An Ontology-based Framework for Development of Clinical Reminder System to Support Chronic Disease Healthcare

Marut Buranarach, Nopphadol Chalortham, Piyatat Chatvorawit, Ye Myat Thein and Thepchai Supnithi

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 ontology-based information and knowledge management framework that is important for chronic disease care management. 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 framework focuses on building of healthcare ontology and clinical reminder system that link clinical guideline knowledge with patient registries to support evidenced-based healthcare. We discuss approaches in integrating clinical reminder services to existing healthcare provider environment by focusing on augmenting decision making and improving quality of patient care services.**

I. 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. Treatments of chronic conditions normally require planning and management to maintain the patients' health status and functioning.

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.

In this paper, we introduce an ontology-based framework based on knowledge engineering approach in providing information and knowledge management to support chronic disease healthcare. Ontology is a standard form for information and knowledge modeling that can allow for automation and interoperability in various applications and systems. We present a prototype development of clinical reminder system to support diabetes healthcare. In this application, reminders can be triggered based on patient data and given recommendations from clinical practice guidelines. Finally, we discuss some approaches and examples of embedding clinical reminder services into existing healthcare provider applications in order to improve quality of patient care services.

Manuscript received November 10, 2009. This work was supported by the National Science and Technology Development Agency, Thailand.

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II. Background and Framework

A. Information and Knowledge Management to Support Chronic Disease Healthcare

The Chronic Care Model (CCM) is a guide to higher-quality chronic illness management in patient care [2]. The model recommends that improving six interrelated components -- self-management support, clinical information system, delivery system redesign, decision support, health care organization, and community resources -- can result in a more effective system in chronic care management. These components aim at producing more informed and knowledgeable patients and healthcare providers. This can result in more productive interactions between them and thus can potentially improve the quality of care and outcomes.

In our framework, we focus on providing information and knowledge management support for two CCM components: decision support and clinical information system. The two components can be summarized as follows:

- **Decision support.** The component focuses on embedding evidence-based guidelines, i.e. clinical practice guidelines (CPG), into daily clinical practice. Evidence-based guidelines normally integrate specialist expertise and are based on proven research studies and results, i.e. evidence-based medicine (EBM).
- **Clinical information system.** The component focuses on utilizing information management system in supporting healthcare process. This include developing patient registries, automatic alerts/ reminders for preventing mal-practice and

The 4th International Symposium on Biomedical Engineering
14-18 December 2009, Bangkok.

monitoring for improving performance of practice team and care system.

In the Diabetes Healthcare Knowledge Management project, we emphasize the need for healthcare knowledge management to support diabetes healthcare processes. Knowledge captured from clinical practice guideline (CPG) should be embedded into healthcare applications to assist healthcare providers' decision making. The guideline knowledge should 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-based chronic care components that provide support for diabetes healthcare processes. Fig. 1 shows a layered architecture for knowledge-based chronic care components to support diabetes healthcare processes.

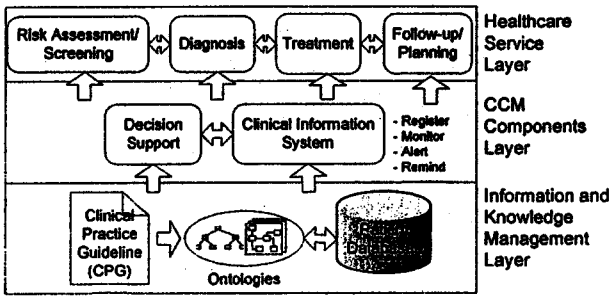


Fig 1. A layered architecture for knowledge-based chronic care components

B. Ontology-based Information and Knowledge Management Framework

In computer science, ontology is a controlled vocabulary that describes objects and the relations between them in a formal way. Ontologies provide a sound basis for sharing domain knowledge between human and computer programs, or between computer programs. An ontology normally defines concepts (or classes), individuals (or instances), properties, relationships and their constraints. Logical formalization of ontology language ensures semantic interpretation, i.e. inference, by computer programs. Ontology is a major instrument toward realization of the Semantic Web vision [3].

In our framework, ontology-based information and knowledge management [4] focuses on providing information and knowledge support for chronic care services. The framework focuses on integration of three forms of information and knowledge: patient registries, clinical practice guidelines and ontologies. The ontology-based framework allows various forms of data to be integrated and associated with the ontology-based knowledge structure [5]. In our project, ontologies provide a means for knowledge acquisition and modeling of the relevant healthcare knowledge. Specifically, ontology is developed based on translation of existing clinical guideline documents. The developed ontology defines common structural schema that can be linked with data in patient registries, i.e. using concept instantiation mechanism. It can also contain sets of production rules that represent decision models and recommendations defined in the clinical guideline to support inferences. Fig 2. shows relationships between ontologies, patient registries and clinical practice guidelines in this framework.

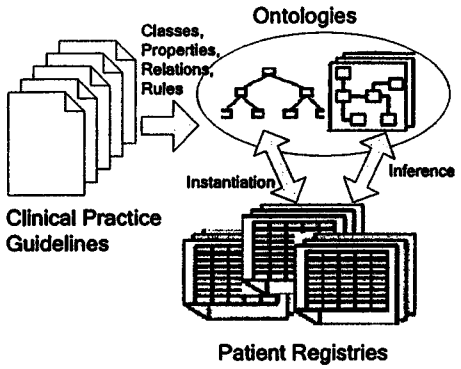


Fig 2. Relationships between ontologies, patient registries and clinical practice guidelines in ontology-based information and knowledge management framework

Although ontologies can be advantageous in numerous ways [6], we emphasize the benefits of ontologies in supporting chronic care services in terms of providing automation and interoperability in clinical information systems.

- **Automation.** Medical personnel are often overloaded by daily tasks and activities. In addition, they are often overloaded by large volume of patients' data. Ontologies can facilitate automated and intelligent processing of data. Such automation embedded in healthcare applications can provide assistance to the human medical personnel to reduce their workload and improve reliability, i.e. reduced errors. It should be emphasized that providing such automation will not replace human medical personnel but rather to assist in their routine tasks.
- **Interoperability.** Clinical databases are often different both in terms of database schema and terminologies. Such heterogeneity makes it difficult for sharing and integration of existing healthcare data. Ontologies can define common structure and meanings, i.e. semantics, which can be shared and reused across systems. Different database schema and used terms can be mapped into common structure and vocabulary that is defined using a standard ontology format. Specifically, the Web Ontology Language (OWL)[1] is the standard interchange format for ontology data that uses XML syntax.

[1] http://www.w3.org/TR/owl-features/

III. Design and Implementation of Ontology-Based Clinical Reminder System

A. Ontology Development

The first step involves ontology design and 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 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.

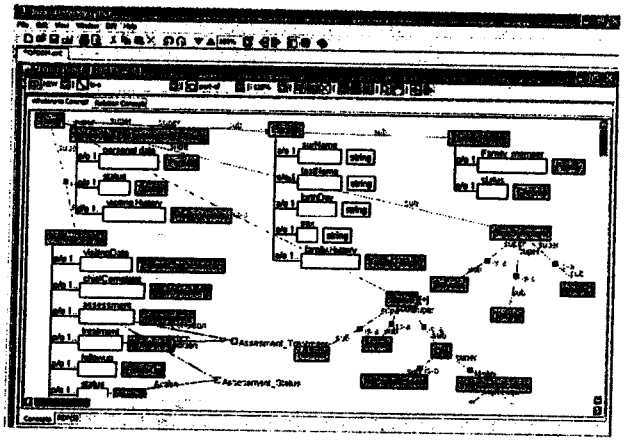


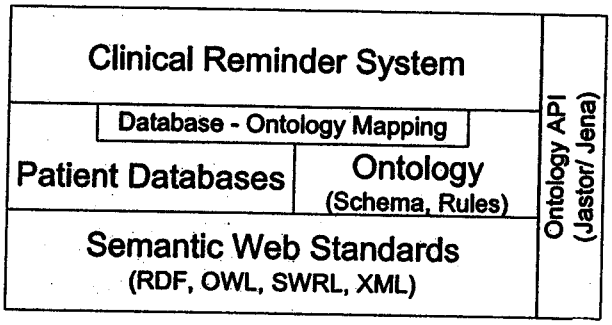
Fig 3. Modeling structural knowledge in diabetes healthcare ontology using the Hozo ontology editor

Diabetes healthcare ontology are designed and developed by a team of knowledge engineers and medical experts, i.e. medical doctors and public health specialists, using the Hozo ontology development tool[2]. 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. 3 shows a structural knowledge modeling in diabetes healthcare ontology using the Hozo ontology editor.
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 that are based on evidence-based guidelines.

B. Ontology-based Reminder System Development

The next step involves development of a reminder system prototype based on the developed ontology. Fig 4 shows a conceptual architecture for ontology-based clinical reminder system development. After the developed diabetes healthcare ontology was exported into OWL format, development of the reminder system prototype must involve integration of the ontology with existing patient databases, i.e. database schema to ontology mapping process. The patient data records can be instantiated based on the ontology classes and properties that can be manipulated via ontology application programming interfaces, i.e. Jastor[3] and Jena[4] API.



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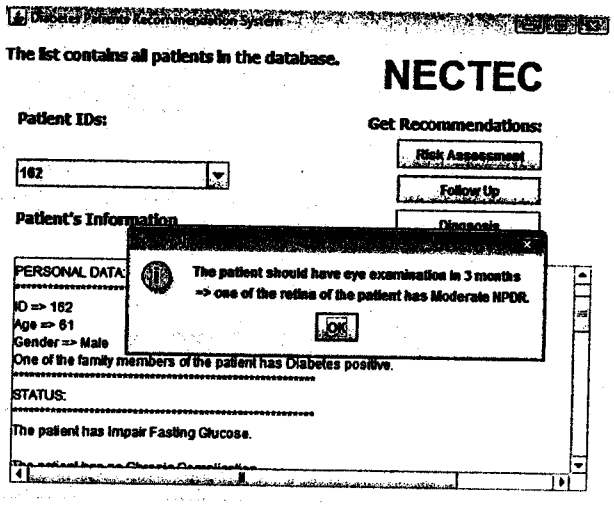

Fig 5. Ontology-based reminder system prototype showing a reminder/ recommendation for a diabetes patient by recommending the next follow-up schedule for eye examination based on the patient's previous eye examination result

[2] http://www.hozo.jp/

[3] http://jastor.sourceforge.net/

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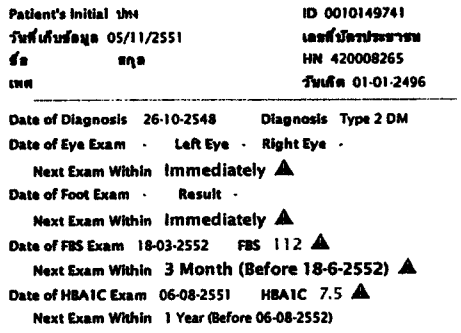
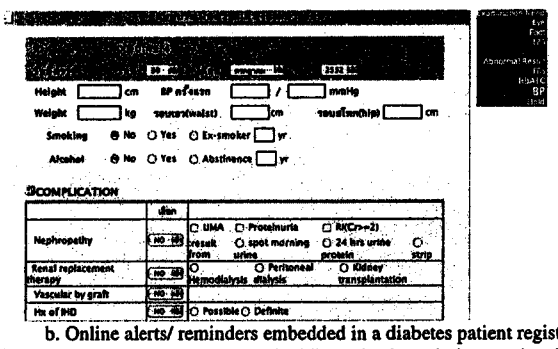
A Java-based prototype of ontology-based reminder system developed for a diabetes patient database is shown in Fig 5. The system retrieved the patient records from an existing data source. The data were then transformed into the ontology-based structure manipulated using the ontology APIs. Some recommendations from the diabetes clinical guideline were transformed into ontology-based rules that enable inferences by the system. Fig 5 exemplifies a case where the system produced a recommendation suggesting the next follow-up schedule of a patient for eye examination based on the patient's previous eye examination results.

IV. Approaches to Integrating Clinical Reminder with Patient Registries

One of the challenges is to apply reliable knowledge into existing healthcare provider environments by focusing on augmenting decision making and improving quality of patient care services. The healthcare knowledge management approach [7] 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.



a. Offline alerts/ reminders embedded in a diabetes patient registry



b. Online alerts/ reminders embedded in a diabetes patient registry

Fig. 6. Two approaches to embedding alert/ reminder service into an existing diabetes patient registry

We present two approaches to embedding alert/ reminder service into existing diabetes patient registries: offline and online reminder. Fig. 6 shows a design of alert/ reminder service added to an existing diabetes patient registry system, i.e. the DMSDD system, a diabetes patient registry software released by the Department of Medical Service, Ministry of Public Health. Fig. 6a shows embedding alert/ reminder service in an offline fashion in form of a patient data report which can be prepared by medical personnel. The report includes alerts and reminders for some recommended tests and some lab test results that were above or below the recommended values. Fig 6b shows embedding alert/ reminder service in an online fashion. Alerts/ reminders are shown as pop-up notification messages while the medical personnel are working with the patient data.

V. Conclusions

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Acknowledgment

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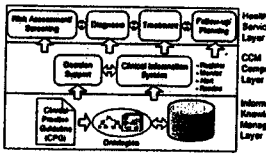

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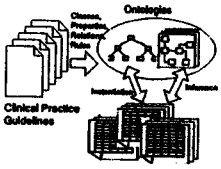

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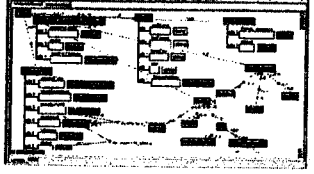

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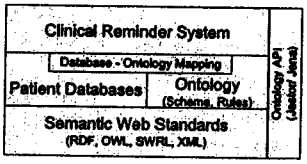

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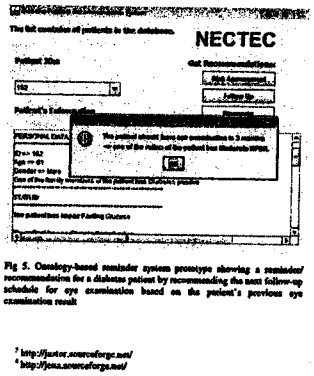

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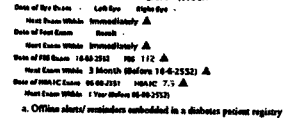

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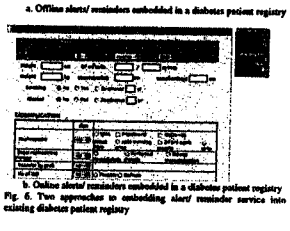

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References

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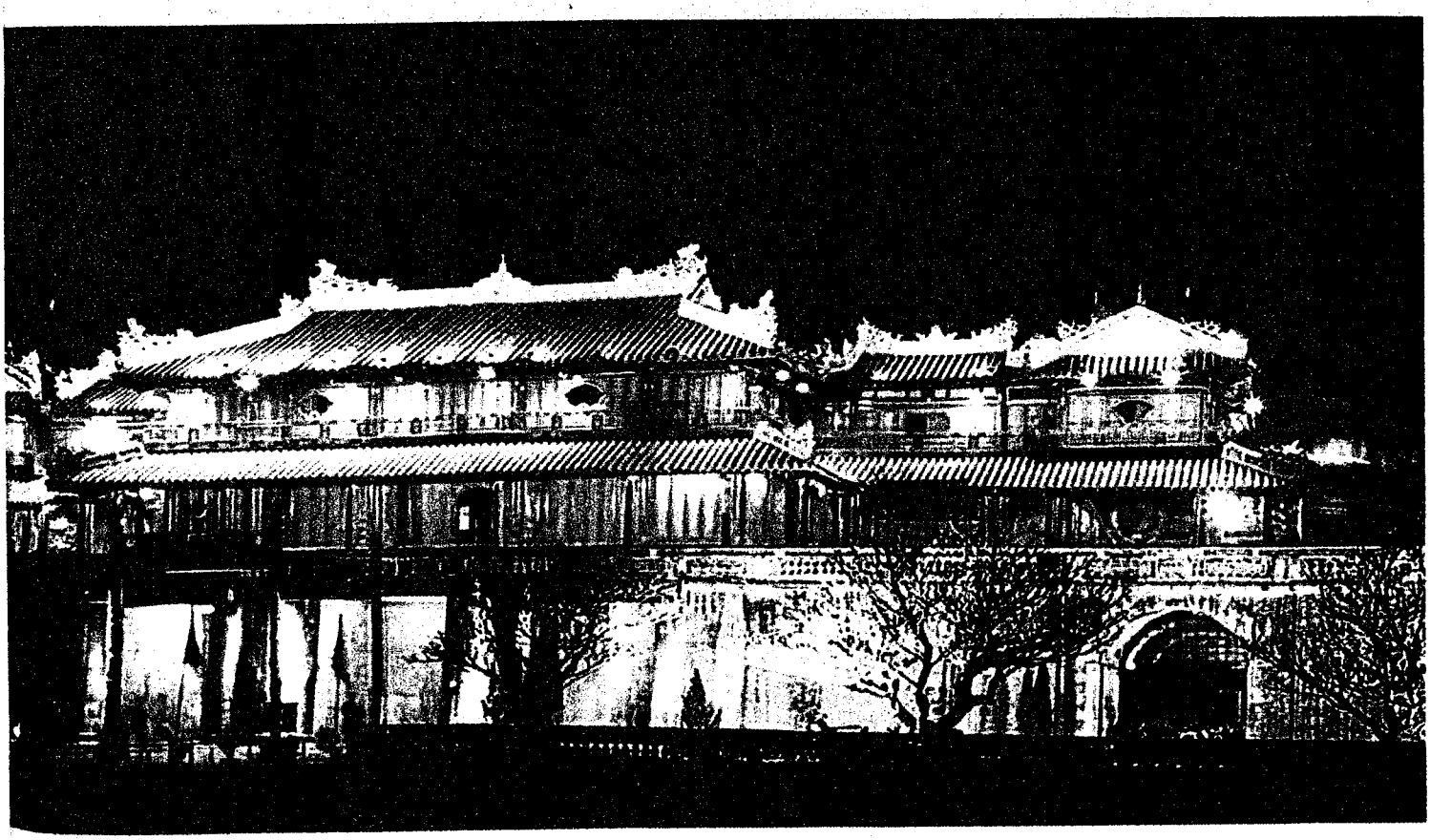
PROCEEDINGS OF THE SIXTH INDOCHINA CONFERENCE
ON PHARMACEUTICAL SCIENCES

PHARMA INDOCHINA VI

THE DEVELOPMENT OF INDOCHINA PHARMACY IN THE CONTEXT OF GLOBAL ECONOMIC RECESSION



DECEMBER 15-18, 2009
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