A Framework for Data and Mined Knowledge Interoperability in Clinical Decision Support Systems

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ABSTRACT

Due to reliance on human knowledge, the practice of medicine is subject to errors that endanger patients’ health and cause substantial financial loss to healthcare institutions. Computer-based decision support systems assist healthcare personnel to improve quality of clinical practice. Currently, most clinical guideline modeling languages represent decision-making knowledge in terms of basic logical expressions. In this paper, we focus on encoding, sharing, and using results of data mining analyses to influence decision making within Clinical Decision Support Systems. A knowledge management framework is proposed that addresses the issues of data and knowledge interoperability by adopting healthcare and data mining modeling standards. In a further step, data mining results are incorporated into a guideline-based decision support system. A prototype tool has been developed to provide an environment for clinical guideline authoring and execution. Also, three real world case studies have been presented, one of which is used as a running example throughout the paper.

Keywords: Clinical Document Architecture, Clinical Decision Support System, Clinical Guidelines, Data Mining, Heterogeneous Healthcare Systems, HL7 v3, Interoperability, Mined Knowledge

INTRODUCTION

Because of the paramount importance of the quality of public health services, these services consume a major portion of governmental spending in many countries. In Canada the provincial government of Ontario invested a total of $28.1 billion in healthcare services during 2003-04 (OMF, 2003). The Canadian Institute for Health Information (CIHI) estimated that the total healthcare spending throughout Canada reached as high as $160 billion in 2007, up from $150.3 billion in 2006; this represents a forecasted annual increase of 6.6% (CIHI, 2007). However, the large volume of spending in healthcare does not necessarily translate to
ideal and error-free health services. The inherent complexity and dynamic nature of the existing medical knowledge and overwhelming amount of diverse medical information adversely affect a practitioner’s medical practice. According to HealthGrades’ fifth annual Patient Safety in American Hospitals Study, medical errors cost the federal Medicare program $8.8 billion and resulted in 238,337 potentially preventable deaths during 2004 through 2006 alone (HealthGrades, 2008).

Clinical Decision Support Systems (CDSS) are computer applications that assist healthcare providers in decision making through timely access to electronically stored medical knowledge in order to improve their decision-making capabilities. A CDSS interacts with practitioners and Electronic Medical Record (EMR) systems to receive the patient data as input and provide reminders, alerts, or recommendations for patient diagnosis, treatment, long-term care planning, and alike. A Clinical Decision Support System requires to access healthcare data and knowledge that are stored in data and knowledge bases. Since these repositories normally have diverse internal representations, data and knowledge interoperability are major issues. To achieve data interoperability two systems that participate in data communication should use the same vocabulary set, data model and data interpretation mechanism or have in place a data translation mechanism. On the other hand, knowledge interoperability refers to the ability of healthcare information systems to incorporate and interpret the knowledge that is produced in other systems. We are mainly interested in knowledge that is generated by data mining algorithms and represented using data mining specific data structures, called “data mining models”.

The most important issues in current healthcare industry that lead us to define the problem addressed in this paper are as follows: i) mining of healthcare data is a valuable source of knowledge; however the extracted knowledge is often used locally by the researchers in a proprietary system and is not made available to other interested users for seamless integration and application (OMG, 1998); ii) there is no specific approach or methodology for seamless integration of mined healthcare knowledge with the clinical decision making process; iii) the healthcare industry suffers from the lack of standardization that is resulted from development of ad-hoc systems and inherited legacy systems; and iv) healthcare information systems are usually heterogeneous and are deployed in a distributed environment that necessitates careful handling of both data and knowledge for achieving interoperability. Based on the above observations we define the research problem in this paper as follows.

Devising methodologies, techniques, and tools to streamline the dissemination and application of data and mined knowledge for clinic decision making purposes in the heterogeneous clinical settings.

However, in this paper we do not directly address the issues such as: patient data privacy, knowledge extraction from healthcare databases, and authenticity of the clinical best practice guidelines.

**PROPOSED APPROACH**

Figure 1 illustrates the proposed approach for clinical data and knowledge interoperability and interpretation within the context of a Clinical Decision Support System. The proposed approach relies on adoption of standards to encode healthcare data and knowledge. In an offline operation, existing healthcare databases are mined using different mining techniques to extract and store clinical mined knowledge. In order to make this knowledge portable it is encoded as data mining models using a specialized XML-based standard, namely Predictive Model Markup Language (PMML). Also, the patient data that are stored in EMR systems are encoded using Health Level 7 version3 (HL7 v3) standard to be made portable between heterogeneous systems. At the point of care, a decision
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