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Implementation of Context Aware Medical Ontology and Health Recommender Framework

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ABSTRACT

Ontology engineering is an important research area in artificial intelligence used in simulation of clinical decision support systems. The implementation of ontology motivated methodology provides good results in systematizing health care. Building knowledge base using ontology based approach can be reused for different problems thereby producing cost effective decision models within the knowledge base. Context information contains any information about an individual, object, place or time. Context is information about demographics, diseases, medication, allergy and so on. This contextual information captured using RFID can be saved in different places, like patient's sensor data on patient's mobile phone, the patient's medical record at the general practitioner's office and the treatment options of a disease in hospital. In this paper, context information has been used for monitoring ECG of heart patient and give an alarm when needed. An alarm to the nearest hospital depending on the critical situation can happen through patient's mobile phone. An ontology based context aware health recommender system proposed thereby helps in critical care of the patient.

KEY WORDS: Ontology, recommender systems**,** knowledge management, smart hospital, context-awareness

1. INTRODUCTION

Ontology development is an explicit specification of terms which is moving from Artificial-Intelligence laboratories to desktops of domain experts. With fast advancement in medical field, the trustworthiness of information is difficult to determine. Hence ontologies are suitable to support a more effective data and knowledge sharing in the medical field. With increasing number of diseases and varied signs and symptoms, medical practitioners finds it difficult to clearly remember and recall all of the information related to the disease (Sieg, 2007). So, ontology-based approach is required to represent entities, ideas and events, along with their properties and relations, as a form of knowledge representation about the medical world (Alani, 2007).

When reusing existing ontology, selecting the best ontology for a given context is important (Alani, 2006). Today's healthcare requires flexibility with aging society. Many old age peoples requirement to live alone needs cost effective ways to apply healthcare. With increasing incidence of chronic diseases and growing ubiquitous technology, information technology (IT) has come to rescue in healthcare (Vilches-Blázquez, 2009). Patients can contribute to their own health outcomes in chronic disease management, where patients are encouraged to think critically and make informed and autonomous decisions. Hence, a patient can promote his health through home based monitoring thereby creating long term care choices.

The increasing cost in healthcare system is the major concern that has caused industry to look for treatment substitutes to reduce cost and improve treatment. Developments in wireless communications, integrated circuits, intelligent monitoring devices and low power devices helps in integrating essential devices to Wireless Body Area Network (WBAN). Monitoring patients from recovery applications to ambulatory monitoring remain to be resolved in areas like system design, configuration and standardization. They facilitate monitoring of chronic conditions or during supervised recovery from an acute event or surgical procedure.

Recommender systems is a filtering method that helps in providing information that are interest to user. When recommender system is used, the user can get advice and get decisions. The paper is organized as follows: section 2 discusses the literature survey, section 3 presents the ontology model, section 4 discusses the framework for context aware ontology recommendation and section 5 provides the conclusions.

Literature review: Ontologies in healthcare are developed to facilitate the reuse and exchange of medical data (Vilches-Blázquez, 2009). The basic advantage of using ontologies in healthcare system is the ability to resolve semantic heterogeneity present within the data. Ontology provides the semantic knowledge aiding in results presented to clinicians (Jonquet, 2010). Consequently, there are diverse ontologies in existence today and the following two rules must be considered while designing a new ontology

- The ontology should be able to provides interoperability among current terminologies
- The ontology should be an initial version to provide further continuous development.

Using ontology can preserve maximum information created by domain experts. For reusing existing ontology many methods are proposed to select the best ontology (Alan, 2001; Stefan, 2009; Fang, 2009). Some drawbacks encountered in this approach is that expert guidance is required as the methods are not fully automatic.

Context modelling require the use of ontologies (Su, 2009) and it allows the growth of sophisticated caregiving medical systems (Adomavicius, 2005). With increase in ontology-based health care systems a framework suitable for smart home environment is proposed in (Burke, 2002). Methodology in which applications exchange their context with other applications/network infrastructure is proposed in (Smith, 2006). Mobile health support system using Java is proposed in (Herlocker, 2004). This mobile device implementation supports context-awareness in pervasive environments and context models are built. For supporting ubiquitous agents, a context broker architecture based on context ontology is developed using OWL (Beale, 2007). All these models deals with generalized concept and is not specific to healthcare domain. In (Waraporn, 2010), knowledge based integration framework that supports interoperability is proposed. The requirements for ontology in medical data integration is proposed in (Ashiq, 2007). However, these models that address hospital needs do not support context-aware applications.

Health aware service ontology model: The health aware ontology model encompasses every conceptual entity that affects hospital care outcomes in an intelligent hospital. It defines Person, Location, Activity, Document, Device and Medical Term as top-level classes of the hospital. Figure 1 shows their main relationships and properties that is basically adopted from.

The class Person defines the general features of a person in a hospital, and has Patient and Hospital Personnel as its sub-classes. The Patient class is further divided into Inpatient and Outpatient sub-classes, and is associated with a Document class which includes the Electronic Heath Records (EHR) and other medical documents. Hospital Personnel have Datatype Properties such as department, office and salary, and have sub-classes including Doctor, Nurse, Lab staff and Non-medical staff. Interactions among persons are important relationships in a hospital. For example, a Doctor treats a patient. In addition, the class Person is associated with other classes such as Location and Activity since persons are mobile and participate in a variety of activities. The Location class generalizes all types of locations in a hospital and defines a set of properties consisting of readerID, locName, humidity, and temperature. Its sub-classes include Ward, Office, Test facility, Waiting room, Surgery room, Building etc. The Device class defines the general features of a device in a hospital and presents Bed and Mobile device as its sub-classes. Bed is considered as a stable device since when it is placed in a ward, it won't be moved for a long time. An inpatient is assigned a bed for her stay in the hospital. Mobile device has sub-classes such as infusion pump, wheel chair etc. Persons and devices are the major objects to be tracked in hospital through RFID technology. Thus, they have RFID tags attached, represented by tagID, and their real-time locations are identified by a readerID and a property locatedIn. The interaction of patient, staff and equipment is identified as a significant event – described by Activity class – at some place during a specific time period (i.e., represented by startTime and endTime). Sub-classes of Activity include Admission, Diagnosis, Testing, Treatment, Transfer and Discharge. These classes are further divided into refined activity classes. The class Medical term defines the basic concepts for medical knowledge so as to be used in documentation. It has Disease and Medicine as its sub-classes. Figure 2 shows the OWL-DL properties of context aware ontology model.

Many application like intelligent surgery monitoring system, automatic shut-off, patient self-diagnosis service, patient diet monitoring service, etc can use the above model to provide context-aware services. Intelligent surgery monitoring system alerts the surgeon in case of heart attack.

Ontology is populated by contextual data from heterogeneous sensors that represent attributes of entities and their activities in the hospital. A context-aware application monitors input (i.e., context) from external sensors and applications, and automatically adapts its behavior to the changing contexts. First-order logic is used (with connectors and, Negation, Imply, etc.) to express contextual information in the form of (subject, predicate, value) which can be easily converted into OWL-DL language or other rule languages for implementation. Ontology-based and rule-based reasoning used are discussed below.

Ontology-based reasoning gathers implicit from explicit contexts depending on class and property characteristics. Reasoning rules is found for relationships like sub Class Of, sub Property Of, disjointWith, inverseOf, Transitive-Property, and Functional-Property.

<u>Objectproperty: (?hasPatient owl:inverseOf ?treatedBy)</u>

<u>Context 1 (explicit)</u>

```
<Doctor rdf:ID="Anirudh">
  <hasPatient rdf:resource="#Leelavathi">
</Doctor>
```

<u>Context 2 (implicit)</u>

```
<Doctor rdf:ID=" Leelavathi">
  <treatedBy rdf:resource="#Anirudh">
</Doctor>
```

In the ontology, hasPatient has inverse property of treatedBy. Context 1 is explicitly defined by user and which shows that Doctor Anirudh has patient named Leelavathi. Through ontology reasoning, a new context (context 2) that patient Leelavathi is treatedBy Doctor Anirudh can be implicitly deduced based the semantics of owl:inverseof. This can be very useful for a personalized patient care service.

Rule-based reasoning is an easy reasoning mechanism that gives conclusions depending on user defined rules.

Rule R1: Automated patient identification before surgery
(SurgeryRoom, hasPresence, Patient)
∧ (SurgeryRoom, hasPresence, Doctor)
∧ (ComputerScreen, locatedIn, SurgeryRoom)
→ (ComputerScreen, ShowPatientInfo, Patient)

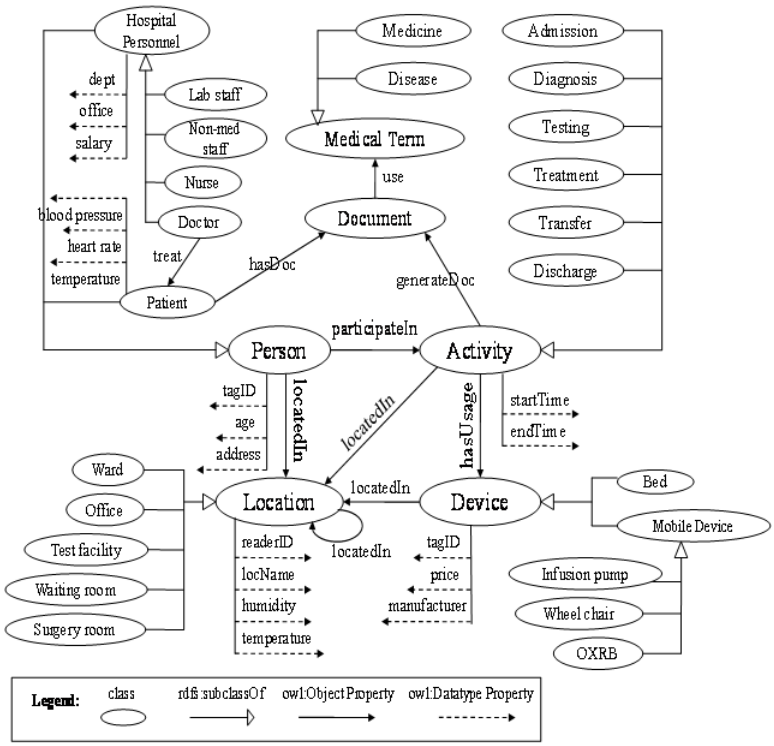

Figure.1. Context aware hospital ontology showing relation and properties

Table.1. OWL-DL properties of context aware ontology model

<owl:Class rdf:ID="OutPatient"> <rdfs:subClassOf> <owl:Class rdf:ID="Patient"/> </rdfs:subClassOf> <owl:disjointWith> <owl:Class rdf:ID="InPatient"/> </owl:disjointWith> </owl:Class>	<OutPatient rdf:about="#"> <hasPatientID rdf:datatype=http://www.w3.org/2001/XML Schema#string> P003A</hasPatientID> <hasPersonName rdf:datatype="http://www.w3.org/2001/XML Schema#string">Mary Liu</hasPersonName> </OutPatient>
(a). Class	**(b). Individual**
<owl:DatatypeProperty rdf:about="#Salary"> <rdfs:domain rdf:resource="#HospitalPersonnel"/> <rdfs:range rdf:resource="http://www.w3.org/2001 /XMLSchema#float"/> </owl:DatatypeProperty>	<owl:ObjectProperty rdf:about="#hasParticipant"> <rdfs:domain rdf:resource="#Activity"/> <rdfs:range rdf:resource="#Person"/> <owl:inverseOf> <owl:ObjectProperty rdf:about="#participateIn"/> </owl:inverseOf> </owl:ObjectProperty>
(c). DataType Properties	**(d). Object Properties**

In rule R1 above, when a surgery room "detects" the presence of a patient and a doctor, the computer screen located in this surgery room will display the patient's medical information. Such an application can eliminate

misidentification of patients which may result in wrong treatment or even death. Other examples of context aware reasoning include providing security alerts when a device or patient is in the wrong location, warning the nurse when a patient's body temperature rises suddenly etc.

Medical Recommender Systems: Any machine learning model of recommender system contains the following phases: Initialization phase, learning phase and prediction phase. During initialization, medical history of patients are collected and features are selected. Any machine learning technique can be used during learning phase. During prediction phase evaluation or similarity between the knowledge base and input data is calculated and prediction is done as in figure 2. Neural network or any soft computing method can be used for building the model, where mapping between input and output attributes take place in the black box. The patients can be treated based on the physical examination of the patient and the recommendations from the knowledge base.

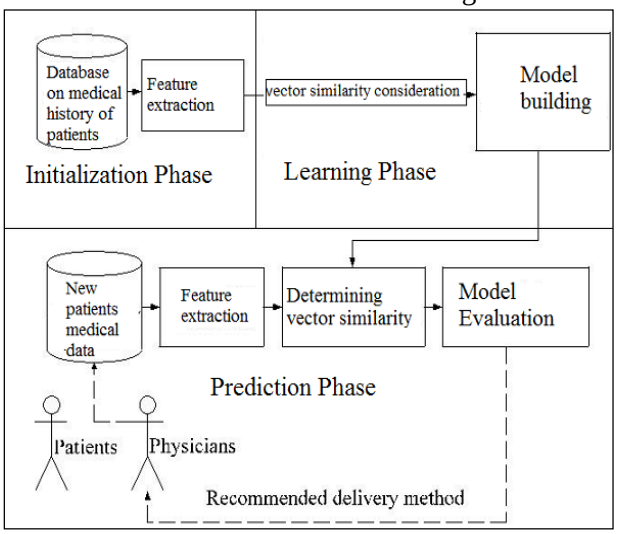

Figure.2. Knowledge based medical recommender system

Recommender techniques can be content based, collaborative, demographic and knowledge based.

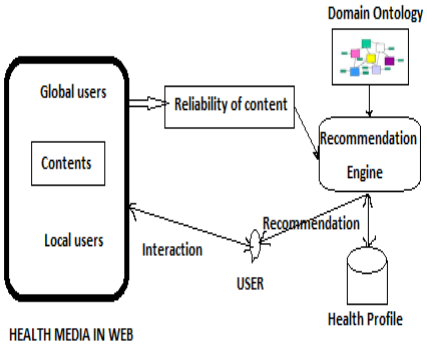

Figure.3. Content based health recommender system.

With huge content in internet, a framework for content based health recommender is proposed in figure 3 which uses content from social media, analyzing the trust level from local to influential global users. Clarification and annotation process on content can be done using domain ontologies. Contents reliability is verified and recommendations are given to user.

2. CONCLUSION

A major challenge facing the healthcare domain is the lack of recommender system with interoperability amongst healthcare systems. This is largely due to the fact that the healthcare lacks a unified terminological set. However, with the growing complexity of information and the increasing need to completely and correctly exchange information among different healthcare systems, the need for precise and unambiguous capture of the meaning of concepts is becoming apparent. Hence, the use of ontologies makes explicit the meaning of terms used in healthcare systems resolving semantic heterogeneity. The proposed context aware ontology medical recommendation shows how recommendations to the patients can be given based on trust.

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