Ontology Based System Architecture to Predict the Risk of Hypertension in Related Diseases

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Abstract

Hypertension is a main public health problem around the globe associated with high death rates. Many clinical decision support systems (CDSS) exist to assist doctors with decision making tasks in the domain of hypertension. Most of these systems are implemented using traditional database methodologies. These systems cannot handle huge amount of data sets. Analyzing, interpreting and processing of data are so difficult in traditional systems. They are not flexible and adaptable to complex requirements and processes and they lack intelligence. Medical knowledge must be represented in a meaningful way in order for the computers to analyze and acquire inferred data. Ontology is among the most powerful tools to encode medical knowledge semantically. The aim of this paper is to propose an ontology based decision support system model to predict the risk of hypertension and diabetics in related diseases. The proposed system uses ontologies as knowledge base, the patient medical profile to be stored in a semantic way and an inference mechanism to infer data in the decision making process. The main advantage of using ontologies in a CDSS is that, different sources can share and reuse the ontological concepts represented in a semantic way and thus integration of data is easier. The proposed system is targeted to implement in health centers in Sultanate of Oman.

Keywords: Hypertension, Diabetic, Clinical Decision Support System, Ontology, Semantic Web, Inference Engine, Semantic Patient Profile

1. Introduction

Hypertension is a main public health problem around the globe associated with high death rates. It is one of the most common medical problems encountered in cases like diabetics, chronic kidney disease (CKD) and cardiovascular diseases. The worldwide prevalence of HTN is approximately 26%, (1 billion people affected) [1]. The prevalence of hypertension has been projected to increase to ≥29% by 2025 [2]. According to nephrologists in Sultanate of Oman, an alarming rise of kidney failure mainly linked to diabetes and high blood pressure is on a steep rise among Omani population [13]. The latest figure published by the World Health Organization (WHO) indicates that the spread of hypertension in the Sultanate is approximately 33 % which is considered a troublesome increase compared to the world level of 25 % to 30 % [3].

Many clinical decision support systems (CDSS) exist to assist doctors with decision making tasks in the domain of hypertension. These systems provide clinicians, staff, patients, and other individuals with knowledge and person-specific information, intelligently filtered and presented at appropriate times, to enhance health and health care. Typical components of CDSSs include a medical knowledge base, patient pro-file and an inference engine to generate case specific treatment/recommendation/conclusion. The knowledge base is typically represented in the form of a set of rules. They contain standard clinical practice guidelines (CPG), and are able to reason individual patient profile and come up with reasoned conclusions. Traditional CDSS are implemented using standard database methodologies. These systems cannot handle huge amount of data sets. Also they are unable to analyze and structure the knowledge to make further inferences from the present knowledge. Most of these systems may have overlapped data since they are developed independent of each other. Medical knowledge must be represented in a meaningful way in order for the computers to analyze and acquire inferred data.
Ontology is among the most powerful tools to encode medical knowledge semantically. The aim of this paper is to propose an ontology based decision support system model to predict the risk of hypertension in related diseases. The proposed system uses ontologies as knowledge base, the patient medical profile to be stored in a semantic way and an inference mechanism to extract data in the decision making process. But if a meaningful (semantic) approach is adopted, more efficient and accurate diagnosis can be done. For example, when a diabetic patient is diagnosed, reminders can be provided by the system that s/he needs to have urgent attention or just a yearly check-up, if needed. For these types of alerts/reminders, system must store and recollect the medical history of the patient diagnosed. Also an intelligent system will be more useful for in-experienced doctors, since it contains the complete guidelines, in a more organized and meaningful way. Trusted knowledge base is considered as one key issue in effective CDSS [19]. The main advantage of using ontologies in a CDSS is that different sources can share and reuse the ontological concepts represented in the ontology and thus integration of data is easier. The proposed system is targeted to implement in health centers in Sultanate of Oman.

The rest of the paper is organized as follows: - Section 2 describes the State of Art. Section 3 presents the methodology used in the proposed architecture which includes the description of ontology, the application of ontologies in Clinical Decision Support System and finally the proposed system architecture to predict the risk assessment of hypertension in related diseases. Section 4 explains the implementation of Phase I. The paper presents the conclusion and future in Section 5 followed by acknowledgement and references.

2. State of Art

ATHENA decision support system is developed for the management of hypertension in primary care in health centers of USA [27]. It implements guidelines for hypertension using Stanford Medical Informatics EON architecture. From the Swedish guidelines for treatment of hypertension, the most widely accepted and scientifically best proved treatment strategies were chosen and implemented as rules and a computer based decision support system was developed in Visual Basic [28]. SNOMED CT [4], an interoperable decision support system was developed to represent knowledge concepts in the hypertension domain, but did not cover all concepts without loss of semantics. Two researchers from the University of Auckland, New Zealand developed an ontology driven framework to enhance and facilitate some important temporal querying requirements in general practice medicine, focusing on prescribing for hypertension [5]. The Web Ontology Language has been used to develop the ontology and the specific queries have been written in Semantic Query-enhanced Web Rule Language. They used the electronic medical record (EMR) data from a General Medical Practice in New Zealand to populate the above ontology. LIGHT [6] is knowledge based clinical decision support system for the management of hypertension. It used a knowledge representation framework based on SAGE and developed a knowledge converter to translate knowledge encoded into the knowledge engine. The authors concluded that the knowledge base for hypertension management became more accurate and practical through the testing process of LIGHT.

3. Methodology

3.1. Ontology

Ontologies were introduced as the conceptual framework of semantic search in late 90’s. Ontology is a formal specification of the concepts within a domain and their interrelationships [18]. It is a methodology which describes the domain knowledge structure in an area of specialty, which promotes its various kinds of knowledge processing intended to provide systematic, semantic links among a collection of related concepts [8]. They are well known for many years in the Artificial Intelligence and Knowledge representation communities [20]. Ontologies are used to represent knowledge. It was initially proposed to model declarative knowledge for knowledge-based systems [21]. It is an abstract model which represents a common and shared understanding of a domain. The most popular definition
of ontology was proposed by Gruber [22] who defined it as “…a formal, explicit specification of a shared conceptualization”.

Domain knowledge is contained in the form of concepts, individuals belonging to these concepts and relationships between the concepts and, between concepts and individuals. Ontologies are the backbone of Semantic Web and they include the descriptions of classes, properties and their instances [23]. Nowadays ontologies are being applied in a number of information retrieval systems to enhance the performance of such systems [5]. Ontology contains both the asserted knowledge and the inferred knowledge. Asserted Knowledge is the knowledge that is explicitly defined by the ontology developers. When ontologies are reasoned by machines, valid deductions and inferences are generated which is called inferred knowledge.

The W3C has developed a language, called OWL that can be used to describe the ontology [24]. It is built on W3C standards XML, RDF/RDFS and extends these languages with richer modeling primitives [3]. OWL is based on description logics. It is an ontology language that can formally describe the meaning of terminology used in Web documents. In general, OWL allows the formalization of a domain by defining classes and properties of those classes, the definition of individuals and the assertion of properties between them, and the reasoning about these classes and individuals [3]. Based on XML documents, W3C has also developed three sub-class languages, namely OWL-Lite, OWL-DL, and OWL-Full.

3.2. Ontology based Approach in Clinical Decision Support Systems

The use of ontologies is well suited for applications in medicine. When certain relations are asserted in the ontology, an ontology reasoner can infer more relations, which is not explicitly asserted in the ontology [25]. Ontologies are used for representing expert knowledge in the medical domain [17]. Right from the beginning to model patient’s medical history, ontologies can be used. Ontology based systems can be used to gather patient details and a patient profile ontology can be generated. A decision support ontology which consists of mainly clinical guidelines is used to analyze the patient profile. Ontology based CDSS can be generated. Any other similar system can easily use the knowledge base just by updating it. So the cost of maintenance of these systems is also less. The implementation of ontologies produces good results in terms of standardizing the guidelines. An ontology-based model provides interoperability among heterogeneous devices and systems, allows context reasoning based on user-defined rules and generate decisions in the form of context-aware predictions.

3.3. System Architecture

Ontology is among the most powerful tools to encode medical knowledge formally [17]. Ontology is a formal specification of the concepts within a domain and their interrelationships [18]. It is a methodology which describes the domain knowledge structure in an area of specialty, which promotes its various kinds of knowledge processing intended to provide systematic, semantic links among a collection of related concepts[32] [8]. Figure 1 represents the ontology driven system model to predict the risk assessment of hypertension in related diseases.
Two ontologies are used in our model. In the initial phase, an ontology driven adaptive questionnaire [9] is developed. This intelligent questionnaire is a patient information collection system. It is adaptive in nature thus asking only related information which is appropriate to patient’s environments. The users can be clinicians or patients themselves [through online]. This adaptive questionnaire will help to filter a clear patient medical history which is very important in the future diagnosis. The questionnaire ontology includes the questions used to collect different information from the patient. The questions related to patient’s family history, diabetic history, smoking history etc. are included as ontological classes. The user interface loads the questions from the questionnaire ontology. The interface is designed in such a way that the patients can enter the information from anywhere online. The questionnaire is of adaptive nature since the questions to be displayed are decided according to the input provided by the patients to the previous questions. The information (answers) provided by the patients for the different questions are written to patient profile ontology. After finishing various histories entered by the patient, the nurse, at triage will enter values of Blood Pressure, height, weight etc. of the patient. When the patient visits the doctor, the doctor diagnosis results are written to the patient profile ontology. If the doctor suggests any lab tests, the test results are also written to the patient profile ontology. After Phase I, the patient semantic profile is generated which includes the complete information about the patient history, current doctor diagnosis results and lab test results. The numerical results are stored in a database for future analysis.

In the next phase, clinical guidelines ontology is developed to include the guidelines followed for diabetic related diseases. Using the clinical guidelines, the semantic patient profile is analyzed by the ontology reasoner. In parallel, a rule engine is used to analyze the numerical values stored in the database. The output of the reasoner and the rule engine [14] together, generates alerts and reminders regarding the patient’s risk related to diabetics. The system thus system thus predicts the risk of having diabetics related to other diseases. In conventional systems, patient data is stored in a database in different formats. So the representation is not semantic and data analysis is really challenging. But according to our system, the patient profile generated is semantic in nature and represented in Web Ontology Language [OWL]. It can be accessed by any third party APIs.

4. Phase I Implementation

As part of the initial phase, we planned to conduct a survey among the users of the current system in the Health Centers of Oman. No survey can achieve success without a well-designed questionnaire. In order to develop a questionnaire, we have sought an innovative approach of generating it automatically.
Automatic Generation of survey questionnaire (SQ) involves two steps. The first step is to represent the concepts as ontology and the second step is to develop a Java based system to read the ontology and generate the set of questions for the survey. The implementation of Step 1, development of survey questionnaire ontology is presented here. The development procedure is as follows:-

- Collect enough information about the chosen domain.
- Identify the key concepts in the domain with their properties.
- Define the relationships among the concepts
- Now ensure that the ontology represents the complete knowledge about the particular domain.
- Validate the structure of the ontology.

The SQ ontology is defined in OWL, and Protégé is used to model the ontology. Protégé is a free, open-source platform that provides a growing user community with a suite of tools to construct domain models and knowledge-based applications with ontology [7].

4.1. Ontology Class Hierarchy

An OWL class is a special kind of resource that represents a set of resources that share common characteristics or are similar in some way [29]. Classes and subclasses are implemented using Protégé ontology editor and OWL. Figure 2 represents the classes and subclasses of the ontology.

![Figure 2. SQ Ontology Classes [30]](image)

4.2. Checking the Consistency using Pellet Reasoner

Pellet Reasoner, a popular open-source reasoner is used to reason the ontology. It can be integrated into Protégé. The reasoner helps to check the consistency. The SQ ontology was tested and validated to verify the correctness of data [31]. If there is no inconsistency, class hierarchy will be inferred by the reasoner. Also all inferred axioms are generated by the reasoner.

The class hierarchy is shown in Figure 3.

![Figure 3. Class Hierarchy [30]](image)
5. Conclusion and Future Work

The application of Information Technology in the field of Medical Science is developing day by day. A decision support system based on the proposed architecture will be a great achievement for the Medical sector in the Sultanate of Oman since this is the first of its kind based on an intelligent approach. Ontology provides a common framework for structured knowledge representation of domain knowledge. Ontology framework provides common vocabulary for medical concepts, concept definitions, relationships, axioms and rules. Ontology reasoner is used to infer knowledge from the knowledge represented in the ontology. Ontology based systems generate decisions in the form of predictions, alerts and reminders.

Implementation of Java based system to read the ontology to generate the set of questions and the proposed architecture is planned as the future scope. A Java based API will be used to build the architecture.

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7. References


