Expert Systems with Applications 39 (2012) 10311–10323

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Multi-agent ontology-based Web 2.0 platform for medical rehabilitation

Chuan-Jun Su *, Chun Wei Peng

Department of Industrial Engineering & Management, Yuan Ze University, 135, Far-East Rd., Chung-Li, Taiwan, ROC

ARTICLE INFO

Keywords:
Rehabilitation medicine
Web 2.0
Ontology
Evidence-based medicine
Knowledge-based system
Agent technology

ABSTRACT

Information technologies have played key roles in a wide range of medical settings such as hospital wards, operating rooms, emergency departments, and rehabilitation centers, rendering biomedical knowledge and data more accessible for human comprehension, comparison, analysis and communication. In this context, ontology has been recognized in the bioinformatics literature as a suitable technique for advancing knowledge and data representations in biomedicine. With the enhancement of automated reasoning and graphical visualizations, ontology-technology can assist human comprehensibility as well as mitigating the complexity inherent to this domain.

Rehabilitation medicine has become an important part field in medicine, as distinct from preventive medicine, health care medicine and clinical medicine. In this article, we aim to address the ontological and epistemological issues of information services through the example of OntoRis, an ontology-based rehabilitation service OntoRis is designed to assist patients in acquiring actionable knowledge about his/her prescribed rehabilitation, and to expedite recovering through providing suggestions and advice drawn from evidence-based medicine. Moreover, OntoRis can also serve as an interactive learning platform for people who are interested in rehabilitation medicine.

1. Introduction

In recent years, rehabilitation medicine has developed rapidly and assumed an important role in modern medicine, alongside preventive medicine and therapeutic medicine. In rehabilitation therapy, most patients just follow a physiatrist's instructions with little knowledge of the reasons for of consequences of those instructions. It is nevertheless crucial for the patient to understand the rationales, procedures, and potential side effects of his rehabilitation. Doing so not only provides the patient with a better understanding of his disability, but also provides basic knowledge of the rehabilitation process related to different aspects of the patient's living situation.

The Internet offers access to vast information resources in nearly every possible domain, but the data are published in a completely "unstructured" and "uncontrolled" way. In addition, its human-oriented representation and its size make any kind of centralized computer-based processing difficult and time-consuming (Śanchez & Moreno, 2006). The task of structuring relevant information and then extracting knowledge from that information is currently performed manually with tremendous effort. A formal representation for structuring knowledge is needed to allow for the automation of knowledge extraction from web resources.

Ontologies comprised of classes, sub-classes, instances, and non-taxonomic relations are an emerging approach to knowledge representation (Smith, Welty, & McGuinness, 2004). Gruber (1995) indicated that *an ontology is the explicit specification of a conceptualization* enabling the sharing and reuse of knowledge. An ontology defines the entities and their relationships with each other, comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary. In essence, an ontology provides shared understanding within a community of people by providing a declarative specification of entities and their relationships with each other and by defining constraints and rules that permit reasoning within the ontology. The behaviors of the entities can be associated with stated or inferred facts that are derived from a reasoner to satisfy a pre-defined goal. Through developing an ontology for rehabilitation, knowledge can be formally modeled by a set of concepts and the relationships between those concepts within rehabilitation medicine.

This paper develops a base ontology for rehabilitation (RO), which serves as a knowledge base to develop an ontology-based knowledge support system. This system, called OntoRis, is a comprehensive domain knowledge resource for a specific rehabilitation therapy equipped with a Web 2.0-enabled discussion forum for the exchange and sharing of experiences among patients and therapists.

The exchange and sharing of experiences can inspire and promote new ideas or useful information for the rehabilitation process. Equipped with these ideas and information, OntoRis can make

* Corresponding author. Tel.: +886 963288844; fax: +886 3 4638907.
E-mail addresses: iecjsu@satuen.yzu.edu.tw (C.-J. Su), s975444@mail.yzu.edu.tw (C.W. Peng).

0957-4174/$ - see front matter © 2011 Published by Elsevier Ltd.
doi:10.1016/j.eswa.2011.09.089

provide patients and therapists with more rehabilitation-related knowledge. However, to ensure that patients do not receive erroneous or potentially harmful information, the user's experience in the forum will be filtered by evidence-based medicine (EBM) prior to integrating it into OntoRis. In other words, the information has to be certified.

The main objective of this paper is to develop an ontology-based rehabilitation information service, OntoRis, and to use Agent technology to explore external ontologies for integration with the OntoRis foundation. These external ontologies will enhance the base ontology and subsequently enrich our rehabilitation knowledge base. OntoRis is designed to assist patients in acquiring comprehensive information about their prescribed rehabilitation, and provide advice derived from evidence-based medicine to expedite recovery. Moreover, OntoRis can also serve as an interactive learning platform for people who are interested in rehabilitation medicine.

Section 2 describes the work related to ontology, mobile agents, and evidence-based medicine. Section 3 presents the OntoRis system design and architecture three, while usage scenarios and implementation are illustrated in Section 4. Finally, Section 5 provides conclusions and suggestions for future work.

2. Related work

2.1. Ontology

Although there is some disagreement in regards to how ontology should be defined (Borst, 1997; Gruber, 1995; Neches et al., 1991), generally an ontology is considered to be a formal, explicit specification of a shared conceptualization (Studer, Benjamins, & Fensel, 1998). An ontology describes the important concepts and relationships of a particular domain, providing a vocabulary for that domain as well as a computerized specification of the meaning of terms used in the vocabulary. An ontology consists of classes, properties, and individuals. A class defines a concept. Instances are elements of classes and are linked to classes via properties. Properties can be used to state relationships between individuals, or between individuals and data values. Ontologies aim to formalize domain knowledge in a generic way and provide a common understanding of a domain. This understanding may then be used and shared by applications and groups. Ontology helps realize reasoning and can be used in data integration (Chang, Sahin, & Terpenny, 2008). Many businesses and scientific communities have adopted ontology as a way to share, reuse and process domain knowledge. Ontologies are now central to many applications such as scientific knowledge portals, information management and integration systems, electronic commerce, and semantic web services (Horridge et al., 2007). Furthermore, ontologies play a key role in information retrieval from nomadic objects, the Internet and heterogeneous data sources.

2.2. OWL

Ontologies are used to capture knowledge about some domain of interest, and different ontology languages provide different facilities. The most recent development in standard ontology languages is OWL (Web Ontology Language) from the World Wide Web Consortium [w3c]. OWL is based on DAML+OIL and an extension of the RDF Schema (Corcho, Fernández-López, & Gómez-Pérez, 2003). OWL can be used to explicitly represent the meaning of terms in vocabularies and the relationships between those terms. This representation of terms and their interrelationships is called an ontology. OWL provides three progressively expressive sublanguages designed for use by specific communities of implementers and users: OWL Lite, OWL DL and OWL Full (McGuinness & Harmele, 2010).

2.3. Mobile agent

The word *agent* was derived from the notion of *software agents* in the area of artificial intelligence (AI). It has been in use since the mid-1970s, with most authors referring to Hewitt's (Hewitt, 1997) use of the term. An agent is a software entity that continuously and autonomously performs tasks as instructed by a user within a particular restricted environment. It is their autonomy which distinguishes agents from general software programs. Autonomy in agents implies that the software agent is able to perform its assigned tasks without direct control (fully autonomous) or with minimal supervision (semi-autonomous). A mobile agent is not bound by the system where it begins execution, but has the unique ability to transport itself from one system to another within a network. Thus, a mobile agent can move to a system containing objects useful to the agent (Bellavista, Corradi, & Stefanelli, 2001; Chiang, 2008). Mobile agent have drawn attention from various fields including software engineering and knowledge engineering (Okada, Eun-Seok, & Shiratori, 1996), as well as the Internet (Magedanz, Rothermel, & Krause, 1996). In their studies of the development of mobile agent programs in the Internet, Etzioni and Weld (1995) suggested that the ability of mobile agent programs to move in the Internet could, in the future, lead to the use of mobile agents to find data or service requests in high-speed data networks. Domel's (1996) studies of the actions of Mobile Tele-script Agents on the Web suggested that providing mobile agents with more intelligence would give them more applicable value in action on the Web. Additionally, in their study of the structure management of distributed application systems, Berghoff, Drobnik, Lingnau, and Monch (1996) used a mobile agent to find the correct addresses for data transmission within the network, so as to reduce network traffic flow. Thus, the use of mobile agents can enhance the performance of distributed application systems.

2.4. Evidence-based medicine and systematic reviews

Evidence-based medicine (EBM) is the integration of best research evidence with clinical expertise and patient values. It aims to apply the best available evidence, gained from the scientific method, to medical decision-making and to assess the quality of evidence available for treatment risks and benefits (Timmermans & Mauck, 2005). Systematic reviews are a keystone of evidence-based medicine. Systematic reviews of randomized controlled trials constitute the top level of evidence for the effectiveness of healthcare interventions because they are more likely to provide valid (i.e., less-biased) evidence of the effectiveness of the trial interventions.

Starting from a clearly defined research question, such reviews use systematic, predefined and explicit methods to identify, select and critically appraise all relevant research, collect and analyze data from eligible studies, and present results and draw conclusions. Where statistical techniques are used to combine the results of the included studies, systematic reviews are often called meta-analyses (Handoll, Gillespie, Gillespie, & Madhok, 2008).

Cochrane collaboration is one of the best-known and respected examples of systematic reviews. Like other collections of systematic reviews, it requires authors to provide a detailed and repeatable plan of their literature search and evaluations of their evidence. Once all the best evidence is assessed, treatment is categorized as "likely to be beneficial", "likely to be harmful", or "evidence did not support benefit or harm".