Exhibiting Context Sensitive Behavior in Gathering Patient Medical History in Diabetes Domain using Ontology

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Abstract

One of the goals of modern health care systems is to collect complete, accurate and correct patient medical history. Simple patient history collection systems fail to collect relevant information from patients. This results in non-availability of full medical history of a patient at the time of doctor diagnosis. This leaves medical experts in a great challenge in order to make correct medical diagnosis. So in addition to the conventional face-to-face consultation, the process of collecting patient history needs automation, more precisely in an intelligent manner. We here propose a model for gathering the patient medical history based on dynamic questionnaire ontology. Ontology is among the most powerful tools to encode medical knowledge semantically. It is an abstract model which represents a common and shared understanding of a domain. The model is explained and implemented for diabetes domain.

Keywords: Patient Profile, Questionnaire Ontology, OWL, Adaptive Questionnaire, Protégé

1. Introduction

During the last few decades, health sectors are witnessing a rapid explosion of maintaining patient health records in e-format. Also people access or exchange any kind of information via Internet. As a natural consequence of this development, it is also expected to exchange patient medical profiles in a secure, reliable and efficient way across different health care units irrespective of physical boundaries. But this is still a dream, which is too far from the reality.

In most of the Health Care Information Management Systems, the patient information is collected on every visit to the hospital the involvement of patients is minimal. A traditional procedure is as follows: When a patient visits a hospital, the nurse will first diagnose the patient and will record the preliminary observations such as readings of blood pressure, height, weight, body temperature etc. about the patient. Other details are collected from the patient itself by the doctor. Here in most of the cases the patient medical history will be incomplete. It results from the following issues that can arise during the collection of patient details:

- Medical Personnel failed to ask the patient, relevant questions about allergies to any medicines, any family history of diabetes etc. [13].
- Medical Staff didn’t act according to the user context. For example the patient is suffering from severe diabetes, but they failed to refer to specialty unit.
- Patient doesn’t want to disclose certain sensitive and personal health problems.
- Possibility of asking unwanted questions by the medical staff.
- Gathering of Patient information is sometimes a time-consuming task.

Many issues discussed here are the consequences of an inefficient patient history collection system. If we have an efficient system that automates the whole process, then it will save resources, time and also nurse can focus more on providing medical care to the particular patient. Also information collected in such a manner will be more structured/ organized and detailed than collected through traditional manual and personal interviews. An automated database system will be able to solve most of the issues presented before. But again the issue is that any automated system will be designed to apply for a vast number of patients, in a general scenario. So the challenge is that, this general system must be capable to record critical information from specific patients also.
In this paper, we are presenting not a normal automation system to collect the patient history and to generate a patient semantic profile. Instead, ontology based dynamic system which will act according to the patient situations, are used to capture the critical information from the patients [11]. In response to the user input/interaction, a dynamic update in the structure of the questionnaire itself will result. Here the method is presented in the context of capturing information form diabetic patients [12]. The adaptive questionnaire ontology is developed using Protégé editor and OWL API is used for the development of the patient history gathering system.

The paper is organized as follows: - Section 2 describes the early systems used in medical domain and their issues and the benefits of using ontology. Dynamic Patient History Collection Model is presented in Section 3. The development of Questionnaire ontology and the adaptive nature of questions are explained here with different scenarios. Section 4 presents the user interfaces of patient, nurse and the doctor. The Implementation of Adaptive Questionnaire is presented in Section 5. Section 6 includes conclusion and future followed by acknowledgement and references.

2. Background

2.1 Dynamic Systems in Medical Care

Early systems in this category used the basic IF… THEN branch statements to analyze the patient history. For example, IF the number of cigarette’s smoked per day are greater than 10, THEN display a high risk alert. In these systems, the relationship between the questions and all possible inputs was hard-coded in the system. But this is not a good way of collecting the medical patient history to create the profile of the patient. It is not suitable for complex systems, since all possible cases have to be incorporated using IF… THEN branch. Also any updates in the sequence of questions require a good amount of work since they are inter-related.

2.2 Benefits of Ontology

Ontologies were introduced as the conceptual framework of semantic search in late 90’s [14]. They are well known for many years in the Artificial Intelligence and Knowledge representation communities [4]. The most popular definition of ontology was proposed by Gruber [1] 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 used for representing expert knowledge in the medical domain [2]. Ontologies are the backbone of Semantic Web and they include the descriptions of classes, properties and their instances [7]. The use of ontologies is well suited for applications in medicine. When certain relations are asserted in the ontology, an ontology reasoner can infer more relations, which is not explicitly asserted in the ontology [3]. Automatic Reasoner is used in the analysis of ontologies. The reasoner will find out any hidden relationship in the ontology. Any other similar system can easily use the knowledge base just by updating it. So the cost of maintenance of these systems is also less [6]. So ontology based systems are very effective to gather patient details and a semantic patient profile can be generated.

Web Ontology Language [OWL] developed by W3C is based on XML is used to describe the ontology [8]. OWL is based on description logics (DL). DL enables for the usage of automatic reasoners for the analysis of ontologies [10]. OWL-Lite, OWL DL and OWL Full are the three sub-languages of OWL. Of these OWL-DL is the one with strong reasoning capabilities.

3. Dynamic Patient History Collection Model

The model consists of three main components. The user interface, the Java engine, and the OWL file which contains the questions. The Java adaptive engine is implemented using OWL API [4]. The Java engine acts as intermediary between the user interface and the ontology. It reads the questions from the ontology and presents it to the user and analyses the user inputs. When the first question is displayed in the interface, if the question is an adaptive question, based on the answer provided by the
user, further sub-questions are prompted; otherwise the first question in the next category is shown to the user. This process is repeated until there are no more questions to be asked. The whole process is of iterative nature. The model is presented in Fig. 1.

Figure 1. System Model

3.1 Modeling of Questionnaire Ontology

To develop questionnaire ontology, we conducted several interviews with medical experts in the field of diabetes to identify such questions which have to be asked to a patient having diabetes. The next task was to group them under different categories such as smoking history, alcohol history, diet history, family history etc. Next the sub-questions to be followed (based on the user input) after a main question were identified. The questionnaire is designed as a successive question-answer pair where question is the main node and the answer is the following node. Depending on input, some questions which are adaptive in nature may be followed by sub-questions, which will be then followed by the answer.

The main classes of the ontology are Physical_History, Smoking_History, Alcolhol_History etc.

Object Properties are used to define relationships between ontology classes [9]. Data properties are used to define relationships between an individual class and XML schema data type [9]. The object property “has_diabetic_type” associates “Patient” and Type_Of_Diabetes classes. The data property “diabetic_type” has values “Type1” and “Type2”.

Figure 2. Questionnaire Ontology

3.2 Adaptive Questions

The system asks domain specific questions. Most of them are designed to have Boolean type answers. For example, consider the question “Do you Smoke?” This question is an adaptive one which expects Yes/No answer. If the answer to the above question is given as Yes, then the system displays the sub question “For How Many Years?” otherwise, it displays questions from next category, say, for example, alcohol related questions. That means, if the answer is No, the system will not ask further questions related to smoking. It proceeds to the next category of questions, for example, alcohol. So the
questionnaire adapts itself as per the patient’s history and it asks only relevant questions according to the patient’s context. Both the scenarios are given in Fig.4.

<table>
<thead>
<tr>
<th>Adaptive Question – Scenario 1</th>
<th>Adaptive Question – Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;&gt;&gt;System Do you Smoke?</td>
<td>&gt;&gt;&gt;System Do you Smoke?</td>
</tr>
<tr>
<td>&lt;&lt;User Yes</td>
<td>&lt;&lt;User No</td>
</tr>
<tr>
<td>&gt;&gt;&gt;System For How Many Years?</td>
<td>&gt;&gt;&gt;System Do you Drink Alcohol?</td>
</tr>
<tr>
<td>&lt;&lt;User 2</td>
<td>&lt;&lt;User Yes</td>
</tr>
<tr>
<td>&gt;&gt;&gt; System How many cigarettes do you smoke?</td>
<td>&gt;&gt;&gt; System For How Many Years?</td>
</tr>
</tbody>
</table>

Figure 4. Adaptive Question Scenario

4. User Interfaces

Protégé, OWL Java API, and pellet reasoner are the tools used in the implementation of adaptive patient history collection system.

4.1 Patient Interface

Prior to the hospital visit, a patient can enter his/her history through a web enabled patient interface. A web enabled interface provides the doctors with complete patient history before the start of diagnosis. Other advantages of a patient interface includes: patient can enter all the history according to their convenience from home, time can be consumed, the patient can answer some questions which are very sensitive/personal, which are otherwise cannot be recorded during face-to-face consultation with the doctor. Patient will be given access to only patient’s interface which is controlled by a login screen. They will not be allowed to view nurse or doctor interface.

Personal History form and Diabetic History form are presented in Fig.5 and Fig.6.

![Personal History Interface](image)

Figure 5. Personal History Interface

![Diabetic History Interface](image)

Figure 6. Diabetic History Interface
4.2 Nurse Interface

When the patient visits the hospital, nurse can view the information entered by the patient through the patient interface. This will help the nurse to arrive at a primary conclusion about the status of the patient. Now as per the recorded patient details, if the patient is at a high risk which requires immediate medical attention, s/he will be referred to intensive care unit. Otherwise, the nurse will examine the patient and records the preliminary observations about the patient such as readings of blood pressure, heart beat, height, weight, body temperature etc. These values are appended to the patient profile.

4.3 Doctor Interface

Similarly like nurse, the system provides complete information of the patient when s/he approaches the doctor for final diagnosis. Doctor can view the patient details entered earlier by the patient and the nurse. Further, the doctor will diagnose the patient and the observations are appended to the patient file. If the doctor suggests any lab tests, the test results are also incorporated in the patient file.

5. Implementation and Results

5.1 Using OWL API to parse Questionnaire Ontology

The Protégé-OWL API is an open-source Java library for the Web Ontology Language and RDF(S) [5]. The API provides classes and methods to load and save OWL files, to query and manipulate OWL data models, and to perform reasoning [5]. OWL API contains a set of interfaces used to manipulate ontologies. It consists of many functions to extract classes, sub-classes, object properties, data properties, and individuals of ontology. For example, getSubClass() is a function used to extract all sub classes of a particular class.
5.2 Adaptive Questionnaire

Questions included in the ontology are of adaptive and non-adaptive nature. If a question is adaptive, as per the user input, further questions will be displayed. If the question does not have any adaptive properties, irrespective of the user input, the next question will be displayed. The first set of questions of adaptive nature is demonstrated in Smoking History Form.

![Image](Please fill the Smoking_history form)

The first adaptive question in this category is *Do you smoke? Yes/No* as shown in Fig. 9. If the user input is *YES*, it triggers a call for additional questions, which is related to smoking as shown in Fig. 10.

![Image](Please fill the Smoking_history form)

If the user input is *NO*, no additional questions related to Smoking will be displayed. Instead the system moves to the first question in the next category as shown in Fig. 11.

![Image](Please fill the Alcohol_history form)

Depending on the adaptive properties of the remaining questions, this process will continue until the end of questionnaire is reached.

6. Conclusion and Future

Patient history collection systems capture better information than face-to-face consultation. It also saves lot of time since the patients can enter their details according to their convenience. Our ultimate aim is to provide doctors, all relevant information related to a patient, so that they can perform a proper risk assessment. In a usual automated system, the number of questions asked to patients will be fixed. But here, since the questionnaire is adaptive, the number of questions asked to each specific patient varies. System has the intelligence to reduce the number of questions according to the user input. Ontology based systems can be extended and reused in a variety of problems in a similar domain. Any updates in the system can be applied directly by updating the questionnaire ontology without any software engineering work.

Generation of semantic patient profile and analysis and prediction of risk factors of diabetes are identified as the future work. Ontologies are semantic models for domains of reality. Ontology based
reasoning makes a way to discover new knowledge, which can lead to new directions in research, particularly in the medical domain.

7. Acknowledgement

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8. References


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