Addis Ababa University

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Design and Implementation of Online Electronic Medical Record System in Ethiopia

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This is to certify that the project prepared by Behailu Eshetu, titled: *Design and Implementation of Online Electronic Medical Record System in Ethiopia* and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Computer Science (in Software Engineering) complies with the regulations of the University and meets the accepted standards concerning originality and quality.

Signed by the Examining Committee:

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Abstract

An Electronic Medical Record system is an application that is a complete repository of patient's medical documents which contains patients' medical history, a summary of all their visits. This information can be shared across different health care organizations. Recently, electronic medical records are considered as a key to increasing quality care. It improves the accuracy medical records, reduces data replication, support fast data retrieval and decreases the risk of lost paper works.

Due to the presence of multiple health care service providing organizations, patients move from one medical institution to the other in need of better service and from place to place due to work and other life circumstances. Because of that maintaining patients' lifetime medical record becomes much difficult. Especially, in a developing country like Ethiopia, patient medical record keeping is done manually. This makes medical records susceptible to damage and loss and difficulty of retrieval when needed.

We employed the waterfall development approach to develop the Online Electronic Medical Record system. First, we studied the existing system through observation and revision of documents collected from different medical institutions. Based on the collected data we prepared a system analysis and design document. Then we developed the Online Electronic Medical Record following the system design document specifications.

Finally, an evaluation of the Online Medical Record system is conducted using a questionnaire involving 5 user categories and 10 voluntary participants from each user group. The result of the evaluation shown that the Online Electronic Medical Record System is easy to use, effective, accurate and help the professionals save their time.

Keyword: Electronic Medical Record, web-based application, electronic health record, patient management system, health information system

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Acronyms

API: Application Programming Interface

CSS: Cascading Style Sheet

EE: Enterprise Edition

HER: Electronic Health Records

EMR**:** Electronic Medical Record.

EJB: Enterprise Java Beans

FMOH: Federal Ministry of Health

FR: functional Requirements

HIS: Health Information system.

HIU: Health Informatics Unit

HTTP: Hypertext Transfer Protocol

JDBC: Java Database Connectivity

JMS: Java Message Service

JNDI: Java Naming and Directory Interface

JPA: Java Persistence API

JSF: Java Server Face

JSP: Java Server Page

JTA: Java Transaction API

KSA: Kingdom of Saudi Arabia.

RMI: Remote Method Invocation

TUTAPE: Tulane University Technical Assistance Program to Ethiopia

UI: User Interface

URL: Uniform Resource Locator

WHO: World Health Organization

Chapter One: Introduction

1.1 Background

Ethiopia has achieved significant gains in the series of Health Sector Development Program (HSDP), where universal health coverage has given the priority to address the major health problems of the country. Despite the gains, still, a lot remains in the quality of health care service. Cognizant of this, the Federal Ministry of Health (FMOH) made quality and equity one of the four priority agendas of the health sector transformation plan. Built on the plan, the National Health Care Quality Strategy was developed and launched in 2016. The strategy aims in transforming the quality of health care in the country and gives due emphasis on experience sharing across facilities and institutions [1].

The terms medical record, health record, and medical chart are used somewhat interchangeably to describe the systematic documentation of a single patient's medical history and care across time within one particular health care provider's jurisdiction [2], The medical record includes a variety of types of "notes" entered over time by health care professionals, recording observations and administration of drugs and therapies, orders for the administration of drugs and therapies, test results, x-rays, reports, etc. [3]. The management of medical records has a long history. For a long time, medical records have been in paper format. However, expansion in healthcare service delivery has seen paper format becoming more problematic. For example, the amount of patient information on paper and the lack of a central storage system led to large volumes of medical records being stored in various locations. It was also noticed that the storage often had fragmented, inaccurate, incomplete, duplicative, and poorly documented information.

In the traditional patient medical record system, the patient's medical information is stored either in a paper-based system or file system. In the paper-based system, every test, medication, and visit for a patient is manually recorded on paper. These records are called charts. Since each department of a hospital is responsible to maintain its own set of records, patients’ privacy is its main concern besides its high space, cost and data processing time requirement. On the other hand, the file system maintains a complete patient record in a single file on a computer.

The Electronic Medical Record (EMR) system has become one of the most important technologies that emerged in the health care sector. It is an application that is a complete

repository of patients' medical documents which contains patients' medical history, a summary of all their visits (lifetime medical story), observations and treatments provided by health care organizations [12]. As a tool, EMR focuses on the improvement of efficiency, patient's experience and care, and improvement in the availability of organized medical data for clinical research and trials. Based on their technical feasibility, EMR systems are classified into various types namely, client-based, Saas-Based and hybrid models [4]. Depending on their interest, medical institutes implement the one that is best suitable for their business.

The role played by ICT towards assisting the health sector in developing countries can be manifested through the development of health care applications as enablers to save lives and use it as a medium to access recent healthcare information, data handling, and processing activities among staff [5]. Electronic Medical Records System (EMRS) is a computerized patient tracking and patient caring system. Medical records are collections of information about patients' health care and are essential for the present and future continuation of care [6].

SmartCare is a nationwide electronic medical record system designed by the initiative of the US Center for Disease Control (CDC) specifically for low-resource countries. Zambia, Ethiopia and South Africa are the three African countries in which the system is implemented. In Ethiopia, The SmartCare software development is conducted by Tulane University Technical Assistance Program to Ethiopia (TUTAPE) and Ethiopian software developers in collaboration with the FMOH and consultants from the United States of America [5, 14]. The main objective of implementing EMRS in Ethiopia was to develop a system that would deliver timely and successive patient data to the physicians and enable the quick collection of data for epidemiological studies, medical audits and business audits [7].

Installation of the network and server infrastructure of the EMR system at all hospital sites was conducted by TUTAPE. After implementation, onsite user training was provided to all health professionals of each hospital. TUTAPE computer and network experts are accountable to provide continuous on-call service for technical assistance during system failure [7, 16].

The adoption of electronic processing of medical data which is expected to improve the quality and efficiency of health care services will lead to an increasing amount of medical data exchanged across institutional boundaries. In Ethiopia also EMR adoption has the same intention but, the implementation faces lots of challenges. The main objective of this project is to provide

a software solution for the existing medical record management systems in Ethiopia. This improves the quality of service provided by the medical institutions in the country and the availability of reliable medical data that can be used for different purposes.

1.2 Motivation

According to the report of the Ethiopian Public Health Institute in May 2018, the major health problems of Ethiopia remain largely preventable communicable diseases, reproductive health-related problems, and nutritional disorders [15]. Despite the major signs of progress made to improve the health status of the population in the last two decades, Ethiopia's population still faces a high rate of morbidity and mortality and the health status remains relatively poor. Health Information System (HIS) is a potentially very important tool for the improvement of the health sector in Ethiopia.

A health information system refers to any system that captures, stores, manages or transmits information related to the health of individuals or the activities of organizations that work within the health sector. Overall, a well-functioning HIS is an integrated effort to collect, process, report and use health information and knowledge to influence policy and decision making, program action, individual and public health outcomes, and research [19].

Many countries use these HIS systems as a tool for providing better health care services to their citizens. Three African countries namely Ethiopia, Zambia, and South Africa also try to improve their health care service by adopting EMR software called SmartCare [20]. Due to the distributed nature of this SmartCare system, it is very difficult to maintain the medical information of individuals at every health care institution because it has infrastructure cost to deploy for all medical institutions in the country and at the same time provide technical support.

The motivation for this work is the unavailability of Electronic Medical Record System that can create a link between medical organizations in maintaining and sharing patient's medical data. Through implementation of a web based EMR system that can be centrally deployed and accessed on Internet it's possible to improve the availability medical data and quality of patient care.

1.3 Statement of the Problem

The World Health Organization (WHO) defines Health Information System (HIS) as "A system that integrates data collection, processing, reporting and using the information necessary for improving health service effectiveness and efficiency through better management at all levels of health services" [6 , 7].

In Ethiopia, most of the public and private medical institutions still rely on the paper-based medical record management system. This is subjected to different problems such as lose or damage of medical records and modification by peoples with malicious intent. This can be an obstacle to the relationship between patients and physicians which may lead to serious medical errors and loss of lives. The unavailability of organized medical records also affects medical research to be conducted at local and national levels. Some institutions use a local medical record system that is a fragmented medical information system characterized by incompleteness and incorrectness.

The existing paper-based medical record system has problems in protecting privacy of patients' confidential medical information. For example, in the visiting rooms, folders of patient charts were piled up where patients and anyone who passes by could access various visible forms. As well when a patient's medical record has to be transferred from one department to another, a runner who transfers these documents could easily view private patient history. An EMR would improve the confidentiality of patients' medical records through authentication and authorization mechanisms implemented for securing the system.

Over the past years, SmartCare was adopted by some health care organizations to digitalize the electronic medical record management system. But, for different reasons, some health sector institutions like St Paul Hospital Millennium Medical College in Addis Ababa abandoned it [6] and returned back to the traditional paper-based system. Some of the barriers for SmartCare use include difficulties with the technology, lack of maintenance and technical support, high initial deployment cost, system complexity, Besides Lack of adequate electronic data exchange between the EMR and other clinical data systems became a barrier such as a lab, radiology, and referral systems [8].The system is also incapable of generating an individual report. There was also an unexpected observation we want to point out which is the unavailability of dedicated information communication technology (ICT) support center in all of the hospitals despite the

implementation of such an expensive server and network infrastructure [2].Our EMR system can provide an opportunity of centralized maintenance and support without physically going to each and every organization to solve this problems.

To summarize the problems in the medical record management systems in Ethiopia, some of the major problems are;

- ✓ Difficulty to maintain confidentiality, availability, and integrity of patient medical record using the paper-based approach.
- ✓ Fragmentation of medical record information maintained in different medical institutions' databases causes the data to lack completeness and correctness. Our system can provide a complete repository to store patient life time medical history.
- ✓ The difficulty of getting relevant medical reports needed by the local government officials and international institutions like WHO.
- ✓ The SmartCare software adopted before has very high maintainability problems due to its deployment architecture.
- ✓ The SmartCare system cannot also provide data exchange mechanisms for other facilities (such as lab, radiology, and referral systems), also it supports only aggregate reports.

1.4 Objectives

General Objective

- The general objective of this project is to design and develop a usable web-Based Electronic medical record system that can be operational throughout the country using Internet.

Specific Objectives

The specific objectives of this project are:

- Investigate the state of the art in an electronic medical record management system through a review of related works.
- Prepare a Software Requirements Specification (SRS) document.
- Design the system architecture.
- Develop a full-fledged electronic medical record management system.
- Prepare a user manual.

- Evaluate the usability of the system by conducting different testing techniques.

1.5 Methods

In order to accomplish the objectives of this study, different methods are will be used. Some of the methods to be used include:-

Development approach

The process model to be used for this project shall be a Waterfall model in that each stage of the waterfall allows us to update the project plan and other deliverables for missing areas or correctness. The decision to use the waterfall methodology is due to the coarse nature of the project, the sequential design process, and progress seen as flowing steadily downwards.

Literature Review

We are going to review different literature that are considered to be relevant for this project in order to get a better understanding of the area and to have detailed knowledge on the various techniques that are essential for designing and implementing an online electronic medical record system.

Data Collection

Relevant data for the purpose of requirement determination is collected from different health care service-providing institutions. This can be done through observation and analysis of different forms and documents.

Development languages and Tools

Various free and open-source tools will be used for the design and implementation of the EMR system. Also, various programming and scripting languages shall be used for the successful implementation of the system.

Testing and Evaluation

After the design and implementation of the system, a user acceptance test will be conducted with selected users in order to evaluate whether the objectives of this project are met or not.

1.6 Scope and Limitations

This project focuses on the design and development of a web-based EMR system for Health care service providing institutions in Ethiopia. Through the provision of a virtual space for each institution to maintain their own private company profile such as the medical staff and other

users relevant information so that they can manage the workflow of their patients' treatment information. The scope of this project is limited to addressing the basic medical institutions operation related to patient information management such as maintaining and accessing patient profile, booking, patient-physician assignment, maintaining clinical and lab diagnosis information's, maintaining and generation of medication or therapy information prescribed for a patient, setting appointments and referrals, sharing certain patient information's like profile information, past medical history, allergies, social history, family history among medical institutions and different departments within institution and generation of various reports on an individual level or aggregate.

Time and budget constraints for the design and implementation of comprehensive solutions coupled with the difficulty of handling other functionalities needed by medical institutions such as billing, room management for inpatients, inpatient progress followup, an advanced diagnosis other than basic clinical diagnosis and laboratory diagnosis, lab test procedures are the major functionalities that are beyond the scope of this project.

1.7 Application of Results

The result of this project work can be used by so many health care service providing institutions in the country to automate the medical record of their patients. The medical staff working in different departments will get relevant help to make decisions about the patients' health status. The output of this project also benefits patients by improving the privacy and availability of their medical records across medical institutions so that they can get better medical treatment where ever they are. This EMR system also benefits medical students and clinical research by providing primary data for their scientific studies and research works.

In addition to that, the output of this project can be used by the Federal Ministry of Health to obtain various reports about the health status of the population in different areas and as a whole in-country level. Also, it can be used as a benchmark for other projects to be done in the same area.

1.8 Organization of the Rest of the Thesis

The remaining part of this document is organized as follows. Chapter Two covers the literature review. Chapter Three presents the previous works that are related to this project. Chapter Four discusses the system analysis of the *Online Electronic Medical Record System to be implemented*

in Ethiopia. In Chapter Five, we will discuss the system design of the system. The implementation and testing of the proposed system are discussed in Chapter Six. Finally, the conclusion made on the project evaluation result, the contribution of this project work and recommendations on possible future work related to the project are presented in chapter 7.

Chapter Two: literature review

2.1 Introduction

In this Chapter, different publications that emphasize “medical record management” are presented. By referring to those publications we can provide sufficient background information about the medical records, medical record systems, and the different techniques that can be used to implement medical record systems.

2.2. Basic Concepts of Medical Record

A medical record has been defined as a chronological written account of a patient's medical examination and treatment that includes the patients’ medical history and complaints, the physician’s physical findings, the result of diagnostic tests and procedures and medications and therapeutic procedures [9]. The term medical record, health record and medical chart are interchangeably used to describe the systematic documentation of a single patient’s medical history across time. The maintenance of complete and accurate medical records is a requirement of health care providers. It is generally enforced as a prerequisite for certification.

Different authors present their views towards the purpose of medical records. For instance Carpenter and Williams [10], in their work explained the purpose of medical records as primary and secondary. According to their discussion, the primary purpose of medical records is to keep the clinicians communicated. While the secondary purposes are reporting the activity of medical services and monitoring the performance of hospitals and researchers.

Medical record-keeping strategies followed by health care institutions vary from one institute to the other. Before the emergence of an electronic way of keeping medical records, the traditional methods have been used to maintain patients' medical history either in a paper-based or computer file-based system. As a country, Ethiopia is categorized as one of the countries that don’t implement uniform record-keeping techniques throughout the country, Instead a variety of medical record strategies have been followed in different institutes [13].

The paper-based medical record is an impediment to the effective delivery of high-quality health care. The record is difficult to access, often lacks information and must be in a single location for single use. Over the past few decades, the increased demand for information forced health care institutes to provide an alternative way to deliver information effectively also significant strides

have been made in automating the record-keeping process. Technology has improved allowing the design and implementation of electronic record-keeping systems that are easy to use. The structures of medical records have become ever more critical with the advent of electronic records. Its medical record models are based on the idea that the treatments are driven by data and each patient is unique so treatment must be personalized [11].

2.3 Electronic Medical Record (EMR)

Electronic medical record (EMR) is a systematized collection of electronically stored demographic and health information of patients in a digital format. EMR systems are designed to store data accurately in searchable digital form to capture the state of a patient across time with key advantages that include the elimination of the need to track down patient's previous paper medical records, reducing data replication, extracting medical data to assess trends and long term changes in a patient and facilitating population-based studies [3].

Since electronic medical records are complex, it requires a new approach according to the demands made by the e-Health ecosystem. The Health Informatics Unit (HIU) of the Royal College of Physicians (RCP) developed a program on medical records that identified the need, reviewed the literature, and established two major streams of work – the Information Laboratory and the Records Standards program [9]. The aim of the HIU's Records Standards program is to improve the quality of clinical information in the hospital setting by developing standards for recording and communicating information about patients. Applying these standards to medical records improves the validity and utility of patient data structuring and the information can be incorporated into electronic records, shared with other healthcare providers, and analyzed for performance monitoring with confidence [9].

There are about 12 generic medical record-keeping standards that are simplified by HIU to 4 in order to increase their usability. It was agreed that the standards should be:-

- Consistent with best medical practices
- Clear and concise
- In line with national guidance on record standard and
- Auditable

2.4. Features and benefits of EMR

The implementation of EMRs requires the participation of different stakeholders both national and local authorities providing input data from their perspectives ,setting the desired outcome, giving direction, defining the scope, and to identify participants from various functional teams to build a fully functional national system[21].Some of the features expected from EMR includes manage patient demographics, manage patient history, manage clinical documentation and notes, capture external clinical documents, manage diagnostic test orders and results, support for standard assessment and many others.

EMR is not only a technology application at the operational level but also a major evolution in the business process, organizational structure, and organizational culture as well. Implementing EMR provides lots of benefits for individuals, organizations and collectively for the medical community. Some of the benefits include it could be used as a reliable data source, improve patients safety, improves users efficiency and effectiveness, improve users satisfaction, provide a hierarchy of distributed responsibilities and workflows. It also improves the quality of care provided by medical institutes [21, 28].

2.5. Electronic Medical Records in Ethiopia

Despite the dominance of paper-based medical records in most of the medical institutes within the country, still many medical institutions implement small independent EMR software that is Operational in a specific institution. Besides Smart-Care is the major electronic medical recording system implemented in hospitals and health care centers. The system has been deployed in many hospitals and clinics in Diredawa, Bahirdar, Harar, and Addis Ababa city administrations of Ethiopia as a pilot, and the Ministry of Health planned to scale it up to other hospitals and regions [18, 19].

Micheale Berhe, et al [7] conducted a cross-sectional study to assess the availability, use, usability and user's satisfaction level of EMR implemented in Ayder Referral Hospital. The overall EMR implementation effectiveness within the hospital was measured by the four dimensions of evaluation in which it was rated good, but the authors also presented that there is a problem towards providing resources to new staff, lack of system updates and maintenance and absence of sufficient user training and technical suport. While in another publication by

Mulusew Andualem Asemahagn [27], assessed the EMR adoption rate, functionality status, and challenges in public health centers from the Amhara Region. According to the finding, there are many medical institutes that don't implement the EMR at all and many of the implemented EMR systems are not functional. From this, we can conclude that the availability of the system differs from institution to institution.

Also, Mikael Gebremariam, et al [18], discussed the intervening conditions in EMR implementation at an organizational level. Some of the conditions include management's acceptance and support for the implementation of EMR. Their resistance is basically sourced from their limited understanding and awareness about the benefits of implementing EMR in their organization. The second intervening conditions are cost and technological factors. The cost-related factors include the cost for hardware and software purchase, hiring technical staff, training the medical staff and continuous support and maintenance. The technological condition covers the hardware, software and quality of services such as usability, security, availability and response time.

Generally, implementation of the EMR system provides a lot of benefits for the patient to get better medical treatment, for the physicians to serve more patients within a short period. Also, it improves medical institutions' efficiency by facilitating patient treatment workflows.

Chapter Three: Related Work

Elsevier [21] tried to assess the benefits of EMR systems other than improving the quality of health care service by considering significant factors such as human factors, ergonomics, workflows and environmental conditions which should be considered to improve the quality and cost of patient care, as well as employee and patient safety. They proposed an EMR system that should be deployed in both wireless and wired networks so that clinical staffs access the system using available types of equipment such as personal computers, laptops, tablets, and PDAs to view history and supporting documentation throughout patient care interaction. They also recommend developers of EMR software need to incorporate human factors into the software usability through the provision of intuitive human-computer interaction.

He, *et al*. [22] focused on helping patients who need continuous care after being discharged from the hospital through the use of modern medical technologies. In the research design of Electronic Medical Records for continuous patient care was proposed, especially by investigating patients with malignant tumors. After designing the overall structure of the EMR system the authors carried out black-box and white-box testing to measure the functionality, reliability, and usability of the designed medical record management system. Their proposed system is found to be feasible according to two perspectives. The first perspective is that the current hardware setting environment, such as the situation of the network server room, its capability of deploying the software system, and the second one is the analysis of the computer use capabilities of users, clinicians, nurses, and other system operators.

Popoola [23] in this work discussed the benefits of the electronic medical records for the Nigerian public health sector and the challenges for the availability of such important systems in the country and also suggested the different approaches that should be followed to address those challenges. The author presented two options to acquire EMR systems. The first one is to design and develop EMR systems from scratch. The second option was to customize free open-source EMR software. The author admits that there is still a debate in Nigeria on which one of the two approaches is best suited. Finally, the authors proposed a community-driven framework for the implementation of a nationwide EHR system. The framework drives EHR implementation through academics, research funding, and a well-articulated collaboration with domain experts and other stakeholders.

Samir, *et al* [24] tried to solve problems in the medical record management system in the Kingdom of Saudi Arabia (KSA) hospitals by designing and implementing a web-based EMR system that can be deployed in every health care service providing institution. In terms of deployment architecture, the proposed system has a similarity with the SmartCare system in [25]. This means it is subjected to the same challenges related to its high infrastructure cost. This has its own contribution to the data fragmentation problem caused by the unavailability of the system to all governmental and non-governmental health care institutions.

Mweebo [25] presented a case study of security issues related to the operationalization of SmartCare. Even though, the area this study is limited to how an electronic medical record (EMR) is used to manage the Human Immunodeficiency Virus (HIV) health information in Zambia, the security concerns can be applied to any other cases. Because the same software is used to manage health information of other cases as well. The author presented that the aim of the SmartCare program in Zambia is to link up services and improve access to health information, by providing a reliable way to collect, store, retrieve and analyze health data in a secure way. In Zambia, SmartCare has expanded since its initiation in 2004 to integrate more than 500 health facilities and has harmonized patient records of more than 308000 individuals across the country. The author mentioned the major challenges to the SmartCare implementation in Zambia to be its high initial cost and security issues, which through the application of authentication and authorization the privacy and security of confidential patient information should be improved. Also other health informatics specialists are advocating for use of Role-based access control specialized firewalls such as Security Information and Event Management (SIEM), and Secure Socket Layer (SSL) or encryption to protect patient information from cyber-crime. But the paper didn’t suggest anything about mitigating the high initial cost problem related to the SmartCare software because the deployment cost of the system is not within the scope of the work.

The objective of the paper in [26] is to assess the perceptions of physicians towards the use, effectiveness, and efficiency of EHR, to identify the differences between electronic and paper-based records, to evaluate the usage of Electronic Health Records, and to analyze satisfaction and challenges faced by the physicians using EHR. The authors make use of both qualitative and

quantitative methods to conduct the study. Data was collected from two different hospitals in Pakistan according to the result from the analysis of the implementation of EMR. Mostly have started but not fully implemented the system due to lack of professionalism among workers, corruption, false data entry to create revenue and lack of evaluation and monitoring put the system in great difficulty. The study used perceptions of doctors to evaluate the efficiency and usage of the EMR system which includes quality data, user-friendliness and patient's and physician's satisfaction and also on EMR effectiveness by checking the working of EMR its quick and satisfactory results its accuracy, adequacy, timeliness, user-friendliness, availability, and reliability. Overall in the study, the physicians were satisfied with the working of EMR and the service offered to patients is better.

Mulusew Andualem Asemahagn [27] assessed EMR adoption rate, functionality status, and challenges in public health centers of the Amhara Region, Ethiopia, by collecting data through phone interviewing of EMR focal persons and data extraction from EMR databases. The author employed Multivariate logistic regression analysis to identify factors affecting system functionality. According to the result, a significant number of health care service-providing institutions didn't adopt the software. Out of the total number of institutions that adopted the software, only 58.7% were functional during the study period. The author underlines this as it is a failure compared to the case with those who did not adopt the system because more budgets were invested for system establishment, material/equipment purchasing, and infrastructure. Based on the findings of the paper, skill gaps, the absence of trained manpower (technical support), system failure, absence/poor maintenance services, budget shortage, and frequent interruption of electric power were mentioned challenges that have an association with the usability of the system. The paper presented that the health information system of the studied region is problematic, because, 12.6% of health care institutions did not adopt the system, and 41.3% of the system which was adopted were non-functional.

Scholl *et al*.[28] presented the challenges related to the adoption of electronic medical record-systems at Sankara Nethralaya hospital in India and the methods and strategies used to overcome those challenges to adapt the system successfully. One of the major challenges at this hospital was the user base which includes skeptical users, those lacking computing skills, and that had a

history of rejecting designs. In order to overcome the above-mentioned challenges, the authors employed a design strategy that considers critical technical and social features of the system intended to support skeptical users and those lacking IT skills. Consider pursuing user interfaces that are very similar to paper records to help users feel more comfortable with adopting the system. The study contributes to the overall understanding of the environment at large hospitals in developing countries as it relates to the adoption of EMR systems

The fundamental point that all of the above authors agreed on is that implementing EMR-systems provides a wide range of benefits for medical institutions by enabling them to establish a smooth relationship with their customers. In addition to that such kind of systems can improves health status of nations through provision of reliable data for researches.

Chapter Four: System Analysis of Online Electronic Medical record System

Overview

This Chapter discusses the functional and non-functional requirements of an Online Electronic Medical record system in the case of Ethiopia and the system models such as the use case model, sequence diagram and activity diagram

4.1 System Requirements

The list of functionalities that the proposed Electronic Medical record system has to offer for the user. The list consists of functional requirements that define what the application must do and non-functional requirements that define the goals of the system.

4.1.1 Functional Requirements

The functional requirement of the system is concerned with the services that the system should provide to users. It refers to the tasks that the proposed Electronic Medical Record System is supposed to accomplish. It must incorporate the steps and procedures followed by the medical staff. Observing the business process concerning maintaining medical records of a patient, reviewing policies and procedures about medical records management; and analyzing different forms and documents used by staffs working in different departments are the methods followed to identify the functional requirements. The main functional requirements of the system include:

Table 4. 1 : Functional Requirements

Req.ID	***Description***
FR1:	The system shall be able to create new user accounts and allow a legitimate user to login.
FR2:	The system shall be able to maintain an Institute profile
FR3:	The system shall be able to maintain and manage staff profile
FR4:	The system shall be able to manage user accounts
FR5:	The system shall be able to maintain and manage patient Information
FR6:	The system shall be able to maintain and manage the patient-physician assignment
FR7:	The system shall be able to maintain diagnostic results
FR8:	The system shall be able to maintain lab orders

Req.ID	*Description*
FR9:	The system shall be able to maintain lab results
FR10:	The system shall be able to maintain patients medical history(patient-related problem list, medication and treatment list)
FR11:	The system shall be able to generate a prescription
FR12:	The system shall be able to maintain and manage patients appointment
FR13:	The system shall be able to manage referral cases
FR14:	The system shall be able to control the patient management workflow
FR15:	The system shall be able to generate reports dynamically

4.1.2 Non-Functional Requirements

The non-functional requirement of the system deals with how well the system provides service to the user.it includes usability, performance, reliability, maintainability and security.

- **The system should be easy to use**

Usability is the easiness of the system a user can learn to operate, prepare inputs, and interpret outputs of a system or component. The system shall be of a user-friendly interface to help users get easily acquainted with the system to ensure the usability of the system there are:

- Well-structured user manuals included in the help menu
- Informative error messages
- Well-formed graphical user interfaces

- **Reliability:**

Reliability is one of the important attributes that every system should have. Therefore, our system needs to be reliable in a way that it must continue operating in an expected way over time. For this, thorough testing will be done.

- **Security requirement**:

The system shall enforce access control to prevent an unauthorized user from getting access into the system and/or to prevent a user from accessing a role for which he/she is not entitled. Also, through implementation of abstraction and Encryption we can enforce integrity of the system and system data.

- **Concurrent user support**:

The system should support concurrent users to communicate with the system.

❖ **Robustness**

The system can cope with errors during execution like negative and positive numbers, text inputs. Moreover, the system continues operating despite abnormalities in input and cases of single application failure.

4.2 System Modeling

System models consist of use case diagrams, class diagrams, sequence diagrams and activity diagrams.

4.2.1. Use Case Diagram

The main concepts of use case modeling are actors and use cases. An actor represents an entity (human or may be system) external to the system which communicates with the system in order to achieve certain goals. On the other hand, the use case describes the functionalities and a sequence of actions that provide something of measurable value to an actor. The use case diagram for the Online Medical record system is presented in *Figure 4.1* below.

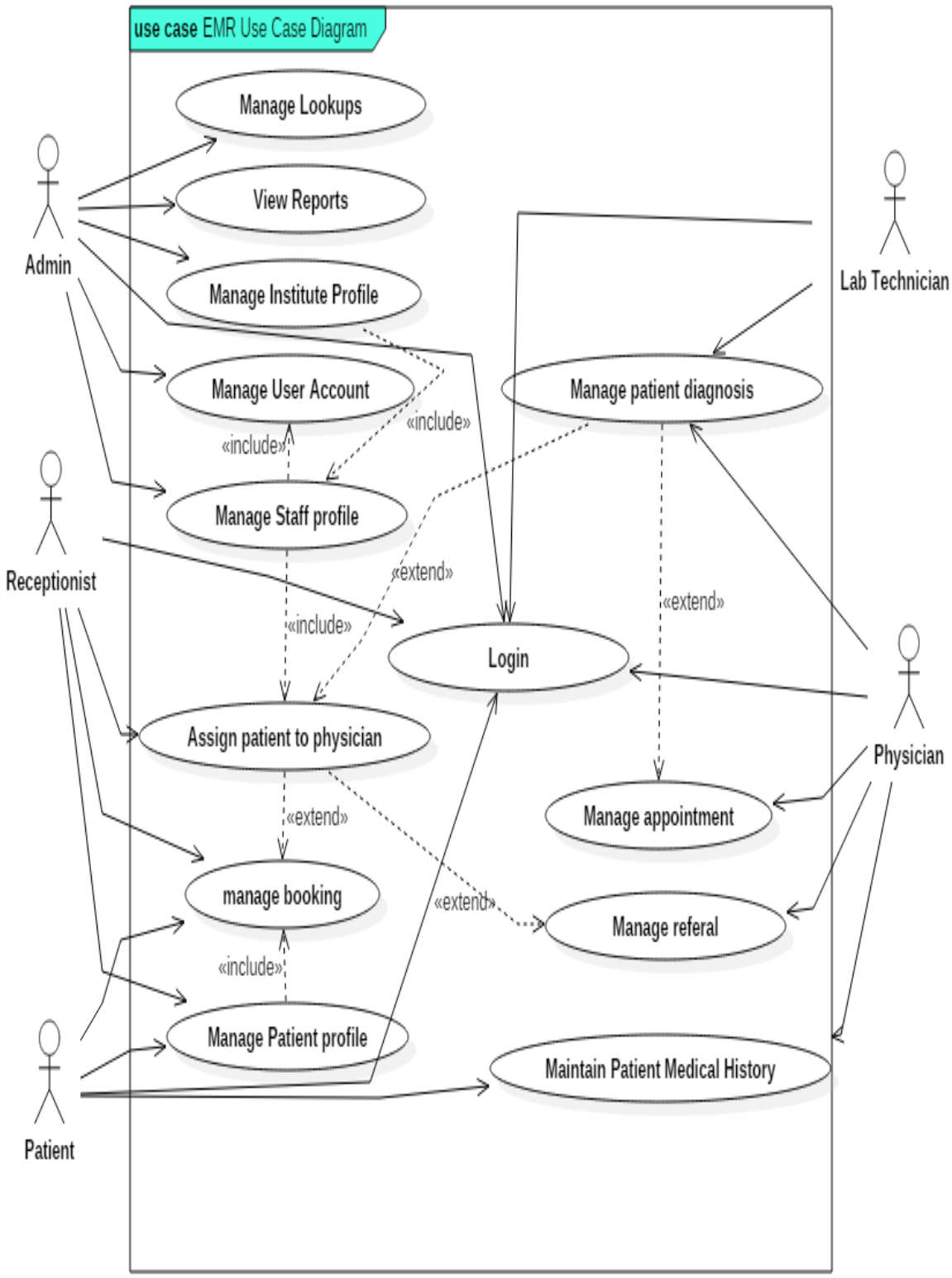

Figure 4. 1 : EMR Use Case Diagram

4.2.1.1 Descriptions of Actors

a. Admin

An admin is a user group that performs administrative tasks such as registering recognized medical institutions and user account management. It operates within two domains. Namely the global admin and local admin.

i. Global admin

Is a group of users responsible for performing an administrative task using the system at a national level, this role is issued for someone who is an employee of the Federal Ministry of Health and has the privilege of system administration. The activities performed by Global admins include registering medical institutions, registering staff for Medical Institutions, creating Local admin accounts for Medical Institution staff, managing user accounts, view user's activity logs and Generating different reports that can be used for medical research or management decisions.

ii. Local admin

Is a user responsible to perform administrative tasks at the institution level. For an individual to resume this role that individual needs to be an employee of a recognized medical institution over which he/she is going to gain an administrative privilege. The list of activities done by Local admins includes managing their institution profile information, registering staff of their institution, managing user accounts in their institution domain, monitor user activity logs and generate different reports.

b. Patient

A patient is an individual who uses the system in the order book for medical support in any of the medical institutions recognized by the system, to track their past medical histories, to check their appointment and referral schedules.

c. Physician

A physician is a professional who is an employee of some medical institution recognized by the system and uses the system to view the patient’s previous medical history, family medical history, social history and list of patients’ allergies in order to provide better care. Also to

maintains a patient's diagnosis information, treatments prescribed for the patient, any new allergies and family medical cases that are relevant for the patient future medical treatments.

d. Receptionist

A receptionist is a person who makes use of the system for booking for patients who don't have access to the system and to set up the patient-physician assignment during regular booking, appointment or referral cases.

e. Lab Technician

Laboratory and radiology technicians are professional that undergo different diagnosis test and encode test results upon a diagnosis order made by physicians. The diagnosis results help physicians make better medical decisions so that the patient gets good treatment.

4.2.1.2 Use case Description

Table 4. 2 : Use case description for Login

Use Case ID :	**SUC-001**
Use Case Name :	**Login**
Actor :	Admin, Receptionist, physician, Lab & rad technician, patient
Description :	In this system use case, the Admin, Receptionist, physician, Lab & rad technician, patient,shall be authenticated and the system displays all features available for each role
Trigger :	When the user has to login into the system
Precondition :	The system must be deployed and launched
Normal Flow :	This use case starts when the User accesses the sign-in feature of the system. 1. The system prompts the User for his/her username and password. 2. The User enters his/her username and password. 3. The system validates the entered information and Authenticate the user 4. The system displays the home page for the role assigned to that user. 5. The use case ends.
Post Condition:	The actor successfully logged in

Alternative Flow:	3.1.If the actor enters wrong username or password, the system displays the wrong username or password message 3.2.The system displays a login page

Table 4. 3 : Use case description for the Manage User Account

Use Case ID :	**SUC-002**
Use Case Name :	**Manage User Account**
Actor :	Admin
Description :	This system use case is built to create and manage system user accounts
Trigger :	When the actor required to enable or disable access privilege to the system
Precondition :	The user must be Authorized medical staff
Normal Flow :	1. The system displays the admin home page 2. Admin select create user link 3. The system displays the user registration form 4. Admin enter input information and click create button 5. The system notifies successfully created message
Post Condition :	User successfully created or updated
Alternative Flow :	4.1.If the user entered the invalid information, then the system displays a validation message and the page is unchanged. 4.2.If the username or user id already exists 4.1.1. The system display user already exists message 4.1.2. The form data restored

Table 4. 4 : Use case description to Manage Institute Profile

Use Case ID :	**SUC-003**
Use Case Name :	**Manage Institute Profile**
Actor :	**Admin**

Description :	This system use case is used to create and update medical institution information.
Trigger :	When the institute is ready to implement the system
Precondition :	The Institute needs to be recognized by MOH
Normal Flow :	1. The system displays the home page 2. Officer select Institute registration link 3. The system displays the Institute registration form 4. Officer fills the form and clicks the save button 5. The system notifies Institute is successfully registered
Post Condition :	The institute is registered successfully
Alternative Flow :	4.1.If the user entered the wrong information, the system validates the form and Displays a validation message 4.2.If the institute is already registered 1.1. The system displays institution already exist message 1.2.The system restores from data

Table 4. 5 : Use case description for Manage Staff Profile

Use Case ID :	**SUC-004**
Use Case Name :	**Manage Staff Profile**
Actor :	**Admin**
Description :	This system use case is used to create and update medical staff information.
Trigger :	When the staff is expected to use the system
Precondition :	The staff need to be a member of an institute recognized by MOH
Normal Flow :	1. The system displays the home page 2. user-select Staff registration link 3. The system displays the Staff registration form 4. User fills the form and clicks the save button 5. The system notifies Staff is successfully registered
Post Condition :	Staff is registered successfully

Alternative Flow :	4.1.If the user entered invalid information, the system validates the form and Displays a validation message 4.2.If the Staff is already registered 4.2.1. The system displays Staff already exist message 4.2.2. The system restores from data

Table 4. 6 : Use case description for Manage Patient Profile

Use Case ID :	**SUC-005**
Use Case Name :	**Manage Patient Profile**
Actor :	**Receptionist, Patient**
Description :	This system use case is used to create and update patient information.
Trigger :	When a patient arrives to institute seeking medical support or a patient need to have a patient account
Precondition :	The receptionist must perform an identity check-up before registering a patient
Normal Flow :	1. The system displays the home page 2. The user selects the patient registration link 3. The system displays the patient registration form 4. The user fills the form and clicks the save button 5. The system notifies that the patient is successfully registered
Post Condition :	the patient is registered successfully
Alternative Flow :	4.1.If the user entered invalid information, the system validates the form and display a validation message 4.2.If the patient is already registered 4.2.1. The system displays the user already exists message 4.2.2. The form will be restored

Table 4. 7 : Use case description for Manage Booking

Use Case ID :	**SUC-006**

Use Case Name :	**Manage Booking**
Actor :	**Receptionist, Patient**
Description :	This system use case is used to register patients seeking medical support
Trigger :	When a patient needs medical support
Precondition :	The patient profile must be maintained in the system
Normal Flow :	1. The system displays the home page 2. The user selects the booking link 3. The system displays the booking form 4. User or Patient fills the form and click the save button 5. The system notifies that the patient has booked successfully
Post Condition :	the patient has booked successfully
Alternative Flow :	4.1.If the Receptionist or patient entered the wrong information, the system validates the form and display a validation message 4.2.If the patient is already Booked 4.2.1. The system displays the patient has already booked

Table 4. 8 : Use case description for Assign Patient to Physician

Use Case ID :	**SUC-007**
Use Case Name :	**Assign patient to physician**
Actor :	**Receptionist**
Description :	This system use case is used to assign the booked patient to the available physician
Trigger :	When a patient booked for medical support
Precondition :	The patient profile must be recorded first and patient booked for treatment
Normal Flow :	1. The system displays the home page 2. The user selects the Patient-Physician assignment link 3. The system displays the Patient-Physician assignment form 4. User fills the form and clicks the save button 5. The system notifies that the Patient-Physician assignment done

	successfully
Post Condition :	The patient has been assigned successfully
Alternative Flow :	4.1.If the user entered invalid information, the system validates the form and Displays a validation message

Table 4. 9 : Use case description for Manage Patient Diagnosis

Use Case ID :	**SUC-008**
Use Case Name :	**Manage Patient Diagnosis**
Actor :	**Physician, Lab Technician**
Description :	This system use case is used to maintain patients medical problems (diseases) and prescribed treatments and medications
Trigger :	When the patient met the physician assigned for
Precondition :	The patient needs to be assigned to a physician
Normal Flow :	1. The system displays the home page 2. Select Patient Diagnosis link 3. The system displays the patient diagnosis form 4. The user fills the form and clicks save button 5. The system notifies that the patient diagnosis saved successfully
Post Condition :	Diagnosis result maintained successfully
Alternative Flow :	1. If the user entered invalid information, the system validates the form and displays a validation message

Table 4. 10 : Use case description for Maintain Patient Medical History

Use Case ID :	**SUC-009**
Use Case Name :	**Maintain Patient Medical History**
Actor :	**Patient, Physician**
Description :	This system use case is used to maintain and display patients medical

	history
Trigger :	When the patient is diagnosed and treated
Precondition :	The patient needs to be diagnosed and get treatments
Normal Flow :	1. Patient, Physician login into the system 2. The system displays the home page 3. Physician select Patient Diagnosis link 2. The system displays the patient diagnosis form 3. Physician, Lab Technician fills the form and clicks save button 4. The system maintains patients medical history 5. No notification displayed
Post Condition :	The patient's Medical History maintained successfully
Alternative Flow :	1. If the Physician entered wrong information, the system notifies that the user entered wrong information and the form does not change 2. To view the patient's medical history 2.1.Patient, Physician view Medical History button 2.2.The system display patient's past medical history in a chronological order

Table 4. 11 : Use case description for Manage Appointment

Use Case ID :	**SUC-010**
Use Case Name :	**Manage Appointment**
Actor :	**Physician**
Description :	This system use case is used to set up and display patients' appointments and referrals.
Trigger :	When the patient needs to be appointed or referred
Precondition :	The patient needs to be diagnosed
Normal Flow :	1. The system displays the home page

	2. User-select Referral or appointment link 3. The system displays the appointment form 4. The physician fills the form and clicks the save button 5. The system maintains patients appointment information 6. The system notifies that the data saved successfully
Post Condition :	The patient's appointment maintained successfully
Alternative Flow :	2.1.If the Physician entered invalid information, The system validates the form and displays a validation message 2.2.Patient and Physician view appointment information and get notification

Table 4. 12 : Use case description for Manage Referral

Use Case ID :	**SUC-011**
Use Case Name :	**Manage Referral**
Actor :	**Physician, Receptionist**
Description :	This use case is used to refer a patient to another institution for better treatment after thoroughly analyzing his/her case
Trigger :	When the physician undergo patient diagnosis and find the case beyond his capability
Precondition :	The patient needs to be diagnosed by physicians, his/her case has to be difficult to handle for a physician assigned to
Normal Flow :	1. The system displays the home page 2. Physician select referral link 3. The system loads the referral page 4. The physician selects an active patient assigned for him/her from the waiting list 5. The system displays patients profile information 6. Physician fill and submit the form 7. The system notifies that the data saved successfully
Post Condition :	The patient's referral information maintained successfully

Alternative Flow :	1.1.On a receptionist home page, the system notifies the user that there is a patient referred to his/her institution 1.2.The receptionist select the patient from the waiting referral lists and assign the patient to an available physician 6.1.If the Physician entered invalid information, the system validates the form and displays a validation message

Table 4. 13 : Use case description for Manage Lookup

Use Case ID :	**SUC-012**
Use Case Name :	**Manage Lookup**
Actor :	**Admin**
Description :	This system use case is to maintain different attributes the are relevant to make the system dynamic
Trigger :	When a new system data was found or the old data needs modification
Precondition :	Discovery of new items of modification of existing items
Normal Flow :	1. The system displays the home page 2. Admin, Physician or Lab-technician select Lookup management link 3. The system expands the link and displays a list of items link 4. The user selects the link for the item to be added or modified 5. The system displays the form 6. The user fill and submit the form 7. The system notifies that the data saved or updated successfully
Post Condition :	Item maintained or updated successfully

Alternative Flow :	6.1.If a user entered invalid information, the system validates the form and displays a validation message 6.2.If the item already exists the system displays item already exist message and restore the form

Table 4. 14 : Use case description for View Report

Use Case ID :	**SUC-013**
Use Case Name :	**View Report**
Actor :	**Admin**
Description :	This use case is used by admin to generate different reports
Trigger :	When a some report data is needed
Precondition :	There must me encoded data in the system
Normal Flow :	1. The system displays the home page 2. Admin, select report management link 3. The system display list of report types 4. The user click the '+' icon to expand the panel 5. The system displays the form 6. The user fill and submit the form or select criteria 7. The system display the report
Post Condition :	Report generated successfully
Alternative Flow :	6.1.If there is no data for

	requested report 6.2.The system display no data found message

4.2.2 Sequence Diagram

Sequence diagrams are interaction diagrams that detail how operations are carried out.It is used to formalize the behavior of the system and to visualize the communication among objects. Sequence diagrams capture the interaction of objects in the context of collaboration. They are time focused and they show the order of interaction visually by using a vertical axis of the diagram to represent the time. The purposes of a sequence diagram are to model high-level interaction between active objects in a system, to model interaction between object instances within a collaboration that realizes a Use Case, to model the interaction between objects within a collaboration that realizes an operation and to model either a generic or specific instance of interaction. Generally, a Sequence diagram is used to formalize the behavior of the system and to visualize the communication among objects. Representation of a sequence diagram involves an actor, use cases, entities, boundaries and controls. The entity objects represent the system data while the boundary objects act as a bridge between the system and an actor. The controllers are objects that mediate between boundaries and entities. The sequence of interaction between a boundary, controller and entity objects are diagrammatically presented in figure 4.2

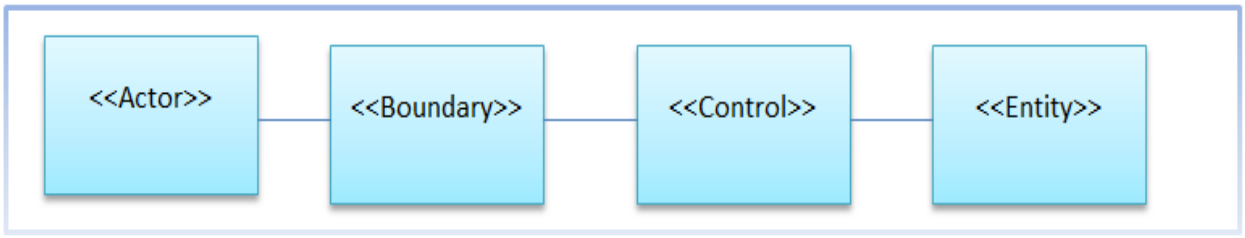

Figure 4. 2 : Boundary, Control and Entity object interaction model

4.2.2.1 Manage User Account

A user account case is used by an administrator to register new users to the system and manage the existing user accounts. The action taken in account management includes temporary user suspension; blocking user account and activating user accounts. The Sequence diagram for the user account Use case is presented below in Figure 4.3

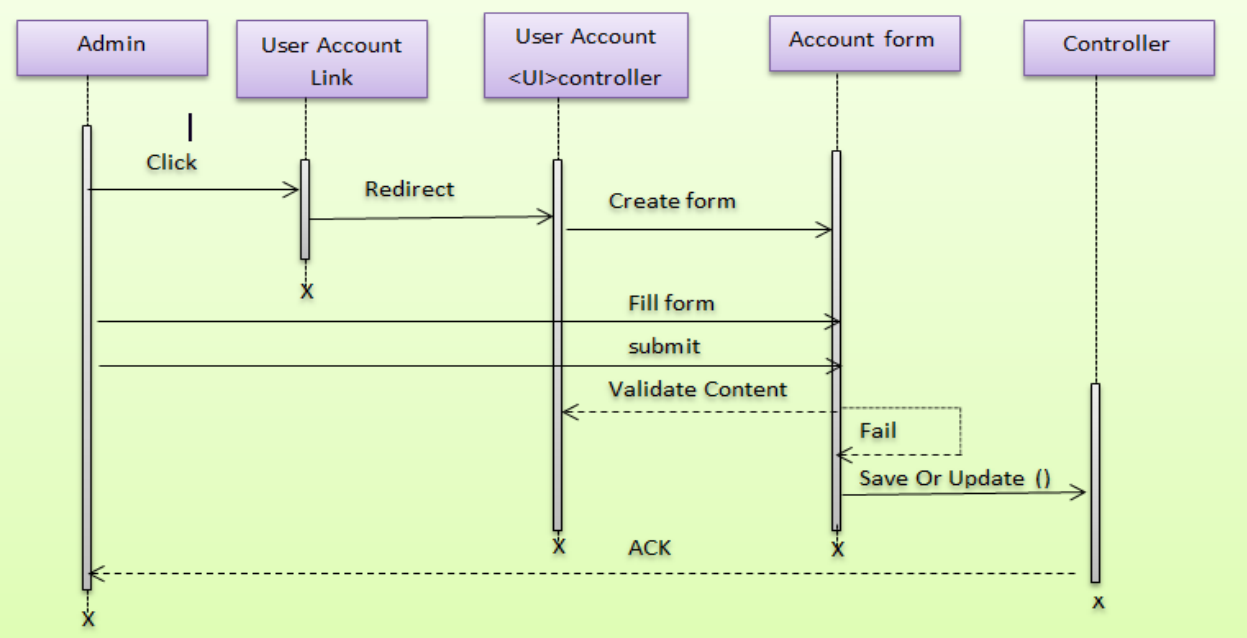

Figure 4. 3 : Sequence Diagram for Manage User Account Use case

4.2.2.2 Manage Institution Profile

The institution profile case is used to maintain medical institutions' basic information. The sequence diagram for maintaining basic Institution information is presented in Figure 4.4

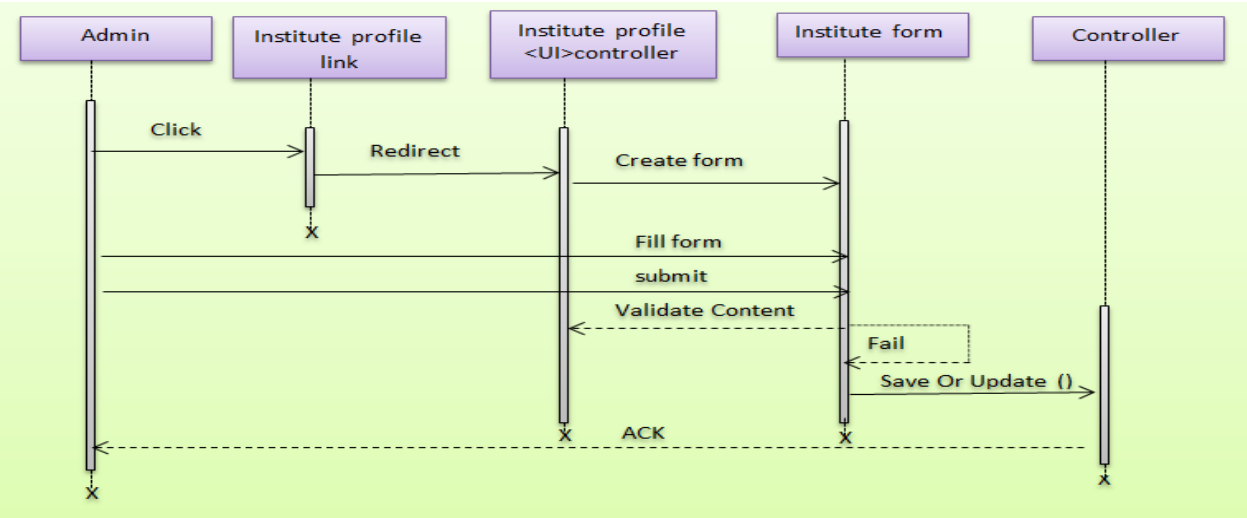

Figure 4. 4 : Sequence diagram for Institution Profile Use case

4.2.2.3 Manage Staff Profile

This use case is used by Admins to maintain the institution's staff members who are going to be system users with some defined role. The sequence diagram is presented in Figure 4.5

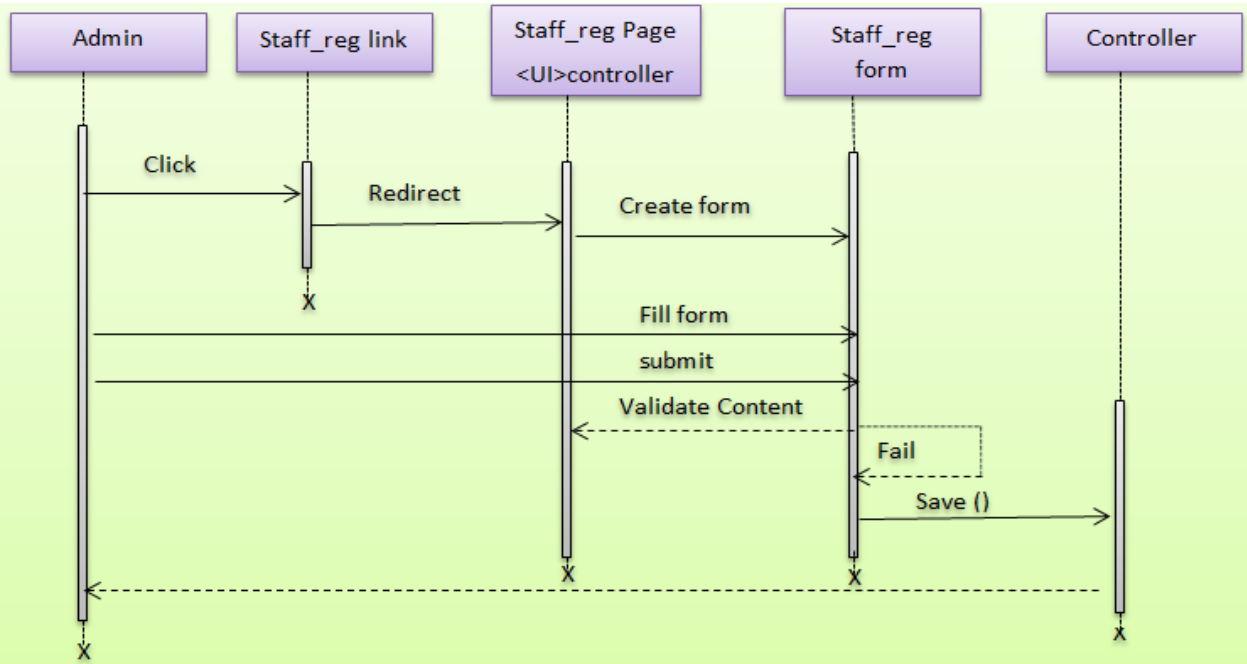

Figure 4. 5 : Sequence diagram for Staff Profile Use case

4.2.2.5 Manage Patients Profile

Receptionists use this use case to maintain the patient's basic profile information on their first arrival. The sequence diagram for the patient profile is presented below in Figure 4.6:

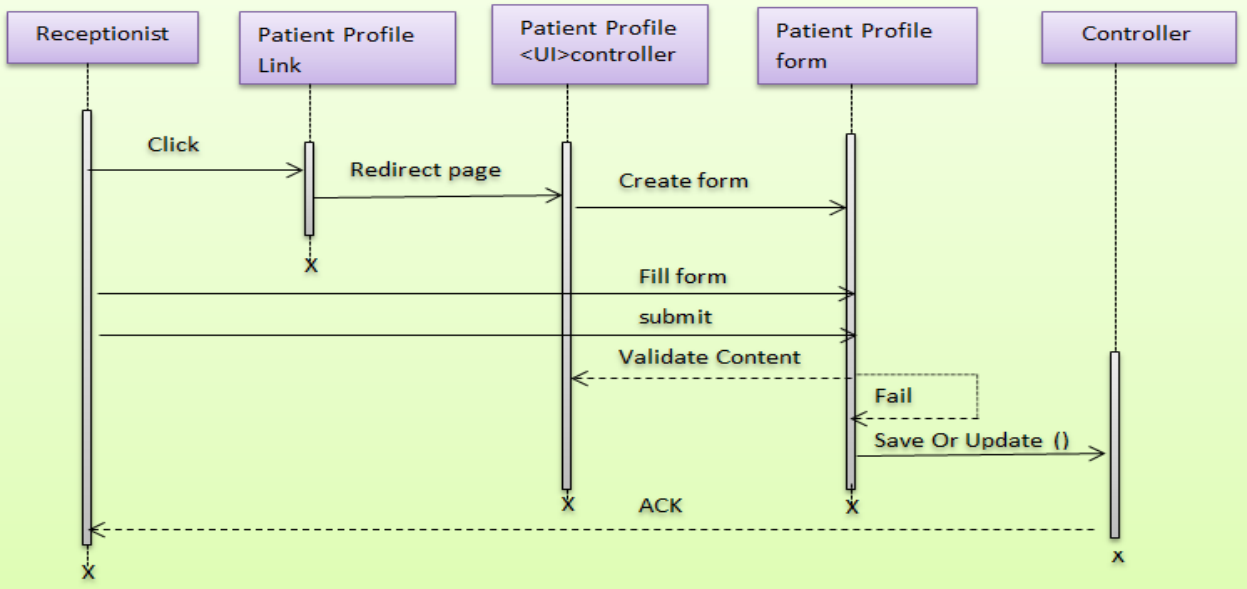

Figure 4. 6 : Sequence diagram for Manage Patient Profile Use case

4.2.2.6 Manage Booking

This case is used by patients or receptionists to place reservations for medical support. The sequence diagram for Booking Use case is presented below in Figure 4.7

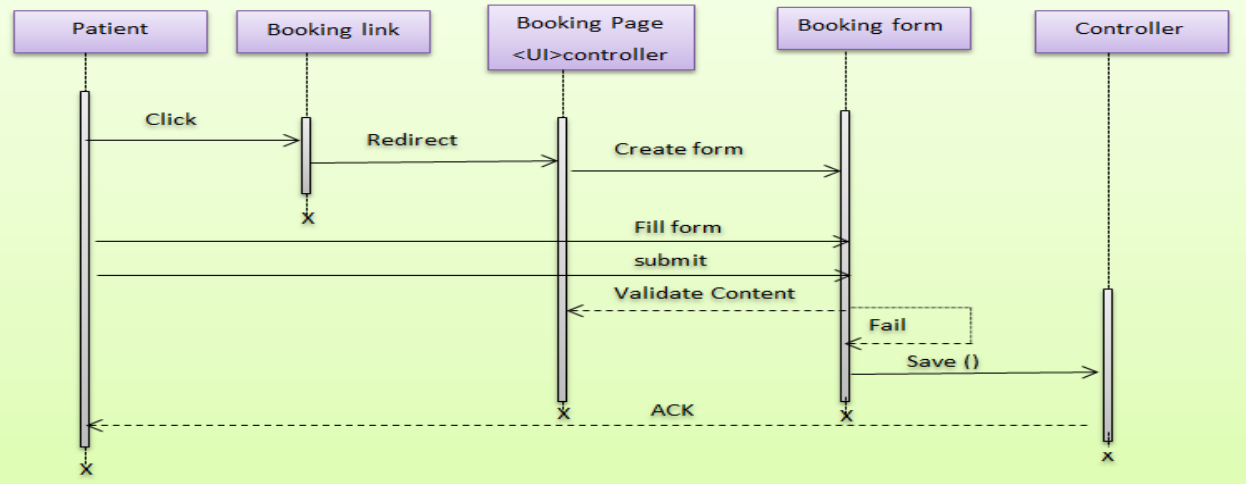

Figure 4. 7 : Sequence diagram for Manage Booking Use case

4.2.2.7 Assign Patient to Physician

The patient-physician assignment use case is used to assign a patient who is booked in some institution for treatment of some medical case to a physician who works in that specific institution and specialized in the specific medical case as the patients' problem. The sequence diagram for *Assign Patient to Physician* Use case is presented below in Figure 4.8

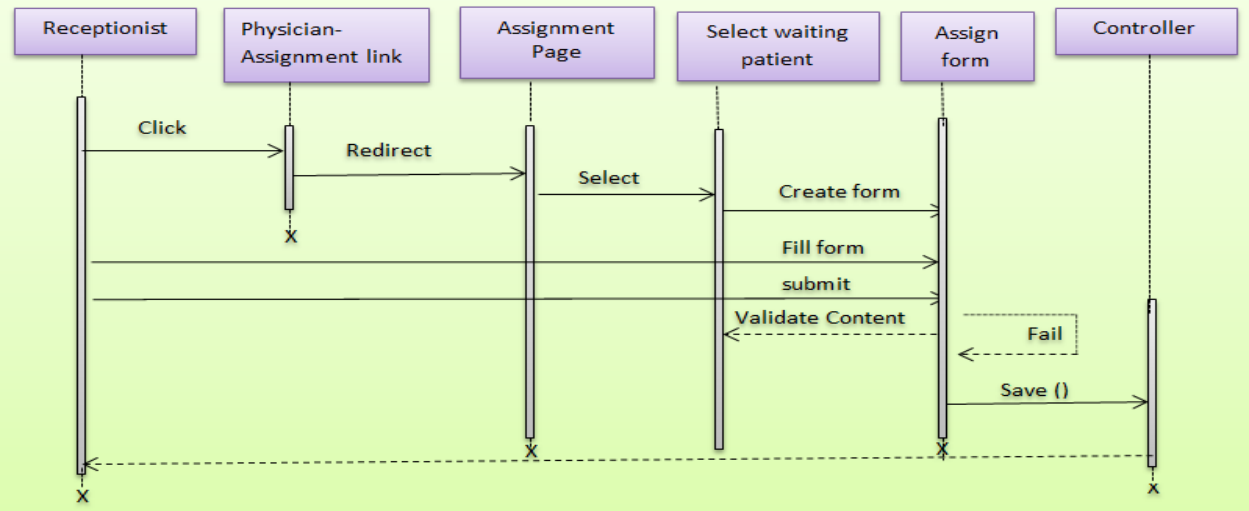

Figure 4. 8 : Sequence diagram for Patient to Physician Assignment Use case

4.2.2.8 Manage Patient Diagnosis

This use case is used to maintain the steps followed by physicians in order to identify the problem (disease) of a patient. The sequence diagram is presented in Figure 4.9

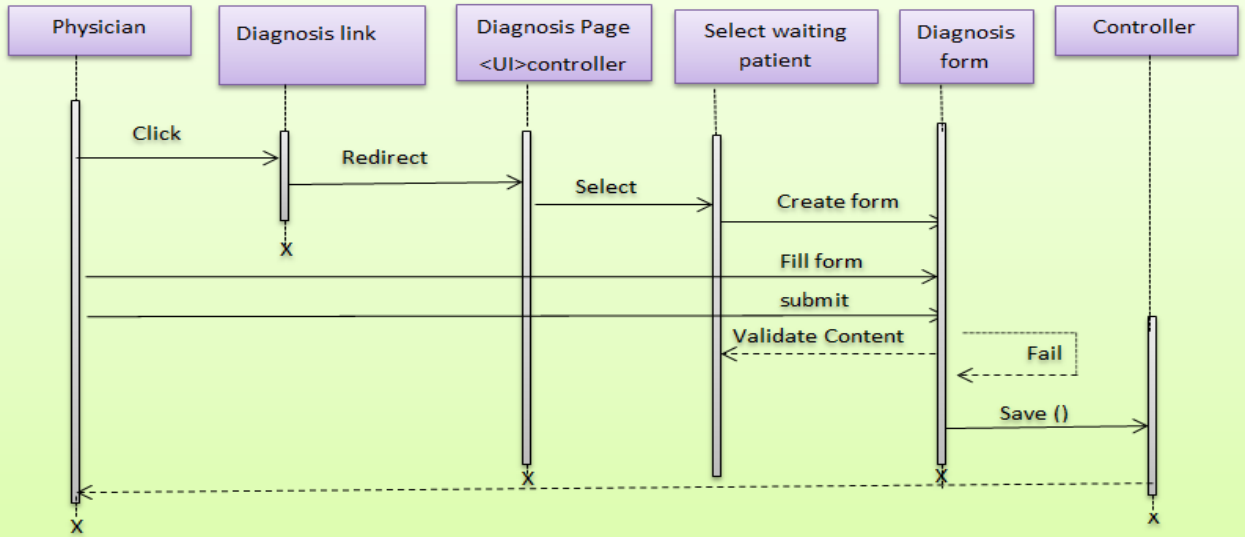

Figure 4. 9 : Sequence diagram for Manage Patient Diagnosis Use case

4.2.2.9 Maintain Patient Medical History

Physicians use the case medical history to maintain the patient's medical information such as diagnosis results, treatments and Medications. The sequence diagram for medical history is presented below in Figure 4.10:

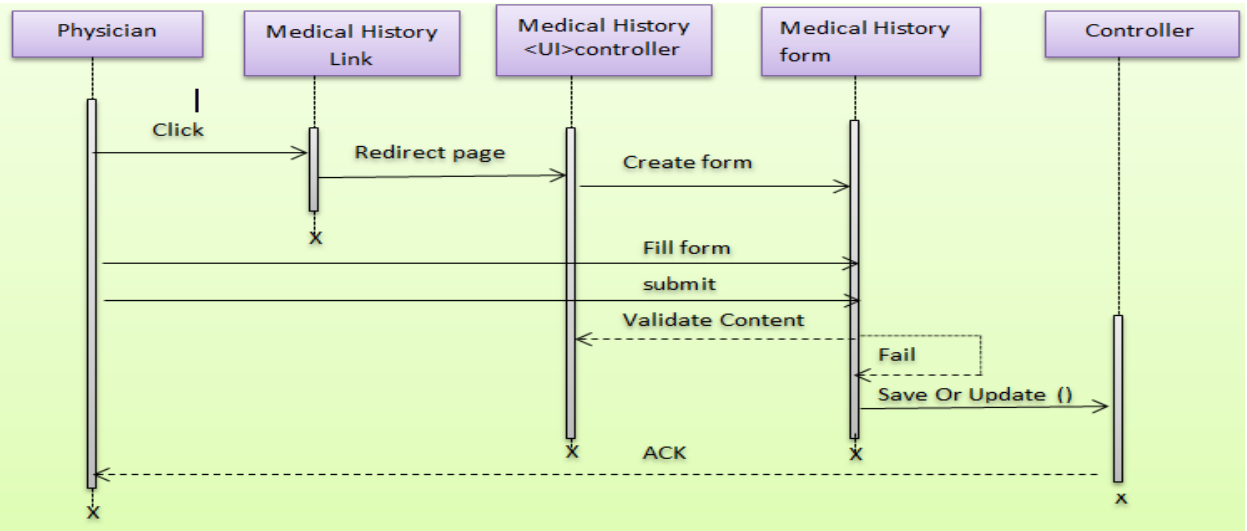

Figure 4. 10 : Sequence diagram for Maintain Patient Medical History use case

4.2.2.10 Manage Appointment

Physicians' uses the cases this to maintain patient appointment. The sequence diagram for patient appointment is presented below in Figure 4.11

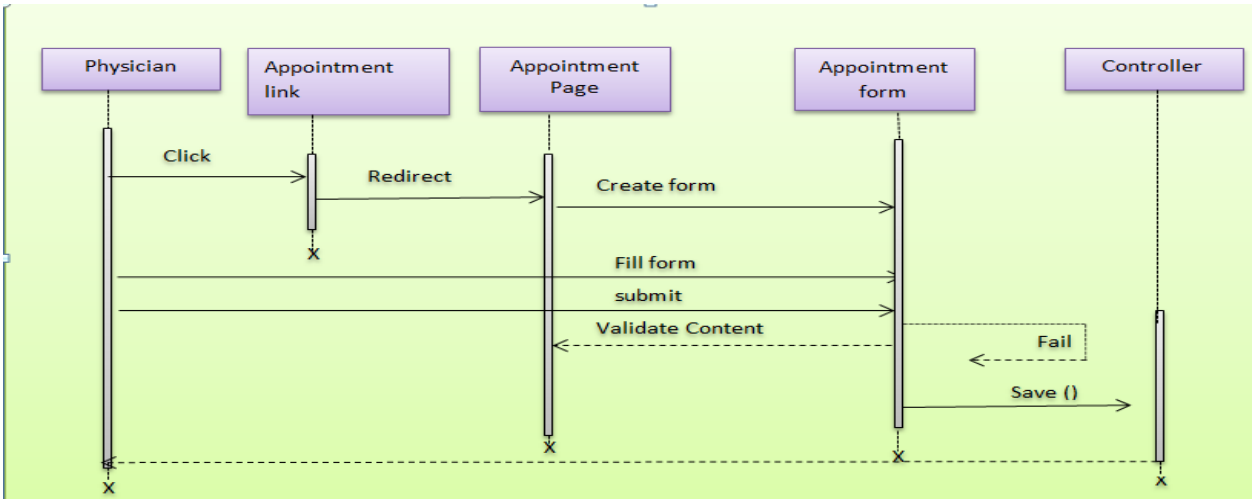

Figure 4. 11 : Sequence diagram for Manage Patient Appointment Use case

4.2.2.11 Manage Referral

Physicians' uses the cases this to refer patients from one health institution to another. The sequence diagram for patient referral is presented below in Figure 4.12

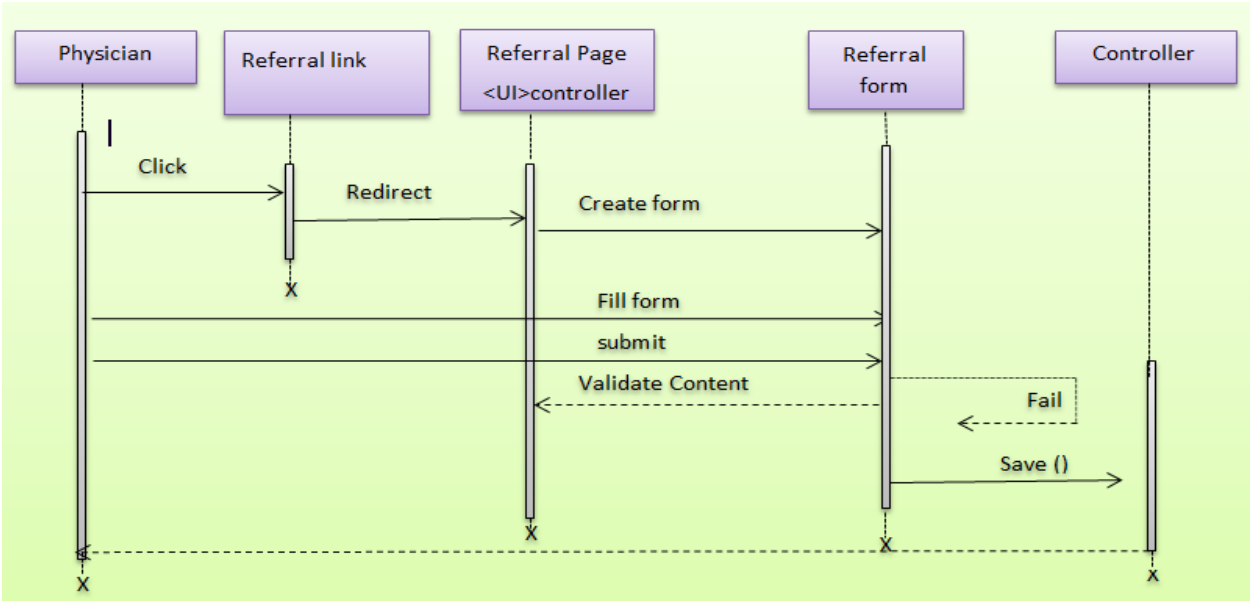

Figure 4. 12 : Sequence diagram for Manage Patient Referral Use case

4.2.3 Activity Diagram

The activity diagram is another important behavioral diagram used to describe the dynamic aspects of the system. It graphically represents a stepwise workflow of activities and actions with the support of choice, iteration and concurrency.

a. Activity Diagram for User Login

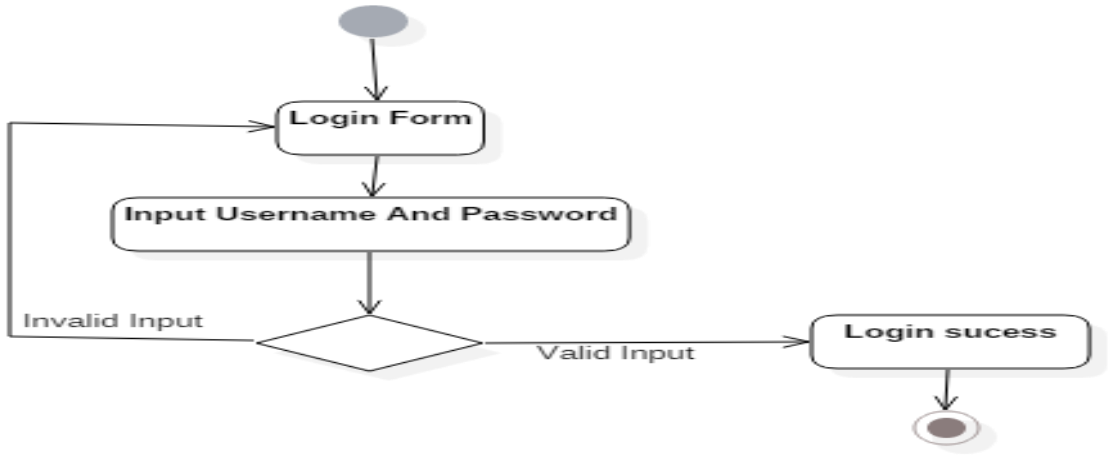

Figure 4. 13 : Activity diagram for User login

b. Activity Diagram for Staff Registration

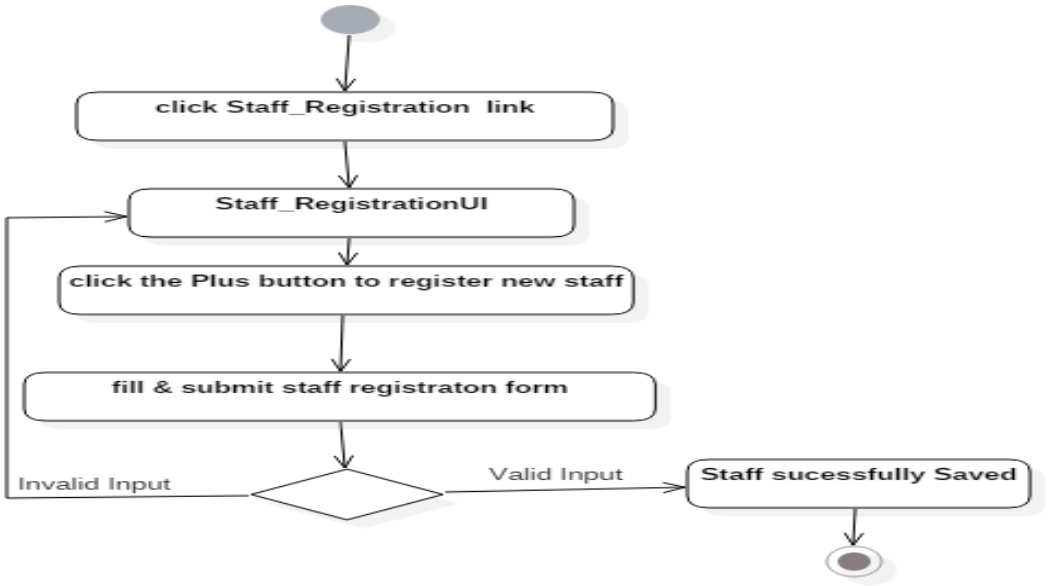

Figure 4. 14 : Activity diagram for Staff Registration

c. Activity Diagram for Patient Registration

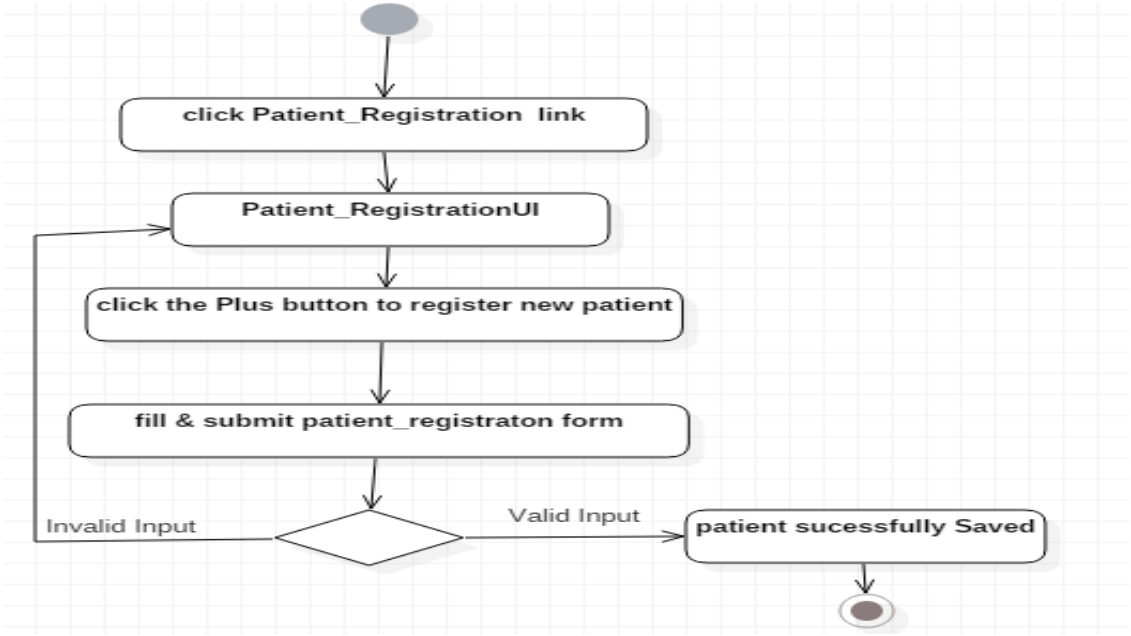

Figure 4. 15 : Activity Diagram for Patient Registration

d. Activity Diagram for Booking

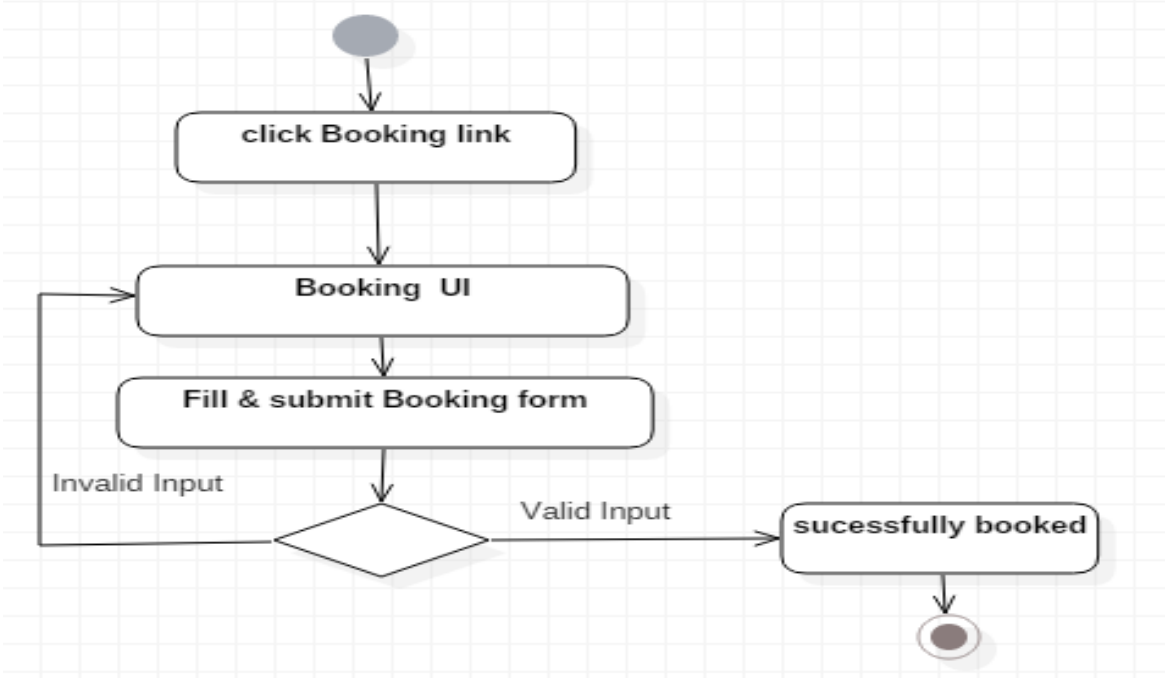

Figure 4. 16 : Activity diagram for Booking

e. Activity Diagram for Patient-Physician Assignment

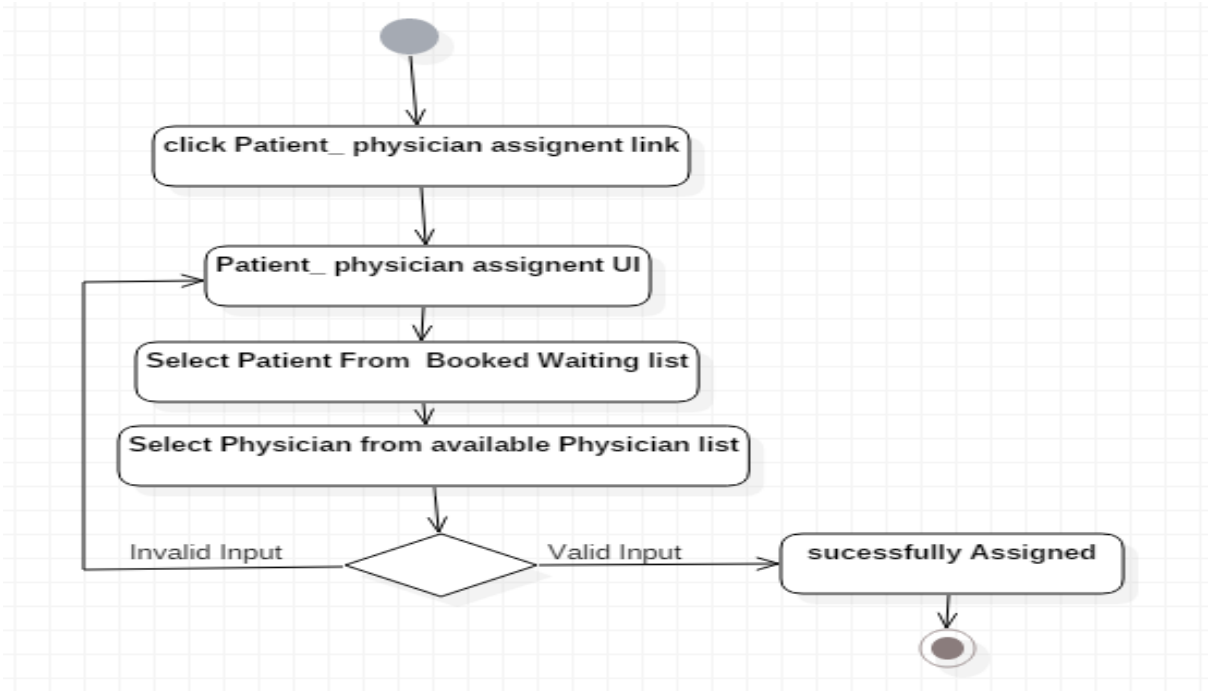

Figure 4. 17 : Activity diagram for Patient-Physician Assignment

f. Activity Diagram for maintaining patient diagnosis

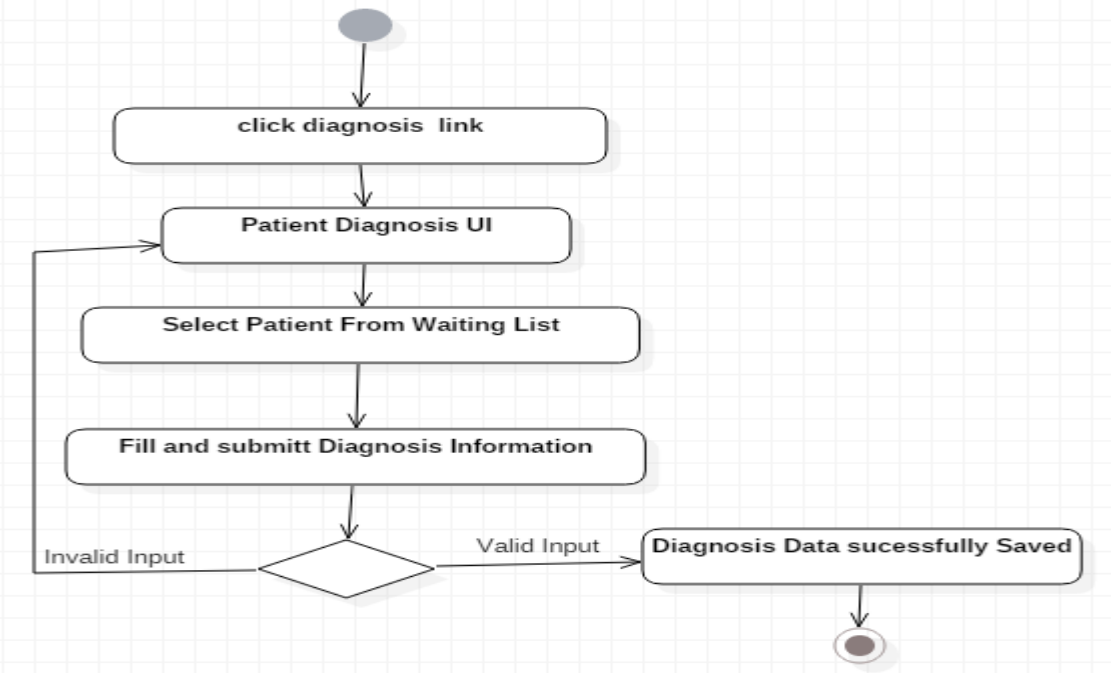

Figure 4. 18 : Activity diagram for Manage patient diagnosis

g. Activity Diagram to setup Referral case

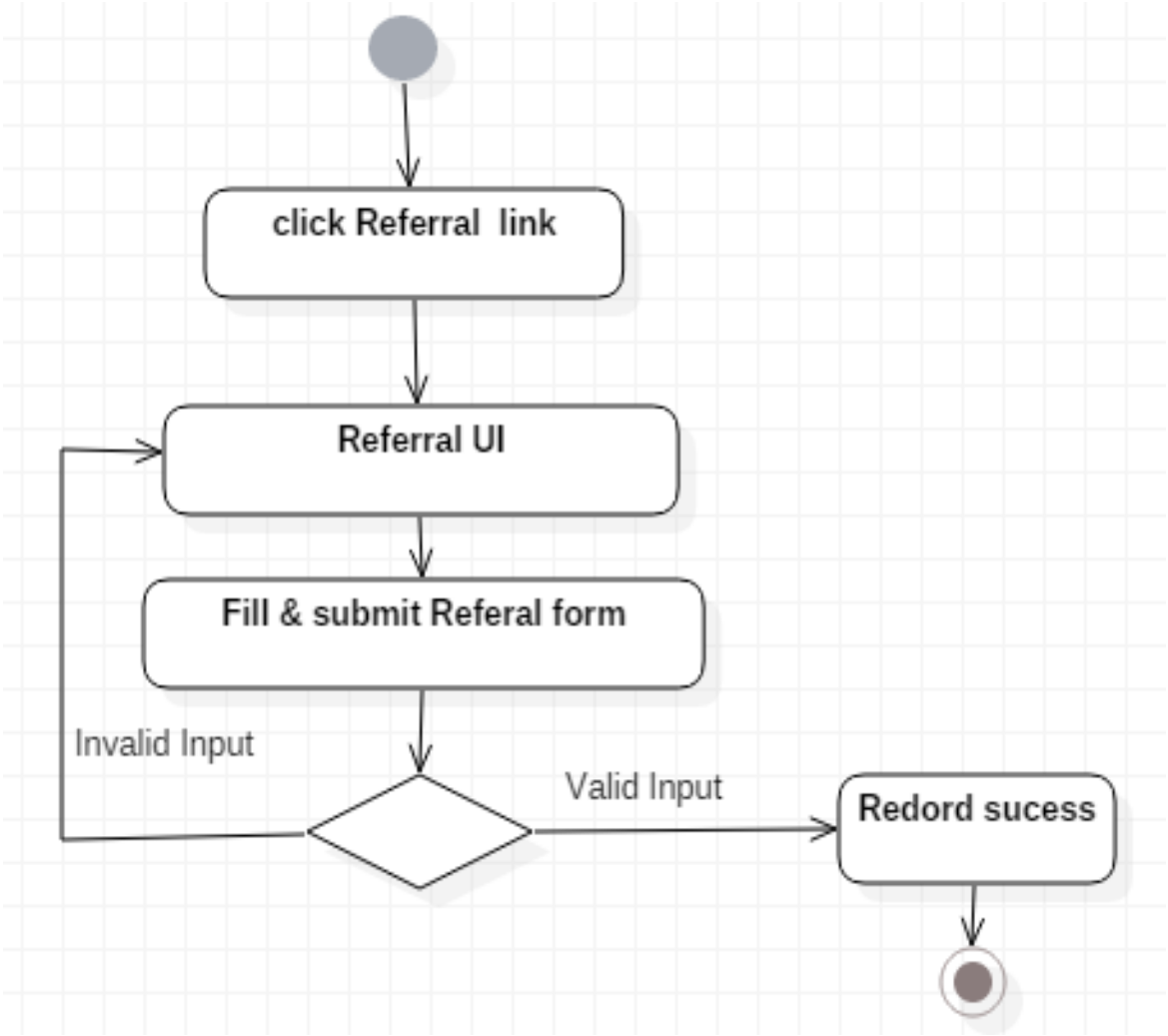

Figure 4. 19 : Activity Diagram to setup Referral Case

4.2.4 Class Diagram

Class diagrams are used to describe the structure of a system in terms of classes, attributes, operations and association of objects in the class. The class diagram of Online Electronic medical records is presented in Figure 4.20.

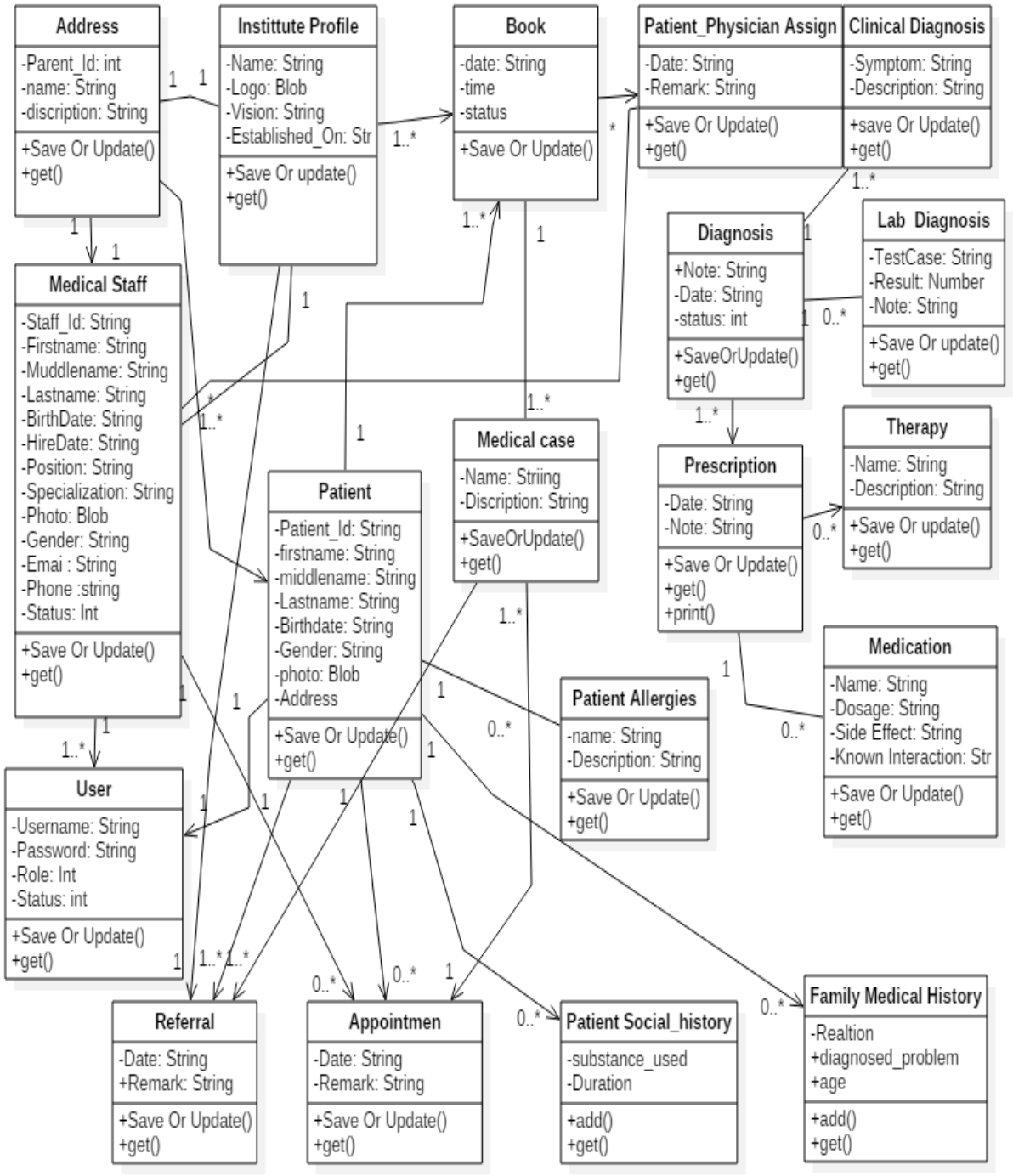

Figure 4. 20 : EMR Class diagram

Chapter Five: System Design of Online Electronic Medical Record System

Overview

In the previous chapter, we have discussed the system analysis models that describe the system from the user's point of view. In the model, the functional and non-functional requirements of the system were identified and the behavior of the system was modeled with the help of sequence and activity diagrams. In this Chapter, we are going to present the design of an Online Electronic Medical Record system in which the internal structure of the system will be discussed. In this section, we are going to discuss the design goal of the system, the proposed software architecture for the system, sub-system decomposition, system hardware/software and persistent database design.

5.1 Design goal

Design goals represent the expected qualities of the system and provide a consistent set of criteria that must be considered when making design decisions. The design goals are derived from the non-functional requirements of the system. The design goals can be generally grouped into performance criteria, dependability criteria, maintenance criteria and end-user criteria

5.1.1 Performance Criteria

Performance is about the time and the software system's ability to meet timing requirements. Performance Criteria consider a variety of factors that have an influence over the performance of the system. The two major performances that we are going to consider in our system are Response time and concurrency control.

a. Response time

The time taken by the system to process data (Sending or requesting data and getting acknowledgment) should be short.in case of network failure also the system should notify the user immediately. Since EJB (Enterprise Java Beans) is the framework selected to implement this project there are many choices that can be used to improve the system speed. Some of them include cache as many beans in the EJB cache as possible, use stateful session beans only when necessary and optimize the use of stateless session beans because stateless session bean instances are pooled and shared by many clients.

b. Concurrency

The system implements concurrency control to support many users using the available bandwidth of the system at the same time.it considers the capabilities from the database side and hardware and web-server capabilities that enable the system to serve several users access the system concurrently. Oracle maintains data consistency in a multi-user environment by using a multi-version consistency model and various types of lock and transaction. Also, the glassfish server permits specifying any isolation level that our database supports.

5.1.2 Dependability Criteria

The dependability of a system indicates the degree of trust that the user has in the system. It reflects the extent of the user's confidence that the system is going to operate as expected and not going to fail during normal use. The system attributes related to dependability are reliability, availability, security, safety and robustness.

a. Reliability

The reliability of the system indicates the probability of the system performing a failure-free operation for a specified period of time in a specific environment.

b. Security

The security of the system refers to the probability of the system resisting accidental and deliberate intrusion. There should be an implementation of an authentication and authorization mechanism to control user's access to the system

5.1.3 Maintenance Criteria

The maintainability criteria are used to measure the ease with which a software product can be modified. It refers to the system's extensibility and portability.

a. Extensibility

The system shall be able to entertain the addition of new functionality and feature without any restriction. This constraint enables the system to gain better acceptance by the users, for its capability to support unrestricted future expansion of the system.

b. **Portability**

The system should have the capability to operate on different platforms, for there could be platform shifting in the future and to gain the acceptance of different institutes having different platforms. It is important to have this constraint into consideration since our system is expected to operate in different institutions that have a variety of platforms.

5.1.4 End-user Criteria

The user criteria are used to measure the consideration of user intuition during system development and the capability of the system to address all the functional requirements. It includes the usability and utility of the system.

a. Usability

The system should be designed to have an intuitive and convenient interface for both less experienced users and system administrators

b. Utility

The utility of the system refers to the user's functional requirements that the system must address.

5.2 The architecture of the System

In this section, we are going to discuss the architecture of the system that represents the interaction between the different components of the system and the users. For the proposed EMR system we are going to implement the client-server type system architecture. In this type of architecture, the server is responsible to accept requests from the client, process the requests and respond to the appropriate response for the client requests. Whereas the client is responsible to initiate the interactions with the servers, invoking services needed from those servers and wait for the responses made by the server. In our project, we are going to make use of two types of servers, namely the application server and database server. The application server is used to access the business logic which is the code that provides the functionality needed to build and run dynamic content. Essentially a framework that allows programs to create and serve dynamic content. On the other hand, the database server plays the role of responding to the requested database services by the application server.

The selected client-server architecture for the online Electronic Medical Record system is going to implement a three-tier layered approach to present the detailed interactions. These three layers involved in our system are the presentation layer, the application layer and the data layer.

Presentation layer

The presentation layer also known as the client layer is the topmost layer of an application.it is the visible part of the system for users. The main function of this layer is to connect the users with the application layer.it passes the information entered by the users in terms of a mouse click or keyboard action to the application layer.

Application layer

The application layer is also known as the Business Logic layer or logical layer.it interacts with the data layer and sends the required information to the presentation layer. The application layer ac as a mediator between the presentation and the data layer. Generally, it controls application functionality by performing detailed processing.

Data Layer

The data layers' main function is to store application data. The application layer communicates with the data layer to retrieve data and to perform operations like insert, update, and delete.

The Architecture of the online EMR system to be implemented in Ethiopia is presented below in Figure 5.1

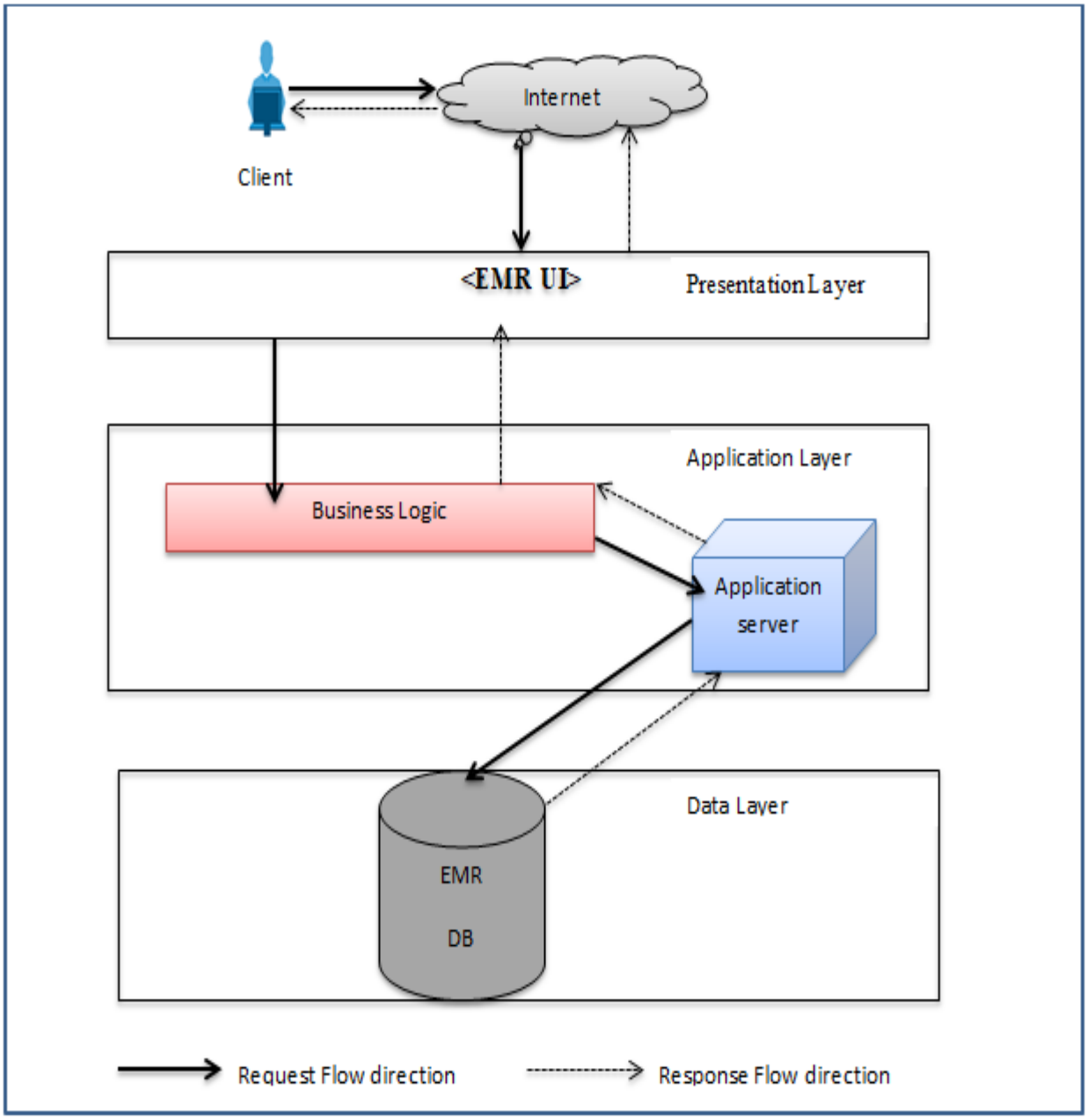

Figure 5. 1 : Architecture of Online EMR System

5.3 Subsystem Decomposition

For the purpose of simplification and reduction of complexity the proposed online EMR system is decomposed into three sub-systems. The sub-systems are the Administration sub-system, Patient management sub-system and medical patient Diagnosis sub-system. The sub-system decomposition for the Online EMR system is presented in Figure 5.2.

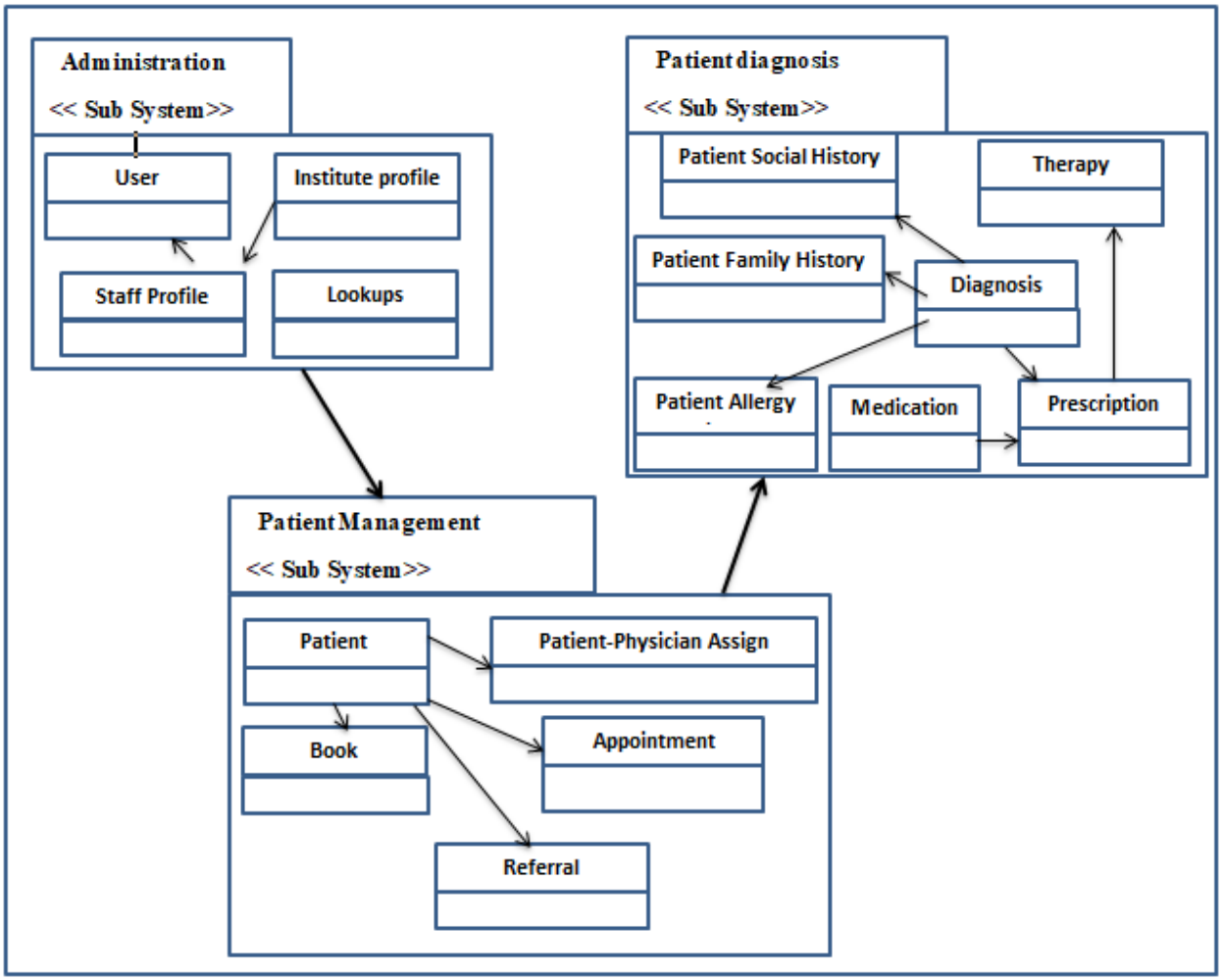

Figure 5. 2 : Sub-systems Decomposition of Online EMR System

5.3.1 Administration sub-system

The Administration sub-system side of the application is used by users to perform basic system administration activities such as registering and managing medical institutions profile information, registering, managing medical staffs profile information for each medical institute, lookup management to make the system dynamically configurable, creating and managing system users and the security auditing of activities logged from all subsystems is done in the administration subsystem.

5.3.2 Patient Management sub-system

The patient management sub-system sections of the system are used for maintaining and manage basic patient profile information and maintain patient treatment workflows. Some of the operations done by this section of the system include Registering and managing patient's profile

information, handling patient's bookings, assigning the booked patients for the available physicians in the institution and maintaining and notifying patient's appointments and referral cases.

5.3.3 Patient diagnosis sub-system

This section of the system is used by physicians and lab-technicians to maintain the patient's medical diagnosis results, a list of medications and treatments prescribed and to maintain the medical history of a patient for future use. Physicians undergo basic clinical diagnosis on their patients and maintain their findings to the system. If lab and radiology diagnoses are required the physicians specify and prescribe the type of diagnosis to be made. The lab technician or radiologist reports back their findings to the physician using the system. Then according to the findings, they are going to prescribe the patient medicine or treatment using the system.

5.4 System Components

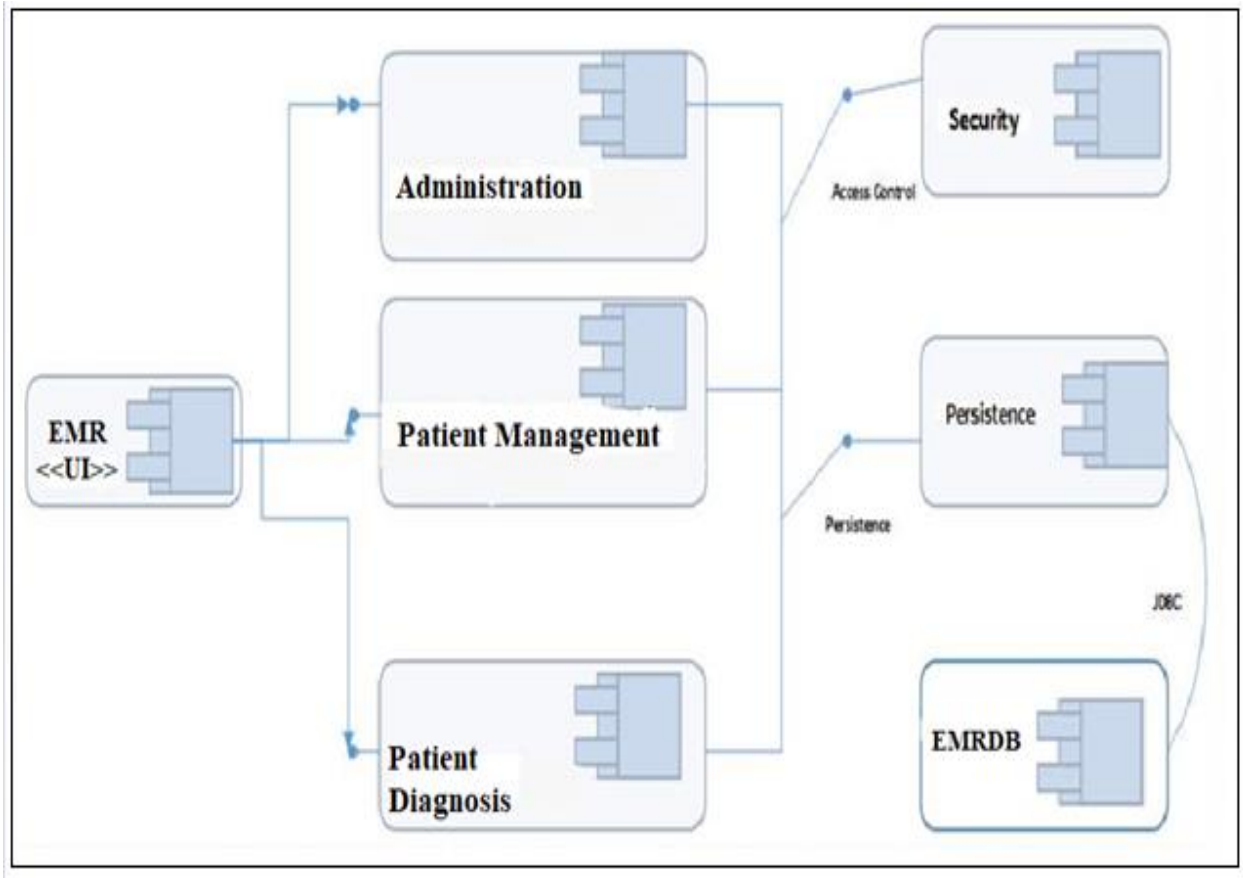

Figure 5. 3 : Component diagram for the Online EMR System

A component mainly refers to physical packages or such logical elements as classes, interfaces, and collaborations. It is the replaceable part of a software system that makes sure the realization of a set of interfaces.

Figure 5.3 depicts the components involved in the proposed online Medical Record system and their interactions.

5.5. Hardware /Software Mapping

The hardware/software mapping provides a high-level view of each component that exists in the system. A deployment diagram is used to describe the relationship of components with the hardware nodes.

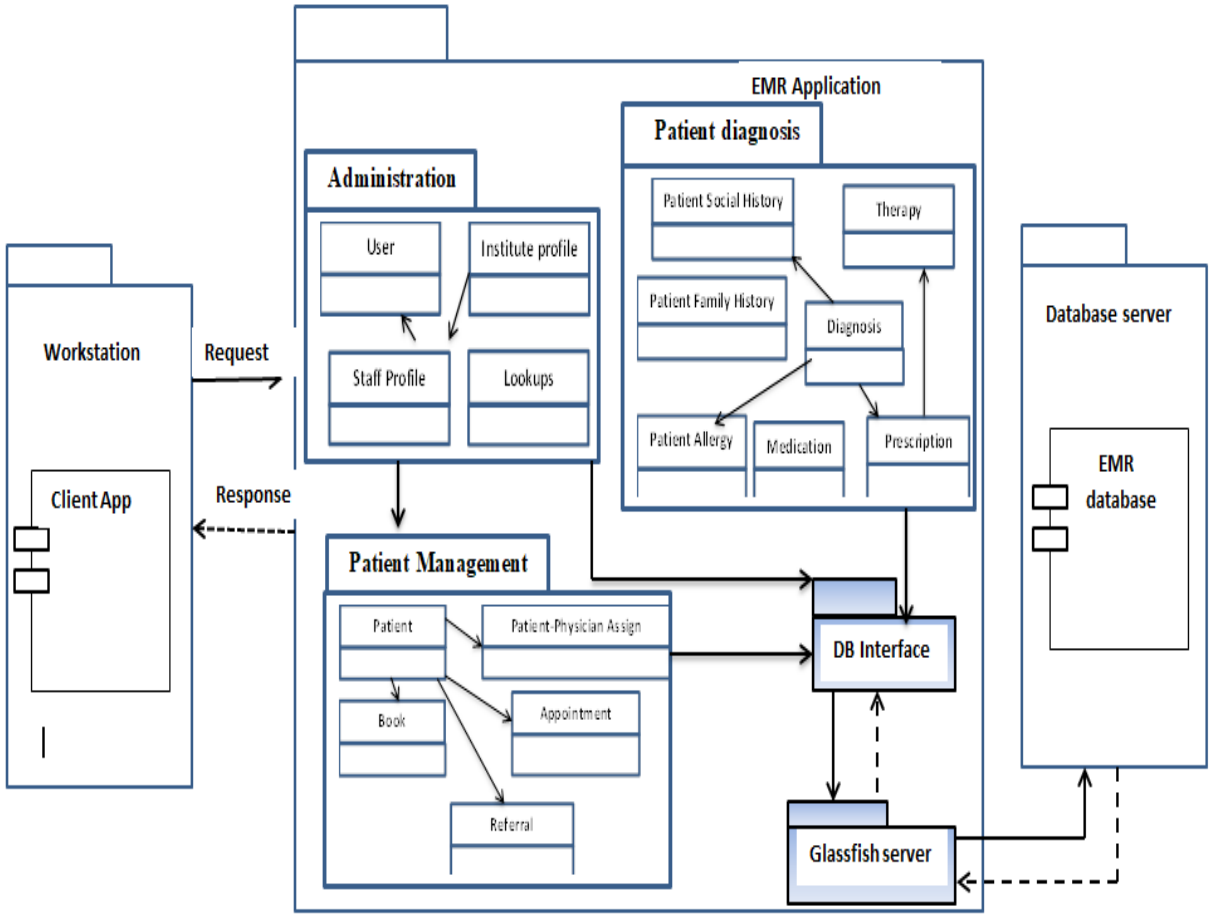

Figure 5. 4 : Hardware/software mapping diagram for Online EMR System

As indicated in Figure 5.4 the system contains three hardware components: the client machine, the application server machine and the database server machine. The client machine contains the

web browser that enables system users to access the application server according to their privilege through HTTPs. The application server or the web server contains the application logic and uses Glassfish Server to handle requests sent from users through HTTPs. Finally, there is the database server that is used to perform tasks such as data analysis, storage, data manipulation, archiving, and other non-user specific tasks. The database server uses the relational database management system which is the Oracle Database server.

5.6 Persistent data storage

Persistent data management is concerned with managing and permanently storing the data for later usage when required. The information related to the Online EMR system is inherently persistent need to be permanently stored in the database system. To this end, entity classes defined in the class diagram in the analysis model shall be mapped into tables and attributes into fields of the respective tables. As defined in the Hardware/Software mapping, the database used to create tables and relationships is Oracle 12c.

All the information stored as persistent data shall be protected by implementing a rule defining unauthorized users should not gain access to the system and the resources thereon. In order to store data persistently in a database, those entity classes identified in the analysis model of the class diagram Online EMR system are transformed into tables and attributes of the classes are also mapped into tables fields.

Chapter Six: Implementation

Overview

In this chapter, we are going to discuss the implementation of the designed online EMR system. This includes different tools and development environments used to develop the system. Also, the screenshots that illustrate the prototype of the system are presented in this chapter. Finally, an evaluation of the system will be done to test its usability by deploying the system on a networked environment and make it accessible for a group of users who are going to fill the evaluation form.

6.1 Development Tools

In order to fulfill the objectives of this project, several tools and technologies were used. Basically, the technologies are used for front-end development, back-end development and communication purpose. The followings are the list of programming, database and communication tools used for the implementation of the designed online EMR system.

Glassfish Server

Is an open-source Jakarta EE platform application server and it supports EJB, JPA, JSF, JMS, RMI, JSP, servlets, etc. Glassfish allows developers to create enterprise applications that are portable, scalable and that integrate with legacy technologies. Some of the main new features it provides are deploy–on–change (provided by NetBeans and Eclipse plugins), session preservation across redeployments and startup time (only a few seconds). Glassfish server 4.1 is used for the development of this project. This provides the following.

- An easy-to-use administration console for configuration and management
- A web container that is responsible for managing the lifecycle of, mapping URL to a particular servlet and ensuring that the URL requester has the correct access right.
- Update tool connectivity for updates and add-on components

Oracle Database

Is a multi-modal database management system produced and marketed by Oracle Corporation. It is a database commonly used for running online transaction processing (OLTP), data warehousing (DW) and mixed (OLTP and DW) database workloads. Oracle Database 12c is

used for the development of this project. Oracle Database 12c is a high-performance enterprise-class database. According to Oracle, this is the first database designed for the cloud.

Primeface

Primeface is an open-source user interface (UI) component library for Java server face-base applications created by a Turkish company Prime Tek Informatics. It has been strongly supported by Oracle, especially with NetBeans. It provides more than 100 JSF components. Primeface5.2 is used in the development of this project.It provides features such as over 100 UI components, Ajax framework, Mobile UI kit, Push framework, Dialog framework, client-side validation Theme Engine and search expression framework.

Java Server Page (JSP)

Is a java standard technology that enables developers to create a dynamic data-driven page for a java web application.It provides a simplified fast way to create dynamic web content.

Java EE

Is an application software platform formed from Oracle based on the Java programming language, originally developed by Sun and then acquired by Oracle. Java EE services are performed in the middle tier between the user machine and the enterprise's databases and the legacy information systems. Its core component is the Enterprise JavaBeans (EJBs), followed by JSPs and Java servlets and a variety of interfaces for linking to the information resources in the enterprise.

The Java EE interfaces include JDBC for database, JNDI for directories, JTA for transactions, JMS for messaging, etc.

EJB technology is the server-side component architecture of the Java platform, enterprise edition.It enables rapid and simplified development of distributed, Transactional, Secure and portable application based on Java technology.EJBs can be one of the three types: Session Bean, Entity Beans or Message-Driven Beans.

For the development of this project, we make use of the Java EE6 platform which provides API for RESTful web service, Managed Beans, Context Dependency Injection (CDI) for java EE platform. Dependency Injection for Java, bean validation and other new features.

Bootstrap

Is a free and open-source CSS framework directed at responsive, mobile-first front-end web development. It basically contains CSS and optional JavaScript-based design templates for typography, form, buttons, navigation and other interface components. The primary purpose of adding it to a web project is to apply bootstrap's choices of size, color, font and layouts to the project. Bootstrap provide basic style definition for all HTML elements. The result is a uniform appearance for prose, tables, and form elements across web browsers. Also, developers can take advantage of CSS classes defined in bootstrap to further customize the appearance of their contents.

The most prominent components of bootstraps are its layout components because they affect the entire web page. It makes web pages rendered well on a variety of devices and windows or screen size. The major reason we used bootstrap in this project is to design a responsive web application that can be used with small, medium and large screen size devices without affecting the look and feel of the application's UI.

6.2 Prototype of the System

This section presents the detailed prototype development for the designed online Electronic Medical Record system. The way the user interacts with the system and some of the interaction results are described using screenshots.

To begin interacting with the system the users are expected to open a web browser and insert the URL (e.g. http://192.168.43.60/Online_EMR-war) the login page will be loaded as presented in Figure6.1

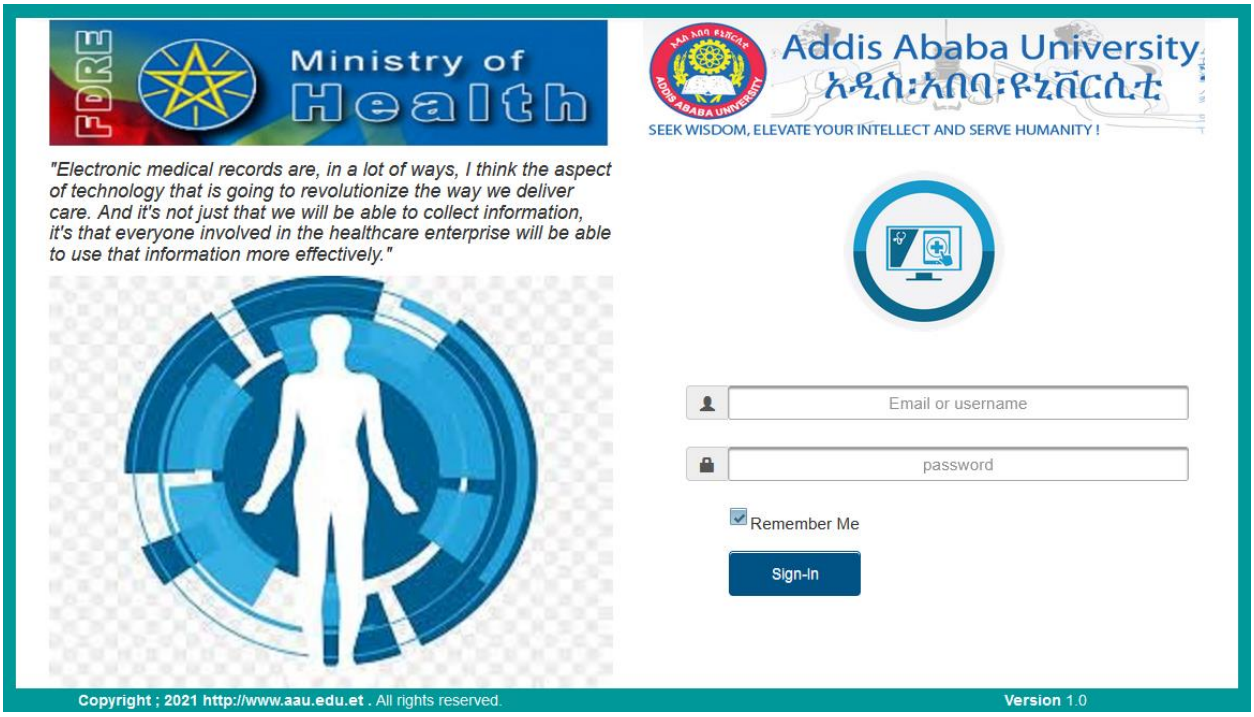

Figure 6. 1 : UI for the system login page

When the user fills a valid credential and clicks the sign-in button the system automatically redirects to the home page granted to the role of that user. The prototype of the system for each role is in this section of the document below.

6.2.1 Global Admin

The global admin home page displays the list of medical institutions registered to use the system. as the list gets bigger the user can search institutions by their name or address to filter the list and click on a single institution to view its detailed information or make any modification. The "+" icon on the top of the page can be used to register a new institution and the left side menu can be used to perform system administration tasks, lookup management and view reports. Some basic UI components aimed to be used by the global admins to perform their assigned tasks are presented.

a. Institution Registration

The UI for maintaining institutions' basic information is presented in Figure 6.2.

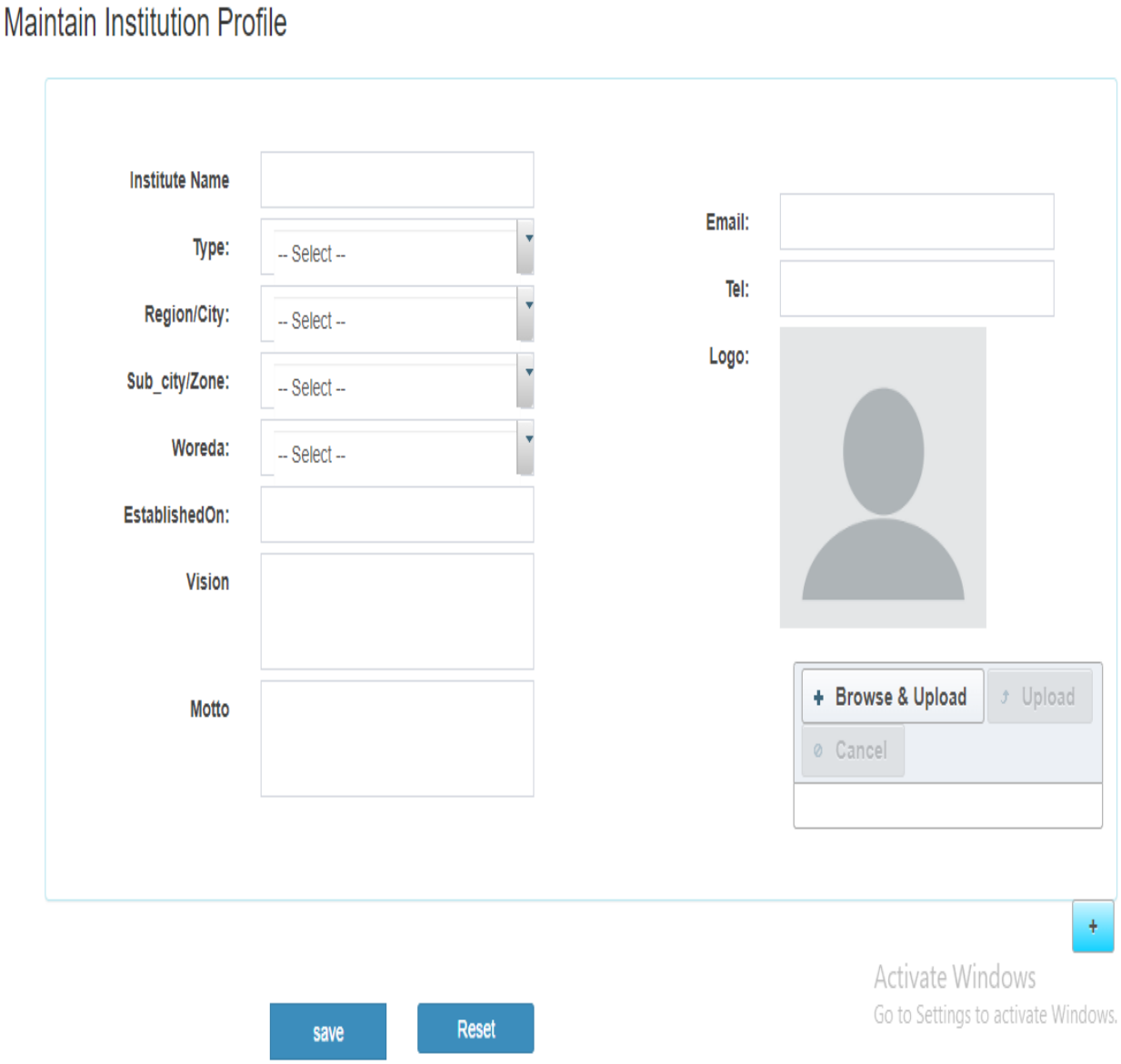

Figure 6. 2 : UI for institution registration

b. Staff Registration

To register a staff member who is going to be a local system administrator for a specific institution the user clicks the "+" button on the bottom of the institution registration panel. Then add staff for that specific institution and click the save or update button on the bottom of the staff data table. The UI for staff registration is presented in Figure 6.3

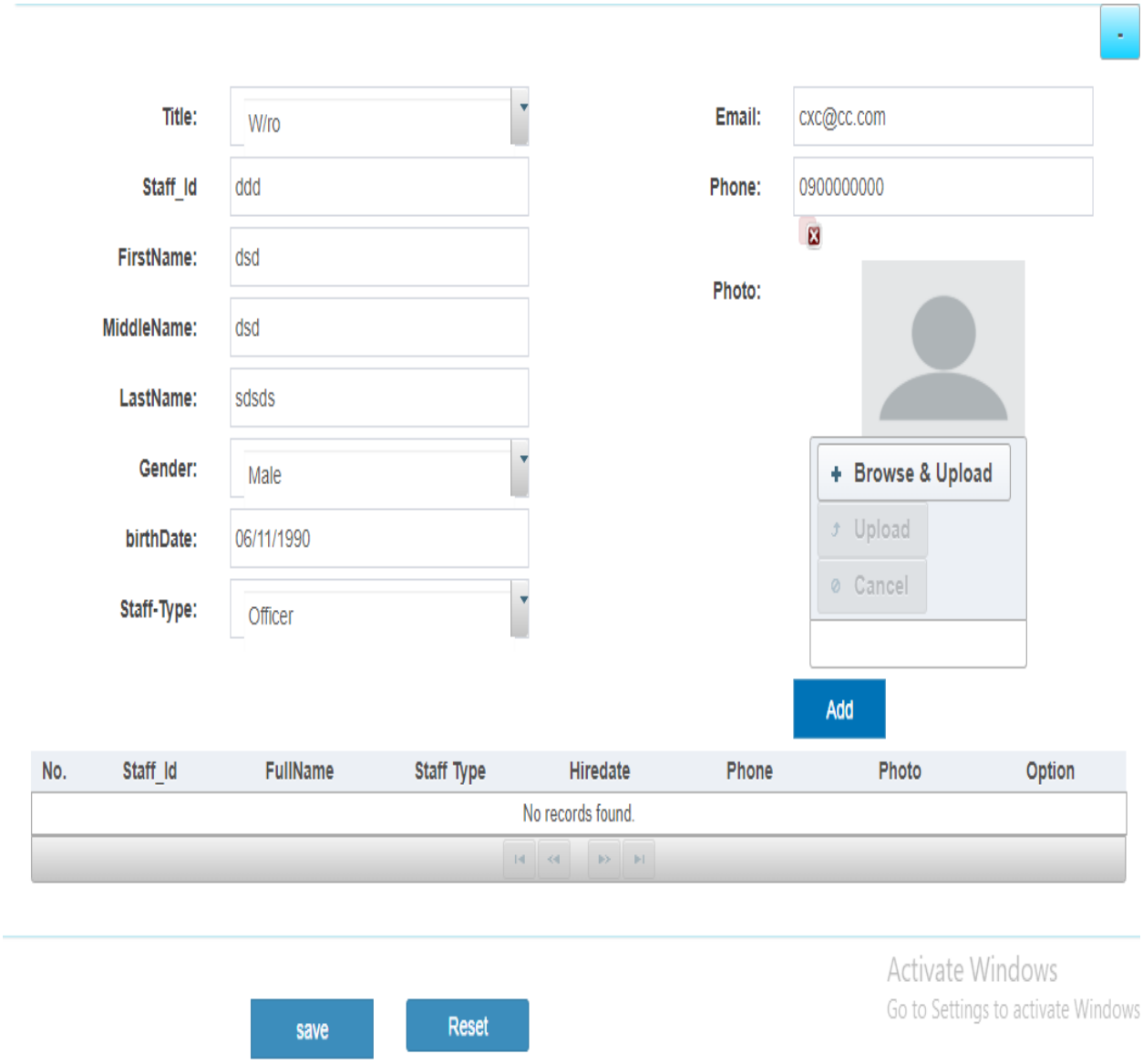

Figure 6. 3 : UI for staff Registration

c. User Management

The user management UI includes registering new users and managing existing users.to register a user we need to specify the institution and a staff who is a member of that institution for whom the account is to bet set.The UI for user mamagment is presented below in Figure 6.4

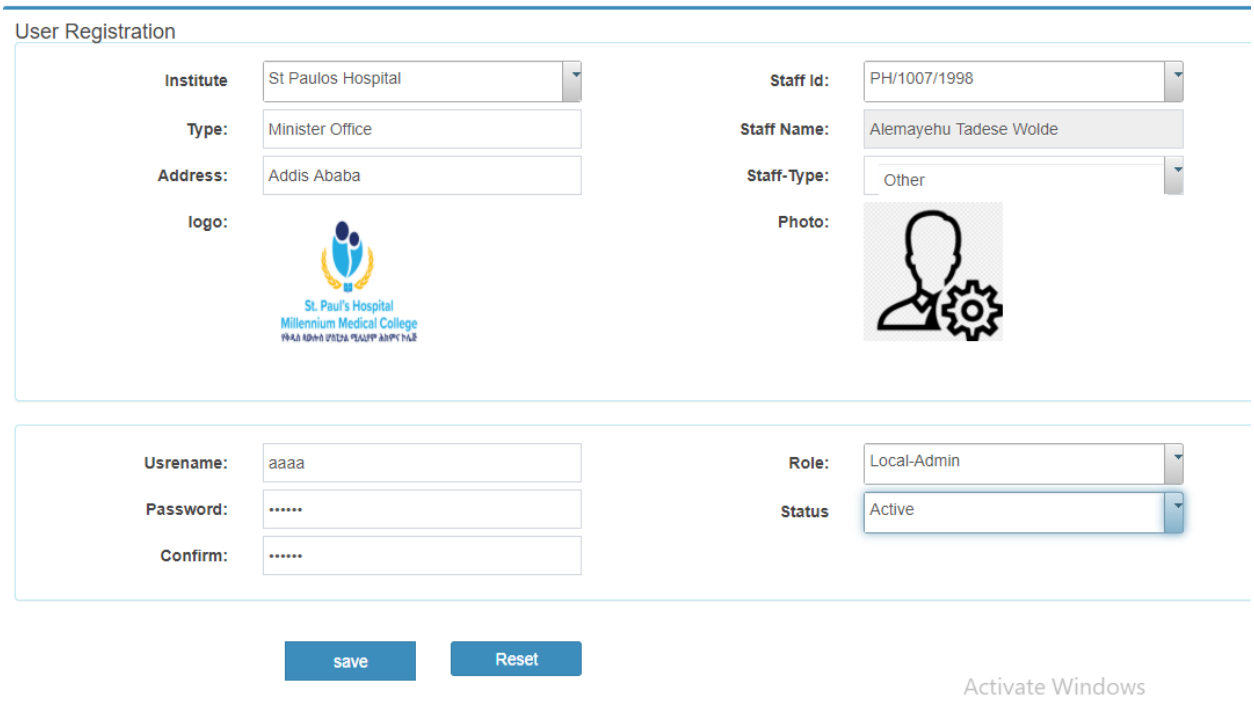

Figure 6. 4 : UI for user registration

d. Password Reset UI

To reset the user's password, all we need to do is select a user from a search table and type a new password with a confirmation.The UI for password reset is presented in Figure 6.5

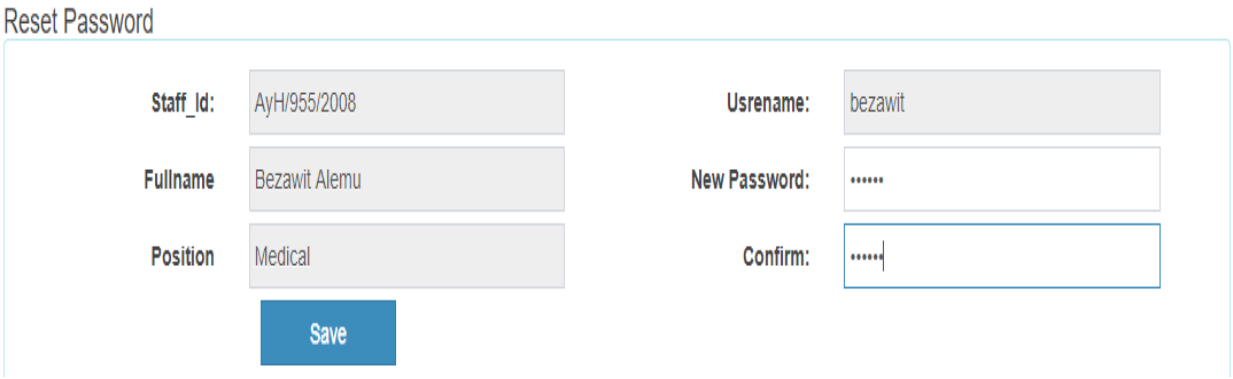

Figure 6. 5 : UI for password reset

6.2.2 Local Admin

The local admin home page contains the links for the different tasks performed by the user.it has personalized features and the user has the right to perform the operations only on the data of his/her institution. *Figure 6.6* presents the home page UI for local admin.The graphs show a real time statistics of data changes.

Figure 6. 6 : UI for Local Admin Home page

Most of the above operations are performed in the same manner as the global admins except for the limitedness of the operations for only one specific medical institution.

6.2.3 Receptionist

The receptionist home page contains the links and notifications for different tasks performed by a receptionist. Figure 6.7 shows the UI for the receptionist home. The graphs provide real time information on system data changes like number of patients grouped by their age.

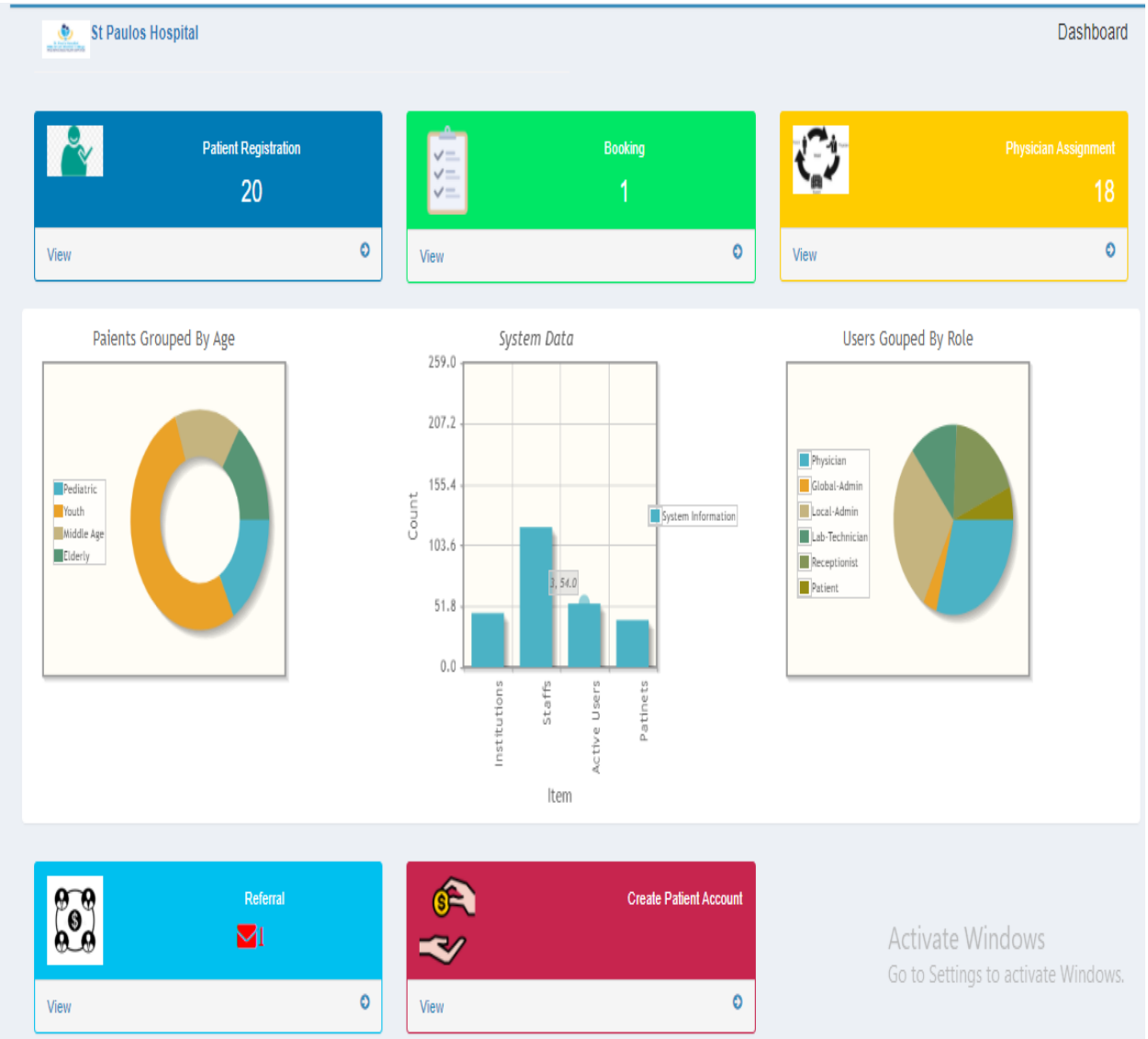

Figure 6. 7 : UI for receptionist Home page

6.2.4 Physician

The UI for physician's home page has a notification for the waiting list for diagnosis, appointments and referral cases with their respective link for the physician signed in to the system. The UI for the physician home page is shown in Figure 6.8

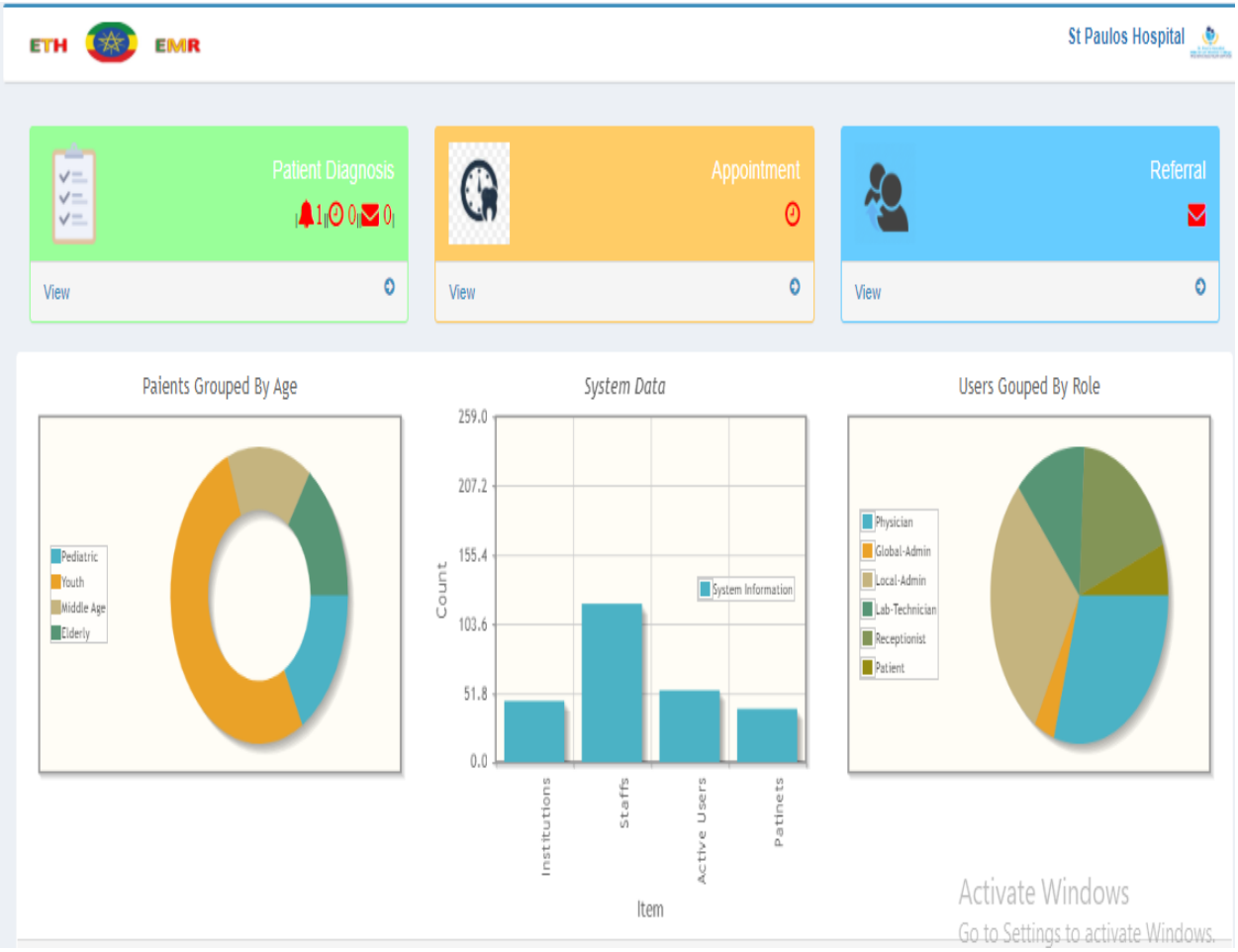

Figure 6. 8 : UI for physician home page

These are only samples of the UI for the Online Electronic Medical Record System. The details of each and every functionality are discussed in the user manual document.

6.3 User Acceptance Testing

In this section, we discussed the usability of the developed online Electronic Medical Record system. The assessment is done to measure the degree to which the implemented software product fulfills the functional and non-functional requirements specified in the fourth chapter of this document and the user satisfaction level after testing the implemented system. To demonstrate the evaluation of the developed online Electronic Medical record system was locally deployed and accessed by staff of three public hospitals and one private clinic. A group of users tested the system guided by the user manual document provided and a survey was conducted through questionnaires (see Annex A. Annex B, Annex C, Annex D, and Annex E) distributed to each user categories to get the users satisfaction level.

While undergoing the assessment 5 different types of user categories (Admin, Receptionist, Physician, Lab-Technician and Patient) were involved. For each user category 10 volunteers fill the questionnaires prepared to evaluate the user satisfaction after properly testing the system. The summary each user category response is presented below in Tables 6.1 – 6.5.

Table 6. 1 : Detailed summary of questionnaire result (Admin group)

Q.No	Strongly disagree(1)	Disagree (2)	Neutral(3)	Agree(4)	Strongly Agree(5)	Total point	Mean
1	0	0	1	3	6	45	4.5
2	0	1	1	3	5	42	4.2
3	0	0	0	4	6	46	4.6
4	0	0	2	3	5	43	4.3
5	0	1	1	4	4	41	4.1
6	0	0	1	5	4	43	4.3
7	0	1	1	3	5	42	4.2
8	0	0	1	2	7	46	4.6
9	0	0	0	3	7	47	4.7
10	0	0	1	4	5	44	4.4
11	0	0	0	3	7	47	4.7
						Overall usability= 88.36%	

Table 6. 2 : Detailed summary of questionnaire result (Reception group)

Q.No	Strongly disagree(1)	Disagree (2)	Neutral(3)	Agree (4)	Strongly Agree(5)	Total point	Mean
1	0	0	0	3	7	47	4.7
2	0	0	1	4	5	44	4.4
3	0	0	0	4	6	46	4.6
4	0	0	0	4	6	46	4.6
5	0	0	0	4	6	46	4.6
6	0	0	0	5	5	45	4.5
7	0	1	0	3	6	44	4.4
8	0	0	1	2	7	46	4.6
9	0	0	0	2	8	48	4.8
						Overall usability=91.56%	

Table 6. 3 : Detailed summary of questionnaire result (Physician group)

Q.No	Strongly disagree(1)	Disagree(2)	Neutral(3)	Agree(4)	Strongly Agree(5)	Total point	Mean
1	0	1	1	4	4	41	4.1
2	0	1	0	3	6	44	4.4
3	0	0	0	5	5	45	4.5
4	0	0	1	4	5	44	4.4
5	0	0	2	4	4	42	4.2
6	0	0	0	3	7	47	4.7
7	0	0	0	2	8	48	4.8
8	0	0	0	3	7	47	4.7
9	0	0	2	5	3	41	4.1
10	0	0	0	2	8	48	4.8
						Overall usability= 89.40%	

Table 6. 4 : Detailed summary of questionnaire result (Lab-Technician group)

Q.No	Strongly disagree(1)	Disagree(2)	Neutral(3)	Agree(4)	Strongly Agree(5)	Total point	Mean
1	0	1	2	5	2	38	3.8
2	0	0	0	4	6	46	4.6
3	0	0	2	3	5	43	4.3
4	0	1	3	2	4	39	3.9
5	0	0	2	3	5	43	4.3
6	0	0	0	4	6	46	4.6
7	0	1	1	3	5	42	4.2
8	0	0	1	3	6	45	4.5
9	0	0	2	4	4	42	4.2
						Overall usability= 85.33%	

Table 6. 5 : Detailed summary of questionnaire result (Patinet group)

Q.No	Strongly disagree(1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree(5)	Total point	Mean
1	0	2	2	4	2	36	3.6
2	0	0	3	3	4	41	4.1
3	0	0	0	3	7	47	4.7
4	0	0	0	4	6	46	4.6
5	0	0	0	5	5	45	4.5
6	0	0	0	3	7	47	4.7
7	0	0	2	3	5	43	4.3
8	0	0	0	4	6	46	4.6
						Overall usability= 87.75%	

The result of the evaluation shown that the Online Electronic Medical Record System is easy to use, effective, accurate and help the professionals save their time.

Chapter Seven: Conclusion and Future Work

7.1 Conclusion

In this project. We developed an Online Electronic Medical Record System. Which is a web based application designed and implemented to be deployed in a centralized server and accessed by all medical institutions over the Internet to facilitate their patient treatment work flows and share patient's medical history across time and organizational boundaries.

To develop the Online Electronic Medical Record System we followed the waterfall development approach in which the major activities like system analysis, system design, system development and testing are done phase by phase. We first studied the existing medical record-keeping approaches both through observation and revision documents used by different medical institutions. Based on the gathered requirements we have done a system analysis and design. As detail presented in chapter four of this document the functional requirements are analyzed and modeled using a use case diagram, sequence diagram and activity diagram. The fifth chapter discusses the system architecture and non-functional requirements of the system. The sixth chapter de discussed the tools and technologies used to develop the system and the prototype of the system.

Then we conducted a usability testing of the Online Electronic Medical Record system using a questionnaire prepared to test standard usability attributes. To test the systems' usability 5 different types of user categories (Admin, Receptionist, Physician, Lab-Technician and Patinet) were involved. For each user category 10 volunteers fill the questionnaires prepared to evaluate the user satisfaction after properly testing the system. The result of the evaluation shown that the Online Electronic Medical Record System is easy to use, effective, accurate and help the professionals save their time.

7.2 Future Work

Even though, the Online Electronic Medical Record system is accepted as usable many things need further improvement. The following are some of the possible future works for the continuation of this project.

- ✓ The need to be extended to a full HER(Electronic Health Record) system through the inclusion of each and every activities done by the Medical staffs as system functionalities
- ✓ Implementation of biometric patient identifications to make the system more usable

- ✓ Incorporate geo location based Medical information service and an Outbreak alert system to make the system more operational.
- ✓ Developing an mobile applications for the system to improve the usability

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ANNEXES

I. Purpose of the questionnaire

The purpose of this questionnaire is to assess the overall usability of the Online Electronic Medical Record System. as a participant you will help us understand whether the system is usable or not and find the system weaknesses that need further improvement

II. Subjects permission

By completing this questioner, you agree that you have used the Online Electronic Medical Record System and give your voluntary consent to participate. If you have any discomfort with this question, you are free to ask for further clarifications.

Annex A

Online Electronic Medical Record System usability testing questionnaire

User category1 : Admin

This questionnaire is intended to know user satisfaction related to the service provided by the online EMR system.

Please provide your honest evaluation result with the criteria after testing the online electronic medical record system properly.

Please uses 'X' to mark your rating (1-5) for each line in the labeled column. Select only one. Based on the labeling **Strongly disagree = 1**, **disagree = 2**,**Neutral=3**, **agree = 4**, **Strongly-agree = 5**

No.	***Evaluation Question***	***Satisfaction level***				
		1	***2***	***3***	***4***	***5***
1	The terminologies used in the online Electronic management system are consistent					
2	The system is easy to use and learn					
3	The system menus are well organized and easy to find.					
4	The system provides proper validation for the user inputs					
5	The system provides Correct and descriptive validation and error messages					
6	The system provides Proper notification for user activities and their status					
7	I found the system flexible, dynamically configurable and adjust settings which suite my task					
8	The system helps me not to make serious errors.					
9	The response time of the system fast enough					
10	The system maintains user activity logs properly					
11	The system provide correct reports in understandable format					

If you have any additional comment about the system, please write it here._____

_____

Annex B

Online Electronic Medical Record System usability testing questionnaire

User category2 : Reception

This questionnaire is intended to know user satisfaction related to the service provided by the online EMR system.

Please provide your honest evaluation result with the criteria after testing the online electronic medical record system properly.

Please uses 'X' to mark your rating (1-5) for each line in the labeled column. Select only one!!!

Based on the labeling **Strongly disagree = 1**, **disagree = 2**,**Neutral=3**, **agree = 4**, **Strongly-agree = 5**

No.	***Evaluation Question***	***Satisfaction level***				
		1	***2***	***3***	***4***	***5***
1	The terminologies used in the online Electronic management system are consistent					
2	The system is easy to use and learn					
3	The system menus are well organized and easy to find.					
4	The system provides proper validation for the user inputs					
5	The system provides Correct and descriptive validation, error and success message for user actions.					
6	The system provides me a notification for tasks I have to do					
7	The system helps me not to make serious errors.					
8	The response time of the system fast enough					
9	I found the system helpful to perform my patient management task faster than I used to					

If you have any additional comment about the system, please write it here.

_____

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Annex C

Online Electronic Medical Record System usability testing questionnaire

User category3 : Physician

This questionnaire is intended to know user satisfaction related to the service provided by the online EMR system.

Please provide your honest evaluation result with the criteria after testing the online electronic medical record system properly.

Please uses 'X' to mark your rating (1-5) for each line in the labeled column. Select only one. Based on the labeling **Strongly disagree = 1**, **disagree = 2**,**Neutral=3**, **agree = 4**, **Strongly-agree = 5**

No.	***Evaluation Question***	***Satisfaction level***				
		1	***2***	***3***	***4***	***5***
1	The terminologies used in the online Electronic management system are consistent					
2	The system is easy to use and learn					
3	The system menus are well organized and easy to find.					
4	The system provides proper validation for the user inputs					
5	The system provides Correct and descriptive validation messages, error and success messages					
6	The system provides Proper notification of waiting patients I have to serve					
7	The system provides Information that support my decision while serving my patients					
8	The system helps me not to make serious errors.					
9	The response time of the system fast enough					
10	I found the system helpful to serve patients faster than I used to					

If you have any additional comment about the system, please write it here._____

_____

Annex D

Online Electronic Medical Record System usability testing questionnaire

User category4 : Lab-Technician

This questionnaire is intended to know user satisfaction related to the service provided by the online EMR system.

Please provide your honest evaluation result with the criteria after testing the online electronic medical record system properly.

Please uses 'X' to mark your rating (1-5) for each line in the labeled column. Select only one. Based on the labeling **Strongly disagree = 1**, **disagree = 2**,**Neutral=3**, **agree = 4**, **Strongly-agree = 5**

No.	***Evaluation Question***	***Satisfaction level***				
		1	***2***	***3***	***4***	***5***
1	The terminologies used in the online Electronic management system are consistent					
2	The system is easy to use and learn					
3	The system menus are well organized and easy to find.					
4	The system provides proper validation for the user inputs					
5	The system provides Correct and descriptive validation messages, error and success messages					
6	The system provides Proper notification of waiting lab test requests					
7	The system help me obtain lab request information and maintain lab test results properly					
8	The system helps me not to make serious errors.					
9	I found the system helpful to complete my task faster than I used to					

If you have any additional comment about the system, please write it here.

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Annex E

Online Electronic Medical Record System usability testing questionnaire

User category5 : Patient

This questionnaire is intended to know user satisfaction related to the service provided by the online EMR system.

Please provide your honest evaluation result with the criteria after testing the online electronic medical record system properly.

Please uses 'X' to mark your rating (1-5) for each line in the labeled column. Select only one. Based on the labeling **Strongly disagree = 1**, **disagree = 2**,**Neutral=3**, **agree = 4**, **Strongly-agree = 5**

No.	***Evaluation Question***	***Satisfaction level***				
		1	***2***	***3***	***4***	***5***
1	The terminologies used in the online Electronic management system are understandable					
2	The system is easy to use and learn					
3	The system menus are well organized and easy to find.					
4	The system provides proper validation for the user inputs					
5	The system provides Correct and descriptive validation messages, error and success messages for my actions					
6	The system provides Proper notification of my appointments					
7	The system help search medical institution and book for medical care easily					
8	The system helps me not to make serious errors.					

If you have any additional comment about the system, please write it here.

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Declaration

I, the undersigned, declare that this project is my original work and has not been presented for a degree in any other university and that all sources of materials used for the project have been duly acknowledged.

Declared by:

Name: **Behailu Eshetu Zeleke**

Signature: _____

Date: _____

Confirmed by advisor:

Name: **Dr. Ayalew Belay**

Signature: _____

Date: _____