Create a Medical information Extraction tool applied on Electronic Patient Record systems mainly for Retrospective Research

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Master of Science Thesis
The Royal Institute of Technology (KTH), Stockholm, Sweden
Degree Project 30HE credits
December 2012
This thesis carried out in collaboration with Södertörns Högskola, Stockholm University
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Abstract

This paper deals with medical data extraction from electronic patient record (EPR) system. Most of the medical data are stored in patient record systems, and data that are much valuable for medical research. If a researcher wants to extract medical information today, it has to be done manually because the data are stored in unstructured textual format in a system created by hospital staff. There is no way of extracting data in structure way. This paper is going to introduce an information extraction application for EPR system that allows the researcher to set up a study with inclusion and parameters for extraction for retrospective surveys in a web user-interface environment. Inclusion is what the researcher would like to study (a defined category or criteria) and parameters specify the characteristics of inclusion the criteria. Result of this application provides an extracted clinical data that is used for retrospective surveys, downloadable to an MS-Excel file.

Keywords: Clinical information, Extract clinical information, Paper based Patient Record (PPR); Computer based Patient Record (CPR), Electronic Patient Record (EPR), and health care system.
Acknowledgement

First of all, I would like to express my deepest gratitude and thanks to my supervisor and examiner Fredrik Kilander and supervisor from Södertörns Högskola and Karolinska Science Park Innovation Business School, Otto Stackelberg. I am ever grateful to both my supervisors for their encouragement, instant feedback and extensive guidance during the research work. With the great help of Otto Stackelberg, I have received valuable instruction to collect the requirements and to understand the requirements for researchers, physicians, and doctors. He also helped me to evaluate the prototype and arranged interviews with system users. Fredrik Kilander helped me in all phases of the research, especially regarding the research methodology, provided the useful comments and feedback about thesis reports structure, language and grammatical errors.

Finally, I would like to give special thanks to my parents for their constant support, encouraging me during my entire masters’ degree.
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<td>Business Logic Layer</td>
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<td>CHCS</td>
<td>Composite Health Care System</td>
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<td>CLR</td>
<td>Common Language Runtime</td>
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<td>COSTAR</td>
<td>Computer Stored Ambulatory Record</td>
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<td>CLEF</td>
<td>Clinical e-Science Framework</td>
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<td>Computer based Patient Record</td>
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<td>Institute of Medicine</td>
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Chapter 1

Introduction

This chapter provides an introduction of the thesis project. Section 1.1 describes the background behind the research work. Section 1.2 specifies the problem definitions of the research work. Section 1.3 presents the research question. Section 1.4 specifies the purpose of this thesis project and section 1.5 discuss research methodologies of this thesis. Finally, section 1.6 presents an outline of the report.

1.1 Background

Electronic patient record (EPR) systems (also called Electronic health records (EHR)) are the golden standard when registering patient information in health care these days. The systems are software based applications and to build these systems one need different technical tools to gather patient information, store the patient information, transferring information electronically, and processing and analyze the patient information. A good electronic patient record system can reduce the duplication of patient information and waste of time, increase the efficiency, and improve the cost effectiveness of the health service. It is most important when it is used for care provision like in clinical audit and research [1].

In the fifth century B.C, the first medical record was developed by Hippocrates and he prescribed two goals: [2]

- The first goal, the record of the medical information should accurately reflect the course of disease.
- The second goal, the record of the medical information should indicate the probable cause of disease.
These two goals are still appropriate for patient record system. But electronic patient record systems can provide additional functionality which is not possible to do with paper based systems. For example: interactive alerts for the clinicians, automatically order what is needed for the patient, and interactive flow charts.

In 1960 Electronic health record (EHR) began experiments with computerized medical recordkeeping. In the late 1960s and early 1970s the first EHR on designed and developed. Approximately 73 clinical and hospitals projects used for business functions and 28 projects processed electronic data with some medical content. Some of the early notable projects included: [3]

- COSTAR (the Computer Stored Ambulatory Record) developed by Barnett, et al, Harvard University,
- HELP (Health Evaluation through Logical Processing) developed by Warner, et al at Latter-Day Saints Hospital at the University of Utah, Salt Lake City.
- TMR (The Medical Record), developed by Stead and Hammond at Duke University Medical Center in Durham, North Carolina
- CHCS (Composite Health Care System), developed by the Department of Defense’s (DoD), USA.
- DHCP (Decentralized Hospital Computer Program) developed by the United States Department of Veterans Affairs (VA).

These hospital systems were developed to improve the healthcare quality, to improve the operation and to reduce unnecessary cost. But in the early days these systems were not very practical because of the complexity of the computer technology for patients and expense.

During the 1990s, the IOM (Institute of Medicine, USA) declared the computer based patient record which is a lifetime patient record system. It included all patient information from all specialities, even dentistry and psychiatry, and this information was available for all providers. The IOM used computer related technologies in healthcare information system for administrator, management and planning for patient care. Later, the IOM identified that the system was not user friendly, difficult to use, not fully interoperable, not realistic and with most data entry done without a GUI (Graphical User Interface) [3].

In the year 2002, an EPR system developed at NHS in England was the largest civilian IT project in the world. EPR systems were also created in various forms in the USA, Australia, Canada, Scotland, New Zealand and European Union countries like Denmark and Sweden. These three countries (New Zealand, Denmark and Sweden) have achieved a high level of
meaningful use of EPR but none has reached 100% in all categories (e.g. sharing clinical information, and data sharing law) [4].

Electronic patient record (EPR) system can include plenty of information to visualize and extract the patient information including medications prescribed, laboratory test results, radiology images, treatment plans, care notes, and immunization history. There are a few medical information visualization systems designed for Electronic patient record system, e.g. Lifelines developed by Plaisant, et al in 1998, Timeline developed by Alex A. T. Bui, Member, IEEE, Denise R. Aberle, and Hooshang Kangarloo in 2007 [5].

To date, no EPR system has focused on how to search and filter information through all patients. This paper presents an individual study of the users (physicians, nurse, doctors and researchers) interacting with a web application to extract structured information from an electronic patient record (EPR) system.

To be able to study a subpopulation within the EPR-system, one needs to decide what category of patients one might be interested in. This is called “Inclusion”. After selecting a specific subpopulation, one needs to decide what characteristics one would like to study within that specific population. This is called a “Parameter”. Users have the option to create and define their parameters however they want. An example of a parameter could be gender, age, time for medical subscription, chest pains or other symptoms etc. This is the basis of the software. After the research work, the “Inclusion” and “Parameters” criteria were figured out. The next step was to build an extraction tool that was linked to the EPR-system. This tool would extract specified data for further analysis.

1.2 Problem Definition

A medical record holds valuable information for research but the problem is that extraction of data from the systems has to be done manually. Information for one retrospective survey could consist of about 500-750 patients from one health care provider. Reviewing and extracting this information manually takes about three months for a fast user. Traditional paper based information storage means a lot of extra maintenance investment. Missing papers from file or unrecognizable poor handwriting, difficulty to organize different reports etc. are common problem with paper based report. These problems hinder the smoothness of patient’s case study. If data are available in papers only, for a researcher it is very time consuming to gather all appropriate patients’ data from various sources and study them. The extra time for such management is considered highly non productive.
1.3 Research Goal
Find out what are the requirements for an extraction tool to be able to specify and extract relevant information from the end user. Propose a clinical information extraction tool from an electronic patient record system based on the identified requirements.

1.4 Research Purpose
The purpose of this work is to arrive at a set of valid requirements (not necessarily complete) for an EPR search parameter tool and extraction tool based on the identified requirements. This thesis aims to create a tool that allows the user to set up parameters for extraction and the extracted information in an easy user-interface environment. The primary benefit of this tool is that one can shorten the time it takes to extract information, and increase the number of studies performed on a faculty. The secondary benefit is that it adds to medical knowledge in a much cheaper way than what currently is possible. Furthermore, the user has the possibility to share his/her results with another user, allowing exactly the same information to be extracted from that user’s pool of the patients.

1.5 Method Description
In order to achieve the goals of the thesis project, I have followed an exploratory approach which comprises of a number of different sequential steps. The first step was a literature review and study for similar tools, systems and works. The data or requirement collection phase then followed, which included interviews and brainstorming sessions with (search operation, researcher and users) people who are the responsible in the existing system. After that, a requirement analysis was started, and when requirements were ready, proposed a paper prototype which was designed and created based on the requirements. The scenario based evaluation technique followed with different users with proposed paper prototype and collect reflection on them. With the prototype as a base, the proposed tool was developed and implemented.

1.6 Ethics and Privacy
The concern for patient integrity and informed consent has become extra highlighted during the past years. The risks of infringement and violation of patient integrity when reading a patient’s medical record is therefore always needed to take into account when performing observational studies. As the current methodology works, the researcher states a hypothesis
that he/she wants to test and then it is mandatory to apply for an ethical approval for certain types of research.

There are six regional boards of research ethical committees in Sweden. These boards are situated in Karolinska Institute in Stockholm, Gothenburg, Umeå, Linköping, Lund and Uppasala [6]. To apply for ethical approval prior to the study is always up to the researcher before conducting a study and it is illegal to go through a patient’s medical record without it. After approval, the researcher identifies the patients to include, proceeding with reading of all their medical records to create the intended database. During this work it is demanded to store the created database on secure computers within a locked department at approved medical research departments. Besides being cumbersome and time consuming, reading all medical records of a patient, even the irrelevant ones, could be looked upon as unnecessary violation of patient integrity since a majority of the information is irrelevant to the hypothesis tested, even if an ethical committee has approved the study.

The application I have programmed will not infringe on any of the integrity laws as they are stated today. The application will not be available for public use, only to those allowed to use the EPR system. The researchers still have to apply for ethical approval prior data extraction, and the data will not be stored anywhere else except for a file in an approved location. The application alone cannot guarantee that extraction of data is always made with an ethical approval, but neither can the current EPR providers. The data is also intended to be de-identified in the review tool, which keeps the researcher from knowing whose record he examines. Furthermore, by setting up a certain set of relevant parameters of interest before data is extracted, the problem with unnecessary infringement of patient integrity will be eradicated. Conclusively in my opinion, this application will not infringe on patient integrity, but merely improve it.

1.7 Report Outline

After this introductory first chapter, chapter 2 Literature Review contains a literature review about traditional paper based patient record (PPR) system, computer based patient record(CPR) system, electronic patient record(EPR) system, and current EPR system in Stockholm county. This chapter also discusses about information extraction application tool which was used for the medical research work. Finally present a proposed architecture of the clinical information extraction tool.
Chapter 3 *Research Methodology* is handles a detailed description of the methods and discussions and why I have chosen these methodologies.

Chapter 4 *Requirement Engineering Process and Analysis* describes the requirement engineering processes and analyses to find user requirements, system requirements, process model the way to visualize and processed data from one table to another table, created use case diagram for administrator and user with data flow diagram, finally represent data model how data are stored and retrieved in database.

Chapter 5 *Prototype Implementation* describes prototype implementation tools and technologies, the way followed procedure and architecture to create application, created database design diagram and relationship, and finally presented integration between web application and database.

Chapter 6 *User Interface Design* presents user interface design, the way design user interface of each requirement graphically and describes them.

Chapter 7 *Prototype Evaluation* evaluates to the implemented hi-fi prototype with a usability testing. To evaluate the usability of the system followed think allowed method to get user thoughts, feelings, opinion and user can take time to think when user interact with system. In the result section presented what results found from the think aloud and finally analyzed the results.

Chapters 8 *Conclusion and Future Work* describes conclusion of the whole research work and discussion of future works.
Chapter 2

Literature Review

This chapter provides a critical literature review that is applied to design an extraction tool for an electronic patient record (EPR) system. Then, started to explore the current electronic patient record system in Stockholm County followed by the current traditional paper based record system. This chapter also explains extraction of medical information for the intended user.

2.1 Traditional paper based patient record (PPR)

During the history of the medical documentation, patients information was stored and organized in a paper based matter. Physicians and researchers are supposed to keep the patients record whenever they want to examine a patient or to meet the purpose for decision making. These records include patient's history, disease symptoms, disease time and date, patient lifestyle, family history, patient height, weight, blood pressure, and temperature, treatment, and consultation date and time with doctors or physicians. PPR documentation has some strength: it is familiar to the user, portable to bedside consultation, lack of break down and can easily be browsed through [7].
These strengths are however relatively sparse in comparison with weaknesses: it can only be used by one person at a time and is stored in one place only, bounding the location. Poor handwriting may also be a subject of confusion to other readers. PPR systems had tendency of being poorly organized and for that reason, were ineffective and time consuming regarding search of information. Sometimes patient records were missing, existed in multiple versions and decision support based on the records was heavily inconvenient [7].

Furthermore, from these insufficient medical records researcher cannot lead to perform retrospective medical studies. All documents are written in a paper based for that reason it takes time to increase the number of studies.

2.2 Computer based patient record (CPR)

Traditional paper based patient records (PPRs) system had several limitations, specially multiple version making, time delay in obtaining records, for searching records. If these records are used computer based it is possible to reduce those limitations or problems. In a computer based patient record (CPR) system, medical documentation are stored in a structured way and each patient records history and disease with symptoms all are stored well organized.

In 1991, the IOM (Institute of Medicine) published a report recommending the implementation of CPR systems. The IOM committee find out the problems of traditional medical documentation then proposed actions and research to improve them. They have proposed architecture to implement the comprehensive CPR system. Their proposed architecture allows storage of different kind of data to the database and manages the database, archive medical documentation and retrieve them, archive image processing and store digital images in the patients records, data exchange allowed to collect data from various sources and transmitted the data from different systems, allowing system reliability and security with login id and password protection [8]. However, their proposed architecture covers the user acceptance and provides secure environment in the computer for patient record system that user study is directly related to my research. But the paper from IOM did not discuss the issue that researcher can use those medical records from various resources for clinical research used those for retrospective study.

In 2001 the committee IOM discussed (Tricia L et al., 2003) about CPR to improve care of the patients and reduce the waste. They have discussed about several benefits of CPR system,
these benefits are categorized from different points of view how they can get benefits from clinical perspective, workflow, administrative and revenue enhancement perspective. They have also mentioned several challenges and barrier to implementing of CPRs e.g. cost high to develop, people concern about their privacy and confidentiality of the patient information and lack of in interest of vendors and government support [8, 9]. It might be another reason that people, vendors and government are getting complexity to use CPR system a large number of stored information system. Usability is one of the most important parts for a usability issue of an application for a group of people or a target group. However, this thesis focuses about usability to the end user and analysis of user experience.

**2.3 Electronic patient record (EPR) system**

Electronic patient record system (EPR) is similar to computer based patient record system (CPR) but the CPR does not necessarily contain a lifetime record in a digital format via internet. In an electronic patient record system, a doctor can send and receive patient information over the internet, and doctors can share that information or any specific disease information with other doctors as well as with hospitals, laboratories, drug stores and emergency room. This can save time to give the fast service to the patient, and get the accurate decision between collaboration with them [10, 11].

There are several benefits if a web based electronic patient records (EPR) are set for collaboration regarding health care activities e.g. healthcare service, medical practices, and education encounters. Online health care services are: one patient can view his/her medical records online and able to get online laboratory results, doctors can check their schedule and change appointments via internet, patient can receive reminder from doctor for regular tests and checkups and if patients have any questions they can mail to their doctor. For the medical practice purpose get benefits from web based medical application medical students or residents can learn or study from a medical expert for any case through the network, physicians and experts can study collaboratively through the network for specific disease, and they can show the results each other through the network [10, 11].

Nowadays, an EPR is a vast source of medical information (e.g. medical history, demographic data and completed procedures) which can be extracted from a windows environment. But the problem is that the data is not prepared for being extracted and there is no designed tool available for retrospective analyses.
2.4 Current EPR system in Stockholm County

Today in Stockholm Country, “TakeCare” is the EPR system. This is the largest e-health installation in Stockholm-, and most of the clinics and hospitals are using it. Their largest unit is Karolinska University hospital. Every day, this system is used by 36,000 active users, 16,000 concurrent users and more than 2.4 million patient records are handled in their database [12].

At the time of this writing TakeCare system is focused on the separate patient and does not allow, simple ways of extracting information from several patients for observational studies.

2.4.1 Retrospective Study based on medical records

An observational study provides data about observed events. A retrospective observational study based on medical records uses existing data. This existing data have been documented for reasons other than research. When researcher used those existing data to create retrospective study sometimes they can get the result or can get decision early to answer the question. For example, “chart view” review is a good example of retrospective study, for this study does not need to involve or interaction with patients. It might be just interaction with only referral doctor of that patient. But a good retrospective observational study does not have to be quick and definitely not dirty. Because for a good retrospective study researcher have to concentrate with the study questions, clarify about hypothesis and outcomes, identify the feasibility issues and determine an appropriate sample size to design retrospective study [13, 14].

There are different kinds of retrospective observational studies but the most common retrospective ones usually conducted today are case series and case control studies. A case reports is unusual or instructive cases that are not previously observed. The studies are new combinations or unexpected happenings of medical condition that is not for granted in medical literature. These several unusual and instructive cases called case series. This retrospective case series can use when create a study about a disease to tested more time to generate hypothesis to get outcomes of the specific disease. There is a problem with a case series retrospective study; researchers have to depend with availability of the data and accuracy of those data about the specific disease. On the other hand sometimes a case series subject selection is bias may occur since investigators self-select the cases, e.g. if a study create about lung cancer, smoke, and asthma, this study may occur bias when asked about how long days smoked or how many cigarette packet he/she smoked. Another problem with
case series study where not possible to create a control group to match the case group to make relation between outcomes [13, 14].

A case-control study consists of occurred cases which are matched with controls. This study is superior because of the presence of the cases and controls. In this way, the researcher can estimate the effect of an exposure on outcome status. The case control retrospective study is useful when studies rare outcomes. A usually low ascertainment of cases acquired at a hospital, and the time it takes to extract information from large patient group, it makes hard to conduct other studies than above described [13, 14].

In this thesis followed case control retrospective study where researcher can match outcomes control and can restrict those outcomes. For that reason, it is clear that to create retrospective studies, there is a need for better interaction with the EPRs. To create retrospective study information is available but there no any such kind of tool or technology that can automatically extract patient information to get specific outcome regarding created study.

2.4.2 Automatic Extraction of information for a similar study

Patient records typically contain huge amount and complex data where most of these data are written in free text by doctors or physicians or clinicians. They describe about the patient medical information e.g. pathologies, patient personal and medical histories, findings made by interviews and so forth. The researcher can use that medical information in several application e.g. statistical analysis, epidemiological studies, decision support, and retrospective studies. The problem is that these descriptive text and complex data are sometimes difficult to extract from database to use in extraction application. All of those text information’s are unstructured and for that reason researcher and physicians are not able to take and properly use those data for their studies [15, 16].

Information extraction (IE) application for an electronic patient record system is responsible for structuring information to extract from free text. This extracted information can be analyzed to explore the outcomes that support for various hypotheses. Over the past several decades, many projects or information extracting tool have been developed to analyze medical notes and extract them using computers regarding their analysis, for instance MedLEE (Medical Language Extraction and Encoding, 1995), CLEF (Clinical e-Science Framework, 2003), MedInX (Medical Information extraction, 2006) and MIDAS (Medical Diagnosis Assistance, 2007) [15, 16].
MedLEE is a medical language extraction and encoding system developed by Carol Friedman et al. at Columbia University. The MedLEE system uses natural language processing technique to extract medical information from unstructured clinical documents and records, admission notes, radiology, cardiology and mammography and patient’s discharge reports. It structures and encodes that information into a standardized format [16, 17].

CLEF (Clinical e-Science Framework) is an information extraction technology developed by Henk Harkema et al. at University of Sheffield, UK. The CLEF system uses for patient information extraction over textual, narrative patients notes. The patient’s information’s are stored in structured way for the purpose to allow the user friendly access to the patients to give the high quality clinical care and biomedical research [18].

MedInX is a medical information extraction system developed by Liliana Ferreira et al. at University of Aveiro, Portugal. The MedInX system used automatic and accurate mapping of free text reports to structured presentations. The MedInX is developed based on NPL (Natural Language Processing) principles and contains several mechanisms to read the documents, language processing to process those reports and finally utilize the external resources (e.g. terminologies and ontology) [19].

MIDAS is a medical diagnosis assistant system developed by Anastasia Sotelsek and Julio Villena-Román at Universidad Carlos III de Madrid, Spain. MIDAS is an advanced, expert and automatic system to extract and integrate the clinical patient record. The system is developed based on natural language processing to automate the assignment of ICD-9 codes to radiology reports. This system also used to achieve the good perception rates of the extracted records [20].

Automatic extraction of information has reached levels of accuracy and adaptability. There are different strengths and weakness of automatic extraction of clinical information. The strengths are fast processing capability, reduction of medical errors, possibilities to cross-link data (e.g. with registers and hospitals) and improved reliability. This type of automatic extraction system has some weakness also, like failure in the integration of data and can perform ascertainment bias on sampling data. However, the presented information extraction systems cannot be directly command with my proposed system. In this system the researcher would create study manually with disease names and outcomes which matches with corresponding electronic patient record system. The proposed extraction tool would match the created inclusion and parameter items and extract information from EPR into the extract information application.
2.5 Information Extraction application to Medical

When researcher has decided what he would like to study, it is needed to be defined that what category of individuals one would like to include in the study, this is called an "Inclusion Criteria". If the researcher wanted to see how many of the myocardial infarctions that took place in year 2011 at Huddinge University Hospital and how many of these we're treated with dilating pharmaceuticals (e.g. Nitrogen, it is not possible to look at all the patients’ record that where admitted to the hospital during 2011. It is required to query what category of people would like to include to this survey. In this case the inclusion would be patients with a discharge diagnosis code of myocardial infarction during the year 2011.

Figure 1: Structure of the proposed application
At the moment, it is only be possible to include patients with a certain discharge diagnosis code due to the structure of the current Electronic Patient Record (EPR) systems. In a near future, however, it will sooner or later be able to add a certain pharmaceuticals or a specific symptom as inclusion criteria. Keeping this in mind, the application will be prepared to add any inclusion criteria which would be required to automate the assignment of different types of codes e.g. diagnosis codes, surgical codes, Laboratory, Measurements, Pharmaceuticals, Radiology (MRI, CT, X-Ray and USG), and SNOMED-CT. These codes used to define the diseases name and description of the symptom.

The parameters are specifying the characters of the inclusion criteria. The definition of a parameter in these settings would be: What specific things does researcher want to study in selected population? If researcher, yet again, take the fictional study in point as an example, an example of a parameter would be prescription of nitrogen during the hospital admittance related to the discharge diagnosis code of myocardial infarction. Other examples of parameters could be gender, age, time for medical subscription of nitrogen, chest pains etc. Whatever you might find interesting to find out about your selected study population is a parameter.

The extraction application that is used to extract the information is the basis of the software. Once the user has decided and programmed inclusion criteria and specified the parameters, he needs an extraction tool that is linked to the current EPR-system in order to extract the specified data. Figure1 shows the work flow of the user.

1. Hypothesis that attempts to set the facts.
2. Add inclusion and parameter (e.g. Inclusion: Heart Attack, Parameter: Chest Pain)
3. Create study (Specify the codes and outcomes)
4. Connect with EPR
5. Extract data from EPR regarding the created study
6. Reviewed extracted data to analyze
Chapter 3
Research Methodology

This chapter presents the research methodologies of this thesis, the methods and why I have chosen these methodologies. The thesis followed the qualitative research method because the qualitative method is used in a situation that needs deeper understanding of people, and to collect information from people. In the theoretical part of this thesis a literatures review is presented to get knowledge about the field. The practical part is concerned with how to get requirements from physicians, nurses and doctors using as interview and brainstorming method, a paper prototyping method to visualize the collected requirements on paper, scenario based evaluation methods to evaluate the designed paper based prototype, a prototype implementation based on the acceptance of the scenario based evaluation. Finally, a usability method used to suit the needs of the user and find out the usability issues.

3.1 Literature review and study

The Literature review is the part of theoretical methodology where analysis of various papers, articles, and books about previous and current work in the field is required. The literature review mainly focuses on materials gathered from different articles published in the ACM, IEEE, Springer Link, SCIRUS, KTH Publication Database DiVA, and ScienceDirect by different experts in the field of extraction and reviewing medical information and software development.
At first I have started to search for “extract medical information” in www.google.com and found an article “Information Extraction from Medical Notes”. Then I extended my search to find more articles regarding medical information extraction field through the www.scholar.google.com, KTH Publication Database DiVa and used KTH library account http://www.lib.kth.se/main/eng/ to get access publications ACM, IEEE, ScienceDirect and SpringerLink. I selected keywords to get more articles e.g. “clinical data extract”, “paper based patient record”, “computer based patient record”, “electronic patient record” and “application of medical data extract”. Because those publishers only publishes articles, journals which maintains high standards like, quality of writing, scope of research, analytical theories etc.

3.2 Interviews and Brainstorming

3.2.1 Interviews

According to Steiner Kvale (1996) et al. [21] interviews are the most popular and commonly used qualitative method for collecting perspective on the research topic. It is most useful when researcher’s wanted to get detailed information about a person’s thoughts and behaviours or if one want to explore a new topic in depth. The conversation with interviewer might be in a structured way that predefined some questions and tries to get answers of those predefined questions or it may lead on in on unstructured way. In this way, subjects talk freely whatever they want about the interview topics [23].

In this master’s thesis, open ended interview was chosen. This was because the interviewee had the option to elaborate his/her view on a particular question. This usually produced a number of ideas which was used as a part of brainstorming used discuss in the later section.

3.2.2 Brainstorming

In 1950, Osborn first came up with the brainstorming technique. Brainstorming is an open discussion form for generating ideas and shares the ideas with team members. This technique is appropriate in the beginning of a project to generate ideas, and illustrate idea related issues. During idea generating phase, group members are not allowed to criticize or question an idea. The main goal of brainstorming is to find different possibilities and not need to wait get for the best idea or to think that your ideas are unworkable. One piece of paper is enough for each idea. Later it should be analyzed in a more structure and convenient way [22, 24].
In this master thesis, both interview and brainstorming technique were used. Because, combining the interview with brainstorming saved time and participants came up with opinions which were used for broad discussion.

### 3.3 Paper Prototyping

Paper or Low-fidelity (lo-fi) prototyping is a technique to present or visualize the actual system on paper and testing them with real user [25]. To test the designed prototype with the real user I used scenario based evaluation technique which is discussed in later section.

In this thesis, a paper prototyping technique was used because it is suitable technique to clarify the requirements from the user and enable a draft interaction design of the system. Usability problems was also detected and redesigned in a very early stage [26].

Drawing each of the pages on paper and shown the end user-physicians, nurses, and researchers. In this way, I tried to collect their opinions, if changes were needed or if they wanted to add anything or if there were find difficulties to understand the interaction.

### 3.4 Scenario based evaluation

Scenario based experiments involves capturing of reactions and opinions concerning the designed paper prototype from end users. Without technical background, users can understand easily and map them to user requirements. This scenario based evaluation is helpful for requirement elicitation and requirement verification. The scenario based testing is most important to combine with other features and to create a flow of the functionality of the system. There are several reasons to follow scenario based testing: users can learn about the product, check the documented requirements, elucidate any missing requirements give suggestions about requirement related issues, and explore expert use of the program. This is the approach that user can participate; give the decision and suggestion if they have any alternative choice regarding created scenario [27, 28].

In this thesis, a scenario based evaluation method was used to get feedback or opinions by showing the paper prototype to people who were thought to be future users. After getting user feedback or suggestions, it was easy to make further changes or improvements before starting implementation of the application.
3.5 Prototype Implementation

The software development started once the user and interview subjects accepted the proposed prototype. The proposed prototype was translated in programming language which consumed a significant time in development life cycle. It is described in Chapter 5 that how the prototypes were implemented. Chapter 6 illustrated the user interfaces regarding the accepted scenario.

3.6 Evaluation and usability testing

In this thesis, usability evaluation was the last phase for the implemented prototypes. The goal of the usability evaluation was to find the issues in the interface and how well identified the functionalities of the user interfaces are from the users. In this way several real user participated during the evaluation of the implemented prototype to identify usability problems, explain their expectation and problems. A think aloud method was chosen for the evaluation process. Chapter 7 describes details of the user evaluation of the implemented prototype.

3.7 Alternative Methods Considered

Alternatively, if this research can be executed with an extended period of time, it would allow a deeper understanding of current electronic patient record system and information extraction application in Sweden. Brainstorming and interview methods were chosen for collecting perspective on the research topic. The alternative methods are case study and participant’s observation which was wanted to use before started to selection of the research methods. The later section expressed why those methods abandoned.

3.7.1 Case Study

Case study is a data gathering method (Leedy and Ormrod, 2005) to understand a complex issue and adds strengths what already known from previous research. This method is used to investigate and analyze the research topic [29]. For that reason, the case study method is appropriate to understand, describe and predictive the research area.

This thesis, the case study method was not chosen because there was no previous case study for the research topic. It is not possible to accomplish the research without getting any previous research.
3.7.2 Participant Observation

Participant observation method (Mack et al., 2005) is a qualitative method which is used in traditional ethnographic research. Researcher will be involved in to the research field to observe the situation [30]. Using this method a researcher can get deeper and more abundant data during the observation.

For this thesis, participant observation method was not chosen due to time constraints, as it takes several months or even more than one year to observe the research field. For the time limitation, this method was not suitable for this research.
Chapter 4

Requirement Process and Analysis

The purpose of the work described in this chapter was to collect user requirements for the application for extraction of medical information and include support for these requirements in the application framework. It was also described how the functional and non-functional requirements were collected to design particular services. Finally, from these functional and non-functional requirements, a designed use case can be driven into the project framework and validate the architecture of the system. The gathered requirements describes how the system will behave, facilitate for the users, and the system domain. The user and the system requirements are described in this chapter.

4.1 User Requirements

User requirements describe the expected service from the system for specific services and the way the system solves requirements. Requirements must be written in a way so that non-technical users can understand them. These requirements are generally defined using external activities and behaviour of the system. A good user requirement comes from real users or stakeholder where they can express their desires, needs, and expectations. However, sometimes it is more difficult to get user requirements from users for developers. The developer do not have a clear idea of user needs and expectations, and the user’s do not have clear idea what new technology may offer them [31].
In this system there were two groups of users: administrator and registered users. Both users have different requirements in this application.

- **Administrator:**
  - Administrator is authorized to control the system.
  - Administrator is able to register users and level of authority to maintain the information for administrator and users.
  - Responsible to maintain database.

- **Registered user:**
  - They are able to login, logout, edit information, change password, use forget password.
  - They are able to add inclusion criteria’s, add parameters, create studies, share studies, receive/open shared studies, view and edit shared inclusions and parameter criteria’s, modify and cancel studies.
  - They can view previously created and new studies.

### 4.2 System Requirements

System requirements provide the in-depth knowledge of the user requirements (e.g. system functions, services, and operational details) and these requirements should be followed to design the architecture of the system. The software developer should analyze these requirements to know what has to be implemented and provided in the proposed system. From the identification of the users, system requirements are classified in two different types: functional and non-functional requirements [31].

#### 4.2.1 Functional Requirements

The Functional requirements express the functionalities and capabilities of the system that must be performed successfully. They define things such as user interface and interaction with application, data manipulation and processing, system calculation, and other specific functionalities that shows how user requirements meet the system goal. When a designer design functional specifications the designer should consider everything from a general view which means that the reader easily can understand and that the user can easily interact with the application without technical knowledge [32,33].

- **Functional Requirements of Administrator:**
  - Login
- Update information of administrator
- Register/delete user
- Active/deactivate user
- Update user information/passwords
- Change administrator password
- Logout

### Functional Requirements of Users:
- Login
- Profile edit
- Add/delete inclusion criteria
- Add/delete parameter
- Create/delete studies
- Share inclusion criteria/Parameter/Study
- Open/receive inclusion criteria
- Password Change
- Logout

#### 4.2.2 Non-Functional Requirements

Non-functional requirements identify the overall system properties and constraints of the system (e.g. system response time, reliability, usability, security and storage requirements). These requirements are more critical to meet than functional requirements. If functional requirements are not met to the system goal, the system is useless [32, 33].

- **Operational Requirements**
  - It will use Visual Studio 2010, ASP.Net(C#), Microsoft SQL Server 2008, HTML, CSS, JavaScript and jQuery
  - System can browse by Microsoft Internet Explorer, Firefox, Google Chrome and Safari.

- **Project Schedule**
  - The development project was submitted on 10\textsuperscript{th} August, 2012
  - Evaluation and usability testing was scheduled at the end of August, 2012.
  - Finally, system was finished at the end of the September, 2012.
4.3 Process Model

Process models present a network of single process how data are processed from one table to another table, and transformation way to get required information. Process model can also transform and process data for multiple interconnected process. There is two type of process model these are [34]:

- FDM (Functional Decomposition Diagram)
- DFD (Data Flow Diagram), these are describing in the following

4.3.1 Functional Decomposition Diagram (FDD)

A functional decomposition (Swapna Kodali, 2007) diagram represents a whole structure of a system. Decomposition is divided each entity into a smaller groups step by step with smaller related parts [34].

During the development process in this application, divided each entity into a smaller group and translated them into a smaller group. Figure 2 shows a Functional Decomposition Diagram (FDD) of the application.

4.3.2 Data Flow Diagram (DFD)

Data flow diagram is a graphical representation (Swapna Kodali, 2007) of how data is processed in a system from one process to another process [34]. To design data flow diagram used four symbols to show the flow of the process and information (Figure 2).

- **Rectangles** represent external entities; by this rectangle shows the sources and destinations of data.

- **Eclipse** representing processes; process symbol used to take data input, validate and process of inputted data and finally get output.

- **Arrows** represent the data flows; by using arrow symbol data are moving between activities.

- **Open ended rectangle** representing data stores; stores database, XML files or physical stores.
ReSeSS Application

Administrator

Register User

Manage User

Create New Study

Inclusion

Add Inclusion

Delete Inclusion

Open Inclusion

Share Inclusion

Parameter

Add Parameter

Delete Parameter

Open Parameter

Share Parameter

Edit Parameter

Outcomes Description

Outcomes Value

Add New Outcome

Edit Inclusion

Edit Inclusion Outcome

Outcomes Description

Code

Specify

Restrict by

Date/Time

Specify

Restrict by

Readings

Specify

Restrict by

Text

Specify

Restrict by

Radiology

Specify

Restrict by

SNOMED-CT

Specify

Restrict by

Outcomes Value

Add New Outcome

Outcomes Description

Code

Specify

Restrict by

Date/Time

Specify

Restrict by

Readings

Specify

Restrict by

Text

Specify

Restrict by

Radiology

Specify

Restrict by

SNOMED-CT

Specify

Restrict by

Figure 2: Functional Decomposition Diagram (FDD)
Each process of a system at first derived a context level DFD. After that regarding the context level DFD derived detailed DFD. A context level DFD shows the conceptual design and process, and what the inputs, outputs and data stores are. In the Figure 3 shows a context level data flow diagram. A detailed DFD shows more details and compressive view of the interaction in sub-process of the system.

**Figure 3:** Data flow diagram (DFD) which illustrates entire flow in the process.

In the login screen, administrator and users enter the login id and password which is supplied to the authentication server. If the login information is valid it will directed to perspective home page screens; for administrators to the administrator home page, and users to the user home page. If they are invalid the user will taken back to the login screen, detail DFD shown in Figure 4.
After login Administrator will be redirected to the User interface of the Administrator which displays administrator tasks that are to be performed. The tasks are register new user, and manage users. From these user interfaces, the administrator adds new users; edits user information, delete users and what will be stored in the database following successful updates, shown in Figure 5.

Figure 4: Data flow diagram for authentication login user

Figure 5: Level 1 Data flow diagram for administrator
Manage user is show list of the registered user from the database and display on the user interface, shown Figure 7.

In the registered user list from user information can be entered and it will be stored in the database, shown in Figure 8.
For users, the first step is login and when a user login successfully he/she will be taken to the UI display set of operation. The operation includes create new study, and previous study, shown in Figure 9.

![User Create New Study DFD](image)

**Figure 9:** Level 1 data flow diagram for the user

![Figure 10: Level 2 data flow diagram for us](image)

**Figure 10:** Level 2 data flow diagram for us
**Figure 11:** Level 3 data flow diagram for user

**Figure 12:** Level 4 data flow diagram for user

**User Previous Study DFD**

**Figure 13:** Level 1 data flow diagram for user
For user, when Previous Study is selected, UI shows with a set of operations. The operations include: extract information, review information, share study, edit study, and delete study shown in Figure 13.

![Data Flow Diagram](image)

**Figure 14**: Level 2 data flow diagram for user

### 4.4 Data Model

The data model expresses what data should be stored in the database and what data should be retrieved from database. The data model is used to design relational database to put in relational database section. This process is used to design the queries that will access and perform the operations on those created tables.

#### 4.4.1 Entity Relationship(ER) Diagram

An entity-relationship(ER) diagram is a graphical representation that shows the relationships between entities in a database. Relationship means how the data is shared between entities. To design ER diagram, three symbols represents three different types of information. Figure 15 show an ER diagram and relation between the symbols.

- The *boxes* or rectangles are used to represent entities,
- The *diamonds* are used to represent the relationships
- The *ovals* are used to represent attributes.
Figure 15: Entity Relationship(ER) Diagram
4.4.2 Data Tables
In this section, designed basic structures of the tables for the project are shown with information about primary and foreign keys shown in Appendices D.

- **Users**: User table is created to store user (Registered user and administrator) information.
- **GenericLists**: GenericLists table created to store code id, code name, description and type.
- **InclusionsAndParameters**: This table created to store inclusion and parameter name with their id, type of inclusion and parameter.
- **PharmaceuticalsLists**: This table created to store information about pharmaceutical.
- **Outcomes**: Outcome table is created to store outcome name and value of the outcome.
- **OutcomeDetails**: Outcome details table is created to store outcome details of the every outcome.
- **Studies**: Studies table is created to store details of the study e.g. study id, study name, etc.
- **Patient**: This table is created for a dummy EPR database. Extract information tool is collect patient information from this table to extract into this system.

4.5 Establish Use Case Diagram
In the 1980’s, Ivar Jacobson stated the idea to design use case diagram and user case scenarios. Later, his idea use case and use case scenario have become more popular in the field of software engineering. A use case is used to discover the interaction between actors which may be one or more users or another computer system and system under consideration. Actors are stayed outside of the system that interacts with system. A uses case start with a users goal and it’s finished when fulfilled users goal. There are three properties to describe a use case [35]:

- **Actor**: type of user who interacts with the system.
  For example: registered users, system administrators
- **System**: actors are used the system.
- **Goal**: the actors use the system to achieve the goal

The required use case diagrams for this project are as follows in Figure 16.
4.5.1 Brief description of Administrator use cases

**Login:** Administrator enters id and password upon the system validates the entered id and password and logs the actor into the system as an administrator. If entered id and password is invalid it shows the message “Invalid id or Password” and redirects to the login page.

**Logout:** Administrator use the “Logout” button upon the System displays “Successful Signed Off” page and redirects to the Welcome Page. If the user closed the browser unexpectedly it is still logged in until the session expired.

**Register user:** Administrator registers the users, and then the users use obtained id and password to enter the system. Administrator enters the user information to register the user. After filling, the user information presses the “Register User” and message shows “User registered successfully”. Precondition is that user has an email.

**Edit/Update user information:** Administrator can edit and update information of the user using “Manage User”. To edit information, first open selected user information and then edit. After editing the user information press the “Update user” button then shows “User update successfully”.

Figure 16: System use case diagram
Delete user: Administrator can delete user accounts. Administrator use “Manage User” then it shows a list of the registered user. To delete user information click “delete” button then open message box “Do you want to open” press “yes” then show “User shows successfully”

Active/Deactivate: Administrator can active or deactivate an account. Administrator uses the “Manage User” then it shows list of the registered user. To active/deactivate users select user name from the register list. In the down shows “Is Active?” select “Yes/No” button to activate/deactivate then press “update user” button and shows “User update successfully”.

4.5.2 Brief description of User use cases

Login: A user should be registered by the administrator. The user enters id and password upon which the system validates the entered id and password and logs the actor into the
system as a user. The user is redirected to the home page. If an invalid id or password was entered the message “Invalid id or Password” is shown and the user gets redirected to the login page again.

**Logout:** If a user uses the “Logout” button then the system displays “You have successfully logged out” and redirects to the Welcome Page. If, the user closes the browser unexpectedly it leads to a finished session.

**Forget Password:** In the login page, there is a link “Forgot Password” which is clicked by the user upon forgetting the password. Then a new message box opens for the users email address then if “Reset Password” button is pressed, the system would send a link to reset the password in users email address.

**Change Password:** To change the current password the user must successfully logged in. The "Change Password" opens a new asking for the old password and the new password twice (for confirmation). The user then press “Change Password” button and the page displays “Your Password changed successfully”.

**Edit/Update user information:** The user can edit and update information in a user profile. After editing the user information the “Update User” then shows the message “User update successfully”. The user is not allowed to edit the user id.

**Create Study:** The inclusion criteria (e.g. heart attack) are added in the “Inclusion”. Each inclusion can have several parameters (e.g. people who had heart attack also had Chest pain, Chest pain is a Parameter). Create study is a saved state of the inclusion and parameters provided with it. It is used for extracting information from the patient record database through the given queries.

**Edit Inclusion/Edit Parameter:** A user use the “Edit Inclusion” function to add outcomes of the inclusion. And used use the “Edit Parameter” function to add outcomes of the parameter. Those outcomes have six properties that are included to create studies. These are: codes (Specify-ICD-8 codes, ICD-9 codes, ICD-10 codes, ÅGK codes and Restrict the codes), date/times (restrict by and time interval), texts (specify-medical referral, and file, and restrict search-related by, time interval), radiology (specify-MRI, CT, X-Ray, USG and restrict-related by, time interval, restrict by), readings (Specify-laboratory, pharmaceuticals, measurements, restrict-restrict by, time interval, related by), and SNOMED-CT codes(specify codes and restrict search).
Figure 18: Use-case diagram of user
**Share Study:** A user can create a study and be able to share the created study with other registered users. The “Share Study” button opens a new message box. The user adds the id of the recipient, and an optional message and then selects “Send” study. It is possible to share with multiple users.

**Receive/Open Study:** When users receive a shared a study from another registered user, the user has received a notification in his/her “Shared Study” button. When the user selects “Shared Study” it opens with inclusion and parameter criteria.

**Share Inclusion/ Parameter:** A user can share “Inclusion” or “Parameter” criteria in two ways, either by creating a new “Inclusion” or “Parameter” or select “Open Inclusion” or “Open Parameter” button. Then the user gets the inclusion and parameter list from favourite list. From this list user can use”Share Inclusion” or “Share Parameter” to share and it is possible to share with multiple users.
Chapter 5
Prototype Implementation

This chapter discusses how the prototype implementation was based on the different levels of user requirements that were presented in Chapter 4. This prototype was built based on web techniques that runs on a web server and can connect remote databases of electronic patient record system (EPR) located in any place of the Internet. This chapter discusses which technologies and software that were used to implement the application, which architectures and procedures that were followed and how components integrate between web applications and database.

5.1 Implementation tools and technologies

The main objective of this thesis was to develop an online medical information extraction tool. The Microsoft .NET framework was chosen to implement the extraction tool. The motivation for the choice of the .NET framework was that in Stockholm County the electronic patient record system (EPR) was developed with the .NET framework. However, in this work the extraction tool was developed to connect with the EPR system to extract medical information. When a user enters the web site URL (Uniform Resource Locator) in the address field to get service, then a Web Server is contacted to bring the pages onto the screen. In the .NET framework, the service IIS (Internet Information System) works as a Web Server. When IIS receives a request, it inspects the type of extension of the requested service. If the client request (Figure 19) has .asp extension then IIS routes the request to asp.dll to handle this request, and if the request comes from .aspx, .ascx etc. it routed to the ASP.NET engine to
handle the request. If the resources (e.g. pages, images and other static content) are saved in a database, ASP.NET contacts the database through ADO.NET (ActiveX Data Objects for .NET) and then sends the requested resources to the client browser [34, 36]. This section discuss all about the tools that were used to implement the online medical extraction tools.

**Figure 19:** Request and response between Client and Web Server [32]

**Internet information service (IIS):** The Internet information service is a web server application for Windows machines formally called internet information server. The features of this application are created by Microsoft for use with Microsoft Windows which provides a security-enhanced, easy to manage, web server for developing reliable web hosting and web services. IIS 7.5 supports HTTP (hypertext transfer protocol), HTTPS (hypertext transfer protocol secure), SMTP (Simple mail transfer protocol), NNTP (Network news transfer protocol), FTP (File Transfer protocol), and FTPS (File Transfer protocol secure) [34, 36].

**Microsoft .Net Framework 4:** The Microsoft .NET framework version 4 includes enhancements for ASP.Net 4 in target areas. Microsoft Visual Studio 2010 express edition is included among these enhancements with new features for improvement of web development. The Common Language Runtime (CLR) provides all the .NET programs and automatic services (e.g. security checking, memory management and optimization) [37].
Microsoft Visual Studio 2010: Microsoft Visual Studio Express is a freeware IDE (Integrated development environment). Microsoft Visual Studio 2010 Express edition was used for the implementation because it’s included with SQL Server Express easy-to-use set of databases doesn’t need to install a SQL Server instance machine.

Microsoft SQL Server 2008 R2 Management Studio Express is a graphical tool which is used to integrate the environment. By this tool it is possible to get all components of SQL Server e.g. accessing, managing, configuring, developing and administrating.

ASP.NET Programming language: The system is implemented using ASP.Net(C#). ASP.Net(C#), which is a popular server side scripting language for writing dynamic web pages. As I mentioned before that Electronic Patient Record System (EPR) was used ASP.NET(C#) programming for that reason the extraction application used the same programming language.

jQuery plugins with ASP.NET: jQuery is a multi-browser fast, lightweight JavaScript library. jQuery has a simple API and a huge number of plug-ins that are available to use and are possible to customize. In this application was used several jQuery API and plug-ins and created a customized a jQuery API resess-script.js.

ADO.NET (ActiveX Data Objects for .NET): ADO.NET provides access to the data sources and data service such as Microsoft SQL server 2008 for a web based application. It is a part of the base class library that is included with the Microsoft.NET framework. ADO.NET was used to connect to the data source; data retrieving manipulate and update data.

5.2 Implementation procedure and architecture

This section discusses what procedures and architecture were followed initially to create the application e.g. write programming code, and logical functions. For this implementation a three layer architecture using ASP.NET(C#) programming was chosen. Later sections discussed briefly about layer architecture.

5.2.1 Developing a Web Application Project using ASP.Net

Visual Studio .NET provides different types of templates and default XML web service methods to help developers to start creates the web application project. In this part, it is described how created, customize and managed the application using ASP.NET [36]. At first was created an ASP.Net master page Main.Master, which is used to create a consistent layout for the pages in the application Re-SeSS (Retrospective Synchronized Surveys). By using the
ASP.NET master pages to define the look, feel and behaviours that wanted to see for all others pages e.g. Index.aspx, Logout.aspx, AdministratorDashboard.aspx, UserDashboard.aspx, etc.

When a web application projects is created using the Visual Studio .NET IDE it automatically creates two primary files: Default.aspx (Active Server Page Extended) and Default.aspx.cs (C# code behind). These files store script and source code that allows web browsers to translate and open web pages.

5.2.2 Three tier Architecture
The Architecture contains three layers (Figure 20) which presentation layer, business layer and data access layers. Each layer has its own code for development; therefore it is easier to maintain and modify the application. In this following section discusses the three layers [38].

**Figure 20:** Three tier Architecture [38]
**Presentation Layer:** The presentation layer includes all user interface representation, how data is displayed and input taken from the user, and how it looks. Presentation layer pages are windows form or .aspx format. In my application created user interface e.g. RegisterUser.aspx, AdministratorDashboard.aspx, UserDashboard.aspx, etc. These pages used where data is presented to the user or input is taken from the user.

**Business Logic Layer (BLL):** The business logic layer contains C# class library components. This class writes business logics such as calculation, and validation of data etc. It works like a middle-man between the application layer and the data access layer. Code Snippet-I has shown a class name UserBLL and writes respective methods for calling AddUser, UpdateUser, DeleteUser, ResetPassword, etc. This layer may reject an “Add User” operation if the user id is already taken by another user. That means the business logic layer is used to make the judgment about the data. Whenever a user wants to update the business logic, user needs to update only this class or any methods of this class.

```csharp
public class UserBLL
{
    private UserDAL userDAL = new UserDAL();
    public string AddUser(UserDTO aUser)
    {
        /* validate business logic */
        if (userDAL.IsLoginIdExist(aUser.LoginId))
        {
            return "Login Id already taken by another user. Please try a different one.;
        }
        if (userDAL.IsEmailExist(aUser.Email))
        {
            return "Email Address already exists";
        }
        try
        {
            return userDAL.AddUser(aUser);
        }
        catch (Exception ex)
        {
            throw ex;
        }
    }
    public bool UpdateUser(string field, string value, int id)
    public void DeleteUser(int deleteId)
    public bool IsEmailExist(string emailAddress)
    public string ResetPassword(string email)
    public bool ChangePassword(UserDTO aUser, string newPassword)
}
```

**Code Snippet 1:** Code snippet of business logic layer “UserBLL.cs”
Data Access Layer (DAL): The data access layer is responsible for data access and manages from database. This layer contents the methods to connect with database using queries or store procedures to perform database operations e.g. data update, insert, delete etc. from database. Code Snippet 2 has shown a “DeleteUser” method from “UserDAL” class to delete the user. In this layer created file data access layer file “UserDAL.cs”

```csharp
class UserDAL
{
    private SqlConnection sqlConnection;
    public UserDAL()
    {
        DbConn aConn = new DbConn();
        sqlConnection = aConn.GetUssdSqlConnection;
    }
    public string AddUser(UserDTO aUser)
    public bool UpdateUser(string field, string value, int id)
    public void DeleteUser(int deleteId)
    {
        try
        {
            sqlConnection.Open();

            SqlCommand command = new SqlCommand("DELETE FROM Users WHERE Id = @id", sqlConnection);
            command.Parameters.AddWithValue("id", deleteId);
            command.ExecuteNonQuery();
        }
        catch (Exception ex)
        {
            throw ex;
        }
        finally
        {
            if (sqlConnection.State != ConnectionState.Closed)
            {
                sqlConnection.Close();
            }
        }
    }
    public bool IsEmailExist(string emailAddress)
    public bool IsLoginIdExist(string login)
}
```

Code Snippet 2: Code snippet of business logic layer “UserDAL.cs”
5.3 Database diagram and relationship

This section provides a database diagram and relationship of tables (Figure 21). For simplicity of the project created only one database to store clinical information.

- The “Users” table stores the administrator and registered user names, and their login information such as UserType, Login Id, Password, First Name, Last Name, email address, gender, Date of Birth etc.
- The “GenericList” table store the Name, Description, types of the codes. The name of the codes is, ICD-10 codes, ICD-9 codes, ICD-8, ÅGK, Laboratory, Measurements, etc. In the description part mentioned the description of each code and the types mention type of codes. It has divided the codes using number such as for ICD-Code type: 1, for ICD-9 code type: 2, for ICD-8 code type: 3, for ÅGK code type: 4, etc. There are thousand of codes, used to define the diseases name and description of the symptom.
- The “PharmaceuticalsList” table store Pharmaceuticals details such as Preparation Name, Substance, ATC Name, Indication, and ATC Code.
- The “InclusionsAndParameter” table store details about inclusion and parameter such as user id, Name, and Type. Here, type means Inclusion or Parameter.
- The “Outcomes” table store the outcome information of inclusion and parameter such as InclusionOrParameterId, FieldName, and Field value.
- The Outcome.Details table store the detail information of outcomes, and details about the different types of codes id and name. These are OutcomeId, CodeType, CodeId, DataType, DateField, Readings Type, Readings Id, Text Type, Text Id, Radiology Type, Radiology Id, SnomeCtType and SnomedCtlId.
- The “StudyPatient” table store the UserID-who created study, PatientID, StudyID, IsReviewed, and IsFlagged
- The “Studies” table store StudyID, StudyName, CreateBy, SharedMessage, IsSaved, CreationDate, and ModifiedDate.
- The “Patients” table is created for storing patient’s information. This table is a dummy table that contains the same data as EPR (but it not directly with EPR). The review page shows the extracted information from this table.
Figure 21: Database diagram and relationship
5.4 Integrating web application with database

User creates a study using “Re-SeSS Application” web application need to be able create own studies, add inclusion items, add parameter items, add inclusion and parameter outcomes, select inclusion and parameter outcome details, extract created studies, and review clinical information. Shared studies need to be accessible, editable and shareable with other users and finally save export patient studies in Excel file. Therefore, a well organized database was essential for the development and maintenance of a clinical information extraction application.

In a static web page, contents of the page are added manually and it’s determined by time that when this page is created. The content of the statics page is e.g. text, images, and other content that cannot change unless the manually change and this contents store in HTML pages not in database. The company Logo, banner, contacts us; company information’s are the examples of a static web page, which are not changeable. On the other hand, a dynamic web page contents dynamically created based on user actions, selection and receive data from external resources or database. In this way users are supposed to select and submit, update of database information, delete information, and insert new information. To make this kind of task by user, user should be registered by administrator. User can get user id and user password to get access to maintain own information [39].

In this application, administrator registers the new user, and then user information is saved to the database. Users can login by using their id and password because that information is saved. A user adds inclusion and parameter to create own study with outcome details of the inclusion and parameter. When the “Save Study” button is clicked, the study is saved in the database and a dynamic response shown. If the “Shared Study” is clicked, an input box pops up where the title and the recipient name is provided and when “shared” is clicked, a response message is shown that it is successfully shared. After the study is extracted and reviewed, it is saved in excel format. If same study is updated and extracted, reviewed and saved later, the new data is just appended in the same excel file.
Chapter 6
User Interface Design

This chapter describes how the graphical user interface was designed based on the user requirements, following the paper prototype and the use case design presented in Chapter 4.

6.1 Application File Design

The prototype application consists of the following pages (Table 1).

<table>
<thead>
<tr>
<th>Program Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Index.aspx</td>
<td>Login page, this page is shown when the user types the web address in the web browser. User enters login id and password to enter the system.</td>
</tr>
<tr>
<td>2. AdministratorDashboard.aspx</td>
<td>This page is the administrator home page. The administrator has two choices, Manage users and Register user.</td>
</tr>
<tr>
<td>3. ManageUsers.aspx</td>
<td>Administrator manages the users e.g. “edit”, “delete”, and “IsActive”.</td>
</tr>
<tr>
<td>4. RegisterUser.aspx</td>
<td>User registration page, the administrator creates a new user.</td>
</tr>
<tr>
<td>5. UserDashboard.aspx</td>
<td>This page is the user home page; after log in the user get this page.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>6. NewStudies.aspx</strong></td>
<td>New study create page, the user get inclusion and parameter option to create study</td>
</tr>
<tr>
<td><strong>7. Outcomes.aspx</strong></td>
<td>This page is for the edit inclusion or edits parameter to add outcomes description and outcomes values.</td>
</tr>
<tr>
<td><strong>8. OutcomeDetails.aspx</strong></td>
<td>This page is for the edit outcomes to add outcome definition of the inclusion and parameter, e.g. code, date/time, readings, text, radiology, and SNOMED-CT.</td>
</tr>
<tr>
<td><strong>9. PreviousStudies.aspx</strong></td>
<td>User can see the list of previous study or saved study. From this page user can edit, delete, extract, share, and review the created study.</td>
</tr>
<tr>
<td><strong>10. Profile.aspx</strong></td>
<td>User profile page, user can edit user profile information</td>
</tr>
<tr>
<td><strong>11. ReviewStudy.aspx</strong></td>
<td>The review page shows the patient information and the reviewer can select two options, reviewed and flagged.</td>
</tr>
<tr>
<td><strong>12. ChangePassword.aspx</strong></td>
<td>This page changes the user’s password.</td>
</tr>
<tr>
<td><strong>13. ResetPassword.aspx</strong></td>
<td>This page reset the user’s password.</td>
</tr>
<tr>
<td><strong>14. LogOut.aspx</strong></td>
<td>This page to logout from the system.</td>
</tr>
</tbody>
</table>

**Table 1: User interface pages**

### 6.2 Application Interface Design

This section shows some screen shots from running the application and all the functionalities are explained accordingly.

#### 6.2.1 Login Page

Figure 23 shows welcome the user to the application. It allows the user to login using their login id and password. Based on their user type the system identifies the user role and permission. If the user entered on invalid id or password it will redirect back to the login page. If the user type is administrator then the “AdministratorDashboard” page is opened and if the user type as user then the “UserDashboard” page will open (Figure 22).
6.2.2 Administrator Home Page

Based on the login id the system identifies the administrator. The administrator can see administrator home page and its two functionalities. An administrator is able to register new users, and manage existing users (edit, delete, active/deactivate). Figure 23 shows the administrator home page view when first entering the system.

6.2.3 User Registration

If the administrator selects the “Register User” option then the user registration form will open (Figure 24). A valid user email address is required to register a new user. After completing the registration process the user gets a valid login id and password to access the system.
If the administrator selects the “Manage user” option then the Manage User page (Figure 25) is opened. The administrator can see the registered users list, delete accounts, user edit information, and active/deactivate a user, change a user’s password, and change a login id.

Figure 25: Manage Users page
6.2.5 Reset Password

The login page has a forget password link to request to the administrator a change of password. The user gets a new page to put email address to reset old password (Figure 26). Then user gets an email confirmation to reset the password and if the user follows the new password links from new password page (Figure 27) then the user can set a new password.

![Image](Forget Password.png)

**Figure 26**: Forget password page

![Image](Enter New Password.png)

**Figure 27**: New password page

6.2.6 New Studies

In the home page, there are three menus “New Studies”, “Previous Studies” and “Account Setting”. Upon selecting “New Studies” a new page opens and the user can see two different boxes for criteria which are “Inclusion” and “Parameter”. User can add inclusion and parameter, and then user can edit, delete and share respectively (Figure 28). For example some inclusion items are Kidney Failure, Blood Pressure and Skin Cancer and parameter items are Heart Attack, Chest Pain, and Age. The save button save the created study. If the mouse pointer is kept on an item of inclusion or parameter, then a pop-up window comes up with outcome (Figure 29) and outcome details (Figure 30). If “Share Inclusion” or “Share Parameter” is selected user have to give their “User id”. This feature is used for sharing the inclusion or the parameter with multiple users. “Open Inclusion” and “Open Parameter” reveals the shared contents.
6.2.7 Outcomes
The outcomes page (Figure 29) comes when select edit inclusion or edit parameter. In this page there are three functions edit outcomes, delete outcomes and add new outcomes. User can edit outcomes to add details outcome (Figure 30) of added inclusion or parameter items.
6.2.8 Outcomes Details

The edit outcomes details page (Figure 31) comes when user select “edit outcomes”. The user can see six more menus under the outcome details. Each menu has two sub menus and these are specifying the parameter and restrict search.

1. **Code:**
   a. Specify > ICD-10, ICD-9, ICD-8, ÄGK
   b. Restrict Search > Related, Restrict by, Time Interval

2. **Date/Time:**
   Time/Date for Parameter, Restrict by, Time Interval

3. **Readings:**
   a. Specify> Laboratory, Pharmaceuticals, Measurements
   b. Restrict Search > Related, Restrict by, Time Interval

4. **Text :**
   a. Specify> Referrals, Medical File Text
   b. Restrict Search > Related, Restrict by, Time Interval

5. **Radiology :**
   a. Specify > MRI, CT, X-Ray, USG
   b. Restrict Search > Related, Restrict by, Time Interval

6. **SNOMED-CT:**
   a. Specify > SNOMED-CT
   b. Restrict Search > Related, Restrict by, Time Interval

---

**Figure 30:** Outcome Details page
6.2.9 Profile Setting
User can change their profile information and change password of user account. After change profile information select update profile and if user wants to reset all user information it is possible also (Figure 31).

![Figure 31: User profile setting page.](image)

6.2.10 Previous Studies
Figure 32 displayed, user can select different options e.g. “Edit/Open Study”, “Share Study”, “Extract Study”, “Delete Study” and “Review Study”.

![Figure 32: Previous Study “PreviousStudies.aspx” page](image)
Share study: When the user created study with inclusion and parameter and their outcome details and saved the created study then this created study comes in previous study. User can share this created study with multiple user and add message to the users (Figure 33).

![Figure 33: Share created study](image)

Extract Study: The user can extract information from electronic patient record (EPR) system based on created study. User select “Extract Information” button from previous study page (Figure 32) then started to extract data from EPR (Figure 34). After completed the extracting its shows “Successfully extracted patients to the study”.

![Figure 34: Extract data from EPR](image)

6.2.11 Review Study
In review page (Figure 35) shows that there are 5 patients and this information comes from EPR after extract study. Now the user can review, flag, select outcomes of text parameter and radiology of the specific patient information, select next patient, and finally export to an MS-Excel file.
**Figure 35:** Review patient information user interface
Chapter 7

Prototype Evaluation

As I stated before, implementation of the proposed prototype has been performed through scenario based evaluation. The proposed paper prototypes were evaluated by three medical students, a researcher and a physician all of them are from Karolinska University hospital. Through the scenario based evaluation process find out the user needs and what they think about the proposed prototypes. Later, their feedback and findings were considered when started to design interface and implementation of the hi-fi prototype. This chapter described in more details of the user evaluation of the implemented proposed prototype. The main reasons to evaluate the prototypes were to access how well a design fulfils user’s needs and where users like it.

7.1 Evaluation Methods and Paradigm

Usability testing is one the most important factor of the quality of web application. There are various usability testing methods available to find the usability problem and improving the usability of an interface before and after deployment. These methods are: heuristic evaluation (HE), cognitive walkthrough (CW), and action analysis [40]. A heuristic evaluation [41] is an approach to evaluation in which knowledge of typical users is applied, often guided by heuristic, to identify the problems. A cognitive walkthrough approach [42] is a task oriented method by which the analyst explores the systems functionalities, that is stimulates step-by-step user behavior for a given task. An action analysis method [40] is divided into formal and back-of the-envelope the actions, that means breaking the task into individual actions such as a move-mouse-to-menu or type-on-the-keyboard and calculating the times needed to perform the actions.
Due to the context of this thesis, to evaluate the system, real users needed to get direct information about how users use the system and what are the exact problems with specific interface and requirement. In this thesis, to evaluate clinical information web application, think aloud method was chosen. The think aloud method allows to participants continuously thinking out loud while using the system. Users will express their thought, feelings, opinions and takes time to think when they were interact with system. To get users feedback using performed some formal task (e.g. select the test subject, select test task, and session of the test).

7.1.1 Selecting test subjects
Selecting test subjects means the people who will evaluate the prototype or who will use the prototype. They will find out the usability issues in the interface and interaction and the data gathered are then analyzed to recommend changes to fix the problem. In 2005, Deborah L. Stone recommended that each participant should have a real user because it is helpful to gather information from real user. It is better not to choose participants randomly for getting feedback [43].

In this thesis to evaluate the application, the test subjects were chosen from a list of medical students, researcher and physicians from Karolinska University hospital. Participant A was a female PhD student at Karolinska University Hospital. She is working in Clinical Neuroscience Department. Participant B was a young medical student medical student of Karolinska University Hospital. He worked in the neurologist department. Participant C was a professor of Karolinska University Hospital in neurologist department. Participant D was a female researcher of Karolinska University Hospital, works in Neurobiology Department. Participant E was a Medical doctor and research preparatory student, Karolinska University hospital in medicine and medical informatics department.

All of the participants were familiar with electronic patient record system, and they had usability experience of web based application. Windows 7 OS (Operating System) was used for three of the experiments, Mac OS and LINUX OS each for one experiment.

7.1.2 Selecting test task
The selected subjects and listed task are listed to be used with think aloud sessions. In 1993, Ericsson and Simon suggested to use simple warm-up task. By this warm-up task it is comparatively easy to think aloud about the system tasks [44].
The testing tasks are a set of interaction scenarios, and each of the scenarios like add inclusion, add parameter, crate study, save study, and, etc. Test task was set for both administrator and registered user. There were two test tasks evaluated for administrator and nine tasks evaluated for registered users. In Appendix C is explained more details about the list of test tasks.

7.1.3 Test Session

The test session were conducted mostly in subject’s personal office in their workplace of Karolinska University Hospital, Stockholm. Each test session was done on their personal laptop, and takes the test tasks during the test session. The participant’s sit as a user and the facilitator take the notes. In the test sessions, the author worked as a facilitator and also worked as administrator. Five participants carried out this experiment provided their feedback. Each of the test session carried out approximately one hour and it was changeable.

7.2 Conducting the test

The participants were informed that if they do not find the application user friendly then should suggest changes which would make the application friendly. They were assured that this is a test for the application usability and not a test of their operating skill.

So, you do not need to worry about if you made any mistake and if you could not find any task. If participant could not find any task or do not know how to interact with the interfaces that means this are not participant fault this is the problem of interface of this application. From participant just want to know the interface designed of the application well to get the requirements. The participants asked questions when they were performing the task, what they were trying to do, what action should have been taken and suggestions for changes [45].

In order to get accurate picture from participants, the facilitator have asked some questions to rate the tasks based on the usability and fulfilment of their required criteria. A Likert scale is an approach [46] to emerge responses from collective responses used with rating scale. Each task was rated on 5 point and the questions were based three factors mentioned below.

- Did the ReSeSS web application provide user friendly to find your tasks?
- Did you get interaction interfaces are placed in right place or page?
- Do you think interaction functions of specific task are necessary for such for tasks or for this whole application?
When participants finished each task, participants can express their overall experience. To express their experience, they could comment on the below factors:

- List of good and bad things about application layout, color, text language, images, internal links, button, pull-down menus and pop up windows are used in task.
- Recommendation that can add in those specific tasks to improve the application.
- Removed unnecessary and irrelevant features from specific tasks.

### 7.3 Results

The test subjects were chosen in order to get the end users feedback. After completion of each task, the participants were rated the tasks based on their experience. The participants used Likert scale to represent their expectation about the system and ranged from 1(strongly disagree) to 5(strongly agree) with in-between ratings 4 (agree), 3(undecided) and 2(disagree).

The following questions were used to take task rating from participants:

- **Did the ReSeSS web application provide user friendly to find your task?**

  All participants were agreed with task 1, task 2, task 3, task 4, task 7, task 8, and task 9 features and designed interfaces and information get easily and tasks done without any difficulties. Two participants neither agreed nor not disagreed about task 5 and task 6. In addition, one participant got difficulties to understand task 11 which is “Export patients information” to be a saved excel file.

- **Did you get interaction and interfaces are placed in right place or page?**

  Three participants agreed that all interaction and interfaces are placed in right place and right page. In addition, these three participants agreed that task 9 and task 10 are appropriate on that place to extract study and then start to review extracted study. Two participants said these two tasks are not right for this place. But these two participants said rest of the tasks are placed in right places and pages.

- **Do you think interaction functions of specific task are necessary for such for tasks or for this whole application?**

  Five of the participants are said that all tasks are necessary for this application. These five participants also said that task 7 and task 8 is a most necessary feature of this application to share and receive inclusion or parameter or created study. One participant said task 10...
reviewed and flagged features are really necessary for such kind of application and also said task 11 which export patient information in a excel file is most important feature of this application for a researcher. Table 2 shows the task rating for each of the task from the five participants based on three factors.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>User friendly to find the information</th>
<th>Features placed in right place</th>
<th>Necessary of features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task-1: Register user (As Administrator)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Task-2: Manage user (For Administrator)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Task-3: Add/delete/ edit inclusion (As User)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Task-4: Add/delete/ edit parameter (As User)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Task-5: Edit outcome and outcome details inclusion/parameter (As User)</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Task-6: Share/Receive inclusion or parameter (As User)</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Task-7: Save study (As User)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Task-8: Share and received study (As User)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Task-9: Extract study (As User)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Task-10: Reviewed and flagged patients information (As User)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Task-11: Export Patients information (As User)</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2: Task rating from participants
Table 3 represents an overall subjective view from all participants of good things, recommendations or suggestions and remove unnecessary feature. In the first column the participants, the second column contains the good things of the application, the third column contains recommendations from the participants for any features, and the fourth column contains unnecessary features suggested to be removed.

<table>
<thead>
<tr>
<th>Test Subject</th>
<th>List of good things</th>
<th>Recommendation for any features</th>
<th>Remove unnecessary features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant-A</td>
<td>✓ All interfaces and interaction is simple and understandable for me.</td>
<td>✓ “Open inclusion” or “Open Parameter” works for received inclusion or parameter, participant suggested that this might be places in two different buttons: “Add Favourites” and “Shared Inclusion list” or “Shared Parameter list”</td>
<td>✓ Remove “Open Inclusion” and “Open parameter”.</td>
</tr>
<tr>
<td></td>
<td>✓ Liked the images and buttons for interaction with their name e.g. edit, share, extract, and review image buttons.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Mostly liked specify and restrict search, especially ICD code and description search is more familiar.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant-B</td>
<td>✓ Group of the features and design is clear and liked layout and colour.</td>
<td>✓ Participant suggested creating a user manual to operate application.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>✓ Less number of menu and submenus, liked hyperlinked of image</td>
<td>✓ Should add edit outcome description and</td>
<td></td>
</tr>
<tr>
<td>Participant-C</td>
<td>Features are designed simple and elegant.</td>
<td>In review page, after reviewed and flagged then export patients information in an excel file, the participants suggested to mentioned different colour for reviewed, flagged, and not-reviewed.</td>
<td>Remove “Open Inclusion” and “Open parameter”.</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------------------</td>
<td>------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Liked the less number of clicks, and every interaction and interfaces are understandable.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mostly liked in review page: Text Parameter and radiology multiple selection from tree view.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Liked review page: flagged, reviewed button, next and previous patient.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant-D</td>
<td>Easy to navigate, easily can move from any place to home page for every interaction.</td>
<td>Add notification by mail or any way to know that other users shared inclusion or parameter or shared a full study.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Liked the consistent location for every page.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant-E</td>
<td>Simple and familiar for me to interaction.</td>
<td>Add rename or edit saved study name.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Liked the hyperlinks</td>
<td>Opinion to add</td>
<td></td>
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</table>
images and buttons, layout and colour of the interface.
✓ Mostly liked, pop up message boxes e.g. inclusion and parameter pop up window, and shared by pop up message box.

“Contact Us” to contact with system administrator.
✓ Add favourite list to save inclusion and parameter that can add for new study.

Table 3: An overall subjective view from all participants

7.4 Analysis of the results

This section analyse the results that were found in the usability testing session. According to Table 2 and 3, it is easy to find the participants expression, recommended features, unnecessary features and satisfaction to perform their given task. This was the goal of the usability testing.

From the grade ratings one can see the test tasks participants interacted easily and finished the task. They had some suggestions (e.g. one participant suggested adding a favourite list when adding inclusion and parameter items). From favourite list user can add listed item and item could save in this favourite lists. One can use same inclusion or parameter from favourite list from into different studies.

One participant suggested using a different colour when a study is saved in an Excel file to understand which patient information is reviewed, flagged, or not reviewed. The Excel file used one column “Reviewed”, 0 = Not reviewed (Colour 1), 1 = Reviewed (Colour 2) and 2 = Flagged (Colour 3). From the different colours the user can easily understand three different kind of information.

Another participant suggested creating a user manual to operate the application. He said it could be understandable for a use if he gets a manual to operate the application to find information for all pages.
One participant suggested to add new feature for notification to receive inclusion or parameter item or shared study, where receiver can get notification that someone shared something to me. Another participant said to add another feature contact us to contact with system admin if user needed.

The subject’s recommendations are an essential part in the future development of the application. However, none of the participants recommended completely new features for administrator or user part. Interestingly, none of the participants found any features that should be removed from the application.
Chapter 8
Conclusions and Future Work

8.1 Summery and Conclusion

This thesis was conducted to the large health care institutions at Karolinska University hospital in Sweden. This institute was using electronic patient record (EPR) system. Chapter 1 and 2 discussed the current scenario of EPR application in Sweden. This work proposed an idea to create a clinical information extraction application to extract clinical information from an electronic patient record system. This extraction application can extract free-text medical phrases which are written by physician or clinicians and extract phrases from unstructured notes. The extraction application was designed and developed for researchers to create their own studies with inclusion and parameter to use retrospective research. This application was able to specify and restrict their created inclusion and parameter e.g. if inclusion is heart attack where heart attack is specify by ICD-10 code, and restrict by time interval (from 2010, April to 2011, April ) and parameters like chest pain by radiology code and restrict by Admission date to discharge date. From these inclusion and parameter item the researcher extract clinical information from EPR. Researcher can review the extracted information without any complexity and if researchers have any confusion about any inclusion item or outcomes of the items they can flagged that item and extract again.

The main research goal of this thesis was to find the requirements to create an extraction application that is able to specify and restrict relevant information from electronic patient
record system. To reach this thesis goal, collected system and user requirements using different methods then created a scenario based paper prototype and evaluated the proposed prototype with real users. The second step was to design and develop a hi-fi prototype. To evaluate the usability of the hi-fi prototype used think aloud method to get expectations and requirements from the users who will be the real user of this implemented prototype. The prototype evaluation chapter mentioned, and discussed and analysed their expectations and feelings. Based on their feedback I conclude that my research goal was met. User feedback was quite positive and they were satisfied with user interface.

8.2 Limitation and Future work

There are some limitations for the current system to which solutions can be provided in the future development. The hi-fi prototype extracted clinical information from a dummy database that was not directly collected from an EPR. I created dummy patient information with inclusion and parameter and their outcome details to extract and review in the prototype. In future development, this application can be given more functionality e.g. researcher or physician can see the list of EPR and connect with a specific EPR to import clinical information. Users could update the Excel file created for his/her study with new inclusions or parameters. Multiple EPR could be selected to import clinical information. There are thousands of codes and descriptions for ICD-9, ICD10, ÅGK, Pharmaceuticals, MRI, CT, X-Ray and USG used in this system. If the administrator wants to add new code or edit code descriptions the administrator should go to a database to finish this task. In a future administrator interface, one can get another menu to maintain the application and in this way the administrator can manage any kind of change regarding code and descriptions.
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Appendix A

Questions for Interview

1. What do you think about current Electronic Patient Record system (EPR)?
2. What are the obstacles you are facing to use Electronic Patient Record system (EPR)?
3. What kind of functions would be helpful for your daily work? All information is available on that system?
   - Patient information searching
   - Summarization of the patient's information
   - ICD Codes (ICD-10, ICD-9, ÅGK)
   - Reading information (Laboratory, pharmaceuticals, Measurement)
   - Medical file/referral text
   - Radiology Codes (MRI, CT, X-Ray, USG)
4. How do you use information searching application e.g. information extraction and review patient information in your work?
5. What are your suggestions and how do you think about free text information and structured information?
6. What about your suggestions to convert free text to a structured form?
   a. Are those data would be helpful for your work?
   b. If it is then, what perspective?
Appendix B

Questions for Scenario Evaluation

1. What is your overall impression about the proposed prototype?
2. Do you think the designed scenarios are useful for searching application to the users? e.g. ICD Codes, reading, medical text, and Radiology
3. Are there any difficulties of information to get extraction and review scenarios?
4. Are the visual displays purely decorative for every scenario with their functions?
5. Do you have any suggestions or idea about any scenario?
Appendix C

Questions for Task Evaluation

Task-1: Register user (As Administrator)
“Register User” is one of the important requirements for an administrator. Only administrator can register a new user to interact the system. The register page gives some information to fill about the user, and administrator created a user id to get the access of the system. Can you find the register page and all other necessary information in particular place to create “New User”?

Task-2: Manage user (As Administrator)
“Manage User” is another important requirement for an administrator. In “Manage User” page administrator can see the lists of the registered user and administrator can “Delete” and “Edit” information of registered users. Can you see such information that is used to manage user and that are placed in right place?

Task-3: Add/delete/ edit inclusion (As User)
By the “Add Inclusion”, user can add the specific diseases symptom or whatever user wants to add for the study. User can delete and can edit outcomes of the specific inclusion items. Can you please add one inclusion item and edit and finally delete the item? What do you think all image and button are placed in right place to interact for adding inclusion?

Task-4: Add/delete/ edit parameter (As User)
By the “Add Parameter”, user can specify the characters of inclusion criteria. User can “Delete” and “Edit” parameter outcomes of the specific inclusion items. Can you please add and edit and finally delete the added parameter? What do you think all image and button are placed in right place to interact for adding parameter?

Task-5: Edit outcome and outcome details inclusion and parameter (As User)
To “Edit Inclusion” and “Edit Parameter” user can add outcomes of the inclusion and parameter e.g. ICD Codes (ICD-10, ICD-9, ÅGK), date/times, Reading information (Laboratory, pharmaceuticals, Measurement), Medical file/referral text and Radiology Codes (MRI, CT, X-Ray, USG). Please interact with the system to edit your added inclusion and
parameter with those properties. Did you find any difficulties to edit inclusions and parameters or edit their outcomes?

**Task-6: Share/Receive inclusion or parameter (As User)**

For example, you have added one inclusion and one parameter. Now you want to share your added inclusion or parameter to another registered user and receive inclusion or parameter from another user. Please share one inclusion and one parameter to another registered user. Can you find such information to share or receive inclusion or parameter?

**Task-7: Save study (As User)**

Study is a combined of inclusion and parameter items. You have already added your inclusion and parameter for your study research. Now, you can save your created study (inclusion and parameter) to use in future whenever you can open and edit. This gives a message to you that you can open your saved study from “Previous Study” page. Please, save your created study and you can see your study in “Previous Study” page. Did you find any difficulty to save your created study and to see your added study in the list of previous study?

**Task-8: Share and received study (As User)**

You have already saved your study and now you can see it in “Previous study” page. In this task you interact with system to share your study apparently you receive share from another registered user.

Did you find any difficulties to perform this task? Did you get all necessary information in precise place?

**Task-9: Extract study (As User)**

You have already created your study with inclusion criteria and specified parameter. Now you connect with current EPR system to extract information regarding your created study. Can you find such information to connect with EPR system and extract information from EPR? Was the information are placed in right group?

**Task-10: Reviewed and flagged patients information (As User)**

The information is extracted from EPR regarding created study. Extracted information is saved in a one study e.g. Study-1: Patient 1 out of 50, which you can review and use flagging.

Can you please open extracted information and started to review those information and use flagging if you get any error? Did you find any difficulties when you were trying to review and flag information? Do you think that such information is placed in the right place?
Task-11: Export Patients information (As User)

“Export Patients” used, when you reviewed patients information and now you want to save the study to your computer in an excel file. In this excel file you can see three types of information, reviewed, not reviewed and flagged information. Can you please export your reviewed study and open it in a excel file? Did you find any difficulties to export patient’s information and all information are placed in right group or place?
## Appendix D

### Data Tables

#### Table: Users

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<th>Description</th>
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<td>Login id for administrator and user</td>
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<td>Password</td>
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<td>Security for Administrator and user</td>
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<td>Gender: Male or Female</td>
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<td>RegisteredDate</td>
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<td>Activate/Deactivate user</td>
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<td>Use for user forget password</td>
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#### Table: GenericLists

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<td>Code name</td>
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#### Table: InclusionsAndParameters

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