ELECTRONIC HEALTH DATA MANAGEMENT SYSTEM

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ELECTRONIC HEALTH DATA MANAGEMENT SYSTEM

By

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DEDICATION

I dedicate this work and these four years of studying efforts and satisfactions, to my precious family, especially to my father, who supported me all the way long with his love, patience and presence.

ABSTRACT

Faculty of Architecture and Engineering

Advisor: Igli Hakrama

The purpose of this thesis is to define the design and implementation of a platform to manage health data flow and exchange among all health facilities, institutions and other entities, in order for them to communicate through means of technology and patients have a greater control and awareness in their medical data.

The system itself is a complex distributed application and it is represented by a group of components each associated with different parts of the system such as Patient Medical Records managed by General Practitioners and their auxiliary staff (nurses, secretaries), Financial Records that store and process the costs of patient encounters, Laboratory Records which keep track of results of the tests done by the patients and can be retrieved at any time requested, Drugs Records and Availability Management that interacts with the pharmacies and pharmaceutical inventories, Emergency Health System, that interacts with the Patient Medical Records in case of emergencies, opting to achieve faster reactions to save the patient's life, Human Resources that manages the information about health information system staff.

The work done consists in the design and implementation of one of these components which is the Patient Medical Records. However the literature used and part of the design covers the other components as well, because they interact with the PMR, even though they are not implemented in here. The application is web-based, built on a Model-View-Control framework, using Java Technologies and other technologies like MySql, HTML,CSS, etc.

Difficulties raised are the lack of a standard in Albania, for exchanging health information electronically, education and training needed, the hardware resources (electronic devices). However the advantages of having such a system in the future, justify the high cost of this difficulties.

Conclusions leave the path open for suggestions and improvements of the non-functional parts of the system, such as security and portability.

ABSTRAKT

Fakulteti i Arkitektures dhe Inxhinierisë

Udhëheqës: Igli Hakrama

Qëllimi i kësaj teze është të përcaktojë strukturën dhe zbatimin e një platforme për të menaxhuar të dhënat shëndetësore dhe shkëmbimin e tyre midis të gjitha objektet shëndetësore, institucionet dhe subjektet e tjera, në mënyrë që ata të komunikojnë me anë të teknologjisë dhe pacientët të kenë një kontroll më të madh në të dhënat e tyre mjekësore.

Sistemi në vetvete është një aplikim kompleks i shpërndarë dhe përfaqësohet nga një grup i komponentëve secili i lidhur me pjesë të ndryshme të sistemit të tilla si të dhënat mjekësore të pacientit të menaxhuara nga mjekët e përgjithshëm dhe stafin e tyre ndihmës (infermierë, sekretarë), të dhënat laboratorike të cilat mbajnë rezultateve të testeve të bëra nga pacientët dhe mund të aksesohen në çdo kohë, regjistrimi i barnave dhe menaxhimi i disponueshmërisë së tyre që ndërvepron me farmacitë dhe inventarët farmaceutike, sistemi i emergjencave shëndetësore, që ndërvepron me të dhënat e pacientit në rast emergjence, duke bërë të mundur reagim më të shpejtë të mjekëve ndaj pacientëve në nevojë, duke i ofruar të dhëna mbi historikun e tyre të shëndetit (alergji, kura, reaksione), burimet njerëzore që menaxhojnë informacionin në lidhje me personelin e sistemit shëndetësor.

Puna e bërë konsiston në hartimin dhe zbatimin e njërit prej këtyre komponentëve: Regjistri i të dhënave të pacientëve (PMR), i cili është dhe baza për komponentët e tjerë. Megjithatë, literatura e përdorur dhe një pjesë e projektimit mbulon dhe komponentët e tjerë, pasi ata ndërveprojnë ngushtë me PMR.

Sistemi është ndërtuar i bazuar në web me modelin Model-View-Control, duke përdorur teknologjitë Java dhe teknologjitë e tjera si MySQL, HTML, CSS, etj.

Vështirësitë e ngritura janë mungesa e një standardi në Shqipëri, për shkëmbimin e informacionit shëndetësor në mënyrë elektronike, edukimi dhe trajnimi i nevojshëm i personelit, pajisje elektronike. Megjithatë avantazhet e të pasurit një sistem të tillë në të ardhmen, e justifikojnë koston e lartë të këtyre vështirësive. Konkluzionet e lënë rrugën të hapur për sugjerime dhe përmirësimet e disa pjesëve të sistemit, të tilla si siguria dhe portabiliteti.

ACKNOWLEDGEMENTS

It was a long way to finally conclude with this work, which has taken me a lot of efforts but that wouldn't have been possible without the presence of many people in my life.

First of all, I want to thank my family for supporting me in all the possible ways and by being always with me in my beautiful and difficult moments.

I want to express an enormous gratitude to my supervisor, prof. Igli Hakrama, not only for the support and the inspiring given to raise the work presented here, but for being at the same time a professor, an advisor and a friend. I am very grateful to all the other professors of Computer Engineering Department in Epoka University who have taught me all these years the fundamentals of computer science and helped me in building knowledge and personality in this field.

A special thanks goes for the staff of the polyclinic nr.1 in Tirana, which offered me the necessary information about patient data management and the daily work procedures. They encouraged and motivated me, with expressing their difficulties with the management of paper-based information.

Special contributors are my friends, who have continuously assisted me with their unconditional love and support.

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Epoka University or other institutions.

Alba Xhani

May 2013

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PREFACE

…and remember "Aal Izz Uell". This phrase, taken from the Indian movie "Three idiots" has been my comfort in some difficult moments. It has a very significant meaning that whatever difficulties you face in life, if you don't lose your faith, everything will be ok.

CHAPTER 1 INTRODUCTION

The Health Information System (HIS) of a country is the collection of the health data of the population that can be retrieved and managed from different health system entities whenever needed using Information Technologies. It may include features like converting the paper-based medical records into electronic ones, make the data available to eligible parties such as general practitioners and the automatic generation of periodical medical reports useful to many institutions inside the health system or that interact with it.

The main cell of the HIS is the health record. According to the report written by PCAST for the president of the USA, about improving healthcare for Americans using HIT, an Electronic Health Record is an electronic record of health-related information for a patient that contains information captured in clinical visits, lab and imaging studies, and other information important to the patient's medical past.

Health Information Systems, in global terms, have had a lot of developments and improvements through years going in a proportional increase with the life expectancy [2].

According to Haux, there have been some lines of development:

1. From paper-based to computer-based medical records storage and processing;
2. From institution-centered departmental towards regional and global HIS;
3. The involvement of patients as HIS users;
4. The usage of HIS for research and study purposes;
5. From simple text data in HIS to images, videos or other data formats;

6. New technologies to improve healthcare quality, like sensor-based technologies

The accuracy and speed of collecting, spreading and using information remains still a challenge not only for developing countries like Albania, but also for many developed countries.

Unfortunately Albania still stands in the first stage of development, with a minimal number of computer-based procedures mainly present in the private health sector.

The weaknesses of the system has not to do with health instruments used to monitor and diagnose health problems, as much as with the processing and storage of the data in an organized way, to be later accessed without any delay or error.

Based on an assessment made from Curatio International Foundation in 2008 [3], it results that some of the weaknesses of HIS in Albania are:

- There is not a unique identifier, hence we have different databases that are pieces of the same puzzle, but with no connection between them,
- Data is spread everywhere, there is not a centralized data warehouse to keep it collected,
- No integrated HIS reports developed and distributed regularly to key stakeholders, etc.

However, there have been some approaches to improve the health system in Albania, by creating two online programs, which more than to the health information, contribute to the statistical aspect and budget calculations of the local clinics.

The fact is, that Albania lacks an organized and well-structured HIS and this makes the communication and interaction between health institutions difficult.

The usage of paper-based records and the so-called "libreza e shendetit" to have health facilities, slow down all the other procedures. To update the right of obtaining a refund for taking drugs in a pharmacy, a patient no matter young or old, goes to the doctor to make a medical visit and prove his/her health state and be eligible to take the refund. All the necessary information that authorizes the pharmacist to give medicine to the patient based on this refunded amount, is written down in the health card, so it is a must for the patient to bring that in the pharmacy. Not only in health cards, but most of the cases it is very difficult for the pharmacist to read and decipher the doctors' calligraphy. The transmission of the electronic data, directly from the doctor to the pharmacist, certainly with the patient authorization would be an optimal solution that would provide accuracy in delivering the medicine to the patients exactly as it is prescribed and time efficiency.

Furthermore, data travelling from low-hierarchy to high-hierarchy institutions is not safe and secure as it may encounter problems on the way. If for any reason data is damaged or something misses, it is very difficult to find the responsible and the source of the problem.

The solution proposed in the thesis is about the efficient design of a web-based distributed application and a large well-structured database that will not only store health records for patients, but also generate necessary reports for GP, specialists, patients, pharmacists or third party institutions of the Health Information System in Albania.

The main component is the Patient-GP interaction system, the patient that has the right to view his medical data and medical history through a web browser, and the General Practitioner who updates the information about the patient as needed. The

manipulation of this data, from the other components leads to what we call a complete Health Information System

Physicians will have fast results while searching the health history, deciding the diagnosis for a patient and prescribe the right medication.

From the other hand, pharmacists will not deal with the handwriting of the doctors, hence will be more accurate in giving medications to patients and in other cases when there is not a prescription available and the patient trusts the pharmacist, having a full view of the patient health history, will increase the credibility on the pharmacist advice.

The precise electronic billing of medical services will avoid the corruption in a certain degree as everything is operated online, without the interaction between doctors and patients.

The implementation is done through Spring MVC framework using as an IDE Spring Tool Suite (STS), which is Eclipse powered and provides a lot of facilities. To give the Webpage a user-friendly appearance, there is used the Twitter Bootstrap which includes some nice CSS3/HTML5 and JavaScript features. The view is structured into JSP. Considering the fact, that most of this technologies where new to me, I spent a lot of time on research and learning, that is why I chose to implement only one of the components that seemed the most important to me: The patient-doctor interaction. Considerable time from the research was dedicated to the requirements definition, because such a system involving a large number of users and data, needs to be well defined and secure.

To conclude with this introduction session, the importance of implementing and improving a digitalized health information system is also mentioned in the remark of

the president of USA, Barack Obama on the Joint Session of Congress on February 24th, 2009:

"Our recovery plan will invest in electronic health records and new technology that will reduce errors, bring down costs, ensure privacy, and save lives." [4]

CHAPTER 2 LITERATURE REVIEW AND TECHNOLOGIES

This chapter consists in the description and analysis of the global background in terms of health information technology for data management and more specifically about the solutions offered from different projects to achieve the digitalization of this system. Then, there is a detailed description of the structure of Health Information System in Albania, the health information flow and what is done so far with the computerization of health services

2.1 Global Background

Global Awareness about the management of health resources and data through the usage of information technology has brought to life a new research branch and many applicative results.

Many developed countries have emerged the design and implementation of Health Management Information Systems. There are some success stories, but there are also some weaknesses of these systems, as to date it hasn't been achieved yet an optimal usage [5]. Very successful initiatives are those offered by private companies, most of the cases independent from the public institutions that offer good solutions.

2.1.1 National Health Information Systems

The devastating development of information and communication technology has inspired many countries to digitalize their National Health System, which is a health system that includes all citizens of a country.

- Australia E-health

The work for e-health development in Australia started in 2008 [6], with the development of a strategic framework as a guide to the national coordination and collaboration in E-health and E-health records started in July 1st, 2012.

E-Health offers to the health service providers a Healthcare Provider Identifier to store and manage the patients' data electronically.

It does not support the replacement of existing medical records or any review of existing clinical nodes.

The patients are not able to insert data into the clinical records, but only authorized healthcare staff can do this. Patients can only enter demographic and basic information about themselves.

- Turkish National Health Information System

A successful implementation of a National HIS is the Turkish one, which is operational, but still not fully-featured [7].

It provides a nation-wide infrastructure for facilitating the efficient sharing of electronic health records. Data are collected from all healthcare institutions (Hospitals, laboratories, etc) to the Ministry of Health servers in Ankara, in a centralized architecture. The messaging infrastructure is based on HL7 v3 (Health Level 7), where number 7 regards to the seven OSI layers. HL7 is a global framework of standards for health information exchange [8]. The communication protocol used, is Web Services [7]. There are plans to enhance this system by adding other features, but the process goes parallel with the implementations of standards for each feature.

2.1.2 Open-source approaches

- Open EMR

OpenEMR is a PHP web-based open source platform for the management of electronic health records and can run on different operating systems [9].

There are different views for users, for example physicians and patients have different interfaces and privileges as well.

This application offers many features and as it is based on the contribution of volunteers among which there are also professionals, it can be adapted to different system designs.

The website that hosts the project, also includes the system architecture, developer manuals with all the functions and demos to test the application.

- OpenMRS

OpenMRS is another open source Web-based Medical Record System but built using Java programming language, MySQL database and Hibernate for mapping objects to database entities [10]. OpenMRS has a wide usage and it a good basis for developing customized MRS systems.

- THIRRA

THIRRA (TeleHealth and Health Informatics for Rural and Remote Areas) in an open source EHR system, PHP based, built with CodeIgnitor Framework on a Hirarchical Model View Control design pattern. It uses PostgreSQL database system and JQuery UI Javascript Framework. It is used in the public health sector of Malaysia, Nepal, Philippines and Sri Lanka [11].

2.1.3 Personal Health Records

According to a report from the U.S. Department of Health and Human Services about PHRs and PHR systems [8] there is no uniform definition of the term “personal health record” in industry or government, because the concept is relatively new and it continues to evolve. This makes collaboration, coordination and policymaking difficult.

In the cases discussed below, PHR are web based- applications offered as an interface to people to store, view and share information about their health, with third parties that might be healthcare providers or other users. The accounts are personal and protected by privacy rules and standards.

- Google Health

Google Health was a PHR that provided the users with a mean to manage their health records and share them with third parties. Google Health [9] may be considered an unsuccessful story, because as it did not have the expected impact, it was discontinued in January 1st, 2013 and all the patients' data where permanently deleted.

- Microsoft HealthValut

HealthVault [10] is a PHR powered by Microsoft that works with health and fitness devices to collect valuable information, then store it in one central location. It allows its users to share information in a network of users or healthcare providers. A user can share a health record with a hospital, but with the possibility to filter data that he/she do not want to share or that are simply unnecessary.

It offers a large range of features, applications, devices and also provides extra information about healthcare.

2.2 Structure of Health Information System in Albania

The Health Information System in Albania in 2008, according to the assessment study made by Curatio [3], is divided into four layers: the municipal, the district, and the region and central layers.

At the top of the hierarchy of the Health Information System is the Ministry of Health. The department for Technology and Health Information of the Ministry of Health collects data from the Health Care Facilities using forms, that include information on facility workload, registered diseases and conditions from hospitals, patient check-ups, child patient care data, and lab activities.

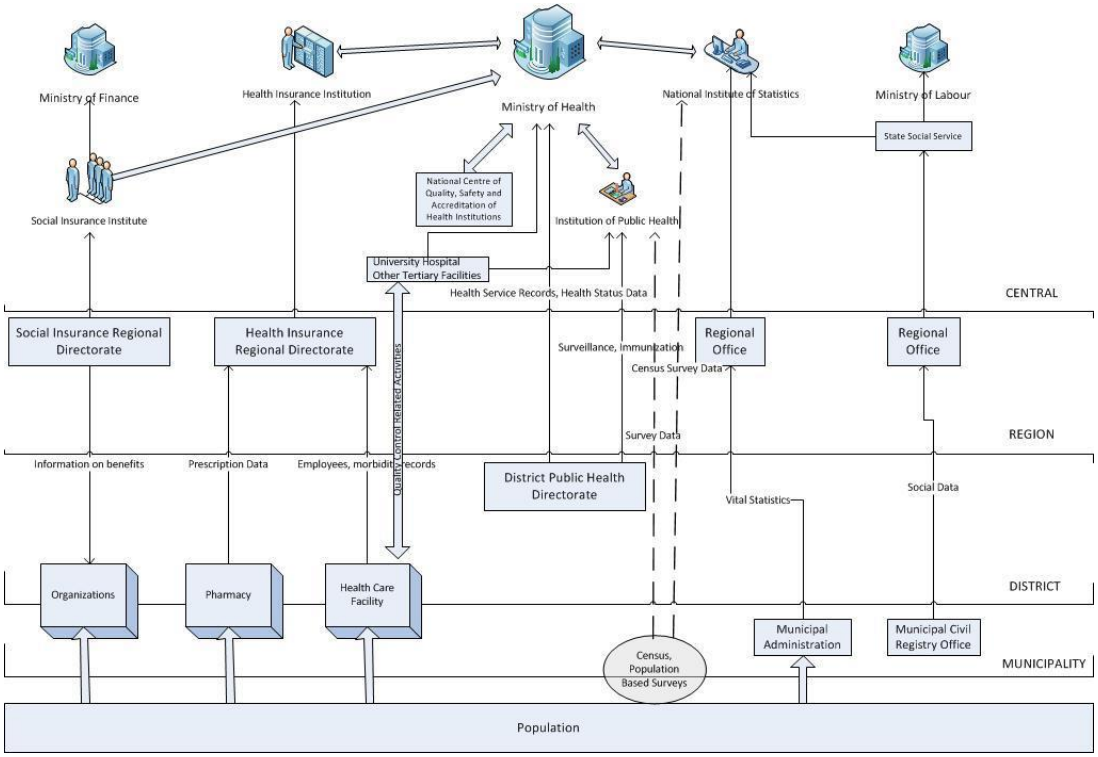

Figure 1 - HIS in Albania

Facilities first submit the forms to the District PHD, which then sends the forms by mail to the Technology and Health Information Department. Most important facilities, like the University Hospital, directly submit the forms to the MoH. The Technology and Health Information Department processes information and produces

summary reports. Information is further forwarded to the National Institute of Statistics (INSTAT), Institute of Public Health and to other institutions.

There is a large data flow between the components of HIS, as data is exchanged as well with other institutions related to Ministry of Finance and Labor. Consequently, it is necessary the establishment of a strong data management system that collects data from all data sources and makes it available to all the users, who would be identified through a unique ID, in all the databases.

2.3 Electronic Health Resources in Albania

According to an interview given from the director of the HII in Albania [11], Health Information System, is in its initial steps and they are going further for the digitalization of all the branches of the health system in Albania. To date, there are two online platforms that have achieved this somehow, but not finalized yet, the citizen electronic register and e-pharmacy.

- Citizen Electronic Registry

The implementation of the Citizen Electronic Register is planned to end in march 2013, but there have been a lot of difficulties on the way, while collecting and inserting data. This platform predicts the registration of all patients, distributed in local clinics. The unique identifier used is the ID card number. Other data collected include doctor's id, patient's name, paternity, surname, birthday and residence.

There are a lot of advantages in the usage of this platform. There are 3.8 million paper-based records, while less citizens, which means that many records are duplicated for different reasons. One of the reasons might be the displacement of the citizens from one city to another.

The purpose of this project is to register patients through the id card, removing so the possible existing duplicates and the exact calculation of the state budget for every clinic, so that the salary of the GP is calculated exactly by the number of the patients, so there is no place for abuses.

A weakness of the system is that the information about health is not included and linked with the other data. I think this is a big disadvantage, because the database must be restructured if any change of this kind is predicted for the future [12]. In that case, data must be recollected, which means time and money gone misused.

- E-pharmacy

Another approach to digitalization is the e-pharmacy platform, an online platform used by the pharmacists to insert data about the prescriptions' refunds covered by the insurance. A patient record includes the patient code, which is not same as his ID card number, prescription id, pharmacist id, the medicine taken, the price, dose and amount. Moreover the pharmacist takes information from the paper-based cards to insert it into the computer.

These two platforms are not connected through any identifier, even though they serve to the same system, which is Health Information System. This is another disadvantage that would require a lot of work in the future, if any improvements were to be done.

- Immunization Information System

Another project focused in easing a HIS branch is the Immunization Information System [13], a pilot project developed in Shkoder, Albania, from the Albanian Ministry of Health in collaboration with Path. The system was about improving the management of the vaccination program, the main purpose of which was to equal access to immunization for all children and reduce the administrative difficulties experienced from the staff.

The system has a central database where information about the newborns and their parents is registered. Each child has his/her own schedule of appointments for the vaccine. When time for the appointment comes close, the children are included in the monthly plan of the health center.

The nurses receive automatically the list of children scheduled for a certain month and can notify parents using their data that is previously registered in the system. They can easily generate the number of vaccine doses required, so they know the quantity to order.

There has also been started testing the mobile version of the application that offers most of the functionality of the web-based system.

There are a lot of benefits provided by the IIS: time efficiency and easiness in tracking a child vaccination history, the possibility for parents to print certificates about the vaccination that are required in schools or other institutions, allows the Ministry of Health calculate the exact budget reserved to the vaccination process, monitor the number of vaccines available, dates of expiration, etc.

The problem is that the system is not implemented in all districts to reach all these benefits.

E-pharmacy, citizen electronic register and the Immunization Information System are three subsystems of Health Information System, but not interconnected with each other through unique identifiers

Anyway these approaches ‘break the ice', and make clinics' staff more aware with the usage of technology in this field.

- SAP

From the other hand, most of the private hospitals here in Albania, use SAP (System Applications and Products) [14], which is a solution for the businesses to store and manage data. It has a wide range of applications, one of which is the healthcare solution. SAP is a full package that includes not only the basic services of healthcare, but also financial procedures and decision making.

There is no data sharing or any other connection between the public and private health sector. For example, a patient that is already registered and has a patient record in the public clinic, once having a visit in a private clinic gets another patient record that does not include the previous health history, and has no connection with the other one at all.

The resources of the World Health Organization, contain an assessment of the Health Information System in Albania in 2008 [3], where one of the areas included where the computerization or digitalization of the system.

According to Chikovani, who has written the report, the goals set for the upcoming years would have been:

- The identification of a standard for Albania for data entry in 3-5 years’ time, defining a strategy and prepare an action plan/timetable how to achieve this.
- The definition of how the different platforms could be linked,

- The definition of the technical requirements for the unique identifier code, timing and procedures for its introduction

2.4 Health Information Exchange Policies and Standards

As a great amount of data is transmitted and processed electronically, the pre-existing standards about the paper-based data exchange, needs to be updated.

An approach for the standardization of Health Information Systems is done by Health Metrics Network (HMN), as a branch of the World Health Organization. HMN has launched a guide for the collection, reporting and use of Health Information Technologies by developing countries [15]. According to HMN, there are six components and their associated standards that make a Health Information System. These components are:

1. Health Information System resources - legislative, regulatory and planning frameworks, information technology tools, financial support, staff and personnel;
2. Indicators - include: determinants of health, health system inputs, health status (level of mortality, disability, etc);
3. Data Sources - population-based (censuses, civil registration) and institution-based(individual and service records), health surveys and research;
4. Data Management - issues of data handling (collection, storage, process-flow, analysis, execution);
5. Information Products - outputs of the data processing, useful information and knowledge;
6. Dissemination and use - accessibility given to decision-makers and other users

According to Goldstein, and Rein [16], the data segmentation as a solution for the protection of sensitive health information provides means of protection for specific elements including patient privacy issues, if applied in all levels of the electronic health information exchange environment. A lot of systems are engaged in data segmentation as it provides: greater autonomy, direct financial and other support and generate evidence.

2.5 Technologies used and definitions

To build the patient-doctor component of EHDMS, I preferred to use Java and its technologies. Java is a High-level Object Oriented programming language. It is platform independent, because it compiles and runs in its own container. It provides debugging, packaging and deployment, features that PHP doesn't have yet.

As Java Desktop Applications run in Java Virtual Machine, Java Web Applications run in a container and this container runs in the web server. I have used Tomcat as a servlet container for the Java Web Application and Apache as web server. An important requirement before starting the work, is the installation of the Java Development Kit (JDK)

To give a frame to the application, I chose Spring Web MVC framework, which offers a well-structured application template with other support features. To understand how this framework works first some definitions are necessary:

- Java Servlet is a Java class that receives and responses to http requests within a web container. It extends HttpServlet class [21];
- Java Server Pages are files that are used to manipulate HTML code through Java.

The Web Application functionality depends on the Front controller (Dispatcher servlet) which handles incoming requests and delegates them to the Controller. To annotate controllers, the <annotation-driven> tag is used and whenever a '@Controller' is met it is scanned for the Request Mapping value. Once the controller that handles the request is found, it returns a model to the servlet. The servlet adds the prefix and suffix as defined in its configuration and sends the model to the requested view. When the view is returned to the front controller, it returns the response to the client browser who initially requested that page.

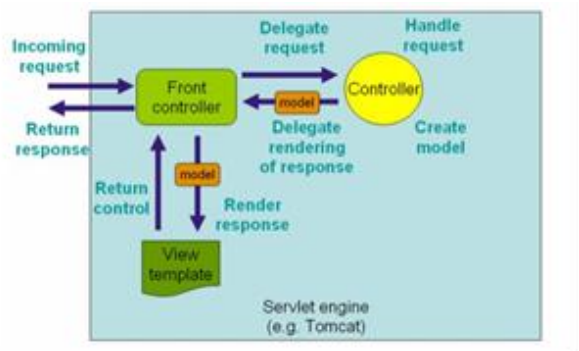

Figure 2 - Dispatcher Servlet Request Handling

Annotations such as @RequestParam, @RequestHeader, @PathVariable, @RequestMapping are used in controllers to provide different control scenarios.

Spring MVC is a very flexible framework. The Spring Template Project comes with

```
package com.ehealth.web.controller;
import java.security.Principal;
import org.springframework.stereotype.Controller;
import org.springframework.ui.Model;
import org.springframework.web.bind.annotation.RequestMapping;
import org.springframework.web.bind.annotation.RequestMethod;

@Controller

public class HomeController {

      @RequestMapping(value="home",method = RequestMethod.GET)

      public String welcome(Model model,Principal principal){

            return "home";

      }

}
```

Figure 4 - Sample Controller

Maven Artifacts as well, which are files necessary for the application to run. They are in the Maven repository which may be either in our local system or stored somewhere else and accessed remotely [22]. Project dependencies, which contain the configuration of these files are defined in an xml file (pom.xml) as below.

```
<!-- Spring JDBC -->
<dependency>
<groupId>mysql</groupId>
<artifactId>mysql-connector-java</artifactId>
<version>5.1.9</version>

</dependency>
```

Figure 3 - Maven Dependency

Dependencies such as spring security, jdbc, etc, are loaded from Maven Repositories.

The view component is an important one, because it manipulates what the user will see in the browser. The technology used to deliver view responses to the user are Java Server Pages. Among HTML syntax, JSP use the JSP Standard Tag Library (JSTL), which is a group of JSP tags which deliver core functionality to JSP applications [23], in terms of markup code. According to their function, the JSTL Tags can be: Core Tags, Formatting Tags, SQL Tags, XML Tags or JSTL Functions.

```
<fmt:message key="title"/>

<c:out value="${model.getPatient()}"/>
```

Figure 5 - JSTL Example

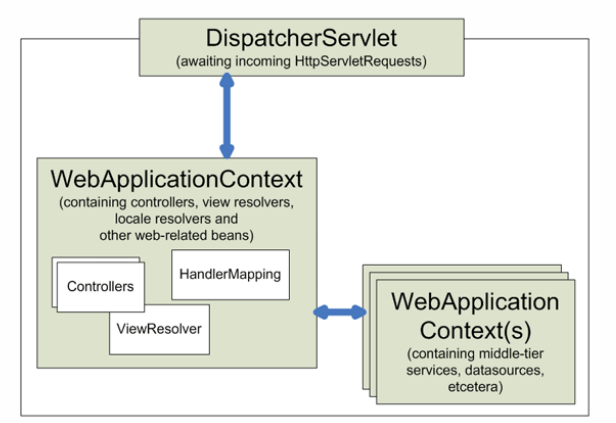

Figure 6 - Context Hierarchy in Spring MVC

One of the benefits of using Spring Tool Suite (STS) an Eclipse powered Integrated Development System, is the documentation which is written very clearly through the comments in each file.

Another file that is generated with the Spring Template Project is the

WebApplicationContext which contains Beans (Java Classes that are Serializable and have a number of properties which can be written or read).

```
<bean id="propertyConfigurer"
class="org.springframework.beans.factory.config.PropertyPlaceholderConfigurer"
p:location="/WEB-INF/classes/jdbc.properties" />
```

Figure 7 - Bean Example

In the above case the bean is just about locating and reading the Jdbc properties, by giving their location.

```
<bean id="dataSource"
class="org.springframework.jdbc.datasource.DriverManagerDataSource"
p:driverClassName="${jdbc.driverClass}"
p:url="${jdbc.url}" p:username="${jdbc.user}" p:password="${jdbc.pass}" />
```

Figure 8 - Database Connection JDBC

This bean reads the database credentials from the properties file and dataSource is shared among all components of the Web application. Further to execute queries for at least the basic functions CRUD (Create, Retrieve, Update, Delete) the database is accessed through the Database Access Objects (DAO) which are Java classes that declare methods to give to the object the value of a database entity and send it to the model.

The above described technologies are the simple basis, over which the application is built.

CHAPTER 3 SOFTWARE ANALYSIS AND SYSTEM DESIGN

This chapter describes the system and user requirements, classified as functional and non-functional requirements. The structure of the requirements and then the software engineering diagrams, based on Unified Modelling Language [17].

3.1 Requirements Specification

Electronic Health Data Management System is a resource of information and interactions for the Healthcare Providers, the patients and those who interact with the health system of the country. It receives data input from users, processes it and distributes it to the network of the Health Information System, according to some standards and rules.

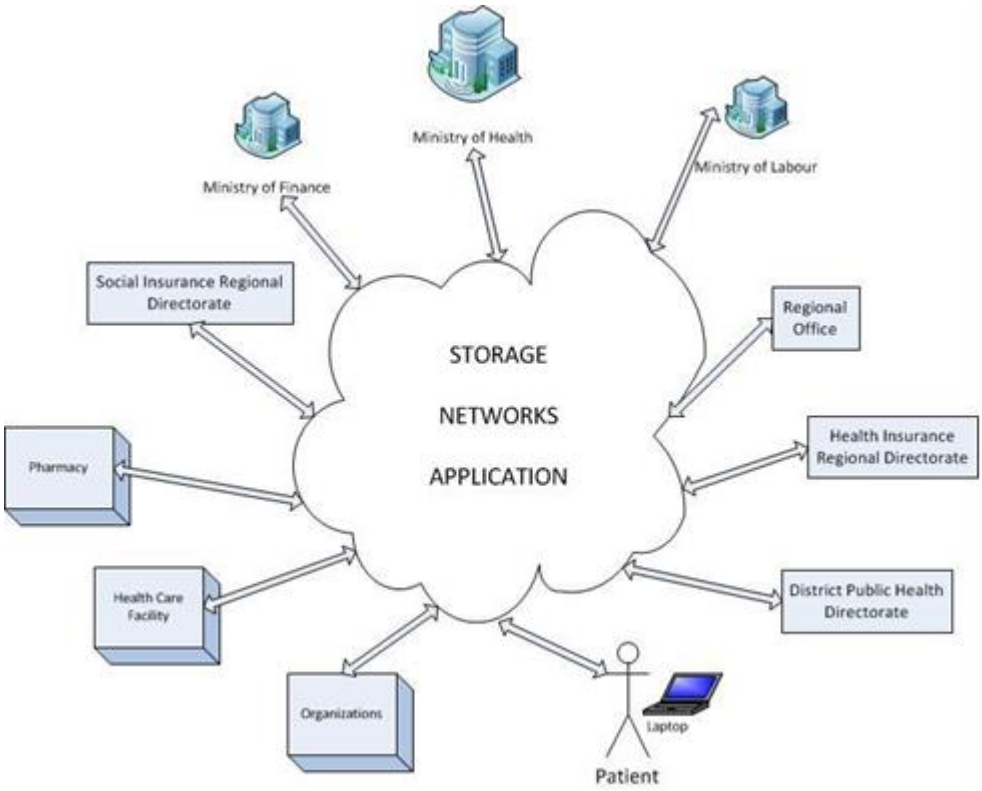

Figure 9 - Centralized EHDMS

3.1.1 Functional Requirements

According to Sommerville [17], the functional system requirements describe the services that the system must provide to the users. They must be complete and consistent.

The main purpose of the Electronic Health Data Management System is to get input data about patients, store it in a well-structured database, with a unique identifier for each user, and generate information, at any time required from the user. On the other hand, the user can be a doctor or physician, a medical assistant, a patient, a pharmacist, a HIS institution and they must have different views and privileges about the system usage.

- User functionality

  User login: every system user has the right to login by providing a username and password

  View and navigate the home page: The home page contains general information regarding to health system, news and announcements and the login link, that is why it can be accessed by every user.

- Patient functionality

  Patient login: the patients have the privilege only to view their data

  Search for a doctor

  Require an appointment, defining the reason, time

  Send inquires or emails to doctors

- Health Facilities Functionality (GP):

  GP login: the GPs have the privileges to view and edit health information about the patient as needed

  Search for a specific patient, by id, name, surname,

Register patients

Update patient medical information

Delete patient record

Create a new prescription

Communicate with the patients through an email system

- Pharmacy functionality

  Pharmacist login: pharmacists have the privilege to view only their clients' data, their medical history

  Process the prescription using the unique key given from the patient

  Mark the prescription as completed

- Visitor functionality

  Search for clinics

  Search for doctors

  Read every information published as public in the website interface of EHDMS

- System functionality:

  Generate daily reports for each clinic, about the patients that are having appointments that day and the doctors performing the visit as well. When the doctor creates a new prescription, the system generates a unique key, which is needed to process the prescription from the pharmacist.

3.1.2 Non Functional Requirements

Non-functional system requirements are the requirements that are not directly related with the functionality that the system delivers to its users, but play a very important role in the overall functionality of the system [17].

- Product Requirements

  The EHDMS must be available as a web-based platform to all the users: patients, clinics and hospital staff, Health System Institutions staff and other users of the platform, 24-hours, and 7 days of the week.

- Organizational Requirements

  Users have to insert their authentication data (health id and password) at any time they want to login. Otherwise they won't have access at their personalized data. Only registered users can login to the system.

- External Requirements

A new user, must agree with privacy rules, and terms and conditions to sign up. Furthermore, the system must be updated with the changes of legislative requirements time after time.

3.2 System design and modelling

According to Sommerville, system modelling is the process of developing abstract models of a system, with each model presenting a different view or perspective of that system [17]. In this section the Unified Modelling Language (UML) will be used, to represent the EMR system functions and scenarios, collaboration between different parts of the system, the objects and classes.

3.1.3 Use Cases and Scenarios

A use case identifies the actors involved in an interaction and names the type of interaction, while the scenario describes the interaction in details, by creating the actions' flow, and how the errors are handled when they occur [17].

In general, there is no need for the actors of the application to communicate with each other, exchanging data by e-mail, or sending requests, because everyone has his/her pre-given duties, based on the role he/she has in the health information system.

If someone makes a change to a record in the database, it is reflected in the system, with the name and role of the person who did the change.

Everyone has to perform the authentication step, in order to log in and load the data stored in the system. Authentication is performed by inserting the health card id and a personalized password.

Once authenticated each one has a different view based on the role and tasks he/she can perform.

The system administrator and the IT department control the privileges of each user according to a predefined standard. They take care about the data periodical backups, system updates and maintenance, technical support, report about devices used, etc.

The health facilities, i.e. General Practitioners, register new patients, update records of existing ones, and arrange appointments, set appointment details, prescribe drugs to the patient if necessary. In case, the GP cannot handle a patient case (it is out of his responsibilities and abilities), the patient goes to the specialist, which performs

the same actions as the GP, except the fact that he has access to a limit number of patients.

The patient can search for doctors. Clinics or just information about diseases, published statistics and surveys, etc. He/she can view the personal medical data, and update general information such as weight, height and password. The patient enquiries an appointment, and confirms prescription receipt.

The pharmacies are connected to the pharmaceutical inventories to order drugs, according to the amount of drugs present in the stock. Once the pharmacy creates an order, and sends it to the inventory, the customer support sends an immediate answer if the order can be processed or not, so for the pharmacist to look for another inventory or wait for the order to complete, with the drugs transportation into the pharmacy. Once received the drugs, the drugs record of the pharmacy and the inventory are updated.

The Ministry of Health operates through the department of Technology and Health Information, which sets and updates system policies, updates physicians data or add new ones, update drugs data, information about diseases, facilities details and generate various reports. Institutions like HII, IPH, INSTAT create the connection of the system with other institutions outside the boundaries of the HIS.

- Use Case #1: Login into the system

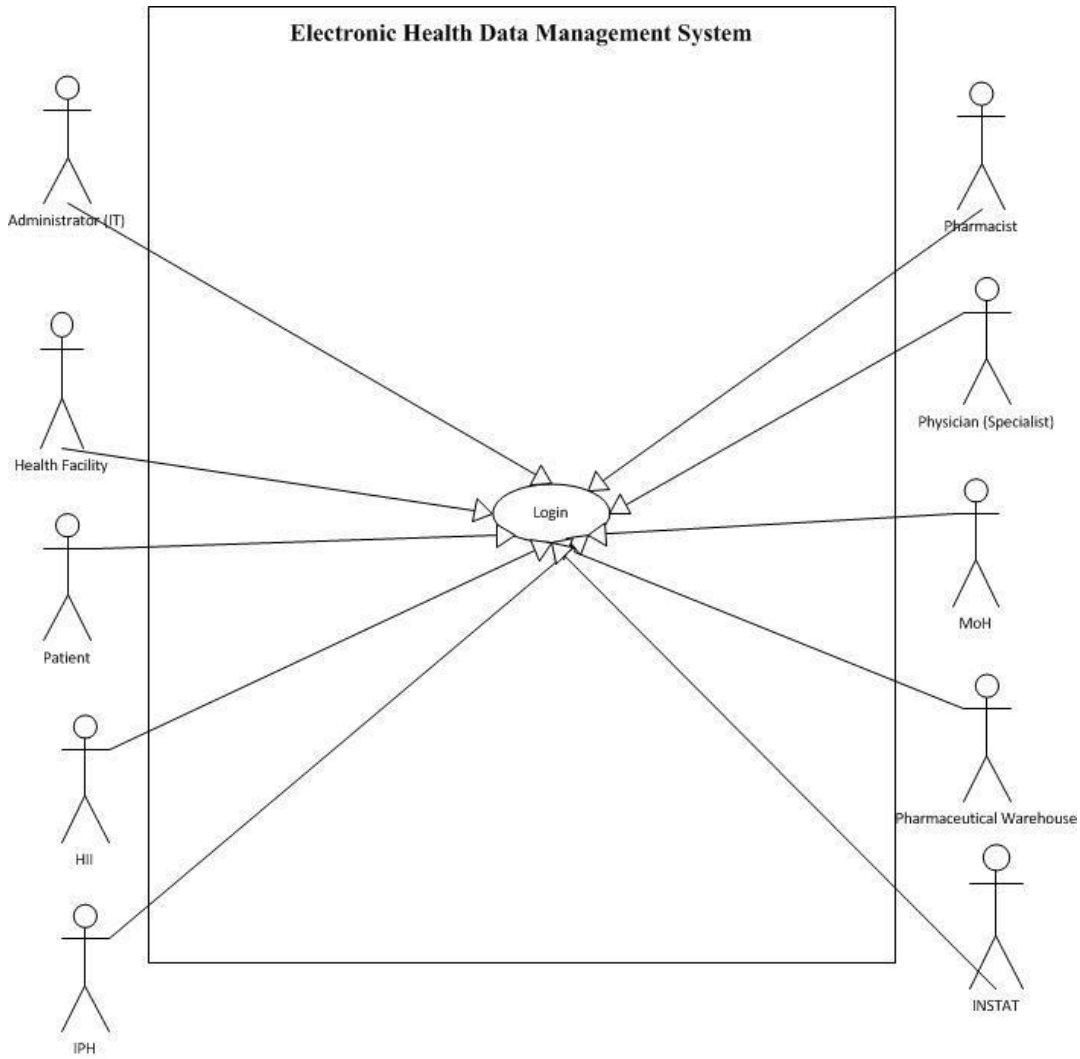

Figure 10 - Use Case: login

Main Success Flow:

All the system users have to provide some authentication information to login into the platform. The authentication required from all is: the health card id and the password.

Possible derivations from the success flow:

The user forgets the password. In this case a password reset is necessary. User receives the reset link by email.

The user exceeds 5 times of entering wrong authentication data. In this case an automatic email is sent to the user, telling him about a possible attack from someone else.

- Use Case #2: Patient Registration

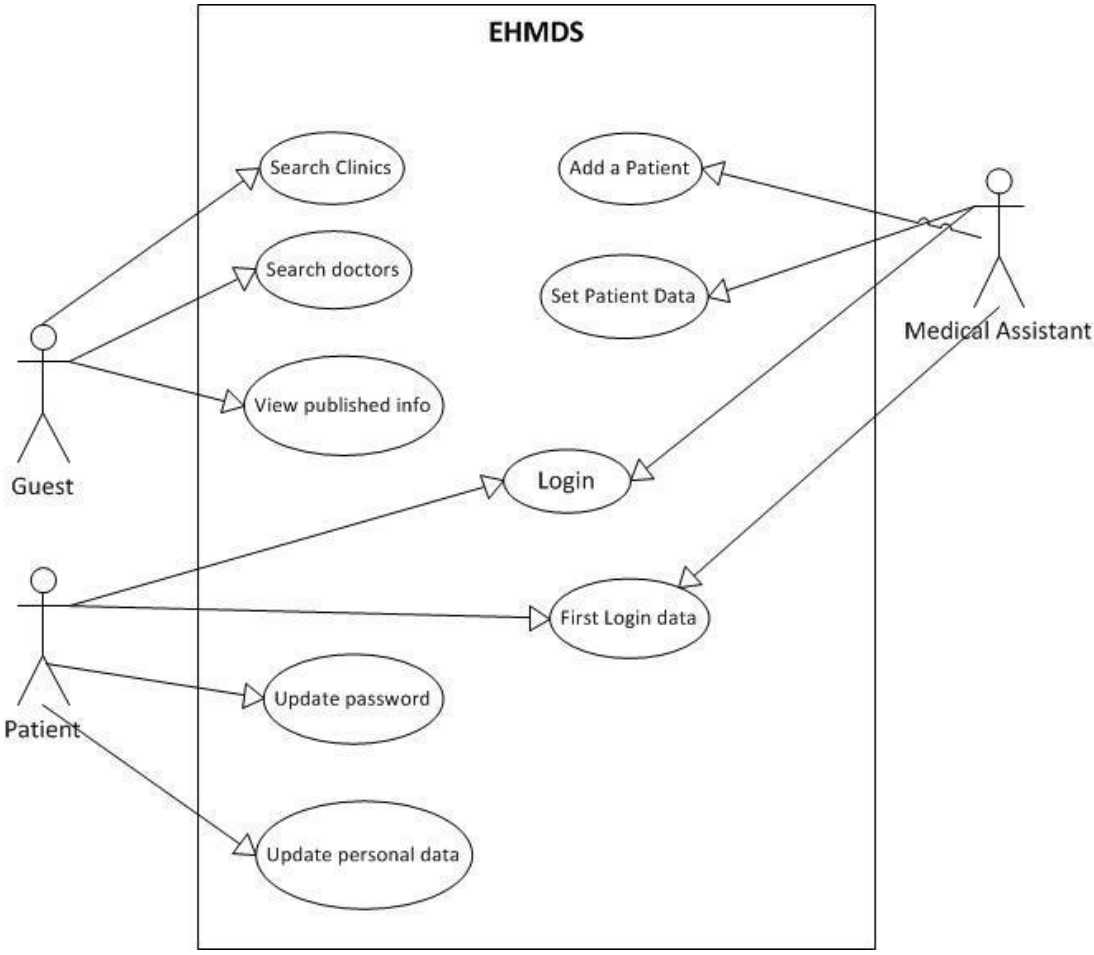

Figure 11 - Use Case: Patient Registration

The user that can perform the patient registration in the system is the GP or the medical assistant of the GP. To be a part of the EHMDS, the patient must provide some documents according to the law and healthcare policies

Main Success Flow:

The patient has accomplished the conditions defined by the policies.

The GP logs in and fills in a form with the patient data. When the form is submitted an email is sent to the patient with the first login information (password and the health id).

When the patient logs in for the first time, he is required to accept the terms and conditions and agree with the privacy policy. Then he is prompted to change the password.

The patient views his medical information. As he is a new user the only information retrieved is the registration date.

The patient can set some health parameters not necessarily required such as weight, height.

Possible derivations from the success flow:

The patient does not provide the GP with the necessary documents. The GP does not perform the registration.

Other use cases are included in the Appendix.

3.1.4 Activity Diagrams

According to Sommerville [17], an activity diagrams, is part of the system modelling that shows the activities of a system process and the flow between them.

- Login Activity

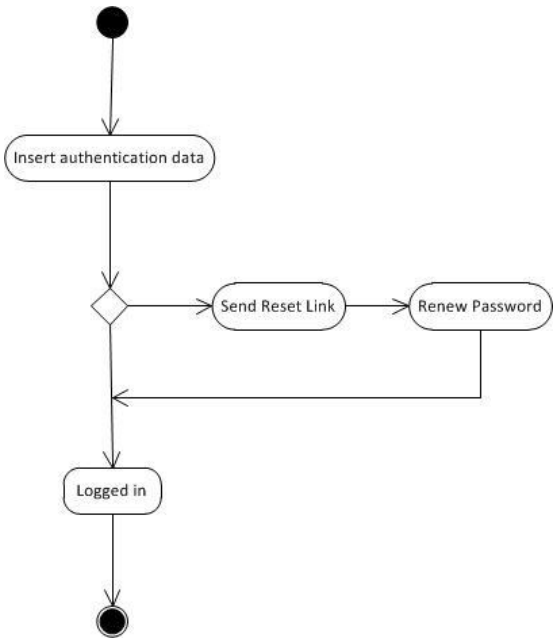

Figure 12 - Login activity

The login activity is performed by all the users. It is very important because no one can gain access to the system if does not provide valid authentication data.

Login is performed, by entering the health id and the password.

Health id is unique for every user, while password is maintained by the user, who can modify it at any time.

It the user is not able to login, he may request a password reset. An automatic e-mail with the rest link, is sent to the user. Once typed the link, he is able to change the password and set a new one.

- Patient Registration Activity

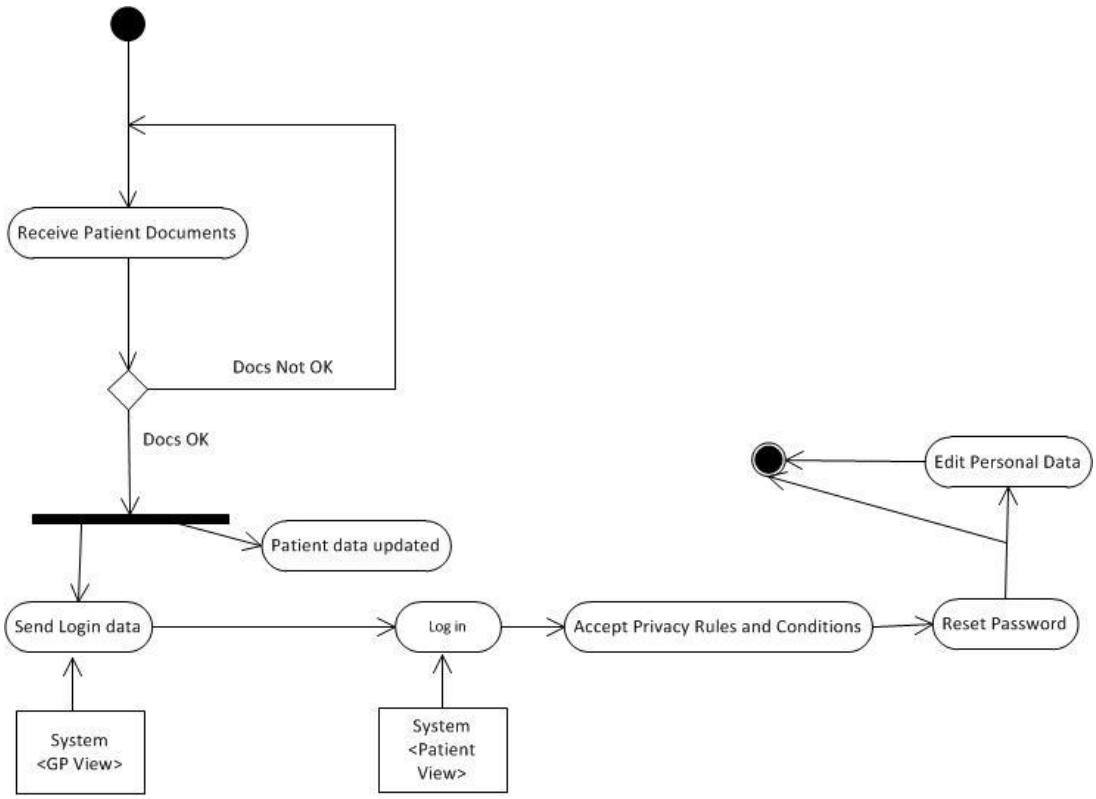

Figure 13 - Patient Registration Activity

3.1.5 Swimlane Diagrams

Swimlane Diagram shows the process activities divided into lanes, where each line presents a system user or a system component.

- Drugs Order Swimlane

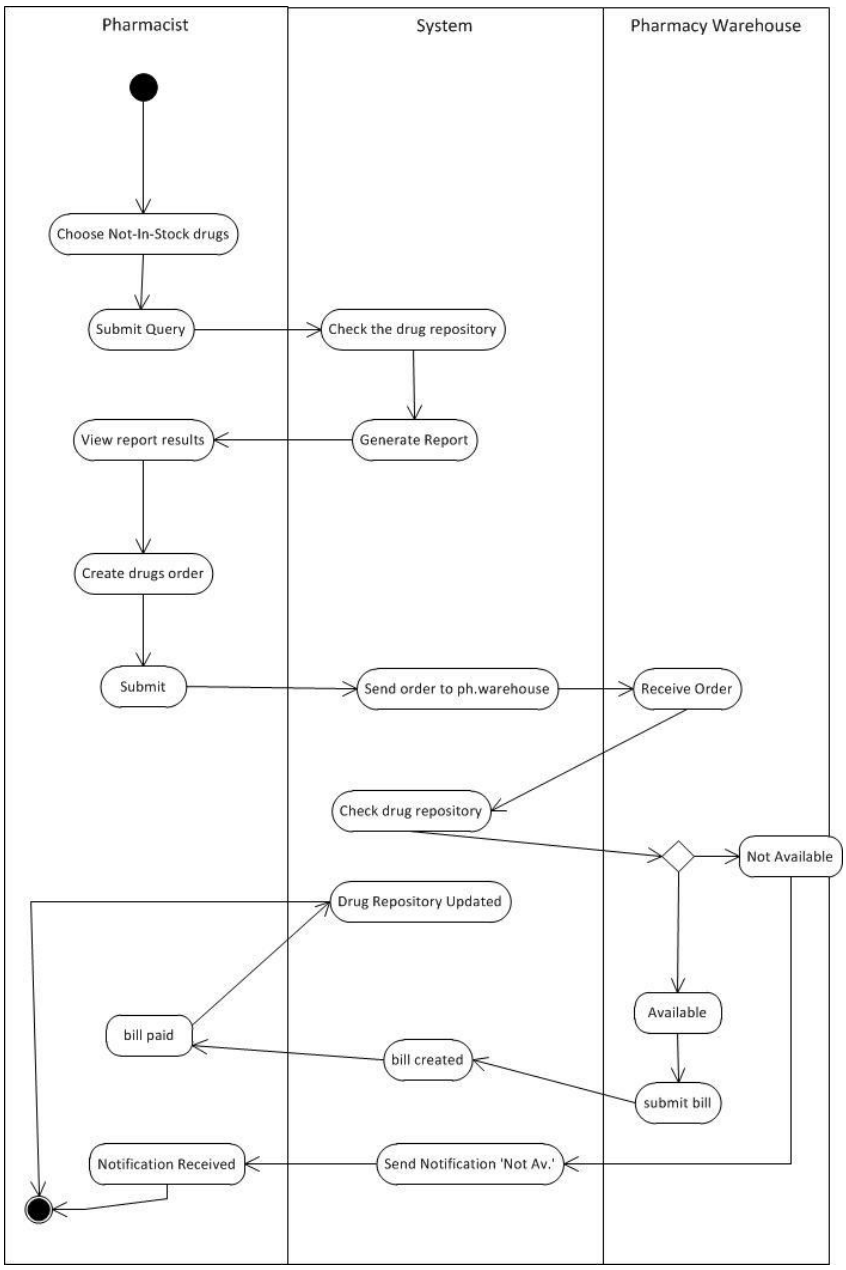

Figure 14 - Drugs Order Swimlane

The swimlane given shows the flow of ordering drugs, which usually includes two main actors, the pharmacy and the pharmaceutical warehouse.

The pharmacist generates periodically a list with the drugs with the status not-in-stock, which means that these drugs are not present in the pharmacy inventory. According to the results, the pharmacist either calls the pharmaceutical warehouse to process the order, or creates and e-order through the system. Once submitted, the

order is sent to the pharmaceutical warehouse. If requested drugs are available, it is continued with the bill generation and payment, and the drugs delivery to the destination.

If requested drugs are not available, then the pharmaceutical warehouse communicates with higher-level suppliers.

3.1.6 Sequence Diagrams

The sequence diagrams, represent the actors' interactions with the objects of a system

- Generate Reports Sequence

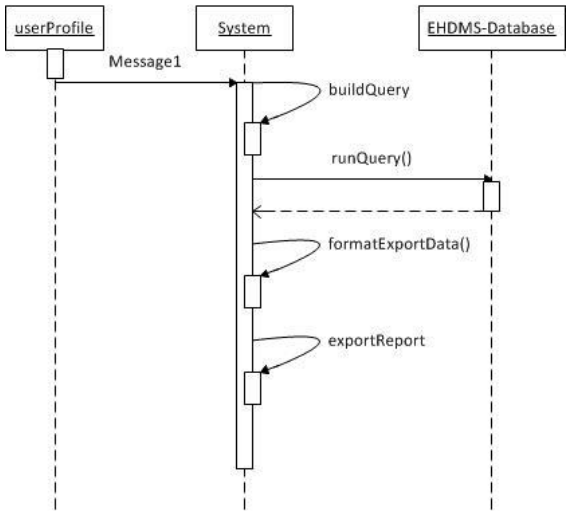

Figure 15 - Report Generation Sequence

The above diagram is about the interactions between the application, database and user object in order to export data, to generate reports that might serve for different purposes. It can be noticed that all the functionality occurs in the system, while the database is accessed to retrieve the data from, as defined from the query entered by the user.

The results of these interactions give a report that satisfies the user requirements. In the studied case, the report might be generated by a IPH employee for statistical purposes.

3.1.7 Class Diagram

The class diagram shows the class components of the system and the relations between them. As the system is too complex to be drawn with all the classes, above there are given only some of the classes that affect the patient medical data

- Electronic Medical Records Class Diagram

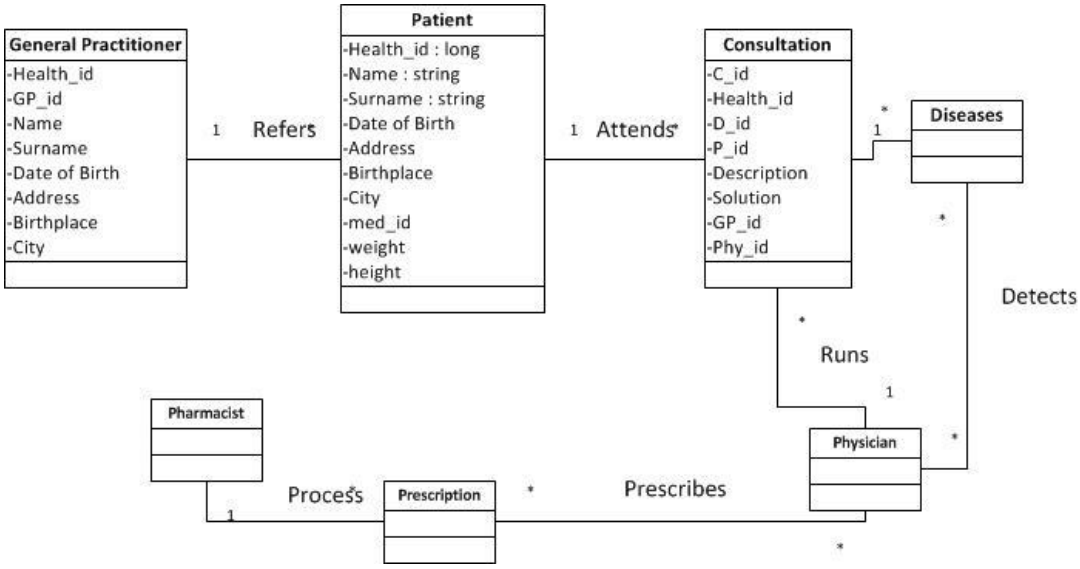

Figure 16 - Class Diagram

3.1.8 Deployment Diagram

The deployment diagram gives a clear view about the system architecture. The system proposed has a multi-layered based architecture, where layers are independent from each other but still communicate in transporting and processing data.

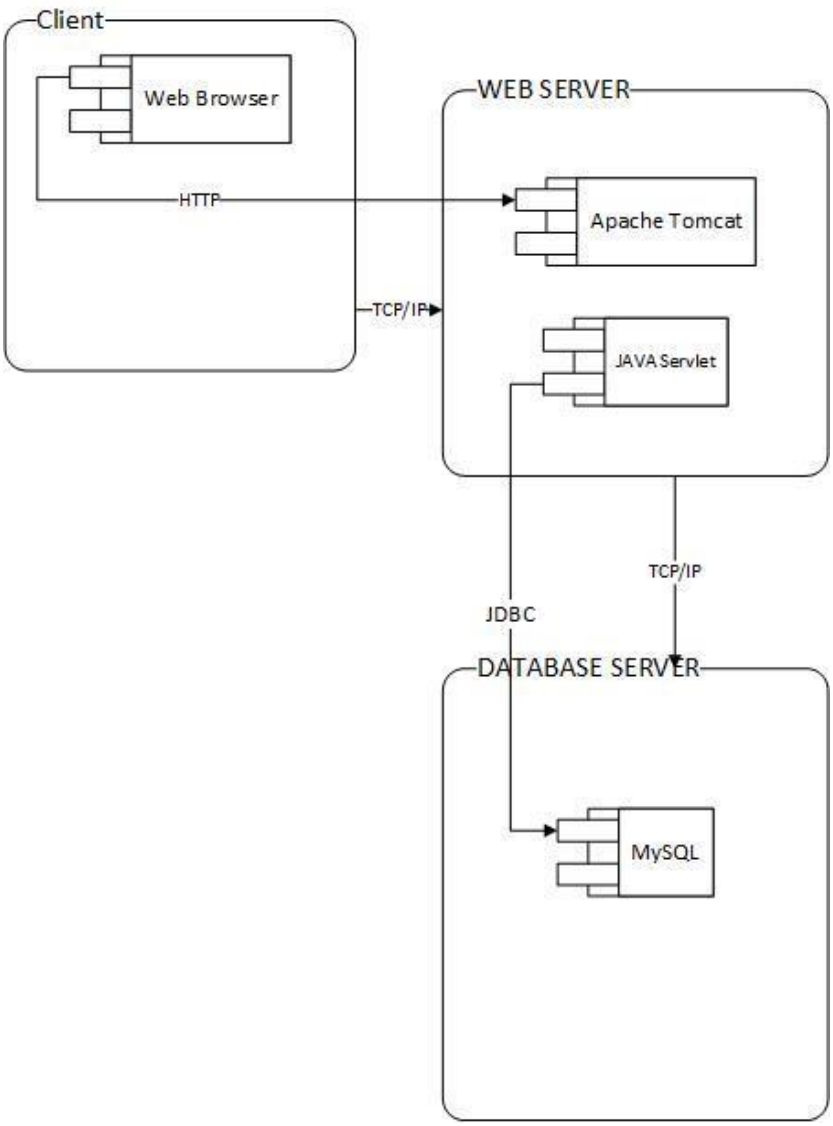

Figure 17 - Deployment Diagram

3.1.9 Entity Relationship Diagram

The Entity Relationship Diagram is a schema that shows the entities associated with their attributes and connections between them that during the implementation stage can be translated as functions

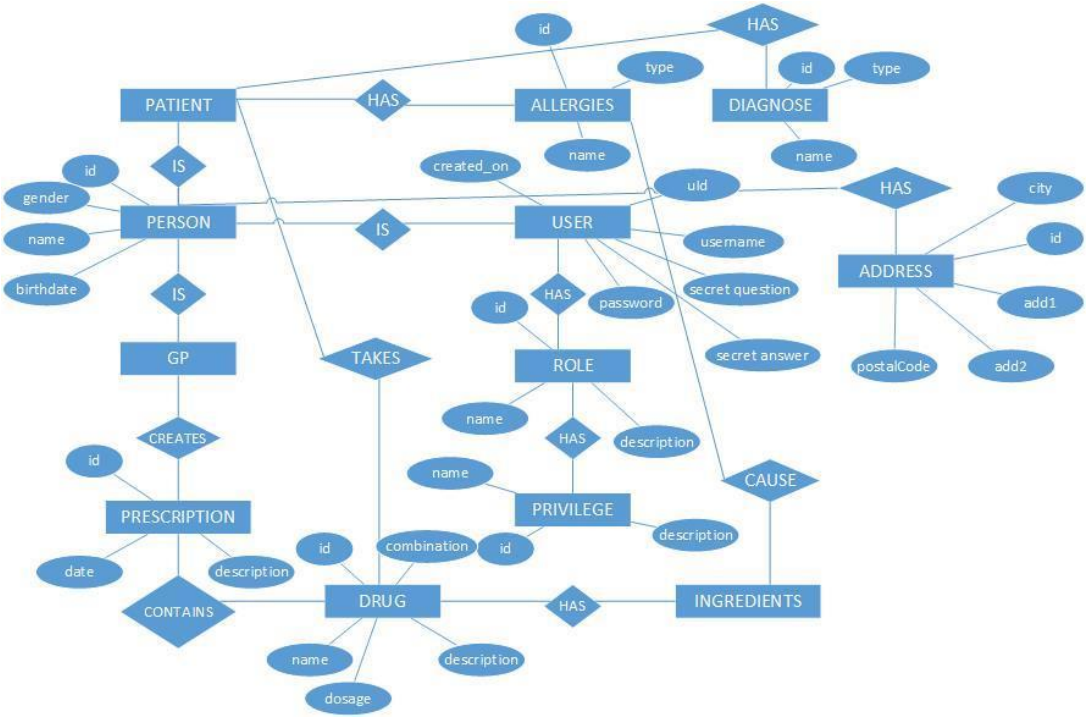

Figure 18 - Entity Relationship Diagram

CHAPTER 4 IMPLEMENTATION

4.1 Database

The database is built using MySql querying language and the administration is handled by PHPMyAdmin, which is open source and easily works through any browser. The database provides persistence to the application and makes it more flexible and easy to adapt to changes. The main table that is accessed first from the application is the users' table, which is very simple but contains important information for providing access to other parts of the application. The password is not stored in plain-text, but using SHA hash. Every user is associated to a role (patient, doctor, or administrator) and a set of privileges (addPatient, addUser, updateVitals, etc)

Server: localhost ▸ Database: alizuel ▸ Table: user

Browse | Structure | SQL | Search | Insert | Export | Import | Operations | Empty | Drop

Field	Type	Collation	Attributes	Null	Default	Extra	Action
u_id	int(11)			No	None	auto_increment	
username	varchar(15)	latin1_general_ci		No	None		
password	text	latin1_swedish_ci		No	None		
e_mail	varchar(30)	latin1_swedish_ci		No	None		
created_on	timestamp			No	CURRENT_TIMESTAMP		
enabled	tinyint(1)			No	None		

Check All / Uncheck All With selected:

Figure 19 - DB Table: Users

Another important table is the diseases table. Diseases are organized in categories and further in groups.

Field	Type	Collation	Attributes	Null	Default	Extra	Action
disease_id	int(11)			No	None	auto_increment	
disesases_cat_id	int(11)			No	None		
diseases_cat_group_id	int(11)			No	None		
disease_name	varchar(40)	latin1_swedish_ci		No	None		
disease_description	text	latin1_swedish_ci		Yes	NULL		
notes	text	latin1_swedish_ci		Yes	NULL		

Check All / Uncheck All With selected:

Figure 20 - DB Table: Diseases

The table Person, includes all data about all those who are part of the Health Information System. Not all people are doctors or patients. It might include as well

people, that are not users of the application, but are still part of the HIS staff. Other important tables are drugs, visits. Below is a screenshot of the structure, fields and types.

Server: localhost ▸ Database: alizuel ▸ Table: person

Browse | Structure | SQL | Search | Insert | Export | Import | Operations | Empty | Drop

Field	Type	Collation	Attributes	Null	Default	Extra	Action
p_id	int(11)			No	None	auto_increment	
name	varchar(20)	latin1_swedish_ci		No	None		
surname	varchar(20)	latin1_swedish_ci		No	None		
gender	varchar(1)	latin1_swedish_ci		No	None		
idcard	varchar(10)	latin1_swedish_ci		No	None		
birthdate	date			No	None		
dead	tinyint(1)			No	0		
death_date	date			Yes	NULL		
cause_of_death	varchar(30)	latin1_swedish_ci		Yes	NULL		
creator	int(11)			No	0		
birthplace	varchar(20)	latin1_swedish_ci		No	None		
address_id	int(11)			No	None		
date_created	datetime			Yes	NULL		
date_modified	datetime			Yes	NULL		
u_id	int(11)			Yes	NULL		
image	text	latin1_swedish_ci		Yes	NULL		

Check All / Uncheck All With selected:

Figure 22 - DB Table: Person

Field	Type	Collation	Attributes	Null	Default	Extra	Action
drug_id	int(11)			No	None	auto_increment	
drug_cat_id	int(11)			No	None		
drug_name	varchar(15)	latin1_swedish_ci		No	None		
drug_description	text	latin1_swedish_ci		No	None		
drug_countereffects	text	latin1_swedish_ci		No	None		
drug_indications	text	latin1_swedish_ci		No	None		
date_created	datetime			No	None		
creator	int(11)			No	None		

Check All / Uncheck All With selected:

Figure 21 - DB Table: Drugs

diseases
diseases_cat
diseases_cat_group
district
doctor
doctor_cat
drugs
drug_cat
drug_ingredient
drug_prescription
facility
facility_person
ingredients
inquiry
location
municipality
patient
patient_program
patient_state
person
person_attribute
person_attribute_type
prescription
program
reason
refunds
role
user
user_role
visit
vitals
vital_type

Field	Type	Collation	Attributes	Null	Default	Extra	Action
visit_id	int(11)			No	None	auto_increment	
patient_id	int(11)			No	None		
doctor_id	int(11)			No	None		
reason_id	int(11)			No	None		
disease_id	int(11)			Yes	NULL		
prescription_id	int(11)			Yes	NULL		
refund_id	int(11)			Yes	NULL		
home	tinyint(1)			No	None		
first-time	tinyint(1)			No	None		
planned	tinyint(1)			No	None		
visit_description	int(11)			No	None		
date_start	datetime			No	None		
date_stop	datetime			Yes	NULL		
creator	int(11)			No	None		
facility	int(11)			No	None		
u_id	int(11)			No	None		

Check All / Uncheck All With selected:

Figure 23 - DB Table: Visit

4.2 Controllers

Controllers are java classes crucial for the application functionality, as they handle all the requests coming from the servlet (front controller), do some check and send the chosen model to the appropriate view. The main controller is login controller, that manages the login request. If the user is not logged in, it redirects to te login page, otherwise it checks for the user role and returns the appropriate url.

```java
package com.ehealth.web.controller;
import javax.servlet.http.HttpServletRequest;
@Controller
public class LoginController {

    private static final Logger logger = LoggerFactory.getLogger(LoginController.class);

     @RequestMapping(value = "/login.alb", method = RequestMethod.GET)
     public String login(ModelMap model, HttpServletRequest req){
         String url = "";
            HttpSession session = req.getSession(false);
            if(session==null){
                  // User is not logged in.
                url="login";
                }else{
                    if(req.isUserInRole("ROLE_USER"))
                        url= "user/welcome";
                    else if(req.isUserInRole("ROLE_ADMIN"))
                        url= "admin/welcome";

                }
            return url;
    }

     @RequestMapping(value = "/loginError.alb", method = RequestMethod.GET)

     public String loginError(ModelMap model) {

         model.addAttribute("loginerror", "true");
         logger.info("Login error");
         return "login";

     }
```

Figure 24 - Code: Login Controller

```java
    @RequestMapping(value = "/logout.alb", method = RequestMethod.GET)
    public String logout(ModelMap model) {
        model.addAttribute("loginfo", "notloggedin");
        return "/home";
    }

    @RequestMapping(value = "inquiry.alb", method = RequestMethod.GET)
    public String in(ModelMap model, Principal principal, HttpServletRequest req) {
        String title = req.getParameter("title");
        String subject = req.getParameter("subject");
        currentUserName = principal.getName();
        model.addAttribute("tit", title);
        model.addAttribute("sub", subject);
        model.addAttribute("iid", currentUserName);

        return "user/inquiry";
    }

    @RequestMapping(value = "vit_retrieve.alb", method = RequestMethod.GET)
    public String dat(ModelMap model, Principal principal,
            HttpServletRequest req) {

        String date = req.getParameter("inputField");
        theDate = date;
        model.addAttribute("ddd", date);

        return "user/vit_retrieve";

    }

    @RequestMapping(value = "addRec.alb", method = RequestMethod.GET)
```

Figure 25 - Code: User Controller

4.3 Security

Spring features include a package to secure the authentication and availability of different pages to different users, based on their roles.

Spring-security executes two queries in the database to realize the log in. It uses the JDBC service and the source ‘DataSource’ which is the bean that contains the database credentials. It gets the user and the user role, and provides the user with access to the view ‘welcome’, otherwise it generates a login error message.

But if the visitor that wants to log in, doesn’t have a predefined role from the database or is not active, then the server outputs the message “Access is denied”.

Figure 26 - View: Home Page

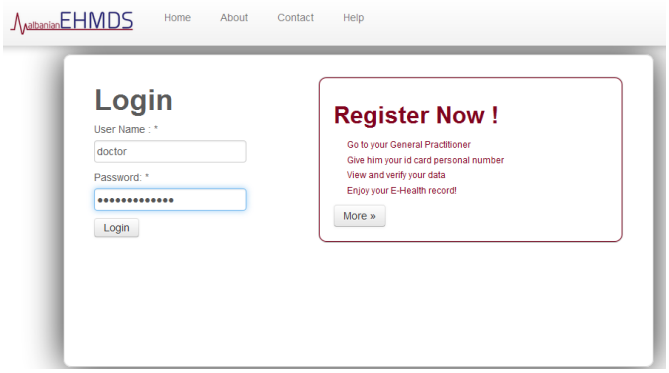

Figure 27 - Login: Doctor

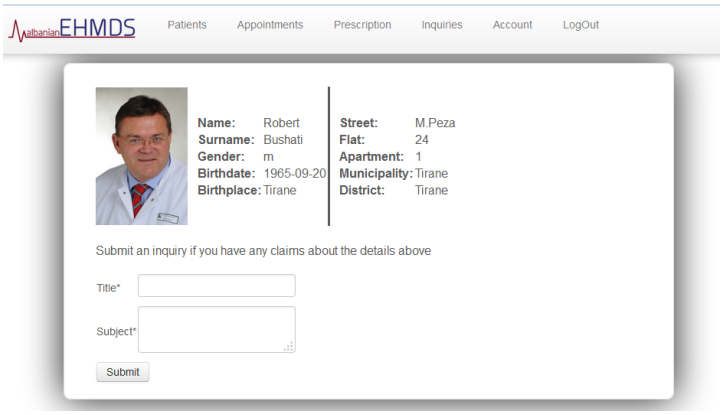

Figure 28 - Login: Doctor

Figure 29 - Access Denied

4.4 View

The application servlet handles the incoming requests and loads the views. The views path is '/WEB-INF/views' that is why the bean that resolves views (class: InternalResourceViewResolver) assigns the prefix '/WEB-INF/views' and the suffix 'jsp'.

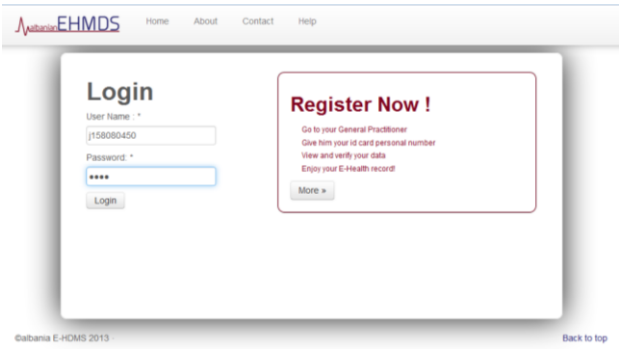

Figure 30 - Login: Patient

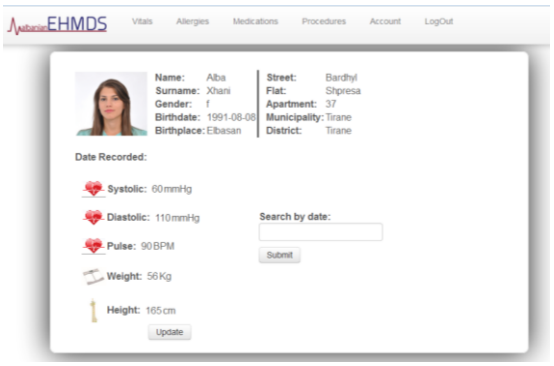

Figure 31 - Patient

CHAPTER 5 CONCLUSIONS AND FUTURE WORK

Information Technologies are "invading" all spheres of our lives, at the amount of data transmitted through electronic media is increasing in an exponential way. The need for speed, facilities and accuracy has been leading to the digitalization of important functions of a government structure. It is time for the health system to evolve and overcome the old methodologies.

The proposed Electronic Health Data Management System is a revolutionary platform for the health system of our country. It means a reorganization of the whole Health Information System that requires a considerable amount of time, investment and training.

There are successful stories like the E-health system in Australia, but there are also unsuccessful ones like Google Health.

This paper brought the implementation of only one component of the health information system, which was the patient-GP component. The system design and model was clear, but the implementation raised some difficulties. Issues to discuss for the future include:

- Create and define privacy rules and standards based on the HMN Framework for developing countries
- Create a plan for educating and training medical staff and patients
- Create an investment and collaboration plan for the financial support
- Create a development team with professionals mainly from the areas of engineering, computer science and medicine.

- Invest in system security, employing several replicate data servers and staff to administrate and maintain back-ups.

As for the distant future, knowing that mobiles are spreading and interfering everywhere, mobile solutions would add more value to the system, providing extra-facilities.

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APPENDIX UML DIAGRAMS

1. Use Cases

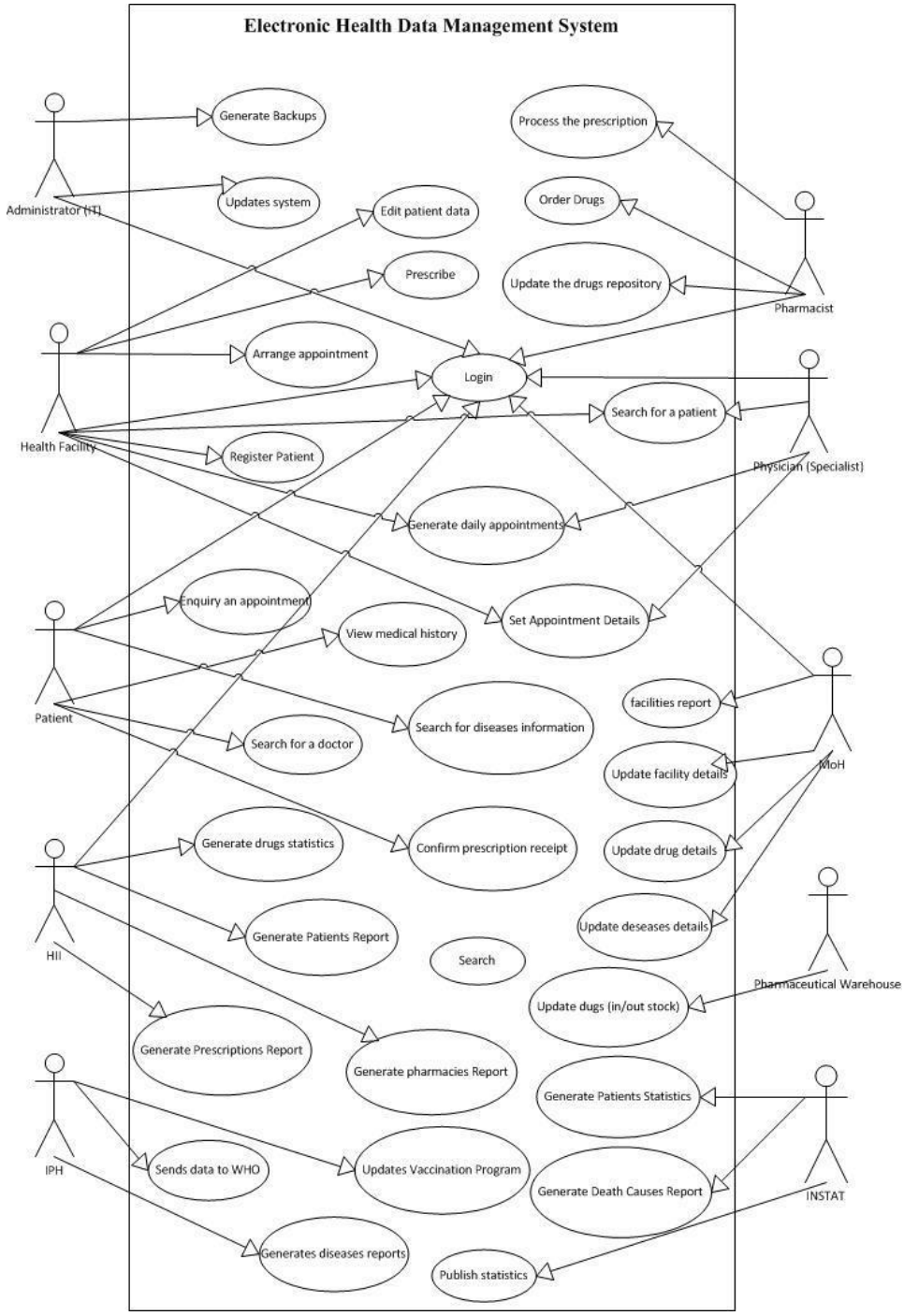

Figure 32 - Use Cases

2. Use Case #3: Appointment Execution

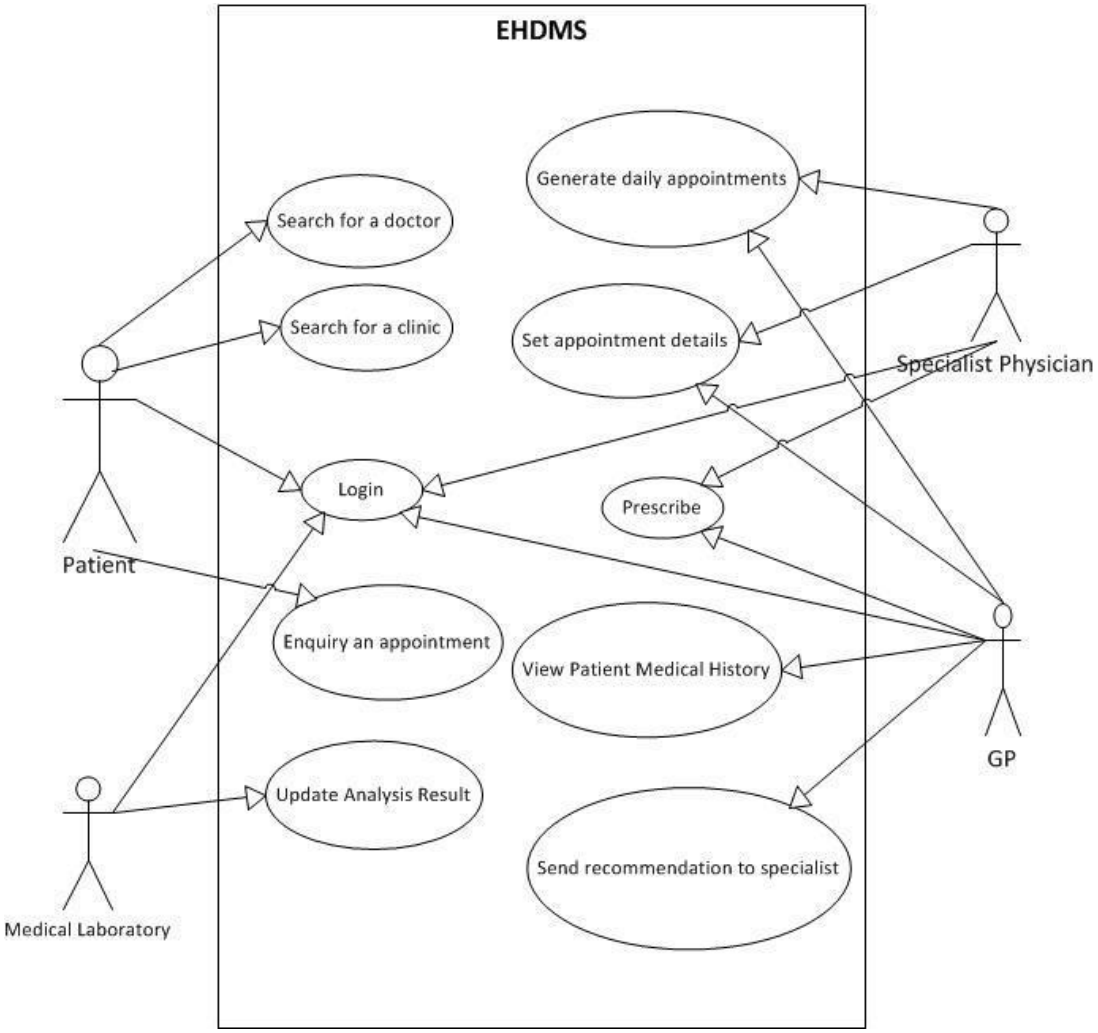

Figure 33 - Use Case: Appointment Execution

Main Success Flow:

The patient logs in, and searches for a health care facility, i.e. a clinic, may be the nearest one. After that he/she acquires an appointment through filling in a form, the appointment request form and submits.

The medical receptionist or secretary logs in, generates the appointments agenda and finds an appropriate time to schedule the requested appointment. Once the employee marks the appointment as assigned, the patient receives an automatic e-mail, with the appointment details (time, place, doctor name).

If any medical analysis is necessary, the medical laboratory performs it and uploads or writes the result.

The GP adds the appointment details into the system and creates a prescription if needed.

If the diagnosis is not clear, the GP recommends the patient to the specialist, generating an appointment unique id that enables the specialist view the patients' data and set the appointment details. The other actions the specialist performs are the same as what the GP does.

It is comprehensive that GP and specialist have different privileges. Only the GP can add and edit patients' data, while the specialist handles only the recommended patients, through the given unique code.

Possible derivations from the success flow:

The patient cannot attend the appointment at the time assigned. In this case he/she makes a request to postpone it. The medical receptionist handles the request and the flow proceeds as the successful one.

3. Use Case #4: Process a Prescription

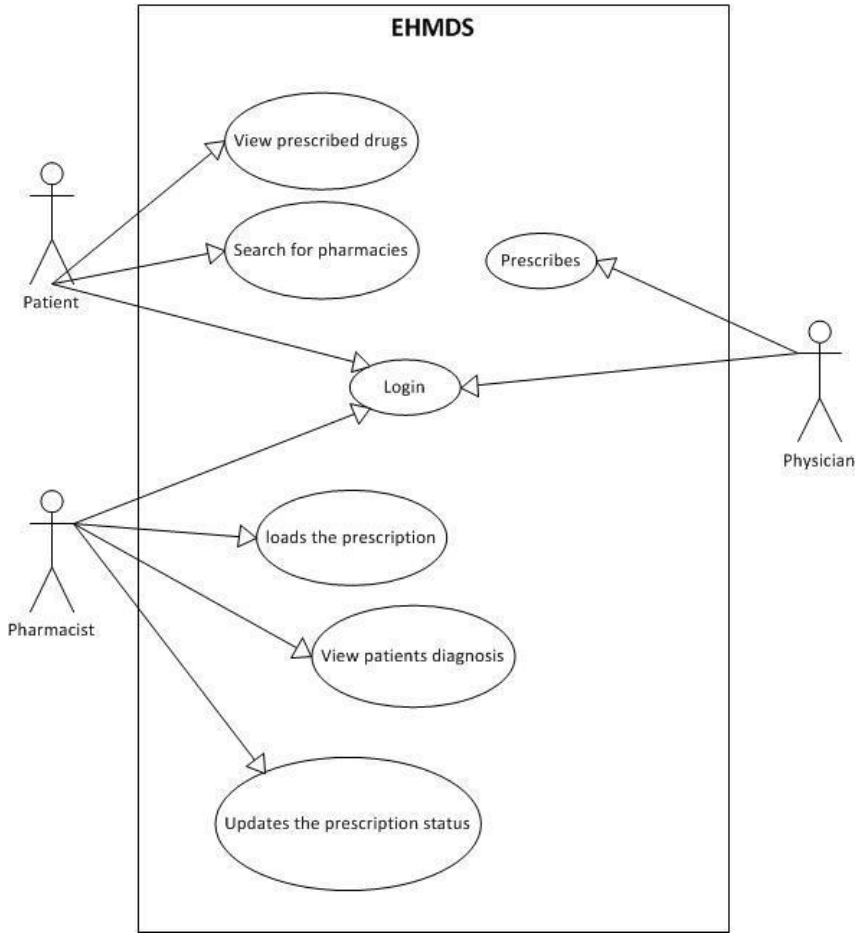

Figure 34 - Use Case: Process a Prescription

Main Success Flow:

The Physician creates the prescription record, related to the patient that will receive it. When he/she submits the prescription form, a unique prescription id is generated and send to the patient. This is the id that the patient gives to the pharmacist.

The pharmacist logs in, and inserts the received id. The prescription loads and the pharmacist executes it, by finding the required drugs and giving them to the patient according to the prescribed amount.

Once the patient receives the drugs and makes the payment, the prescription is assigned as completed, and the information is added in the medical history of the patient.

Possible derivations from the success flow:

The pharmacist does not have in the stock one of the prescribed drugs.

He/She calls the Pharmaceutical Inventory to order drugs, or fills in an electronic order. In both cases, the order will be stored electronically

The patients turns back later to check again, or goes to another pharmacy.

4. Use Case #5: IPH reports generation and flow

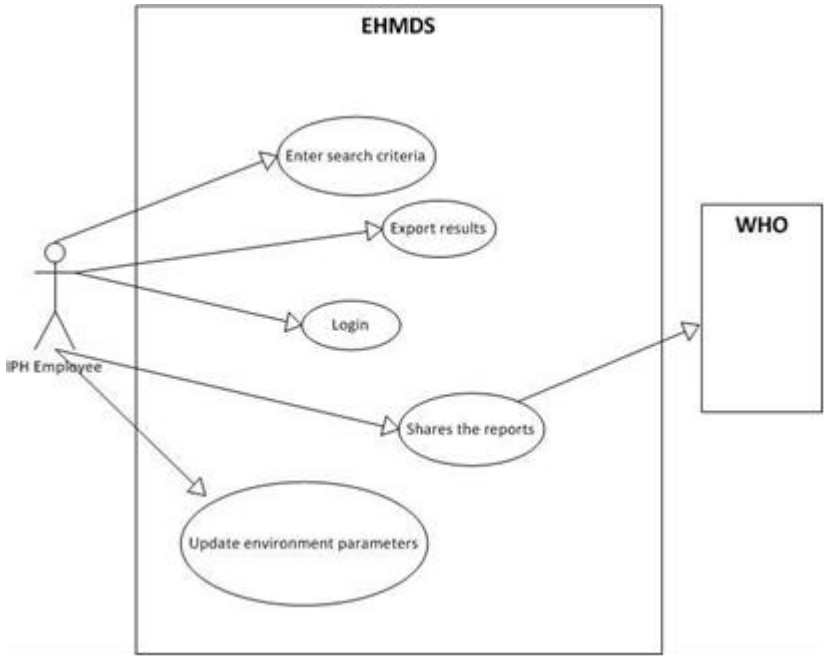

Figure 35 - Use Case: IPH reports generation

The Institution of Public Health is responsible for collecting and analysing the data about infectious diseases, their spread, environmental or food factors, writing results in form of research studies or reports and finally sharing them with the World Health Organization according to the requested indicators [3].

Main Success Flow:

The IPH employee logs in.

The employee collects data, by performing a search query filling some search parameters and conditions such as time range for which the data is needed.

The employee analysis the data and writes a report with the conclusions.

The IPH responsible team checks the report and the final version is sent to WHO and stored in the system archive.

The results are announced in the website interface of the EHMDS

5. Use Case #6: Drugs order (Pharmacies)

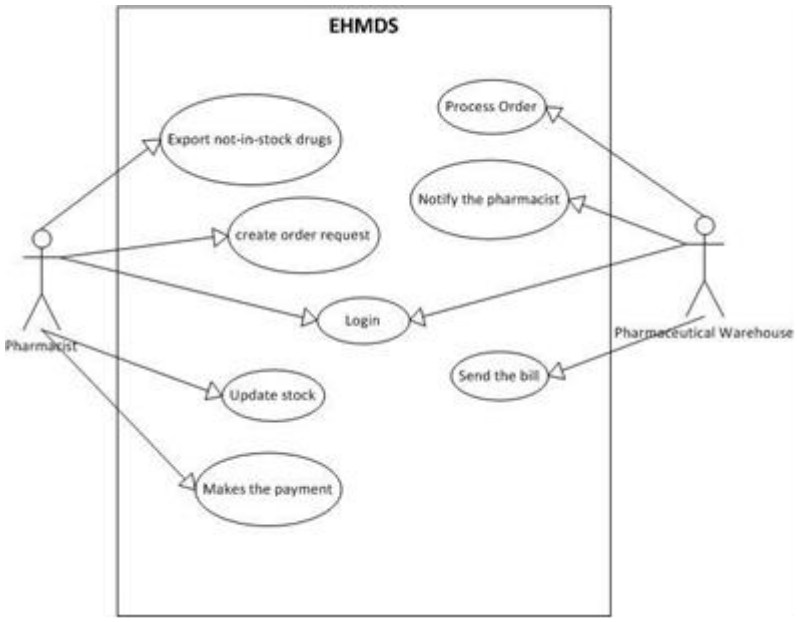

Figure 36 - Use Case: Drugs order

Main Success Flow:

Pharmacist logs in and queries the drugs with the state not-in-stock, which means that these drugs are not in the pharmacy stock.

Pharmacist fills an order request by providing with information about missing drugs such as (pharmaceutical name of the drugs, amount needed, pharmacy address, etc).

The employee of the pharmaceutical inventory receives the order.

The order is processed and another employee makes the physical transportation of the drugs into the pharmacy.

Pharmacist receives the bill and makes the payment

Possible derivations from the success flow:

The drugs requested by the order form cannot be found in the pharmaceutical inventory. The employee sends a notification to the pharmacist.

The pharmacist either can wait and try again later, or send the order to another pharmaceutical inventory.

6. Appointment activity

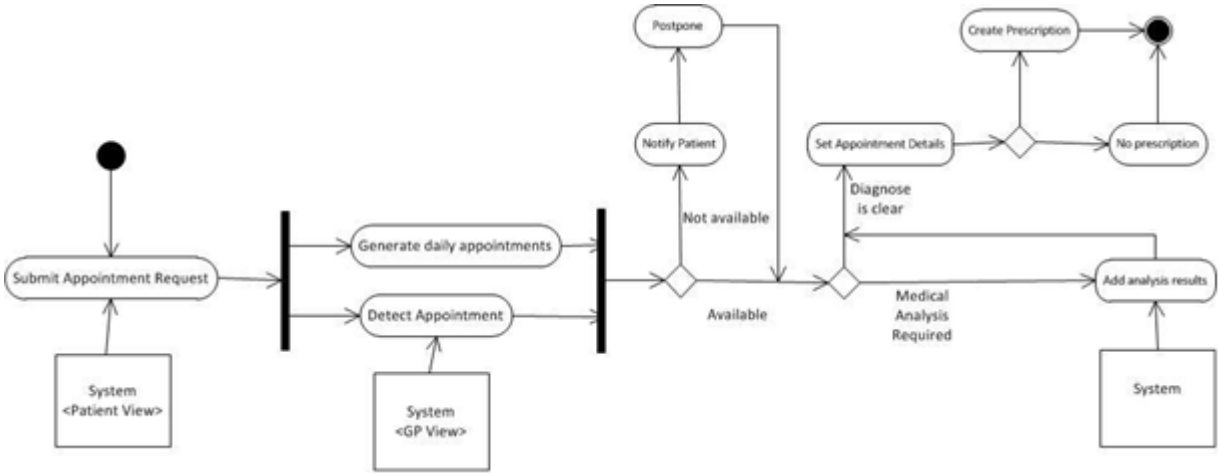

Figure 37 - Appointment Activity

The diagram above describes the activity of handling an appointment, starting from the submission of the appointment request from the user, who is the patient in this case.

The General Practitioner or the medical assistant detects the appointment request and processes it.

If the schedule does not match the patients request about the appointment time, then it is postponed to another time and the patient is notified about this change.

The GP performs the medical visit, sets the appointment details and if it is necessary creates a prescription for the patient.

7. Prescription Processing Activity

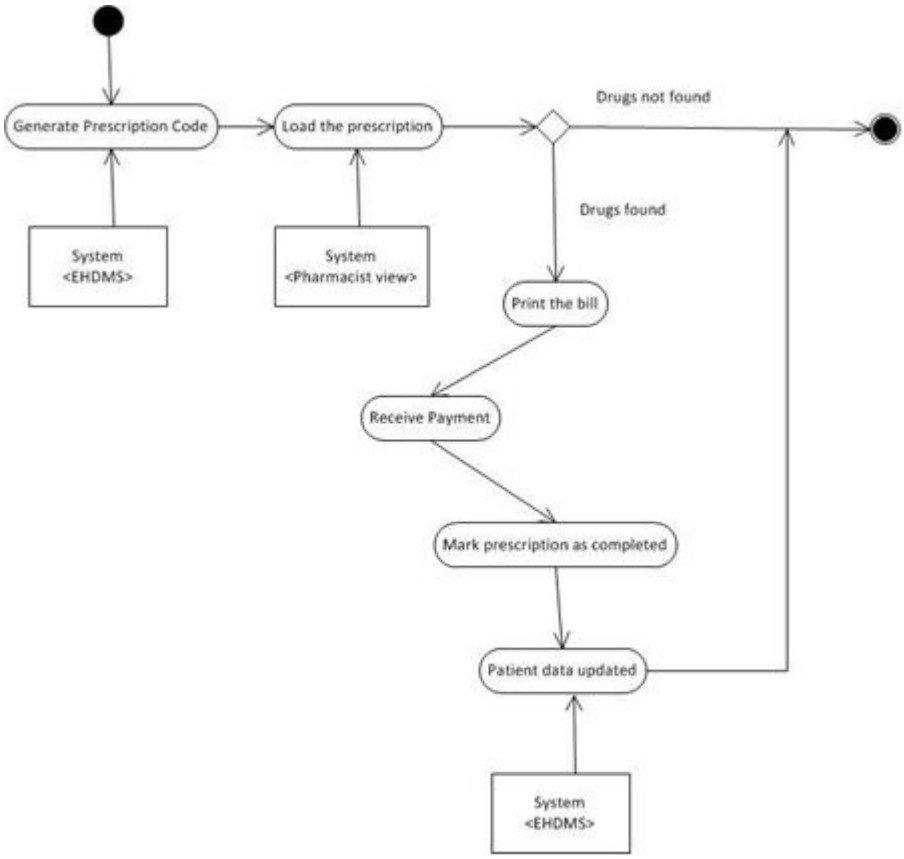

Figure 38 - Prescription Processing Activity

The Prescription processing activity describes the flow that the prescription follows from being created, to being converted into drugs in the patient hands.

Once the GP creates the prescription in the system, a unique prescription id is associated to it. The unique identifier gives the possibility to the pharmacist to access the electronic prescription and provide the patient with the drugs.

The bill generates automatically as well. Once the patient makes the payment, the pharmacist marks the prescription as completed.

If prescription remains with the status pending for a long time, the patient receives automatic remainders.