A Semantic Web Framework to Support Knowledge Management in Chronic Disease Healthcare*

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Abstract. Improving quality of healthcare for people with chronic conditions requires informed and knowledgeable healthcare providers and patients. Decision support and clinical information system are two of the main components to support improving chronic care. In this paper, we describe an ongoing initiative that emphasizes the need for healthcare knowledge management to support both components. Ontology-based knowledge acquisition and modeling based on knowledge engineering approach provides an effective mechanism in capturing expert opinion in form of clinical practice guidelines. The Semantic Web framework is adopted in building a knowledge management platform that allows integration between the knowledge with patient databases and supported publications. We discuss one of the challenges, which is to apply the healthcare knowledge into existing healthcare provider environments by focusing on augmenting decision making and improving quality of patient care services.

Keywords: Ontology-based Knowledge Management, Knowledge-based Decision Support, Clinical Information System.

1 Introduction

Chronic illness is typically defined as condition that requires ongoing activities from both the patient and care givers in its treatment. Chronic conditions, such as diabetes, heart diseases, hypertension, etc. are major public health problems in developing countries, as well as in developed countries. As reported in 2004, it was suggested that approximately 45 percents of the US population have chronic illness [1]. While current healthcare systems are designed primarily to treat acute conditions, specific focus is increasingly applied to people with chronic conditions [2]. Treatments of chronic conditions normally require planning and management to maintain the patients' health status and functioning.

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Healthcare processes heavily depend on both information and knowledge [3]. Information systems are typically integrated into hospitals to support organization processes such patient record entry and management, result reporting, etc. Although medical databases and information management systems are common, healthcare knowledge, which is important for medical treatment, is rarely integrated in supporting healthcare processes. It has been recognized that integration of knowledge into institutional workflows can help to improve the quality and efficiency of healthcare delivery system [4].

This paper describes our ongoing project in applying knowledge management to augment diabetes healthcare processes. A healthcare knowledge management framework is designed to support two chronic care components: decision support and clinical information system. Ontology is used as a means for knowledge acquisition and modeling based on expert opinion in form of clinical practice guidelines. Ontology-based healthcare knowledge management framework is a core component that focuses on building a repository of knowledge resources to support knowledge activities, i.e. problem solving and decision making. The framework utilizes the Semantic Web technologies in providing a knowledge management platform that allows linking between the knowledge with patient databases and supported publications. Finally, we discuss one of the main challenges, which is to apply the knowledge resources into the existing healthcare provider environments by focusing on augmenting decision making and improving quality of patient care services.

2 Healthcare Knowledge Management for Chronic Disease

In the Diabetes Healthcare Knowledge Management project, we emphasize the need for healthcare knowledge management to support diabetes healthcare processes. The Chronic Care Model (CCM) [2] is a guide towards improving quality of healthcare for people with chronic conditions. The model aims at producing more informed and knowledgeable patients and healthcare providers that can result in higher quality of chronic care. Decision support and clinical information system are two of the main components for improving chronic care. These components must rely on relevant and reliable information and knowledge in order to assist healthcare providers to deliver higher-quality care service. Knowledge captured from clinical practice guideline (CPG) should be embedded into healthcare applications to assist healthcare providers' decision making. In addition, updates in the medical guideline knowledge are typically based on proven research studies and results, i.e. evidence-based medicine (EBM). As a result, convenient access to medical publication databases, such as PubMed[1], the Cochrane Library[2], etc. should be provided and linked with the guideline knowledge. The guideline knowledge can also be integrated with existing hospital databases, e.g. patient registries. For example, based on a patient's clinical data, a clinician may be automatically reminded about the routine examinations that the patient should receive based on the medical guideline recommendations. Together, they allow for knowledge-enabled chronic care components that provide support for the diabetes care processes.

[1] http://www.pubmed.gov/
[2] http://www.thecochranelibrary.com/

3 Ontology-Based Healthcare Knowledge Management Framework

3.1 Knowledge Resources

Ontology-based knowledge management [5], [6], [7] framework focuses on providing information and knowledge support for the knowledge-enabled chronic care services. In Fig. 1, the framework focuses on integration of three forms of knowledge resources: ontologies, patient registries and evidence-based healthcare resource repository. The Semantic Web technologies are adopted for building a knowledge management platform that allows various forms of data to be integrated and associated with the ontology-based knowledge structure [8]. Ontologies provide a means for knowledge acquisition and modeling of the relevant healthcare knowledge. Two types of ontologies are utilized. The first type is developed based on translation of existing clinical guideline documents. This ontology type is mainly used in providing structural schema for the data in patient registries, i.e. concept instantiation. It also contains sets of production rules that represent decision models defined in the guideline to support inferences. The second type is controlled medical vocabulary, i.e. Medical Subject Headings (MESH)[3], which is a standard set of controlled vocabulary arranged in hierarchical structure for indexing and retrieving medical publications. MESH terms and structure are utilized as lightweight ontology used for semantic-based indexing and access to the evidence-based resource repository. Vocabulary mapping is a process of translating CPG-based ontology concepts on into MESH terms in order to allow linking the different types of knowledge resources.

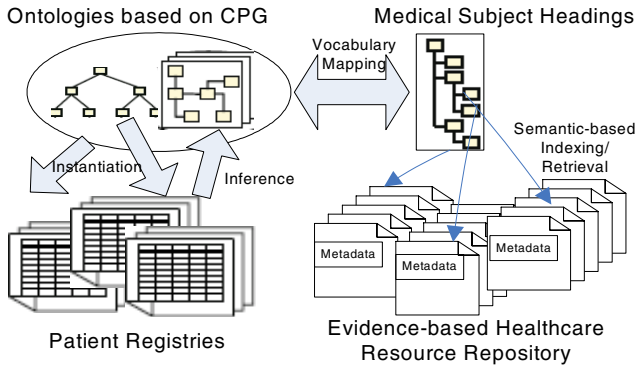

Fig. 1. Knowledge resources in ontology-based healthcare KM framework

3.2 Ontology Development

Ontology development in this project relies on expert opinions in form of clinical guidelines. Clinical guideline recommendations are normally provided based on the best available evidence. Thus, ontologies developed based on the guidelines typically

[3] http://www.nlm.nih.gov/mesh/

represent reliable knowledge and are agreeable in terms of expert opinions. In developing the ontologies, the clinical guideline for diabetes care issued by Thailand's Ministry of Public Health was translated from free text into a formal representation using the knowledge engineering approach.

The development can be divided into two major phases: knowledge acquisition and modeling and knowledge verification. In the knowledge acquisition and modeling phase, diabetes healthcare ontologies are designed and developed by a team of knowledge engineers and medical experts, i.e. medical doctors and public health specialists, using ontology development tools, which result in drafted ontologies. In the knowledge verification phase, a group of medical doctors who are diabetes specialists are invited to a public hearing session to verify and give additional comments on the drafted ontologies. The results are verified ontologies, which can be deployed in healthcare applications and services.

a) Structural Knowledge b) Procedural Knowledge

Fig. 2. Diabetes healthcare knowledge modeling using Semantic Web standards

Two forms of knowledge are distinguished: structural and procedural knowledge.

1. Structural Knowledge. This knowledge type allows the computer to be able to make use of patient's clinical data. Thus, the knowledge provides structural information, i.e. schema, of patient's clinical data. This includes personal data, assessment and therapeutic data and history, which are critical for decision support and clinical information systems. OWL and RDF standards are utilized in defining structural knowledge and its instantiation respectively. Fig. 2a shows a simplified structural knowledge modeling and its instantiation using OWL/RDF syntax format.

2. Procedural Knowledge. This knowledge type represents the guideline recommendations that help to support decision making in medical diagnosis, treatment and planning processes. This process-oriented knowledge together with the patient's clinical data will assist the healthcare providers to make well-informed decisions. Numerous models have been developed to formally represent medical guideline knowledge, such as GLIF[4], DeGel[5], etc. We utilize the Semantic Web Rule Language (SWRL) [9] to construct decision models based on the clinical guideline knowledge. Fig. 2b shows a procedural knowledge modeling for a diabetes diagnosis process based on the defined structural knowledge using SWRL syntax format.

3.3 Evidence-Based Healthcare Resource Repository

Development and updates of medical guideline knowledge typically rely on proven research studies and results in medical literature, e.g. journals and publication databases. Guideline recommendations are usually provided with reference to publications. In our project, evidence-based healthcare resource repository is the component that provides a uniform and semantic-based access to medical literature. Similar to the federated medical search approach [10], [11], the repository consists of wrappers developed for each individual source for query translation and integration of search results. The medical subject headings (MESH) terms assigned to the retrieved resources are used as subject indexing terms that will allow for semantic-based search and navigation based on MESH hierarchical structure. To link the guideline knowledge with medical literature, vocabulary mapping between concept terms defined based on the medical guideline and MESH terms must be provided. This will enable the medical guideline knowledge to be linked with the supported evidence that can be accessed through a search interface as exemplified in Fig.3.

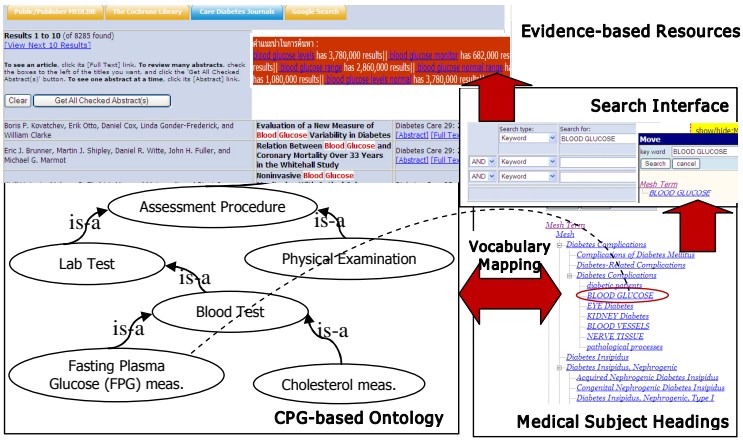

Fig. 3. Medical guideline knowledge linked with the evidence-based resources

[4] http://www.openclinical.org/gmm_glif.html
[5] http://www.openclinical.org/gmm_degel.html

4 Discussion

One of the challenges is to apply reliable knowledge into existing healthcare provider environment by focusing on augmenting decision making and improving quality of patient care services. The healthcare knowledge management approach [4] focuses on embedding knowledge into the clinical work environment that would not require the providers to explicitly request for, i.e. using automatic alerts and reminders. Medical errors and omissions in healthcare process may be minimized by means of detection and prevention. For example, based on medical knowledge from the guideline, an automatic reminder may be triggered when a patient has not received some recommended tests within some recommended periods. Alerts can be triggered to inform the provider when the patient's lab test data is above or below recommended values, which may affect the clinician's decision making. In addition, the knowledge based on medical guideline recommendations may be used to support monitoring of practices for assuring quality control.

In this paper, we have provided a healthcare knowledge management framework that is important for chronic disease care management. The framework is designed to support two chronic care components: decision support and clinical information system. The framework focuses on building of healthcare knowledge resources that link clinical guideline knowledge with patient registries and medical literature databases to support evidenced-based healthcare. The Semantic Web technologies provide an effective platform to support the knowledge management process. It supports modeling of ontologies and metadata in the standard formats that can enable semantic-based integration, processing and access of the knowledge resources. Our future work will focus on embedding and applying the knowledge to the existing healthcare applications and services and conducting user evaluations.

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