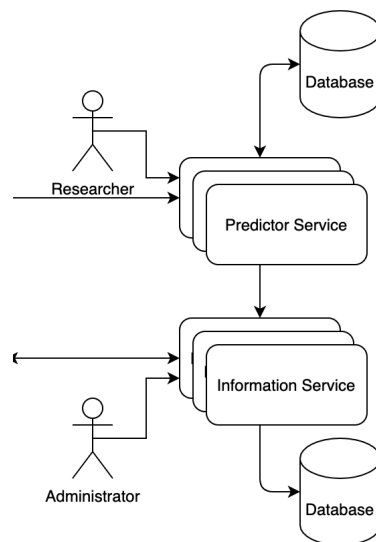
In this chapter we will cover extensively the inner workings of the backend services, namely the Information and the Prediction services We will go through their internal architectures as well as some key areas of interest.

11.2 Information Service

The Information Service(internally known as uortmc-infobe) is the service that handles the information of our entities, namely the patients, the scans, the end-users and their interconnections, additionally it handles authentication and includes the notification system, capable of notifying a given end-user for the completion of their tasks.

11.2.1 Technology Stack

The Information service uses a number of libraries to achieve its goals, the most important ones are listed below

- Django framework

- psycopg2 database driver

Django Framework

Django is a free and open-source, python based web framework that uses the model-template-view(MTV) architecture pattern. It is maintained by an american 501(c)(3) non-profit organisation called Django Software Foundation (DSF). Django offers the code infastructure to develop RESTFul[R. Fielding (2014)] microservices with ease, and its the backbone of both of our microservices

psycopg2 database driver

psycopg2 is a famous postgres database driver for python. psycopg2 offers the interface for our postgres database connection, implementing the server-client protocol behind the scenes.

11.2.2 Code Architecture

The Information service is designed to be a fully Object Oriented Entity[Stroustrup (1988)]. The architectural design of the Information Service can be seen below.

Figure 11.2: OOP Diagram

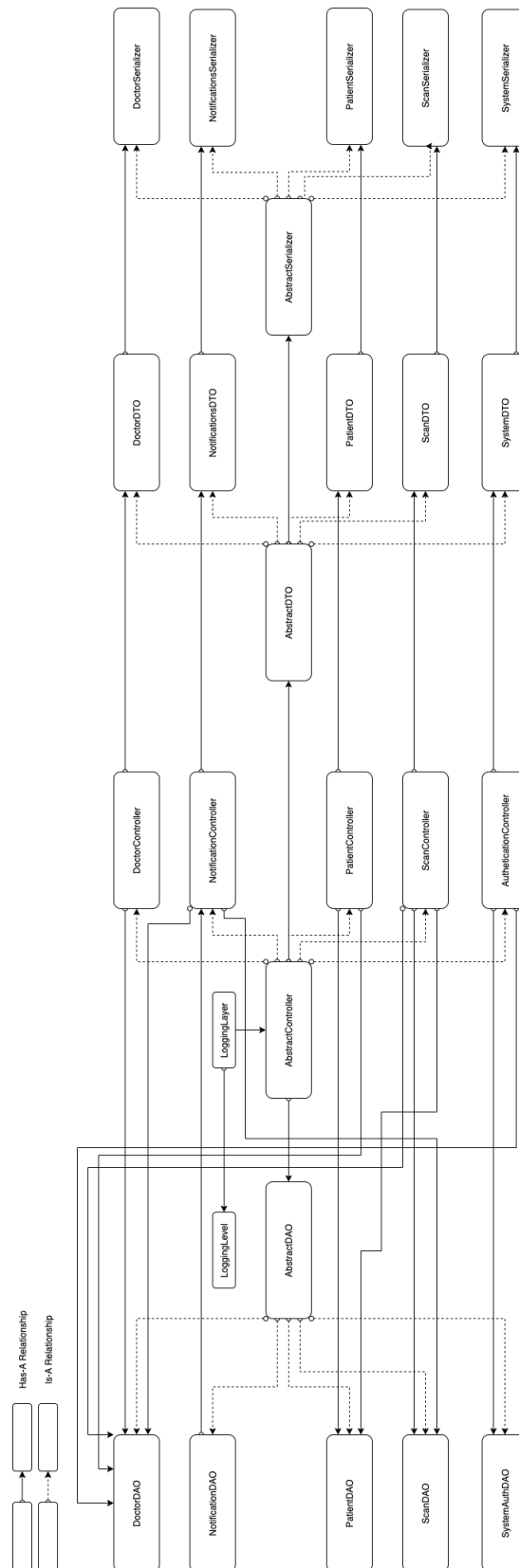The entrypoints for the requests, are the following classes

- **DoctorController**: This Class handles everything related to the Doctor Entity.

- **NotificationController** : This Class handles everything related to the Notification Entity.

- **PatientController** : This Class handles everything related to the Patient Entity.

- **ScanController** : This Class handles everything related to the Scan Entity.

- **AutheticationController** : This Class handles everything related to the Authentication service.

When a request is sent to the Information service, the proper Class is selected based on the request endpoint and details. Then the respective class will use the rest of the classes services to perform the needed actions and respond to the request accordincly. A exhaustive list of the rest major classes are given below.

DoctorDAO	Handles the SQL Queries of Doctor Entity
NotificationDAO	Handles the SQL Queries of Notification Entity
PatientDAO	Handles the SQL Queries of the Patient Entity
ScanDAO	Handles the SQL Queries of the Scan Entity
SystemAuthDAO	Handles the SQL Queries of the Authentication service
AbstractDAO	Used to describe any DAO(Data Access Object) available
LoggingLayer	Used by controllers to notify the operator in case of errors
LoggingLevel	Used by LoggingLayer to describe the severity of an error
AbstractController	Used to describe any controller available
AbstractDTO	Used to describe any DTO(Data Transfer Object)'s available
DoctorDTO	The responce objects for Doctor Entities
NotificationsDTO	The responce objects for Notification Entities
PatientDTO	The responce objects for Patient Entities
ScanDTO	The responce objects for Scan Entities
SystemDTO	The responce objects for Authentication Entities
AbstractSerializer	Used to describe any serializer available
DoctorSerializer	Used to convert Doctor DTO responce into JSON
NotificationsSerializer	Used to convert Notification DTO responce into JSON
ScanSerializer	Used to convert Scan DTO responce into JSON
SystemSerializer	Used to convert SystemAuthDTO responce into JSON

11.2.3 Database Medium

The Information Service uses an RDBMS(Relational Database Managment System)[Friedrichsen (1995)] called Postgres. PostgreSQL is a open-source and free relational database emphasizing on extensibility and SQL standard compliance. The relational diagram of the Information Service can be seen below.Additional information relating the E-R Diagram can be found in chapter 4

Figure 11.3: E-R Diagram
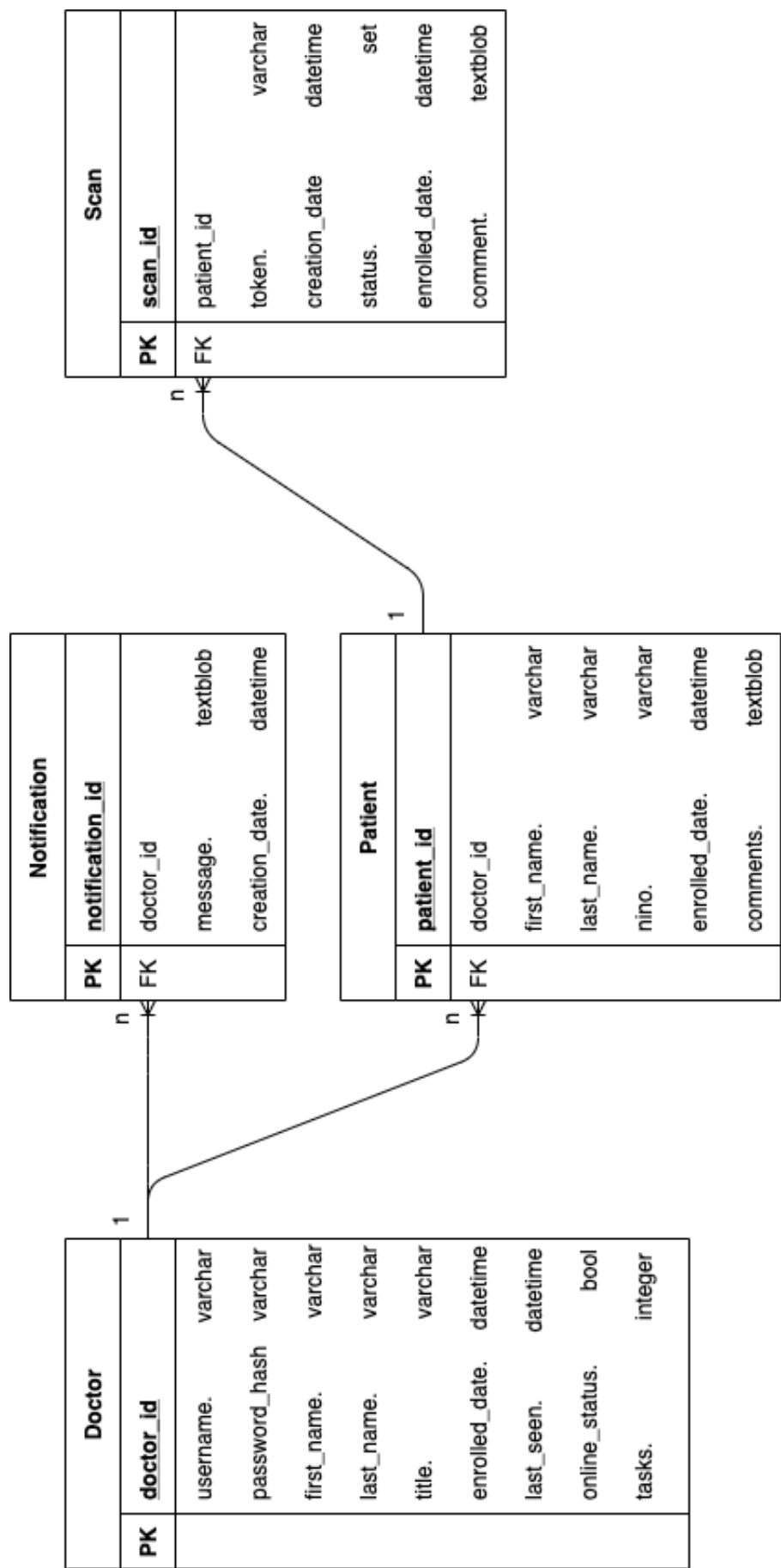
11.3 Prediction Service

The Prediction Service(internally known as uortmc-taskbe) is the service that handles the prediction proccess ultrasound images, it has also the responsibility of notifing the end-user when a task is completed, by calling the Information Service's Notification service. In this section we will briefly look at the Prediction Service internals, except from the prediction itself. For more information on the prediction proccess please refer to chapter 12

11.3.1 Technology Stack

The Prediction service uses a number of libraries to achieve its goals, the most important ones are listed below

- Django framework (see paragraph 11.2.1)

- psycopg2 database driver (see paragraph 11.2.1)

- base64 decoders

- imghdr image library

- Pykka actors

base64 decoder

base64 decoding library is a famous decoding library for python. it offers the capability of encoding and decoding messages in base64 format. We use this library for the ultrasound image scan transmission from the frontend application into the predictor service.

imghdr image library

imghdr library provides the capability of the Prediction service to recognise if a given image is corrupted or not (for more information please refer to the paragraph 10.2.3).

Pykka Actors library

'Pykka is a Python implementation of the actor model[Hewitt (2015)]. The actor model introduces some simple rules to control the sharing of state and cooperation between execution units, which makes it easier to build concurrent applications'.[Stein (2010)] Pykka actors are used imghdr library provides the capability of the Prediction service to recognise if a given image is corrupted or not (for more information please refer to the paragraph 10.2.3)

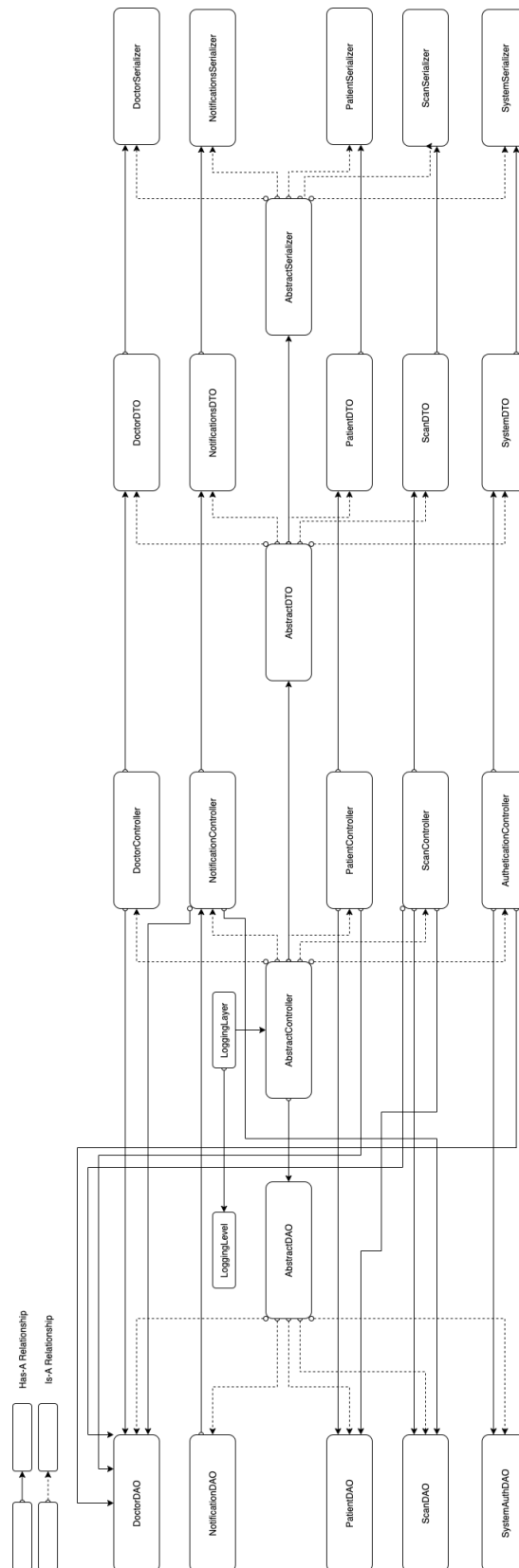### 11.3.2 Code Architecture

The Information service is designed to be a fully Object Oriented Entity[Stroustrup (1988)]. The architectural design of the Information Service can be seen below.

Figure 11.4: OOP Diagram

The entrypoints for the requests, are the following classes

- **DoctorController**: This Class handles everything related to the Doctor Entity.

- **NotificationController** : This Class handles everything related to the Notification Entity.

- **PatientController** : This Class handles everything related to the Patient Entity.

- **ScanController** : This Class handles everything related to the Scan Entity.

- **AutheticationController** : This Class handles everything related to the Authentication service.

When a request is sent to the Information service, the proper Class is selected based on the request endpoint and details. Then the respective class will use the rest of the classes services to perform the needed actions and respond to the request accordincly. A exhaustive list of the rest major classes are given below.

DoctorDAO	Handles the SQL Queries of Doctor Entity
NotificationDAO	Handles the SQL Queries of Notification Entity
PatientDAO	Handles the SQL Queries of the Patient Entity
ScanDAO	Handles the SQL Queries of the Scan Entity
SystemAuthDAO	Handles the SQL Queries of the Authentication service
AbstractDAO	Used to describe any DAO(Data Access Object) available
LoggingLayer	Used by controllers to notify the operator in case of errors
LoggingLevel	Used by LoggingLayer to describe the severity of an error
AbstractController	Used to describe any controller available
AbstractDTO	Used to describe any DTO(Data Transfer Object)'s available
DoctorDTO	The responce objects for Doctor Entities
NotificationsDTO	The responce objects for Notification Entities
PatientDTO	The responce objects for Patient Entities
ScanDTO	The responce objects for Scan Entities
SystemDTO	The responce objects for Authentication Entities
AbstractSerializer	Used to describe any serializer available
DoctorSerializer	Used to convert Doctor DTO responce into JSON
NotificationsSerializer	Used to convert Notification DTO responce into JSON
ScanSerializer	Used to convert Scan DTO responce into JSON
SystemSerializer	Used to convert SystemAuthDTO responce into JSON

11.3.3   Database Medium

The Information Service uses an RDBMS(Relational Database Managment System)[Friedrichsen (1995)] called Postgres. PostgreSQL is a open-source and free relational database emphasizing on extensibility and SQL standard compliance. The relational diagram of the Information Service can be seen below.Additional information relating the E-R Diagram can be found in chapter 4

Figure 11.5: E-R Diagram
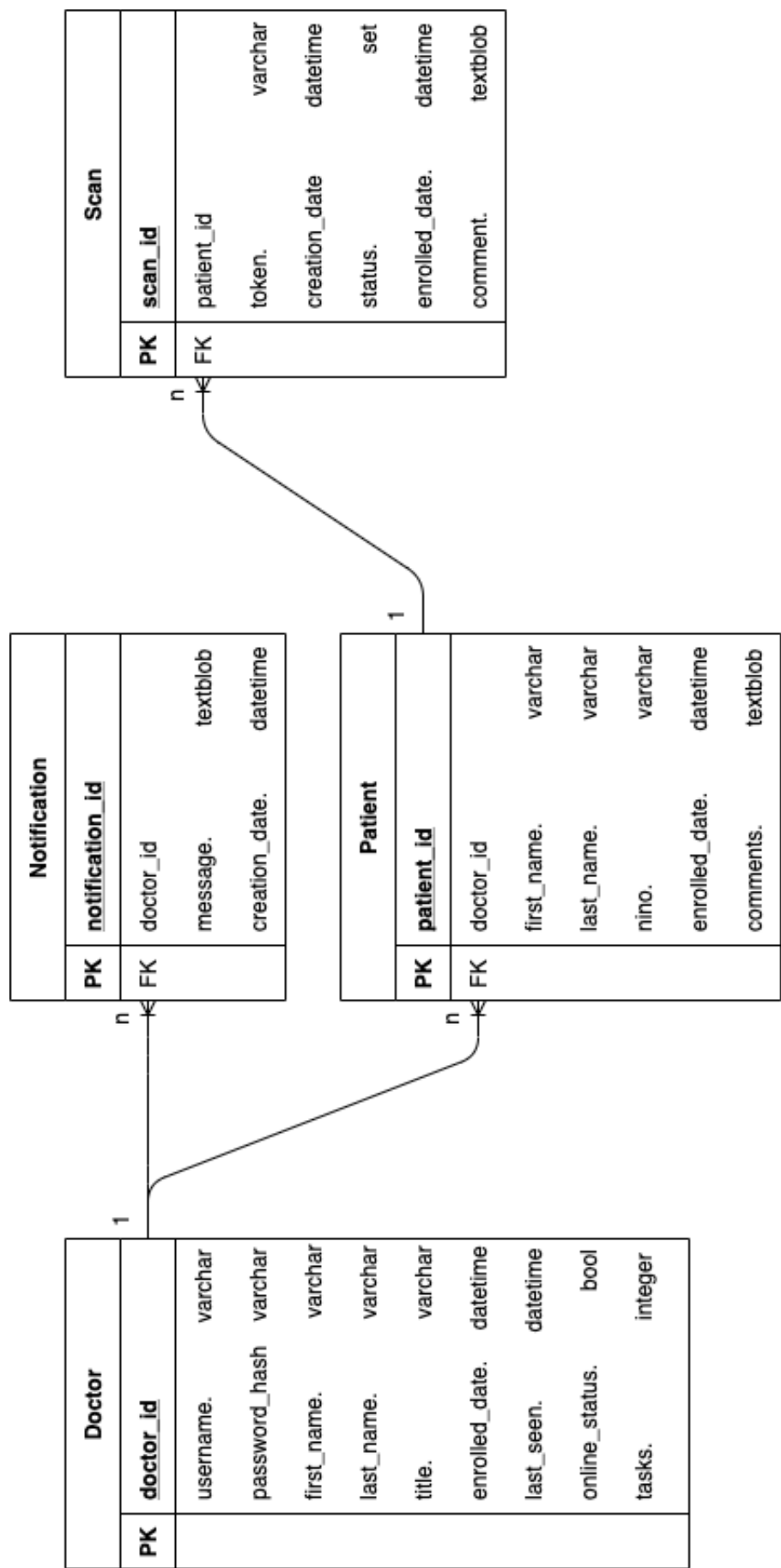
Chapter 12

The Prediction Proccess

...

12.1 ...

....

12.2 ...

...

12.2.1 ...

12.3 Summary

...

Chapter 13

CICD-Versioning-Deployment

...

13.1 ...

....

13.2 ...

...

13.2.1 ...

13.3 Summary

...

Chapter 14

Starting The Application Locally

...

14.1 ...

....

14.2 ...

...

14.2.1 ...

14.3 Summary

...

Chapter 15

Discussion, Conclusion and Future work

...

15.1 ...

....

15.2 ...

...

15.2.1 ...

15.3 Summary

...

Chapter 16

Reflection

...

16.1   ...

....

16.2   ...

...

16.2.1   ...

16.3   Summary

...

References

Barth, A. (2011), 'HTTP State Management Mechanism', Internet Requests for Comments.
  URL: *https://tools.ietf.org/html/rfc6265*

Berners-Lee, T. (2005), 'Uniform Resource Identifier (URI): Generic Syntax', Internet Requests for Comments.
  URL: *https://tools.ietf.org/html/rfc3986*

Eun Ju Ha, J. H. B. (2021), 'Ha ej, baek jh. applications of machine learning and deep learning to thyroid imaging: where do we stand? ultrasonography. 2021 jan;40(1):23-29. doi: 10.14366/usg.20068. epub 2020 jul 3. pmid: 32660203; pmcid: Pmc7758100.'.
  URL: *https://pubmed.ncbi.nlm.nih.gov/32660203/*

Fine Needle Aspiration Biopsy of Thyroid Nodules (2019).
  URL: *https://www.thyroid.org/fna-thyroid-nodules/¿*

Friedrichsen (1995), *Concepts of database management*, Cengage Learning.

Hewitt, C. (2015), 'Actor model of computation: Scalable robust information systems'.

International Organization for Standardization (1994), 'Information technology — digital compression and coding of continuous-tone still images: Requirements and guidelines', ISO/IEC 10918-1.

Jacques, N. (2018), 'Introducing axios, a popular, promise-based http client'.
  URL: *https://www.sitepoint.com/axios-beginner-guide/*

Josefsson, S. (2006), 'The Base16, Base32, and Base64 Data Encodings', Internet Requests for Comments.
  URL: *https://tools.ietf.org/html/rfc4648*

Kaplan, H. (2014), 'A Session Identifier for the Session Initiation Protocol (SIP)', Internet Requests for Comments.
  URL: *https://tools.ietf.org/html/rfc7329*

Leach, P. (2005), 'A Universally Unique IDentifier (UUID) URN Namespace', Internet Requests for Comments.
  URL: *https://tools.ietf.org/html/rfc4122*

Manber, U. (1996), 'A simple scheme to make passwords based on one-way functions much harder to crack', *Computers and Security* **15**(2), 171–176.
  URL: *https://www.sciencedirect.com/science/article/pii/016740489600003X*

National Insurance Manual (2021).
  URL: *https://www.gov.uk/hmrc-internal-manuals/national-insurance-manual/nim39110*

Newman, S. (2020), *Monolith to microservices: evolutionary patterns to transform your mono-lith*, O'Reilly Media, Inc.

Pautasso, C., Zimmermann, O. and Leymann, F. (2008), 'Restful web services vs. "big" web services', *Proceeding of the 17th international conference on World Wide Web - WWW 08* .

R. Fielding, E. (2014), 'Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content', Internet Requests for Comments.
URL: *https://tools.ietf.org/html/rfc7231*

Rescorla, E. (2000), 'HTTP Over TLS', Internet Requests for Comments.
URL: *https://tools.ietf.org/html/rfc2818*

Rivest, R. (1992), 'The MD5 Message-Digest Algorithm', Internet Requests for Comments.
URL: *https://tools.ietf.org/html/rfc1321*

Stein, M. (2010), 'Pykka — pykka 3.0.0 documentation'.
URL: *https://pykka.readthedocs.io/en/stable/*

Stroustrup, B. (1988), 'What is "object-oriented programming"?', *Software, IEEE* **5**, 10 − 20.

T. Bray, E. (2014), 'The JavaScript Object Notation (JSON) Data Interchange Format', Internet Requests for Comments.
URL: *https://tools.ietf.org/html/rfc7159*

Yergeau, F. (2003), 'UTF-8, a transformation format of ISO 10646', Internet Requests for Comments.
URL: *https://tools.ietf.org/html/rfc3629*