An Ontological Approach for Guideline-based Decision Support System

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Abstract

Diabetes mellitus (DM) can increase premature death and decrease the quality of life due to vascular complications. Optimal assessment and management during surgery for diabetic patients is very important. Clinical guidelines are used to standardize clinical practice and improve the outcomes, but they are underutilized at the point of care. There have been considerable efforts to operate computerized clinical guidelines within Clinical Decision Support Systems (CDSS). An ontological approach was used to computerize the key concepts and relationships in the clinical guidelines so as to allow clinical knowledge sharing, update and reuse. The paper proposed the methodology for designing and developing an ontology-driven CDSS for perioperative management of the diabetic patient. Clinical guideline decision rules were represented as JENA rules for the JENA reasoning system. Fuzzy logic wasalso employed due to the non-explicit nature of clinical decision making.

Keywords: Ontology; Clinical Guidelines; Clinical Decision Support System; Jena; Fuzzy; Diabetes; Surgery

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1. Introduction

Diabetes is the leading cause of death in many countries. Surgery in diabetic patients is more complicated than nondiabetic patients. Appropriate assessment and management during surgery are needed. Tight glycemic control can minimize surgical complications, but hypoglycemia may also occur. Severe hypoglycemia can increase the mortality rate and cardiovascular deaths.In order to address the issues, we can adopt structured approaches such as clinical guidelines. Clinical guidelines are systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances [1]. Taichung Hospital developed clinical guidelines for perioperative management of the diabetic patient. Clinicians can use the guidelines to standardize clinical practice and ultimately to improve the outcomes of patients. However, reference [2] indicated that medical guidelines are underutilized at the point of care. The issues can be tackled by providing decision making to assist clinicians with an ontology-driven clinical decision support system (CDSS). The aims of this study are to computerize and execute guidelines in perioperative management of the diabetic patient for CDSS with an ontological approach.

2. Related works

2.1 Clinical Decision Support Systems (CDSS)

CDSS is an "active knowledge system which use patient data to generate case-specific advice", according to Wyatt and Spiegelhalter's 1991 definition [3]. CDSS is a good medium for the computerization and execution of clinical guidelines. Clinical guidelines may be utilized in ontology-driven CDSS because of their structured approaches. The clinical guidelines may be computerized into a machine-understandable format. The machine-understandable guidelines maythen be used by a CDSS with a more sophisticated capability such as for clinical knowledge sharing, update, reuse and lastly decision support.

2.2 Ontology

An ontology is a model of a particular field of knowledge-the concepts and their attributes, as well as the relationships between the concepts” [4]. Ontology describes and organizes domain knowledge in a manner machines can be read and humans can understand, which leads data annotation, decision support, information retrieval, and natural-language processing to be promoted with computer systems or applications [5]. The advantage of using ontology for the decision support part of the system is that the properties in a domain ontology and relationships among them may be explicitly described.

2.3 Web Ontology Language (OWL)

The Web Ontology Language (OWL) [6] is the latest standard in ontology languages from the World Wide Web Consortium (W3C). OWL is applied when information is not only presented, but also needs to be processed. The OWL language is focused on DL since the DL reasoning algorithms are well understood and have been used successfully in several projects.

2.4 Jena

Jena is a Java framework for building Semantic Web applications and includes a general purpose rule-based reasoner [7]. It can be used to perform reasoning based on OWL and RDFS ontologies. We can write the decision rules in Jena rule syntax and then Jena inference engine uses the rule set to infer recommendations based on patient profiles.

2.5 Fuzzy logic

The term "fuzzy logic" was first introduced with the proposal of fuzzy set theory by Zadeh[8]. Fuzzy logic variables may have a truth value with range in degree between 0 and 1 [9]. Since uncertainty is inherent in fields such as medicine, fuzzy set theory can be considered as a suitable formalism to deal with the imprecision intrinsic to many medical problems. Fuzzy logic plays an important role to render precise what is imprecise in the area of medicine.

3. System architecture

The overall architecture of the ontology-driven CDSS is illustrated in Figure 1. First, a domain ontology pertaining to perioperative management of the diabetic patient was built in using the Protégé-OWL editor. We subsequently transform the clinical guideline decision rules into JENA rule syntax, which can then be inputted to an inference system JENA. Otherwise, the decision rules containing linguistic variables will be transformed to fuzzy rule sets. Next, a patient ontology was created to generate standardized descriptions of a patient, which in turn serve as patient instances used to execute the decision rules. One domain expert, an endocrinologist, was recruited to participate in the construction and evaluation of the ontology.

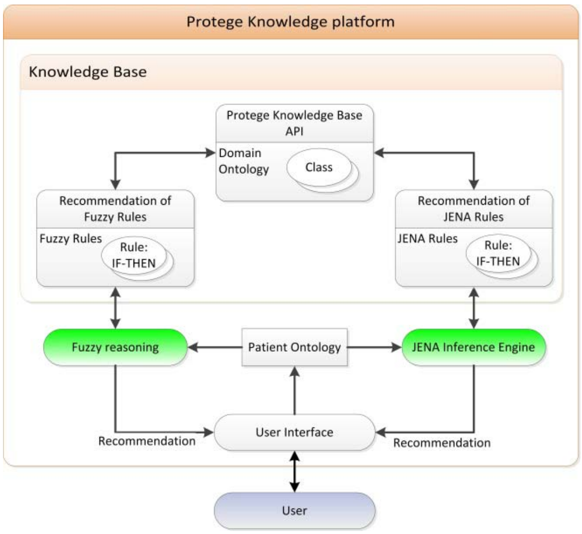

Figure 1: Proposed System Architecture

4. Ontology-driven CDSS method

We employ a four-stage method for ontology based information system designed by Kitziemsky [10]. The study method includes four stages: specification and conceptualization, formalization, implementation, and evaluation and maintenance. Details of the four stages are explained below:

4.1 Specification and conceptualization

In order to develop a domain ontology, the ontology domain and scope need to be defined first. The domain ontology was limited to concepts for perioperative management of the diabetic patient. Ontology content was supplied by the guidelines for perioperative management of the diabetic patient implemented in Taichung Hospital. To conceptualize the domain ontology, we identified and analyzed the domain concepts by extracting textual information of guidelines with the domain expert's aid. Some classes and the descriptions of their concepts in the domain knowledge are shown in Table 1.

Table 1. Description of some classes in the domain ontology

Class	Description
Disease	Concepts about an illness which affects a person
Anesthesia	Concepts about anesthesia used during surgery
Medication	Concepts about medication need for diabetic patient undergoingsurgery

4.2 Formalization

4.2.1 Domain Ontology Development

The second stage is to design and develop the domain ontology for perioperative management of the diabetic patient and the rule sets. The domain ontology was developed with the Protégé-OWL editor. A top-down approach was used to create the classes. We start with a general concept of Disease before defining subclasses such as Diabetes. After classes were created, properties were added and finally individuals were completed [11]. The ontology was revised and refined with the assistance of the domain expert. We have 2 main classes in the domain ontology, Disease and Management. The Management class is further subdivided into 6 subclasses and the Disease class consists of 2 subclasses. The list of classes in the domain ontology is presented in Figure 2. In the ontology, instances have a key role because we can specify their classes. Some object property and data property assertions can be added to each instance. Medical measures do not make sense to have many instances. The singleton pattern for the instances of Medication class was adopted [12]. Each class can only have one instance, which can avoid confusion while expressing facts. The singleton pattern is presented in Figure 3.

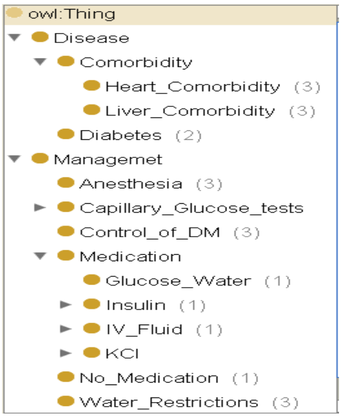

Figure 2: Indented list of classes in the domain ontology

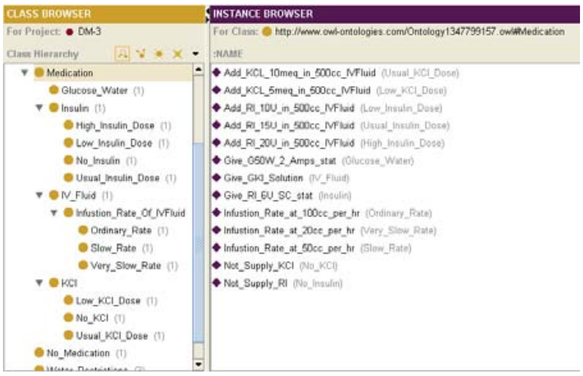

Figure 3: The singleton pattern

4.2.2 Formalization of Rules

Clinical guideline decision logic is captured and represented as Jena rules. We give an example to illustrate the Jena rule syntax. For example, "If a type 2 diabetic patient has a general anesthetic for surgery, intravenous fluid administration will be recommended.", which could be translated into Jena rule syntax and shown as follows: (?x rdf:type Patient)(?x has_Diabetes T2DM)(?x has_AnesthesiaGeneralized_Anesthesia)(?y rdf:typeIV_Fluid) -> (?x was_Suggested_to ?y)

This example indicates if ?x an instance of class “Patient”, which has an object property with “T2DM”, an instance of class “Diabetes”, via “has_Diabetes” property, and has an Object property with “Generalized_Anesthesia”, an instance of class “Anesthesia”, via “has_Anesthesia” property, then ?y an instance of class “IV_Fluid” is recommended.

When patients are getting ready for a surgery, they will be asked to take nothing by mouth. Intravenous (IV) fluid supplement will be ordered to avoid dehydration. However, diabetic patients often have other comorbidities, such as heart failure, and too much water will be worsen by heart failure. Fuzzy logic has been applied to the problem of controlling fluid resuscitation [13]. Therefore, we also used fuzzy logic to decide the infusion rate of IV fluids. Here we will consider only two variables: heart failure and hepatic failure. The severity of failure may be either none to mild, moderate or severe so we divide them into three corresponding fuzzy sets. For convenience, they correspond to 3 membership functions in the range of 0 to 10. Figure 4 is the corresponding membership functions of Heart Failure. The range of input variables membership functions is presented in Table 2.

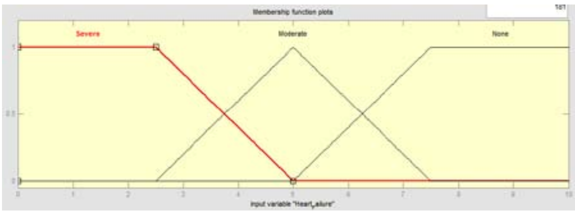

Figure 4: The membership functions of Heart Failure display in Matlab system

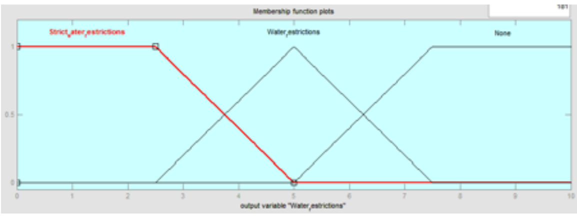

Figure 5: The membership functions of Water Restrictions display

Table 2. Range of input and output variables membership functions

Range of the input variables membership functions			
	Severe	***Moderate***	***None to Mild***
Heart Failure	0 ~ 5	2.5 ~ 7.5	5 ~ 10
Hepatic Failure	0 ~ 5	2.5 ~ 7.5	5 ~ 10
Range of the output variable membership functions			
	Strict Water Restrictions (20 cc/hr)	***Water Restrictions (50 cc/hr)***	***None (100 cc/hr)***
Water Restrictions	0 ~ 5	2.5 ~ 7.5	5 ~ 10

Table 3. Rule table for deciding what action should be taken

Hepatic Failure	**Heart Failure**		
	Severe	***Moderate***	***None to Mild***
Severe	Strict Water Restrictions	Strict Water Restrictions	Strict Water Restrictions
Moderate	Strict Water Restrictions	Water Restrictions	Water Restrictions
None to Mild	Strict Water Restrictions	Water Restrictions	None

The next step is to decide what action should be taken for each combination of set memberships. The recommendation for water restrictions depends on the severity of Heart Failure and Hepatic Failure. This question can be addressed in general terms using intuitive notions because some situations are obvious. For example, if Heart Failure is None to Mild and Hepatic Failure is None to Mild then water restrictions should be clearly not needed. For the purposes of this illustration, we designate three categories of Water restrictions labeled None, Water Restrictions and Strict Water Restrictions. The various membership combinations for Heart Failure and Hepatic Failure are assigned to these categories as shown in Table 3. Figure 5 is the corresponding membership functions of Water Restrictions. The range of output variables membership functions is presented in Table 2.

4.3 Implementation

A patient ontology allows to represent patient clinical situations by incorporating patient properties such as age, medical history, laboratory tests, and the values to these properties. It in turn serves as patient instances used to evaluate the rules sets in generating the recommendations. There are two main types of properties, Object properties and Data type properties. Each property has a domain and a range. Table 4 presents some of the properties in patient ontology. A Graphical User Interface (GUI) will be created so that data entry is easy for clinicians and the recommended result can be displayed through the interface.

Table 4. Some of the defined properties in the patient ontology

Property Name	Property Type	Domain	Range
Control DM with	Object	Patient	Control of DM
has Anesthesia	Object	Patient	Anesthesia
Capillary Blood Glucose Is	Datatype	Patient	integer
sex	Datatype	Patient	String

4.4 Evaluation and Maintenance

The developed ontology-driven CDSS will be evaluated by clinicians. A survey in terms of perceived usefulness, satisfied degree and behavioral intentions to use should be conducted amongst the clinicians. The feedbacks given by the clinicians will be used to revise and refine the ontology-driven CDSS.

5. Discussions and conclusions

In this paper we discussed about the need of developing an ontology-driven CDSS in perioperative management of the diabetic patient setting. The paper described the issues that medical guidelines were underused by clinicians at the point of care. We can make use of a CDSS with an ontological approach to address the issue. The proposed ontological-approach took account of one guideline and its corresponding domain ontology to establish the guideline execution system.

Jena inference engine can use the rule set to infer recommendations based on patient profiles. Moreover, medical guidelines often contain inequality and algebraic formula, and Jena built-in functions can deal with these situations. Clinical guidelines often include a fuzzy logical structure that makes fuzzy logic suitable for the non-explicit nature of clinical decision making. The validation of the ontology still continues to joint with the domain experts at present. At last, in order to verify the ontology-driven CDSS, clinicians will be surveyed in terms of perceived usefulness, satisfied degree and behavioral intentions to use.

Acknowledgment

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References

[1] M. J. Field and K. N. Lohr, Clinical Practice Guidelines: Directions for a New Program, Washington, DC: National Academies, 1990.

[2] S. Hussain and S. S. R. Abidi, Ontology Driven CPG Authoring and Execution via a Semantic Web Framework, Proc. of 40th Annual Hawaii International Conference on System Sciences, pp.135-135, 2007.

[3] J. Wyatt and D. Spiegelhalter, Field trials of medical decision-aids: potential problems and solutions, Proc. of the Annual Symposium on Computer Application in Medical Care, p.3, 1991.

[4] M. A. Musen, Domain ontologies in software engineering: use of Protege with the EON architecture, Methods Inf Med, vol. 37, pp.540-550, 1998.

[5] T. J. Bright, E. Yoko Furuya, G. J. Kuperman, J. J. Cimino, and S. Bakken, Development and evaluation of an ontology for guiding appropriate antibiotic prescribing, J. Biomed. Inform., vol. 45, pp.120-128, 2012.

[6] D. L. McGuinness and F. Van Harmelen, OWL web ontology language overview, in W3C recommendation, 2004.

[7] D. Reynolds, Jena 2 inference support, Online manual at http://jena. sourceforge. net/inference/index. html, 2004.

[8] L. A. Zadeh, Fuzzy sets, Information and Control, vol. 8, pp.338-353, 1965.

[9] V. Novák, I. Perfilieva, and J. Močkoř, Mathematical Principles of Fuzzy Logic, The Kluwer International Series in Engineering and Computer Science, Kluwer Academic Publishers, 1999.

[10] C. E. Kuziemsky, F. Lau, I. Bilykh, J. H. Jahnke, G. McCallum, C. Obry, A. Onabajo, and G. M. Downing, Ontology-based information integration in health care: a focus on palliative care, Proc. of Eleventh Annual International Workshop on Software Technology and Engineering Practice, pp.164-172, 2003.

[11] N. F. Noy and D. L. McGuinness, Ontology development 101: A guide to creating your first ontology, Standford knowledge Systems Laboratory Technical Report KSL-01-05 and Stansford Medical Informatics Technical Report SMI-2001-0880, 2001.

[12] C. Mathieu, E. S. Eltaher, P. Sarathy, and S. Gilles, OWL Ontology for Solar UV Exposure and Human Health, in Advances in Semantic Computing. vol. 2, M. Joshi, H. Boley, and R. Akerkar, Eds., 2010.

[13] J. H. T. Bates and M. P. Young, Applying Fuzzy Logic to Medical Decision Making in the Intensive Care Unit, Am. J. Respir. Crit. Care Med., vol. 167, pp.948-952, 2003.