Addis Ababa University

College of Natural Sciences

Semantic Web based Healthcare Recommendation System: the case of Diabetics

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This is to certify that the thesis prepared by Melaku Fissie , titled: ***Semantic Web based Healthcare Recommendation System the case of Diabetics*** and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Computer Science complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

This work proposes a Recommendation System in diabetes healthcare in order to improve the quality of life of Diabetes patients. Diabetes is a permanent disease in which the human body's cells either do not respond properly to insulin, or insulin production is insufficient. If the disease is not treated well and on time, it can lead to severe health problems like heart disease, blindness, failure of kidney, and amputations of the lower extremity. Therefore, this chronic disease needs dietary control, physical exercise and insulin management.

However, among people in the developing countries like Ethiopia, permanent diseases are growing to be causes of death. These problems are becoming worse due to the scarcity of specialists, practitioners and health facilities. In Ethiopia, there has been observed a threat of increased diabetes prevalence and the number of death rates imputed to diabetes reached above 21,000 in 2007.

In an effort to address such problem, this project attempts to design and develop a prototype semantic web based healthcare recommendation system that can provide advice for physicians and patients to facilitate the diagnosis and treatment of diabetic patients. To this end, we use semantic technology for building ontology knowledge repository to provide data integration and medical recommendations for diabetes management. First, we build the ontology of diabetic knowledge is acquired using interviews from domain experts which are from Black Lion Hospital Diabetes Center. Relevant documents analysis method is also followed to capture knowledge. Then, the acquired knowledge is modeled using ontology that represents concepts involved in diagnosis and treatment of diabetes and to enter and link concepts and data for diabetes ontology, we used Protégé-owl editor tool.

The ontology model provides knowledge into which information on individual patient including blood glucose examination information and recommendation are derived. Based on ontology's structure, the model can collect, store and share information from heterogeneous sources, Reason over knowledge. Furthermore, ontology has been proven a better way of describing managed data. In this project, we mainly focus on the ontology development process for Type II diabetes only.

Keywords: Ontology, OWL, SWRL, Healthcare, Recommendation System

Dedicated To

My Family.

I would like to dedicate this research to my parents and family for all the love and support they have given me throughout my education journey and throughout my life.

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List of Acronyms and Abbreviations

API	Application Program Interface
CADA	Chinese Aged Diabetic Assistant
DDCO	Disease-Drug Correlation Ontology
DL	Description logic
DM	Diabetes mellitus
HTTP	Hyper Text Transfer Protocol
ICT	Information Communication Technology
IDRA	Intelligent Diet Recommendation Agent (
JSP	Java Server Pages
MoHA	Mobile Health Advisor System
OWL	Ontology Web Language
PC	Personal computer
RDFS	Resource Description Framework Schema
SWHRS	Semantic Web Healthcare Recommendation System
SWRL	Semantic Web Rule Language
T1DM	Type I Diabetes Mellitus
UI	User Interface
UML	Unified Modeling Language
URI	Universal Resource Identifier
W3C	World Wide Web Consortium
XML	Extended Mark up Langage

Chapter 1

Introduction

This chapter presents background of the research, the statement of problem, as well as the research objectives. It also presents the research methods, scope and limitation, and finally the organization of the document.

1.1 Background

Healthcare organizations are required to give prompt services and follow-up for patients. They rely on data and information for every aspect of their service delivery. Huge amount of data are generated in a mostly unstructured paper environment and this leads them to give less efficient healthcare service. Healthcare quality, cost and patient safety are adversely affected and compromised by the current largely paper-based system in Ethiopia.

Chronic diseases are ongoing, incurable illnesses mainly caused by poor nutrition, excessive use tobacco and alcohol and lacks of physical activity [4]. Peoples affected by such diseases require long-term treatments under constant supervision by different healthcare providers (nurses, doctors, family members, social caregivers), which is costly and time consuming. Chronic disease like diabetes needs dietary control, physical exercise and insulin management. Peoples with chronic diseases require long life treatments under continuous supervision by different healthcare providers. Diabetes mellitus (DM) one of chronic disease has been a serious health problem in Ethiopia for many years. It is a chronic disorder characterized by hyperglycemia and associated with major abnormalities in the metabolism of carbohydrate, fat, and protein. Moreover, it is accompanied by a marked propensity to develop relatively specific forms of renal, ocular, neurologic, and premature cardiovascular disease. DM therapy requires a continuous plan and management for DM patients to control the blood glucose level and to monitor progress of DM's complications. Diabetes is a long-lasting disease associated with irregularly high levels of glucose (sugar) in the blood. If the disease is not treated well and on time, it can lead to severe health problems like heart disease, blindness, failure of kidney, and lower extremity complications **[**15**]**.

Diabetes is a chronic disease in which the human body's cells either do not respond properly to insulin or insulin production becomes insufficient. In order to understand the concept of diabetes, it is important to know how our body cells use glucose to produce energy. Insulin enables the body cells to absorb glucose. Nevertheless, diabetic individuals either cannot produce this hormone properly or their body cannot appropriately use it for usual body functions. Consequently, this creates the accumulation of glucose in the blood and when the accumulated glucose is not used by the body cells, then signs of diabetes start to come out [15].

However, the existing practices for medical treatment need patients to see specialist for diagnosis and treatment. Other medical physicians may not have sufficient knowledge or skill to deal with certain diseases like diabetes. Nevertheless, the waiting time for treatments usually takes a few days or weeks. The patients may suffer throughout their life since most of the diseases like diabetes could only be treated at the early stage [4].

Information communication technology (ICT) has been proposed in this regard as an essential tool for addressing the problem of fragmented and inaccessible clinical information. Information technology such as electronic health records, E prescribing, clinical decision support systems, electronic management of chronic disease and bar coding of drugs and biological products have been proposed to be employed as workable means to reduce health care costs and improve patient safety [1]. ICT has become a key solution to enhance quality of life for chronic patients through implementation of different constant chronic diseases remote supervision applications. The use of those applications has become essential plan for long-term care facilities capable of reducing medical expenses and replacing hospital visits. Even though there are many applications for different remote supervision, there is still a need of new technology than can make them work together by sharing knowledge.

With today's population growth, the number of people with chronic diseases increases significantly resulting in large patient data management. For this reason, the existing technology needs some improvement in order to provide shared services. There is a need to transform current web into semantic web based technology to enable a large amount of data to be collected, stored and shard easily. Ontology has been promising as an interesting solution in semantic web to represent shared knowledge and enable access to a variety of digital resources. Ontology in home based monitoring application has been interesting solution to represent shared knowledge and other solutions have been reported, good examples can be found in [5] a paper shows combination of different technology including ontology for management of data in home-based monitoring scenarios. In [6] ontology-based healthcare context information model have been developed for healthcare services and in [7] ontology for health-care knowledge was developed to support clinical decisions for chronically ill patients.

Having a semantic web based healthcare recommendation system will ensure that patients healthier, despite the fact that they are infected with one or more disease. Additionally, since most of our hospitals are still operating manually; this will encourage the hospitals to adopt the computerized or automated system.

In this project, Ontology knowledge specification will be used to represent knowledge about diabetic patient information relevant in appropriate follow-up and inform recommendation and provides in which information on individual patient including examination data and recommendation are derived.

In this study, the researcher needs to develop a low-cost automated semantic web based diabetes health care recommendation system, which can lessen the social economic burden and materialize an individualized diabetes mellitus management.

1.2 Statement of the Problem

A study conducted by Wild et al. [28] shows that the occurrence of diabetes in people at any age throughout the world was predicted 2.8% in 2000 and 4.4% in 2030. The numbers of people living with diabetes were one hundred seventy-one million in 2000 and will be expected to increase to three hundred sixty-six million in 2030. Moreover, an increase in the number of people between 2000 and 2030 will reside in the cities of less-developed countries and there will be a rise in the numbers of adults living with diabetes by 69% in less-developed countries. Similarly, the number of adults living with diabetes is expected to increase by 20% in more developed countries.

As there are many patients with chronic diseases in Ethiopia, the number of people who need constant assistance is increasing. Nevertheless, the current scenery depicts the long patient and operation waiting lists, shortages of hospital beds, community care and inadequate medical facilities and professionals to provide patients with health care in emergency units and other healthcare departments.

Patient's daily life routine is completely dependent on the schedule of all care providers. She/he has to wait for medical checkups or any other medical exercises. Too many visits to the hospital/clinic and appointments of laboratories for medical tests disturb the daily life. Diabetes patients suffer many types of complications. They need special type of care (diet, exercise), patient by self or a doctor cannot provide the healthcare that patient needs.

The nature of diabetes is a lifelong disease and cannot be treated for once and last. Because of this, patients need consistent treatment. However, in our country, there are no sufficient numbers of specialists and medical doctors [8]. This condition leads to disproportional numbers of physicians and patients. Because of this problem, patients are not getting enough diagnoses and treatment. Thus, the significance of conducting this project is to support physicians in the diagnosis and treatment of diabetic patients. If diabetic patients get proper treatments, they can control their sugar level, which will further enable them to minimize the number of deaths, which could result due to diabetes.

Ontologies can facilitate automated and intelligent processing of data. Such automation embedded in healthcare applications can assist the human medical personnel to reduce their workload and improve reliability, i.e. reduced errors. It should be emphasized that providing such automation will not replace human medical personnel but rather to assist in their routine tasks. Lack of data integration that is important factor for healthcare recommendation applications since patient information from various sources needs to contribute together in health support process.

Hence, the aim of this study is to design and develop a semantic web based healthcare recommendation system for diagnosis and treatment of diabetes that assists to control the sugar level of patients, and in order to minimize the number of deaths because of diabetes.

1.3 Objective

1.3.1 General Objective

The general objective of this study is to design and develop a semantic web based healthcare recommendation system that can provide advice for physicians and patients in order to facilitate the diagnosis and treatment of diabetic patients.

1.3.2 Specific Objective

With the aim of achieving the above general objective, the study also has the following specific objectives:

- ✓ To undertake an investigation and a literature review to understand the knowledge dynamics around healthcare recommendation system for diabetics.
- ✓ To develop and implement a semantic web based healthcare recommendation system for diabetes patients.
- ✓ To make use of semantic web technologies in developing ontology model to collect and share data for diabetes diseases.
- ✓ To conduct usability testing of prototype system.

1.4 Scope and Limitation of the Study

The scope of this project is to design and develop semantic web based healthcare recommendation system for diagnosis and treatment of diabetic patients.

The system gives possible treatments for diabetic patients. These include suggesting medications one should take, foods should be eaten, physical exercises, foods to be avoided or limited, and monitoring glucose level in the blood.

Diagnosis and treatment of diabetes using semantic web based system helps to reduce death rate because of diabetes. Nevertheless, it does not provide diagnosis and treatment facilities for gestational and other type of diabetes.

The ontology model developed in this project provides to collect and share data from different sources and generate recommendation for chronic diabetic patients.

However, as a limitation, the system model to be developed is limited for diabetic patient only, but the same ontology approach can be applied to others chronic diseases.

1.5 Methodology

In this work, with the aim of achieving the objective the following methods and techniques will be used.

- ✓ **Literature Review**

In order to have deep understanding on the problem of this study, it is vital to review several literatures that have been conducted in the field so far. For this reason, related literature such as books, articles, proceeding papers and some other sources that are retrieved from the internet are consulted so as to understand the domain knowledge, concepts, principles and methods that are important for developing semantic web based systems. More over to identify the existing technologies and tools analyse the current situations and make the system faceable.

- ✓ **Methods of Knowledge Collection**

In this study knowledge is acquired from both documented sources and non-documented sources knowledge are acquired from Internists and medical doctors who work in the Black Lion Hospital by using interview and from medical books, training manuals and journal medical articles. Moreover, National Guidelines for diabetes in Ethiopia is used to understand about the treatments of diabetes.

- ✓ **System Development and Implementation Tool**

Implementation is done using appropriate programming languages, emulators and other software tools. To achieve the objective of the project, several tools and technologies will be used. The tools used to develop the system are described as follows.

Protégé 4.3: to facilitate the development of Ontology of the system being integrated in OWL API

OWL API 3.5: Java API for creating, manipulating and serializing diabetes Ontologies.

NetBeans 7.1: as integrated development environment for the client side application of the system and server side application of the system.

Java 2 Enterprise Edition (J2EE): The java programming language is used to develop application of the system.

Java Server Pages (JSP): is used to design the web interface of the system.

- ✓ **Testing and Evaluation**

  Proper usability testing will be made and the newly proposed system will be evaluated in terms of its goals and contributions. Usability of Semantic Web based Healthcare Recommendation system from different perspective will be evaluated from different users' perception. Seven Diabetes Clinic staffs and are selected by applying purposive sampling technique from Black Lion Hospital Diabetes Center for usability testing of the prototype system. Usability testing will be done to see the quality of recommendation and to access to what extent the SWHRS satisfies the users.

1.6 Significance of the Study

Through the implementation of this work, the proposed system can be used to recommend the medication, diet, and exercise compliance of diabetes patients. Through improved technologies, it can promote provision accessible and low-cost health assistance and to provide the best possible quality of life for individuals with diabetes.

Ontologies can facilitate automated and intelligent processing of data. Such automation embedded in healthcare applications can assist the human medical personnel to reduce their workload and improve reliability, i.e. reduced errors. The work will support the diabetes patients to improve the quality of daily life and they can get the basic instructions and treatments regarding their health status.

Generally the main importance of this healthcare system is at once to enhance the quality of treatment and to adapt to a semantic system, which is more easily understood by man and machine than the syntactic based system. It is also advantageous for remote and rural areas that have scarcity of medical professionals and medication facilities. Hence, the result of this study will be used as an input for the development of a full-fledged healthcare system that can be used for diagnosis and treatment of diabetes.

1.7 Organization of the Document

The remaining of this document is divided into seven chapters.

Chapter 2 describes the literature review about the existing ontology for personalized system, description of diabetes diseases, at the end it present review of the technologies involved in the project development including semantic web and ontology technology.

Chapter 3, the current health care recommendation system trend and the general overview of proposed semantic web based healthcare recommendation system briefly described.

Chapter 4 contain requirement analysis and system analysis model including use case of the proposed solution, define classes, properties and instances. Chapter 5 gives the system design proposed solution of the system, general system architecture of the system.

Chapter 6 discusses the system development tools applied for implementing the Semantic Web based Healthcare Recommendation System. Moreover, the prototype and testing of the system are also detailed in this chapter.

Finally, in chapter 7 conclusion of the research work and its future works are presented and discussed.

Chapter 2

Literature Review

In this chapter, we review various relevant and related issues and concepts concerning the healthcare recommendation systems. It also focuses tools and technologies that have been used to develop the proposed and implemented semantic web based health care recommendation system.

2.1 Diabetes Management

Diabetes is a disease that prevents the body from properly using energy from the food we eat. People with diabetes either don't have enough insulin, or the insulin they have doesn't work as it should to get sugar into the body's cells for energy. Type 1 diabetes occurs because the insulin producing cells of the pancreas are damaged. People with type 2 diabetes produce insulin, but it is either too little or does not work properly. Type 2 diabetes is most common in those over 40 who are overweight. Controlling blood sugar (glucose) levels is the best way to reduce risks for long-term complications like eye disease, kidney disease, and damage to nerves and blood vessels [13]. Diabetes is managed through proper meal planning, exercise and, if needed, medication. Type 2 diabetes is controlled with the following methods:

- ✓ Meal planning and exercise (physical activity)
- ✓ Medicine taken by the mouth
- ✓ Insulin or other injectable medications

Blood glucose levels are closely regulated by insulin, major regulator of intermediary metabolism. The principal organ of glucose transport is liver which store glucose as glycogen and release in the peripheral tissue when need. This high blood sugar produces the classical symptoms of frequent urination, increased thirst and increased hunger [14]

According to [15], International studies have shown lifestyle modification, including dietary changes and exercise can assist in managing Type 1 diabetes and reduce the risk of developing mainly Type 2 diabetes by up to 58%. The study notes that, Type 1 diabetes mellitus is characterized severe insulin deficiency hence administration of insulin is essential while Type 2 diabetes mellitus, is characterized by tissue resistance to the action of insulin combined with a relative deficiency in insulin secretion. By, controlling your blood sugar levels can help prevent these complications. Although long-term complications of diabetes develop gradually, they can eventually be disabling or even life threatening.

Research by [16] shows, some of the major potential complications of diabetes include Heart and blood vessel disease which increases the risk of various cardiovascular problems, including coronary artery disease with chest pain, heart attack, stroke, narrowing of arteries and high blood pressure.

The study further notes, Diabetes complications may be prevented or minimized through the early detection and effective management of the disease. These factors, coupled with the benefits of primary intervention approaches, highlight the considerable potential for health, social and economic gains through diabetes monitoring. Manual methods of monitoring such as the use of Log Sheet, unscheduled Doctor visits, inconsistent diabetes monitoring creates a major problem since this process is tiring and time consuming while it creates a challenge of untimely monitoring due to lack of consistency and accuracy records of glucose levels making diabetes management unmanageable and a threat to the patient's life.

2.2 Technologies and Tools

2.2.1 Semantic Web

The main idea in semantic web is to have interlinked data on web defined in meaningfully way, to be used for automation, integration and reuse across various applications. The World Wide Web that is written in Hyper Text Mark-up Language (HTML) is designed to be understood and interpreted by humans. Gradually by increasing the amount of available data on the current web, the process of finding, organizing, accessing and maintaining the information for the users turns to be extremely difficult. Therefore, this notion comes up that by shifting the retrieval of data from users to the computers; the web can be optimized and become much more goal based rather than task based. Such a desire leads to the concept of semantic web that is brought up to enhance some of the weaknesses of the current web.

The inventor of World Wide Web, Tim Berners-Lee, introduces the term semantic web. The idea behind that is to extend the capabilities of the current classic web of documents and create a web of data that can be accessed and processed directly or indirectly by machines, devices and computers in addition to users [31].

The ultimate goal of semantic web is to provide a common framework that allows data to be shared and reused across applications, enterprises and community boundaries and enables computers and people to work in cooperation [32]. For Semantic web in order to work effectively it should have access to on structured collections of information and sets of inference rules.

2.2.2 Ontology

The term ontology initially comes from philosophy in which it is a theory about the nature of existence. In the context of knowledge sharing ontology is an explicit specification of a shared conceptualization of a domain of interest. From the view of computer science and artificial intelligence, ontology represents a domain of knowledge or discourse as a set of concepts (classes), their attributes (properties), instances of those concepts (individuals) and the relationships in which classes and individuals can be related to one another [17].

Implementation of ontology is the heart of all semantic web based knowledge representation while database schema models data at the physical or logical level, ontology is known for modeling the knowledge in the semantic level. Therefore, it performs a vital task in representation of a particular domain, which allows for automatic reasoning and interpretation with applicable semantic context. Based on its independence from the lower levels of data models, ontology is capable of integrating and sharing data between heterogeneous information resources and specifying interfaces to independent, knowledge-based services. While offering advantages to facilitate interoperability among multiple heterogeneous systems, ontology also provides services for answering queries and reusing knowledge resources [17]. In other words, ontology can be used as a way of communication between the human being and a system or system-to-system.

Ontology can be used in information retrieval and knowledge management. The more perfect the framework of domain ontology is the more accurate information can be provided [18]. Since the construction of ontology from scratch is a very time consuming task, ontology developers try to reuse existing ontologies whenever possible. However, handling complex ontologies that are constructed from multiple knowledge domains also brings another issue up that needs to be addressed by ontology engineering. The knowledge represented by ontology that has been developed for one purpose can be published and reused for other purposes as well.

There are many ways of writing down Ontology or languages used to develop Ontology.

- ✓ RDFS (Resource Description Framework Schema)
- ✓ OWL (Ontology Web Language)

RDFS is the weakest ontology language and allows building a simple hierarchy of concepts, and a hierarchy of properties. While OWL allows saying everything that RDFS allows, and much more such as describing class relationship, inverse property and detail description for every classes in the domain. OWL has the ability to describe classes in more interesting and complex ways. OWL facilitates greater machine interpretability of web contents than that supported by XML, RDF, and RDF schema (RDF-S).

Ontologies are used for representing expert knowledge in the medical domain [19]. Ontologies are the backbone of Semantic Web and they include the descriptions of classes, properties and their instances [20]. The use of ontologies is well suited for applications in medicine. When certain relations are asserted in the ontology, an ontology reasoner can infer more relations, which is not explicitly asserted in the ontology [3]. Automatic reasoner is used in the analysis of ontologies. The reasoner will find out any hidden relationship in the ontology. Any other similar system can easily use the knowledge base just by updating it. Therefore, the cost of maintenance of these systems is also less.

Web Ontology Language [OWL] developed by W3C is based on XML is used to describe the ontology [8]. OWL is based on description logics (DL). DL enables for the usage of automatic reasoners for the analysis of ontologies [10].

OWL-Lite, OWL DL and OWL Full are the three sublanguages of OWL. Out of these, OWL DL is the one with strong reasoning capabilities. In our system, we have used Ontology to represent the concept about diabetes. The language we have used to develop this ontology is OWL Full (Ontology Web Language) with Ontology reasoner.

The SWRL was used to describe the relationship between the rules. SWRL is based on semantic rules [23]. Rules of the SWRL are evolved from Rule Markup Language (RuleML) [23]. SWRL rule has an antecedent part and a consequent part to reason where the results combined with OWL ontology. SWRL is a specification of W3C at present time

The basic pattern, which used instance to express the inferential results and concept and relationship the inferential premise in RuleML, was also retained in SWRL. SWRL may be regarded as the combination of rules and ontology, through which the relationships and terms described in ontology can be used directly when writing rules. At first, the relationship between these classes would have additional rules to be described, but the description in ontology may be used directly in SWRL [23]. There is a relationship of cause and effect between them.

For reasoning upon the description logic languages used to formalize UML class and object diagrams, three widely used tableau-based provers: Pellet, Fact++, and RacerPro. All of them provide sound and complete reasoning based upon the tableau method. The features they support, and evaluate their expressivity in terms of the inferences they provide upon Tboxes and Aboxes, the advanced features they support for ontologies development, their access mechanisms for clients.

All the reasoning services offered by Pellet are reduced to consistency checking which is determined with tableau algorithms.

2.3 Ontology in Healthcare Domain

Traditionally the base of the medical knowledge has been located in the heads of experienced doctors, the ones who have dedicated years of training and practice in order to make correct decisions in diagnosis of diseases and their effective treatments [35]. This practice worked well in the past when production of the new data needed huge amount of effort and the flow of the new data was not as great as to overwhelm the experts. New modern experimental techniques changed this situation quickly by providing huge amount of information.

During the last few decades, this information has been collected and evaluated in different databases and by now, a great amount of medical knowledge can be accessed via Internet [35]. Assimilating this great amount of information to retrieve the best results is impossible for humans; therefore, by introducing the concepts of semantic web and ontology in the World

Wide Web, the sources of medical knowledge have also altered to get the benefits of these concepts in storing and representing their information.

Currently, it is extensively accepted that ontologies can make a major contribution to the design and implementation of information systems in the medical field [35]. Ontology can be indeed useful in medicine where it can enhance the efficiency of information management dramatically and improve the reliability and consistency of communication, especially when heterogeneous actors and different environments are involved. Creation of medical ontologies also brings great advantages to the health care system. Ontologies can be utilized to build more powerful and more interoperable information systems in healthcare. In addition, they can support the need of the healthcare process to transmit, re-use and share patient data.

Besides all above, possibly the most significant benefit that ontologies may bring to healthcare systems is their ability to support the indispensable integration of knowledge and data [35]. In spite of all the advances in the construction of medical ontologies, most of standard medical ontologies are built as a single domain-specific ontology.

2.3.1 Diabetic Ontology

There have been several attempts to develop diabetes mellitus (DM) related ontology.

A.X. Qu et al in [33] have developed a semantic structure that helps in discovering treatments for a disease from drug entities that are already approved for another disease. They have striven to make relationships between the pharmacological aspects of drugs and knowledge of biological systems and disease processes in their proposed semantic infrastructure. This work is done based on the design of Disease-Drug Correlation Ontology (DDCO). The developed DDCO that is formalized in OWL integrates multiple ontologies, vocabularies and datasets that extracted from pharmacological and biological domains. Their knowledge framework, which is capable of interconnecting drug actions and disease mechanisms across biological contexts, demonstrates a great flexibility for data mining and reasoning across the range of human diseases. Although, their system recommends a great structure of relationships between drugs and diseases, however, it is mainly focused on the chemical and pharmacological aspects of drugs and it can be specifically applied in the process of discovery of drug development. The proposed system in this project is mainly concentrated on the medication, diet and insulin can be applied as a recommendation system for diabetic patient.

Jaya in 2011 [34], discusses the construction of ontology of diabetes's symptoms. This work aims to diagnose and predict the diabetes in the earlier stage and helps to provide the possible meaningful factors which leads to diabetes. However, the work does not give recommendation for diabetic patient.

The system that has been modeled in [30] for anti-diabetic drugs is to aid the physicians to make a right decision in selecting the anti-diabetic drugs. They have constructed two separate ontologies in their work: patient data ontology and anti-diabetic drugs ontology. Patient data ontology is applied to store personal information, history and test results of the patients and anti-diabetic drugs ontology has been designed to be used as the source of medicine knowledge. Based on the results of some tests such as liver function test, glucose level of the patient, and the medicine knowledge in the anti-diabetic drugs ontology, they have applied some rules to their rule engine. The result of the rule engine is considered as the drug recommendation for the diabetic patients. Although their system can be applied as drug recommendation system for diabetic patients, but it has a poor capability to be generalized to other diseases and to be applied in a real system. The assumption of the system is based on one disease and no part has been designed for analyzing different diagnoses. The use of some reliable resources such as the American Association of Clinical Endocrinologists data in the construction of ontology [30] is a positive point, however since their ontology have been built from the scratch, its development into more applicable one is still an extremely time-consuming task.

However, existing ontology did not pay attention to important concepts in recommendation activities, such as assessment, diagnosis, treatment and follow-up activities. Therefore, we attempted to define a new diabetes ontology including the above concepts for implementing diabetes healthcare focusing on recommendation activities.

2.4 Summary

This chapter reviewed varies relevant and related issues and concepts concerning the fundamental and general definitions and forms of healthcare recommendation systems, tools and technologies used to develop the semantic web based healthcare system.

One of the main reasons for building an ontology-based application is to use a reasoner to derive additional truths about the concepts you are modeling. In RDF, everything is represented as a resource and they are expressed as statement or triples (Subject, Property, and Object) identified through unique resources id, which is known as URI (Universal Resource Identifier).

Ontology provides a common framework for structured knowledge representation of domain knowledge. Ontology framework provides common vocabulary for medical concepts, concept definitions, relationships, axioms and rules. Ontology reasoner is used to infer knowledge from the knowledge represented in the ontology. Ontology based systems generate decisions in the form of predictions, alerts and recommendations.

In our system, we have used Ontology to represent the concept about diabetes. The language we have used to develop this ontology is OWL Full (Ontology Web Language) with Ontology reasoner. Ontologies developed based on the guidelines typically represent reliable knowledge and are agreeable in terms of expert opinions. The diabetes healthcare ontology was designed and developed by a team of knowledge engineers and medical experts.

An ontology based healthcare management system for diabetes is essential to improve healthcare organizations capacity to make decisions for cost- effective allocation of resources, plan preventive and treatment services, target priority population groups and track the impact of environmental change and prevention and control strategies. For our ontology development, we used some of the above mention factors responsible for as medical recommendation for patient with high glucose level.

Chapter 3
Related Work

There are related works to our study in the literature. In this chapter we chose the most related to present and review the existing system prototypes that have been implemented as solution for healthcare recommendation services.

3.1 Chinese Aged Diabetic Assistant (CADA)

Chinese Aged Diabetic Assistant (CADA) is the Project developed in china with participation of Saint Louis University and is supported by Microsoft Research as a part of a 2-year grant from Microsoft to study the use of "Smart Phones" in the care of older people in China with diabetes. The system sends daily messages to elderly patients with diabetes in China. The messages will include recommendations and guidelines related to physical activity, blood glucose monitoring, blood pressure monitoring, weight and waist measurement, and eating habits. Patients will be taught how to input daily glucose level and his/her affective state. Additionally, physicians may input the patient's measurements and heath goals during office visits. A graphical representation of the trends of the various indicators and personal health goals can be displayed. This technology could change the way doctors and patients interact, and it has the potential to help older patients take charge of their own health [9].

3.2 MediNet

MediNet is a healthcare management system for diabetes and cardiovascular disease. The system is designed to relay information from patient monitoring devices to a central server via a cellular network. At the server, a data-reasoning engine extracts all relevant information and alerts medical officers about severe cases. It also recommends appropriate responses such as a follow-up visit or phone call. The system can also send suggestions directly to patients via SMS message or pre-recorded voicemail [29]. But doesn't afford the implementation cost and also the system does not have ontological approach.

3.3 Mobile Based Patient Follow-up System

The project Mobile Based Patient Follow-up System designed using Amharic and English language provides continual follow-up for outpatients and prevents them from traveling long distance for follow-up from resource-poor environments. It also creates an opportunity for health professionals and patients to stay in contact. In addition, it can be used as a tool to increase the level of support and information available to patients and health workers. These positive changes can result in reduced hospitalization rates as well as a decrease in the number of days spent in hospital. The system considers the patients that are discharged from hospitals and to follow up their daily healthy status and to monitor them through their mobile phone with their respective location (including GPS coordinates). On the server side, the system manages any communication between health worker and patients, and gives privilege to diagnosis and access followed-up information [1].

3.4 The intelligent ontological based diabetic food recommendation systems

The intelligent ontological agent for diabetic food recommendation [3] applied ontology in developing a food recommender system for diabetes patients. Two main ontologies were developed: Taiwanese food ontology consists of food items divided into six major groups: rice and grains, vegetables, fruits, milk, fats, meat and protein. The personalized food ontology consists of three main groups of the user profiles: personal profile, diet goals and favorite foods. The system can recommend some food choices for the user's dinner menu using a fuzzy inference mechanism.

Lee et al., [17] provide the fuzzy ontology that produces the Intelligent Diet Recommendation Agent (IDRA) for diabetic patients. It prescribes the required dinner allowance based on his/her metabolic rate. Nevertheless, the system provides diet for diabetic persons only. A balanced diet is one of the significant factors for humans.

However, in these systems there is no inference mechanisms used for the dynamic updating of the ontology. The systems considers recommendation activities based only food does not consider any other recommendation such as medication, insulin and exercise activities.

3.5 Mobile Health Advisor System (MoHA)

The work on Mobile Health Advisor System (MoHA) for sexually transmitted (STI) disease provides advice based on the lists of symptoms being displayed by the system. These symptoms are compiled from STI treatment guidelines and by consultation with specialists in the area. The system, in this particular work is only applicable for STI not any other diseases [2].

3.6 Decision support for remote monitoring of patients with heart failure

As pointed out in [10] propose a system of decision support for remote monitoring of patients with heart failure. The system is based on an ontology that includes patient data: posture, pulse sensor, physical activities and alerts. The decision aid is based on inference using rules managed by an inference algorithm. This system does not take into account physiological measures that are connected to the heart failure like blood pressure and weight data, nor the patient's environment such as temperature and humidity. Moreover, the context of the patient is very small for such physical activity as it contains statements: run, walk or anything, and the posture he has only two states: lying or standing. Finally, the proposed inference algorithm is not optimal because a rule can have multiple conditions, for each condition the algorithm cover all the facts base, when he could have in some cases use the results of other conditions.

3.7 Design and Testing of a Personal Health System to Motivate Adherence to Intensive Diabetes Management

Kumar [23] developed a disease management system designed to motivate adherence to an intensive monitoring routine in patients with Type I Diabetes Mellitus (T1DM), DibetNet as the system is called was tested and analyzed. DiabetNet is an interactive, networked and predictive game, which can be played within a community developed in this system. The game can only be played after a patient checks at least three glucose measurement for the day, and enters three records of carbohydrate consumption. The patient views his/her earlier data (glucose, carbohydrate and insulin) upon entering the record as prerequisite and is challenged to predict the upcoming glucose measurements, and then measure actual glucose level. The patient gets points depending on the difference between the estimated and measured result, also points are earned by entering data and qualifying to play the game. The system do not contain domain ontologies that provide a controlled vocabulary standard to better share information and make it more generic. In most cases, information about the patients are not fully exploited, although these data are strongly related and should be exploited in the same process to ensure decision support and recommendations' more accurate.

3.8 Mobile Application for Diabetes Control

The paper Mobile Application for Diabetes Control in Qatar discusses about mobile application developed to help diabetes patient in Qatar to manage their disease using glucose monitoring and diet management [24]. Glucose monitoring in this case involve recording the relevant data and sending it to the healthcare center by the patients; while for diet management, ontology concept is used to represent Qatari food items and their nutritional value, then the patients will be advised about the appropriate food. The system has three components: patient module, which can be used for recording blood glucose level, food consultation, recording food intake, view statistics for glucose data; server module with database where patients information is stored, food ontology reasoning is also done at this module; and physician module, which is an interface to the server module. The systems are characterized by the absence of semantics, which implies that the machine is not able to interpret the results. The lack of ontology's reduces their performance and making them difficult to share and evolve.

3.9 Summary

In this chapter, having studied literatures of different healthcare recommendation systems that used ontology and not used ontology, which are related and relevant to our proposed system are investigated and analyzed. From the analysis of the related works, we came up with the following major problems of present day healthcare recommendation systems, which may lead us to better design consideration.

- ✓ In conventional systems, patient data is stored in a database in different formats. Therefore, the representation is not semantic and data analysis is really challenging.
- ✓ The above review shows that some of the systems that are discussed are based on technologies, which are characterized by the absence of semantics, which implies that the machine is not able to interpret the results. The lack of ontology's reduces their performance and making them difficult to share and evolve.
- ✓ In addition, they use data formats specific to them, making the information and data not generic and communication with other systems very complicated. Without the use of ontologies, the inference process becomes very complex and difficult to change because the handled information is poorly structured so difficult to exploit.
- ✓ Those ontology-based systems only partially integrate ontologies and do not contain domain ontologies that provide a controlled vocabulary standard to better share information and make it more generic. In most cases, information about the patients are not fully exploited, each system is based on part of data, although these data are strongly related and should be exploited in the same process to ensure decision support and recommendations' more accurate.
- ✓ However, existing ontology did not pay attention to important concepts in recommendations activities, such as assessment, diagnosis, treatment and follow-up activities

As a conclusion, our proposed work is based on how ontology technology could be used to overcome the above challenges by adopting some previously defined diabetes ontology design schemes providing data sharing and treatment recommendations. However, comparing to the reviewed works, our work differs in focusing more on recommendation activities such as medication, diet intake and insulin intake recommendations for diabetic Patients.

The proposed system uses Ontology for backend request handling. Unlike the database backend systems, the system processes the request based on the concept.

We have used first ever approach of OWL base ontology, semantic ontological domain concepts definitions and SWRL based rules to generate diet, Medication and insulin intake suggestions. Previously, no reasoning and inference based technique has been used for, Medication and insulin intake assistance for diabetics. Furthermore, our implementation integrates knowledge from various domains for, Medication and insulin intake suggestions. No such consideration has been done previously. Our integration approach shows the real benefit of using ontologies i. e. integration and sharing of concepts from various domains knowledge base, defines new relationships among these domains concepts and integrated it into one system.

Furthermore, our recommendation system is based on user-friendly interface fashion, which makes our effort to be used in real and practical life.

Chapter 4
System Analysis

This chapter presents the existing healthcare recommendation conditions and overall analysis of the proposed model for semantic web based healthcare recommendation system. The components of the proposed model with their functionalities and interactions are explained in detail.

4.1 Current healthcare support system for diabetics

A shortage of doctors and healthcare centers spells inadequate treatment for many in the developing world, especially in rural areas. As Ethiopia is one of developing country the healthcare, service is provided only in limited health organization in urban area and it is very limited or poor in rural area. The country not only has limited number of health centers but also a shortage of health professionals to cover the health services for the nation at large [5]. To get the healthcare service, the patient has to go to the nearby healthcare center and consult the health workers at the centers irrespective of whether the workers are specialized in the area of his diseases or not.

Moreover, the shortage of a well-equipped laboratory services in the health services forces the health workers to use the treatment method based on syndromic approach to treat the patients. A patient who wants to receive a health service must go to the health center early in the morning and get registered to get a card for medical records. Since the number of health workers are limited in numbers the user is expected to stay at the center and waits up until his\her turn comes to see the health workers. This process takes many hours and even a couple of days to a worst case. In addition to the time they waste the patient might be asked for a costly service fee, which he /she might not afford.

In general the current system is not motivating system for patients to diagnosis from time to time and to consult health professionals when needed, due to the shortage of the health professionals.

Diabetes is a chronic disease, which requires special attention both from healthcare providers and from patients. Its treatment procedure is typically complicated and requires many interactions between medical personnel and patients. However, due to the limited number of medical personnel and the increasing number of patients, the time and attention that the medical personnel can spend with each patient becomes less and less. Further, most diabetes patients are elderly people and working people who cannot conveniently travel to meet with their doctors regularly. When knowledge related to the diagnosis of diabetes is acquired from more than one health center, it may be conflicting or inconsistent.

We used an ontological approach to model the key concepts and relationships to allow clinical knowledge sharing, update and reuse. This paper presents the methodology for designing and developing a semantic web technology based Healthcare Recommendation System for provide healthcare support and appropriate recommendations activities for diabetes patients.

4.2 The Proposed System

As explained in the previous chapters, there are several benefits of ontologies in the Semantic Web context. The developed Semantic Web application for this project is based on making use of Semantic Web technologies to show the benefits of such technologies.

The current system study shows that public healthcare organizations have a lot of problems. To minimize the problems, the system to be developed will support long-term diabetic patients support treatment and recommendation activities. Diabetes mellitus monitoring includes maintain health condition weight, physical activates, and regular medical examinations and tests. In fact, regular medical examinations and tests seem to be time consuming for both doctors and patients. Therefore, diabetes patients must monitor and manage their blood sugar constantly with diet control, exercise therapy, medication, etc. However, diabetes patients have difficulty managing this by themselves and they need constant management assistance and the help of their friends -and family to maintain a lifestyle in which the diet is coordinated with exercise and activities. Therefore, there is a need for a system that is able to effectively allow control of the blood sugar of diabetes patients.

In this project, a SWHRS for diabetes patients was described where information, such as the blood sugar level of the diabetes patient, types of meals, types of exercise, etc. is acquired through user interface. Based on this information the system was able to recommend appropriate treatment by advising the patient about meal and exercise control, medication, etc.

The proposed system produces a diabetes patient recommendation system based on semantic web technology web can assist diabetes mellitus patients to monitor their glucose level according to the glucose level readings, intake food, medication, and physical activities. The system works based on manual data input.

We sought to design a community-based, user-oriented system for the self-management of diabetes, taking into account user perspectives of both patients and healthcare professionals. Patients report information such as regular blood glucose, diet, exercise, medications and other lifestyle factors may also be entered.

This study implemented a system that can be applied to diabetes only. Therefore, more research is needed to develop a system that can be applied to chronic diseases which can be caused by diabetes, such as high blood pressure, hardening of the arteries, cataracts, nephropathy, etc.

This work proposes a system that offers effective treatment advice for diabetes patients, and allows timely management of their blood sugar level. The system design is based on ontological knowledge base through reasoning, to obtain the above-mentioned recommendation.

The SWHRS system can be used on PC at any place where internet connection is available so even sitting at home patient can use SWHRS for their diabetes management.

4.2.1 Functional Requirements

Functional requirements describe the activities and services information system or an application needs to provide. It is also function or service needed in an information system to satisfy business needs.

The functional requirements of the system include:

1. The system allows users to send their examination result to the system.
2. The system allows users to register their personal information details.

3. The system allows users to receive medication recommendation
4. The system allows users to receive diet intake recommendation
5. The system allows users to receive Insulin recommendation
6. The system allows users to receive exercise recommendation
7. The system allows administrators to manage access to the system.
8. The system allows to generating different types of reports

4.2.2 Non Functional Requirement

Non-Functional requirements describe user visible aspects of the systems that are not designated to the functional behavior of the system. Non-functional requirements correspond to the process of explaining the features, characteristics, attributes, and constraints of the information system used to limit the boundaries of the proposed solution. The non-functional requirements deal on performance, efficiency, reliability, flexibility and expandability. The non-functional requirements of the SWHRS systems are the following

1. User Interface (UI)

The system is a web-based application each form is available online. Users can have access to the system from anywhere using the web browsers (Internet Explorer, Firefox, Google Chrome, etc). We should make the system web pages front-end simple and easy to understand and to interact with. Patients can easily interact with the system using web forms. Furthermore, health professionals can access the system through web browsers on their personal computer.

2. Documentation

System users and system administrators will be provided with a short and brief documentation on how to use the systems. System administrator will also receive documentation about the structure of Ontology and the code of the system. This will help the system administrator to use and make changes or modification on the system resources and further for troubleshooting of the system in the case of failure.

3. Performance Characteristics

The system should be capable of handling multiple users at a time with reasonable processing time. It should have to be available all the time. As the system is a web-based system, many users can access it simultaneously. Therefore, unless there are Internet connections, hardware and software requirement constraints, the system can support many users and execute their queries at the same time.

4. Error Handling

Error could rise from the user of the system or from the system itself. The system should have to handle both errors when they appear. The run time error should be handled by systems and errors occurred due to wrong doing of users would be handled by appropriate exception handling mechanisms.

5. System Modification

With the system, there may be the need for the system modification to update the system. Developers or any other trained person that knows the code behind the system and have knowledge about Ontology can do this modification. The modification can be possible without putting any problem on the system since the system will be developed using Object Oriented approach.

6. Security Issues

Since the user of the system does not have any access to the back end of the system or Ontology, any user can use the system without any security issue. In addition, the system will not have any sensitive data that will be exposed to the user.

4.3 Analysis Model

To produce a model of the system that captures all functionalities and that eliminates contradictory requirements, we need to construct the analysis model based on the requirements of the system. According to [5], system analysis contains three models: functional, object and dynamic models. Use case diagrams describe the functional model, class diagrams describe object model, and sequence, state chart and activity diagrams describe the dynamic model. In this project, the analysis model is described with use case, sequence and class diagrams.

4.3.1 System Use Case

4.3.1.1 Actors of the System

There are actors that interact with the system. Table 4.1 shows those actors with their description.

Table 4-1System Actors and their Description

No.	Actors	Descriptions
1.	Patient	A patient is an authorized and responsible for filling, blood glucose result to the system and getting recommendations that come from the system.
2.	System Administrator	An authorized user who is responsible for the maintain functionality of the system and to administer the system users

4.3.1.2 System Use Case Diagram

Figure 4.1shows the system use case with actors interacting with processes in the system

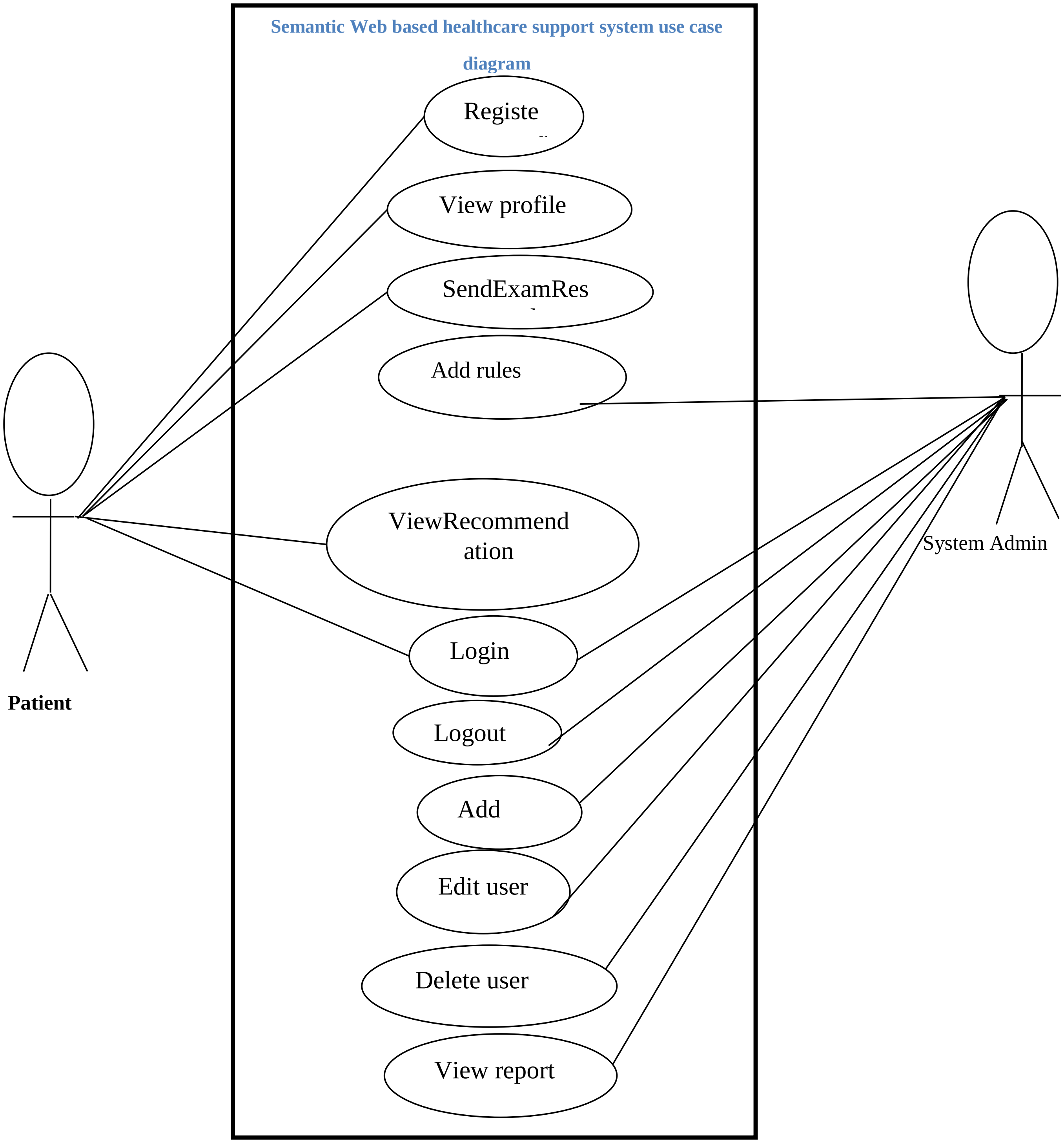

Figure 4-1 Use case Diagram

4.3.1.3 System Use Case Description

Table 4-2 Description of Register Patient Use Case

Use case Name	Register
Actors	Patient
Description	Allow patient to input personal information to the system
Pre-condition	The patient must be logged into the system
Flow of events	1. The patient selects the Registration button and clicks on it 2. The system displays personal information registration form. 3. The patient fills the data on the form.. 4. The patient selects "Register button" to begin registering to the system.
Post-condition	The patient personal information will be submitted successfully.

Table 4-3 Description of Send Examination Result Use Case

Use case Name	SendExamResult
Actors	Patient
Description	This allows patient to send their blood glucose information to the system
Pre-condition	The patient must be logged into the system
Flow of events	1. The patient starts the system. 2. The system display user interface and menu. 3. The patient selects "SendExamResult" to fill the forms. 4. The system displays the Examination forms. 5. The patient selects the fill the form to be submmited. 7. The patient then hit "create" button to send the examination result 8. The system sends the filled form to the server.
Post-condition	The examination result information will be uploaded successfully.

Table 4-4 Description of View Recommendation Use case

Use case Name	ViewRecommendation

Actors	Patient
Description	Allow patient to get **Recommendations from the system**
Pre-condition	The patient must be logged into the system
Flow of events	1. The patient selects the **Get Recommendations** button and clicks on it 2. The system displays the received recommendations the system. 3. The patient selects "Save" button to save after reading the recommendations. A1 4. The system save the recommendations for future use
A1	1. The patient can discard the recommendations after reading by selecting "Discard" button
Post-condition	Reading the received recommendations

Table 4-5 Description of View Profile Use case

Use case Name	**View profile**
Actors	Patient
Description	Allow patient to see their personal profile
Pre-condition	The patient must be logged into the system
Flow of events	1. The patient selects the View profile button and clicks on it. 2. The system displays personal information. 3. The system clothes the personal information form.
Post-condition	Viewing the personal information.

Table 4-6 Description of View blood glucose graph Use case

Use case Name	**View blood glucose graph**
Actors	Patient
Description	Allow patient to view their blood glucose level en the form of graph
Pre-condition	The patient must be logged into the system
Flow of events	1. The patient selects the view blood glucose level button and clicks on it 2. The system displays the blood glucose level graph. 3. The system displays all the available forms/procedures. 4. The patient selects "Save" button to save after seeing the blood glucose level graph. A1 4. The systems save the blood glucose level graph for future use
A1	1. The patient can discard the blood glucose level graph after reading by selecting "Discard" button
Post-condition	Viewing blood glucose level graph successfully.

Table 4-7 Description of Modify Systems Use case

Use case Name	Modify Systems
Actors	System Administrator
Description	The system administrator wants to modify the system
Pre-condition	The system administrator needs to have a privilege to change or Modify the system.
Flow of events	1. The system Administrator wants to modify the system. 2. The system administrator opens the system code. 3. The system displays the code. 4. The system administrator makes any modifications and save it. 5. The system displays the performed modifications.
Post-condition	The modification applied to the system.

Table 4-8 Description of Logout Use case

Use case Name	logout
Actors	System Administrator
Description	Allows user to log out from the system.
Pre-condition	The patient must be logged into the system
Flow of events	1. The user selects log out button. 2. The system logout and display the home page.
Post-condition	The users will logout successfully.

Table 4-9 Description of Login Use case

Use case Name	Login
Actors	Patient and System Administrator
Description	This allows to identify system users and to access system functionality.
Pre-condition	The users must have username and password.
Flow of events	1. The system displays login form. 2. The user enters username and password. 3. The system validates users input.A1 4. The user logged in to the system.
A1	1. The system displays error message. 2. The user repeat step 2. Otherwise, the user terminates login form.
Post-condition	The login task will be done successfully.

Table 4-10 Description of Edit User Use case

Use case Name	Edit user
Actors	System administrator
Description	Allows system administrator to edit registered system users.
Pre-condition	The system administrator must be logged in to the system
Flow of events	1. The system administrator select “Administration” tab

	2. The system display administration page. 3. The system administrator identifies the user whose profile will be edited. 4. The system administrator edits the user profile and clicks "Update" button. 5. The system updates the user profile.
Post-condition	System user's profile will be edited successfully.

Table 4-11 Description of Delete User Use case

Use case Name	**Delete user**
Actors	System administrator
Description	Allows system administrator to delete system users.
Pre-condition	The system administrator must be logged in to the system
Flow of events	1. The system administrator select "Administration" tab 2. The system display administration page. 3. The system administrator identifies the user who will be deleted. 4. The system administrator selects the user and clicks delete button. 5. The system deletes the user profile
Post-condition	The user will be deleted successfully.

Table 4-12 Description of View Report Use case

Use case Name	**Generate report**
Actors	System administrator
Description	Allows The system administrator to see or view the stored report
Pre-condition	The system administrator must be logged in to the system
Flow of events	1. The system administrator select "Administration" tab 2. The system display administration page. 3 The system administrator attempts to open the file. 3. The system displays the file 4. The system administrator views the report
Post-condition	The stored file or report will be viewed successfully.

4.4 Class Diagram

In order to clarifies the ontology's structure we provide UML class diagram explaining the whole ontology model content in term of classes, their relations and data property of each class that we have mapped during ontology design. Figure 4.2 is UML class diagram shows the general structure of our ontology domain, it contain six main classes. In addition, the figure shows different relationships between classes, their cardinality, as well as data properties of each class.

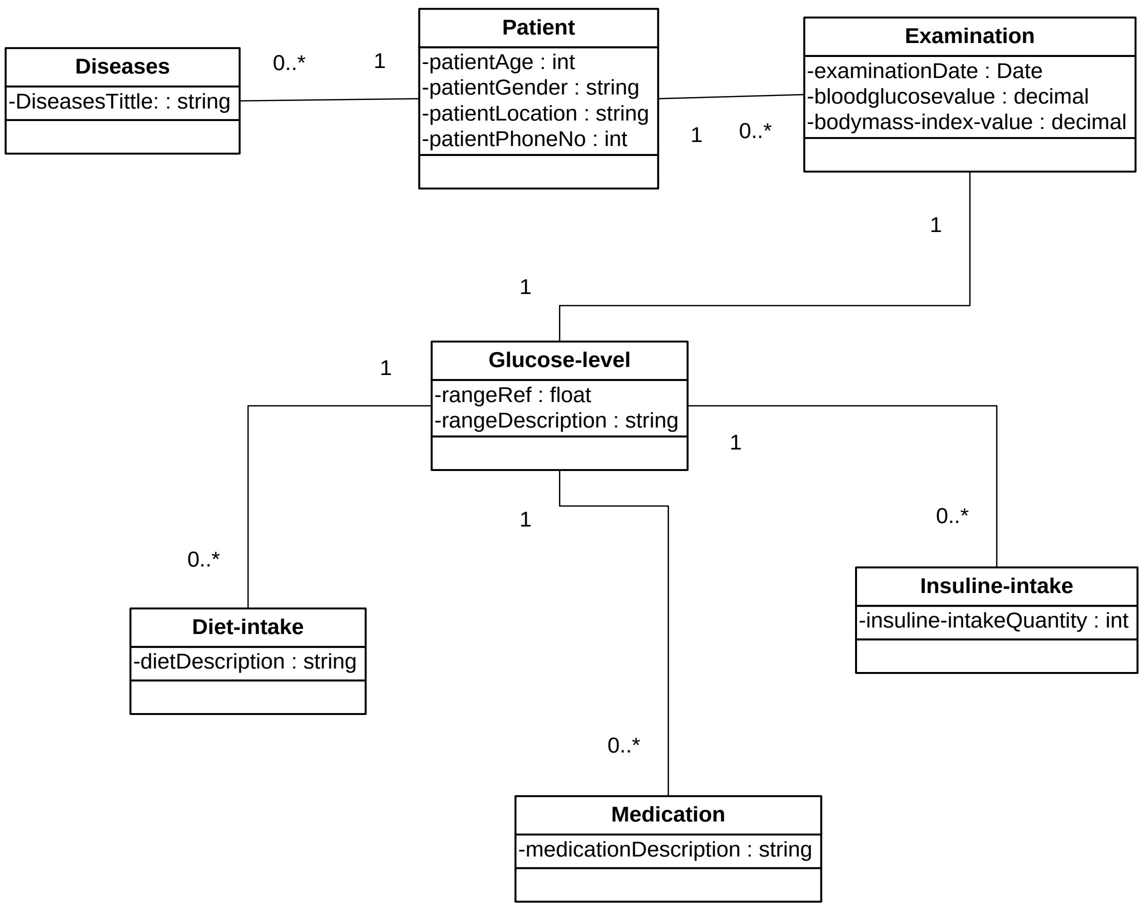

Figure 4-3 Class Diagram

4.5 Sequence Diagrams

Sequence diagram shows the interaction between object entities to accomplish the tasks described in use case diagram. To show the interaction of objects in the system the following sample sequence diagram shown in figure below.

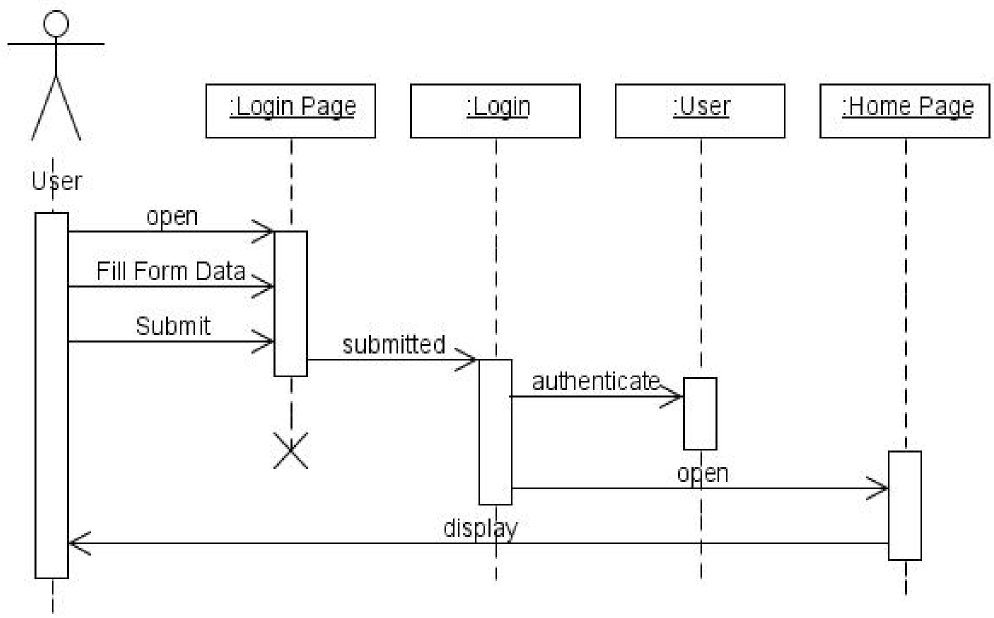

Figure 4-4 Login Sequence Diagram

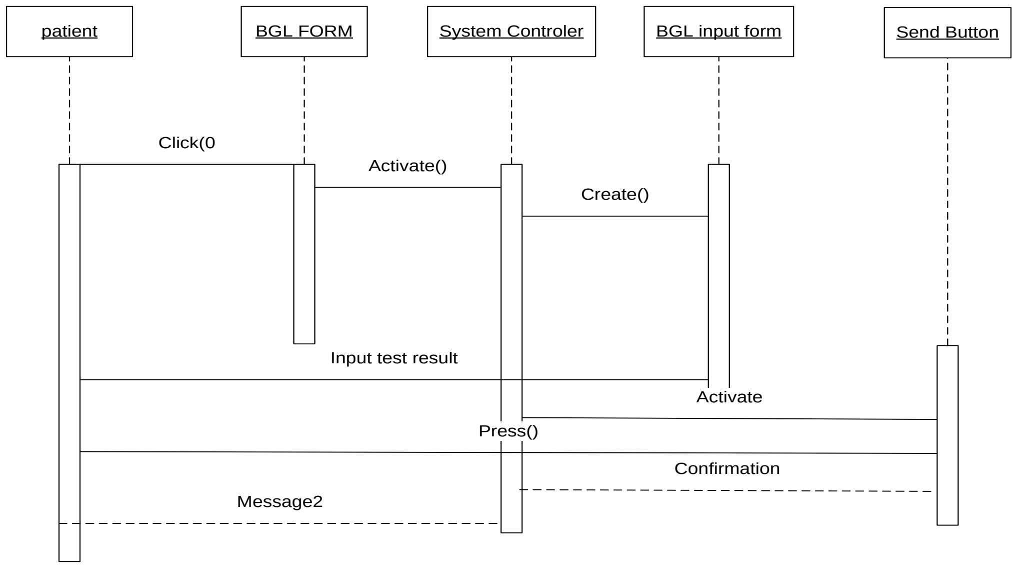

Figure 4-5 Send examination result Sequence Diagram

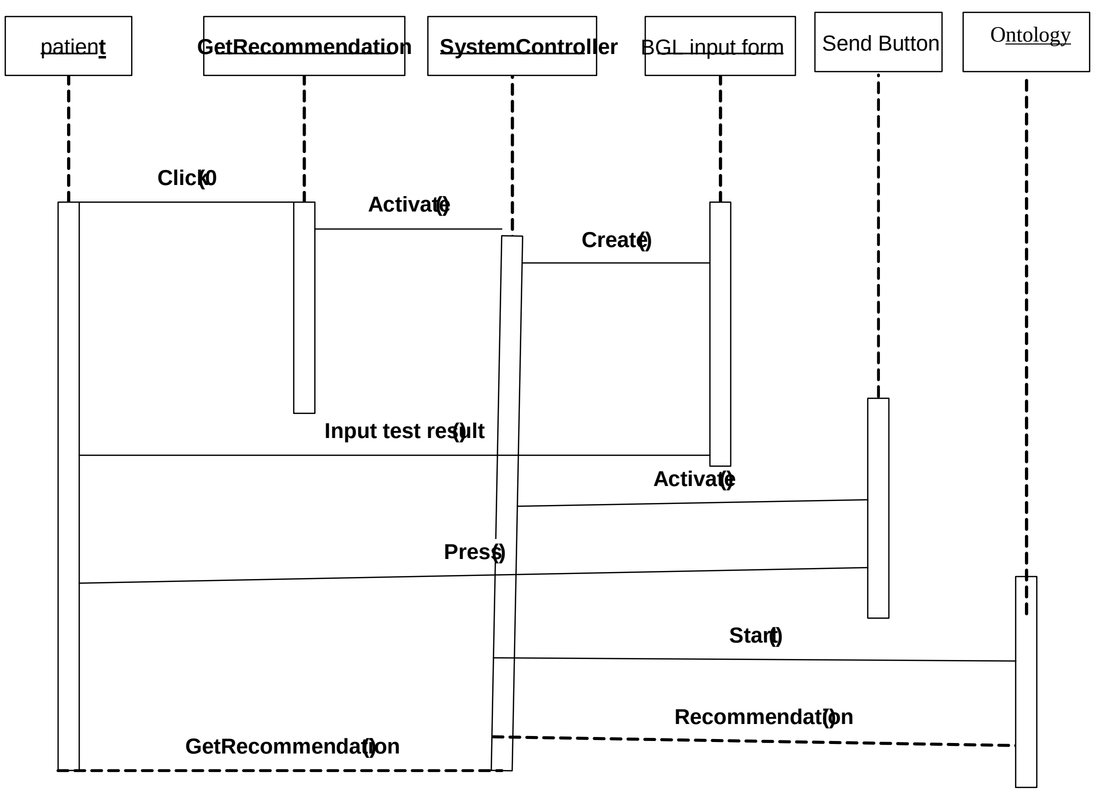

Figure 4-6 Get Recommendation Sequence Diagram

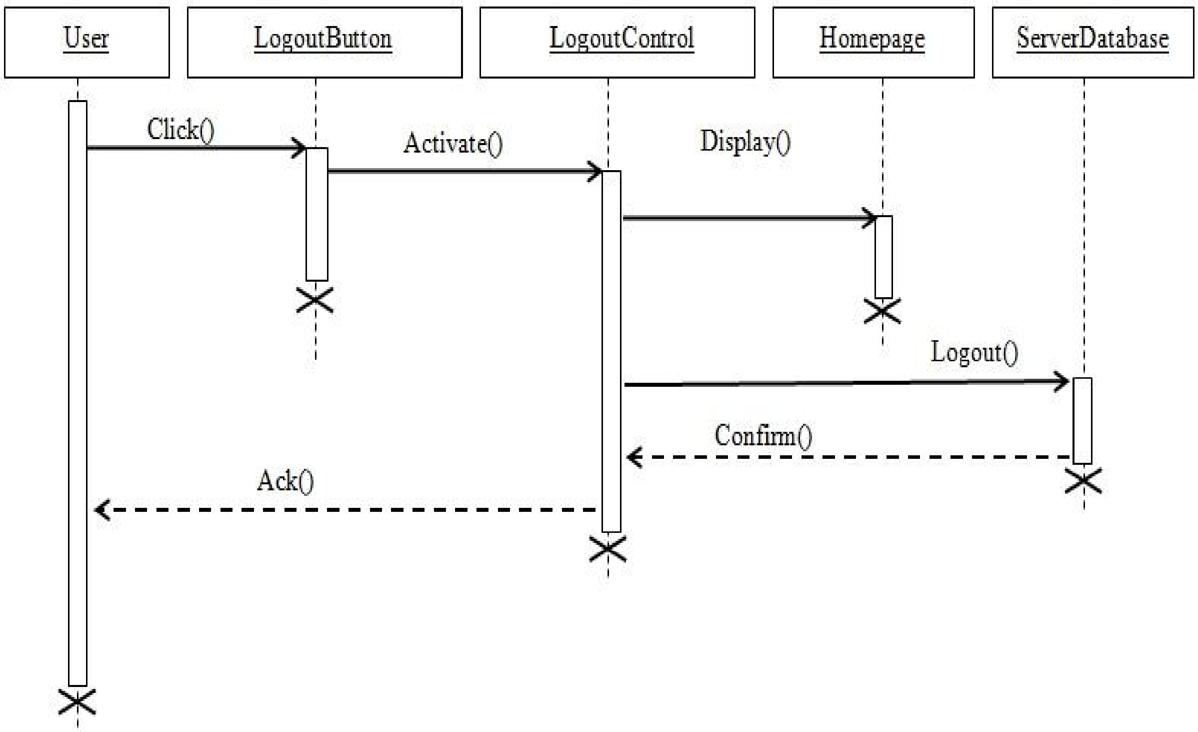

Figure 4-7 Logout sequence diagram

Chapter 5

System Design

This chapter describes the proposed solution that the system should have by transforming the functional requirements into subsystem decomposition and the non-functional requirements into design goals.

5.1 Design Goals

Design goals show the system qualities on the perspective of the system's nonfunctional requirements. The following are design goals that are expected to be achieved in the proposed system.

1. **Security:** System users' authentication with username and password are playing big roles in ensuring security. Therefore, the system is secure from unauthorized user access.
2. **Cost:** Based on the target and mission of the system owner, the system implementation would run at reasonable cost.
3. **User Interface**: The system should possess a very simple user interface that let users feel easy when using it. Since it is web based the interface elements involved are thought to be very familiar to anyone having prior experience. The interfaces comprise of buttons and links which are very simple to use and make users feel comfortable in using.
4. **Documentation**: System Administrator and user of the system should be provided with proper documentation on how to use the system.
5. **Performance**: Since the system is available online for users there may be many users using the systems at a time and the system should have to support multiple users at a time concurrently.
6. **Availability**: The system should be available at any time the user want to access that means the system should be available 24 hours to provide the service. The system

should be able to use its utmost performance to handle greater throughput and ensure availability.

7. **Reliability**: The output of the system should have to be always similar for the same request.
8. **Modifiability**: The system should have to be easily modifiable to support changes or upgrading without causing problem to other systems functionality and to insure this, the system is designed using the layered architecture, and one module can be modified without affecting the other as long as the interface is not affected.

5.2 Proposed System Architecture

This system architecture shows the overall organization and communication between the users and the system, and its components: web client and system server.

User can access the system through a web client. The Web client component defines users of the system, which access the system through Http protocol. The client send request using browser software found on a client machine and the system responses for request reaches to the system through Internet connection. The users use the web browser interface to enter their blood glucose value and body mass index value from examination result and to send the value to the web server to get different recommendation from the web application. The communication between the client and server is through Http protocol.

The second component of the system is a web server on which an application runs and communicates with data storage to provide responses for the user. The server side application of the system with Diabetic Ontology and semantic web rules (SWRL) resides on the web server.

The communication between the mobile user and web server side of the system is through Internet connection.

The following figure shows the general system architecture of the system.

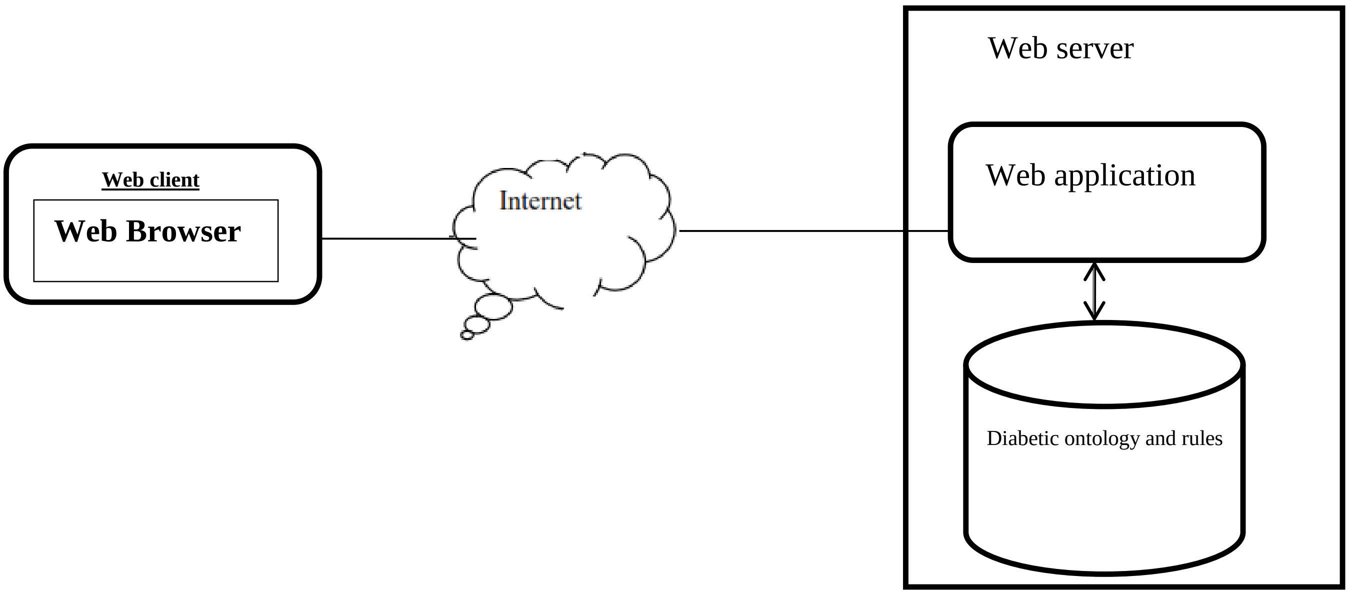

Figure 5-1 General system architecture of the system

5.3 System Decomposition

This system decomposition describes the services of the system that will be given to the user. In addition, it shows the subsystems decomposition on the entire system.

To reduce the complexity of the system, it will be built on a layered architecture. A layered architecture enhances maintenance so that the modification of one part of the system will be handled without affecting the others. All layers should interact only with the layers right next to them. Each layer is not allowed to interact with layers it do not have direct accesses. This policy makes the code more readable and easily maintainable. The system will have four logic layers to achieve design goals of the system as shown in the figure 5.2.

The Interface Layer represents the web browser, which is used to access the presentation layer. The presentation layer is created using java server page web forms.

The Application Logic Layer is defines business rules using code behind files of web forms. The Service layer realizes services that are designed as web services so as to maintain interoperability, and extensibility. Users accessing SWHRS using web browsers use the business logic layer to work on different functionalities. The Data Access layer is used to access data from the data storage

The following figure 5.2 shows subsystem decomposition of the system.

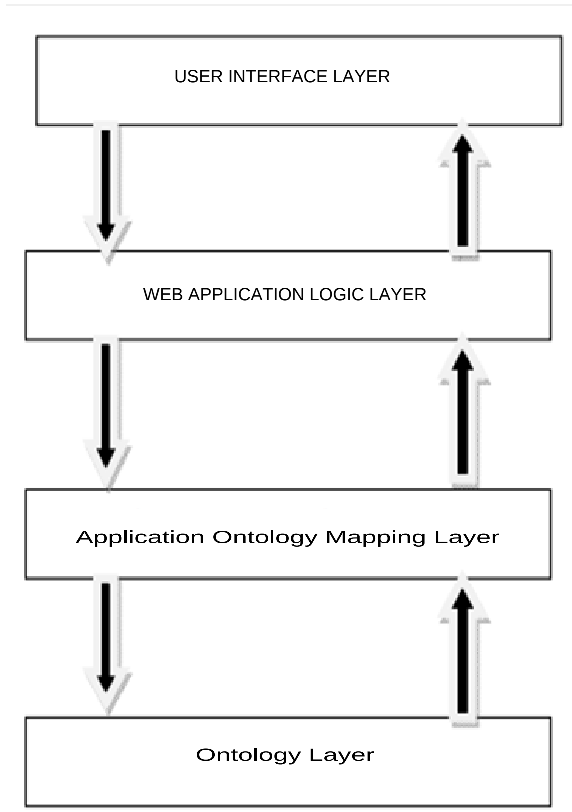

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Figure 5-2 Layered Architectures

The detail description about each layer will be described as follows.

5.3.1 The User Interface Subsystem:

This is a layer on which all the user interface codes are implemented. This subsystem is mainly responsible to facilitate the interaction of the user with the system. The services at this subsystem are accepting user inputs, shaping them in such way that they can be used by the system, and displaying results processed by the system.

5.3.2 Application Subsystem:

The application logic layer consists of sub systems that handle the functional requirements. This sub systems interact together in order to make the system functional. The subsystems of the application logic layer contain different classes to maintain their functionality. This subsystem is mainly responsible for managing any operation and communication in relation to get recommendations. The application logic sub systems as indicated in Figure 5.3 are:

1. Recommendation subsystem
2. Report Management subsystem

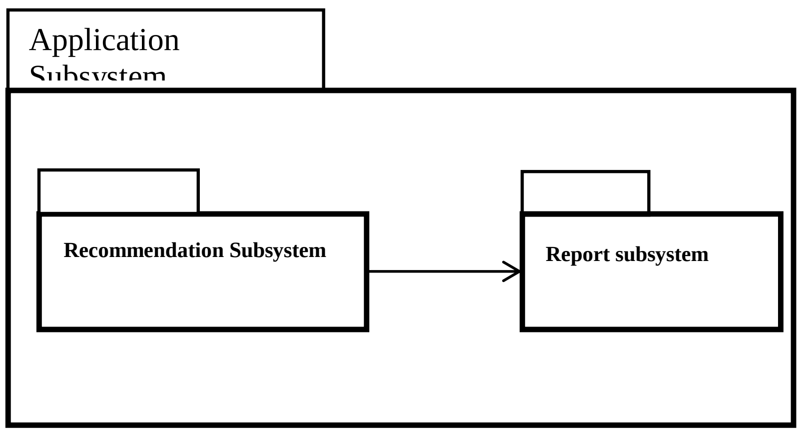


Figure 5-3 Application Logic Subsystem

The subsystems of the application logic layer contain different classes to maintain their functionality. Figure 5.4 show the interaction of classes both in Recommendation subsystem.

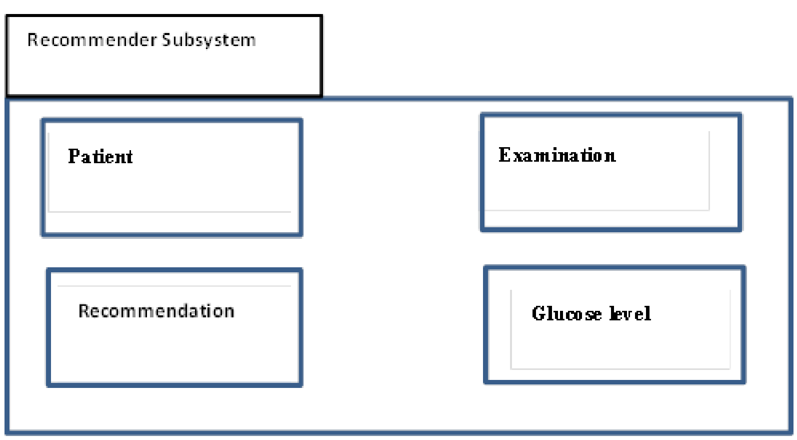


Figure 5-4 Recommendation Subsystem

Figure 5.5 Report Generating Subsystem to generate reports based on the reported cases. The subsystem consists of functionalities to generate report from the reported cases.

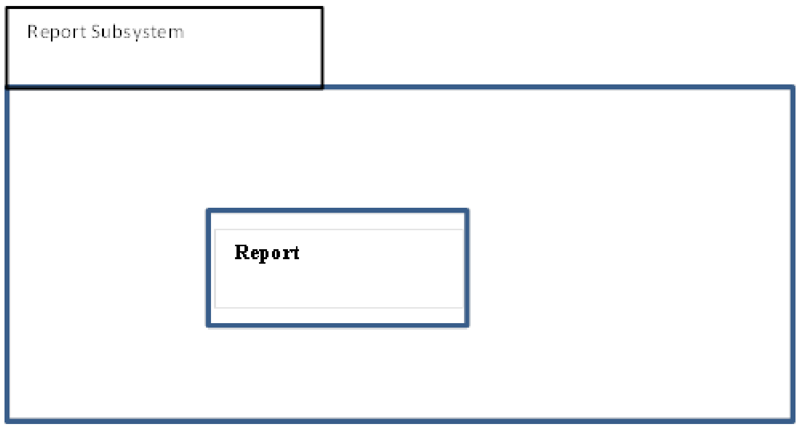


Figure 5-5 Report Generating Subsystem

5.3.3 Application Ontology Mapping Subsystem:

This subsystem is responsible for connecting web application logic layer with Ontology layer. It is an interface between the Ontology layer and the application layer. In this layer Ontology model is used to load the Ontology used for the application and the Ontology reasoner is used to reason and produce the result from the loaded Ontology using the rules determined to govern the reasoner.

5.3.4 Ontology Subsystem:

This subsystem is the bottom layer of the design it contains the Ontology knowledge base and semantic web rules (SWRL) used for the systems. In side Ontology layer knowledge is represented in a class and the relationship between classes are kept as an object and data property. To limit the scopes of the relationship between classes Ontology uses domain and range in relationship or property.

5.3.4.1 Ontology design and Development

In the our ontology design process we suppose to describe all elements required for ontology design and gives the ability to conceptualize ideas of interested domain. There are fundamental steps for development of ontology as well-founded conceptual model that defines the vocabulary and the functional relations between the concepts presented as follows:

- ✓ Determine the domain and scope of the ontology.
- ✓ Identify important concept in the ontology.
- ✓ Define the classes and the class hierarchy,
- ✓ Define (the object properties) or relationship between classes
- ✓ Define instances (individuals),
- ✓ Define data properties of the defined individuals.
- ✓ Check the consistency of the model
- ✓ Implement ontology in the working domain.

In our proposed system, the ontology contains information from six main domains; the first one is person domain presenting general information of patients. The second contains patient's vital sign measurement data including blood glucose value, examination date and body mass index value. The third one contains patient's qualitative information derived from appropriate diabetic questionnaires explaining patient's daily health status. Finally, recommendation domain contains information about different patient recommendations such as diet, insulin intake exercise, and medication. Those recommendations are assigned to each patient based on blood glucose value.

In the development process, we implement all the relationship between concepts and setting up some logical rules. After ontology design we develop end user interface by using the Semantic web technology such as OWL API to come up with ontology capable of collecting information from heterogeneous sources including personal information, Patient blood glucose data in the end patient's recommendation including diet, insulin and medication intake are also displayed based on the actual glucose content.

5.3.4.1.1 Classes and Class Hierarchy

Classes provide an abstraction mechanism for grouping resources with similar characteristics. It specifies concept of the domain as collection of abstract objects defined with the same values of aspects. In the next section we are going to explain the role of each class during our ontology as they presented in Figure xx within this project we have classifies the whole ontology into 6 main classes and 12 sub classes, as we can see from Figure 5.7

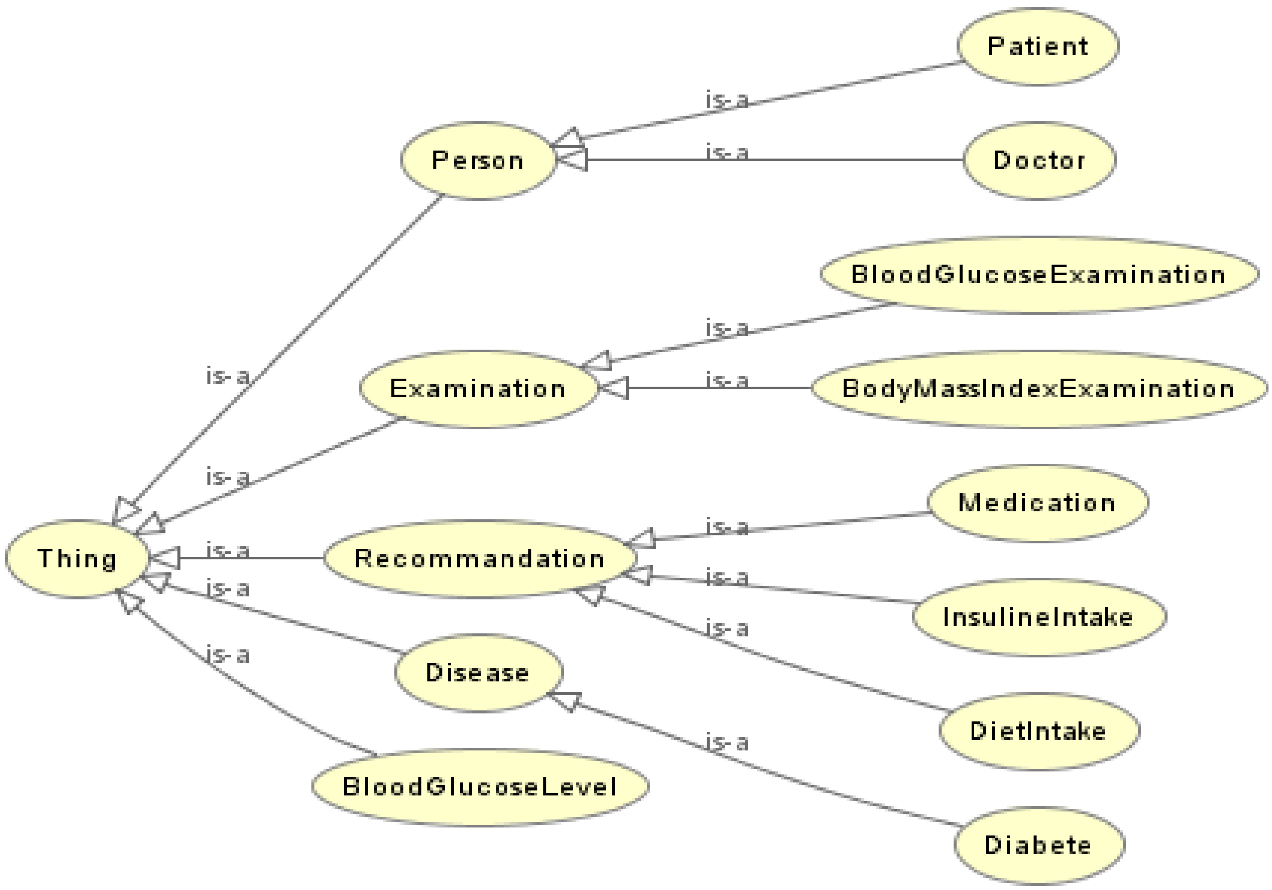


Figure 5-6 Ontology Class Hierarchies

1. **Person class** contains information about human, which is categorized in this project such as patient and healthcare providers. Each patient is also linked with the diseases class, vital sign measurement classes and diabetic questionnaire class by means of different relationship. This class will contain all type of individuals patient who will interact with this model, it also contain all necessary information used to describe each person.

2. **Disease class** is class contains information about what type of disease we are describing. As our many focus for this project is diabetes diseases, we describe diabetic diseases, the individuals of this class have direct relationship with patient and indirect relation to the corresponding vital sign measurement such as blood glucose and body mass index.

3. **Examination class** is a class describes all type of examinations (test) that should be taken for diabetic patient including: blood glucose and body mass index. Each examination has a direct link to a specific patient external-stimulus class, as well as some recommendation. It contains also information about the time at which examination has taken place and the value of each measurement.
4. **Recommendation Class** is a super class of diet-intake, medication and insulin intake, type of foods, drinks medications type and insulin dose are provided here as recommendation for patient with diabetes based on the blood glucose level acquire in the model and based on the answered questionnaire.

5.3.4.1.2 Object Properties

In Ontology design object Proprieties describe how classes are related to each other's same domain by providing relationship between individuals of those classes. The object properties used in this project are mentioned in the figure below.

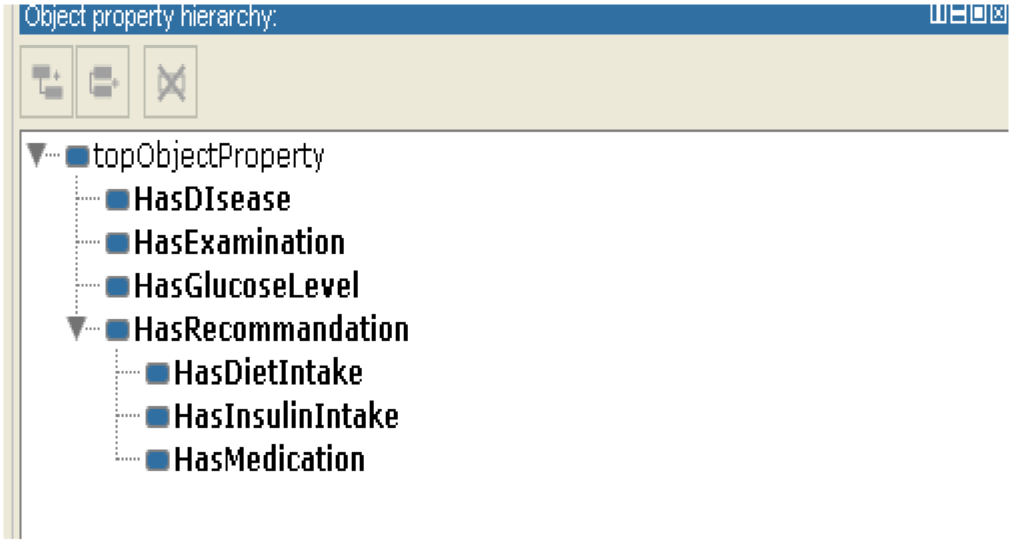


Figure 5-7 Object Properties

Table 5-1Object property Description

Object property	Description
HasDesease	object property for individuals of class patient. It provides the relationship between individual of class patient and disease.
HasExamination	object property for individuals of class patient. It provides the relationship between individual patient and examination class.
Hasglucoselevel	object property of class glucose level, it provides relation between blood glucose-exam and corresponding glucose level depend their blood sugar value.
HasRecommendation	a super property of HasDiet-intake and hasInsulin-intake and HasMedication, it provide links between glucose-examination and recommendation. After glucose examination each result should have some feedback recommendation about what quantity and quality of diet and insulin-intake as well as medication-intake equivalent to sugar level obtain.

Hasinsulin	the object property for individuals of subclass insulin-intake. It provides the relationship between individual of subclass insulin-intake and glucose Examination class. The domain of this property is insulin-intake and the range is glucose Examination.
HasDiet	object property of individuals of blood-glucose-examination class. It provides the relationship between individual of blood-glucose-Examination and Diet-intake
HasMedication	object property of individuals of glucose level class. It provides the relationship between individual of glucose level and Diet-intake.

5.3.4.1.3 Data properties

Data properties link individual of class within a domain to it data value while object properties link individuals to individuals. In this section we present some data properties that have been used in ontology development. Data properties play fundamental role when describing individual's characteristics and enabling data value to be saved. The data properties used in our project are presented in figure xx

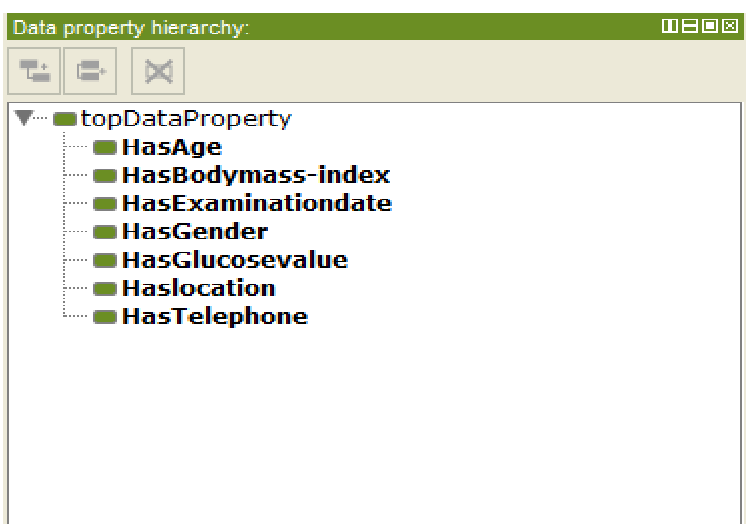


Figure 5-8 Data Properties

Table 5-2 Data property Description

Data Properties	Descriptions
HasAge	Data type property used for providing additional information to individual of patient class and it should have integer value
Haslocation, -	Data type property used for providing additional information to individual of patient class and it has a string value
HasGender	Data type property used for providing additional information to individual of patient class and it has a string value.
HasTelephone	Data type property used for providing additional information to individual of patient class in order to distinguish them and it should have integer value
HasBodymass-index	used to store data about body fat measured based on patient height and weight. It provides good proportion of overweight or underweight, this data property is very usefully in blood glucose management, since major risk factors of type 2 diabetes are associated with the accumulation of excess body fat in term of obesity.
HasGlucosevalue	used to storing value of each examination class's individuals as blood glucose measurement, data value are stored in "float" data type. The stored value are very usefully for diabetic patient supervision, it provide us the real situation of patient's blood glucose.
HasExaminationdate	data type property is used for storing the time for examination class's individuals this property is important in vital sign measurement as it provide the exact time at which

	the measurement have took place it store it data value in "date time" data type.

5.4 Hardware Software Mapping

The hardware software mapping of the system shows the relationship between nodes and independent software components. The systems client application can be deployed on mobile device and desktop computers, the application server deploys the application subsystems and the Ontology of the system resides on Ontology server.

The hardware and software mapping is modeled using deployment diagrams and depicts a static view of the run-time configuration of processing nodes and the components that run on those nodes. In other words, deployment diagrams show the hardware for a system, the software installed on that hardware, and the middleware used to connect the disparate machines to one another. This section of the project shows the set of hardware and software components in SWHRS. In SWHRS, web browsers request a server and the server depending on the request the server returns the appropriate page using Hyper Text Transfer Protocol (HTTP).

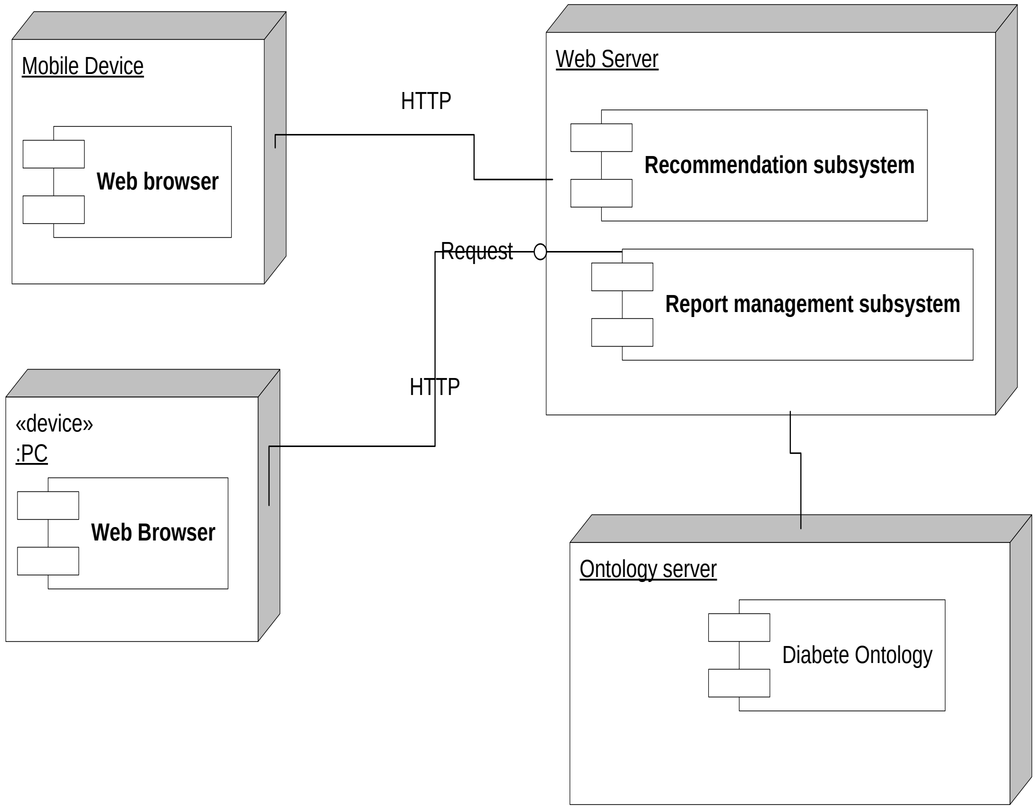


Figure 5-9 Deployment Diagram

Chapter 6

Implementation and Testing

This chapter discusses the system development tools applied for implementing the Semantic Web based Healthcare Recommendation System. Moreover, the prototype and testing of the system are also detailed in this chapter.

6.1 Development Environment

To achieve the objective of the project, several tools and technologies were used. The tools used to develop the system are described as follows.

Protégé 4.3: The plug in protégé is used to facilitate the development of Ontology of the system being integrated in OWL API

OWL API 3.5: The Java API for creating, manipulating and serializing diabetes Ontologies.

Java 2 Enterprise Edition (J2EE): The java programming language is used to develop application of the system.

Wireless Toolkit 2.5.2: The Plug in Wireless toolkit 2.5.2 is used to facilitate the development of the mobile client side application of the system.

Java Server Pages (JSP): Java server page is used to design the web interface of the system.

NetBeans 7.1: The netbeans 7.1 is used as integrated development environment for the client side application of the system and server side application of the system.

6.2 System Prototype

The system is composed of a web application, which handles the business logic of the system. In this section, screen shots of the major components along with their description are given.

6.2.1 Home Page

When user accesses the website hosting the application, the system displays home page of the website. The home page of the website is shown in figure 6.1. The home page consists of hyperlinks to open different pages, options observing different prevention methods and different information related to diabetes disease.

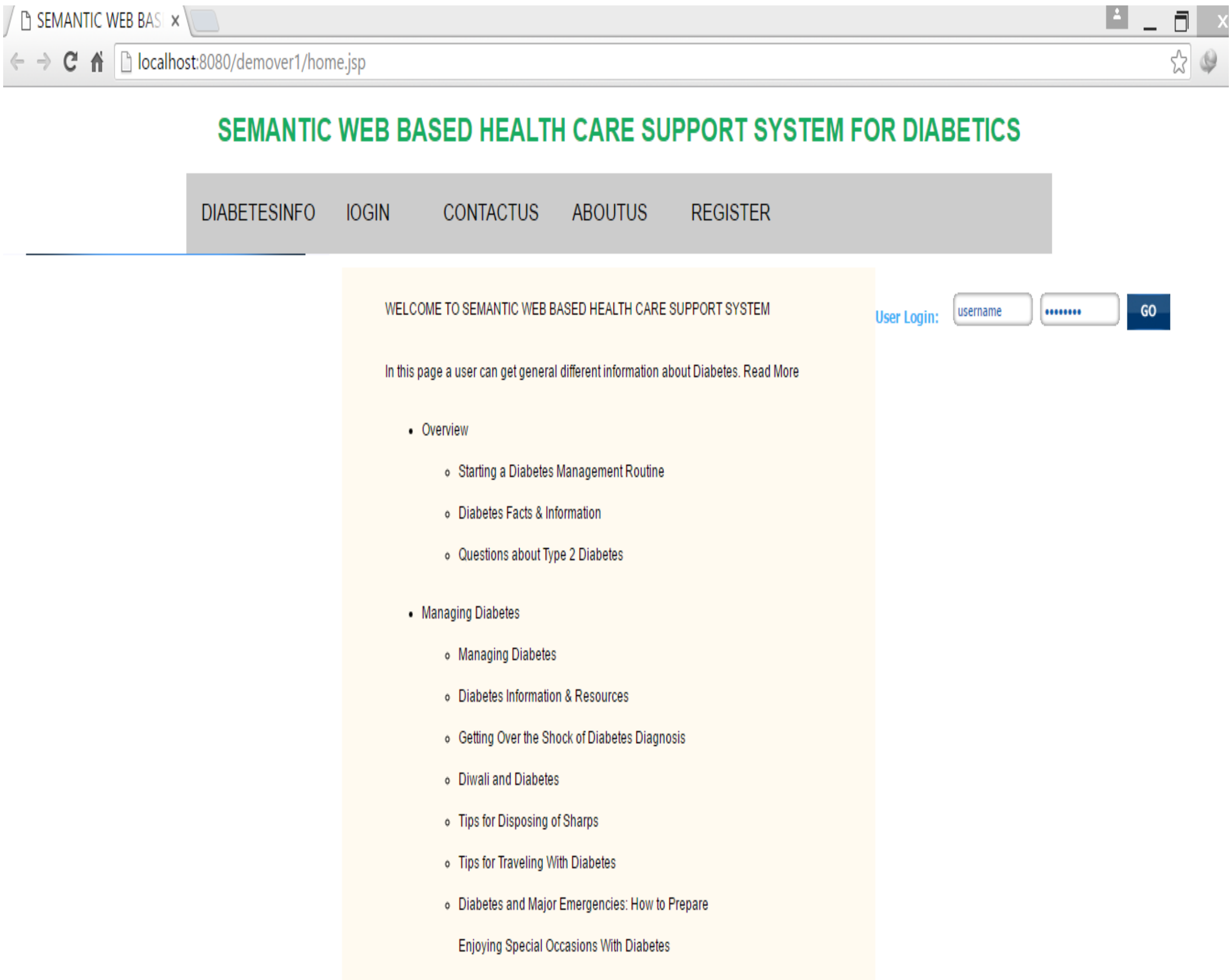


Figure 6-1 the Home Page of the System

6.2.2 Patient Registration Page

The user can register using a page displayed when "Patient Registration Page" is opened. The page is shown in figure 6.2. The user can fills the form to get different recommendation from the system. After filling the form the user submits the detail information, the system saves the information for future use.

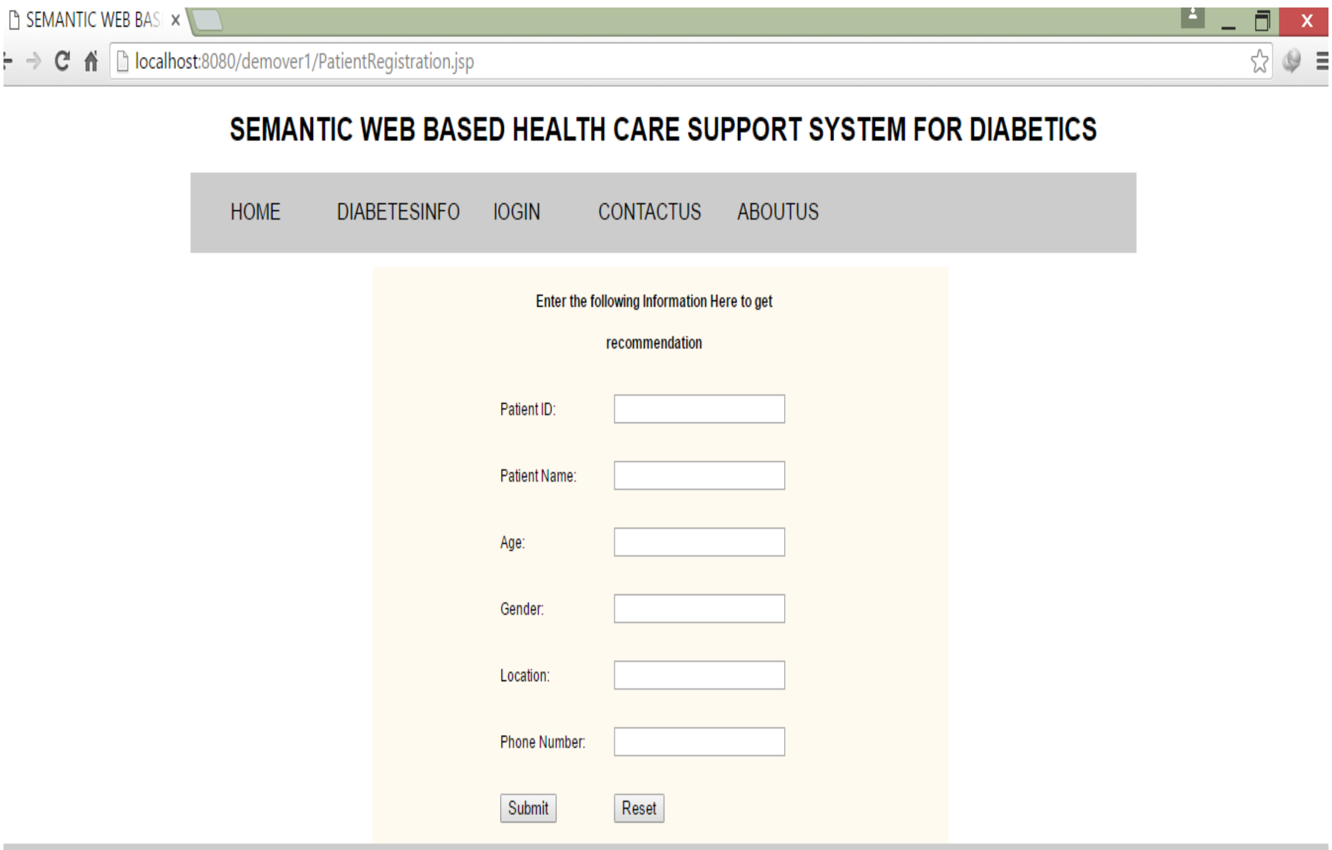


Figure 6-2 the Registration Page of the System

6.2.3 Recommendation page

First, the user login to the system by entering their user name and password to get recommendation from the system. After the login process, the patient homepage will be displayed as shown in figure 6.3. The user press the get recommendation link on the left side of patient homepage then the examination form will be displayed to enter the examination result as shown in figure 6.4.

Users input blood glucose test result value among three ranges: below 4.0, 4.1-7.0, and over 7.0 and input the BMI value then they hit get recommendation button. After these parameters are extracted from users, the system can derive the recommended medication, diet and insulin intake.

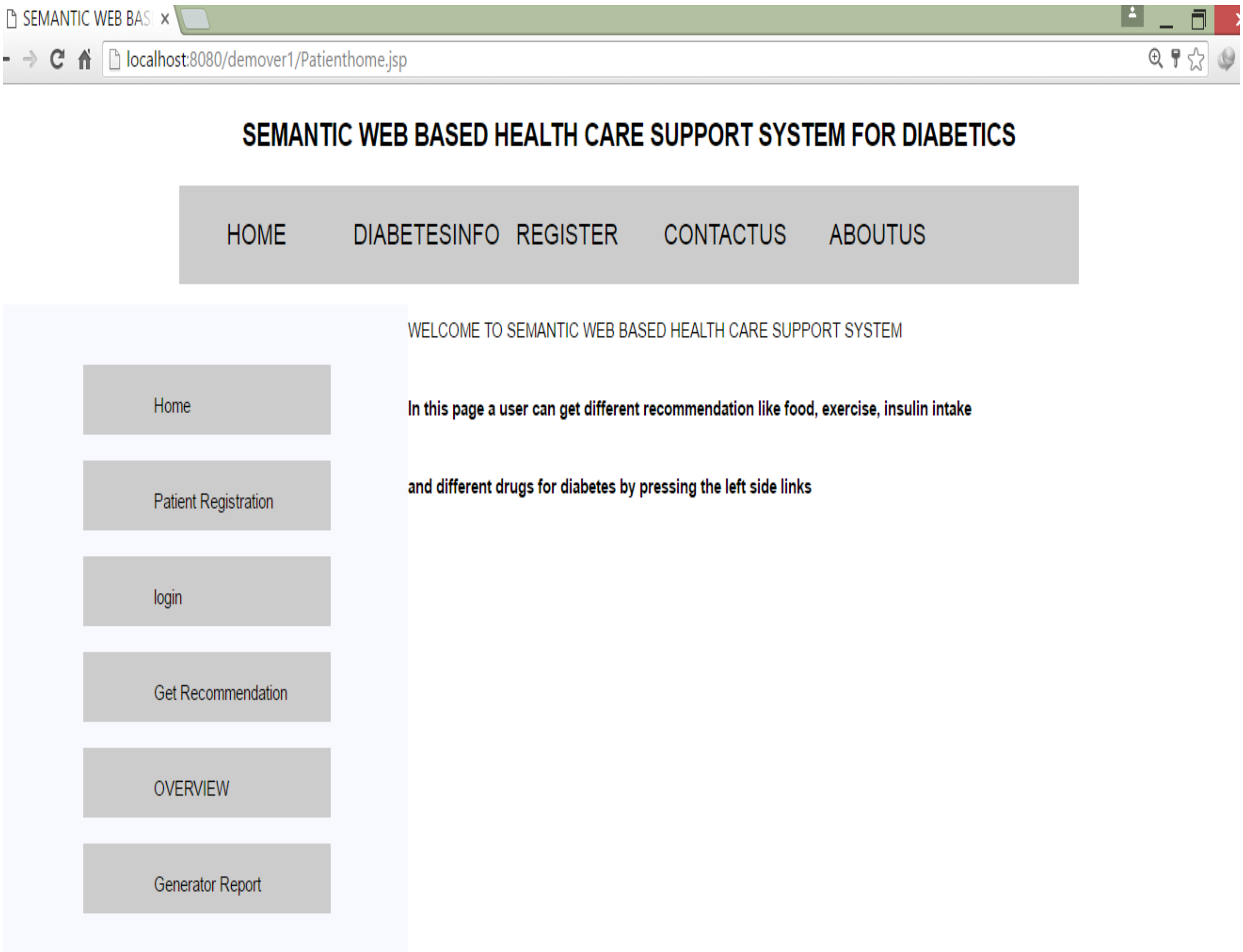


Figure 6-3 Patient Home Page of the System

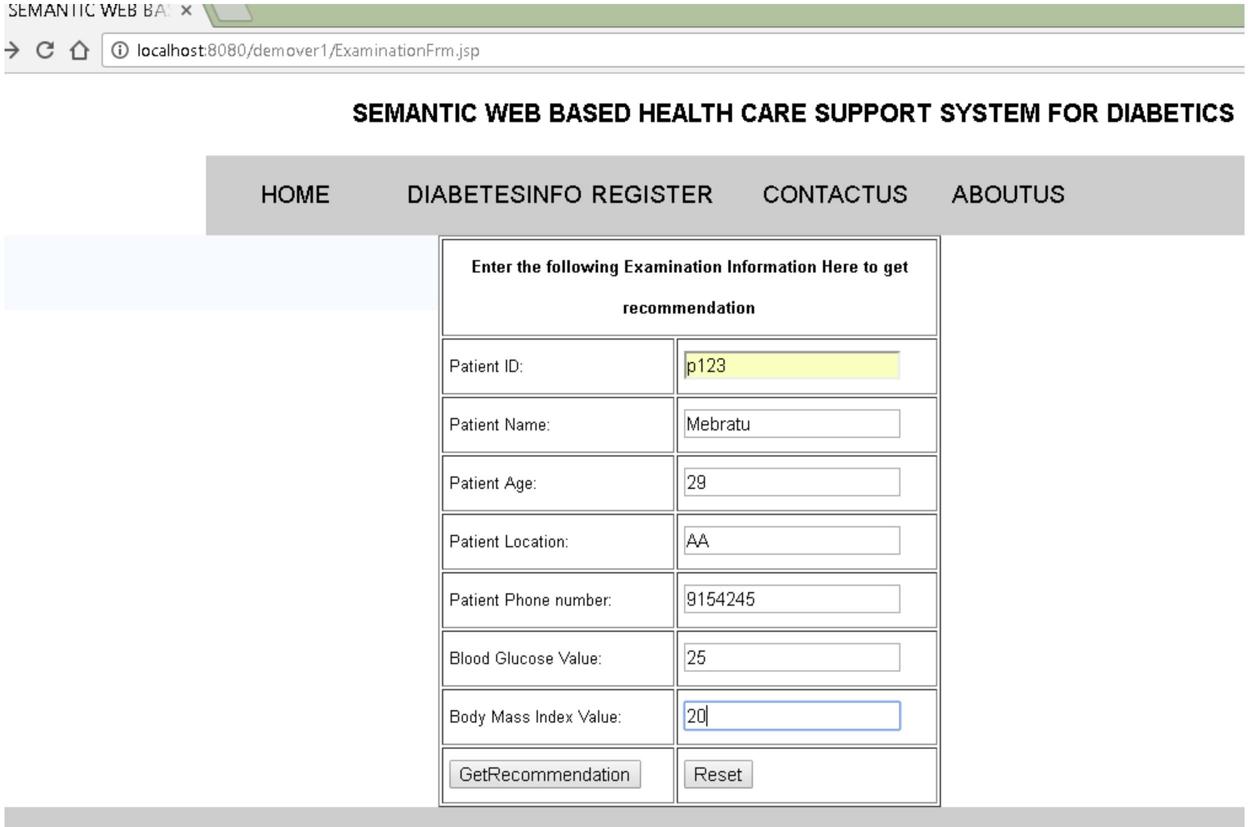


Figure 6-4 Examination Result Form Page

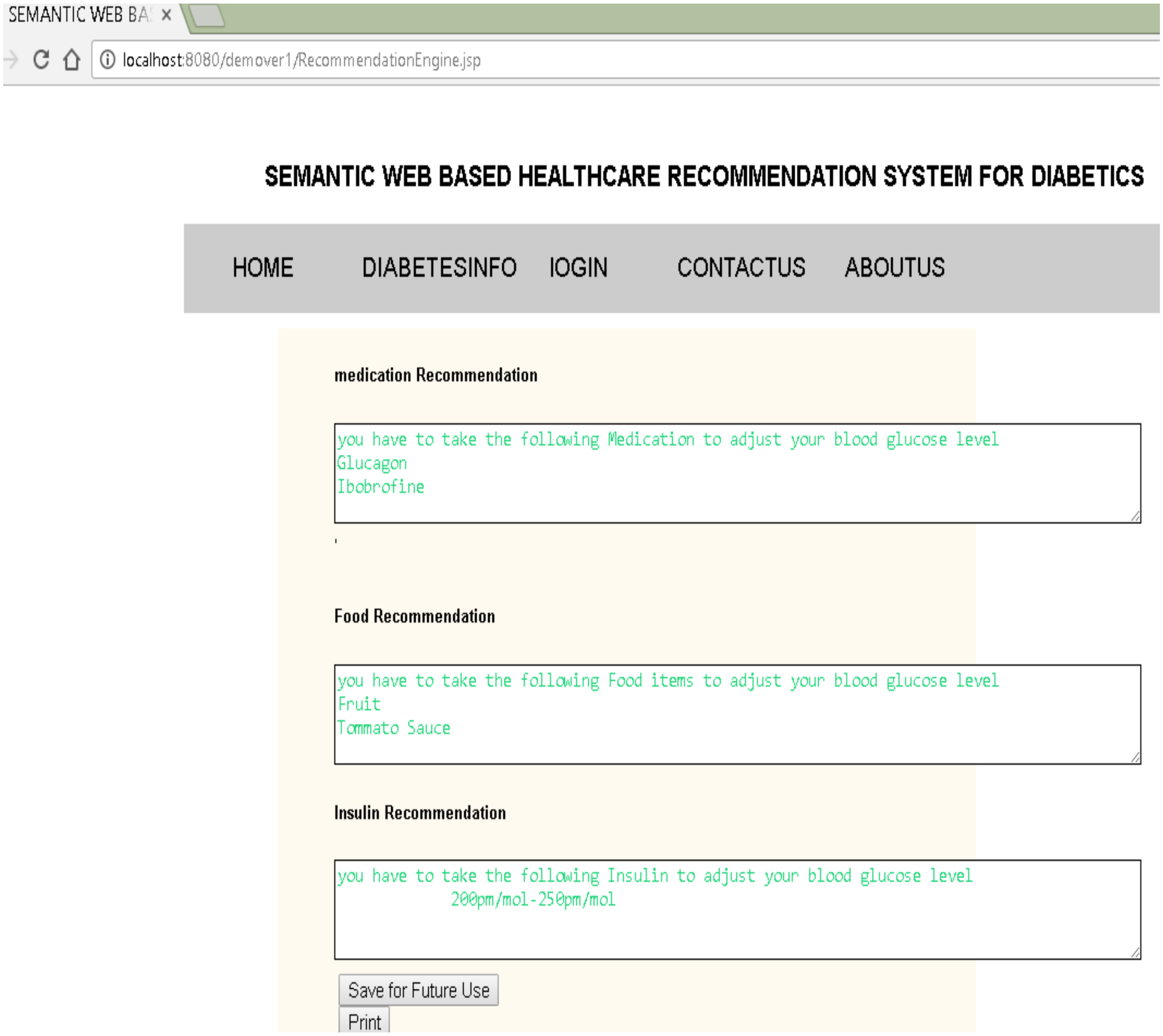
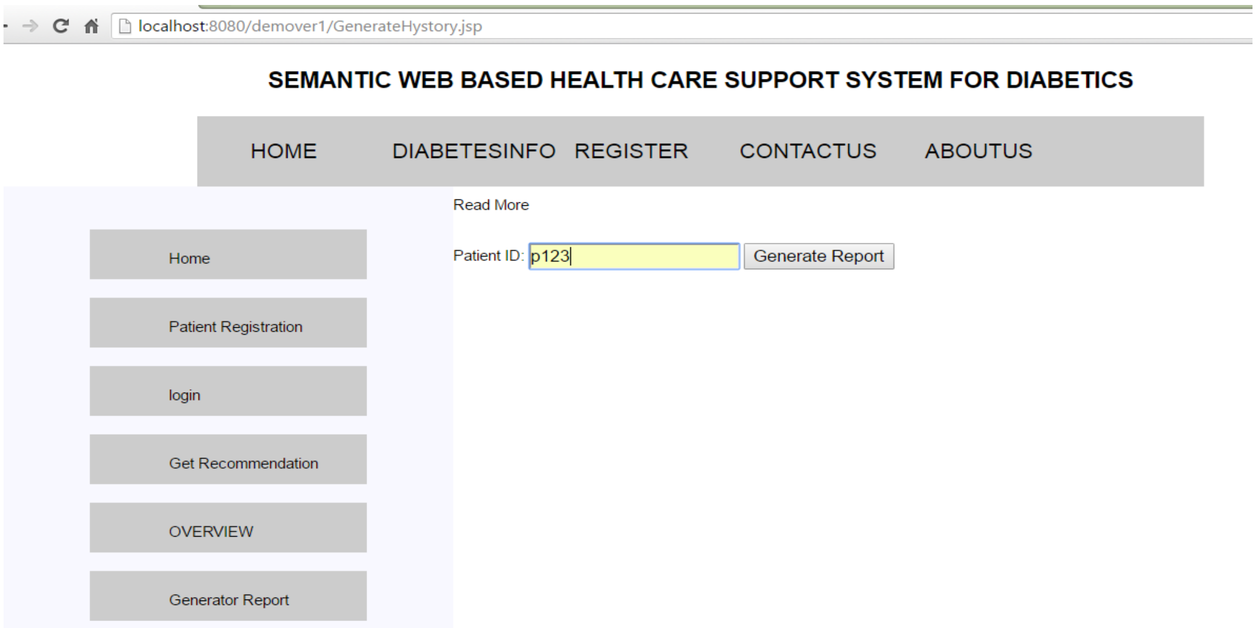
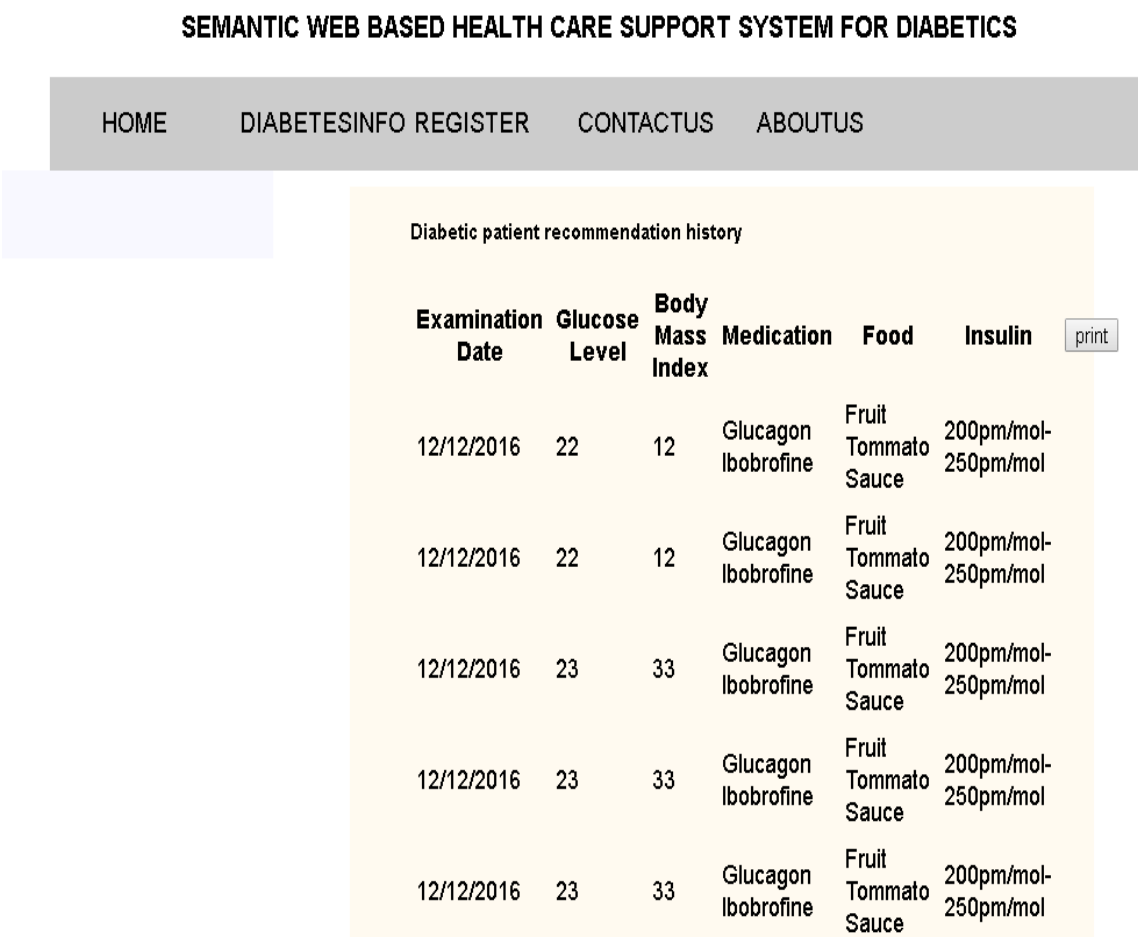


Figure 6-5 Recommendation Page





Examination Date	Glucose Level	Body Mass Index	Medication	Food	Insulin
12/12/2016	22	12	Glucagon Ibobrofine	Fruit Tommato Sauce	200pm/mol-250pm/mol
12/12/2016	22	12	Glucagon Ibobrofine	Fruit Tommato Sauce	200pm/mol-250pm/mol
12/12/2016	23	33	Glucagon Ibobrofine	Fruit Tommato Sauce	200pm/mol-250pm/mol
12/12/2016	23	33	Glucagon Ibobrofine	Fruit Tommato Sauce	200pm/mol-250pm/mol
12/12/2016	23	33	Glucagon Ibobrofine	Fruit Tommato Sauce	200pm/mol-250pm/mol

Figure 6-6 Report Generation Page

6.3 Testing

In this section, usability of Semantic Web based Healthcare Recommendation system from different perspective is evaluated from different users' perception.

Depending on the data collected from health professionals and reviewed from national health guidelines the SWHRS system provides the recommendations for diabetes patient after receiving a blood glucose value from users request. Using Ontology developed for this purpose the system recommends different recommendations such as medications, food and insulin dosage.

The system is tested with different real data to meet the functional requirements, which are identified in the requirement analysis. Moreover, this testing is used to find any kind of error that existed in the entire system development and to correct them.

The system testing is performed by Tikur Anbessa Specialized Hospital Diabetes Clinic staffs and we maintained the system based on their opinion and suggestion.

Every domain expert evaluator offers various patients test to the prototype system and search recommendations made by the prototype system. The evaluators assess the accuracy of the prototype system by using the following standards, these are: simplicity of use and interact with the prototype system, attractiveness of the prototype system, efficiency in time , the ability of the prototype system in making the right recommendations and the importance of the prototype system in the domain area. These evaluation standards are customized from Pu et al. [36]. The questionnaires used to test the performance of the prototype system by domain experts is found in appendix C.

The researcher fixed values for each attributes of the questionnaire for evaluating the usability of the prototype system on the side of the end-users. The values for all attributes are fixed as excellent = 5, Very good = 4, Good = 3, Fair = 2 and Poor = 1. This allows the domain experts to put their values for each criteria of evaluation. The following table 6.1 illustrates the outcomes achieved after evaluation by domain experts.

No.	Criteria of evaluation	Poor	Fair	Good	Very good	Excellent	Average
1.	Simplicity to use and interact with the prototype system	0	1	1	1	2	3.80
2.	Attractiveness of the prototype system	0	0	1	1	4	4.50
3.	Efficiency in time	0	0	1	1	4	4.50
4.	The ability of the prototype system in making right recommendations	0	0	2	1	4	4.28
5.	Importance of the prototype system in the domain area	0	0	0	1	5	4.83
		Total average					4.38

Table 6-1 Usability evaluation by end users

As shown in the above table 6,1 33.33% of the evaluators scored the simplicity to use and interact with the prototype system criteria of evaluation as excellent, 16.67% as very good, 16.67% as good and 16.67% as fair. The second evaluation criteria attractiveness of the prototype system showed a greater rate of attractiveness by the evaluators the majority is scored 66.67% as excellent, 16.67% as very good, and 16.67% as good.

In the efficiency of the prototype system with respect to time criteria of evaluation, 66.67% of the evaluators scored as excellent, 16.67% as very good, and the rest 16.67% as good.

Moreover, when asked if the prototype system the ability of the prototype system in making right recommendations criteria, half of the evaluators as excellent scored while 33.33% and 16.67% of the evaluators scored it with good and very good respectively.

To this end, equal scores were given for importance of the prototype system in the domain area criteria, 83.33% of the evaluators gave the prototype system excellent while 16.67% rated the prototype system as very good. Finally, the average performance of the prototype system according to the evaluation results filled by the domain experts is 4.38 out of 5 or 87%, which is above very good.

Chapter 7
Conclusions and Future Works

7.1 Conclusion

In this work, a healthcare recommendation system based on the Semantic Web technologies has been proposed to aid physicians and patients in making the right decision in selecting suitable recommendation for the diabetic diseases. Our approach in this work offers semantic web based recommendation system through which patients can access the basic instruction of diet, insulin, medications and exercise that improves the quality of patient's life.

This study presented a healthcare recommendation system intended to help diabetic patients manage their blood glucose levels. The Semantic Web based Healthcare Recommendation system that is a result of this and other research will help these patients better regulate their blood glucose levels through the use of ontology based approach.

we presented our ontology-based healthcare recommendation system, especially focused on ontology development process. The implemented system relies on knowledge, which is structured through domain ontology for standardizing concepts and allowing subsequent updates as well as reuse. This ontology supports data sharing and can generate recommendations for diabetic patient. The model is a Protégé-based knowledge representation used for linking concepts and data for diabetes diseases.

In addition, initial testing proved system usefulness and feasibility. The system possesses high reliability and the cost of system setup and use is low. Application of these emerging technologies and similar implementation of the system, can thus produce improvements in the lives of those living with diabetes and reduce the public and private health care costs associated with treating the disease.

7.2 Future works

For future study, we will strengthen patent's ontology weights using artificial neural in the system. The ontology in this thesis is developed as a proof of concept and for showing the advantages of data sharing. The following work can be done to improve the system:

- ✓ The system will integrate new patient ontology and drug ontology to arrange priority of drugs. The system not only recommends drugs classification, but also the system will recommend generic drugs.
- ✓ This work can be expanded by considering others values necessary for diabetic management such as diabetic symptoms, patient’s genes.
- ✓ The ontology can collect and search the information for diabetic diseases, the model can be expanded by applying same approach on others chronic diseases.

This ontology is valuable for future knowledge reuse within others medical applications. We recommend the further development toward to practical use of such Systems, as it can help to improve diabetic patient self-management capability

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Annexes

Annex A: Sequence Diagram

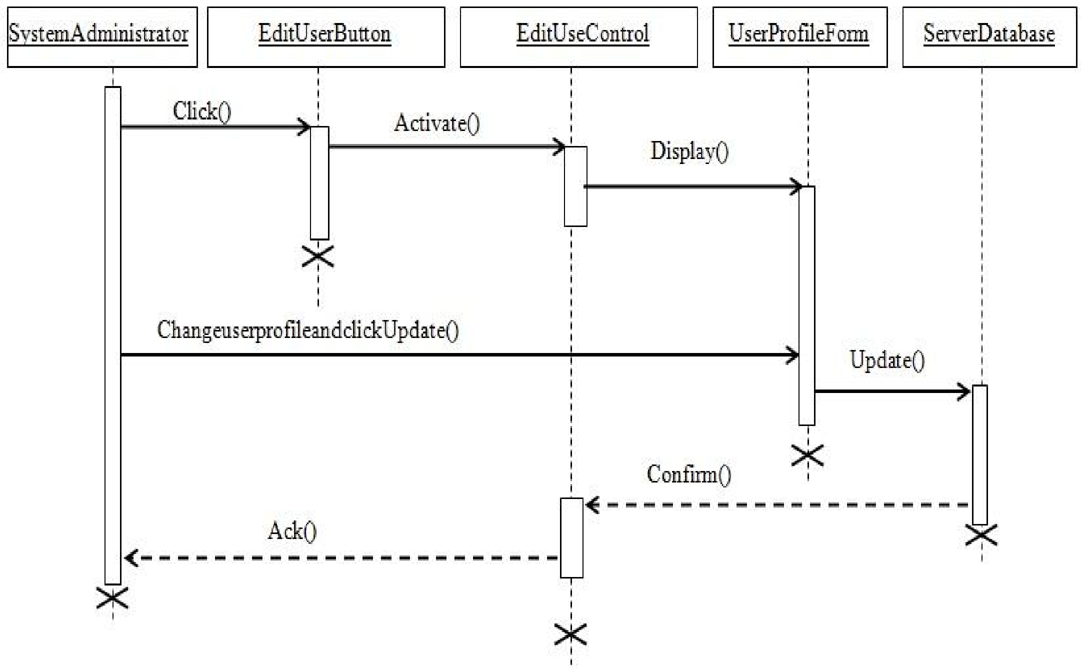

Figure 0-1 Edit user sequence Diagram

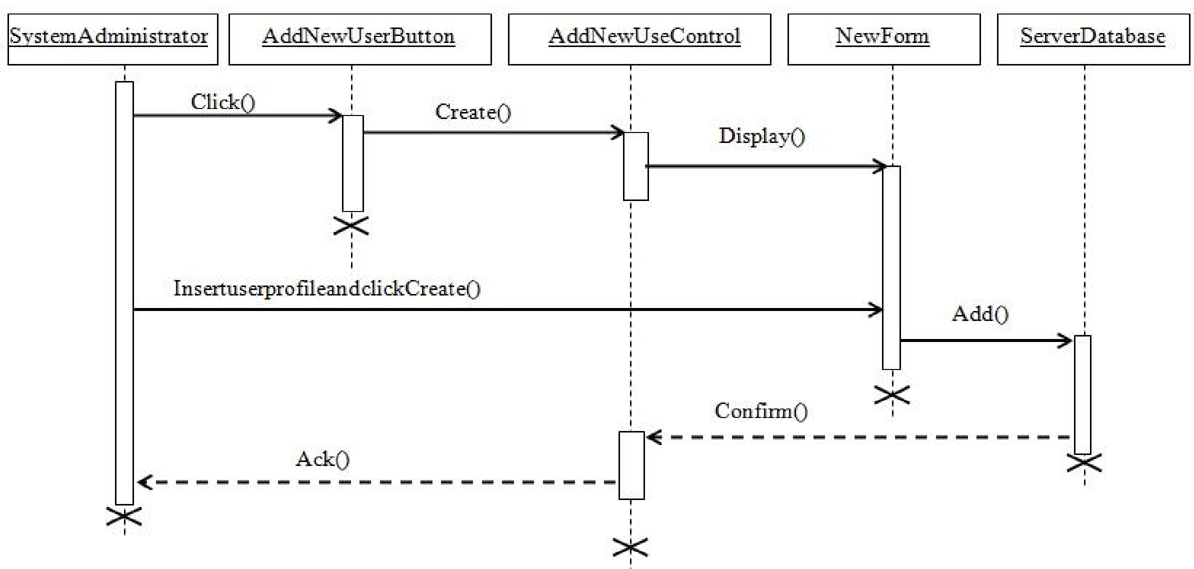

Figure 0-2 Add User Sequence diagram

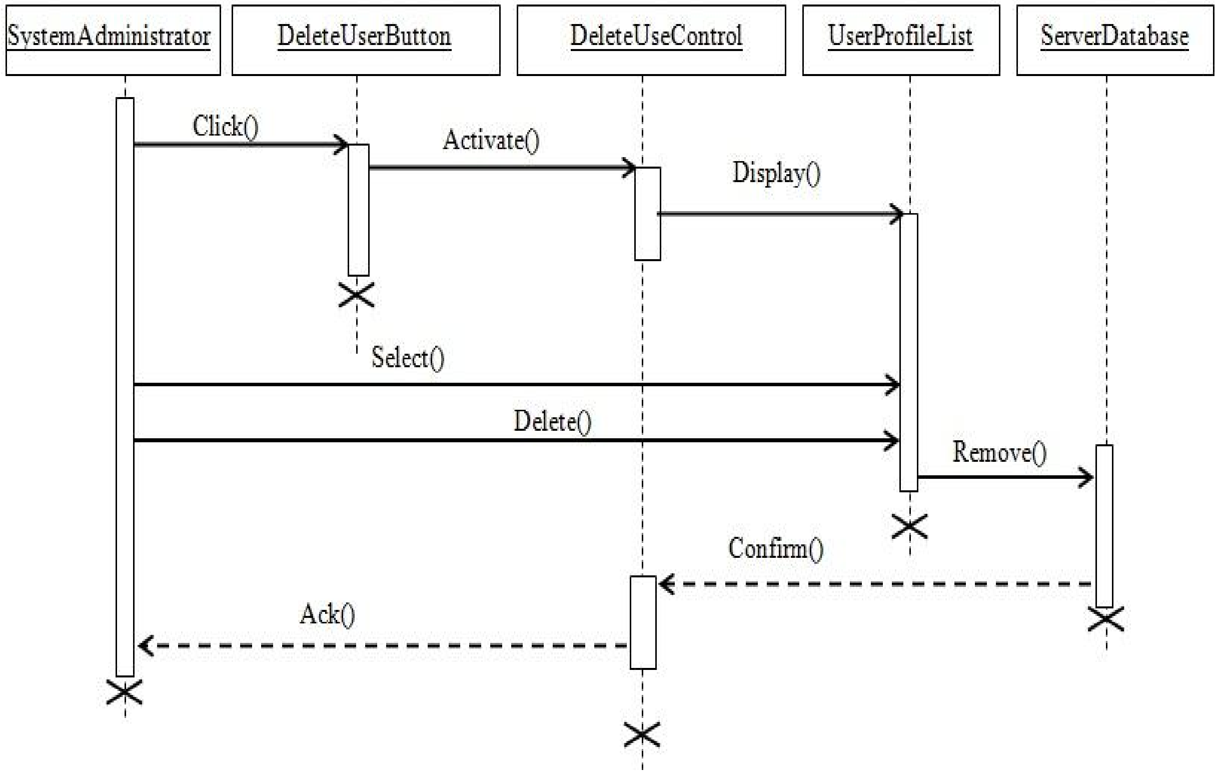

Figure 0-3 Delete user sequence Diagram

Annex B: java owl API code to generate recommendation

```
<%@page import="org.semanticweb.owlapi.vocab.PrefixOWLOntologyFormat"%>
<%@page import="org.semanticweb.owlapi.model.OWLDataPropertyExpression"%>
<%@page import="java.util.Map"%>
<%@page import="java.util.Set"%>
<%@page import="org.semanticweb.owlapi.reasoner.SimpleConfiguration"%>
<%@page import="com.clarkparsia.pellet.owlapiv3.PelletReasonerFactory"%>
<%@page import="java.util.logging.Logger"%>
<%@page import="java.util.logging.Level"%>
<%@page import="org.semanticweb.owlapi.model.OWLOntologyCreationException"%>
<%@page import="org.semanticweb.owlapi.model.IRI"%>
<%@page import="org.semanticweb.owlapi.apibinding.OWLManager"%>
<%@page import="org.semanticweb.owlapi.reasoner.OWLReasonerFactory"%>
<%@page import="org.semanticweb.owlapi.model.PrefixManager"%>
<%@page import="org.semanticweb.owlapi.reasoner.OWLReasoner"%>
<%@page import="org.semanticweb.owlapi.model.OWLOntology"%>
<%@page import="org.semanticweb.owlapi.model.OWLOntologyManager"%>
<%@page import="org.semanticweb.owlapi.model.OWLAxiom"%>
<%@page import="org.semanticweb.owlapi.model.OWLLiteral"%>
<%@page import="org.semanticweb.owlapi.model.OWLDataProperty"%>
<%@page import="org.semanticweb.owlapi.model.OWLClassAssertionAxiom"%>
<%@page import="org.semanticweb.owlapi.model.OWLNamedIndividual"%>
<%@page import="org.semanticweb.owlapi.model.OWLClass"%>
<%@page import="org.semanticweb.owlapi.model.OWLDataFactory"%>
<%@page import="org.semanticweb.owlapi.model.OWLOntologyID"%>
<%@page import="uk.ac.manchester.cs.owlapi.dlsyntax.DLSyntaxObjectRenderer"%>
<%@page import="org.semanticweb.owlapi.io.OWLObjectRenderer"%>
 <!DOCTYPE html>
<html>
   <head>
           <link rel="stylesheet" href="newone.css" />
              <script language="javascript" type="text/javascript">
```

```
function clearText(field){
   if (field.defaultValue == field.value) field.value = '';
   else if (field.value == '') field.value = field.defaultValue;
}
</script>
 </head>
   <body>
    <%    String BASE_URL="http://localhost/HSS/diabete_ontology.owl";
   //private static final File BASE_URL = new File("C:\\wamp\\www\\HSS\\diabete_ontology.owl");
      OWLObjectRenderer renderer = new DLSyntaxObjectRenderer();
   OWLOntologyID currentOntologyID;
   OWLDataFactory factory;
   OWLClass owlClass;
   OWLNamedIndividual individual;
   OWLClassAssertionAxiom classAssertion;
   OWLDataProperty dataProperty;
   //OWLLiteral literal;
   OWLAxiom ax;
   OWLOntologyManager manager;
   OWLOntology ontology;
   OWLReasoner reasoner;
   PrefixManager pm ;
   OWLReasonerFactory reasonerFactory ;
      String PatientsList="retrieving list of Patients....\n";
      String indvidualList="";
      String individualAge="";
   String individualGender="";
      manager = OWLManager.createOWLOntologyManager();
        try {
                   IRI ontologyIRI = IRI.create(BASE_URL);
         ontology = manager.loadOntologyFromOntologyDocument(ontologyIRI);
        // ontology = manager.loadOntologyFromPhysicalURI(ontologyIRI);
```

```
reasonerFactory = PelletReasonerFactory.getInstance();
reasoner = reasonerFactory.createReasoner(ontology, new SimpleConfiguration());
factory = manager.getOWLDataFactory();
pm = (PrefixManager) manager.getOntologyFormat(ontology);
individual = factory.getOWLNamedIndividual("project:melak", pm);
indvidualList=" individual name:"+individual;
System.out.println(" individual name:"+individual);
renderer = new DLSyntaxObjectRenderer();
Map<OWLDataPropertyExpression, Set<OWLLiteral>> assertedValues = individual.getDataPropertyValues(ontology);
System.out.println("retirned individuals:"+assertedValues);
for (OWLDataProperty dataProp : ontology.getDataPropertiesInSignature(true)) {
    for (OWLLiteral literal : reasoner.getDataPropertyValues(individual, dataProp)) {
        Set<OWLLiteral> literalSet = assertedValues.get(dataProp);
        boolean asserted = (literalSet != null && literalSet.contains(literal));
        System.out.println((asserted ? "asserted" : "inferred") + " data property for " + renderer.render(individual) + " : "
            + renderer.render(dataProp) + " -> " + renderer.render(literal));
    }
}
((PrefixOWLOntologyFormat)pm).setDefaultPrefix(BASE_URL + "#");
Map<String, String> prefixMap = pm.getPrefixName2PrefixMap();
OWLClass personClass = factory.getOWLClass("project:patient", pm);
System.out.println("Individuals are:\n");
for (OWLNamedIndividual Patient : reasoner.getInstances(personClass, false).getFlattened()) {
    System.out.println("Patient : " + renderer.render(Patient));
    PatientsList= PatientsList+renderer.render(Patient)+"  is a patient"+"\n";
        }
//get a given individual
individual= factory.getOWLNamedIndividual("project:melak", pm);
//get values of selected properties on the individual
```

```
        OWLDataProperty hasAge = factory.getOWLDataProperty("project:HasAge", pm);
        OWLDataProperty    hasGender=    factory.getOWLDataProperty("project:HasGender",
pm);
        OWLObjectProperty  hasExamination  =  factory.getOWLObjectProperty(":HasGender",
pm);
         System.out.println("Tadegew's properties value are:\n");
        for (OWLLiteral age : reasoner.getDataPropertyValues(individual, hasAge)) {
           // textArea.append("Age:"+age+"\n");
            individualAge= "Tadegew has age: " + age.getLiteral();
            System.out.println("Tadegew has age: " + age.getLiteral());
        }
        for (OWLLiteral gender: reasoner.getDataPropertyValues(individual, hasGender)) {
            //textArea.append("Gender:"+gender+"\n");
            individualGender="Tadegew's Geder is:"+gender.getLiteral();
            System.out.println("Tadegew's Geder is:" + gender.getLiteral());
        }
            } catch (OWLOntologyCreationException ex) {
            System.out.println(ex.getMessage());

//Logger.getLogger(OntologyBasedRecommendationEngine.jsp.getName()).log(Level.SEVE
RE, null, ex);
        }
                <h1>Recommender System</h1>
          <table border="10" width="300%" cellpadding="500" c>
               <tbody>
        <form>


                 <tr>
            <h2>U have to take the following drugs</h2>
<!--            <label for="textarea"></h2>U have to take the following drugs</h2></label>-->
            <textarea          name="medication"          rows="4"          cols="70"          value="
"><%=individualGender.toString()%>
            </textarea>
            </tr>
```

```
        <tr>        <h2>Recommended Food</h2>
        <textarea name="foodIntake" rows="4" cols="70" textareaObject.value="text"
><%=PatientsList.toString()%>
        </textarea>
        </tr>
        <tr>
        <h2>Recommended Insulin</h2>
        <textarea name="insulinIntake" rows="4" cols="70" ><%= individualAge %>
        </textarea>
  </tr>
      </form>
        </tbody>
        </table>
       </div>
        </div>
      </body>
</html>
```

Annex C: Usability evaluation form

The importance of this evaluation form is to evaluate to what extent the prototype system is usable by the end-users in the domain area. I would like to thank for your cooperation and valuable information.

The values for all attributes in the following table are fixed as: Excellent = 5, Very good = 4, Good = 3, Fair = 2 and Poor = 1.

No.	Criteria of evaluation	Poor	Fair	Good	Very good	Excellent	Average
6.	Simplicity to use and interact with the prototype						
7.	Attractiveness of the prototype system						
8.	Efficiency in time						
9.	The accuracy of the prototype system in reaching a decision to identify the diabetes types						
10.	The ability of the prototype system in making right recommendations						
11.	Importance of the prototype system in the domain area						
		Total average					

N.B: Put ”X“ symbol on the available place for the corresponding attribute values for each criteria of evaluation.

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

Declared by:

Name: Melaku Fissie

Signature: ________________________________

Date: ____________________________________

Confirmed by advisor:

Name: Mesfin Kifle (PhD)

Signature: ____________________________________

Date: _____________________________________