Quality of Life through Quality of Information
J. Mantas et al. (Eds.)
IOS Press, 2012

doi:10.3233/978-1-61499-101-4-118

Virtual Medical Record Implementation for Enhancing Clinical Decision Support

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Abstract. Development of clinical decision support systems (*CDS*) is a process which highly depends on the local databases, this resulting in low interoperability. To increase the interoperability of *CDS* a standard representation of clinical information is needed. The paper suggests a CDS architecture which integrates several *HL7* standards and the new *vMR* (virtual Medical Record). The clinical information for the *CDS* systems (the *vMR*) is represented with Topic Maps technology. Beside the implementation of the *vMR,* the architecture integrates: a Data Manager, an interface, a decision making system (based on *Egadss*), a retrieving data module. Conclusions are issued.

Keywords. Clinical decision support, Topic Maps, virtual Medical Record, *HL7* standards

Introduction

Several solutions for clinical decision systems (*CDS*) have been developed in the last years in order to improve the healthcare act. Some of these solutions are: *Asbru, Proforma, Degel, ASTI, Gaston, Egadss*, etc. [1, 2]. Usually these systems have as outputs: recommendations, alarms and reminders for medical purposes. In order to generate these outputs, the systems need knowledge databases. Knowledge can be seen as: medical rules (which are derived from the narrative guidelines), patient data, data regarding medical staff, etc. A major problem of the *CDS* regards the retrieving of patient data and other clinical statements which are needed; a solution which is developed in a medical unit is hard to be deployed in other location because it depends on the local database structure. Important reasons for limitation of implementing *CDS* in medical units is the use of different models, the lack of a standard representation of clinical information and terminologies associated that are used in medical institutions [4]. Any knowledge representation technique has to be developed in such a way to fully cover the domain it deals with. The healthcare domain is very large, complex, and in continuous changing. Aiming to achieve better capabilities for their work, medical personnel and researchers from the healthcare and information technology domains often face the need of a data model able to represent this domain in a more accurate manner.

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Topic Maps (*TM*) is a technology that could be the proper solution. Using *TM*, knowledge can be represented in a subject-oriented way. Furthermore, knowing only one aspect about a subject, one could find that subject by doing a single step. In [5] this is called "at a distance of a click". This feature of the *TM* standard brings enhanced findability for the informational constructs within the representation of a domain as complex as healthcare.

HL7 group is developing a data model that aims to become a standard for the representation of medical knowledge for *CDS*: the virtual Medical Record (*vMR*). This data model should help the interoperability between different *CDS* and medical data sources [4]. A solution which implements *HL7* standards is presented in [6].

Based on *vMR* model and Topic Maps, we suggest a solution for generating medical recommendation. In this paper we describe the representation of medical data in a "*vMR*-Topic Maps" knowledge base and the communication with a *CDS*.

1. System implementation

In order to generate medical recommendations based on different medical knowledge source our system has as main components: *Data Manager, Inference engine* (from *Egadss), HL7 CDA Component, Interface, TM-vMR* (Figure 1). In the next paragraphs the different components are described.

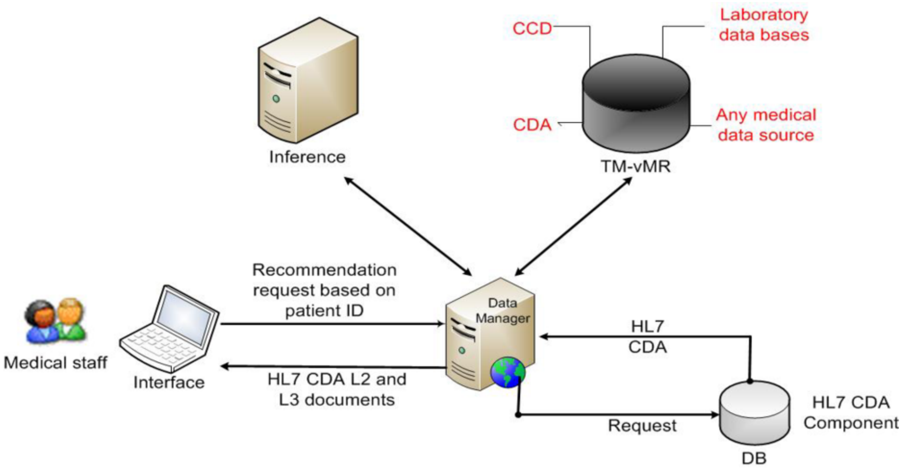

Figure 1. System Architecture

To obtain information from different databases (that could be a laboratory or radiology database) and then represent the information in *HL7 CDA (HL7 Clinical Document Architecture)* format and send it to the decision system, the *HL7 CDA Component* has been developed. The *HL7 CDA Component* implementation is developed in *Visual Studio .Net 2008*, in *C#* language, as a web service. The databases for the current activity are on *SQL Server 2008*, but the solution is similar for *Oracle* or *MySQL*.

The inference engine is based on *Egadss* open source solution [7]. In order to have a standardized communication, the interface between databases and "recommendation generator" - *Egadss* - has as inputs *HL7 CDA* (*Level 3*) messages and *HL7 CDA* (*Level*

2) as outputs. *Egadss* uses *Arden Syntax* standard, as well, which is a clinical guideline formalism [7]. The communication between all the components of the *CDS* is based on web services; these are implemented for *HL7 CDA Components,* decision making system or the interface. To manage the connection and the sequence of different web services calls, a *Data Manager* was developed. In order to achieve this, three communication channels are implemented, with: *Interface*, *HL7 CDA Component* and the *inference engine (Egadss).* The interface allows the medical staff and the patients to visualize the steps of the protocols, medical information regarding a patient, and different alarms, as well as inserting feedback concerning the recommendations. The interface is implemented using *ASP.Net* platform with C#. A more detailed description of the architecture can be found in [8].

Besides the use of *HL7 CDA documents*, other sources can be added to the system through the *Data Manager*. One of these sources is a *virtual Medical Record (vMR)* that implements the specifications from [9]. The *vMR* is represented with *Topic Maps* technology.

2. *TM-vMR* knowledge base

"Topic Maps is a technology for encoding knowledge and connecting this encoded knowledge to relevant information resources. Topic maps are organized around topics, which represent subjects of discourse; associations, representing relationships between the subjects; and occurrences, which connect the subjects to pertinent information resources", [10]. Instances of *TM* standard are called *topic maps*, and they are digital representations of knowledge about different domains made in a subject-oriented manner. Topic Maps could be used to represent "anything whatsoever" [10], which is why this technology is suited for the representation of the vast medical knowledge domain concerning CDS. Using *Topic Maps* the data elements from the *vMR* are represented as the topics of a topic map and the relations between these elements are represented as associations.

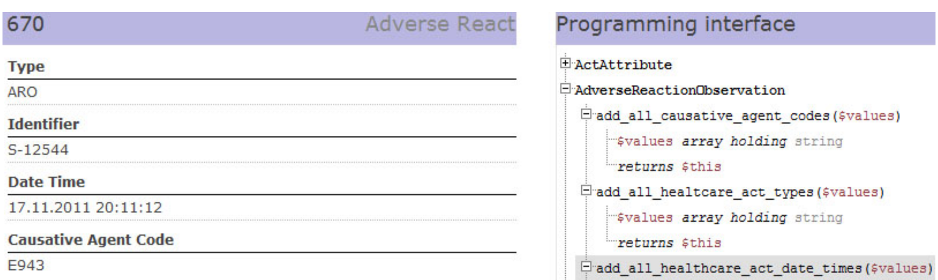

Figure 2. Adverse Reaction Observation representation and programming interface in *TM-vMR*

The software used to represent the *vMR* as topic map is *Topincs*, an easy-to-use development tool for the web databases, based on the *TM* standard [5], allowing an easy representation of *vMR* data elements ("topics and associations"). The software allows the *topic map* developer to customize the behavior of the application, through a programming interface (Figure 2, right side). This programming interface is automatically generated based on the serialization names (names assigned to all relevant items in the data bases) corresponding to the elements within the *topic map* schema of the represented domain. Defining the *topic map* schema and serialization names is the topic map developer's job, and this was done in the previous stages of this project (as it was described in [11]). To make the content of the *topic map* accessible, a *PHP* object is used. In *Topincs* this object is named *tobject*, and its virtual programming interface is driven by the constraints of its topic type [5]. Every medical concept presented in the *vMR-Domain Analysis Model* (e.g., *encounter, observation, substanceAdministration, Adverse Reaction Observation*) is accessed using a *tobject* (Figure 2, left side). In order to add new elements to the knowledge base, we use the *Topincs* interface for the *vMR*. To interact with the *tobjects,* the different functions from the programming interface are called. Separate functions for deletion, creation or modification of a *tobject*, which are not present in the interface, can also be called.

From the physicians' perspective, this application could be viewed as an easy-to-use knowledge base, with an emphasis on the information retrieval. An informational construct within this knowledge base, a topic, is a conceptualization of a subject, and it is presented to the user in terms of: description of the subject, links to resources relevant to the subject, relationships and/or perspectives in which the subject is involved, hierarchical related topics, and so on.

From the point of view of information technology applied in healthcare, this approach can be an easy-to-implement solution for the medical knowledge web databases, with reduced costs, based on well-known technologies (*Apache, MySQL, PHP – AMP* solution).

3. *CDS* connection to *vMR*

TM-vMR is used by the existing *CDS* as a patient data source. Web services are developed for the communication between the *Data Manager (CDS)* and the *TM-vMR* knowledge base. In order to add web services to the existing *Topincs* open source software, we used *NuSOAP* toolkit. The web services are calling the different functions which are associated with a certain medical concept – *tobject* – in order to allow the access of various *CDS* systems to the medical data represented in the *TM-vMR*.

These web services allow the retrieving of information from the *TM-vMR* based on the functions, related to each *tobject*, from the "programming interface" (Figure 2, right side). These services are consumed from the *Data Manager*. This is a client server architecture where the server is the *TM-vMR* and the client is the *Data Manager.* Based on the data needed for a certain patient, the *Data Manager* calls the web services from the *TM-vMR* knowledge base, in order to generate new medical recommendations. To connect the *Data Manager* to the *TM-vMR,* the *Service Model Metadata Utility Tool* is used, generating the needed proxy (set of functions) to enable the communication between PHP web services (*TM-vMR*) and .NET client (*Data Manager*).

4. Conclusions

We present a solution which is based on *HL7* standards in order to improve de interoperability of CDS and clinical data sources. The novelty of this work is the implementation of the *vMR* (proposed by *HL7* group) in combination with *Topic Maps*, taking the advantages of using cutting-edge technology. The use of *Topic maps* technology for the representation of medical data gives extensibility for the *vMR* data model. It keeps a low level of costs, as well, being developed with cheap (freeware) technologies and software. High levels of integration and compatibility with applications which implement *HL7* standards for interoperability of health information technology are also achieved. The software used to map the *vMR-DAM* into a topic map is *Topincs*, which provides a very flexible and easy to learn/use environment.

Since target users are medical personnel, researchers from the healthcare and information technology domains, medical application developers, with little or no knowledge about *TM* standard, a special package of *Topincs* services was developed in order to avoid/eliminate the need of *TM* specialists. The development of the topic map followed the *vMR-DAM* as accurate as possible so the two models are virtually identical, and subsequent changes can be easily done.

The system was tested for protocols regarding diabetes management, for prescribing the dosage of: insulin, sodium chloride, potassium, glucose. The results of these tests met the physician's requirements.

Next step in developing the existing system is the development of a module that is able to integrate, in an automatic manner, clinical data in the *TM-vMR* based on different sources (CDA, CCD, etc.).

Implementing *TM-vMR* will help the medical staff to increase the quality of medical care, reduce the variation in medical practice, give more efficient treatments, and use new medical knowledge in their current clinical practice.

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