

Ontology-Based Personalized System to Support Patients at Home

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Abstract

Chronic diseases are incurable diseases that require long term supervision and treatments by medical professionals. The most common chronic diseases are cardiovascular disease, obesity, diabetes respiratory diseases and cancer. With information and communication technology many applications have been implemented to facilitate different clinical decision making process. With new technology, personalized healthcare systems are in place to enable patients with chronic diseases to acquire continuous and long-term medical services at home. This improves healthcare delivery since medical services can be accessed at any place. Today high prevalence of chronic diseases poses technological challenges to existing personalized healthcare systems including data integration and personalized recommendation plan.

This research investigates how semantic technologies could be used to address the above challenges. The goal of this thesis is to use semantic technology for building ontology knowledge repository to provide data integration and medical recommendations for home based diabetes management systems. This ontology focuses on organizing knowledge related to vital sign measurement, questionnaire and recommendations for diabetic patients. To enter and link concepts and data for diabetes ontology, we used Protégé-owl.

The ontology model provides knowledge into which information on individual patient including vital-sign data, questionnaires based 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 to be a better way of describing managed data. Therefore ontology based technology could be implemented in the personalized systems to enhance remote care for home-patient.

Keywords: <Ontology, Personalized System, healthcare, Chronic Diseases, Data Management>

Preface

This thesis has been submitted to the Faculty of Engineering and Science of the University of Agder, Norway in partial fulfillment of the requirements for the degree of Master of Information and Communication Technology (ICT). The work has been carried out in the period from January to June 2014. The main objective of this work was to investigate how semantic technologies can be used to address some challenges presented in the personalized systems for home patient. This work was conducted under the supervision of Jan Pettersen Nytun and Rune Fensli.

I would like to express my sincere gratitude to Professor Rune Fensli and Jan Pettersen Nytun my supervisors, for their guidance, encouragement and good suggestions during this project and studies at Agder University. I would like to deeply thank my family, friends and colleagues who supported and encouraged me during my master study especially those who given me professional guidance.

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LIST OF ABBREVIATION

API	Application Programming Interface
DAML	DARPA Agent Markup Language
HTML	Hypertext Markup Language
ICT	Information and Communication Technology
RDF	Resource Description Format
RIF	Rule Interchange Format
SHOE	Simple HTML Ontology Extensions
SPARQL	Simple Protocol and RDF Query Language
OWL	Web Ontology language
OWL DL	Web Ontology language description logic
OIL	Ontology infrastructure language
XOL	Ontology Exchange Language
UML	Unified Modeling Language
URL	Uniform Resource Locator

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1 Introduction

Chronic diseases are ongoing, incurable illnesses mainly caused by poor nutrition, excessive use tobacco and alcohol and lacks of physical activity. Peoples affected by such with diseases require long term treatments under constant supervision by different healthcare providers (nurses, doctors, family members, social care givers), which is costly and time consuming. 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. In this chapter we are going to describe some challenges of the existing applications, technology solution we are proposing and how we can implement it, in the end we describe different steps to be accomplished during this thesis work.

1.1 Background

Chronic diseases are incurable illnesses that can be controlled. The most common known chronic diseases are diabetes, heart diseases, breast cancer, copd, stroke, obesity. Patients with chronic diseases require long term supervision by medical personnel. In order to deal with that high patient demand, a mechanism of developing personalized system has been adopted to support patient at their home place. Patient with chronic diseases can acquire medical services through different applications such as real-time remote, web based and mobile based applications. there are many applications that have been implemented for that purpose as shown in[1][2][3]. Those systems contain knowledge describing patient's health condition and the medical care plan.

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 ontology based technology to enable a large amount of data to be collection, store and share easily in the field of bioinformatics.

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 [4] a paper shows combination of different technology including ontology for management of data in home-based monitoring scenarios, In [5] ontology-based healthcare context information model have been developed for healthcare services and in [6] ontology for health-care knowledge was developed to support clinical decisions for chronically ill patients.

As definition ontology is a knowledge representation defining common vocabulary for shared information within a domain. ontology has many advantages such as “to share common understanding of information structure among people and software agent, enable reuse of domain knowledge, separate domain knowledge from operation knowledge and analysis of domain knowledge ” [6,pp.1]

1.2 Problem Statement

Personalized healthcare systems allow patients to participate in medical services such as remote monitoring and medical social services, for healthcare provide it help them to keep constant patient’s health status under continuous supervision. Due to fast increase of people with chronic diseases, many applications are used today to provide different remote services. Therefore there is a need of technology that can be used to integrate those applications to enable such large patient data to be shared between different healthcare domains. Due to technology infrastructure behind those applications data integration is a key challenges. Here we addressed some challenges found in the existing application:

- Lack of data integration: data integration is important factor for tele-monitoring application since patient information from various sources needs to contribute together in supervision process.
- Lack of context data: context information is a major factor that can influence diagnostic supervision.
- Medical recommendation Knowledge for the remote applications is required in order to display medical feedback after acquiring patient’s vital sign data.

My research question is how ontology knowledge representation can be used to collect medical data from different sources? .The second question is how ontology knowledge representation can be used to generate medical recommendation based on patient vital sign measurement?

1.3 Literature Review

Chronic diseases are ongoing, incurable diseases that can be controlled but not cured and are the most cause of death in the world. The most common known chronic diseases are diabetes, heart diseases, breast cancer, copd, stroke, obesity. According to the World Health Organization, among 58 million deaths; 30% of them are caused by Cardiovascular Diseases , Cancer took 13% of the total, Chronic respiratory diseases have

7% and Diabetes is 2% [8]. Lacks of physical activity, poor nutrition, excessive use tobacco and of alcohol are responsible for much suffering and early death related to chronic diseases. Good news is that, those diseases can often regularly manageable through relevant diet, physical exercises and treatment.

In next section we describe the most common types of chronic diseases, their major causes finally we show the role of ICT in chronic diseases management.

Heart disease: is caused by damage of the blood vessels of the heart, this bad condition come when a substance called plaque builds up in the walls of the arteries narrows the arteries, as result it make harder for blood to flow through. Heart disease is the most cause of mortality as it took 30% of all deaths occurred. Heart disease has become popular in the developing countries from the last decades but now it spread worldwide [9],[10].The main cause of heart diseases are Blood vessel inflammation, smoking, high mount of cholesterol in blood and high blood sugar.

Cancer: is a disease describes a range of diseases in which abnormal cells grow out of control. There are many types of cancer such as cervical cancer, skin cancer, breast cancer and oral cancer. All organs of the body can become cancerous. The main cause of cancer is cigarette smoking or sun exposure.

Chronic respiratory diseases: there are number respiratory diseases such as obstructive pulmonary disease and asthma. Chronic obstructive pulmonary Disease is caused by airflow limitation that is not fully reversible. Asthma is caused by reversible obstruction of the airways; smoking and weather change are the main reason of chronic respiratory diseases [10].

Diabetes: is characterized by disorders in glucose metabolism; this comes from a lack of insulin hormone which controls blood glucose levels or inability of body's tissues to respond to insulin secretion. There are three types of diabetes namely: type 1, type 2 and gestational diabetes. Type 1 is insulin dependent; it affects people at low age. Type 2 is insulin resistant generally affect adult and gestational diabetes that affect pregnant women .The most common type of diabetes is type 2, which accounts about 90% of all diabetes [9]. For more detail about diabetes will be explained in the next chapter.

Peoples with chronic diseases require long life treatments under continuous supervision by different healthcare providers. ICT is one of the key solutions to enhance quality of life for chronic patients through personalized applications. There are numerous application implemented for that purpose to provide medical services such as video consultation, remote vital sign measurement, appointment scheduling and medication reminder, examples are shown in [1][2][3]. As result those applications allow patient at home to participate in personal treatments.

By definition, personalized systems also known as "home-based telemonitoring systems" are the applications enabling exchange of medical data between a patient at home and a healthcare professional located in a medical Centre. The general scenario is represented in Figure 1.1.

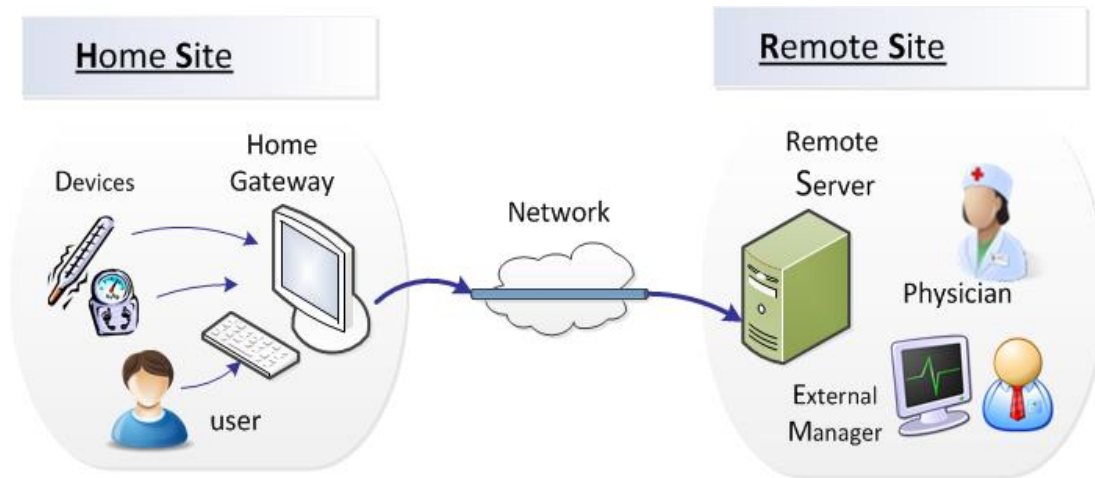


Figure: 1.1 Home-Based telemonitoring Architecture[11].

In general, home-based telemonitoring scenario includes two sites: the home site and the healthcare site linked by a communication network. At the home site; patients take measurements (e.g. blood glucose, blood pressure) periodically to monitor their current health condition. The information acquired using medical devices are transmitted to healthcare site through home gateway network. On health care site the server device is used to manage information from the home sites and make necessary analysis[11]. As additional those application cannot provide high quality of service without close collaboration among different beneficial. All concerned people should be properly informed in order to help the remote system to provide long-term care delivery with efficiency. According to the statistics [8] chronic diseases are widespread, therefore different home-based telemonitoring applications need to work in collaboration in order to provide improved services. With semantic technology data sharing and management between different home-based telemonitoring applications is possible. Many chronic diseases need to be managed, but in this work we focused on diabetes diseases management.

1.4 Problem Solution

People with chronic diseases require regular supervision. With technology personalized healthcare systems are in place to enable patients can to acquire regular supervision at home. Today high prevalence of chronic diseases poses technological challenges to existing personalized healthcare systems include data integration and personalized recommendation plan. Our research is based on how ontology technology could be used to overcome the above challenges.

Ontology has been implemented into personalized applications to improve their healthcare delivery. examples are in [11] [4] [5] [6]. After evaluating the above Ontologies based system for chronic disease management, we found that they provide medical data gathering and sharing, but they don't contain knowledge about personalized recommendation plan. In this work we enhance the existing work by creating ontology knowledge providing data sharing while predicting some prevention plan.

1.4.1 Solution Method

In order to handles the problem addressed in the problem statement, we have create ontology model predict diabetic patient information relevant in remote vital sign measurement and inform some recommendation based on nutrition, medication and insulin injection. The developed model achieved it objectives by performing the following task using protégé-owl ontology editor environment tools:

- Identify different variable required in diabetic Patient supervision and establish relationships between them.
- Build knowledge acquisition that acquires personal information, such as patient general information, vital sign measurement data and context data.
- We integrate an existing ontology-base questionnaire reserved for diabetic patient containing information about health status in order to share data from different sources.
- Build a prevention knowledge containing recommendation (nutrition diet, medication and insulin intake) associated to blood sugar level evaluation.

Based on the above works, the developed ontology model is able to acquire patient data from heterogeneous sources, Reason over knowledge and generate recommendations.

1.4.2 Scope and Limitation

As motioned in the title, ontology is designed to support personalized system for patient for home. Due to time limit of the project constraint the ontology model is developed to collect and share data for diabetes diseases only, but the same ontology approach can be applied to others chronic diseases, in additional the user interface is not implemented.

1.5 Report Outline

This section describes the different steps to be accomplished during the thesis work; it is divided into six chapters. First chapter briefly gives Background information about the topic, presents some literature review on chronic diseases and the role of ICT for chronic diseases management, address the weakness of the existing application, present the goals of the project and finally introduces the content of the report.

Chapter two describes the literature about the existing ontology for personalized system, description of diabetes diseases, in the end it contains reviews of the technologies involved in the project development including semantic web and ontology technology. Chapter three gives step by step prototype implementation including architecture of the proposed solution, define classes, properties and instances. Chapter four contain visualization of the result and validation of the implemented model, chapters five discuss on result and future work. Finally chapter six gives the conclusion of the work.

2 Theoretical Background

This chapter covers the research findings related to ontology technology involved in medical applications. research work on the Semantic Web technology, semantic web technology is a new technology which is still in process, the basic elements of semantic web are also described including ontology, XML, RDF, OWL and sparql. In additional final type diabetes diseases are described their major causes.

2.1 Existing Ontologies

There are large numbers of research findings related to ontology technology involved in medical applications. ontology is a knowledge representation mainly used in semantic web [12]. The main purpose of ontology is to capture the domain knowledge in such a way that it is understandable to machines. The Ontologies in health sector are very emerging today see in[11],[5], [6]. In this part we evaluate the existing ontology prototypes that have been implemented as solution for personalized healthcare services.

First in [11] a home ontology for integrated management in telemonitoring scenarios (HOTMES) has been implemented. It contains a clear description of the information that can be monitored in home based scenario and that information came from different heterogeneous data sources. They use SPARQL rules to describe individual rules in combination with an instance to provide personalized management services.

Figure 2.1 shows the general description of the scenario.

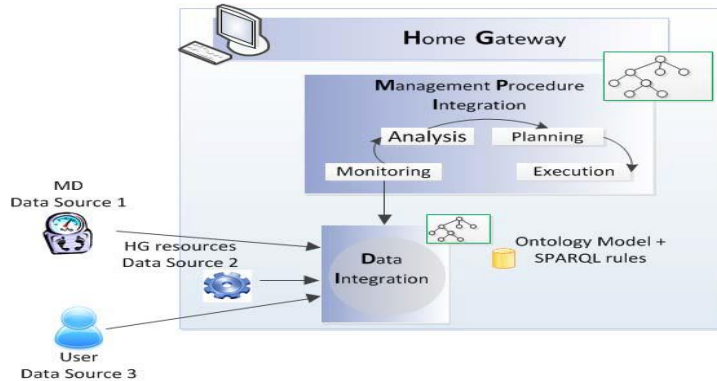


Figure: 2.1 Data and Management Integration Structure [5]

Based on Figure 2.1 HOTMES contains four main tasks namely: monitoring, analysis, planning and execution of tasks. Monitoring task where a physician specify different information to be monitored include vital constant measurement (e.g. blood pressure) that a patient should perform and its schedule. In Analysis

task the acquired measurement are evaluated to detect abnormalities. Finally planning and execution tasks are configured to remind the patient to take a medicament.

Secondly in [5]ontology has been implemented based on integration of three different information model, common patient context information, environmental and patient data general information. The system is based on devices environment related to human bodies, that sense dynamic information according to the context of users and collects dynamic context information from devices. Service provider is transmitted to the context-aware inference, which infers such context information by transforming the collected context information. The Context Manager determines an item set through the inference rule after referencing a healthcare service ontology model with respect to the transmitted context information. The descriptions are shown in Figure 2.2.

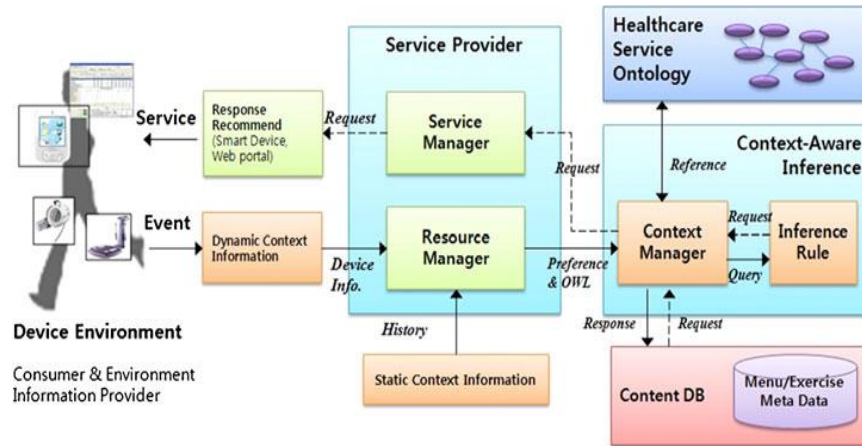


Figure: 2.2 Architecture of U-healthcare service system [7].

Lastly in [6] ontology for chronically ill patient have been implemented based on two process, the first one is patient personalization process adapted to the contents of ontology information observed in the health-care record of a given specific patient, The second personalization process uses the first ontology of a patient to manage patient by planning intervention plans describing health-care general treatments. Ontology knowledge contains information about nineteen diseases, two syndromes and five social issues.

2.2 Diabetes

Diabetes is a chronic disease which occurs when the pancreas does not produce enough insulin, or when the body cannot effectively use the insulin it produces, that result in heterogeneous disorders of glucose metabolism with common characteristic of high blood glucose. People with diabetes are characterized by the symptoms such as; frequent urination, increased hunger, Weight loss, Fatigue, darkened skin. according to World Health Organization Diabetes is among the most known chronic diseases which caused

many death around the world, 2% of death come from diabetes[13].There are three types of diabetes namely, types 1 which insulin dependent and affect people at low age, type 2 is insulin resistant generally affect adult and gestational diabetes that affect pregnant women. The most common type of diabetes is type 2, which accounts about 90% of all diabetes [14]. The next sections describe different diabetes types in details.

2.2.1 Type of Diabetes

Type 1 diabetes also called “juvenile diabetes” is mostly developed in young people and many people suffer from it. The main reason came from heredity where Genes are passed down from biological parent to child. Type 1 is mainly caused by lack of insulin due to the destruction of insulin-producing beta cells in the pancreas. For safe precaution, patient with type 1 diabetes must use insulin shots or an insulin pump to control blood glucose levels [14].

Type 2 diabetes is the most common type of diabetes, developed often in middle-aged and for older people. Type 2 is caused by a combination of factors such as insulin resistance, fat, and liver cells which are insufficient to use insulin effectively. The most causes of type 2 diabetes are Genetic susceptibility, environmental factors, obesity and being physically inactive [14].

Gestational diabetes is type of diabetes developed for pregnant woman due to insulin resistance hormone secretion caused by main factor include the hormonal changes and metabolic demands of pregnancy together with genetic and environmental factors.

2.2.2 Diabetes Management

People with diabetes often need to manage their situation by regularly taking medication, insulin injection and other recommendation such as physical activity and diet. We have choose to work on type 2 diabetes because is the mostly commonly known type of diabetes. In this section we only focus on type 2 diabetes management.

The major problem for diabetes type 2 is high blood glucose level. Normally body sugar is made from the food we eat, when the concentration of sugar becomes high in blood, people suffer from Diabetes. Therefore people living with Diabetes have to manage the sugar level through daily balance of concentration of glucose in the blood stream. There are many factors that can be used to react to high or low blood glucose including insulin-glucose correlation, diet regulation, medication and physical exercises.

Normal Blood glucose values in human body should not be below 4mmol/l and should be great than 7mmol/l[15].

In the next section we describe in detail the role of important factors responsible in blood sugar regulation and how we must use them.

Insulin-Intake: insulin is a hormone made by the pancreas. The pancreas lies just behind the stomach. The function of insulin hormone is to help our bodies to use glucose for energy production. Insulin is always used by type 1 patient but even some people with Type 2 diabetes need it for their blood sugar control. For diabetes treatment Insulin responds to high levels of glucose in the blood by lowering it to normal level. There are six main types of insulin we describe how to use them and how long they active in a human body[14], [16].

- Rapid-acting analogues insulin is used before or after taking food, it has quick reaction on glucose regulation in the body and is lasting for some hours.
- Long-acting analogues are injected once a day to provide insulin lasting reaction about 24 hours.
- Short-acting insulin is injected few minutes before a meal to cover the rise in blood glucose levels that occurs after eating and it can last for up to eight hours.
- Medium- and long-acting insulin is taken once or twice a day, it can last up to 30 hours.
- Mixed insulin is a combination of medium- and short-acting insulin.
- Mixed analogue is a combination of medium-acting insulin and rapid-acting analogue.

In Figure 2.3 show example of variation of blood sugar (red) and the sugar-lowering hormone insulin (blue) in humans during the course of a day with three meals.

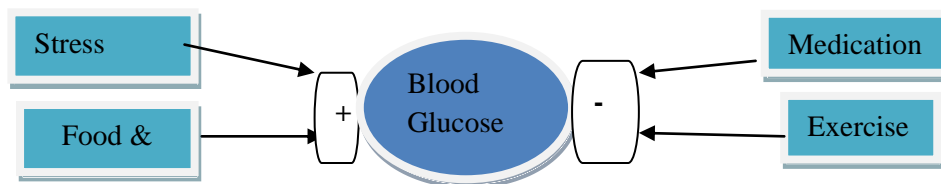


Figure: 2.3 Major factors of glucose valuation

Medication: there are different types of Diabetes medication used to lower blood glucose levels and they work in different ways. People with type 2 diabetes may need medication with insulin. Diabetes medication cannot cure diabetes but keep patient in normal life. There are several diabetes medications available for lowering blood sugar level including Biguanide, Sulphonylureas, Alpha glucosidase inhibitor, Prandial glucose regulators, glucophage, Thiazolidinediones (glitazones), Incretin mimetics, DPP-4 inhibitors, Metformin, Starlix, acarbose, glyset. [14], [16].

Physical exercises: Physical exercise acts as the blood glucose regulation reducing the need for insulin intake and medication. Obesity is the major factor of diabetes type 2. Regular physical activity play important role to enhance weight loss and reduce your body fat which is the main cause of obesity. secondly it help to keep blood glucose, blood pressure, cholesterol and triglycerides to normal condition, as result when taking physical activity regularly, it prevent from getting the diseases such as type 2 diabetes, heart disease and stroke

Diet Regulation: Disorder in meal intake introduces large challenges for blood glucose control. Food regulation tells you how much and what kinds of food you can choose to eat for keeping your normal blood sugar. We describe some healthy diet that reduces risk of diabetes complications, but we also recommend to not smoking and limiting alcoholic drinks. Here we list type of some foods recommended for blood sugar regulation : vegetables, whole grains, fruits, non-fat dairy products, beans, lean meats and Fish [17]. For our ontology development we used some of the above mention factors responsible for blood glucose regulation as medical recommendation for such patient with high glucose level.

2.3 Semantic web

Semantic web technology is a project of World Wide Web Consortium (W3C), under direction of Tim Berners-Lee inventor of web. The purpose of semantic web innovation was to improve and extend the functionality the current web by adding new functionality of computer information knowledge understandable for People and computer for being used in automatic reasoning [12]. Tim Berners-Lee defines Semantic Web as: “an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation”[18].

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 Semantic Web infrastructure enables not just web pages allows different services such as databases, services, sensors, personal devices and even household appliances to consume and produce data on the web”[18]. For Semantic web in order to work effectively it should have access to on structured collections of information and sets of inference rules.

Figure 2.4 shows seven layer describing hierarchy components used in the semantic web proposed by Tim Berners-Lee. There are many technologies involves in semantic web application development such as URL,

Unicode, RIF, proof and digital signature. In this work we used ontology vocabulary, RDF+RDF schema, and XML+XML schema. The ontology vocabulary is represented by OWL (Web Ontology Language) used for information collections and knowledge reasoning. XML provides syntax for the structure of document's content. RDF is used to express Meaning of document's structure by encodes it into sets of triples. RDF Schema provides the vocabulary to define the properties and classes of RDF data [12].

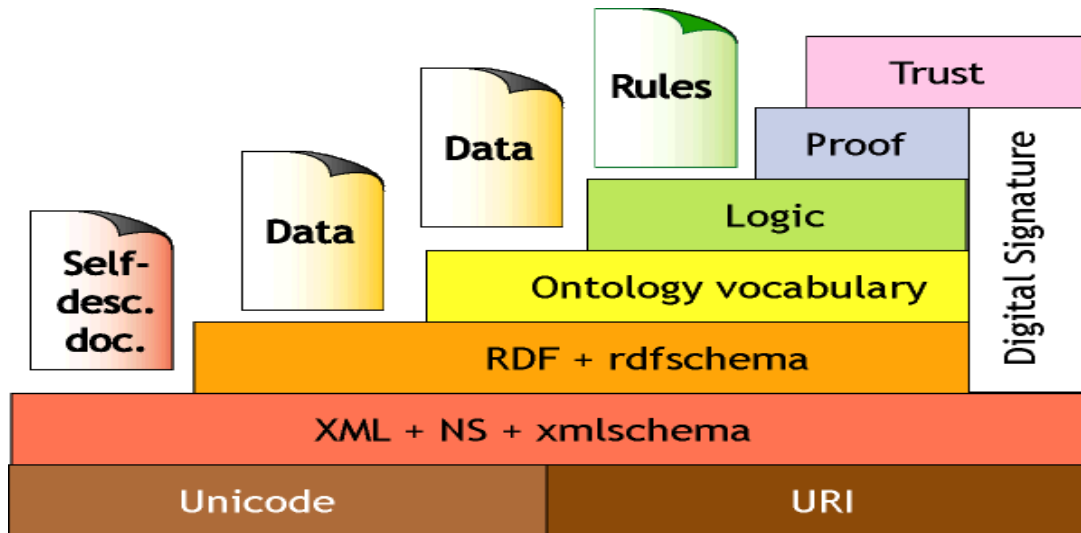


Figure: 2.4 Seven layer Stack [19].

2.3.1 Xml –xml schema

XML is mark-up language designed for creation of structured data of documents on web, it was designed to transport and stores data of web, XML is the most tools for data transmissions between all kinds of applications. XML schemas define the structure of elements in xml document and describe the grammar of XML languages. XML Schemas defines the contents, structure and semantic of XML documents. With xml and xml namespaces the ability of reusing xml vocabulary is increased. Within xml based technology sharing the common XML Schemas allows data integration; therefore Semantic Web should easily integrate with the current Web. In semantic web XML allows users to add arbitrary structure to their documents, this is the reason why it meaningfully in semantic web.

2.3.2 RDF-RDF schema

The Resource Description framework (RDF) is a language for representing information on web and provides Meaning of document's structure. It is a W3C recommendation data model for representing metadata. RDF's data structure enables exchange and reuse of structured metadata; it is based on the XML syntax and has graph structure. In RDF data are presented in a structure consist of subject, a predicate and

object. this structure means that a particular thing (subject) has a property (predicate) with a particular value (object) [19].

➤ Let take an example showing how information can be organize in RDF triple format:

Joy plays Tennis

Tennis is kind of sport

Joy likes music

John live with joy

Figure 2.5 shows how information is presented in graph of RDF triple based example above.

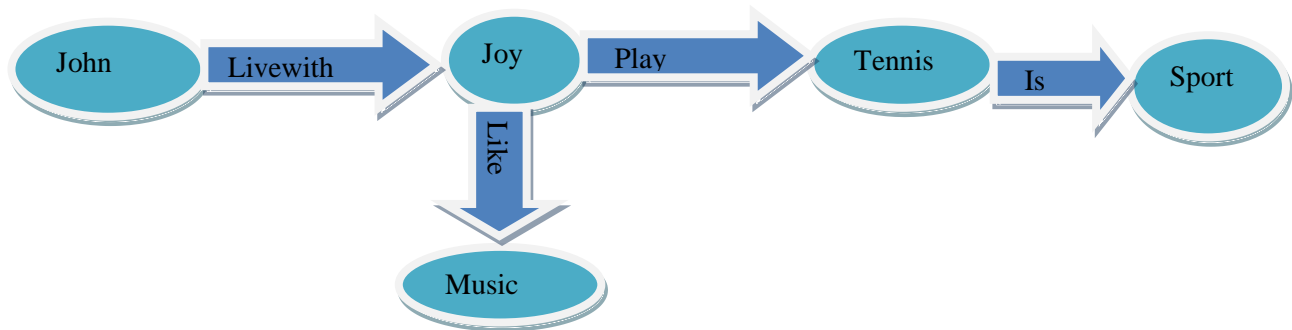


Figure:2.5RDF data in triple

In the Figure 2.5 we can see that two objects are linked with each other with the predicate. First John is linked with joy with a predicate “livewith” because they are live together, secondly joy is linked with tennis with predicate “ play “and joy and music are linked by “like” as she like music.

RDF schemas are extensions of RDF describing classification of classes and properties using RDF knowledge representation language. Classes in RDF Schema enable resources to be defined as instances of classes and subclasses, as result it provides the fundamental elements for the description of Ontologies. In RDF schema classes are used in the same way like in object oriented programming languages [20].

The frequently used elements of RDF Schemas are the following:

- rdfs: range of rdf: property :It defines the range of the property.
- rdfs: domain of rdf :property: It defines the domain of the property
- rdf: type :It defines an instance has a type of a class
- rdfs: subclassOf : It defines a class is a subclass of another class
- rdfs: subPropertyOf : it defines a property is a sub property of another property

Example presented in Figure 2.6 illustrates the use of the RDF Schema vocabulary for describing classes and properties and showing taxonomy of classes and their connection to data value.

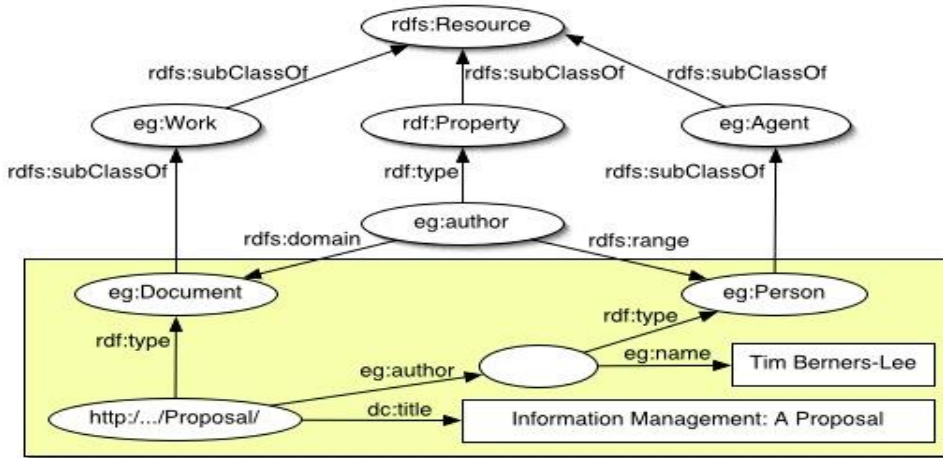


Figure:2.6 RDF-schema Graph [21]

This example illustrates the way in which RDF can be used to describe real world things of relation between document and people. The classes in relation are classified in the example include person, document and a set of the properties are used to relate members of these classes. The above RDF schema shows example of how author property is used to describe relation between document and people. It also shows that all documents are considered to be works, and that all people are agents.

2.3.3 SPARQL

SPARQL is a RDF query language used to query data from semantic web resources. It allows users to retrieve and manipulate data stored in Resource Description Framework (RDF) format. RDF data format is used to model the information implemented in web resources, in SPARQL query are presented in triple form namely subject, predicate and object. SPARQL query provide significant mechanism for answering question of the users by allowing users to write queries about data from RDF content of ontology. Here we describe some important SPARQL query mostly used. SELECT query is used to extract raw values from a SPARQL endpoint, CONSTRUCT query used to extract information from the SPARQL endpoint and transform the results into valid RDF data. ASK query is used to provide a simple True/False result for a query on a SPARQL endpoint [21].

Example of Select SPARQL Query represents the question. “What are the names of patients who have diabetes diseases and their address?”

We provide some explanation of the following select query code:

PREFIX AB : <http://example.com/exampleOntology#> is URL name of the active ontology. The variable to be returned are presented by a symbol ?, SPARQL query processor search for sets of triples that match the triples patterns then, binding the variables in the query to the corresponding parts of each triple.

```
PREFIX AB : <http://example.com/exampleOntology#>

SELECT ?name
WHERE {?patient AB:Hasdesease AB:Diabete;
Patient AB:Hasaddress?address.
}
} } Graph Pattern
```

2.3.4 OWL

Ontology plays important role for knowledge representation within a semantic web domain. Ontology use taxonomy for information collections by defining classes, properties for define relations among classes and store their data value. In Here we describe the mostly used ontology language OWL as one component of semantic web, but detailed information on ontology is described in the next page.

OWL is an ontology representation language defined by Word Wide Web consortium. It provides more vocabularies for semantic representation of the information. OWL language within semantic is used for publishing and sharing Ontologies on the World Wide Web. OWL has been developed as a vocabulary extension of RDF and is derived from the DAML+OIL Web Ontology Language. Its primary purpose is to bring the expressive and reasoning power of description logic to the semantic web.[22].

OWL sub-language

The OWL language includes three sub-languages that provide different levels of expressiveness and computation completeness namely: OWL Lite, OWL DL and OWL Full. For building owl ontology we have to choose one of sub- language. According to [22] OWL Lite is a simplest sub- language used supports developers where simple classification hierarchy and constraints are needed . Furthermore OWL DL is based on the Description Language therefore developing ontology OWL DL can use automatic reasoner tools to check ontology’s consistency and build class hierarchy automatically OWL DL is used in the situation where maximum expressiveness is required. At last OWL Full is the most expressive sub-language, supporting users where automatic reasoning is not required and in the condition OWL Lite and OWL DL are insufficient to represent a complex ontology.

2.3.5 Ontology

This part gives a short description of Ontologies; some mostly used ontology languages, also the choice of ontology language used will be explained here.

Ontology Definition

Ontology is a concept coming from philosophy as study of the nature of existence or reality in general. It attempts to describe the entities of existence, how such entities can be grouped, related within them, and subdivided according to similarities and differences. It classified as one major branch of metaphysics philosophy [21].

In computer science and information science ontology is defined as data model representing domain knowledge by describing a set of concepts within a domain and relationships between them. It defines as common vocabulary for users who want to share information. Ontology has been adapted in semantic web as formal encoding of the concepts, relations, objects and constraints within semantic model [7]. Ontology is used in many areas including artificial intelligence, the Semantic Web, software engineering, biomedical informatics, library science and information architecture.

Ontology languages

In order to ensure that computer recognizes ontology knowledge representation, there are abundances formal languages that can be used to define, construct Ontologies and encode ontology knowledge into computer readable language. The main difference among them lies in the degree of expressiveness and most of them are based on XML syntax. Here we present some interesting ontology languages in semantic web context.

There are many ontology languages, but here we describe some of them, firstly DAML+OIL is new version of DAML and OIL language combines features of both, Now it has been replaced (owl). The second is Ontology Exchange Language (xol) which is mainly designed bioinformatics Ontologies and act as intermediate language designed to provide a format for exchanging Ontologies among different ontology developer. The Third one is Simple HTML Ontology Extensions (shoe) designed to hind knowledge in web pages by allowing information such as class, subclass and property relationships to be described. Shoe is defined as extension of HTML. Lastly owl is defined as a latest version of the above languages and it provide many features for ontology development. . In this project, we prefer to use OWL languages because

they provide an enriched expressiveness in the descriptions of concept and bring the reasoning power of description logic to the semantic web.

3 Solution Approach

For ontology model development we require to conceptualized ideas and made structure of interested concepts in the working area, in order to have a complete picture of the domain. We briefly describe classes, properties, individuals and we provide some restriction for those classes. For the design we need ontology editor tools, there more tools available for ontology design, here we discuss only ontology tool of choice.

Figure 3.1 presents the overview ontology structure workflow it contains ontology specification explaining the method used for ontology conceptualization; secondly it presents different tools that have been used for ontology design. Ontology web language (owl) as it presented is used for knowledge representation where set of classes, properties, individual and data value have been defined and mapped together using that language. A Sparql tool is used to make a set of query in order to display the ontology content.

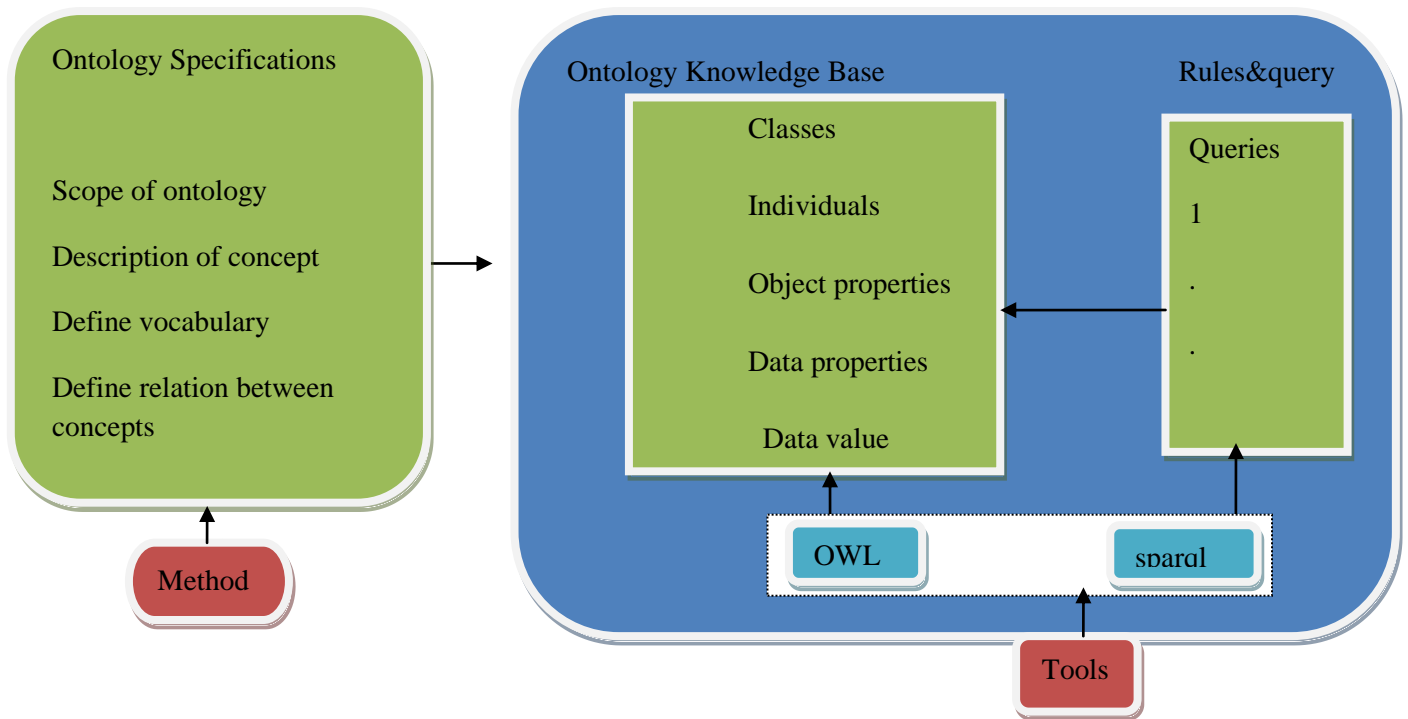


Figure: 3.1 Ontology Structure Workflow

3.1 Tools for Developing Ontology

There are a numbers of tools and environments available for building Ontologies. These tools provide facilities for ontology development process and for future ontology application. According to [24] the first

ontology tool was Ontolingua developed for building frame based applications created by the knowledge systems Laboratory at Stanford University, later other tools were developed to build ontology such as: OntoUML, Webonto, Onto Edit, OIEd and finally Protégé was developed as the latest tool, as of today is the mostly used because of its advantages. Table 3.1 describes comparison of different available ontology editor tools in term of availability, graphical view, developers and Extensibility.

Table 1: Ontology editor tools

Features	Ontololingua	Onto Edit	WebODE	Protégé
developer	Stanford university	Ontoprise	UPM	Stanford university
Availability	Free Web access	Freeware and Licenses	Free web access license	Open source
Extensibility	none	plugins	plugins	plugins
Software-architecture	Client/server	Standalones and client server	Client/server	Standalone
Graphical views	No	No	No	Yes

In this project we have chosen to build ontology with Protégé system and its environment, because of the following advantages:

- Protégé is a free open source environment and it can be used on many kinds of platform.
- Protégé's user interface is user friendly.
- Protégé has built-in query tabs which help to make the query easily.
- Protégé is standalone tool, so it can be used without Internet

With Protégé-based ontology, the file can be imported into and exported from different formats including XML, HTML, RDF and JAVA.

3.1.1 Protégé implementation environment tools

Protégé is a free open source editing tool and knowledge acquisition environment developed by Stanford University. Protégé have been developed in Java and support ontology web language (owl) [25]. Protégé environment presents the user interface with a set of tabs allowing user to access to a different element of these system's functionality and provides a rich set of knowledge-modeling structures to support the

creation, visualization of Ontologies in various representation formats. Protégé contain build-in reasoner namely: Fact++ and hermit used for describing logic. In our project we preferred to use Fact++, because of it features.

There are two main ways of modeling Ontologies in protégé namely, Protégé Frames Editor, and Protégé OWL Editor. Frame based editor enables users to build Ontologies that are frame-based, while Protégé OWL Editor: enables users to build ontology for the Semantic Web. As we are dealing with medical data ontology for semantic web application, we prefer to work with Protégé-OWL editor, as it provides expressive way during ontology development. Protégé-OWL editor also enable developer to edit and visualize classes, properties, instances (individuals) and define their logical and relationship without any programming code.

3.1.2 FaCT++ Analyzing and Reasoning Tool

Fact++ is a new DL reasoner developed at University of Manchester. It is designed as a platform for experimenting new tableaux algorithms, optimization technique and provides reasoning support for the Description Logic. It is available for free download. FaCT++ uses To Do list to control the application rules. The basic idea behind this approach is that rules may become applicable whenever a new concept is added to the old system [26]. In this project we have use FaCT++ for ontology consistency checking because it has been proved to be correct since it fixes bugs much more stable and faster.

According to [27] FaCT++ use three stages for reasoning execution, namely Preprocessing stage where knowledge base is loaded into reasoner, at this stage knowledge is transformed into reason's internal representation using several optimizations techniques. The second is Classification; here different named concepts are classified into different order using several optimizations. The final stage is Satisfiability where reasoner perform checking in order to decide problems for given couple of concepts.

3.2 Design specification

In the design specification process we suppose to describe all elements required for ontology design and gives the ability to conceptualize ideas of interested domain. There some 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.

3.2.1 General Structure of the domain Ontology

This ontology is developed for storing, linking concepts and data for diabetes diseases. The ontology contain information from six main domains, the first one is person domain presenting general information of patients such as age, gender and address. The second contains patient's vital sign measurement data including blood glucose measurement 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, and medication. Those recommendations are assigned to each patient based on blood glucose value.

We used with protégé tool for ontology design. 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, which we have mapped in protégé during ontology design Figure 3.2 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.

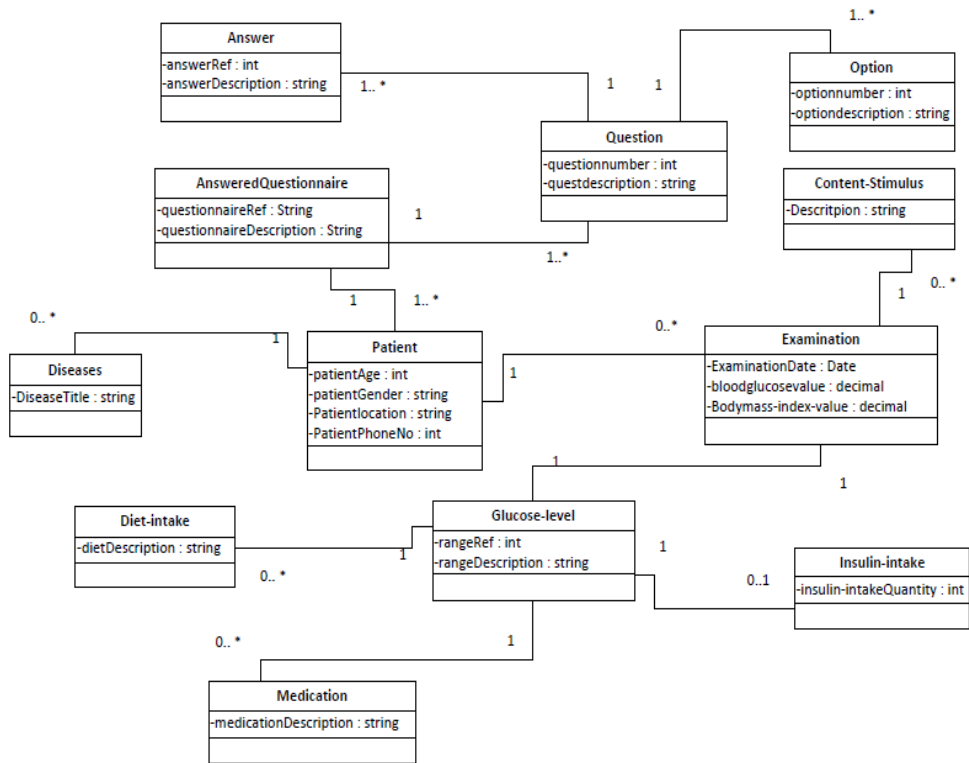


Figure: 3.2 General structure of ontology domain

3.2.2 Classes and Class Hierarchy

Within Protégé environment the whole picture of ontology domain are described into 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. For ontology design we use OWL language. Every OWL class is associated with a set of individual. In the next section we are going to explain the role of each class during our ontology as they presented in Figure 3.3 Within this project we have classifies the whole ontology into 6 main classes and 12 sub classes, as you can see from Figure 3.3.

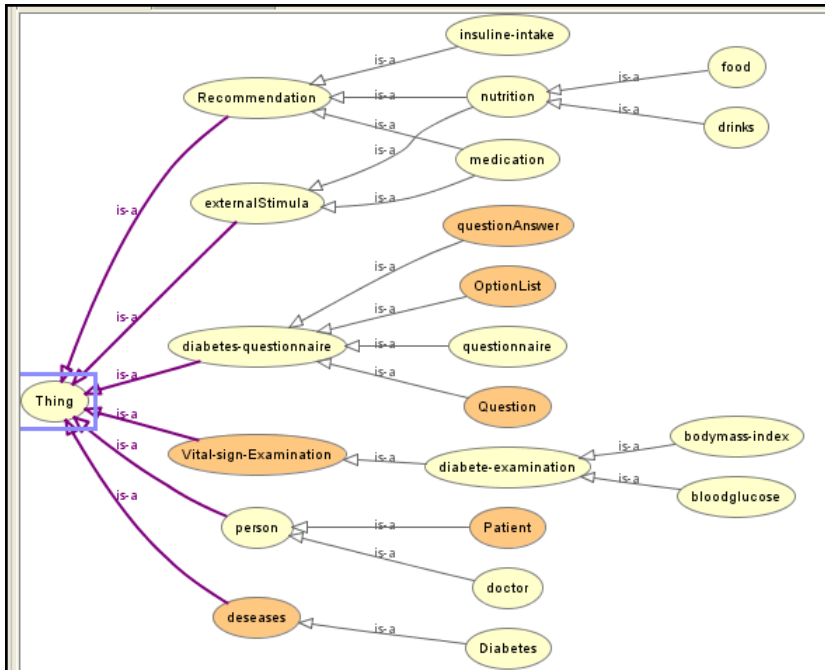


Figure: 3.3Classes and class hierarchy

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 such as patient name, address, gender, age.

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.

Vital sign measurement 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.

Questionnaire class describes the concept of diabetes questionnaire; an instance of this class is configured in order to detail a sequence of questions to be answered together after taking measurement indicating patient's feeling. Questionnaire will contain a list of questions and each question has set of option to be

selected as an answer. Individual of questionnaire is direct linked to each patient and a specific examination because a patient after having exam he must fill in a questionnaire.

A Sample questionnaire

Information from patient questionnaires is very important in vital sign measurement because it provide additional information about patient is health condition. Sample questionnaire presented in table 2 is derived from diabetic questionnaire available in [29]. We prefer to use it because it contains information related to diabetic vita sign monitoring such as regularity of medication intake, diabetes-related aspects of diet including foods, alcohol consumption, regularity of self-monitoring of blood glucose and physical activity. The questionnaire contains eight questions and all questions have same choice of option. The set of answers are provided from option list based on information described in each question.

Table 2: Diabetes questionnaire

Questions	Options
I check my blood sugar levels with care and attention	1.Applies to me very much 2.Applies to me to a consider-able degree 3.Applies to me to some degree 4.Does not apply to
The food I choose to eat makes it easy to achieve optimal blood sugar levels	
I keep all doctors’ appointments recommended for my diabetes treatment.	
I take my diabetes medication (e. g. insulin, tablets) as prescribed.	
Occasionally I eat lots of sweets or other foods rich in carbohydrates	
I record my blood sugar levels regularly antibiotics or steroids at the moment.	
I do regular physical activity to achieve optimal blood sugar levels	
I strictly follow the dietary recommendations given by my doctor or diabetes specialist	

External-stimulus Class is a superclass of nutrition, medication classes, these classes provide information called context data. Those are the factors that can influence the variation of blood sugar of diabetic patient both negatively and positively including drugs, foods and drinks. The individuals of this class are linked to Blood glucose test indicating which factor among them has influence variation of Blood glucose.

- Food quantity: indicates the quantity of a certain type of food consumed by the patient. Each
- Instance of acquired food data will be expressed by a numerical value and the units in grams

- Liquid quantity: an instance of this class will be used to ask the patient about the quantity of liquids he or she usually drinks. It can be general or restricted to a certain type of liquid each instance of acquired liquid data will be expressed by a numerical value and the units in liters.
- Medication: an instance of the medication class will be used to ask and the patient about the type of medication taken.

Recommendation Class is a superclass 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.

We provide sample glucose insulin correlation balancing concentration of sugar in the blood stream. Table 4 shows a set of glucose value and the corresponding Insulin-intake. Those values are obtained using android smartphone application designed for blood glucose regulation; application is free downloaded from internet.

Table 3: Glucose –insulin correlation

Glucose value in Mmol/l	Insulin intake in pmol/l
10	300
9	200
8	200
7-7.5	100
4-6	50
3-3.9	30

3.2.3 Sample data input

Our sample data was inputted into protégé environment. In order to clarify the ontology content we provide a table which shows different classes individuals and data value that we have worked with. Table 5 shows eight patients individuals and three data type properties describing characteristics of each patient including patient's age, genders, address and their phone numbers. The second part of the table shows 10 blood glucose individuals of vital sign examination, their three data type properties including blood glucose value expressed mmol/l, date at which examination have took place and body mass-index-value.

Table 4: Sample data

Individuals	Data value		
patient class	HasAge	Hasgender	Haslocation
Ange	30	female	Grimstad
Oreste	57	male	Grimstad
Tian	56	female	Grimstad
Faustin	45	male	Arendal
John	22	male	Lillesand
Joy	47	female	Arendal
Diabetes-exam class	HasExaminationDate	HasGlucoseValue	HasBodyMassIndexValue
BloodglucoseExam1	22/2/2014	3 mmol/l	29 kg/m ²
BloodglucoseExam2	3/2/2014	8 mmol/l	25.5 kg/m ²
BloodglucoseExam3	4/2/2014	4 mmol/l	19.2 kg/m ²
BloodglucoseExam4	6/2/2014	4.5 mmol/l	17.8 kg/m ²
BloodglucoseExam5	8/2/2014	5 mmol/l	23 kg/m ²
BloodglucoseExam6	10/2/2014	5.5 mmol/l	21 kg/m ²
BloodglucoseExam7	12/2/2014	6.5 mmol/l	25 kg/m ²
BloodglucoseExam8	1/3/2014	7.7 mmol/l	28.3 kg/m ²
BloodglucoseExam9	20/3/2014	7mmol/l	25

3.2.4 Object Properties

In Ontology object Properties describe how classes are related to each other's same domain by providing relationship between individuals of those classes. Each object property has range and domain class. The object properties used in this project are mentioned in the figure below and we have briefly described some of them.

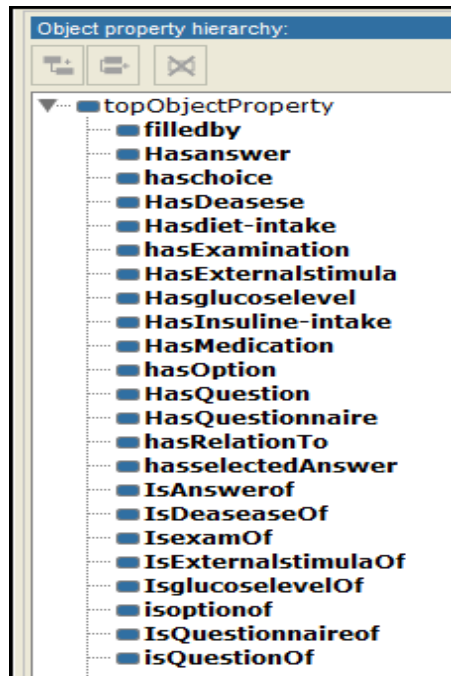


Figure: 3.4 object properties

HasDesease is the object property for individuals of class patient. It provides the relationship between individual of class patient and disease. The domain of this property is patient and the range is disease, for a person to be called patient she must has a diseases use of this property are shown in Figure 3.4.



Figure: 3.5 HasDesease

HasExamination is declared as object property for individuals of class patient. It provides the relationship between individual patient and examination class. The domain of this property is patient and the range is an examination and his inverse property is IsexamOf figure 3.6 show how this property works.

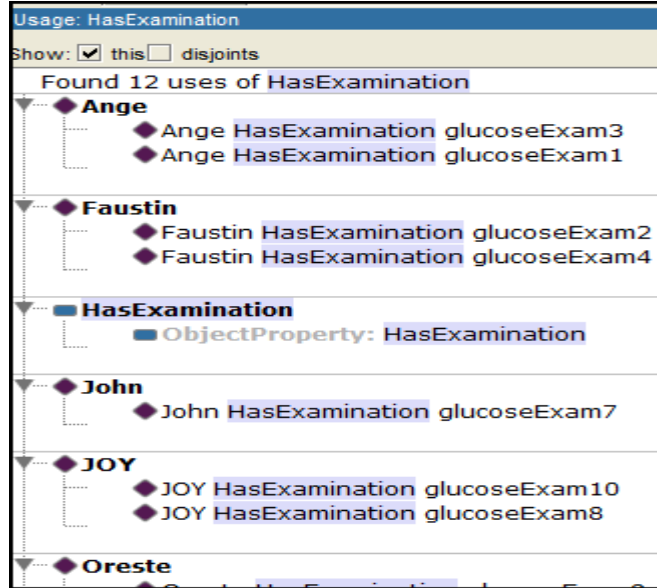


Figure:3.6 HasExamination.

HasQuestionnaire is the object property for individuals of class patient. It provides the relationship between individual of class patient and Questionnaire. The domain of this property is patient and the range is Questionnaire and it has an inverse called isQuestionnaireOf. As you can see from figure 3.7 below, it links patient individual and the corresponding questionnaire.

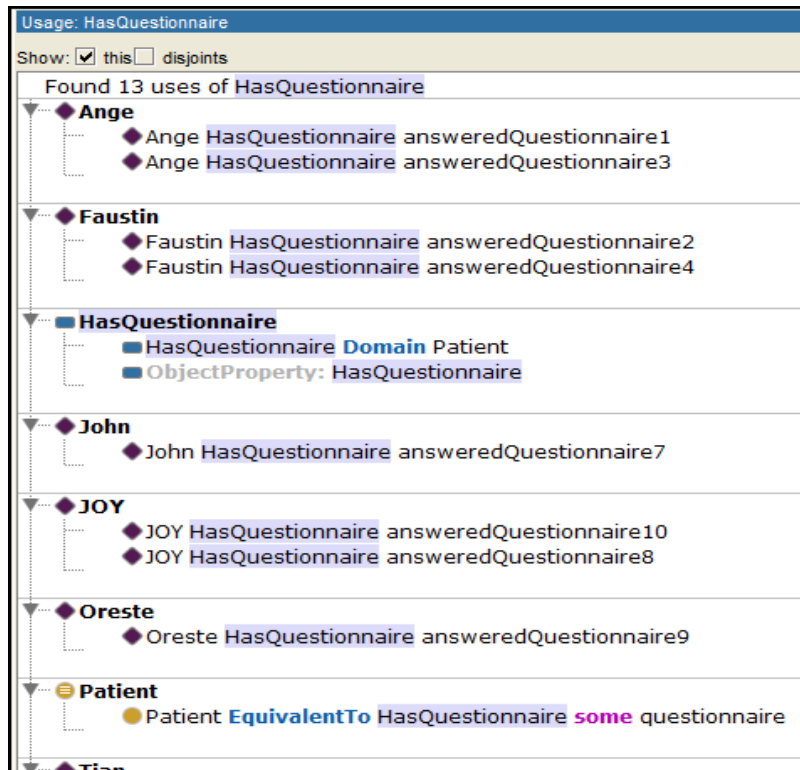


Figure:3.7 HasQuestionnaire.

HasQuestion

HasQuestion is the object property for individuals of class Questionnaire. It provides the relationship between individual of class Questionnaire and class Question and has inverse of isQuestionOf the general usage of this property is presented in figure 3.8. The domain of this property is Questionnaire and it ranges to Question.

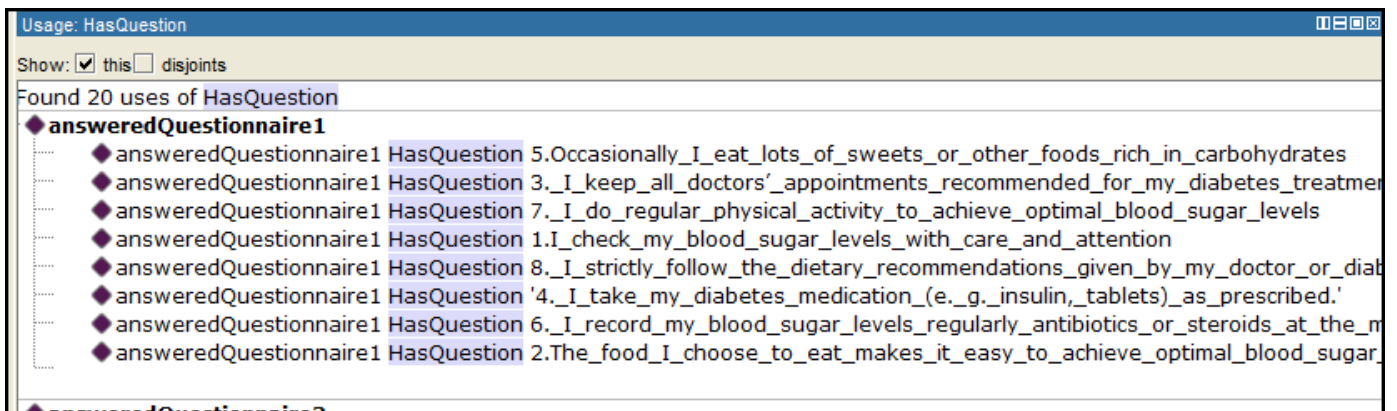


Figure: 3.8 HasQuestion properties

Hasglucoselevel is object property of class glucose level, it provides relation between glucose-exam and corresponding glucose level depend their blood sugar value. The domain of the property is blood glucose-exam and the range is glucose level figure 3.9 shows relation blood glucose exam with the corresponding glucose level.

Usage	Description
Usage: Hasglucoselevel	
Show: <input checked="" type="checkbox"/> this <input type="checkbox"/> disjoints	
Found 14 uses of Hasglucoselevel	
glucoseExam1	glucoseExam1 Hasglucoselevel lowglucoselevel
glucoseExam10	glucoseExam10 Hasglucoselevel highglucoselevel
glucoseExam2	glucoseExam2 Hasglucoselevel highglucoselevel
glucoseExam3	glucoseExam3 Hasglucoselevel lowglucoselevel
glucoseExam4	glucoseExam4 Hasglucoselevel NormalGlucoseLevel
glucoseExam5	glucoseExam5 Hasglucoselevel NormalGlucoseLevel
glucoseExam6	glucoseExam6 Hasglucoselevel NormalGlucoseLevel
glucoseExam7	glucoseExam7 Hasglucoselevel highglucoselevel
glucoseExam8	glucoseExam8 Hasglucoselevel highglucoselevel

Figure: 3.9 HasGlucoselevel.

HasRecommendation is 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** is 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.

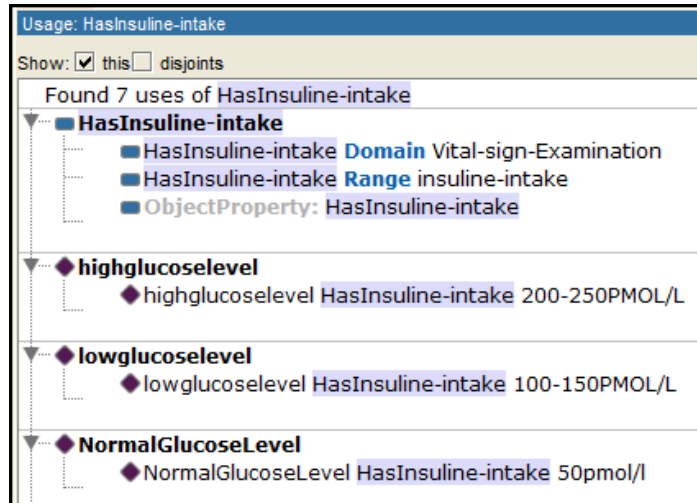


Figure: 3.10 HasInsulin-intake

- **HasDiet** is object property of individuals of blood-glucose-examination class. It provides the relationship between individual of blood-glucose-Examination and Diet-intake. The domain of this property is blood-pressure-examination and the range is Diet-intake.

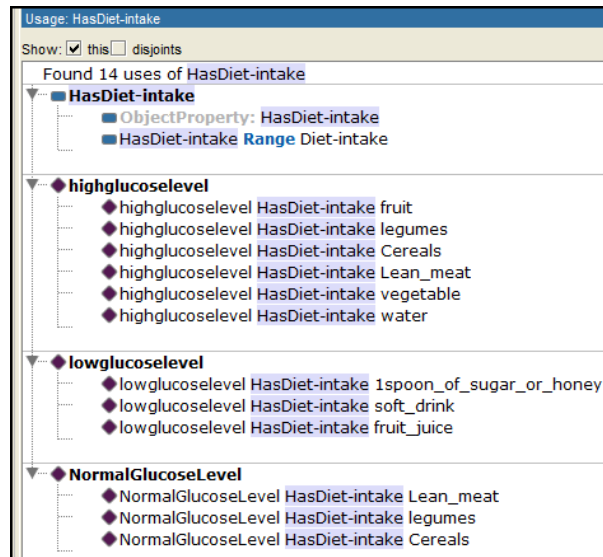


Figure: 3.11 HasDiet property usage.

- **Hasmedication** is object property of individuals of glucose level class. It provides the relationship between individual of glucose level and Diet-intake. The domain of this property is glucose level and the range is Diet-intake.

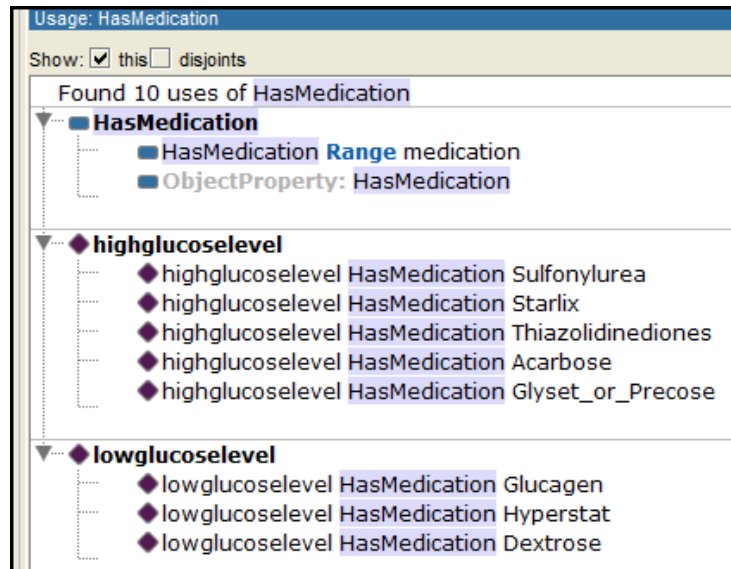


Figure: 3.12 HasMedication

3.2.5 Data properties

Data properties link individual of class within a domain to its 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 a fundamental role when describing individual's characteristics and enabling data values to be saved. The data properties used in our project are presented in figure 3.13.

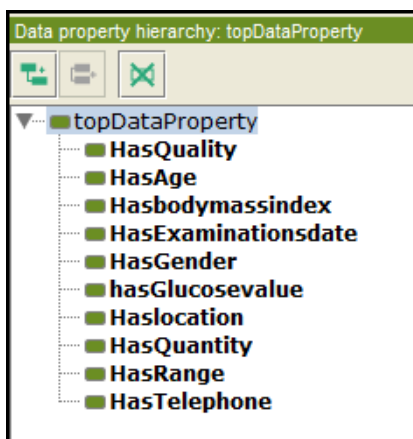


Figure: 3.13 Data Properties

HasAge, Haslocation, HasGender and HasTelephone are Data type property used for providing additional information to individual of patient class in order to distinguish them. Each data type has its own

data format. Age and phone number should have integer value, while address and gender have a string value. In the figure below we have describe some data properties of individual called Ange.



Figure: 3.14 Some Data Properties of Patient

HasBodymass-index is 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. The table 3.5 classifies risk of type 2 diabetes according to body mass index value.

Table 5: Body mass index classification

Classification	Body Mass Index (BMI)	Risk of Diabetes
Underweight Average	< 18.5 kg/m ²	Low risk
Normal range	18.5–24.9 kg/m ²	Moderate
Overweight	≥25 kg/m ²	Increased
Obese class 1	30.0–34.9 kg/m ²	Severe
Obese class 3	≥ 40.0 kg/m ²	Very Severe

HasGlucosevalue is 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.

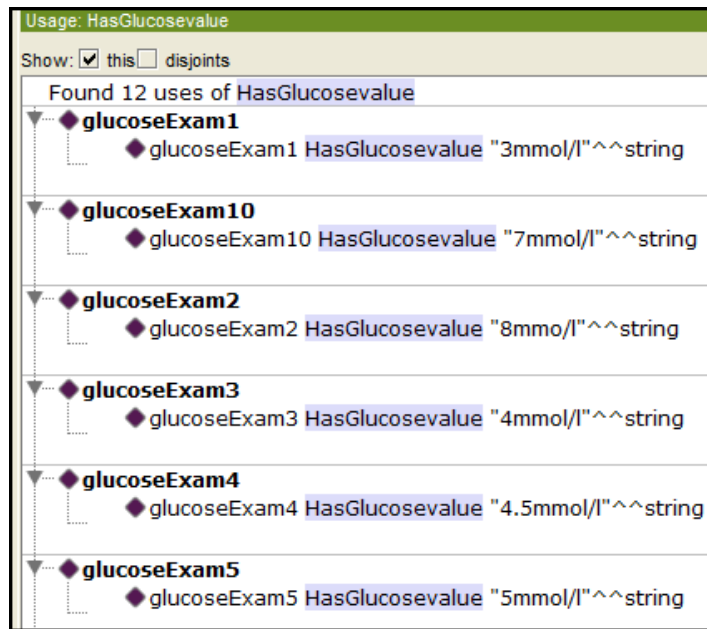


Figure: 3.15 HasGlucosevalue

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.

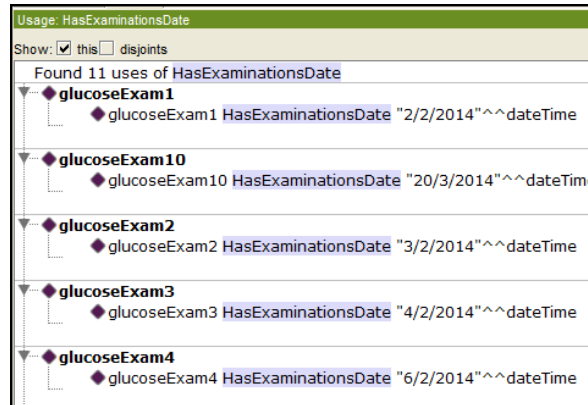


Figure: 3.16: HasExaminationDate property

3.2.6 Instances of classes

The axioms of instances are set of individual associated to the same object and data properties. Object and Data property of instance are common for all individuals of the same class. The individual's difference is based data properties describing individual's characteristics. Here we are going to describe all the properties associated to individuals of each class

Instance of patient

Instance of patient class are those individuals having same properties describing individuals of patient class. We have described 6 patients with different properties relevant for the working domain.

Faustin

Faustin is instance of class patient having three object properties that link it to other instance and four data properties describing characteristics of each instance. One links the individual of patient to individual of diseases, for a person to be a patient she must have some sicknesses. The second property links Faustin to instance bloodglucoseexamination class, Patient with diabetics' diseases has take blood glucose measurement regularly to insure their health status. The third property links Faustin to instance of the questionnaire, each patient have to fill in a questionnaire in order to provide some additional information. In the figure below we describe all Faustin's 'properties

Property assertions: Faustin	
Object property assertions +	
HasExamination	glucoseExam2
HasQuestionnaire	answeredQuestionnaire2
HasQuestionnaire	answeredQuestionnaire4
HasDeasese	diabete
HasExamination	glucoseExam4
Data property assertions +	
HasTelephone	9706256
Haslocation	"arendal"^^string
HasGender	"male"^^string
HasAge	"45"^^int

Figure: 3.17 Patient's properties

Instance of Examination

Instance of examination are set of individuals with same properties describing examination class. We provided 10 blood glucose examinations individuals where one patient can have more than 1 blood glucose test in different days. Here we are going to describe all properties associated to one instance of examination class called glucoseExam1.

GlucoseExam1

GlucoseExam1 is an Instance of blood-glucose-examination class with different object properties that link it to instances of others classes. Hasglucoselevel links the glucoseexam1 to individual of glucose level. The second one links instances of glucoseExam1 to instance eternal-stimuli class in order to investigate the factors that have influenced glucose level variation. In this case Isexamof property link glucoseExam1 to individual Ange, HasExternalstimula properties link bloodglucoseExam1 of 6.5mmol/l with stress as external factor, from this relation we can understand that stress is the only cause of this high glucose level. GlucoseExam1 has two data properties describing GlucoseExam1's characteristics including HasGlucosevalue with value 6.5mmol/l, Hasexaminationtime Of 2/2/2014 and Hasbodymassindex of 29kg/m².

Property assertions: glucoseExam1	
Object property assertions +	
■	HasExternalstimula Food
■	HasGlucoselevel lowglucoselevel
■	hasRelationTo answeredQuestionnaire1
■	IsexamOf Ange
Data property assertions +	
■	Hasbodymassindex 29.0f
■	HasExaminationsDate "2/2/2014"^^dateTime
■	HasGlucosevalue "3mmol/l"^^string

Figure: 3.18 Examination's properties

Instance of AnsweredQuestionnaire

Answeredquestionnaire is class which includes all kinds of answered questionnaires of each patient, containing formation about patient's felling. We have work only with 10 answered questionnaires individuals and each questionnaire contain 8 questions, where each one has a single answer. We took one of the answeredquestionnaire individual namely; Answeredquestionnaire1 it properties.

Answeredquestionnaire1

Answeredquestionnaire1 has relation to patient who filled it, the second property link it to the corresponding examination, the third link Answeredquestionnaire1 to a set of question and the corresponding answer Figure 3.19 shows questionnaire linked to a set of question and each question have answers .

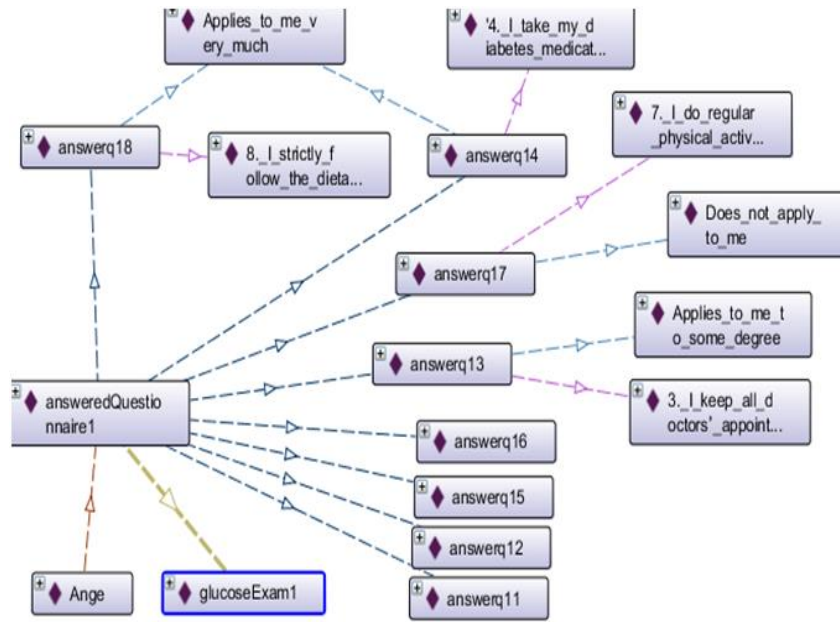


Figure: 3.19 RDF graph for AnsweredQuestionnaire1

Instance of glucose level

In blood glucose measurement is necessary to classifies patient by their blood glucose value. From medical perspective blood glucose value should be in the following ranges: for low blood glucose level the value should be less than 4mmol/l, normal level value should be between (4-6.9) mmol/l, lastly high blood glucose level the glucose value >7mmol/l.

Instance of glucose level are set of individuals having the same properties describing glucose level concept. Those individuals classify each blood glucose exam into three different levels namely, low, normal and high.

Highglucoselevel

Highglucoselevel is an Instance of glucose level class having four object properties that link them to instances of others classes. In this project HasDiet property links Highglucoselevel to individuals of Diet intake such as vegetables, fruit, water, cereals. Hasinsulin link Highglucoselevel to individual of insulin-intake class 200-250pmmol/l. Hasmedication link Highglucoselevel to individual of medication as recommendation corresponding Highglucoselevel result; this will insure patient blood glucose regulation. Lastly Isglucoselevelof property link Highglucoselevel to different exams with glucose value greater than 7mmol/l as you can see in figure 3.20.

Property assertions: highglucoselevel	
Object property assertions +	
<input checked="" type="checkbox"/>	HasInsuline-intake 200-250PMOL/L
<input checked="" type="checkbox"/>	Hasdiet-intake Cereals
<input checked="" type="checkbox"/>	Hasdiet-intake vegetable
<input checked="" type="checkbox"/>	Hasdiet-intake Lean_meat
<input checked="" type="checkbox"/>	Hasdiet-intake legumes
<input checked="" type="checkbox"/>	IsglucoselevelOf glucoseExam10
<input checked="" type="checkbox"/>	HasMedication Sulfonylurea
<input checked="" type="checkbox"/>	HasMedication Starlix
<input checked="" type="checkbox"/>	HasMedication Thiazolidinediones
<input checked="" type="checkbox"/>	IsglucoselevelOf glucoseExam9
<input checked="" type="checkbox"/>	IsglucoselevelOf glucoseExam8
<input checked="" type="checkbox"/>	HasMedication Acarbose
<input checked="" type="checkbox"/>	IsglucoselevelOf glucoseExam4
<input checked="" type="checkbox"/>	HasMedication Glyset_or_Precose
<input checked="" type="checkbox"/>	Hasdiet-intake fruit
<input checked="" type="checkbox"/>	Hasdiet-intake water
Data property assertions +	
<input checked="" type="checkbox"/>	HasRange "7-20Mmol"^^string

Figure:3.20 Glucose level's properties.

Instance of recommendation

Instance of recommendation are set of individuals with same properties describing recommendation class. Those individuals are used to provide feedback recommendation based patient blood glucose level. Those individuals include insulin, diet intake and medication. Those recommendations can help patient to regulate his or her blood sugar level. .

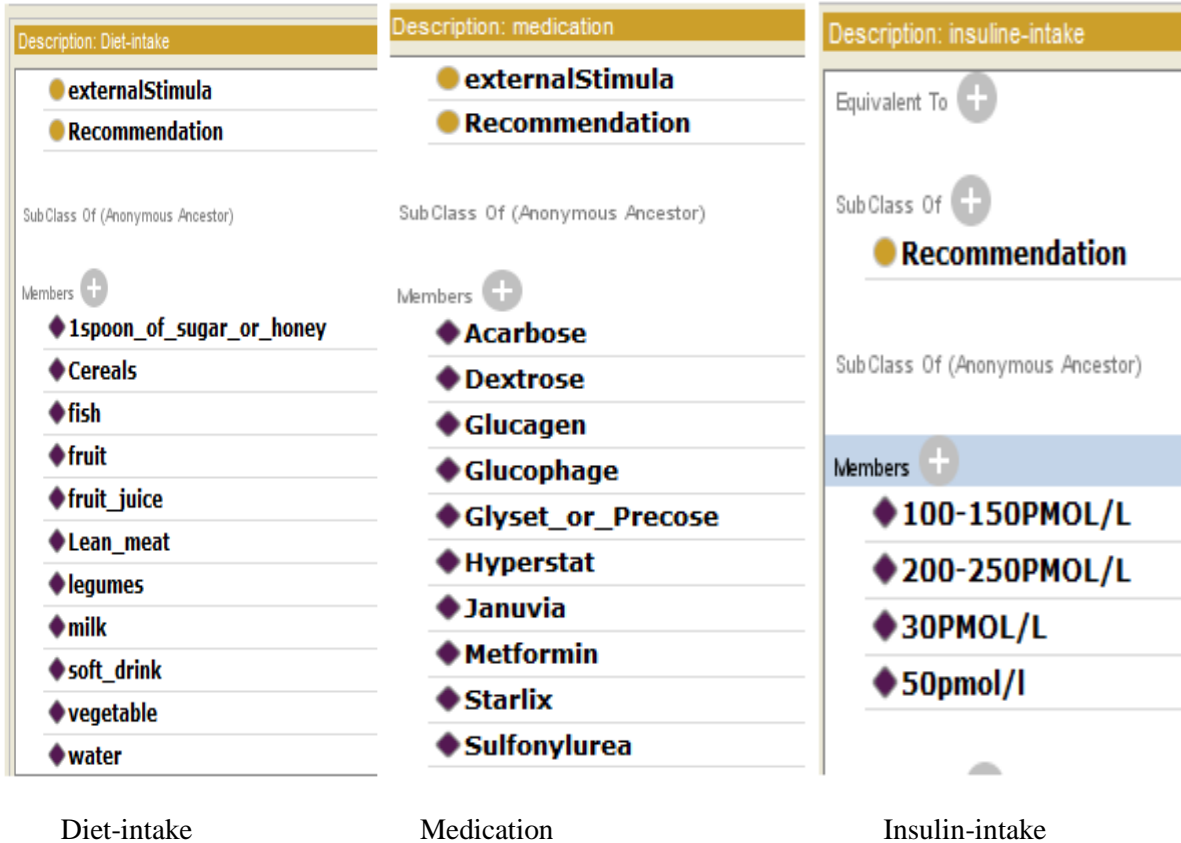


Figure: 3.21 instance of recommendation

4 Result and verification

This part of the thesis presents visualization and validation of the designed ontology results. We used protégé onto Graph Plug-in tool and UML object diagram for visualization of the result. For ontology verification we used SPARQL queries to retrieve and manipulate data from the ontology repository. Into this work ontology knowledge is developed based on presence of numbers of interrelated factors. We classified them into different domains and each domain interacts with others in relation manner.

4.1 Visualization of the ontology

Onto Graph is used to display the content of the developed model into graphical ways showing all the relationship between instances. Visualization explains the general structure of the ontology and relationships existing among entities. Firstly we used graphical presentation to display information available within the diabetes disease management ontology. Secondly we used UML object diagram to provide ideal picture of our model content. Object diagrams describe the static structure of a system and they are used to test the accuracy of class diagrams.

- An example of the diabetic patient ontology visualization with ontoGraph plug-in tool is illustrated in Figure 4.1.

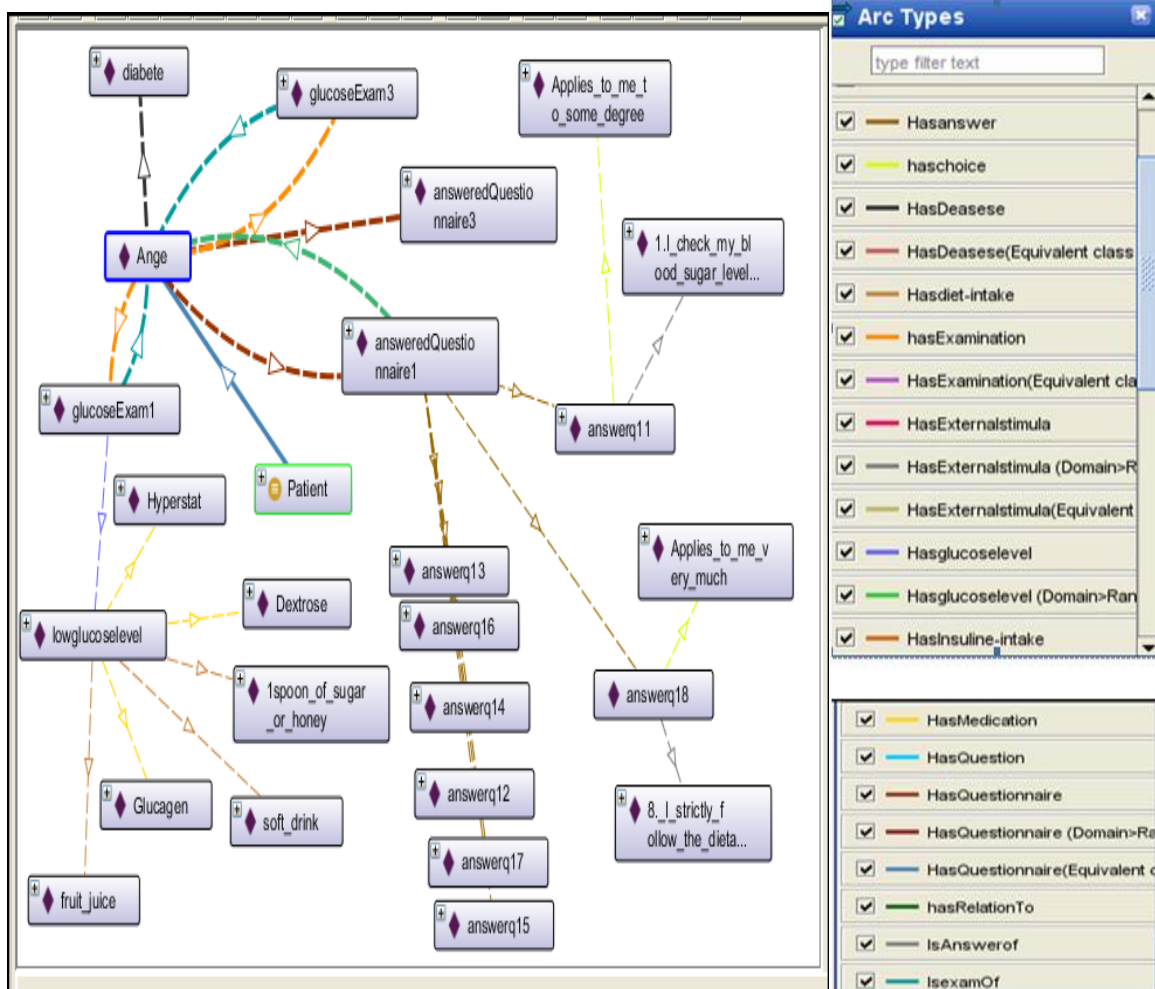


Figure: 4.1 Ontology Visualization using ontoGraph plug-in tools.

Figure 4.1 example shows the general understanding of the ontology content, we took a sample of patient instance “ANGE”; we display information associated to her. As you can see with aid of ontoGraph plug-in tools all individual who are linked to her displayed in relation manner.

- Figure 4.2 illustrate the content of ontology using different objects (instances). In this sample example we show some relation related to two objects of patient class. As you can see relationships between different individuals in our ontology domain are displayed, data value of each object are also displayed.

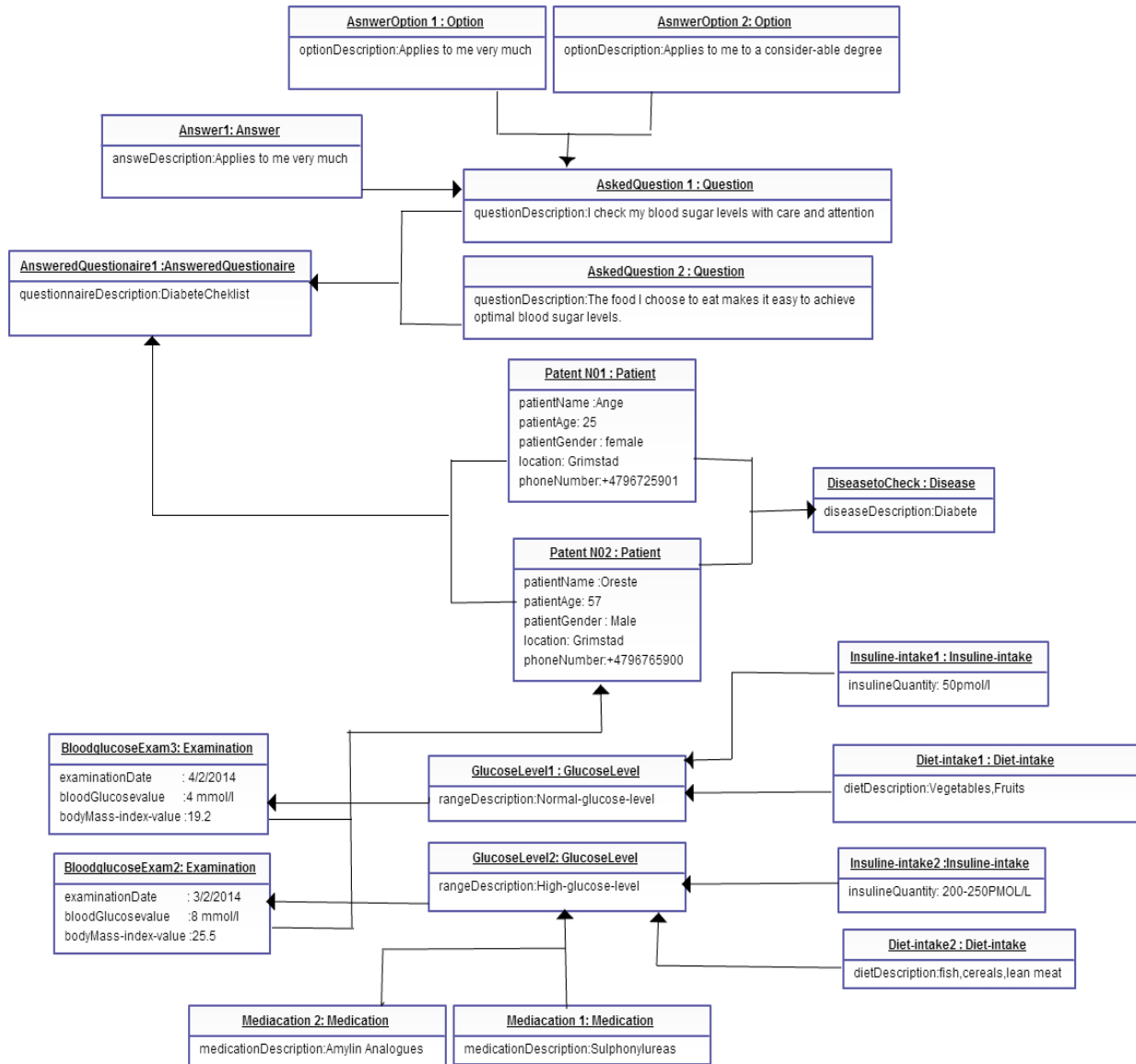


Figure: 4.2 Ontology Visualization using object diagram

4.2 Information Retrieval and Verification

Validation is important step in system development. It used for testing system's functionalities by checking whether the model satisfies the user requirement. During ontology development Querying is important step, it used as testing tool in order to know how well the ontology is answering to the question asked by the user. Information stored inside the ontology can be retrieved to be used for further Analysis, the results are obtained using a query tools. In protégé there are two types of Query systems SPARQ and DL query. In our project we prefer to used Simple Protocol and RDF Query Language (SPARQ) to extract Information from ontology. SPARQL is a query language which can be used to retrieve and manipulate data stored in Resource Description Framework (RDF) format. In SPARQL each query has SPARQL pattern part consisting of subject, predicate and object.

Information Retrieval

1. Query about Patient's general description

In this query we retrieved patient personal description, that information are patient name, his age, gender and address as location, such information provides the overview about patients and can be used for patient's statistic as it is displayed in figure 4.3.

We provide some explanations of the first query in order facilitate the understanding of others query

- PREFIX A :< <http://www.semanticweb.org/user/ontologies/2014/1/thes#>> :indicate the URL name of the active ontology , prefix A is name of active ontology
- SELECT is SPARQL query used to select data Rdf data from dataset
- Patient: subject
- ? : Is used to indicate Variables of the value to be returned such as Patient, age and gender
- HasAge, Hasgender, Haslocation : predicates
- Age, gender : objects

```

PREFIX A:<http://www.semanticweb.org/user/ontologies/2014/1/thess#>
SELECT ?Patient?Age?Gender
WHERE {?Patient A:HasAge?Age.?Patient A:HasGender?Gender.}

```

Patient	Age	Gender
Ange	"30"^^<http://www.w3.org/2001/XMLSchema#int>	"female"^^<http://www.w3.org/2001/XMLSchema#string>
JOY	"47"^^<http://www.w3.org/2001/XMLSchema#int>	"female"^^<http://www.w3.org/2001/XMLSchema#string>
Oreste	"57"^^<http://www.w3.org/2001/XMLSchema#int>	"male"^^<http://www.w3.org/2001/XMLSchema#string>
John	"22"^^<http://www.w3.org/2001/XMLSchema#int>	"male"^^<http://www.w3.org/2001/XMLSchema#string>
Faustin	"45"^^<http://www.w3.org/2001/XMLSchema#int>	"male"^^<http://www.w3.org/2001/XMLSchema#string>
Tian	"56"^^<http://www.w3.org/2001/XMLSchema#int>	"female"^^<http://www.w3.org/2001/XMLSchema#string>

Figure: 4.3 Patient's general description query

2. Query about patient's blood glucose test history

From this figure we set up a query asking to display patient and their blood glucose value and body mass index value at different time, in order to compare their blood sugar level with the body mass index. The information displayed in this query can give relevant information about patient health status and based on those information it can be easy to evaluate each patient.

```

PREFIX A:<http://www.semanticweb.org/user/ontologies/2014/1/thess#>
SELECT ?Patient?Glucosevalue?BodyMassIndex
WHERE {?Patient A:HasExamination ?diabeteExamination.
?diabeteExamination A:HasBodyMassIndex?BodyMassIndex.
?diabeteExamination A:HasGlucosevalue?Glucosevalue}

```

Patient	Glucosevalue	BodyMassIndex
John	"6.5mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"25.0"^^<http://www.w3.org/2001/XMLSchema#float>
Faustin	"4.5mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"17.8"^^<http://www.w3.org/2001/XMLSchema#float>
Tian	"5mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"23.0"^^<http://www.w3.org/2001/XMLSchema#float>
Ange	"4mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"19.2"^^<http://www.w3.org/2001/XMLSchema#float>
JOY	"7mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"25.0"^^<http://www.w3.org/2001/XMLSchema#float>
Oreste	"6.5mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"30.1"^^<http://www.w3.org/2001/XMLSchema#float>
Faustin	"8mmo/l"^^<http://www.w3.org/2001/XMLSchema#string>	"25.5"^^<http://www.w3.org/2001/XMLSchema#float>
Ange	"3mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"29.0"^^<http://www.w3.org/2001/XMLSchema#float>
JOY	"7.7mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"28.3"^^<http://www.w3.org/2001/XMLSchema#float>
Tian	"5.5mmol/l"^^<http://www.w3.org/2001/XMLSchema#string>	"21.0"^^<http://www.w3.org/2001/XMLSchema#float>

Figure: 4.4 blood glucose test history query

3. Query about patient's answered questionnaire and related blood glucose test

In this query to know which patient's blood test number and the corresponding answered questionnaire, because for each blood test patient have to fill in a questionnaire providing additional information. Those displayed information help us to know how many examination have been taken, the number of questionnaire that have been filled and the date at which those action have took place. Based on that information we can have the much information about patient's health status by looking into patient's blood glucose value, and compare them to information provided into questionnaire.

```
PREFIX A:<http://www.semanticweb.org/user/ontologies/2014/1/thess#>
```

```
SELECT ?Patient ?AnsweredQuestionnaire ?GlucoseTestNumber?ExamDate
WHERE (?Patient A:HasQuestionnaire?AnsweredQuestionnaire.
?AnsweredQuestionnaire A:hasRelationTo?GlucoseTestNumber.?GlucoseTestNumber A:HasExaminationsdate?ExamDate.)
```

Patient	AnsweredQuestionnaire	GlucoseTestNumber	ExamDate
Faustin	answeredQuestionnaire4	glucoseExam4	"6/2/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Oreste	answeredQuestionnaire9	glucoseExam9	"10/3/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Ange	answeredQuestionnaire3	glucoseExam3	"4/2/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
JOY	answeredQuestionnaire8	glucoseExam8	"1/3/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Tian	answeredQuestionnaire5	glucoseExam5	"8/2/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Ange	answeredQuestionnaire1	glucoseExam2	"3/2/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Tian	answeredQuestionnaire6	glucoseExam6	"10/2/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
John	answeredQuestionnaire7	glucoseExam7	"12/2/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Faustin	answeredQuestionnaire2	glucoseExam2	"3/2/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
JOY	answeredQuestionnaire10	glucoseExam10	"20/3/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>

Figure: 4.5 questionnaire and related blood glucose test

4. Query about how many examinations have been taken by patient called Ange?

Here want to know how many blood glucose tests have been taken by a specific patient, order to understand how often the patient is aware on his diseases management.

```
PREFIX A:<http://www.semanticweb.org/user/ontologies/2014/1/thess#>
```

```
SELECT (COUNT(?diabeteExamination) AS ?howmany)
WHERE {A:Ange A:hasExamination ?diabeteExamination.}
```

howmany
"2"^^<http://www.w3.org/2001/XMLSchema#integer>

Figure: 4.6 Query about Examinations

5. Query about questions and answers provided in questionnaire1

We just want to know the answer that have been provided into questionnaire number one Based on those answers the healthcare provides can understand patient's view.

```

PREFIX A:<http://www.semanticweb.org/user/ontologies/2014/1/thess#>

SELECT ?Question?Answer

WHERE {A:answeredQuestionnaire1 A:Hasanswer?Q.?Q A:IsAnswerof ?Question.?Q:A:haschoice ?Answer.}

```

questions	Answer
2.The_food_I_choose_to_eat_makes_it_easy_to_achieve_optimal_blood_sugar_levels	Applies_to_me_very_much
5.Occasionally_I_eat_lots_of_sweets_or_other_foods_rich_in_carbohydrates	Applies_to_me_to_a_consider-able_degree
3._I_strictly_follow_the_dietary_recommendations_given_by_my_doctor_or_diabetes_specialist	Applies_to_me_very_much
3._I_keep_all_doctors'_appointments_recommended_for_my_diabetes_treatment.	Applies_to_me_to_some_degree
1.I_check_my_blood_sugar_levels_with_care_and_attention	Applies_to_me_to_some_degree
5._I_record_my_blood_sugar_levels_regularly_antibiotics_or_steroids_at_the_moment	Applies_to_me_to_some_degree
7._I_do_regular_physical_activity_to_achieve_optimal_blood_sugar_levels	Does_not_apply_to_me
4._I_take_my_diabetes_medication_(e._g._insulin_tablets)_as_prescribed.'	Applies_to_me_very_much

Figure: 4.7 query about answer from questionnaire

6. Query about high glucose level's medication recommendation

This query helps us to know different medications reserved for patient with high blood glucose level .

```

PREFIX A:<http://www.semanticweb.org/user/ontologies/2014/1/thess#>
SELECT ?medication
WHERE {A:highglucoselevel A:HasMedication?medication}

```

medication
Acarbose
Thiazolidinediones
Glyset_or_Precose
Sulfonylurea
Starlix
Metformin

Figure: 4.8 Medication for high glucose level

7. Query about food recommendation for a specific patient (oreste)

In our ontology we have data about three different recommendations (diet, medication, insulin) and those recommendations are classified into two ranges, one is for patient with low glucose level, and another is for people with high glucose level and normal, so from this query we want to get diet-intake recommendation for a patient called Oreste.

```
PREFIX A: <http://www.semanticweb.org/user/ontologies/2014/1/thess#>
SELECT ?Diet
WHERE {A:Oreste A:hasExamination?diabeteExamination
.?diabeteExamination A:Hasglucoselevel?glucoselevel.?glucoselevel A:Hasdiet-intake?Diet}
```

Diet
legumes
Cereals
vegetable
fruit
water
Lean_meat

Figure: 4.9 Food recommendations for a specific patient

8. Query about patients who have “Glucophage” as medication recommendation

In the model we have provide different medication recommendation based on different level of glucose value, in this query we want to retrieve patients who need medical recommendation called “Glucophage”

```
PREFIX A: <http://www.semanticweb.org/user/ontologies/2014/1/thess#>
SELECT DISTINCT ?patient
WHERE {?patient A:hasExamination?diabeteExamination
.?diabeteExamination A:Hasglucoselevel?glucoselevel.?glucoselevel A:HasMedication A:Glucophage}
```

patient
Faustin
Ange
John

Figure: 4.10 Query about patients who need glucophage medication

9. Query about insulin intake for patient with normal glucose level

Information provided into query, tell us what quantity of insulin a patient with a normal glucose level can take.

PREFIX A:<http://www.semanticweb.org/user/ontologies/2014/1/thes#>	
SELECT ?Insulin	
WHERE {A:NormalGlucoseLevel A:HasInsulinIntake ?Insulin.}	
	Insulin
50pmol/l	

Figure: 4.11 Insulin intake for patient with normal glucose level

5 Discussion

In this thesis we have developed ontology for collecting information required in home diabetes disease supervision. The ontology model contains information from six domains include person description, vital-sign measurement, questionnaires, context-stimulus and medical recommendation. In the development process we implement all the relationship between concepts and setting up some logical rules. After ontology design we have come up with ontology capable of collecting information from heterogeneous sources including personal information (age, gender, address), Patient blood glucose data (blood glucose value, examination date, body mass index), information from patient questionnaires explaining in detail patient's health situation, in the end patient's recommendation including diet, insulin and medication intake are also collected based actual glucose evaluation.

The solution proposed in this thesis can be used in the design of personalised system to enhance patient supervision in term of data sharing. The developed ontology provides three solutions, it can easily reuse within others ontology based medical applications; the ontology can collect and share data from different sources and generate recommendation (diet, insulin and medication) for diabetic patient. Due to limited project time, we developed ontology for home diabetes management; the same approach can be extended to other diseases. In additional ontology knowledge is accessed through Protégé environment, so the ontology can be extended by developing user interface for end users.

We used protégé-owl editor tool for ontology implementation, because it is easy to learn and use, they are others alternatives tools and languages that can be used for ontology development including Onto Edit, Web protégé and TopBraid Composer. We also used SPARQL for setting up rule and retrieve information from ontology repository, they are others query languages such as; SquishQL, RDFPath, Versa, TRIPLE intended to provide a proper query for RDF documents.

6 Conclusion and Future work

6.1 Conclusion

Chronic diseases are ongoing, incurable illnesses which require long term treatment and supervision. Using ICT solution, people with such diseases can be supervised at their home place. Today many ontology based applications are deployed to enhance personalized system for chronic ill patient. But those applications don't provide medical recommendations during remote vital sign measurement.

The major task in this thesis was to develop ontology knowledge based that can be used in the management of diabetes. This ontology supports data sharing and can generate recommendations for diabetic patient in the remote supervision.

The developed ontology focused on conceptualization of the required concepts during remote vital sign measurement and makes them available at one place. The model is a Protégé-based knowledge representation used for linking concepts and data for diabetes 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 home patient self-management capability.

6.2 Future work

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:

- 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.
- Further development of end users interface using the Semantic web technology such as Jena, sesame or OWL API is important.

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Appendix

Sample of RDF Code

```
<?xml version="1.0"?>

<!DOCTYPE Ontology [
  <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
  <!ENTITY xml "http://www.w3.org/XML/1998/namespace" >
  <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
  <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" >
]>

<Ontology xmlns="http://www.w3.org/2002/07/owl#"
  xml:base="http://www.semanticweb.org/user/ontologies/2014/1/thess"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xml="http://www.w3.org/XML/1998/namespace"
  ontologyIRI="http://www.semanticweb.org/user/ontologies/2014/1/thess">
  <Prefix name=""
IRI="http://www.semanticweb.org/user/ontologies/2014/1/thess#"/>
  <Prefix name="owl" IRI="http://www.w3.org/2002/07/owl#"/>
  <Prefix name="rdf" IRI="http://www.w3.org/1999/02/22-rdf-syntax-ns#"/>
  <Prefix name="xsd" IRI="http://www.w3.org/2001/XMLSchema#"/>
  <Prefix name="rdfs" IRI="http://www.w3.org/2000/01/rdf-schema#"/>
  <Prefix name="thess"
IRI="http://www.semanticweb.org/user/ontologies/2014/1/thess#"/>
  <Prefix name="questionnaire"
IRI="http://www.semanticweb.org/questionnaire#"/>
  <Annotation>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <Literal datatypeIRI="&xsd:string"> Model used to improve patient
primary care at home</Literal>
  </Annotation>
  <Declaration>
    <Class abbreviatedIRI="questionnaire:OptionList"/>
  </Declaration>
  <Declaration>
    <Class abbreviatedIRI="questionnaire:Question"/>
  </Declaration>
  <Declaration>
    <Class abbreviatedIRI="questionnaire:questionAnswer"/>
  </Declaration>
  <Declaration>
    <Class abbreviatedIRI="questionnaire:questionnaire"/>
  </Declaration>
  <Declaration>
    <Class IRI="#Diabetes"/>
  </Declaration>
  <Declaration>
```

```

    <Class IRI="#Patient"/>
</Declaration>
<Declaration>
    <Class IRI="#Recommendation"/>
</Declaration>
<Declaration>
    <Class IRI="#Vital-sign-Examination"/>
</Declaration>
<Declaration>
    <Class IRI="#bloodglucose"/>
</Declaration>
<Declaration>
    <Class IRI="#bodymass-index"/>
</Declaration>
<Declaration>
    <Class IRI="#diseases"/>
</Declaration>
<Declaration>
    <Class IRI="#diabete-examination"/>
</Declaration>
<Declaration>
    <Class IRI="#diabetes-questionnaire"/>
</Declaration>
<Declaration>
    <Class IRI="#doctor"/>
</Declaration>
<Declaration>
    <Class IRI="#drinks"/>
</Declaration>
<Declaration>
    <Class IRI="#externalStimula"/>
</Declaration>
<Declaration>
    <Class IRI="#food"/>
</Declaration>
<Declaration>
    <Class IRI="#insuline-intake"/>
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    <Class IRI="#medication"/>
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<Declaration>
    <Class IRI="#nutrition"/>
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</Declaration>
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  <ObjectProperty IRI="#HasExamination"/>
</Declaration>
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  <ObjectProperty IRI="#HasExternalstimula"/>
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<Declaration>
  <ObjectProperty IRI="#HasMedication"/>
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abbreviatedIRI="questionnaire:4._I_take_my_diabetes_medication_(e._g._insulin,_
tablets)_as_prescribed."/>
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</Declaration>
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  <NamedIndividual IRI="#fruit"/>
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</Declaration>
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  </ObjectSomeValuesFrom>
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    <Class abbreviatedIRI="questionnaire:questionAnswer"/>
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    <Class abbreviatedIRI="questionnaire:questionnaire"/>
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    <Class abbreviatedIRI="questionnaire:questionAnswer"/>
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  <ObjectSomeValuesFrom>
    <ObjectProperty IRI="#HasExternalstimula"/>
    <Class IRI="#externalStimula"/>
  </ObjectSomeValuesFrom>
</EquivalentClasses>
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  <ObjectSomeValuesFrom>
    <ObjectProperty IRI="#HasInsuline-intake"/>
    <Class IRI="#insuline-intake"/>
  </ObjectSomeValuesFrom>
</EquivalentClasses>
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    <Class IRI="#Patient"/>
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  <Class IRI="#diabetes-questionnaire"/>
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  <Class IRI="#diabetes-questionnaire"/>
</SubClassOf>
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</SubClassOf>

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  <Class IRI="#diseases"/>
</SubClassOf>
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  <Class IRI="#Patient"/>
  <Class IRI="#person"/>
</SubClassOf>
<SubClassOf>
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  <Class IRI="#Vital-sign-Examination"/>
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  <Class IRI="#person"/>
</SubClassOf>
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  <Class IRI="#nutrition"/>
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<SubClassOf>
  <Class IRI="#insuline-intake"/>
  <Class IRI="#Recommendation"/>
</SubClassOf>
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  <Class IRI="#Recommendation"/>
</SubClassOf>
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  <ClassAssertion>
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    <NamedIndividual
abbreviatedIRI="questionnaire:2.The_food_I_choose_to_eat_makes_it_easy_to_achie
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abbreviatedIRI="questionnaire:4._I_take_my_diabetes_medication_(e._g._insulin,_
tablets)_as_prescribed."/>
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abbreviatedIRI="questionnaire:5.Occasionally_I_eat_lots_of_sweets_or_other_food
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    <NamedIndividual
abbreviatedIRI="questionnaire:6._I_record_my_blood_sugar_levels_regularly_antib
iotics_or_steroids_at_the_moment"/>
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  <ClassAssertion>
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    <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_to_a_consider-able_degree"/>
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  <ClassAssertion>
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    <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_very_much"/>
  </ClassAssertion>
  <ClassAssertion>
    <Class abbreviatedIRI="questionnaire:OptionList"/>
    <NamedIndividual abbreviatedIRI="questionnaire:Does_not_apply_to_me"/>
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  <NamedIndividual IRI="#1spoon_of_sugar_or_honey"/>
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  <NamedIndividual IRI="#200-250PMOL/L"/>
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>
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  <NamedIndividual
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tablets)_as_prescribed."/>
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<ObjectPropertyAssertion>
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  <ObjectPropertyAssertion>
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  </NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_to_a_consider-able_degree"/>
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    <ObjectPropertyAssertion>
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abbreviatedIRI="questionnaire:3._I_keep_all_doctorsâ€™_appointments_recommended
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    <ObjectPropertyAssertion>
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abbreviatedIRI="questionnaire:Applies_to_me_to_some_degree"/>
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    <ObjectPropertyAssertion>
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    <ObjectPropertyAssertion>
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tablets)_as_prescribed."/>
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        <NamedIndividual
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    <NamedIndividual IRI="#glucoseExam2"/>
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  <ObjectPropertyAssertion>
    <ObjectProperty IRI="#hasRelationTo"/>
    <NamedIndividual IRI="#answeredQuestionnaire3"/>
    <NamedIndividual IRI="#glucoseExam3"/>
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  <ObjectPropertyAssertion>
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    <NamedIndividual IRI="#answeredQuestionnaire4"/>
    <NamedIndividual IRI="#glucoseExam4"/>
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  <ObjectPropertyAssertion>
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    <NamedIndividual IRI="#answeredQuestionnaire5"/>
    <NamedIndividual IRI="#glucoseExam5"/>
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  <ObjectPropertyAssertion>
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    <NamedIndividual IRI="#answeredQuestionnaire6"/>
    <NamedIndividual IRI="#glucoseExam6"/>
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  <ObjectPropertyAssertion>
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    <NamedIndividual IRI="#answeredQuestionnaire7"/>
    <NamedIndividual IRI="#glucoseExam7"/>
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  <ObjectPropertyAssertion>
    <ObjectProperty IRI="#hasRelationTo"/>
    <NamedIndividual IRI="#answeredQuestionnaire8"/>
    <NamedIndividual IRI="#glucoseExam8"/>
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  <ObjectPropertyAssertion>

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        <ObjectProperty IRI="#hasRelationTo"/>
        <NamedIndividual IRI="#answeredQuestionnaire9"/>
        <NamedIndividual IRI="#glucoseExam9"/>
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        <ObjectProperty IRI="#IsAnswerof"/>
        <NamedIndividual IRI="#answerq11"/>
        <NamedIndividual
abbreviatedIRI="questionnaire:1.I_check_my_blood_sugar_levels_with_care_and_att
ention"/>
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    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#haschoice"/>
        <NamedIndividual IRI="#answerq11"/>
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abbreviatedIRI="questionnaire:Applies_to_me_to_some_degree"/>
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    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#IsAnswerof"/>
        <NamedIndividual IRI="#answerq12"/>
        <NamedIndividual
abbreviatedIRI="questionnaire:2.The_food_I_choose_to_eat_makes_it_easy_to_achie
ve_optimal_blood_sugar_levels"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#haschoice"/>
        <NamedIndividual IRI="#answerq12"/>
        <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_very_much"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#IsAnswerof"/>
        <NamedIndividual IRI="#answerq13"/>
        <NamedIndividual
abbreviatedIRI="questionnaire:3._I_keep_all_doctorsâ€™_appointments_recommended
_for_my_diabetes_treatment."/>
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    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#haschoice"/>
        <NamedIndividual IRI="#answerq13"/>
        <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_to_some_degree"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#IsAnswerof"/>
        <NamedIndividual IRI="#answerq14"/>
        <NamedIndividual
abbreviatedIRI="questionnaire:4._I_take_my_diabetes_medication_(e._g._insulin,_
tablets)_as_prescribed."/>
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    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#haschoice"/>
        <NamedIndividual IRI="#answerq14"/>
        <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_very_much"/>
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      <NamedIndividual IRI="#answerq15"/>
      <NamedIndividual
abbreviatedIRI="questionnaire:5.Occasionally_I_eat_lots_of_sweets_or_other_food
s_rich_in_carbohydrates"/>
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    <ObjectPropertyAssertion>
      <ObjectProperty IRI="#haschoice"/>
      <NamedIndividual IRI="#answerq15"/>
      <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_to_a_consider-able_degree"/>
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    <ObjectPropertyAssertion>
      <ObjectProperty IRI="#IsAnswerof"/>
      <NamedIndividual IRI="#answerq16"/>
      <NamedIndividual
abbreviatedIRI="questionnaire:6._I_record_my_blood_sugar_levels_regularly_antib
iotics_or_steroids_at_the_moment"/>
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    <ObjectPropertyAssertion>
      <ObjectProperty IRI="#haschoice"/>
      <NamedIndividual IRI="#answerq16"/>
      <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_to_some_degree"/>
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    <ObjectPropertyAssertion>
      <ObjectProperty IRI="#IsAnswerof"/>
      <NamedIndividual IRI="#answerq17"/>
      <NamedIndividual
IRI="#7._I_do_regular_physical_activity_to_achieve_optimal_blood_sugar_levels"/
>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
      <ObjectProperty IRI="#haschoice"/>
      <NamedIndividual IRI="#answerq17"/>
      <NamedIndividual abbreviatedIRI="questionnaire:Does_not_apply_to_me"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
      <ObjectProperty IRI="#IsAnswerof"/>
      <NamedIndividual IRI="#answerq18"/>
      <NamedIndividual
IRI="#8._I_strictly_follow_the_dietary_recommendations_given_by_my_doctor_or_di
abetes_specialist"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
      <ObjectProperty IRI="#haschoice"/>
      <NamedIndividual IRI="#answerq18"/>
      <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_very_much"/>
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    <ObjectPropertyAssertion>
      <ObjectProperty IRI="#haschoice"/>
      <NamedIndividual IRI="#answerq21"/>
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abbreviatedIRI="questionnaire:Applies_to_me_to_some_degree"/>

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  <NamedIndividual IRI="#answerq23"/>
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abbreviatedIRI="questionnaire:Applies_to_me_very_much"/>
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  <NamedIndividual abbreviatedIRI="questionnaire:Does_not_apply_to_me"/>
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  <NamedIndividual IRI="#answerq26"/>
  <NamedIndividual
abbreviatedIRI="questionnaire:Applies_to_me_to_some_degree"/>
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  <NamedIndividual IRI="#glucoseExam1"/>
  <NamedIndividual IRI="#Food"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion>
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  <NamedIndividual IRI="#glucoseExam1"/>
  <NamedIndividual IRI="#lowglucoselevel"/>
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  <NamedIndividual IRI="#glucoseExam1"/>
  <NamedIndividual IRI="#Ange"/>
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  <NamedIndividual IRI="#glucoseExam1"/>
  <NamedIndividual IRI="#answeredQuestionnaire1"/>
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<ObjectPropertyAssertion>
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  <NamedIndividual IRI="#glucoseExam10"/>
  <NamedIndividual IRI="#stress"/>
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  <ObjectProperty IRI="#HasGlucoselevel"/>
  <NamedIndividual IRI="#glucoseExam10"/>
  <NamedIndividual IRI="#highglucoselevel"/>
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  <ObjectProperty IRI="#IsexamOf"/>

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    <NamedIndividual IRI="#glucoseExam10"/>
    <NamedIndividual IRI="#JOY"/>
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    <NamedIndividual IRI="#glucoseExam2"/>
    <NamedIndividual IRI="#sport"/>
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    <NamedIndividual IRI="#glucoseExam3"/>
    <NamedIndividual IRI="#food"/>
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    <NamedIndividual IRI="#glucoseExam3"/>
    <NamedIndividual IRI="#lowglucoselevel"/>
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    <NamedIndividual IRI="#glucoseExam3"/>
    <NamedIndividual IRI="#Ange"/>
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    <NamedIndividual IRI="#glucoseExam4"/>
    <NamedIndividual IRI="#insuline"/>
</ObjectPropertyAssertion>
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    <ObjectProperty IRI="#HasGlucoselevel"/>
    <NamedIndividual IRI="#glucoseExam4"/>
    <NamedIndividual IRI="#NormalGlucoseLevel"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion>
    <ObjectProperty IRI="#IsexamOf"/>
    <NamedIndividual IRI="#glucoseExam4"/>
    <NamedIndividual abbreviatedIRI="questionnaire:Faustin"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion>
    <ObjectProperty IRI="#HasExternalstimula"/>
    <NamedIndividual IRI="#glucoseExam5"/>
    <NamedIndividual IRI="#food"/>
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    <NamedIndividual IRI="#glucoseExam5"/>

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    <NamedIndividual IRI="#NormalGlucoseLevel"/>
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<ObjectPropertyAssertion>
  <ObjectProperty IRI="#IsexamOf"/>
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  <NamedIndividual abbreviatedIRI="questionnaire:Tian"/>
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<ObjectPropertyAssertion>
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  <NamedIndividual IRI="#glucoseExam6"/>
  <NamedIndividual IRI="#food"/>
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  <NamedIndividual IRI="#glucoseExam6"/>
  <NamedIndividual IRI="#NormalGlucoseLevel"/>
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  <NamedIndividual IRI="#glucoseExam7"/>
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  <NamedIndividual IRI="#glucoseExam7"/>
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  <NamedIndividual IRI="#glucoseExam8"/>
  <NamedIndividual IRI="#highglucoselevel"/>
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  <NamedIndividual IRI="#glucoseExam8"/>
  <NamedIndividual IRI="#JOY"/>
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  <NamedIndividual IRI="#glucoseExam9"/>
  <NamedIndividual IRI="#highglucoselevel"/>
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  <ObjectProperty IRI="#IsexamOf"/>
  <NamedIndividual IRI="#glucoseExam9"/>
  <NamedIndividual IRI="#food"/>

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  <NamedIndividual IRI="#glucoseExam9"/>
  <NamedIndividual IRI="#Oreste"/>
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  <NamedIndividual IRI="#highglucoselevel"/>
  <NamedIndividual IRI="#200-250PMOL/L"/>
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<ObjectPropertyAssertion>
  <ObjectProperty IRI="#HasMedication"/>
  <NamedIndividual IRI="#highglucoselevel"/>
  <NamedIndividual IRI="#Starlix"/>
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  <NamedIndividual IRI="#highglucoselevel"/>
  <NamedIndividual IRI="#Sulfonylurea"/>
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  <NamedIndividual IRI="#Glyset_or_Precose"/>
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  <NamedIndividual IRI="#Thiazolidinediones"/>
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  <NamedIndividual IRI="#Acarbose"/>
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  <NamedIndividual IRI="#Lean_meat"/>
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  <NamedIndividual IRI="#highglucoselevel"/>
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  <NamedIndividual IRI="#highglucoselevel"/>
  <NamedIndividual IRI="#fruit"/>
</ObjectPropertyAssertion>

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  <NamedIndividual IRI="#highglucoselevel"/>
  <NamedIndividual IRI="#legumes"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion>
  <ObjectProperty IRI="#IsglucoselevelOf"/>
  <NamedIndividual IRI="#highglucoselevel"/>
  <NamedIndividual IRI="#glucoseExam10"/>
</ObjectPropertyAssertion>
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  <ObjectProperty IRI="#IsglucoselevelOf"/>
  <NamedIndividual IRI="#highglucoselevel"/>
  <NamedIndividual IRI="#glucoseExam4"/>
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  <NamedIndividual IRI="#glucoseExam9"/>
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  <NamedIndividual IRI="#highglucoselevel"/>
  <NamedIndividual IRI="#glucoseExam8"/>
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  <NamedIndividual IRI="#lowglucoselevel"/>
  <NamedIndividual IRI="#30PMOL/L"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion>
  <ObjectProperty IRI="#HasMedication"/>
  <NamedIndividual IRI="#lowglucoselevel"/>
  <NamedIndividual IRI="#Hyperstat"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion>
  <ObjectProperty IRI="#HasMedication"/>
  <NamedIndividual IRI="#lowglucoselevel"/>
  <NamedIndividual IRI="#Dextrose"/>
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  <ObjectProperty IRI="#HasMedication"/>
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  <NamedIndividual IRI="#Glucagen"/>
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  <NamedIndividual IRI="#lowglucoselevel"/>
  <NamedIndividual IRI="#fruit_juice"/>
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  <NamedIndividual IRI="#lowglucoselevel"/>
  <NamedIndividual IRI="#soft_drink"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion>

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    <ObjectProperty IRI="#Hasdiet-intake"/>
    <NamedIndividual IRI="#lowglucoselevel"/>
    <NamedIndividual IRI="#1spoon_of_sugar_or_honey"/>
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    <ObjectProperty IRI="#Is glucoselevelOf"/>
    <NamedIndividual IRI="#lowglucoselevel"/>
    <NamedIndividual IRI="#glucoseExam4"/>
</ObjectPropertyAssertion>
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    <ObjectProperty IRI="#Is glucoselevelOf"/>
    <NamedIndividual IRI="#lowglucoselevel"/>
    <NamedIndividual IRI="#glucoseExam3"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion>
    <ObjectProperty IRI="#Is glucoselevelOf"/>
    <NamedIndividual IRI="#lowglucoselevel"/>
    <NamedIndividual IRI="#glucoseExam2"/>
</ObjectPropertyAssertion>
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    <NamedIndividual IRI="#lowglucoselevel"/>
    <NamedIndividual IRI="#glucoseExam7"/>
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    <NamedIndividual abbreviatedIRI="questionnaire:Faustin"/>
    <Literal datatypeIRI="&xsd:int">45</Literal>
</DataPropertyAssertion>
<DataPropertyAssertion>
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    <NamedIndividual abbreviatedIRI="questionnaire:Faustin"/>
    <Literal datatypeIRI="&xsd:string">male</Literal>
</DataPropertyAssertion>
<DataPropertyAssertion>
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    <NamedIndividual abbreviatedIRI="questionnaire:Faustin"/>
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</DataPropertyAssertion>
<DataPropertyAssertion>
    <DataProperty IRI="#Haslocation"/>
    <NamedIndividual abbreviatedIRI="questionnaire:Faustin"/>
    <Literal datatypeIRI="&xsd:string">arendal</Literal>
</DataPropertyAssertion>
<DataPropertyAssertion>
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    <NamedIndividual abbreviatedIRI="questionnaire:Tian"/>
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<DataPropertyAssertion>
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    <NamedIndividual abbreviatedIRI="questionnaire:Tian"/>
    <Literal datatypeIRI="&xsd:string">female</Literal>
</DataPropertyAssertion>
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    <NamedIndividual abbreviatedIRI="questionnaire:Tian"/>
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    <NamedIndividual IRI="#Ange"/>
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    <NamedIndividual IRI="#Ange"/>
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    <DataProperty IRI="#Haslocation"/>
    <NamedIndividual IRI="#Ange"/>
    <Literal datatypeIRI="&xsd;string">grimstad</Literal>
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    <DataProperty IRI="#HasAge"/>
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    <NamedIndividual IRI="#JOY"/>
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    <NamedIndividual IRI="#John"/>

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    <Literal datatypeIRI="&xsd:string">male</Literal>
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  <DataPropertyAssertion>
    <DataProperty IRI="#HasTelephone"/>
    <NamedIndividual IRI="#John"/>
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  <DataPropertyAssertion>
    <DataProperty IRI="#Haslocation"/>
    <NamedIndividual IRI="#John"/>
    <Literal datatypeIRI="&xsd:string">lillesand</Literal>
  </DataPropertyAssertion>
  <DataPropertyAssertion>
    <DataProperty IRI="#HasRange"/>
    <NamedIndividual IRI="#NormalGlucoseLevel"/>
    <Literal datatypeIRI="&xsd:string">4-6.9Mmol</Literal>
  </DataPropertyAssertion>
  <DataPropertyAssertion>
    <DataProperty IRI="#HasAge"/>
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  <DataPropertyAssertion>
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    <NamedIndividual IRI="#Oreste"/>
    <Literal datatypeIRI="&xsd:string">male</Literal>
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    <NamedIndividual IRI="#Oreste"/>
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    <NamedIndividual IRI="#glucoseExam1"/>
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  </DataPropertyAssertion>
  <DataPropertyAssertion>
    <DataProperty IRI="#HasGlucosevalue"/>
    <NamedIndividual IRI="#glucoseExam1"/>
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  </DataPropertyAssertion>
  <DataPropertyAssertion>
    <DataProperty IRI="#Hasbodymassindex"/>
    <NamedIndividual IRI="#glucoseExam1"/>
    <Literal datatypeIRI="&xsd;float">29.0</Literal>
  </DataPropertyAssertion>
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    <DataProperty IRI="#HasExaminationsDate"/>
    <NamedIndividual IRI="#glucoseExam10"/>
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  <NamedIndividual IRI="#glucoseExam2"/>
  <Literal datatypeIRI="&xsd:dateTime">3/2/2014</Literal>
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  <NamedIndividual IRI="#glucoseExam2"/>
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  <NamedIndividual IRI="#glucoseExam4"/>
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  <NamedIndividual IRI="#glucoseExam5"/>
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<DataPropertyAssertion>
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  <NamedIndividual IRI="#glucoseExam5"/>
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  <NamedIndividual IRI="#glucoseExam6"/>
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    <DataProperty IRI="#HasQuantity"/>
    <NamedIndividual IRI="#lowglucoselevel"/>
    <Literal datatypeIRI="&xsd;string">15-20grams</Literal>
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    <NamedIndividual IRI="#lowglucoselevel"/>
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    <ObjectProperty abbreviatedIRI="owl:topObjectProperty"/>
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<SubObjectPropertyOf>
    <ObjectProperty IRI="#IsExternalstimulaOf"/>
    <ObjectProperty abbreviatedIRI="owl:topObjectProperty"/>
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</InverseObjectProperties>
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</InverseObjectProperties>
<FunctionalObjectProperty>

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    <ObjectProperty abbreviatedIRI="questionnaire:IsQuestionnaireof"/>
</FunctionalObjectProperty>
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    <Class IRI="#externalStimula"/>
</ObjectPropertyDomain>
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    <Class IRI="#Vital-sign-Examination"/>
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    <Class abbreviatedIRI="questionnaire:OptionList"/>
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    <Datatype abbreviatedIRI="xsd:float"/>
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<!-- Generated by the OWL API (version 3.4.2) http://owlapi.sourceforge.net -->
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