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An Ontology-Based Decision Support System for Interventions based on Monitoring Medical Conditions on Patients in Hospital Wards

By

Tian Zhao

Supervisors: Rune Fensli, Jan Pettersen Nytun

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University of Agder

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Abstract:

In this project we present our research and implementation of an ontology-based clinical decision support system, which is supported by Sørlandet Sykehus Kristiansand. We discuss the generic technology of designing decision support systems as well as the practical implementation in our project. Firstly, we design the system structure using UML in Eclipse, based on which, the system is built in Protégé using ontology techniques. And then patients' information and clinical rules are added in the system as the form of individuals. Finally, SPARQL query is used to query for the decisions based on the calculation of patients' information and the clinical rules. Our system can continuously monitor vital signs parameters of patients and calculate a risk triage at several levels. In collaboration with valuable experiences from medical expertise, our system helps medical personnel at hospital wards to improve patient care and therefore is of great values in clinics.

Keywords: clinical decision support system (CDSS), ontology, OWL, Protégé, patients' information, SPARQL query

Preface

This report is the result of the master thesis IKT 590 (30 ECTS) which is part of our fourth semester MSc study at the Faculty of Engineering and Science, University of Agder (UiA) in Grimstad, Norway. The work on this project started from 1 January 2014 and ended on 2 June 2014. We have completed the main goal of our project "An Ontology-Based Decision Support System for Interventions based on Monitoring Medical Conditions on Patients in Hospital Wards".

This project is supported by a hospital in Kristiansand, Norway, which is dealing with patients with a table called TILT (Tidlig Identifisering av Livstruende Tilstander, which means Early Identification of Life-Threatening Conditions in English). We would like to thank our project supervisors Professor Rune Fensli and Jan Pettersen Nytun for the guidance in giving feedback on technical and content of report throughout this project. Through this thesis work, we learnt a lot about project content and technical report writing.

Grimstad

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Tian Zhao

Abbreviations

CDSS	Clinical Decision Support System
OWL	Web Ontology Language
OPCS	Office of Population Censuses and Surveys
NICE	National Institute for Clinical Excellence
CPG	Clinical Practice Guidelines
CP	Clinical Pathways
COMET	Co-morbidity Ontological Modeling & ExecuTion
CHF	Chronic Heart Failure
AF	Atrial Fibrillation
TILT	Tidlig Identifisering av Livstruende Tilstander

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1 Introduction

In this project we will design a clinical decision support system, which could output decisions and suggestions automatically according to the patients' information and their testing results.

In Section 1.1, the motivation of this thesis is introduced. Section 1.2 illustrates the problems need to be solved while Section 1.4 reviews literature with similar problems. Then we get our solutions in Section 1.4. At last, Section 1.5 gives the outline of this thesis.

1.1 Background and Motivation

Patients in hospital wards always have long term treatment, so clinical personnel should also work for a long term, including recording patients' history data, dealing with multiple tasks simultaneously, and concern the condition changes by testing regularly. Ideally clinical experts should make optimum, efficient and professional judgement according to their knowledge and experience, which could be used as good decisions for patients. However, in practice errors usually happen, for the reasons of negligence, misjudgement, insufficient time to send message, lack of attention or fail to exchange information at shift handovers. Even a small mistake may lead to an awful consequence, due to the large number of people that involved in the patient care progress, including patients, clinical professionals and their families and friends,. Thus clinical service centres are trying hard to find efficient methods to ensure and improve patient safety during treatment. Some professionals proposed the decision support systems, which could deal with patients' information and manage test data, as well as output appropriate decisions or suggestions as results[1].

By this motivation, we try to use ontology techniques to build a clinical decision support system, which can generate early identification of life-threatening conditions of patients in hospital wards. This project is supported by Sørlandet Sykehus Kristiansand - one hospital in Kristiansand, Norway. This project can improve automated medical diagnosis and therefore benifit both clinical professionals and patients for saving time and human resources. This project makes patients in hospital wards access to their disease condition diagnosis and clinical suggestions automatically. In addition, this project can also help the personnel in hospital significantly in saving time and serving personalised and tailored care for patients in serious conditions.

1.2 Problem Statement

For patients in a labile phase of treatment in hospital wards, clinical personnel need a continuous and follow-up care, in order to improve patients' safety and stablize the conditions. Thus it is an important breakthrough in medical field to design the decision support system, which can support continuous monitoring of vital sign parameters, calculate a risk triage at several levels, and give expert based advices for interventions.

The clinical decision support system we are going to design in this project may implement the following functions:

1. Having a clear and general structure of vital sign testing table, whose elements can be easily changed and updated;

2. Storing patients' information as examples, which could be accessed directly by the system;

3. Formulating some clinical rules for decision making and inserting them into the system;

4. Dealing with patients' information and tes data based on inserted clinical rules, and making proper decisions.

1.3 Literature Review

In this part we will introduce some similar designed clinical decision support systems, from which we could learn the importance of using OWL ontology in medical diagnosis, as well as how to implement such kind of systems.

1.3.1 Preoperative Clinical Decision Support System

In 2011, Matt-Mouley Bouamrane, Alan Rector and Martin Hurrell used OWL ontology to build a clinical decision support system, in order to support patient information modelling and preoperative clinical decision making. Semantic web technology was used to design and implement this system, which is knowledge-based. This system is ontology-based, which help to develop the model, the user interface and the automated logic reasoned. This system is also expert-based, which help to avoid doctors' misjudgement. Large amount of patients' information could be stored into the system, which help to make correct decisions for both new and existing patients, as well as patients in specific situations. The basic process that the system work is shown in Figure 1.

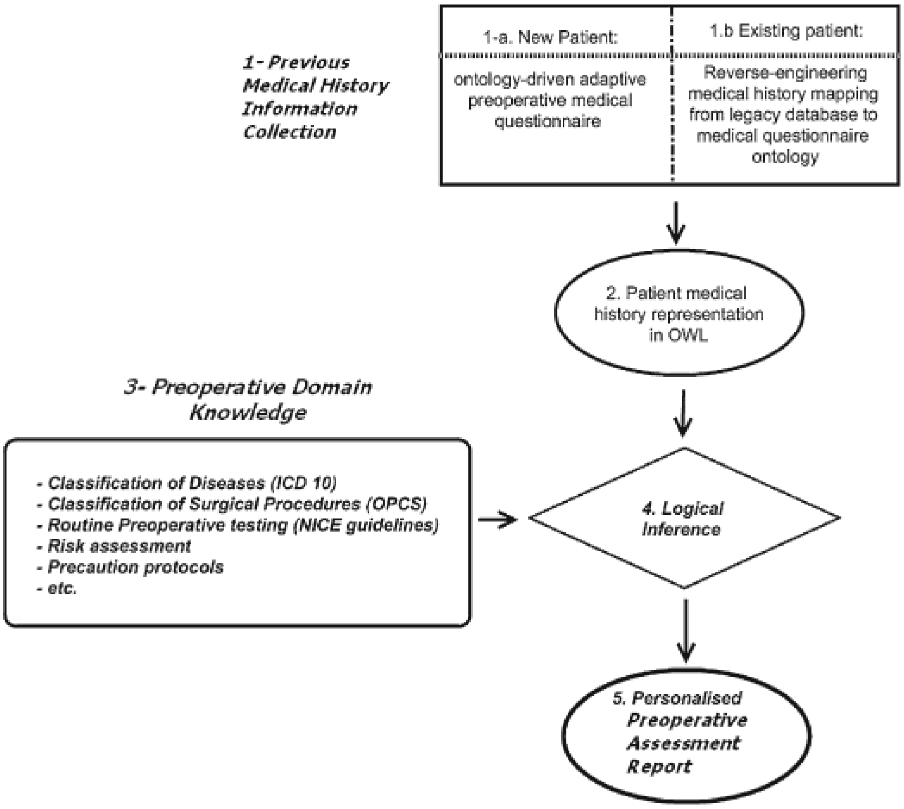

Figure 1 Overview of knowledge-based preoperative decision support system [1]

This project focuses on the assessment of ontology-based preoperative decision support system. some important knowledge inserted in the system includes classification of morbidities using the ICD-10 International Classification of Diseases, classification of surgical procedures based on OPCS (Office of Population Censuses and Surveys) and other relevant evidence-based preoperative assessment medical knowledge such as the NHS NICE (National Institute for Clinical Excellence) routine preoperative tests guidelines. This system using NICE guidelines shows the ontology techniques could help to implement some pragmatic and useful functionalities, and provide a good example of clinical ontology-based reasoner, which is beyond the capabilities of a traditional rule engine. In this system, decision making is based on five factors: age, ASA, comorbidities, type of surgical procedure and risk grade of surgical procedure. For each test, there are three possible results: “test recommended”, “test not recommended” or “consider test”. In Figure 2 a small part of NICE guidelines are shown.

Grade 1 Surgery - Adults with ASA 2 with comorbidity from Renal Disease

Test	age in years			
	16 to 40	40 to 60	60 to 80	over 80
Chest X-ray	NO	NO	NO	
ECG	NO			YES
Full Blood Count				
Haemostasis	NO	NO	NO	NO
Renal Function	YES	YES	YES	YES
Random Glucose	NO	NO	NO	NO
Urine Analysis				
Blood gases	NO	NO	NO	NO
Lung function	NO	NO	NO	NO

Figure 2 NICE preoperative guidelines based on patients' ages [1]

As there are five factors that lead to different decisions, there are large amount of combinations of them. For example, for the age factor, we consider different tables for children under 16 years old and adults over 16 years of age. Totally, the authors declare that there are at least 1242 different possible cases.

This system implement a lot of improvements based on the earlier preoperative decision support systems. Firstly, it could collect patients' information according to individual medical context. Secondly, it could arrange and manage domain knowledge from a vast repository, including classification of surgical procedures and morbidities, and guidelines for routine preoperative tests [1].

1.3.2 Clinical Guidelines Based Comorbid Decision Support

In this project, the authors Samina Abidi, Jafna Cox, S. Sibte Raza Abidi and Michael Shepherd designed an ontology-based clinical decision support framework, which could deal with comorbidities in medical. The authors derive the disease-specific clinical pathways (CP) according to clinical practice guidelines (CPG) and medical synthesis knowledge. Then they abstract medical and procedural knowledge, based on which they use ontology to computerize the CP. COMET (Co-morbidity Ontological Modeling & ExecuTion) system is suggested by the authors, as it could handle comorbid chronic heart failure and atrial fibrillation, and is web-accessible.

The aligning CP process is at the knowledge modelling level instead of the knowledge execution level. It is well established when the common CP need to be mapped to the ontology modelled CP. As shown in Figure 3, four parts are contained in the methodological approach: knowledge identification and synthesis, knowledge modelling, knowledge alignment and knowledge execution.

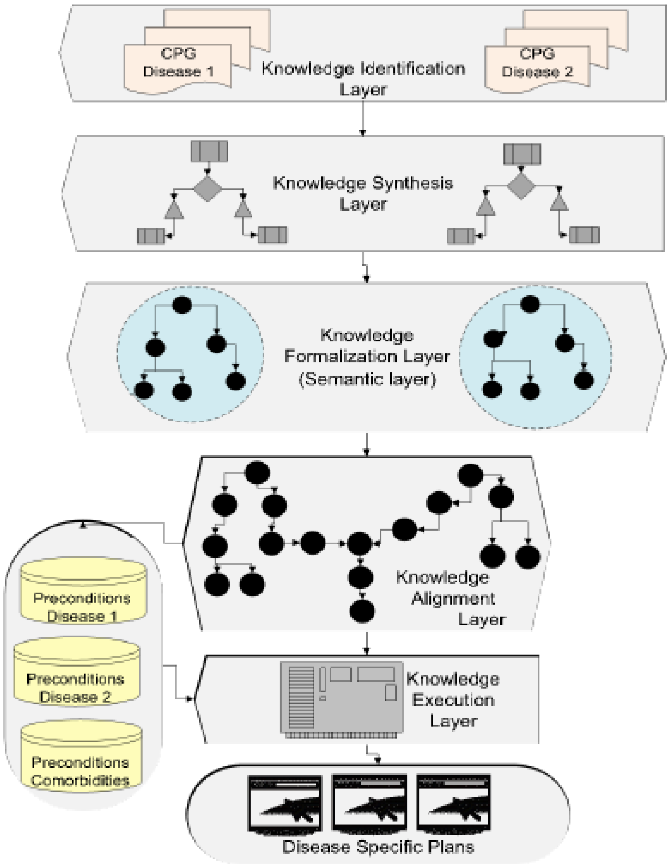

Figure 3 Methodological Approach [2]

This designed decision support system is about Chronic Heart Failure (CHF), the knowledge synthesis exercise yielded algorithms for the diagnosis of CHF is shown in Figure 4.

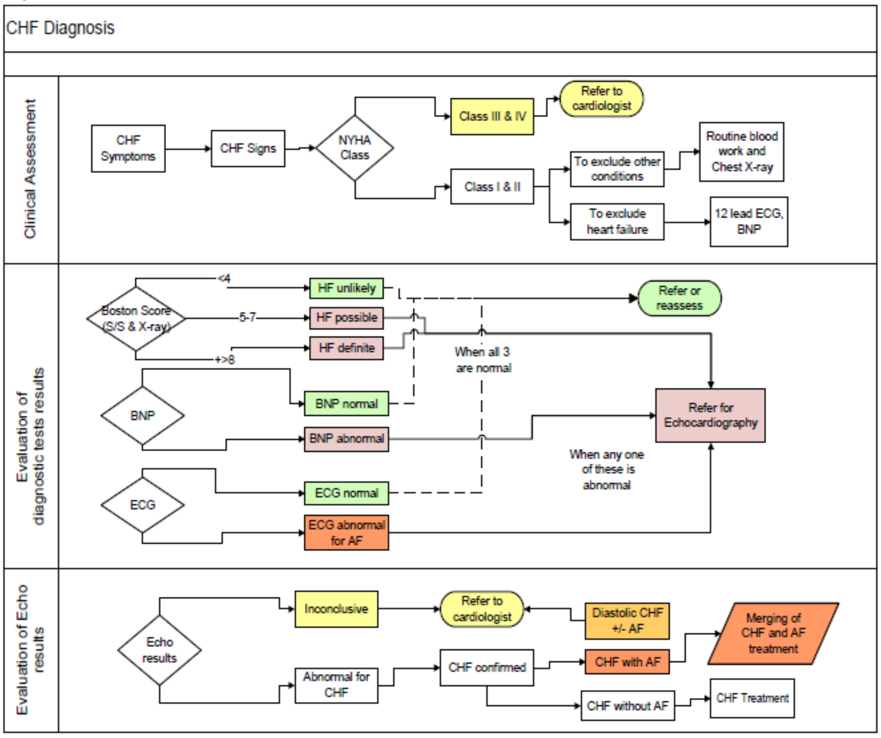

Figure 4 CHF Diagnosis Algorithm [2]

The system is built in OWL using the ontology editor Protégé, and the flow diagram is shown in Figure 5.

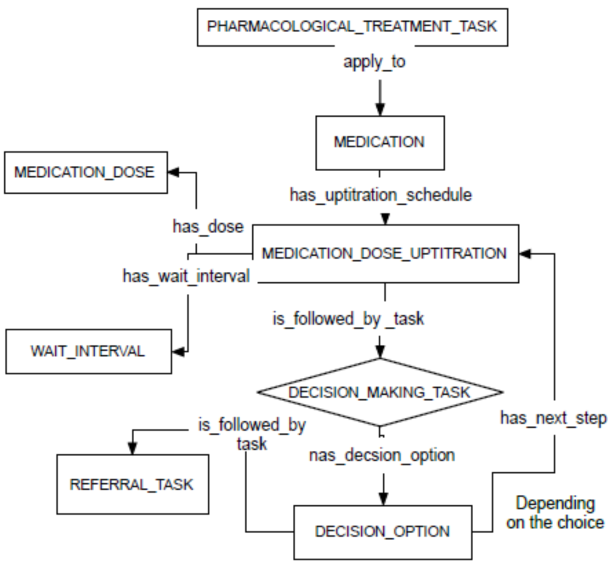

Figure 5 Classes and properties modelling medication dose uptitration [2]

In order to align comorbid knowledge, the authors integrated the expert knowledge and experience of diagnosing CHF and AF, and made a plan of aligning CHF and AF, which is shown in Figure 6. In the figure, the dashed arrows indicate the alignment between the plans of CHF and AF to handle comorbid CHF+AF.

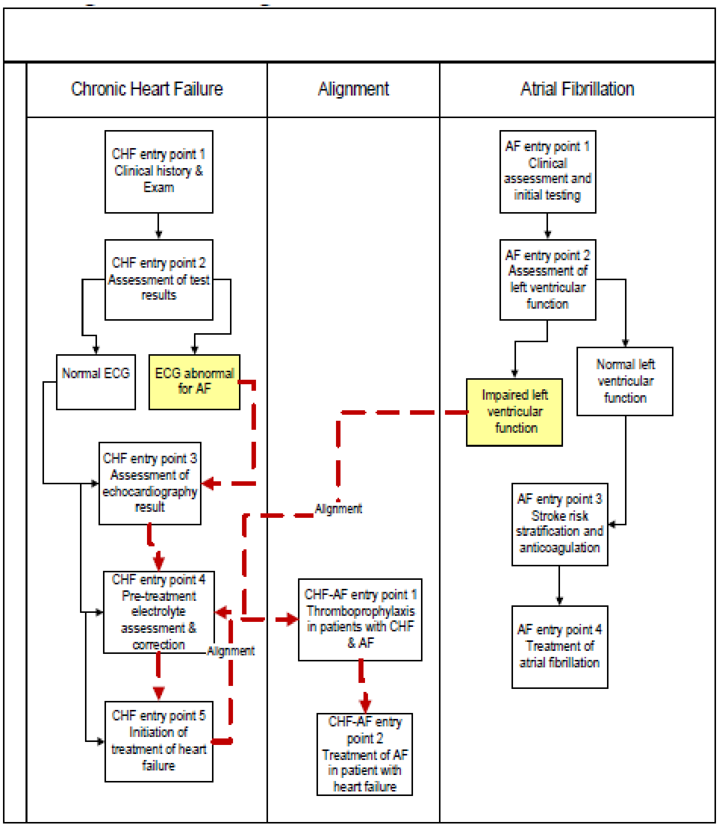

Figure 6 Aligning CHF and AF plan [2]

This ontology-based decision support system has lots of advantages with the comorbid CP model. First of all, it helps to avoid duplication of intervention tasks, resources and diagnostic tests. Secondly, it could reuse the results of common activities. Thirdly, it ensures patient safety when different clinical activities are crossing different CP, which are technically compatible. Finally, it makes standards that could be used in multiple institutions [2].

1.4 Problem Solution

The main task of this thesis is to develop a clinical decision support system which can be used for patients' treatment. Real vital sign test table and scoring methods is provided by the hospital, and we stored them in our system. Due to the limitation of time, we do not use complex rules and real patient data. As a demo system, this project just contains a few assumed patients and rules, which are enough to test and verify the designed structure and functions. The methods of solution can be summarized as follows:

1. Firstly, according to the TILT table from hospital, the structure of a clinical decision support system is modelled by ontology techniques;

2. Secondly, assumed clinical rules and example patients are added in the system as individuals;

3. Thirdly, logic of the designed system is evaluated by SPARQL queries according to inserted patients' information and test data;

4. Finally, decisions are printed out to check the validation of the system;

The implemention of these solutions will be described in detail in the fourth Chapter.

1.5 Thesis Outline

The remaining thesis is structured as follows:

1. Chapter **错误!未找到引用源。** presents the clinical background, including the resource from hospital, the vital signs background and the examples and rules we use in this project.

2. In Chapter **错误!未找到引用源。**, a brief introduction of technical background adopted in this project is given, including UML, ontology and SPARQL query.

3. In Chapter **错误!未找到引用源。**, the whole implementing process is shown, including the whole structure, classes, properties and individuals.

4. In Chapter **错误!未找到引用源。**, tests on the system utilizing SPARQL query and the executing results are presented.

5. Discussions are in Chapter **错误!未找到引用源。**.

6. Chapter **错误!未找到引用源。** gives the conclusions and future works in this thesis.

2 Clinical Techniques

As we mentioned before, this project is supported by a hospital in Kristiansand, Norway. The whole project in the hospital is called Tidlig Identifisering av Livstruende Tilstander (TILT), which means Early Identification of Life-Threatening Conditions in English. The central idea of the project is giving scores to some main factors related to patients based on their vital signs and environment, and then calculate a total score in order to make proper decisions. The decisions include an expert calling, emergency supporting and the frequency to evaluate a new score. Factors in the TILT table include respiration frequency, pulse oximetry, blood pressure, body temperature and CNS (Central Nervous System), which will be described seperately in this Chapter.

2.1 Respiration Frequency

For an individual, respiration frequency (also named as respiratory rate or breathing frequency) is defined as the number of breaths taken per minute. In clinic, an individual with an increased respiratory rate can be diagnosed as tachypnea. On the contrary, a lower than normal respiratory rate should be related to the bradypnea [3].

Typically, the average respiration frequency is 12 breaths per minute for a healthy young male in his peaceful condition, i.e. he is resting in bed at sea level. This value would be impacted by position, sex, size, age, altitude, activity, fever, as well as some other illness. In most cases, compare to male adults, children and women may have higher figure of respiration frequency [4].

Respiration frequency can serve as an important clinical diagnosis and be measured in two ways. In the first method, doctors count the chest ups and downs for patients for half a minute and double times as the final respiration frequency. In addition, some medical devices, such as the optical breath rate sensor, are also widely used in clinic to monitor patients' breath [5].

The value of respiration frequency is commonly investigated as an indicator of potential respiratory dysfunction. However, the respiratory rate suffers a serious limitation, which is the significant influence from inner and outer factors, such as crying, sleeping, agitation, age and so on. For this reason, we cannot use respiration frequency separately to figure out a serious respiratory disorders of patient.

2.2 Pulse Oximetry

Pulse Oximetry is a kind of non-invasive blood-oxygen monitor, which can show the percentage of blood that is loaded with oxygen. The acceptable figure of pulse oximetry of a people in the normal condition (i.e. without pulmonary pathology breathing in the room at sea level calmly) is between 95 to 99 [6].

Figure 7 Pulse Oximetry [7]

As shown in Figure 7, the pulse oximetry is always be placed on a fingertip or earlobe or some other thin part of the patient's body. The sensor in pulse oximetry sends light of two wavelengths. When the light pass through the body, the absorbance can be caused by the pulsing arterial blood alone. The venous blood, skin, bone, muscle, fat, and even nail polish has no influence on the absorbance. The photo detector on the other side of sensor can measure the difference of absorbance of the two light and get the blood-oxygen in this way.

Generally speaking, due to its simplicity of testing and the continuous and immediate ability to provide oxygen saturation measurements, the pulse oximetry can be widely used in clinical situations. For example, it is used to assess patient's oxygenation in emergency medicine or detect abnormalities in ventilation or diagnosis of some sleep disorders.

However, there is still some limitations in clinical using. The most important one is that the pulse oximetry only measures the percentage of bound haemoglobin. This makes it inaccurate in some special cases, such as Cyanide poisoning or Methemoglobinemia. In addition, it gives no indication of base deficit, carbon dioxide levels, blood pH, or bicarbonate (HCO3-) concentration. So the blood gases check in a laboratory may also be required [8].

2.3 Blood Pressure

In medicine, the arterial pressure of the systemic circulation is named as Blood pressure (BP). The blood pressure is caused by heart's pumping action and therefore varies between a maximum (systolic) and a minimum (diastolic) pressure. The fluctuation is caused by the viscous losses of energy during the blood flow in the circulation system. In clinic, the blood pressure serves as one of the four main vital signs (the three others are body temperature, respiratory rate, and pulse rate) and is often used by medical professionals and healthcare providers [9].

Due to many factors, such as age and sex, the blood pressure various a lot from person to person and moment to moment. Usually, the older people and male tend to have a higher blood pressure. Some other potential factors are exercise, emotional reactions, sleep, digestion, time of day, circadian rhythm, disease, drugs or alcohol, stress and obesity. Some experts found that the average blood pressure of 100 human subjects is 120/80 mm Hg in a study and this average value is considered as normal range [10].

The most commonly used measurement is sphygmomanometer. Because it use the height of a column of mercury to reflect the circulating pressure, the blood pressure are customarily recorded in millimetres of mercury (mm Hg), as the normal blood pressure mentioned above. To get the accurate record of blood pressure, the clinics and the patients should follow the guidelines and take the right measurement, which is not complex or difficult [11].

2.4 Body Temperature

The body temperature is the most common indicator for body condition. The medical/clinical thermometer is used for the measurement, which is shown in Table 1.

The body temperature may be influenced by many factors: the place of measurement, the time of day and level of activity of the person. The often used places for measurement in clinic and the typical temperature are listed in the following table. It should be mentioned that the body temperature may fluctuates about 0.5℃ throughout the day, i.e. lower temperatures in the morning and higher temperatures in the late afternoon and evening [12].

Table 1 normal body temperature [13]

Position	Name	Normal Temperature (℃)
In the anus	Rectal temperature	35.7 – 37.5
In the mouth	Oral temperature	36.2 – 37.2
Under the arm	Axillary temperature	34.7 – 37.3
In the ear	Tympanic temperature	35.7 – 37.5
In the vagina	Vaginal temperature	--

In the urethra	Urethral temperature	--
On the skin of the forehead	--	--
Over the temporal artery	--	--

2.5 CNS (Central Nervous System)

The central nervous system (CNS) is the part of the nervous system consisting of the brain and spinal cord. In our project, CNS is to present a patient's respond, in order to know how the patients feel immediately right now [14].

2.6 TILT Score System

Based on the above introduction, we could now give out the whole system with the TILT scores. Patients should test the five factors and get a score for each of them, then calculate the final score by adding those scores. The TILT Score System is shown in Table 2.

Table 2 TILT Score System [15]

Early Identification of Life-Threatening Conditions TILT-score							
	3	2	1	0	1	2	3
Respiration frequency		<9		9 - 14	15 - 20	21 - 29	⩾30
Pulse oximetry		<40	41 - 50	51 - 100	101 - 110	111 - 129	⩾130
Blood pressure	<70	71 - 80	81 - 100	101 - 199		⩾200	
temperature		<35		35 – 38.4		⩾38.5	
CNS (Central Nervous System)				Awake and pays attention	Responds to indictment	Responds to pain	Does not respond

Our decision support system could not only calculate the total score of one filled TILT table, but also give out the doctors suggestions based on both the total score and eight judging rules. The total score gives a clue of the frequency of filling the TILT table, and the eight judging rules are related with the specific scores of each testing item. We also give an example of each judging rule, in order to check whether the system could give out the right results. As mentioned before, our rules and patients' information are all not real. We just assumed them in order to check and show the validation of our decision support system. The rules are shown in Table 3, and the examples are shown in Table 4.

Table 3 Rules of TILT Score System

TILT table total score	Patient testing frequency
0	New control within 24 hours
1	New control within 8 hours
2	New control within 4 hours
3 or 4	New control within 1 hours
>4	Contact the doctor immediately
If TILT table total score >3, check the following rules:	

	Respiration Frequency	Pulse Oximetry	Blood Pressure	Temperature	Suggetion
Rule1	3	<2	<2		Symptoms of Hyperventilation
Rule2	>=2	>=2			Symptoms of Cardio-pulmonary disease
Rule3		3	>=2	0	Symptoms of Cardiac failure
Rule4		>=2		2	Symptoms of infection
Rule5		>=2	3		Symptoms of reduced cardiac activity
Rule6				2	Symptoms of Hypothermia
Rule7	0	3	>1	2	Symptoms of Atrial Fibrillation
Rule8	1 or 2	3	0		Symptoms of physical activity

Table 4 Examples of TILT Score System

	Name	Respiration Frequency	Pulse Oximetry	Blood Pressure	Temperature	CNS	Total Score
Filled TILT table 1	Faustin	2	1	0	0	2	5
Filled TILT table 2	Angelique	0	2	1	0	3	6
Filled TILT table 3	Tian	3	1	0	0	1	5
Filled TILT table 4	Mary	3	3	1	0	0	7
Filled TILT table 5	Jack	1	3	2	0	1	7
Filled TILT table 6	John	0	2	1	2	0	5
Filled TILT table 7	Lily	1	2	3	0	0	6
Filled TILT table 8	Ann	1	0	0	2	2	5

Filled TILT table 9	Lucy	0	3	2	2	0	7
Filled TILT table 10	Sissi	1	3	0	0	1	5
Filled TILT table 0	Heidi	0	0	0	0	0	0
Filled TILT table 11	Ben	0	2	3	2	0	7

3 Technology Background

In this chapter, the background of two main technology, i.e. clinical decision support system and ontology techniques will be discussed detailed.

3.1 Clinical Decision Support System (CDSS)

In this part, we will introduce the history of decision support system and the technical details of the implementation in medicine.

3.1.1 Decision Support System (DSS)

Decision support system (DSS), which is used to support decisions for managers at all levels, is firstly proposed in the 70th of last century. Today, due to the benefit of computer science (such as database, internet, etc.), the DSS technology is enjoying a fast and well development. By utilizing these technologies, DSS can manage and transport the information at all levels.

Basically, a decision support system has a structure consists of data management, model management components and user interface. For some advanced DSSs, other components, like a knowledge management component, may also be contained. In the next few sections, each of these components (subsystem) of DSSs will be described.

Data Management Subsystem

Similar as general data management systems the data management systems of DSSs could collect data from all the source providers. The data sources are extracted prior and entered into a DSS database or a data warehouse. Usually，DSSs have independent data management systems. And in some small DSSs, there is no separate database. Thus if needed, the data should be entered into the DSS model as soon as they are collected by sensors.

Model Management Subsystem

The model management subsystems of DSSs are important for developing DSS applications, and contains completed models and necessary building blocks. The applications are standard software with financial, statistical, management science, or other quantitative models. Such a model management subsystem also contains the custom models written for the specific DSS and a model-based management system (MBMS).

User Interface

The user interface of DSSs provides all kinds of communications between the users and the systems. This component is considered as an important component of DSSs, because of the flexibility and simple using for all the users. Today, most interfaces are Web-based. Among them, some advanced interfaces supplemented by voice. Similar as the function of database management system (DBMS), the user interface subsystem may be managed by software called user interface management system (UIMS).

DSS Intermediaries

In the past, when use a DSS to make decisions, the managers should get the analysing and the reporting results through an intermediary person. Nowadays, for the Web-based DSSs, it becomes easier. The DSSs could make decisions automatically, especially when supported by an intelligent knowledge component.

Knowledge-Based Subsystems

Sometimes the problem that needs to be solved by a DSS is complex for the data is not complete and not enough. Thus dealing with such unstructured and semi-structured problems, expert knowledge is required. A knowledge-based system could solve this problem, with pre-storing expert knowledge or by learning from experiments. Therefore, advanced DSSs are equipped with a knowledge-based (or an intelligent) subsystem, which can provide the required expertise to solve part of the problem, or provide knowledge to enhance the functions of the DSS.

One knowledge component could contain one or more expert (or intelligent) subsystems, in order to draw expertise from the organizational knowledge base. A DSS that with such a component is referred as an intelligent DSS, a DSS/ES, or a knowledge-based DSS (KBDSS) [16].

3.1.2 Clinical Decision Support System

Clinical decision support system (CDSS) refers to those DSS used for medical purpose. It could help clinical experts make fast and accurate decisions and consequently save time and human resource, as well as avoid risk of mistakes. Generally, the inputs of CDSS are the testing data of patients. The CDSS will use one or more items to do analysing and calculating and getting the proper advices as results. In addition, not only the clinical personnel, but also the patients can benefit from the advantages of CDSS. The CDSS can transmitting information for long distance and therefore make remote monitoring possible for every patient.

3.1.3 The Key Technology of CDSS

The main purpose of modern CDSS is to assist personnel in the tele-medical centre to make decisions at the point of remote monitoring, which means that personnel could interact with a CDSS to determine diagnosis though analysis of a patient’s test data.

In CDSS, the patient’s information should be used as the input of the system. There are two main structure of the operation of CDSS. In some cases, the personnel would wait for the CDSS to output the “best” choice, and then help the patient to take right actions. However, in some new systems, the personnel in the tele-medical centre should work together with the CDSS to analyse the patient’s data, and give a combined result. Typically, this kind of CDSS will output some suggestions or choices for the personnel to refer and the personnel can elites some useful or important information according to their own analysis. By this way, the system can achieve a better result than only use the knowledge of human or CDSS [17].

There are already some previous published theories of CDSS for the personnel in tele-medical centre to make good decisions. In order to provide supports to the health care professional, many different methodologies are utilized by a CDSS. There are two groups of these methodologies: knowledge-based ones and nonknowledge-based ones, which are introduced as follows:

3.1.3.1 Bayesian Network

The Bayesian network is based on Bayes' rule, which foresights the occurrence of one event by analyzing the probability of another given event, like a knowledge-based graphical representation. It shows a set of variables and probabilistic relationships between diseases and symptoms, using conditional probabilities. That means it gives the updating result in the form of probability based on other available information and new evidence. Used in CDSS, the Bayesian network can utilize the given patients' symptoms to calculate the probabilities of the possible diseases.

One advantage of Bayesian network is that it calculate the probabilities using local distributions for one step. And for a human, understanding direct dependencies and local distributions is easier than concerning complete joint distribution. However, it is difficult to get the knowledge of probability for possible diagnosis. It is impractical for large complex systems working by giving multiple symptoms, which would be overwhelming for users [18].

A typical example of Bayesian Network CDSS is called DXplain, which uses the Bayesian logic to build a clinical decision support system. Based on the different symptoms, it produces a set of hierarchical diagnoses that could be decided to be a specified disease [19].

3.1.3.2 Rule-Based System

An expert system that is rule-based focus on capturing knowledge of domain experts into expressions, which can be evaluated by rules. Firstly, enough rules should be compiled into a rule base. Secondly the system will evaluate current working knowledge depend on the rule base, and then link them to each other until a decision is achieved.

The advantages of a rule-based expert system is that it can easily store a large amount of information, and it is logical in the decision-making process for the specified rules. However, it's hard for an expert to transfer their knowledge into distinct rules, which are required by effective systems. This causes some limits in some cases of the useage of rule-based methods [20].

In the 1970s, Edward Shortliffe in Stanford University developed a rule-based expert system in the clinical setting called MYCIN. It defined about 600 rules in the rule base, and help to identify the bacteria types that lead different infections. In early 1980s, another rules-based expert system was developed by the Stanford AI group, which called ONCOCIN and coded in Lisp subsequently, which could use shorter time to make decisions. The Stanford Oncology Clinic used this system as a production [21].

3.1.3.3 Causal Probabilistic Network

Causes and effects are the primary basis behind the causal network methodology. This kind of algorithm uses nodes to represent items such as symptoms, patient states or disease categories. And it specifies the relationships between causes and effects, with the networks between nodes. A system which is built based on this methodology uses probabilities to determine which path is the best fit, by tracing all the trail from the nodes of symptom to the nodes of disease classification.

Causal probabilistic network can model the process of a long-time disease, or the relations and interaction among diseases. On the other hand, the elements which cause certain symptoms would be unknown, which leads to problems of choosing the level of details to build the model [22].

CASNET could be an example uses causal probabilistic network, it assisted in the diagnosis of glaucoma. It featured a hierarchical representation of knowledge by classifying all nodes into one tier, which is from symptoms, states and diseases [23].

3.1.3.4 Logical Condition

The first step of logical condition methodology is to give a variable and a bound. Then the second one is to check whether the variable is within the bounds or not, according to the result. And the final step is to make a decision based on the previous two steps. A decision table should be beneficial for analyzing the representation of the statements.

The idea of logical condition is simple, and the functions it could implement are not complex. However on the other side, it cannot be used for systems that are complex.

Logical conditions are primarily used to provide alerts and reminders in clinical field. For example, in a logical condition CDSS, when a patient's heart rate is too low, an alert will ring to warn an anesthesiologist; when the health condition of a patient is not good and he/she needs a nurse come, a reminder will work; at the same time, a reminder will come to a doctor when it is time for him/her to discuss the smoking cessation with his/her patients [24].

3.1.3.5 Neural Network

Artificial Neural Networks (ANN) is a nonknowledge-based adaptive CDSS. ANN use artificial intelligence (machine learning) to update the result by learning from past experiences/examples, as well as recognize patterns in clinical information. Neural Network mainly contains neuron and connections. Neurons are nodes, and connections have the function to transfer signals from one neuron to another, in the direction of forward or loop. There are three main layers of an ANN: Input (data receiver or findings), Output (communicates results or possible diseases) and Hidden (processes data). Learning a large amount of data will help the system to become more efficient.

ANN have a lot of advantages: 1) It provides input from experts with no need of programming; 2) When the input data is not complete, it can make educated guesses of the missing data and improve the inputs due to the adaptive system learning; 3) No large databases to store outcome data with associated probabilities are needed in ANN CDSS.

However, the training process may be time consuming, for it requires large amount of data to be learned. This will lead to the ineffective of the system. Additionally, it's hard to interpret and doubt the system's reliability, due to the creating of its own formulas of the system. These formulas are made to measure and link data, which depends on the long time statistical recognition patterns [25].

There are a set of CDSS using Neural Network, for instance, diagnosis of skin sicknesses, psychiatric emergencies, appendicitis, myocardial infarction, and back ache. The ANN's diagnostic were occasionally better than professionals' when predict the pulmonary embolisms. Moreover, applications which depend on ANN are widely used in ECG waveforms analyzing [26].

3.1.3.6 Genetic Algorithms

In 1940s, the Massachusetts Institute of Technology proposed the concept of Genetic Algorithm (GA), which is a nonknowledge-based method. GA calculate the survival of the fittest using Darwin's evolutionary theories. GA help to rearrange information from patients' data using mutation and crossover to produce better solutions. The main and only challenge is to define a proper fitness function.

GA do not need a concrete algorithms, just generates an optimal solution by a set of iterative process. The most important thing is to build a proper fitness function, which could define the rule to evaluate the solutions, thus the best solutions can be picked out. But it's undesirable for personnel because of the lack of transparency in the reasoning involved decision support systems [27].

GA could be used in many situations in order to solve a problem, for example, treatment therapy, multiple drugs and symptoms. Diagnosing the female urinary incontinence proved that GA were validate and useful [28].

In our project we choose rule-based methodology, we assumed eight clinical rules for decision making, if one patient's situation match to onne of the rules, he/she will get a specific suggestion.

3.1.4 The Challenges of CDSS

To offer a high-quality, effective serve for clinicians, patients and consumers, developers have made a lot of improvements in designing, developing, presenting, implementing, evaluating, and maintaining processes of CDSSs. However, more effort are still required. By using an iterative, consensus-building method, Sittig, Dean F., et al. list the top 10 grand challenges in CDSS in rank-ordered, as shown in Table 5. In the following sections, we will have a deep discussion for some of them.

Table 5 Grand Challenges in CDSSs [29]

No.	Challenges
1	improve the human-computer interface
2	disseminate best practices in CDS design, development and implementation
3	summarize patient-level information
4	prioritize and filter recommendations to the user
5	create an architecture for sharing executable CDS modules and services
6	combine recommendations for patients with co-morbidities
7	prioritize CDS content development and implementation
8	create internet-accessible clinical decision support repositories
9	use free text information to drive clinical decision support
10	mine large clinical databases to create new CDS

3.1.4.1 Clinical Challenges

Up to now, many CDSSs have been proposed by medical institutions and software companies. These CDSSs cover nearly every aspect of clinical tasks and achieve success in varying amounts. The representative examples are the implement of CDSS in pharmacy and billing sectors.

However, the CDSSs also meet great challenges in preventing or reducing successful adoption and acceptance. Specifically, the developer should consider about the clinical workflows and the demands of staffs to ensure the system serve as a fluid and integral part of the workflow. In most cases, the developers tend to focus only on the decision making function of the CDSS and neglect to plan for how the system will be used by clinician. Generally, the CDSS systems are stand-alone to the current report system in clinical. This means the clinician should stop the current system and change to CDSS to get the service. Obviously, the CDSSs break the workflow and cost precious time for clinical application.

Another potential contention might be the amounts of alert given by the CDSS. In other words, the CDSSs are not smart enough to highlight the most important suggestion for clinicians. When all messages, not matter if do they need escalation, are reported to clinicians, they may be annoyed and pay less attention to the information. This may lead some important messages be missed and cause accidents.

3.1.4.2 Technical Challenges & Barriers to Implementation

Another challenges for clinical decision support systems are steep technical in medicine, as the biological systems are too complex. There are many challenges from various aspects in dealing with this complex. Here we only discuss two of them.

The first one is that the CDSS should cover plenty of information for analysis. For example, to build an electronic evidence-based medicine system, the developers should consider the information of patients' symptoms, medical history, family history and genetics, the treatment process and even the published clinical data about the disease and medicinal effectiveness. The problem comes from the comprehending and analysis these information.

Secondly, the integration of different research result into the CDSS is difficult. As record, tens of thousands of clinical trials are published in a given year. They use different kinds of data and analysis through various aspects. It is a great challenge for the developers to incorporate these research on an ongoing basis in both initial design and updating process of CDSS. This is especially true when some clinical papers appear confliction, which is common in such an area far from perfect.

3.1.4.3 Evaluation

Before a CDSS be implemented in clinic, a comprehensive evaluation is required. These evaluations usually focus on two aspects: the efficiency of clinical workflow and the effectiveness of the systems' support. However, it is impossible to use a general method to evaluate all CDSSs, as they are designed for various purposes and focus on different aspects. This means it is difficult to propose a standard for the CDSS.

For example, to evaluate a diagnostic decision support system, we may compare its outcome with the suggestions from physicians or other decision support systems. The rate should be given according to the comparison result. When it comes to an evidence-based medicine system, we had better to focus on the patient improvement [30].

3.2 Ontology Techniques

Ontologies are structural frameworks to organize information, which build a shared vocabulary to denote types, properties and interrelationships of a set of concepts represented within a domain [31]. Ontology captures the structure of a domain and model the domain with possible restrictions. It describes the knowledge about the domain and represents a particular state of affairs by use of individuals in the domain [32].

3.2.1 Components of an Ontology

Most ontologies describe individuals (instances), classes (concept), properties, and relationships into following form: Subject predicate object.

Common components of an ontology are:

Individuals: Instances or objects.

Classes: Sets, collections, concepts and classes in programming.

Properties: Aspects, properties, features and characteristics.

Relationships: Ways in which classes and individuals can be related to one another.

Function terms: Complex structures formed from certain relations, which can be used in place of an individual term in a statement.

Restrictions: Formally stated descriptions of what must be true in order for some assertions to be accepted as inputs.

Rules: Statements in the form of an if-then (antecedent-consequent) sentence that describes the logical inferences and can be drawn from an assertion in a particular form.

Axioms: Assertions (including rules) in a logical form that together comprising the overall [33].

The main reasons to develop an ontology is to share the structure of information among people or software agents, and to enable the reuse of domain knowledge. It can make domain assumptions explicit, separate domain knowledge from the operational knowledge and then analyse domain knowledge.

3.2.2 Protégé 4.3

Protégé-OWL is a free, open-source platform editor with tools supporting OWL. Domain models and knowledge-based applications have been developed in Java [34]. The Protégé-OWL editor enables users to build ontologies for the Semantic Web, particularly in the W3C's Web Ontology Language (OWL) [35]. It provides a rich set of knowledge-modelling structures and actions to support the creation, visualization and manipulation of ontologies in various representation formats. It also enables users to load and save OWL ontologies, edit visualized classis, properties and Semantic Web Rule Language (SWRL), execute reasoners to describe logic classifiers and edit OWL individuals to mark up Semantic Web [36].

3.2.3 OWL Language

OWL is the most recent developed language among standard ontology languages, which is from the World Wide Web Consortium. An OWL ontology consists of Individuals, Properties, and Classes.

Individuals, also called instances, represent objects in the domain which we are interested in. Individuals in OWL are related to properties, and constitute a knowledge base.

Classes also called concepts, describe the concepts in the domain. A class in OWL can classify the individuals into groups based on their common characteristics. An individual is a member of a class indicates that a concrete instance can be created under the semantic classification. A class can have subclasses to represent concepts more specificly than the class. A class can also have a superclass, which is more general than the class.

Properties, also called slots or roles, provide relationship between different objects, and describe the properties of classes and individuals. There are two types of properties in OWL:

1. Object properties (owl:ObjectProperty) relate individuals (instances) of two OWL classes.
2. Datatype properties (owl:DatatypeProperty) relate individuals (instances) from OWL classes to literal values.

In practical terms, developing an ontology includes the following steps:

Firstly classes in the ontology are difined and arranged in a taxonomic (subclass–superclass) hierarchy. Then the users should define properties and describe allowed values for these properties. In the end, the proper values are filled in properties of instances [37].

3.3 SPARQL Query

In the use of ontology, SPARQL query has a very important role. Ontologies are designed in a certain way so that they allow finding out certain information by queries applied on the ontology for evaluation and supporting decisions. Using queries we could know how well the ontology is answering the question of the users. In this project we will use SPARQL query language to select individuals' of patients with specific characteristics.

RDF (Resource Description Framework), which provides a simple way to represent distributed data, is a standard model for data interchange on the Web. A triple is a simple way to show the relationship between two things. The standard way to access RDF data uses a query language called SPARQL, which is short for SPARQL Protocol And RDF Query Language. The Turtle language is used to represent SPARQL query patterns in our project [38].

The natural language is like a Tell-and Ask system, that means, when some facts are told, we could ask questions based on the facts. For example:

Tell: Lily is Sarah's mother.

Ask: Who is Sarah's mother?

Answer: Lily.

In the SPARQL query, we use the same pattern with Turtle language to query information. Use the example above, we have the syntax of SPARQL as following:

Tell: :Lily :is :Sarah's mother.

Ask: ?Who :is :Sarah's mother

Answer: Lily.

Now we should introduce some important keywords of SPARQL query, which are SELECT and WHERE. A SPARQL SELECT query contains two parts: a set of question words and a question pattern. The keyword WHERE indicates the selection pattern, which is written in braces. The question words with "?" in front are displayed after keyword SELECT. And in the braces followed keyword

WHERE, some information and relationships related to the question words needed to query. Use the example above we have the query codes as follows:

SELECT ?Person

WHERE{?Person :is : Sarah's mother }

And the answer should be Lily after executing.

4 Implementation of System Functionalities

In this chapter, technical requirements and system designing process will be described. Firstly, we will show how we prepare before implementation of our CDSS. And secondly, the specific steps will be displayed.

4.1 Requirements and Preparation

As the main goal of this project is to build an ontology based decision support system, which could help doctors and nurses to analyse patients' situations and give suggestions, the system should fulfil the following functional requirements.

Basic functions:

1. System design: the TILT table which has five parameters should be represented in the form of classes and properties according to description logic (i.e., OWL) of the system. Each parameter has different options, which should be assigned specific values.

2. Data storage: patients' information and filled TILT tables should be stored in the system.

3. Rule-based system: All the clinical rules to make decisions should be stored in the system, as well as the possible suggestions.

Advanced functions:

1. Total score: use the SPARQL query to calculate the total score of the specific filled TILT tables.

2. Decision making: based on the calculated total score and the pre-stored clinical rules, use the SPARQL query to give decisions automatically.

4.2 Technique Solutions

To design the clinical decision support system, we first use Eclipse and Unified Modelling Language (UML) to draw the picture of the system structure. UML provides a standard way to visualize the design of a system [39]. And then we use the software Protégé to set the classes, properties and individuals based on the whole structure of the system. These two aspects will be introduced separately in the following two subchapters.

4.2.1 Knowledge Arrangement

First we have the most general class called TILTtable. Each TILTtable has five vital signs – RespirationFrequency, PulseOximetry, BloodPressure, Temperature and CNS. And each of those vital signs has several options, which has different scores from 0 to 3. When TILTtable has been filled by one patient, it becomes FilledTILTtable. It will have five CollectedAnswers named filledtxx in the system, and each has its own option. The descriptions of different range of total scores are stored in the system as individuals, as well as the suggestions of each rule. This system could calculate the total score using SPARQL query, and clinical decision rules are pre-stored in the system, these two could be combined to output the suggestions automatically. The whole structure of the decision support system is shown in Figure 8.

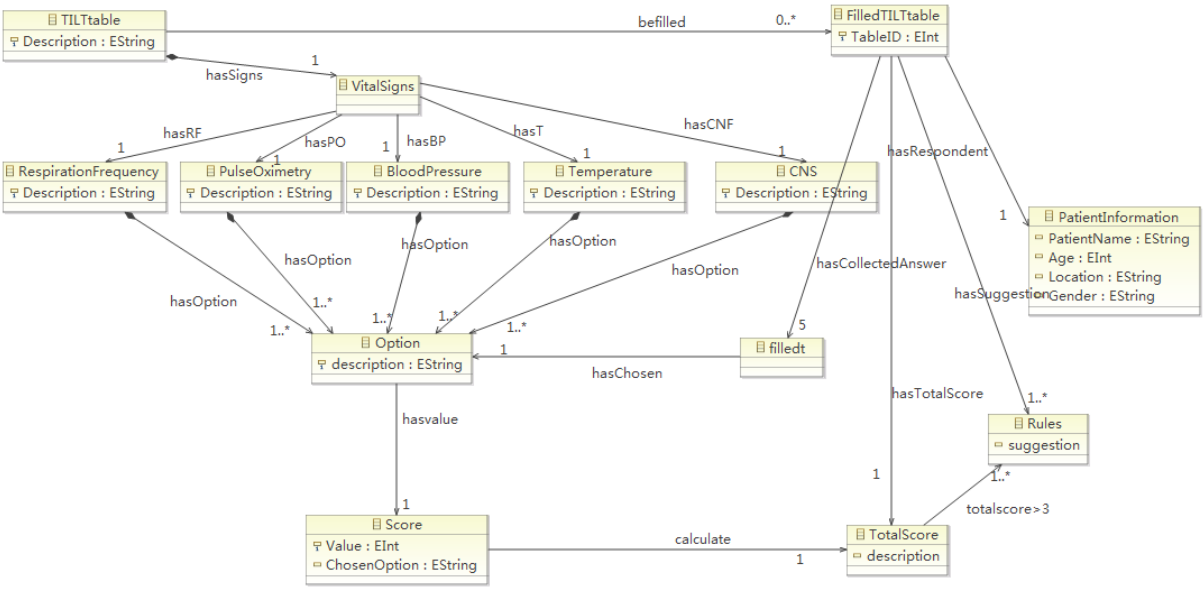

Figure 8 the Whole Structure of the Decision Support System

4.2.2 Ontology-Based Modelling of Decision Support System

Later on we will describe and explain our classes, properties and individuals specifically with figures.

4.2.2.1 <u>Classes and Class Hierarchy:</u>

All the classes we designed in this system are shown in Figure 9.

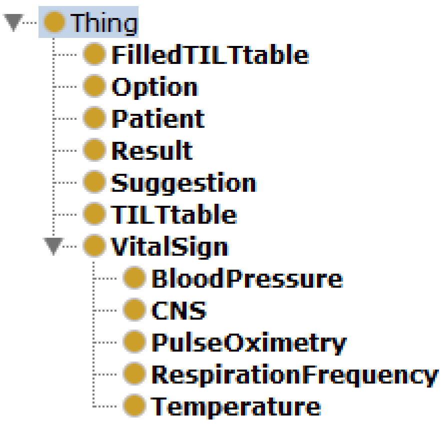

Figure 9 Classes of the System

As introduced before, we have classes called TILTtable, FilledTILTtable, Option, Patient, Result, Suggestion and VitalSign. And class VitalSign has five subclasses: BloodPressure, CNS, PulseOximetry, RespirationFrequency and Temperature.

4.2.2.2 Object Properties of Ontology:

An object property links two individuals to each other. Object properties have their range and domain. In this project we have seven object properties. Some object properties are inverses of each other. The object properties which are used in this project are mentioned in Figure 10 below.

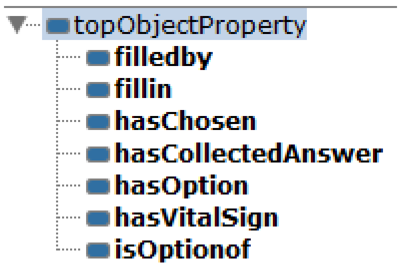

Figure 10 Object Properties of the system

filledby is the object property of class Patient, It shows which patient has filled in one specific TILT table. It provides the relationship between individuals of class FilledTILTtable and class Patient. It inverses of object property fillin. The domain of this property is FilledTILTtable and it ranges to Patient. The usage of this object property is shown in Figure 11, Figure 12 and Figure 13.

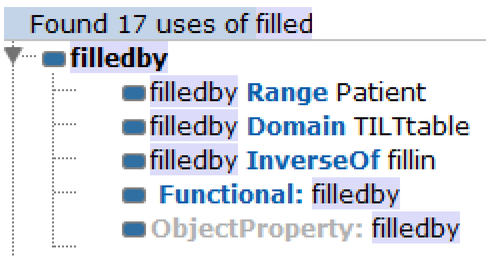

Figure 11 Usage of filledby

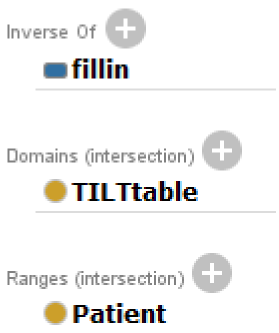

Figure 12 Inverse, Domain and Range of filledby

Figure 13 filledby Related Individuals

fillin is the inverse object property of filledby. It provides the relationship between individuals of class Patient and class FilledTILTtable. It ranges from class Patient to class FilledTILTtable.

hasChosen shows which option has been chosen by one specific TILT table. It provides the relationship between individuals of items of class FilledTILTtable and class Option. Part of the usage of this object property is shown in Figure 14.

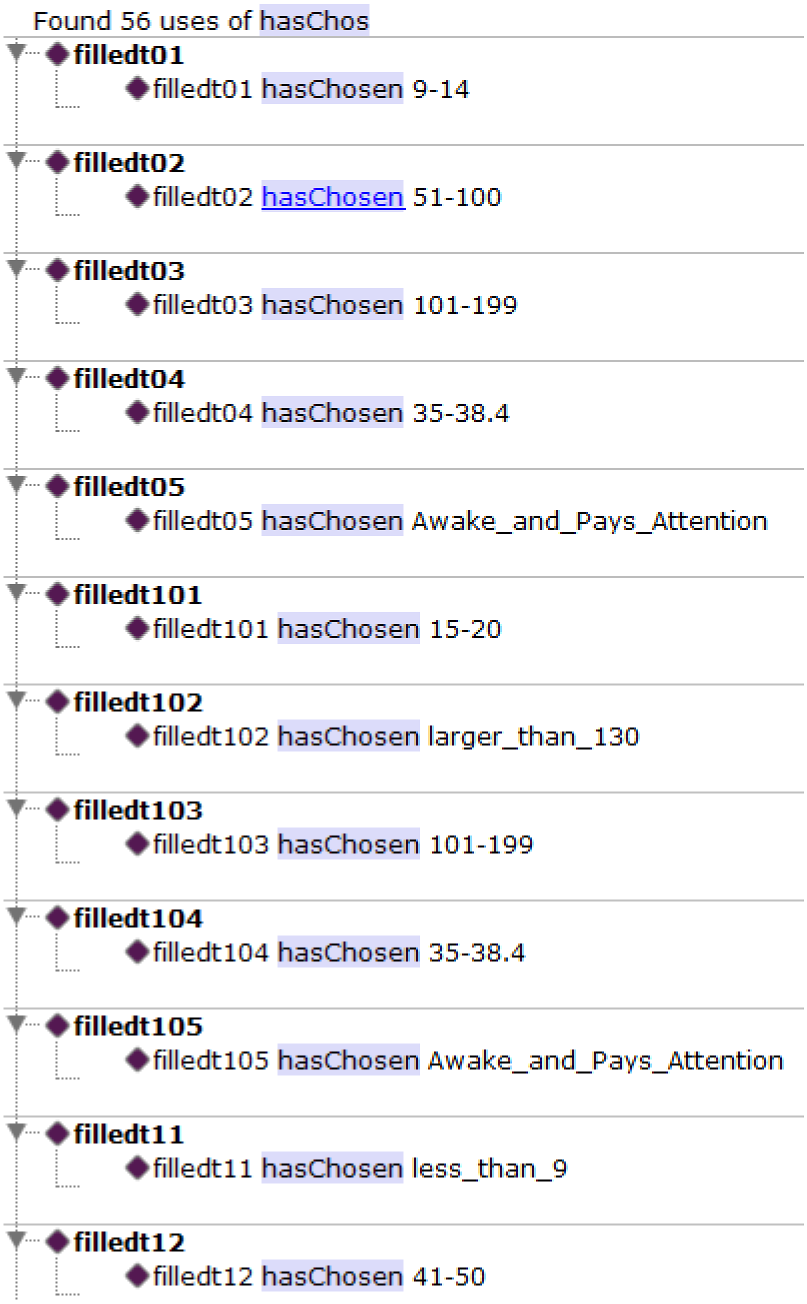

Figure 14 Usage of hasChosen

hasCollectedAnswer is the object property of class FilledTILTtable, It shows which vital sign has one patient tested in one specific TILT table. Part of the usage of this object property is shown in Figure 15.

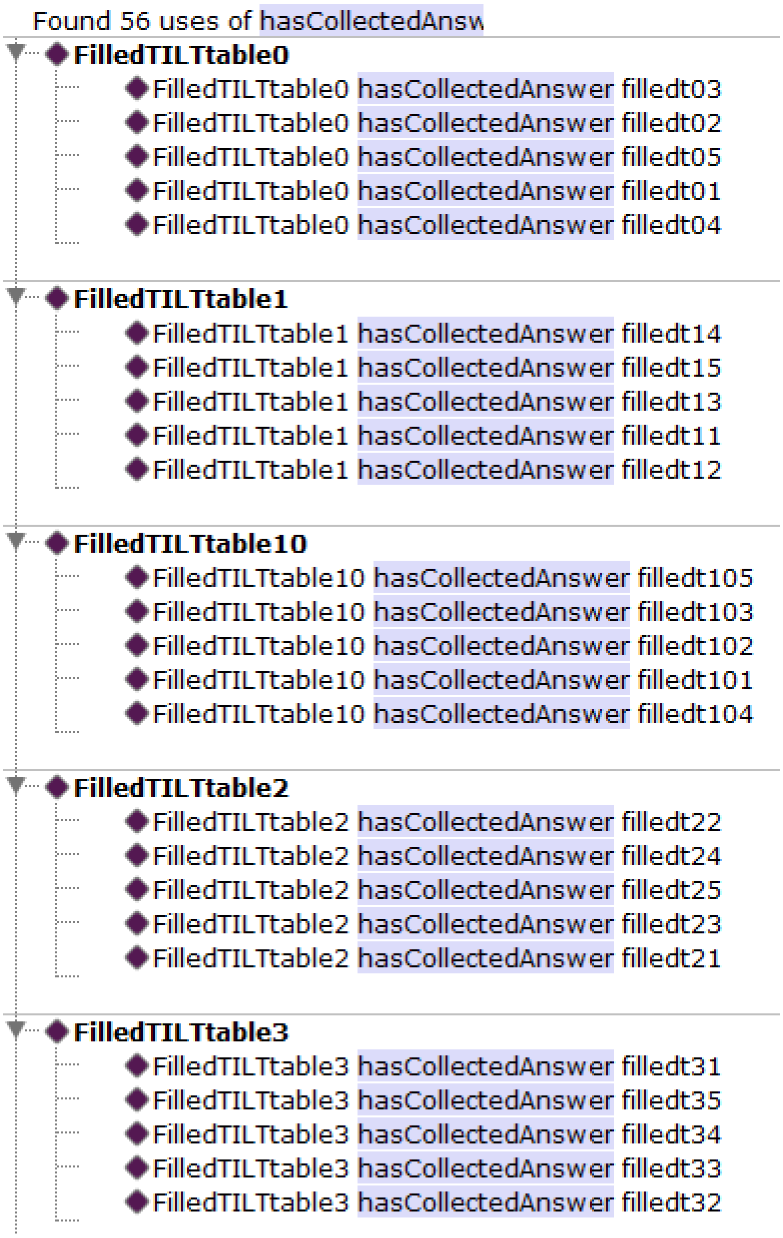

Figure 15 Usage of hasCollectedAnswer

hasOption is the object property of class VitalSign, It shows which options belong to one specific vital sign of a TILT table. It provides the relationship between individuals of class VitalSign and class Option. It inverses of object property isOptionof. The domain of this property is VitalSign and it ranges to Option. The usage of this object property is shown inFigure 16, Figure 17 and Figure 18.

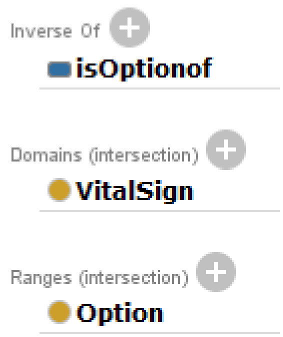

Figure 16 Inverse, Domain and Range of hasOption

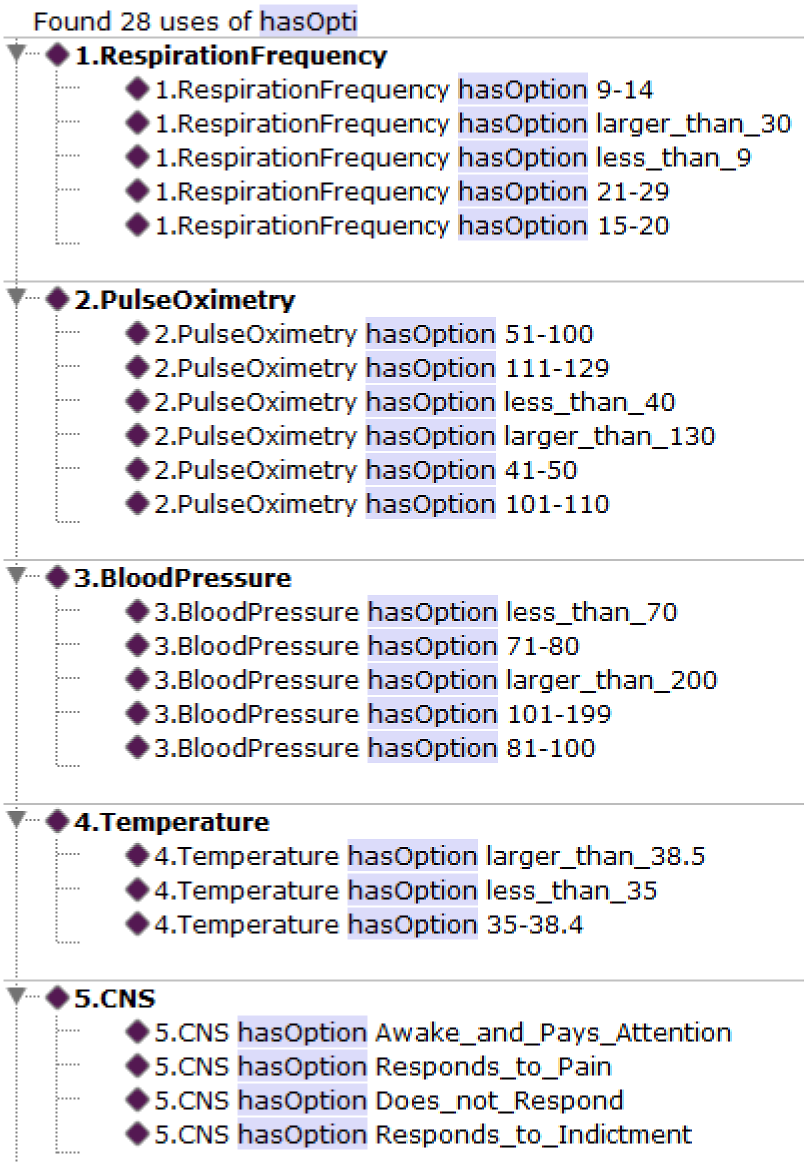

Figure 17 Usage of hasOption (i)

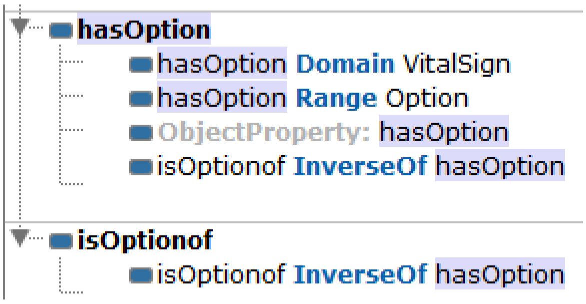

Figure 18 Usage of hasOption (ii)

isOptionof is the inverse object property of hasOption. It provides the relationship between individuals of class Option and class VitalSign. It ranges from class Option to class VitalSign.

hasVitalSign shows which vital sign does one specific tested item belong to. It provides the relationship between individuals of filled items of class FilledTILTtable and class VitalSign. The usage of this object property is shown in Figure 19.

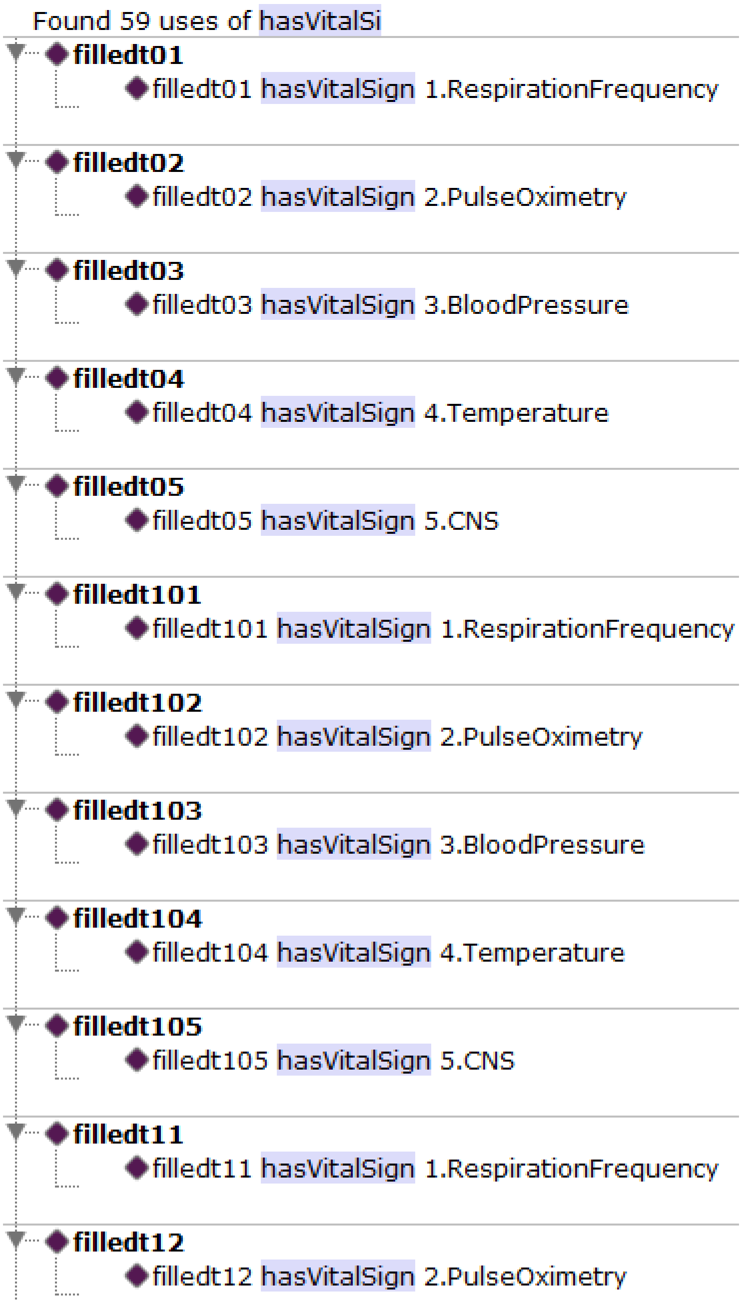

Figure 19 Usage of hasVitalSign

4.2.2.3 <u>**Data Properties of Ontology:**</u>

In this section we will present some data values that has been used in our decision support model. In an ontology system, data type properties play a fundamental role, which means they are used to save real data values for the individuals of classes. In this project, we used seven data properties, which are shown in Figure 20.

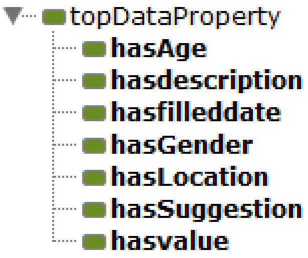

Figure 20 Data Properties of the System

hasAge, hasGender and hasLocation are data properties of individuals of class Patient. For one patient who need to fill in the TILT table, he/she should provide some patient information like age, gender and location to the doctors. To make the patient information more comprehensive, we could add patient ID, system enter password, name and so on. In our project, we name the individuals of class Patient just with the real names, and we did not implement a user interface, so we only record the age, gender and location of the patients. The usage of these three data properties are shown in Figure 21, Figure 22 and Figure 23.

Figure 21 Usage of hasAge

Figure 22 Usage of hasGender

Figure 23 Usage of hasLocation

hasdescription is the data property to show what the total score of one specific TILT table means. According to Table 2, we divided the possible total scores into five situations, each of them has their own description. The usage of hasdescription is shown in Figure 24.

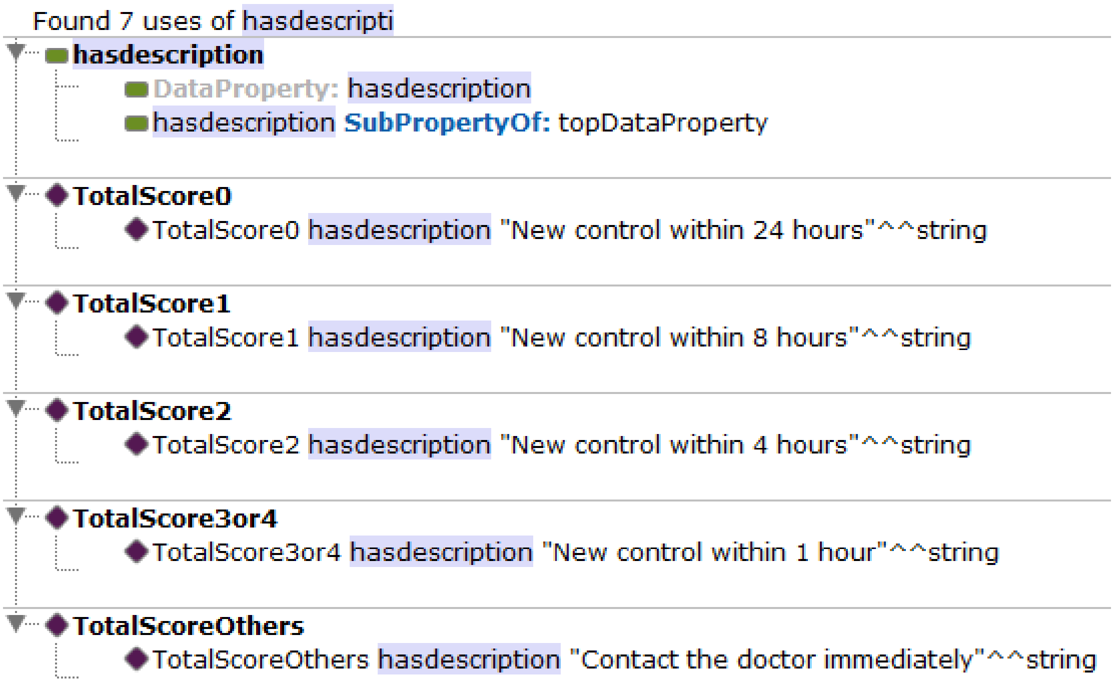

Figure 24 Usage of hasDescription

hasfilleddate is the data property of class FilledTILTtable. Each TILT table that has been filled should has a recorded date, which helps the doctors to collect the history data. The usage of data property hasfilleddate is shown in Figure 25.

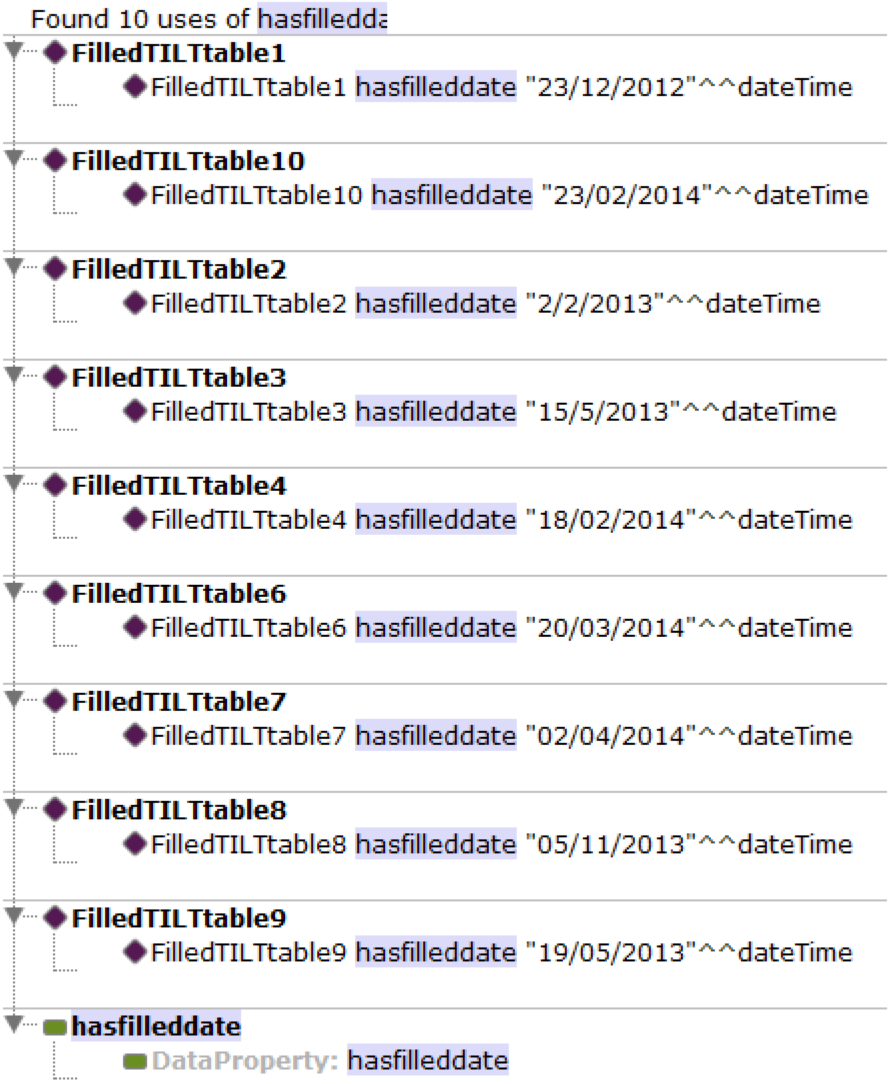

Figure 25 Usage of hasfilleddate

hasSuggestion is the data property of individuals of different rules. As shown in Figure 2, we have eight clinical rules to help the system make decisions, so we add eight individuals match to the eight rules, each of which has one specific suggestion. The usage of data property hasSuggestion is shown in Figure 26.

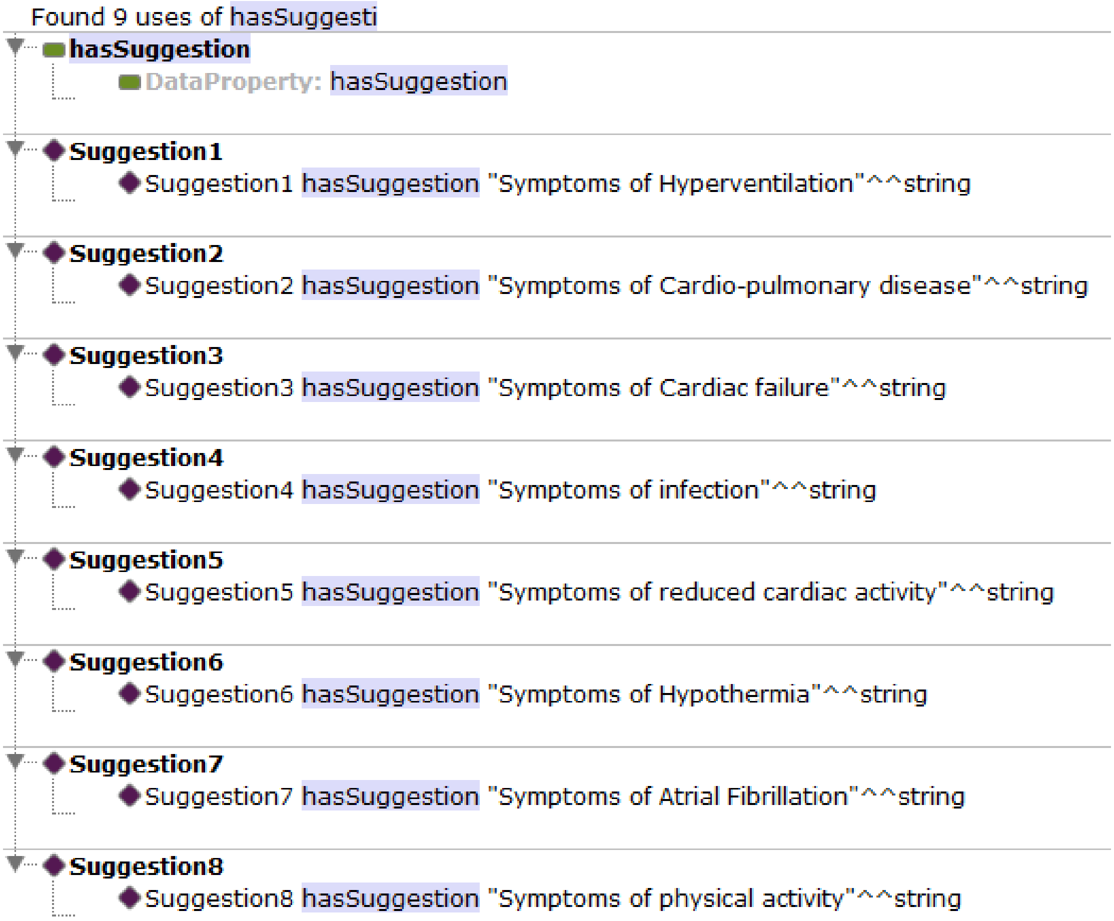

Figure 26 Usage of hasSuggestion

hasvalue is the data property of class Option. As shown in Table 1, in one TILT table, we have five vital signs, and each vital sign has three to five options. As a result, we have totally 24 different options. Each option has a value from 0 to 3. Part of the usage of data property hasvalue is shown in Figure 27.

Figure 27 Usage of hasvalue

5 Validation of the Ontology-Based Decision Support System

5.1 Ontology Graph of Decision Support System

The graph of the ontology-based decision support system could be generated by Protégé to show the relationships between individuals and classes, as shown in Figure below. We implemented all functions we mentioned in Chapter 2. All the individuals are introduced in Chapter 3, so here we just show the graph of all the classes in Figure 28, and individuals of Patient and Result in Figure 29 and Figure 30 as examples, other concrete graphs could be found in Appendix.

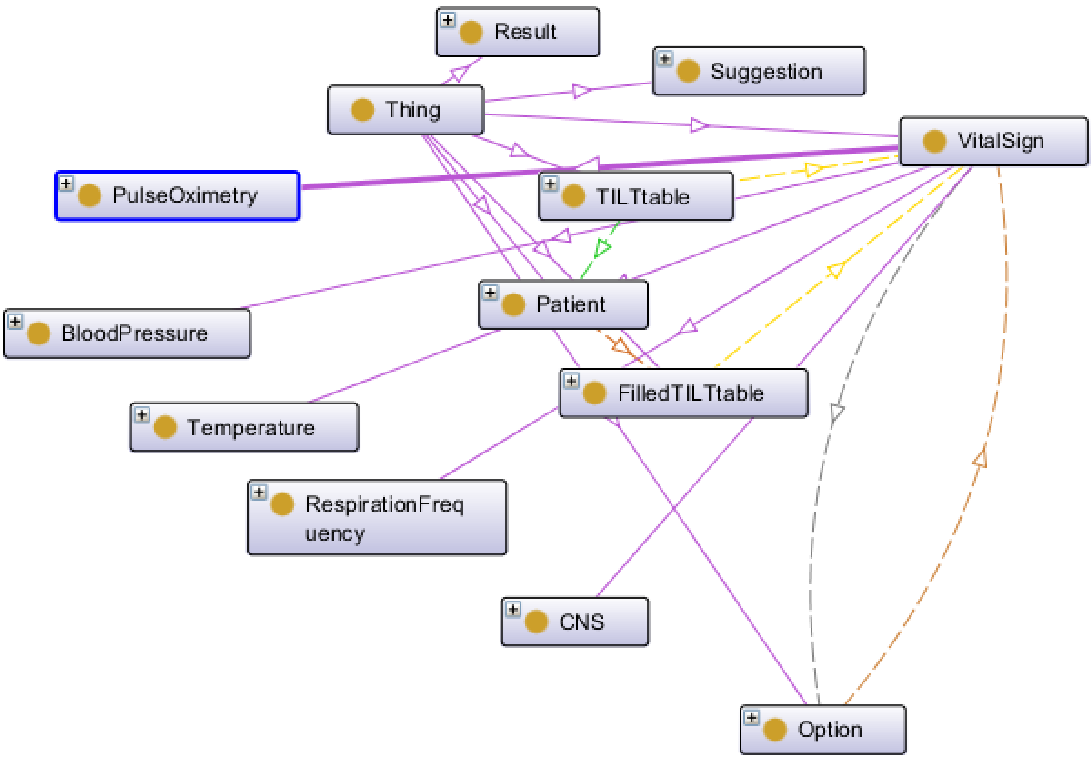

Figure 28 Graph of All Classes

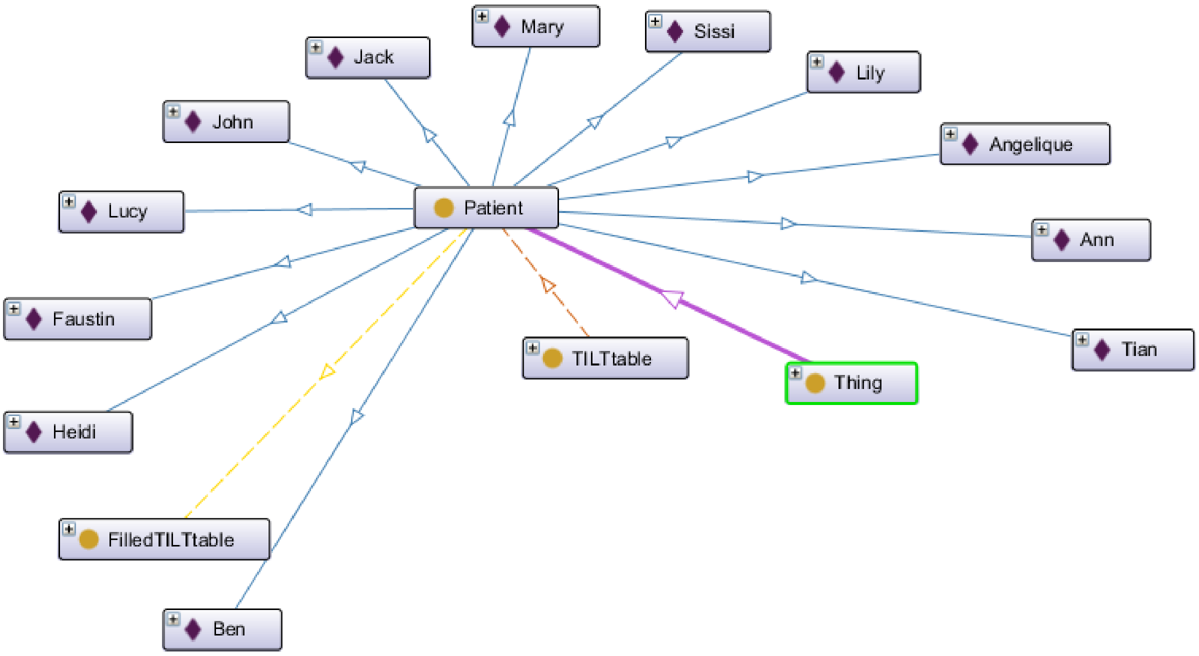

Figure 29 Graph of All Patients

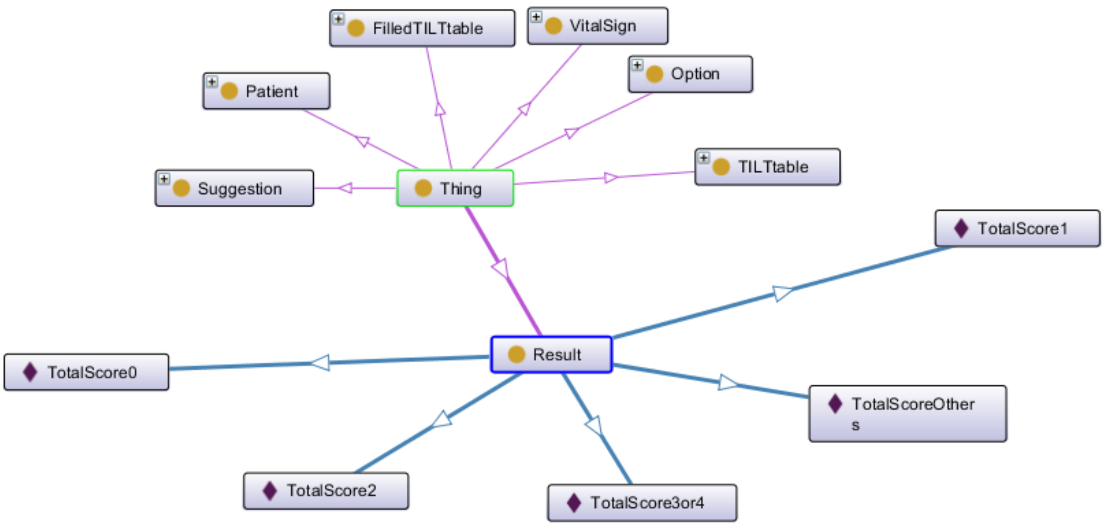

Figure 30 Graph of All Results

5.2 Query Retrieval Process

Query has a very important role in ontology system designing process. Ontologies are designed in a certain way, so that they allow us to find out certain information by queries applied on the ontology for evaluation and supporting decisions. SPARQL queries are the only way that we could know how well the ontology is answering the question of the users. Thus in this project we will use SPARQL query language to select informations as well as to implement the functions mentioned in Chapter 2.

SPARQL query language is able to retrieve and manipulate data stored in Resource Description Framework (RDF) format. RDF is a format used to model the information implemented in web resources, where the concepts are described from triple as subject, predicate and object.

In this Chapter, we will show the main queries, which could both display some important information of our system, and illustrate the implementation of the important functions. To be concise, we use filled TILT table 3 as an example.

Query 1: patient name, filled table and filled date

In this query we will display the result of the name of all patients and their corresponding filled tables. We use the triple pattern of PatientName fillin FilledTILTtable, FilledTILTtable hasfilleddate Date. And we use SELECT query to get the information of the name and date of the filled TILT tables.

The codes of Query 1 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?PatientName ?FilledTILTtable ?Date

WHERE{ ?PatientName A:fillin ?FilledTILTtable. ?FilledTILTtable A:hasfilleddate ?Date }

And the results we get from the codes above is in Figure 31.

PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?PatientName ?FilledTILTtable ?Date
WHERE{ ?PatientName A:fillin ?FilledTILTtable. ?FilledTILTtable A:hasfilleddate ?Date }

PatientName	FilledTILTtable	Date
Jack	FilledTILTtable5	"30/12/2013"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Lucy	FilledTILTtable9	"19/05/2013"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Lily	FilledTILTtable7	"02/04/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Angelique	FilledTILTtable2	"2/2/2013"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Ben	FilledTILTtable11	"02/03/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
John	FilledTILTtable6	"20/03/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Mary	FilledTILTtable4	"18/02/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Sissi	FilledTILTtable10	"23/02/2014"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Ann	FilledTILTtable8	"05/11/2013"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Heidi	FilledTILTtable0	"23/11/2013"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Faustin	FilledTILTtable1	"23/12/2012"^^<http://www.w3.org/2001/XMLSchema#dateTime>
Tian	FilledTILTtable3	"15/5/2013"^^<http://www.w3.org/2001/XMLSchema#dateTime>

Figure 31 Query 1: patient name, filled table and filled date

Query 2: vital signs and selected options of one specific filled TILT table

In this query we display which option has been chosen by patient in a specific filled TILT table. We use the triple pattern FilledTILTtable hasCollectedAnswer CollectedAnswer, CollectedAnswer hasVitalSign VitalSigns, CollectedAnswer hasChosen SelectedOptions, then we could know which option has been chosen in one specific TILT table.

The codes of Query 2 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?VitalSigns ?SelectedOptions

WHERE{ A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer. ?CollectedAnswer A:hasVitalSign ?VitalSigns. ?CollectedAnswer A:hasChosen ?SelectedOptions }

And the results we get from the codes above is in Figure 32.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?VitalSigns ?SelectedOptions
WHERE{ A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer. ?CollectedAnswer A:hasVitalSign ?VitalSigns. ?CollectedAnswer A:hasChosen ?SelectedOptions }
```

VitalSigns	SelectedOptions
4.Temperature	35-38.4
5.CNS	Responds_to_Indictment
3.BloodPressure	101-199
1.RespirationFrequency	larger_than_30
2.PulseOximetry	101-110

Figure 32 Query 2: vital signs and selected options of one specific filled TILT table

Query 3: patient name, vital signs and values of vital signs

In this query we display one specific patient name and his/her tested vital signs, as well as each chosen option's value. We use the triple pattern FilledTILTtable hasCollectedAnswer CollectedAnswer, Answer hasVitalSign VitalSigns, CollectedAnswer hasChosen SelectedOptions, then we could know the values of the selected option in one specific TILT table.

The codes of Query 3 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?PatientName ?VitalSigns ?Value

WHERE{ ?PatientName A:fillin A:FilledTILTtable3. A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer. ?CollectedAnswer A:hasVitalSign ?VitalSigns.

?CollectedAnswer A:hasChosen ?SelectedOptions. ?SelectedOptions A:hasvalue ?Value }

And the results we get from the codes above is in Figure 33.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?PatientName ?VitalSigns ?Value
WHERE{ ?PatientName A:fillin A:FilledTILTtable3. A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer. ?CollectedAnswer A:hasVitalSign ?VitalSigns.
?CollectedAnswer A:hasChosen ?SelectedOptions. ?SelectedOptions A:hasvalue ?Value }
```

PatientName	VitalSigns	V
Tian	4.Temperature	"0"^^<http://www.w3.org/2001/XMLSchema#int>
Tian	5.CNS	"1"^^<http://www.w3.org/2001/XMLSchema#int>
Tian	3.BloodPressure	"0"^^<http://www.w3.org/2001/XMLSchema#int>
Tian	1.RespirationFrequency	"3"^^<http://www.w3.org/2001/XMLSchema#int>
Tian	2.PulseOximetry	"1"^^<http://www.w3.org/2001/XMLSchema#int>

Figure 33 Query 3: patient name, vital signs and values of vital signs

Query 4: patients who has chosen options that has value 3

In this query we use two new keywords CONSTRUCT and FILTER. CONSTRUCT could help to build a rule that fits our needs. For example, we know Lily is Sarah's mother, Sarah is Ann's mother. And we use CONSTRUCT to build a rule of mother's mother is grandmother, then we could query for Ann's grandmother's name. Then the answer should be Lily. We could write some conditions or requirements in the braces behind the keyword FILTER. And then we will filter the information that match those conditions or requirements.

Options with value 3 could reflect a dangerous situation of a patient. So patient who has chosen one or more options that has value larger than 3 should be displayed in this query. We use CONSTRUCT query to build a rule that the filled TILT tables which have options with value 3 to be "true". We also use the function FILTER to filter the patients who has the situation "true".

The codes of Query 4 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

CONSTRUCT { ?PatientName A:hasvalue true }

WHERE { ?PatientName A:fillin ?FilledTILTtable.?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.

?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value. FILTER (?Value>2) }

And the results we get from the codes above is in Figure 34.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
CONSTRUCT { ?PatientName A:hasvalue true }
        WHERE { ?PatientName A:fillin ?FilledTILTtable.?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.
?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value.FILTER (?Value>2) }
```

Subject	Predicate	Object
Jack	hasvalue	"true"^^<http://www.w3.org/2001/XMLSchema#boolean>
Lucy	hasvalue	"true"^^<http://www.w3.org/2001/XMLSchema#boolean>
Lily	hasvalue	"true"^^<http://www.w3.org/2001/XMLSchema#boolean>
Angelique	hasvalue	"true"^^<http://www.w3.org/2001/XMLSchema#boolean>
Ben	hasvalue	"true"^^<http://www.w3.org/2001/XMLSchema#boolean>
Mary	hasvalue	"true"^^<http://www.w3.org/2001/XMLSchema#boolean>
Sissi	hasvalue	"true"^^<http://www.w3.org/2001/XMLSchema#boolean>
Tian	hasvalue	"true"^^<http://www.w3.org/2001/XMLSchema#boolean>

Figure 34 Query 4: patients who has chosen options that has value 3

Query 5: calculate total score of one filled TILT table

As planed we should use the query to calculate the total score of TILT tables automatically. We use the function SUM (?A) AS (?B), where B is the accumulation of all As. In this query, A means the value of every selected option of one specific filled TILT table. Then B should be the total score of the specific table.

The codes of Query 5 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT (SUM(?Value) AS ?TotalScore)

WHERE { A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value }

And the results we get from the codes above is in Figure 35.

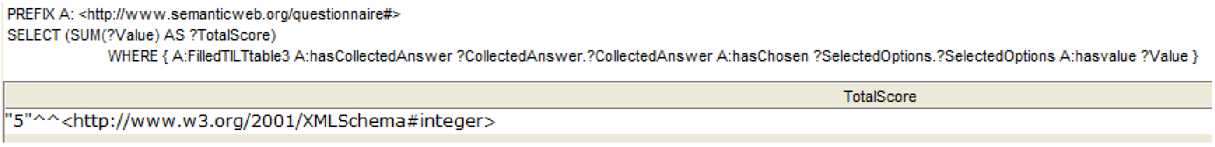

Figure 35 Query 5: calculate total score of one filled TILT table

Query 6: total scores of all filled TILT tables

We could calculate the total score of one specific filled TILT table, then we need to show all the filled TILT tables' total scores. We use one new statement GROUP BY in this query, which function is to arrange the querying information to be shown into groups. Here we have the total scores into groups of all filled TILT tables in our system.

The codes of Query 6 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?FilledTILTtable (SUM(?Value) AS ?TotalScore)

WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value }

GROUP BY ?FilledTILTtable

And the results we get from the codes above is in Figure 36.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable (SUM(?Value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value }
        GROUP BY ?FilledTILTtable
```

FilledTILTtable	TotalScore
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable0	"0"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>

Figure 36 Query 6: total scores of all filled TILT tables

Query 7: the filled TILT tables with total scores larger than 4

Even though the scores of all vital signs may be less than 3 of one specific filled TILT talbe, the total score 4 could also reflects a dangerous situation of the patient. Thus we use the statement HAVING to get the filled TILT tables that have total scores larger than 4. The function of HAVING is almost the same as FILTER. However, HAVING operates over the grouped solution sets, FILTER operates over the un-grouped ones [40].

The codes of Query 6 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?FilledTILTtable (SUM(?Value) AS ?TotalScore)

WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value }

GROUP BY ?FilledTILTtable

HAVING (?TotalScore > 4)

And the results we get from the codes above is in Figure 37.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable (SUM(?Value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value }
        GROUP BY ?FilledTILTtable
        HAVING (?TotalScore > 4)
```

FilledTILTtable	TotalScore
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>

Figure 37 Query 7: the filled TILT tables with total scores larger than 4

Query 8: the vital sign with the largest value in one filled TILT table

Only the total score cannot show the concrete situation of one patient, sometimes we need to know which vital sign has the largest value comparing with others, in order to know the worst aspect of the patient's situation. Here we use the function MAX (?A) AS (?B) to calculate the maximum value of one filled TILT table. In the function, A represents the information that we consider, and B should be the max ones among A.We use FilledTILTtable3 (has only one item with maximum value) and FilledTILTtable4 (has two items with maximum value) as examples.

The codes of Query 6 for FilledTILTtable3 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT DISTINCT ?dangerousitems ?value

WHERE

{

{SELECT (MAX(?Value) AS ?max_value)

WHERE {A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value. } GROUP BY ?max_value}

{SELECT ?value

WHERE {A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SeletedOptions.?SelectedOptions A:hasvalue ?value.}GROUP BY ?value}

FILTER (?value = ?max_value)

A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasVitalSign ?dangerousitems.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value.

}

And the results we get from the codes above is in Figure 38.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT DISTINCT ?dangerousitems ?value
WHERE
{
{SELECT  (MAX(?Value) AS ?max_value)
            WHERE {A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value. } GROUP BY ?max_value}
{SELECT ?value
    WHERE {A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SeletedOptions.?SelectedOptions A:hasvalue ?value.}GROUP BY ?value}
FILTER (?value = ?max_value)
A:FilledTILTtable3 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasVitalSign ?dangerousitems.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value.
}
```

dangerousitems	value
1.RespirationFrequency	"3"^^<http://www.w3.org/2001/XMLSchema#int>

Figure 38 Query 8: the vital sign with the largest value in filled TILT table 3

The codes of Query 6 for FilledTILTtable4 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT DISTINCT ?dangerousitems ?value

WHERE

{

{SELECT (MAX(?Value) AS ?max_value)

WHERE {A:FilledTILTtabl48 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value. } GROUP BY ?max_value}

{SELECT ?value

WHERE {A:FilledTILTtable4 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SeletedOptions.?SelectedOptions A:hasvalue ?value.}GROUP BY ?value}

FILTER (?value = ?max_value)

A:FilledTILTtable4 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasVitalSign ?dangerousitems.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value.

}

And the results we get from the codes above is in Figure 39.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT DISTINCT ?dangerousitems ?value
WHERE
{
{SELECT  (MAX(?Value) AS ?max_value)
            WHERE {A:FilledTILTtable4 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value. } GROUP BY ?max_value}
{SELECT ?value
   WHERE {A:FilledTILTtable4 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SeletedOptions.?SelectedOptions A:hasvalue ?value.}GROUP BY ?value}
FILTER (?value = ?max_value)
A:FilledTILTtable4 A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasVitalSign ?dangerousitems.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value.
}
```

dangerousitems	value
2.PulseOximetry	"3"^^<http://www.w3.org/2001/XMLSchema#int>
1.RespirationFrequency	"3"^^<http://www.w3.org/2001/XMLSchema#int>

Figure 39 Query 8: the vital sign with the largest value in filled TILT table 4

Query 9: the items with maximum values of all the filled TILT tables

After querying the vital signs with maximum value of one specific filled TILT table, we could show all those items with maximum values of all filled TILT tables at the same time. For the practical reason that total score larger than 4 means a dangerous situation, here we show only the items with maximum values of the filled TILT tables that have total score 4. In this query we use the concept of Subquery, which means in one main query, there are several subqueries inside. The system will execute the subqueries from the front to end, then return the final querying information to the main query.

The codes of Query 9 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT DISTINCT ?FilledTILTtable ?dangerousitems ?Value

WHERE

{

{SELECT ?FilledTILTtable (MAX(?value) AS ?max_value)

WHERE {{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)

WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }

Group By ?FilledTILTtable

HAVING (?TotalScore > 4)

}?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. } GROUP BY ?FilledTILTtable}

{SELECT ?Value

WHERE {?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value.} GROUP BY ?Value}

FILTER (?Value = ?max_value)

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasVitalSign ?dangerousitems.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value.

}

And the results we get from the codes above is in Figure 40.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT DISTINCT ?FilledTILTtable ?dangerousitems ?Value
WHERE
{
{SELECT  ?FilledTILTtable (MAX(?value) AS ?max_value)
    WHERE {{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
                WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
                Group By ?FilledTILTtable
               HAVING ( ?TotalScore > 4)
}?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. } GROUP BY ?FilledTILTtable}
{SELECT ?Value
    WHERE {?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value.} GROUP BY ?Value}
FILTER (?Value = ?max_value)
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasVitalSign ?dangerousitems.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?Value.
}
```

FilledTILTtable	dangerousitems	Value
FilledTILTtable10	2.PulseOximetry	"3"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable6	2.PulseOximetry	"2"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable6	4.Temperature	"2"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable9	2.PulseOximetry	"3"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable8	5.CNS	"2"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable8	4.Temperature	"2"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable4	2.PulseOximetry	"3"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable4	1.RespirationFrequency	"3"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable3	1.RespirationFrequency	"3"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable7	3.BloodPressure	"3"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable1	5.CNS	"2"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable1	1.RespirationFrequency	"2"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable5	2.PulseOximetry	"3"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable2	5.CNS	"3"^^<http://www.w3.org/2001/XMLSchema#int>
FilledTILTtable11	3.BloodPressure	"3"^^<http://www.w3.org/2001/XMLSchema#int>

Figure 40 Query 9: the items with maximum values of all the filled TILT tables

Query 10: the description based on the total score of the filled TILT table

As shown in Table 2, patients have different testing frequency based on the total score of their filled TILT tables. In this query we could get the testing frequency after calculating the total scores of the filled TILT tables. Based on the grouped filled TILT tables with calculated total score, we use a subquery to query the description of the queried total scores.

The codes of Query 10 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?FilledTILTtable ?TotalScore ?description

WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)

WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. } GROUP BY ?FilledTILTtable}

{SELECT ?Score ?description

WHERE{?TotalScore A:hasTotalValue ?Score.?TotalScore A:hasdescription ?description}}

FILTER (?Score = ?TotalScore)}

And the results we get from the codes above is in Figure 41.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?description
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
            WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. } GROUP BY ?FilledTILTtable}
{SELECT ?Score ?description
WHERE{?TotalScore A:hasTotalValue ?Score.?TotalScore A:hasdescription ?description}}
FILTER (?Score = ?TotalScore)}
```

FilledTILTtable	TotalScore	description
FilledTILTtable0	"0"^^<http://www.w3.org/2001/XMLSchema#integer>	"New control within 24 hours"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Contact the doctor immediately"^^<http://www.w3.org/2001/XMLSchema#string>

Figure 41 Query 10: the description based on the total score of the filled TILT table

Query 11: doctor's suggestion of one specific clinical rule

As shown in Table 2, we also have eight clinical rules that help the system to output the suggestions automatically. As the eight rules are only related to the values of four vital signs' options, in this query we first define four varioubles match to those four values (value1, value2, value3 and value4), and then use the function FILTER to filter the filled TILT tables that according to one of the eight clinical rules. And of course we just need to query the filled TILT tables with total scores larger than three.

The codes of Query 11 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?FilledTILTtable ?TotalScore ?Suggestion

WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)

WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }

Group By ?FilledTILTtable

HAVING (?TotalScore > 3)}

{SELECT ?FilledTILTtable ?Suggestion

WHERE{

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.

FILTER(?value1 = 3 && ?value3 < 2 && ?value2 < 2)

A:Suggestion1 A:hasSuggestion ?Suggestion}}}

And the results we get from the codes above is in Figure 42.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
            WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
            Group By ?FilledTILTtable
           HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
FILTER(?value1 = 3 && ?value3 < 2 && ?value2 < 2)
A:Suggestion1 A:hasSuggestion ?Suggestion}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable3	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Hyperventilation"^^<http://www.w3.org/2001/XMLSchema#string>

Figure 42 Query 11: doctor's suggestion of one specific clinical rule

Query 12: show the suggestions of all filled TILT tables with total score larger than three

After querying one specific rule, we hope to check all the filled TILT tables that match to those all eight clinical rules. Here we use the keyword OPTIONAL which could show part of the ontology graph and do not influence each others. The filled TILT tables with total scores larger than three but do not match to the eight rules will display nothing in the suggestion part.

The codes of Query 12 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?FilledTILTtable ?TotalScore ?Suggestion

WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)

WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }

Group By ?FilledTILTtable

HAVING (?TotalScore > 3)}

{SELECT ?FilledTILTtable ?Suggestion

WHERE{

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.

OPTIONAL{A:Suggestion1 A:hasSuggestion ?Suggestion FILTER(?value1 = 3 && ?value2 < 2 && ?value3 < 2)}

OPTIONAL{A:Suggestion2 A:hasSuggestion ?Suggestion FILTER(?value1 >= 2 && ?value2 >= 2)}

OPTIONAL{A:Suggestion3 A:hasSuggestion ?Suggestion FILTER(?value1 > 0 && ?value2 = 3 && ?value3 >= 2 && ?value4 = 0)}

OPTIONAL{A:Suggestion4 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value4 = 2)}

OPTIONAL{A:Suggestion5 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value3 = 3)}

OPTIONAL{A:Suggestion6 A:hasSuggestion ?Suggestion FILTER(?value4 = 2)}

OPTIONAL{A:Suggestion7 A:hasSuggestion ?Suggestion FILTER(?value1 = 0 && ?value2 = 3 && ?value3 > 1 && ?value4 = 0)}

OPTIONAL{A:Suggestion8 A:hasSuggestion ?Suggestion FILTER(?value1 = 1 && ?value2 = 3 && ?value3 = 0 || ?value1 = 2 && ?value2 = 3 && ?value3 = 0)}

}}}

And the results we get from the codes above is in Figure 43.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
        Group By ?FilledTILTtable
       HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion1 A:hasSuggestion ?Suggestion FILTER(?value1 = 3 && ?value2 < 2 && ?value3 < 2)}
OPTIONAL{A:Suggestion2 A:hasSuggestion ?Suggestion FILTER(?value1 >= 2 && ?value2 >= 2)}
OPTIONAL{A:Suggestion3 A:hasSuggestion ?Suggestion FILTER(?value1 > 0 && ?value2 = 3 && ?value3 >= 2 && ?value4 = 0)}
OPTIONAL{A:Suggestion4 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value4 = 2)}
OPTIONAL{A:Suggestion5 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value3 = 3)}
OPTIONAL{A:Suggestion6 A:hasSuggestion ?Suggestion FILTER(?value4 = 2)}
OPTIONAL{A:Suggestion7 A:hasSuggestion ?Suggestion FILTER(?value1 = 0 && ?value2 = 3 && ?value3 > 1 && ?value4 = 0)}
OPTIONAL{A:Suggestion8 A:hasSuggestion ?Suggestion FILTER(?value1 = 1 && ?value2 = 3 && ?value3 = 0 || ?value1 = 2 && ?value2 = 3 && ?value3 = 0)}
}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of physical activity"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Hypothermia"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of reduced cardiac activity"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Hyperventilation"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Cardio-pulmonary disease"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Atrial Fibrillation"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Cardiac failure"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of reduced cardiac activity"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of infection"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	

Figure 43 Query 12: show the suggestions of all filled TILT tables with total score larger than three

Query 13: show the suggestions, descriptions and total scores of all the filled TILT tables

Based on the queries above, we could query for the suggestions, discriptions and total scores of all the filled TILT tables at the same time. And this query could illustrate that our system implement all the functions in Table 2.

The codes of Query 13 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?FilledTILTtable ?TotalScore ?Suggestion ?description

WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)

WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. } Group By ?FilledTILTtable}

{SELECT ?Score ?description WHERE{?TotalScore A:hasTotalValue ?Score. ?TotalScore A:hasdescription ?description.}} FILTER (?Score = ?TotalScore)

{SELECT ?FilledTILTtable ?Suggestion

WHERE{

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.

?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.

OPTIONAL{A:Suggestion1 A:hasSuggestion ?Suggestion FILTER(?value1 = 3 && ?value2 < 2 && ?value3 < 2)}

OPTIONAL{A:Suggestion2 A:hasSuggestion ?Suggestion FILTER(?value1 >= 2 && ?value2 >= 2)}

OPTIONAL{A:Suggestion3 A:hasSuggestion ?Suggestion FILTER(?value1 > 0 && ?value2 = 3 && ?value3 >= 2 && ?value4 = 0)}

OPTIONAL{A:Suggestion4 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value4 = 2)}

OPTIONAL{A:Suggestion5 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value3 = 3)}

OPTIONAL{A:Suggestion6 A:hasSuggestion ?Suggestion FILTER(?value4 = 2)}

OPTIONAL{A:Suggestion7 A:hasSuggestion ?Suggestion FILTER(?value1 = 0 && ?value2 = 3 && ?value3 > 1 && ?value4 = 0)}

OPTIONAL{A:Suggestion8 A:hasSuggestion ?Suggestion FILTER(?value1 = 1 && ?value2 = 3 && ?value3 = 0 || ?value1 = 2 && ?value2 = 3 && ?value3 = 0)}

}}}

And the results we get from the codes above is in Figure 44.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion ?description
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. } Group By ?FilledTILTtable}
{SELECT ?Score ?description WHERE{?TotalScore A:hasTotalValue ?Score. ?TotalScore A:hasdescription ?description.}} FILTER (?Score = ?TotalScore)
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion1 A:hasSuggestion ?Suggestion FILTER(?value1 = 3 && ?value2 < 2 && ?value3 < 2)}
OPTIONAL{A:Suggestion2 A:hasSuggestion ?Suggestion FILTER(?value1 >= 2 && ?value2 >= 2)}
OPTIONAL{A:Suggestion3 A:hasSuggestion ?Suggestion FILTER(?value1 > 0 && ?value2 = 3 && ?value3 >= 2 && ?value4 = 0)}
OPTIONAL{A:Suggestion4 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value4 = 2)}
OPTIONAL{A:Suggestion5 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value3 = 3)}
OPTIONAL{A:Suggestion6 A:hasSuggestion ?Suggestion FILTER(?value4 = 2)}
OPTIONAL{A:Suggestion7 A:hasSuggestion ?Suggestion FILTER(?value1 = 0 && ?value2 = 3 && ?value3 > 1 && ?value4 = 0)}
OPTIONAL{A:Suggestion8 A:hasSuggestion ?Suggestion FILTER(?value1 = 1 && ?value2 = 3 && ?value3 = 0 || ?value1 = 2 && ?value2 = 3 && ?value3 = 0)}
}}}
```

FilledTILTtable	TotalScore	Suggestion	description
FilledTILTtable0	"0"^^<http://www.w3.org/2001/XMLSchema#integer>		"New control within 24 hours"^^<http://www.w3.org/2001
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of physical activity"^^<http://www.w3.org/200	"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Hypothermia"^^<http://www.w3.org/2001/	"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Hyperventilation"^^<http://www.w3.org/20	"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Atrial Fibrillation"^^<http://www.w3.org/20	"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>		"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of infection"^^<http://www.w3.org/2001/XMLS	"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of reduced cardiac activity"^^<http://www.w3.	"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>		"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Cardio-pulmonary disease"^^<http://www.	"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Cardiac failure"^^<http://www.w3.org/2001	"Contact the doctor immediately"^^<http://www.w3.org/2
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of reduced cardiac activity"^^<http://www.w3.	"Contact the doctor immediately"^^<http://www.w3.org/2

Figure 44 Query 13: show the suggestions, descriptions and total scores of all the filled TILT tables

Query 14: show the filled TILT table with more than one suggestions

Sometimes one filled TILT table may match to more than one rule. In this project, we use filledTILTtable11 as an example, which match to the fourth, fifth and sixth rules at the same time. This query is based on the four defined values mentioned in Query 11. And we also use the keyword OPTIONAL to pick out which rules that filledTILTtable11 matches.

The codes of Query 14 is as follows:

PREFIX A: <http://www.semanticweb.org/questionnaire#>

SELECT ?Sug1 ?Sugn2 ?Sug3 ?Sug4 ?Sug5 ?Sug6 ?Sug7 ?Sug8

WHERE{

A:FilledTILTtable11 A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.

A:FilledTILTtable11 A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.

A:FilledTILTtable11 A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.

A:FilledTILTtable11 A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.

OPTIONAL{FILTER(?value1 = 3 && ?value3 < 2 && ?value2 < 2) A:Suggestion1 A:hasSuggestion ?Sug1}

OPTIONAL{ FILTER(?value1 >= 2 && ?value2 >= 2) A:Suggestion2 A:hasSuggestion ?Sug2}

OPTIONAL{FILTER(?value1 > 0 && ?value2 = 3 && ?value3 >= 2 && ?value4 = 0) A:Suggestion3 A:hasSuggestion ?Sug3}

OPTIONAL{FILTER(?value2 >= 2 && ?value4 = 2) A:Suggestion4 A:hasSuggestion ?Sug4}

OPTIONAL{FILTER(?value2 >= 2 && ?value3 = 3) A:Suggestion5 A:hasSuggestion ?Sug5}

OPTIONAL{FILTER(?value4 = 2) A:Suggestion6 A:hasSuggestion ?Sug6}

OPTIONAL{FILTER(?value1 = 0 && ?value2 = 3 && ?value3 > 1 && ?value4 = 0) A:Suggestion7 A:hasSuggestion ?Sug7}

OPTIONAL{FILTER(?value1 = 1 && ?value2 = 3 && ?value3 = 0 ‖ ?value1 = 2 && ?value2 = 3 && ?value3 = 0) A:Suggestion8 A:hasSuggestion ?Sug8}

}

And the results we get from the codes above is in Figure 45.

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?Sug1 ?Sugn2 ?Sug3 ?Sug4 ?Sug5 ?Sug6 ?Sug7 ?Sug8
WHERE{
A:FilledTILTtable11 A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
A:FilledTILTtable11 A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
A:FilledTILTtable11 A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
A:FilledTILTtable11 A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{FILTER(?value1 = 3 && ?value3 < 2 && ?value2 < 2) A:Suggestion1 A:hasSuggestion ?Sug1}
OPTIONAL{ FILTER(?value1 >= 2 && ?value2 >= 2) A:Suggestion2 A:hasSuggestion ?Sug2}
OPTIONAL{FILTER(?value1 > 0 && ?value2 = 3 && ?value3 >= 2 && ?value4 = 0) A:Suggestion3 A:hasSuggestion ?Sug3}
OPTIONAL{FILTER(?value2 >= 2 && ?value4 = 2) A:Suggestion4 A:hasSuggestion ?Sug4}
OPTIONAL{FILTER(?value2 >= 2 && ?value3 = 3) A:Suggestion5 A:hasSuggestion ?Sug5}
OPTIONAL{FILTER(?value4 = 2) A:Suggestion6 A:hasSuggestion ?Sug6}
OPTIONAL{FILTER(?value1 = 0 && ?value2 = 3 && ?value3 > 1 && ?value4 = 0) A:Suggestion7 A:hasSuggestion ?Sug7}
OPTIONAL{FILTER(?value1 = 1 && ?value2 = 3 && ?value3 = 0 ‖ ?value1 = 2 && ?value2 = 3 && ?value3 = 0) A:Suggestion8 A:hasSuggestion ?Sug8}
}
```

Sug1	Sugn2	Sug3	Sug4	Sug5	Sug6	Sug7	Sug8
			"Symptoms of infection"	"Symptoms of reduced cardiac activity"	"Symptoms of Hypothermia"		

Figure 45 Query 14: show the filled TILT table with more than one suggestions

6 Discussion and Evaluation

This project aims at building an ontology-based system for the hospital in Kristiansand, Norway, which could make decisions automatically according to the information filled in the TILT (Tidlig Identifisering av Livstruende Tilstander) tables. This ontology-based system focuses on collecting patients' information (the answers of TILT tables), calculating the score and outputting the decisions according to the clinical rules.

In this project, we designed the whole system structure in Eclipse firstly. Secondly, classes, properties and individuals were added into Protégé, which is based on the system structure. In the next step, we added information of patients and filled tables into the system. Later on we used SPARQL query to calculate the sum score of the tables, as well as the maximum score of each table. At last we could output the suggestions automatically we need according to the sum score and the clinical rules.

According to the requirement of this project, our ontology-based decision support system has several advantages as following:

1. This project combines clinical knowledge with computer science. Comparing with traditional clinical systems, the use of computer makes it convenient for medical personnel to collect patients' information, analyse patients' situations and give proper diagnoses to patients. Especially, the function of decision support could filter the important patients' information automatically and avoid medical errors to some extent.

2. This project uses the advanced ontology techniques, which has a significant advantage in information management. Different from the data-based traditional methods to manage information, ontology-based techniques could represent the relationships between elements. In Protégé, classes are defined to classify data into different levels, and properties are defined to show the relationships between those levels. Patients' information could be stored and managed as individuals, which are specific instances of classes.

3. This system could be updated and maintained conveniently. For one aspect, patients' information is easy to be added, inquired and deleted by clinical personnel in the system. For another aspect, the rules for decision support can be revised according to the new clinical research results and do not need to modify the project's structure. So the update of the system will not be complex and costly.

4. This project can not only be used for multiple diseases, but also can be extended in many aspects. By combining with the Internet techniques, this system could be used for remote monitoring of patients. This will improve the convenience and reduce the cost of patients at the same time. Moreover, based on ontology structure, our system could be used for other domains, not only for clinical usage.

However, this system is not mature and complete enough. The following shortages could impact its implementation:

1. The system is not convenient to be operate in clinics. It should be friendlier to the user. The collection of patients' information still needs manually inputs, which leads to increased workload and errors. Moreover, clinical personnel may not familiar with the codes of SPARQL query, thus there may be some problem when they analysing patients' information.

2. More advanced clinical rules for decision support should be used in this system. Large amount of new clinical research results have been published every year, which could be introduced into our system in order to improve the level of clinical diagnosis.

7 Conclusion and Outlook

7.1 Conclusion

This project successfully implement the clinical decision support system for the hospital in Kristiansand, based on the tables and rules of TILT. We use Protégé to build the ontology-based TILT table, which uses classes and properties to show the structure of the table. Then we created some specific individuals to be concrete items of a TILT table. After implementing all the relationships between individuals and classes, this knowledge-based ontology model is capable of storing information of any filled TILT tables, which contains a set of vital signs, related options and patients' answers, as well as dates it was filled and general patient records like age, gender, and location.

By using SPARQL query technology, the ontology-based decision support system could output some useful information, such as the filled TILT tables and the patients who filled them. According to the knowledge from experts, each answer in the TILT table refers to a score. In the system, we could use functions to calculate the total score of the filled TILT tables. Base on both the total score and the clinical rules for decision making, the system could output suggestions for patients immediately.

This system could be used for clinical management and diagnosement. By saving time and human workloads, as well as avoiding clinical errors, the system improves the efficiency of clinical decision support.

7.2 Outlook

For the system is not perfect and has many disadvantages, we still have some work in the future to make it better. The future work we could do is as follows:

1. Design an interface for information collection. Test data from vital sign sensors could be imported automatically and other information should be delivered to the system in the form of electronic questionnaire.

2. Design a friendly GUI for clinical personnel. In the GUI, medical staff can check and manage patients' information conveniently, as well as receive and response the diagnose suggestions.

3. Introduce more personal information to the system as diagnostic indicators. Based on them, more accurate model can be generated for clinical decision support and more advanced medical research results.

4. Before implemention in clinics, more tests and evaluations should be done for the system. in addition, pre commissioning is also required.

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Appendix A the System Background Codes

We could save these codes in a text file, and open this file using Protégé. Then the system could be shown in Protégé.

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<?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/questionnaire"
     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/questionnaire">
    <Prefix name="" IRI="http://www.semanticweb.org/questionnaire#"/>
    <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="xml" IRI="http://www.w3.org/XML/1998/namespace"/>
    <Prefix name="xsd" IRI="http://www.w3.org/2001/XMLSchema#"/>
    <Prefix name="rdfs" IRI="http://www.w3.org/2000/01/rdf-schema#"/>
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        <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
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(TIILT) - Early Identification of Life-Threatening Conditions</Literal>
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    </Declaration>
    <Declaration>
        <Class IRI="#CNS"/>
    </Declaration>
    <Declaration>
        <Class IRI="#FilledTILTtable"/>
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    </Declaration>
    <Declaration>
        <Class IRI="#Patient"/>
    </Declaration>
    <Declaration>
        <Class IRI="#PulseOximetry"/>
    </Declaration>
```

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    <Declaration>
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    </Declaration>
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    <ClassAssertion>
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    </ObjectPropertyAssertion>
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        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt102"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt103"/>
```

```
        <NamedIndividual IRI="#101-199"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt103"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt104"/>
        <NamedIndividual IRI="#35-38.4"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt104"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt105"/>
        <NamedIndividual IRI="#Responds_to_Indictment"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt105"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt11"/>
        <NamedIndividual IRI="#less_than_9"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt11"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt111"/>
        <NamedIndividual IRI="#9-14"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt111"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt112"/>
        <NamedIndividual IRI="#111-129"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
```

```
        <NamedIndividual IRI="#filledt112"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt113"/>
        <NamedIndividual IRI="#less_than_70"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt113"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt114"/>
        <NamedIndividual IRI="#larger_than_38.5"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt114"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt115"/>
        <NamedIndividual IRI="#Awake_and_Pays_Attention"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt115"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt12"/>
        <NamedIndividual IRI="#41-50"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt12"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt13"/>
        <NamedIndividual IRI="#101-199"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt13"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
```

```
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt14"/>
        <NamedIndividual IRI="#35-38.4"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt14"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt15"/>
        <NamedIndividual IRI="#Responds_to_Pain"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt15"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt21"/>
        <NamedIndividual IRI="#9-14"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt21"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt22"/>
        <NamedIndividual IRI="#111-129"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt22"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt23"/>
        <NamedIndividual IRI="#81-100"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt23"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt24"/>
        <NamedIndividual IRI="#35-38.4"/>
    </ObjectPropertyAssertion>
```

```
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt24"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt25"/>
        <NamedIndividual IRI="#Does_not_Respond"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt25"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt31"/>
        <NamedIndividual IRI="#larger_than_30"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt31"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
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        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt32"/>
        <NamedIndividual IRI="#101-110"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt32"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt33"/>
        <NamedIndividual IRI="#101-199"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt33"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt34"/>
        <NamedIndividual IRI="#35-38.4"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt34"/>
        <NamedIndividual IRI="#4.Temperature"/>
```

```
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt35"/>
        <NamedIndividual IRI="#Responds_to_Indictment"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt35"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt41"/>
        <NamedIndividual IRI="#larger_than_30"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt41"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt42"/>
        <NamedIndividual IRI="#larger_than_130"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt42"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt43"/>
        <NamedIndividual IRI="#81-100"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt43"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt44"/>
        <NamedIndividual IRI="#35-38.4"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt44"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt45"/>
```

```
        <NamedIndividual IRI="#Awake_and_Pays_Attention"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt45"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt51"/>
        <NamedIndividual IRI="#15-20"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt51"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt52"/>
        <NamedIndividual IRI="#larger_than_130"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt52"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt53"/>
        <NamedIndividual IRI="#71-80"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt53"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt54"/>
        <NamedIndividual IRI="#35-38.4"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt54"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt55"/>
        <NamedIndividual IRI="#Responds_to_Indictment"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
```

```
            <NamedIndividual IRI="#filledt55"/>
            <NamedIndividual IRI="#5.CNS"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasChosen"/>
            <NamedIndividual IRI="#filledt61"/>
            <NamedIndividual IRI="#9-14"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasVitalSign"/>
            <NamedIndividual IRI="#filledt61"/>
            <NamedIndividual IRI="#1.RespirationFrequency"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasChosen"/>
            <NamedIndividual IRI="#filledt62"/>
            <NamedIndividual IRI="#111-129"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasVitalSign"/>
            <NamedIndividual IRI="#filledt62"/>
            <NamedIndividual IRI="#2.PulseOximetry"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasChosen"/>
            <NamedIndividual IRI="#filledt63"/>
            <NamedIndividual IRI="#81-100"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasVitalSign"/>
            <NamedIndividual IRI="#filledt63"/>
            <NamedIndividual IRI="#3.BloodPressure"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasChosen"/>
            <NamedIndividual IRI="#filledt64"/>
            <NamedIndividual IRI="#less_than_35"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasVitalSign"/>
            <NamedIndividual IRI="#filledt64"/>
            <NamedIndividual IRI="#4.Temperature"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasChosen"/>
            <NamedIndividual IRI="#filledt65"/>
            <NamedIndividual IRI="#Awake_and_Pays_Attention"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
            <ObjectProperty IRI="#hasVitalSign"/>
            <NamedIndividual IRI="#filledt65"/>
            <NamedIndividual IRI="#5.CNS"/>
        </ObjectPropertyAssertion>
        <ObjectPropertyAssertion>
```

```
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt71"/>
        <NamedIndividual IRI="#15-20"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt71"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt72"/>
        <NamedIndividual IRI="#less_than_40"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt72"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt73"/>
        <NamedIndividual IRI="#less_than_70"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt73"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt74"/>
        <NamedIndividual IRI="#35-38.4"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt74"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt75"/>
        <NamedIndividual IRI="#Awake_and_Pays_Attention"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt75"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt81"/>
        <NamedIndividual IRI="#15-20"/>
    </ObjectPropertyAssertion>
```

```
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt81"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt82"/>
        <NamedIndividual IRI="#51-100"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt82"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt83"/>
        <NamedIndividual IRI="#101-199"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt83"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt84"/>
        <NamedIndividual IRI="#larger_than_38.5"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt84"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt85"/>
        <NamedIndividual IRI="#Responds_to_Pain"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt85"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt91"/>
        <NamedIndividual IRI="#9-14"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt91"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
```

```
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt92"/>
        <NamedIndividual IRI="#larger_than_130"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt92"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt93"/>
        <NamedIndividual IRI="#larger_than_200"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt93"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt94"/>
        <NamedIndividual IRI="#35-38.4"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt94"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasChosen"/>
        <NamedIndividual IRI="#filledt95"/>
        <NamedIndividual IRI="#Awake_and_Pays_Attention"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#hasVitalSign"/>
        <NamedIndividual IRI="#filledt95"/>
        <NamedIndividual IRI="#5.CNS"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#isOptionof"/>
        <NamedIndividual IRI="#larger_than_130"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#isOptionof"/>
        <NamedIndividual IRI="#larger_than_200"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#isOptionof"/>
        <NamedIndividual IRI="#larger_than_30"/>
```

```
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#isOptionof"/>
        <NamedIndividual IRI="#larger_than_38.5"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#isOptionof"/>
        <NamedIndividual IRI="#less_than_35"/>
        <NamedIndividual IRI="#4.Temperature"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#isOptionof"/>
        <NamedIndividual IRI="#less_than_40"/>
        <NamedIndividual IRI="#2.PulseOximetry"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#isOptionof"/>
        <NamedIndividual IRI="#less_than_70"/>
        <NamedIndividual IRI="#3.BloodPressure"/>
    </ObjectPropertyAssertion>
    <ObjectPropertyAssertion>
        <ObjectProperty IRI="#isOptionof"/>
        <NamedIndividual IRI="#less_than_9"/>
        <NamedIndividual IRI="#1.RespirationFrequency"/>
    </ObjectPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#101-110"/>
        <Literal datatypeIRI="&xsd;int">1</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#101-199"/>
        <Literal datatypeIRI="&xsd;int">0</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#111-129"/>
        <Literal datatypeIRI="&xsd;int">2</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#15-20"/>
        <Literal datatypeIRI="&xsd;int">1</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
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        <NamedIndividual IRI="#21-29"/>
        <Literal datatypeIRI="&xsd;int">2</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
```

```
        <NamedIndividual IRI="#35-38.4"/>
        <Literal datatypeIRI="&xsd;int">0</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#51-100"/>
        <Literal datatypeIRI="&xsd;int">0</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#71-80"/>
        <Literal datatypeIRI="&xsd;int">2</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#9-14"/>
        <Literal datatypeIRI="&xsd;int">0</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasAge"/>
        <NamedIndividual IRI="#Angelique"/>
        <Literal datatypeIRI="&xsd;int">28</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasGender"/>
        <NamedIndividual IRI="#Angelique"/>
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    <DataPropertyAssertion>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasAge"/>
        <NamedIndividual IRI="#Ann"/>
        <Literal datatypeIRI="&xsd;int">50</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasGender"/>
        <NamedIndividual IRI="#Ann"/>
        <Literal datatypeIRI="&xsd;string">Female</Literal>
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    <DataPropertyAssertion>
```

```
        <DataProperty IRI="#hasLocation"/>
        <NamedIndividual IRI="#Ann"/>
        <Literal datatypeIRI="&xsd;string">Buskerud</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#Awake_and_Pays_Attention"/>
        <Literal datatypeIRI="&xsd;int">0</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasAge"/>
        <NamedIndividual IRI="#Ben"/>
        <Literal datatypeIRI="&xsd;int">32</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasGender"/>
        <NamedIndividual IRI="#Ben"/>
        <Literal datatypeIRI="&xsd;string">Male</Literal>
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        <NamedIndividual IRI="#Ben"/>
        <Literal datatypeIRI="&xsd;string">Oslo</Literal>
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        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#Does_not_Respond"/>
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    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasAge"/>
        <NamedIndividual IRI="#Faustin"/>
        <Literal datatypeIRI="&xsd;int">31</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasGender"/>
        <NamedIndividual IRI="#Faustin"/>
        <Literal datatypeIRI="&xsd;string">Male</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasLocation"/>
        <NamedIndividual IRI="#Faustin"/>
        <Literal datatypeIRI="&xsd;string">Arendal</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasfilleddate"/>
        <NamedIndividual IRI="#FilledTILTtable0"/>
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    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasfilleddate"/>
        <NamedIndividual IRI="#FilledTILTtable1"/>
        <Literal datatypeIRI="&xsd;dateTime">23/12/2012</Literal>
    </DataPropertyAssertion>
```

```
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    <NamedIndividual IRI="#FilledTILTtable10"/>
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    <NamedIndividual IRI="#FilledTILTtable11"/>
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<DataPropertyAssertion>
    <DataProperty IRI="#hasfilleddate"/>
    <NamedIndividual IRI="#FilledTILTtable3"/>
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    <NamedIndividual IRI="#FilledTILTtable4"/>
    <Literal datatypeIRI="&xsd;dateTime">18/02/2014</Literal>
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    <NamedIndividual IRI="#FilledTILTtable6"/>
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    <DataProperty IRI="#hasfilleddate"/>
    <NamedIndividual IRI="#FilledTILTtable8"/>
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    <NamedIndividual IRI="#FilledTILTtable9"/>
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</DataPropertyAssertion>
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    <Literal datatypeIRI="&xsd;int">25</Literal>
```

```
    </DataPropertyAssertion>
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        <NamedIndividual IRI="#Heidi"/>
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        <NamedIndividual IRI="#Heidi"/>
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        <NamedIndividual IRI="#Jack"/>
        <Literal datatypeIRI="&xsd;int">35</Literal>
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        <NamedIndividual IRI="#Jack"/>
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        <NamedIndividual IRI="#John"/>
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    <DataPropertyAssertion>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasGender"/>
        <NamedIndividual IRI="#Lily"/>
        <Literal datatypeIRI="&xsd;string">Female</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasLocation"/>
        <NamedIndividual IRI="#Lily"/>
```

```
        <Literal datatypeIRI="&xsd;string">Oppland</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasAge"/>
        <NamedIndividual IRI="#Lucy"/>
        <Literal datatypeIRI="&xsd;int">32</Literal>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasGender"/>
        <NamedIndividual IRI="#Lucy"/>
        <Literal datatypeIRI="&xsd;string">Female</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasLocation"/>
        <NamedIndividual IRI="#Lucy"/>
        <Literal datatypeIRI="&xsd;string">Vestfold</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasAge"/>
        <NamedIndividual IRI="#Mary"/>
        <Literal datatypeIRI="&xsd;int">30</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasGender"/>
        <NamedIndividual IRI="#Mary"/>
        <Literal datatypeIRI="&xsd;string">Female</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasLocation"/>
        <NamedIndividual IRI="#Mary"/>
        <Literal datatypeIRI="&xsd;string">Oslo</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#Responds_to_Indictment"/>
        <Literal datatypeIRI="&xsd;int">1</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasvalue"/>
        <NamedIndividual IRI="#Responds_to_Pain"/>
        <Literal datatypeIRI="&xsd;int">2</Literal>
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        <NamedIndividual IRI="#Sissi"/>
        <Literal datatypeIRI="&xsd;int">45</Literal>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasGender"/>
        <NamedIndividual IRI="#Sissi"/>
        <Literal datatypeIRI="&xsd;string">Female</Literal>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasLocation"/>
```

```
        <NamedIndividual IRI="#Sissi"/>
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        <NamedIndividual IRI="#Suggestion1"/>
        <Literal datatypeIRI="&xsd;string">Symptoms of Hyperventilation</Literal>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasSuggestion"/>
        <NamedIndividual IRI="#Suggestion2"/>
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        <DataProperty IRI="#hasSuggestion"/>
        <NamedIndividual IRI="#Suggestion3"/>
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        <NamedIndividual IRI="#Suggestion4"/>
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        <DataProperty IRI="#hasLocation"/>
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        <NamedIndividual IRI="#TotalScore1"/>
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    <DataPropertyAssertion>
        <DataProperty IRI="#hasdescription"/>
        <NamedIndividual IRI="#TotalScore1"/>
        <Literal datatypeIRI="&xsd;string">New control within 8 hours</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasTotalValue"/>
        <NamedIndividual IRI="#TotalScore2"/>
        <Literal datatypeIRI="&xsd;int">2</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
        <DataProperty IRI="#hasdescription"/>
        <NamedIndividual IRI="#TotalScore2"/>
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        <NamedIndividual IRI="#TotalScore3or4"/>
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    <DataPropertyAssertion>
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        <NamedIndividual IRI="#TotalScore3or4"/>
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    <DataPropertyAssertion>
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```
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    <NamedIndividual IRI="#TotalScoreOthers"/>
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    <NamedIndividual IRI="#TotalScoreOthers"/>
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    <NamedIndividual IRI="#TotalScoreOthers"/>
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<DataPropertyAssertion>
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    <NamedIndividual IRI="#TotalScoreOthers"/>
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<DataPropertyAssertion>
    <DataProperty IRI="#hasTotalValue"/>
    <NamedIndividual IRI="#TotalScoreOthers"/>
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<DataPropertyAssertion>
    <DataProperty IRI="#hasTotalValue"/>
    <NamedIndividual IRI="#TotalScoreOthers"/>
    <Literal datatypeIRI="&xsd;int">15</Literal>
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<DataPropertyAssertion>
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    <NamedIndividual IRI="#TotalScoreOthers"/>
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<DataPropertyAssertion>
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    <NamedIndividual IRI="#TotalScoreOthers"/>
    <Literal datatypeIRI="&xsd;string">Contact  the doctor immediately</Literal>
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```
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    <NamedIndividual IRI="#larger_than_130"/>
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<DataPropertyAssertion>
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    <NamedIndividual IRI="#larger_than_200"/>
    <Literal datatypeIRI="&xsd;int">2</Literal>
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<DataPropertyAssertion>
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    <NamedIndividual IRI="#larger_than_30"/>
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</DataPropertyAssertion>
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    <DataProperty IRI="#hasvalue"/>
    <NamedIndividual IRI="#larger_than_38.5"/>
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<DataPropertyAssertion>
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</DataPropertyAssertion>
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    <NamedIndividual IRI="#less_than_70"/>
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    <NamedIndividual IRI="#less_than_9"/>
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    <ObjectProperty IRI="#fillin"/>
</InverseObjectProperties>
<InverseObjectProperties>
    <ObjectProperty IRI="#isOptionof"/>
    <ObjectProperty IRI="#hasOption"/>
</InverseObjectProperties>
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</FunctionalObjectProperty>
<ObjectPropertyDomain>
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```

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            <Class IRI="#TILTtable"/>
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        <ObjectPropertyDomain>
            <ObjectProperty IRI="#fillin"/>
            <Class IRI="#Patient"/>
        </ObjectPropertyDomain>
        <ObjectPropertyDomain>
            <ObjectProperty IRI="#hasOption"/>
            <Class IRI="#VitalSign"/>
        </ObjectPropertyDomain>
        <ObjectPropertyDomain>
            <ObjectProperty IRI="#hasVitalSign"/>
            <Class IRI="#FilledTILTtable"/>
        </ObjectPropertyDomain>
        <ObjectPropertyDomain>
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            <Class IRI="#TILTtable"/>
        </ObjectPropertyDomain>
        <ObjectPropertyDomain>
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            <Class IRI="#Option"/>
        </ObjectPropertyDomain>
        <ObjectPropertyRange>
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            <Class IRI="#Patient"/>
        </ObjectPropertyRange>
        <ObjectPropertyRange>
            <ObjectProperty IRI="#fillin"/>
            <Class IRI="#FilledTILTtable"/>
        </ObjectPropertyRange>
        <ObjectPropertyRange>
            <ObjectProperty IRI="#hasOption"/>
            <Class IRI="#Option"/>
        </ObjectPropertyRange>
        <ObjectPropertyRange>
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            <Class IRI="#VitalSign"/>
        </ObjectPropertyRange>
        <ObjectPropertyRange>
            <ObjectProperty IRI="#isOptionof"/>
            <Class IRI="#VitalSign"/>
        </ObjectPropertyRange>
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            <DataProperty IRI="#hasAge"/>
            <DataProperty abbreviatedIRI="owl:topDataProperty"/>
        </SubDataPropertyOf>
        <SubDataPropertyOf>
            <DataProperty IRI="#hasdescription"/>
            <DataProperty abbreviatedIRI="owl:topDataProperty"/>
        </SubDataPropertyOf>
</Ontology>
```

<!-- Generated by the OWL API (version 3.4.2) http://owlapi.sourceforge.net -->

Appendix B Graphs of the CDSS

The graphs of all the classes, properties and individuals are shown in the following figures separately:

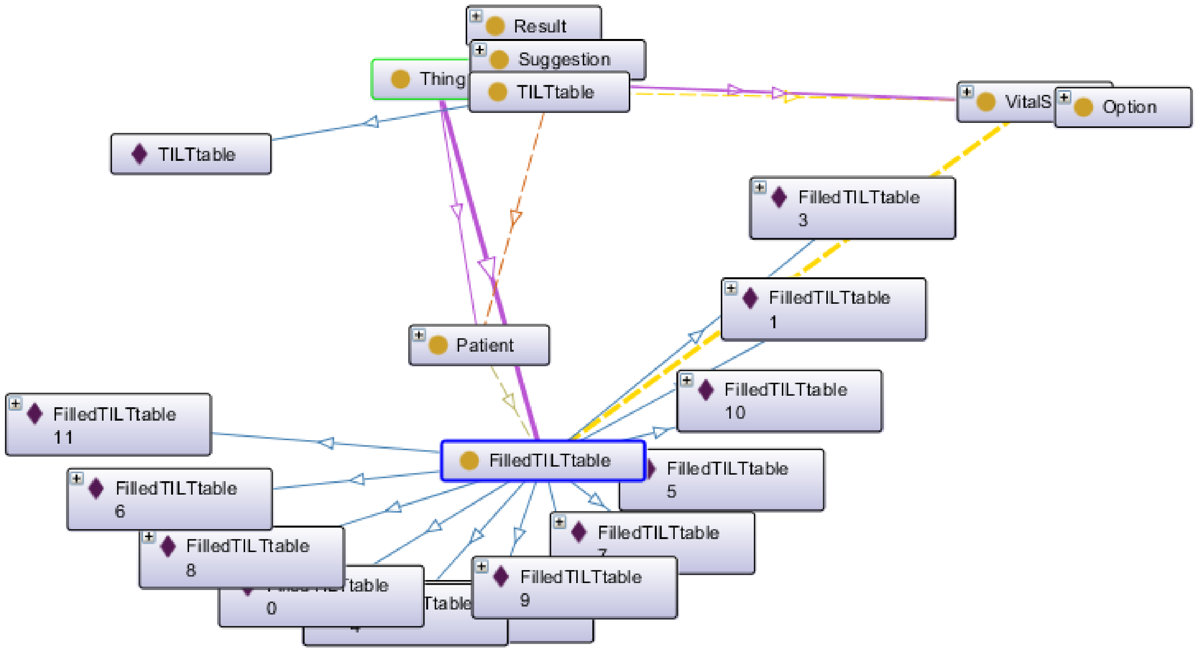

Figure 46 Ontology Graph of Filled Tables

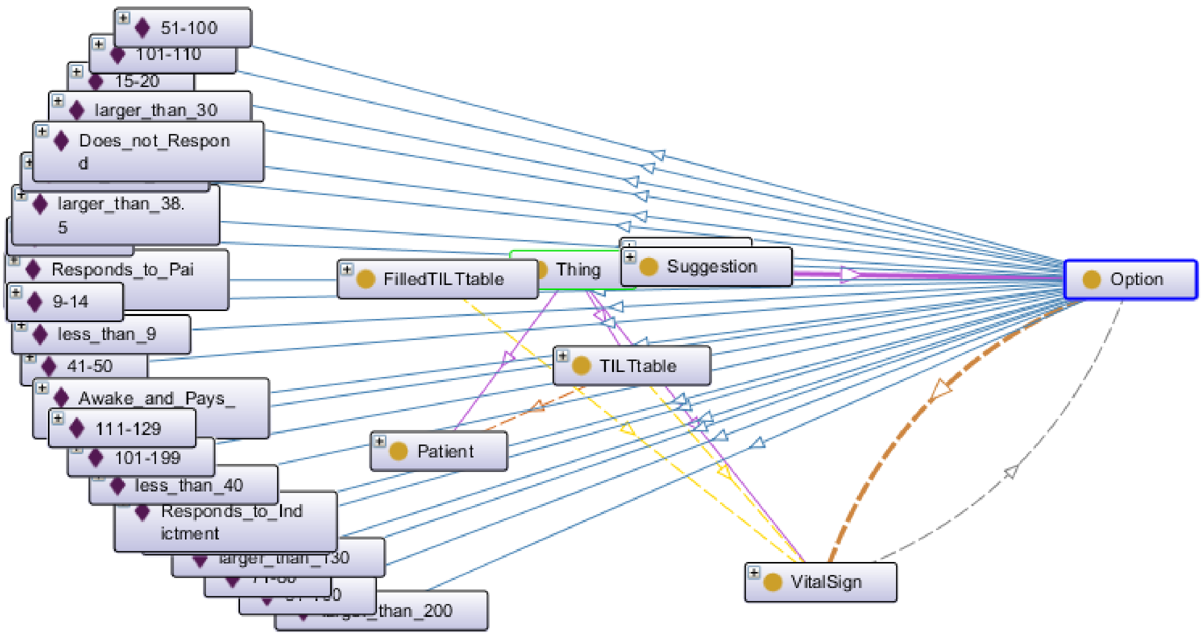

Figure 47 Ontology Graph of Options

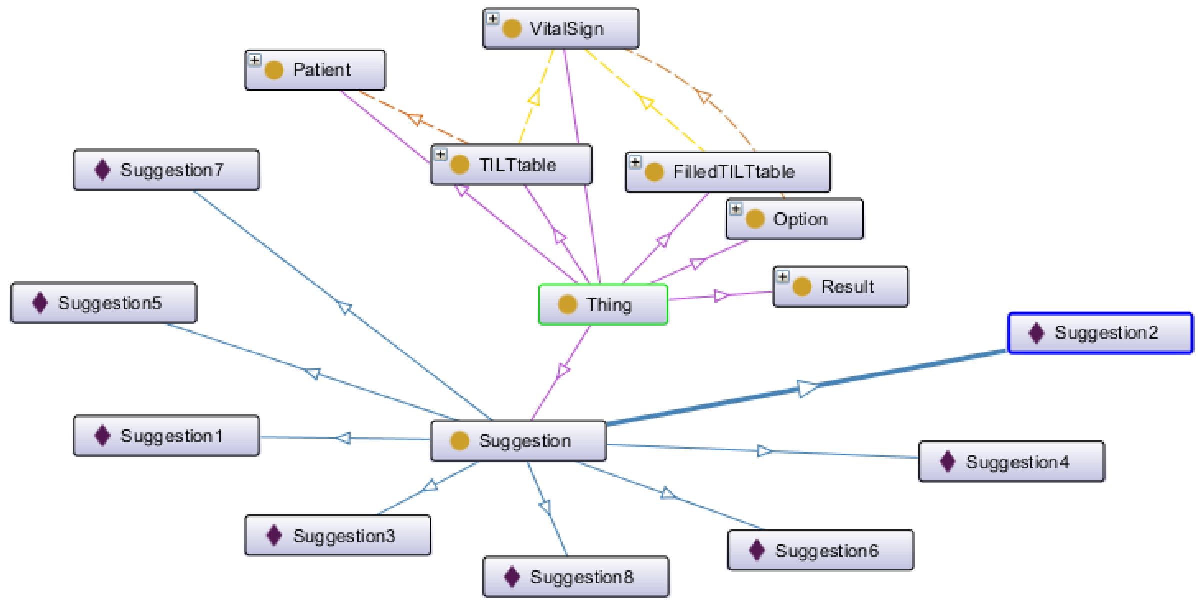

Figure 48 Ontology Graph of Suggestions

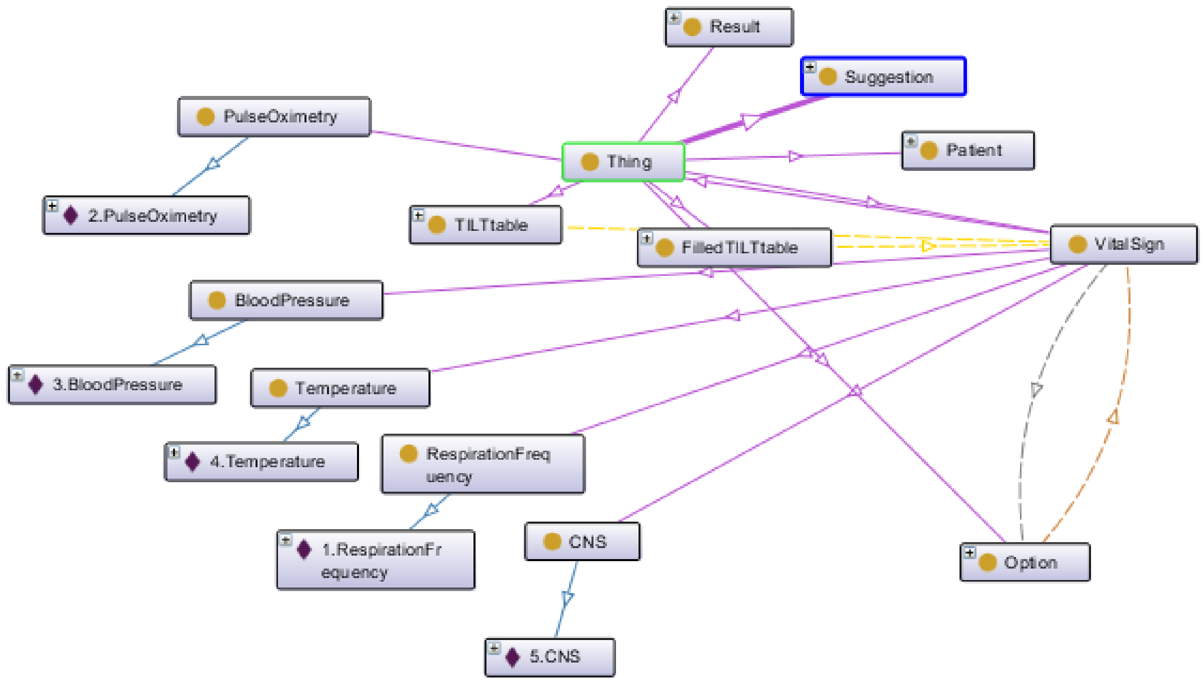

Figure 49 Ontology Graph of Vital Sign

Appendix C SPARQL Query for the Eight Clinical Rules

In Query 13 of Chapter 5, we show the suggestions for all the filled TILT tables. In order to present that our SPARQL query is working well for each rule, we will show the query for eitht clinical rules separately, the results are as follows:

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
            WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
            Group By ?FilledTILTtable
           HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion1 A:hasSuggestion ?Suggestion FILTER(?value1 = 3 && ?value2 < 2 && ?value3 < 2)}

}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Hyperventilation"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	

Figure 50 SPARQL Query for Rule1

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
            WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
            Group By ?FilledTILTtable
           HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion2 A:hasSuggestion ?Suggestion FILTER(?value1 >= 2 && ?value2 >= 2)}
}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Cardio-pulmonary disease"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	

Figure 51 SPARQL Query for Rule2

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
        Group By ?FilledTILTtable
       HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion3 A:hasSuggestion ?Suggestion FILTER(?value1 > 0 && ?value2 = 3 && ?value3 >= 2 && ?value4 = 0)}
}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Cardiac failure"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	

Figure 52 SPARQL Query for Rule3

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
        Group By ?FilledTILTtable
       HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion4 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value4 = 2)}
}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of infection"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of infection"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	

Figure 53 SPARQL Query for Rule4

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
        Group By ?FilledTILTtable
       HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion5 A:hasSuggestion ?Suggestion FILTER(?value2 >= 2 && ?value3 = 3)}
}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of reduced cardiac activity"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of reduced cardiac activity"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	

Figure 54 SPARQL Query for Rule6

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
        Group By ?FilledTILTtable
       HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion7 A:hasSuggestion ?Suggestion FILTER(?value1 = 0 && ?value2 = 3 && ?value3 > 1 && ?value4 = 0)}
}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of Atrial Fibrillation"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	

Figure 55 SPARQL Query for Rule7

```
PREFIX A: <http://www.semanticweb.org/questionnaire#>
SELECT ?FilledTILTtable ?TotalScore ?Suggestion
WHERE{{SELECT ?FilledTILTtable (SUM(?value) AS ?TotalScore)
        WHERE { ?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer.?CollectedAnswer A:hasChosen ?SelectedOptions.?SelectedOptions A:hasvalue ?value. }
        Group By ?FilledTILTtable
       HAVING ( ?TotalScore > 3)}
{SELECT ?FilledTILTtable ?Suggestion
WHERE{
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer1. ?CollectedAnswer1 A:hasVitalSign A:1.RespirationFrequency. ?CollectedAnswer1 A:hasChosen ?SelectedOption1. ?SelectedOption1 A:hasvalue ?value1.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer2. ?CollectedAnswer2 A:hasVitalSign A:2.PulseOximetry. ?CollectedAnswer2 A:hasChosen ?SelectedOption2. ?SelectedOption2 A:hasvalue ?value2.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer3. ?CollectedAnswer3 A:hasVitalSign A:3.BloodPressure. ?CollectedAnswer3 A:hasChosen ?SelectedOption3. ?SelectedOption3 A:hasvalue ?value3.
?FilledTILTtable A:hasCollectedAnswer ?CollectedAnswer4. ?CollectedAnswer4 A:hasVitalSign A:4.Temperature. ?CollectedAnswer4 A:hasChosen ?SelectedOption4. ?SelectedOption4 A:hasvalue ?value4.
OPTIONAL{A:Suggestion8 A:hasSuggestion ?Suggestion FILTER(?value1 = 1 && ?value2 = 3 && ?value3 = 0 || ?value1 = 2 && ?value2 = 3 && ?value3 = 0)}
}}}
```

FilledTILTtable	TotalScore	Suggestion
FilledTILTtable10	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	"Symptoms of physical activity"^^<http://www.w3.org/2001/XMLSchema#string>
FilledTILTtable8	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable7	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable3	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable4	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable9	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable5	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable1	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable11	"7"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable6	"5"^^<http://www.w3.org/2001/XMLSchema#integer>	
FilledTILTtable2	"6"^^<http://www.w3.org/2001/XMLSchema#integer>	

Figure 56 SPARQL Query for Rule8