Clinical Decision Support Based on Topic Maps and Virtual Medical Record

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***Abstract*— Clinical decision support (*CDS*) systems are limited by the lack of access to medical data. This paper presents a system that takes advantage of different standards (*HL7 CDA, Arden Syntax*) in order to have access to various data sources. The system consists of units used for retrieving, in a standardized format, medical data, an inference module and a data manager part, that connects all the systems components.**

Keywords – HL7 standards; clinical decision support; Topic Maps.

I. INTRODUCTION

Using the medical decision support systems (*CDSS*) brought an improvement of healthcare act [1]. The outputs of these systems usually are free text recommendations, alarms and reminders for medical purposes. The first step in obtaining these is the interaction of two major types of actors: medical staff and IT specialists. In order to obtain computer interpretable "medical knowledge", the results of the discussions between the two types of actors are then put in a computer interpretable format, followed by discussions, verifications, implementation and updates (as result of incompleteness, new research, and so on) [1] [2]. Based on patient medical data (e.g., patient data: blood pressure, heart rate, etc.) and taking the advantage of having the medical knowledge in a computer interpretable format, the use of an inference engine lead to new medical recommendations. The development and implementation of *CDS* "include members with different expertise, including medical informatics" [2].

Advantages of using *CDS* are: faster the implementation of new medical knowledge, integration of local databases, decrease of costs, view patient data in a graphic manner for each step which should be followed, to avoid reading a vast amount of data regarding each step of a narrative medical guideline [1]. Multiple *CDS* (clinical decision support) solutions have been developed: *Asbru* [3], *GLARE* [4], *GASTON* [5], *Egadss* [6], *Gello* [7], etc.

Studies about statistical data in the establishment of these support systems in healthcare are presented in [2]. One of the statistics shows that the use of *CDS* increased physicians' performances in 64% of the studies and regarding the patient outcomes 13% of studies established a benefit. In [8], it is stated that in over 90% randomized controlled, clinical practice improved, based on the use of *CDS*.

There is a major challenge of these systems, the interoperability between them and other medical information systems (*EHR*, *EMR* or different medical local databases) [2]. New steps in solving this problem are made by *HL7* group by developing a data model that wants to become a standard for the representation of medical knowledge for *CDS* (clinical decision support), the name of the data model is *virtual Medial Record* (*vMR*).

During the time, those they work with data, information and knowledge were confronted with the need of a data model able to represent their real words into machine-readable formats. There were developed a lot of data models claiming that they are the most eligible for some specific tasks, and they were, but they also have limits, and sometimes, the models were designed with a high machine-readability, but they lack in human-readability.

In this paper, we present a solution that implements the proposed *vMR* and other standards as: *Topic Maps* (used for the representation of the *vMR*), *HL CDA* (*Health Level 7 Clinical Document Architecture*), *Arden Syntax* (formalism for the representation of medical rules). This project is focused on the development of an application that has to store data from different medical documents and to develop a connection with *CDS* based on documents in a *vMR* format/vocabulary to improve the healthcare act by allowing the access to more vast and relevant clinical information in order to generate more accurate clinical recommendations.

This paper is structured as follows. System architecture and used technologies are reveled in section two. Different standards and the benefits they bring are presented in section three. Section four illustrates aspects of implementing the *vMR* with the help of *Topic Maps* and the connection of the *vMR* with an existing solution. Conclusion and future research directions are presented in section five.

II. SYSTEM ARCHITECTURE

The project has as main components: *Data manager*, *Interface*, *Inference engine*, *HL7 CDA Component* and *TM-vMR* (for the representation of medical information with the help of *Topic Maps* technologies and implementing *vMR* data model). All these components are further presented in the next sections. A first model was presented in [9]; in this paper a more complex and detailed architecture is revealed (software technologies, implementation of various modules or the interaction between modules). In Figure 1, an overview of the system architecture is presented. In order to implement this architecture and the different standards, several tools are used:

- *.Net* with *C#* for the development of the *Interface*, *Database* services and *Data Manager*,
- *Java* for the inference part, using *Arden Syntax* formalism for the representation of medical rules
- *Topincs* (*PHP* based) for the implementation of the *vMR* data model with the help of *Topic Maps (TM)* resulting the *TM-vMR* module

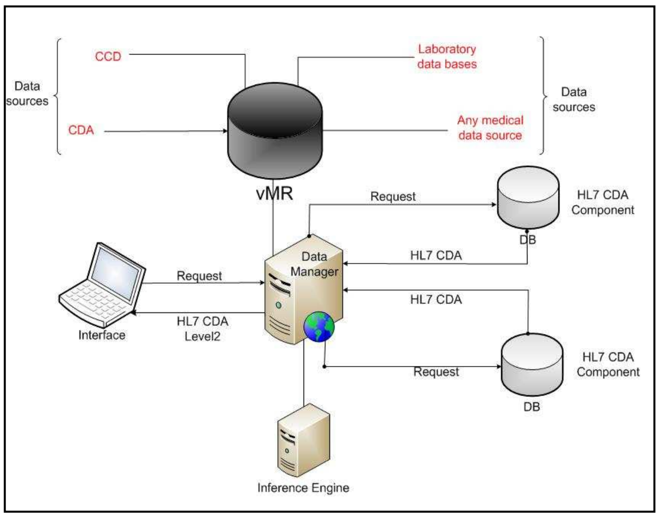

Figure 1. System Arhitecture

Concerning *TM-vMR* the domain which has to be represented was already sketched. The concepts and the relationships between them were defined in *vMR DAM (Domain Analysis Model)* [10]. They were further used to create a *TM* schema that allows populating the topic map in a schema-driven way. The software used to represent that domain is *Topincs*, “a software for rapid development of web databases” [11].

The implementation of this architecture will allow:

- to create the basis for a further integration of medical knowledge sources that are encoded in various technologies,
- the connection of any *vMR* compatible *CDS* to a medical web database,
- extensibility for *vMR DAM*, given by the possibility to connect it to virtual any other electronic knowledge source, through the *TMDM (Topic Maps Data Model)*
- capacity of representing “anything whatsoever”. TM can be viewed as an envelope for any other knowledge representation, and there are studies about how to represent the most important of these *KM* (Knowledge Representation) technologies with the help of *TM* technology [12],
- to offer a package of services especially designed for *CDS* developers,
- to create a tool that permits users to use a database without the need of knowledge about the technology that database stands on,
- to bring a semantic technology, with unlimited applicability within the domain of information representation,
- development of a collaborative solution for the capturing of medical information.

III. USE OF DIFFERENT STANDARDS

The reasons for developing a *CDS* that is implementing the different standards for the communication and knowledge representation are presented in the next paragraphs.

A. vMR

As stated in [2] [13] [14] [15], important reasons for limitation of implementing *CDS* in medical units are: the use of different models, the lack of a standard representation of clinical information and terminologies associated that are used in medical institutions. To meet these needs, the *Working Group HL7 CDS vMR* initiated the *vMR* project, which had as objective to support the development of scalable and interoperable *CDS*, by establishing a “standard model to represent clinical information inputs and outputs that can be transmitted between systems *CDS* and other medical systems.” [15]. This model contains 131 medical data elements. The *vMR* data model appeared as a necessity for the interoperability between different *CDS* and data sources. This data model allows the representation of a large range of information concerning the patient. In the development of the *vMR* model (the patient data and the requirements to be integrated in) 22 institutions from 4 different countries, have been involved (representing 20 *CDS* systems). *vMR* data model is in process of becoming a standard for the representation of medical knowledge used in different *CDS* systems in order to solve the problem of interoperability [16]. This model is not mandatory to be used as the unique data source for *CDS* but it can be used for the interoperability of the existing system. Other representations (e.g., *HL CDA*) of medical data can be used in order to make the *CDS* more adaptable to a local context. The *vMR* will be represented with the help of *Topincs* (a *Topic Maps* open source software) [11]. The access to medical data will be made (through the *Data Manager*) with the help of different service already existing in this software and new ones which are to be developed.

B. Topic Maps

TMs deliver the right information in the right context to the right person at the right time [17]. A technology that can represent "anything whatsoever" [18]; such a technology is very useful as a response to one of the main requests of this project, to integrate many medical knowledge sources at the input of *CDS* systems. *Topic Maps* can "be applied to any application domain you can think of" [17].

One of the most important challenges in topic map authoring is to keep the level of "subjectivism" of the topic map as low as possible. That means that any topic map author leaves a personal "fingerprint" on the final representation, firstly depending on his/ her individual knowledge about the represented domain and his/her ability to view, conceptualize and represent subjects within the application domain.

"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." [18]. *Topic Maps* has as attributes: semantic, semantic web, extensibility, flexibility, high representative power, envelope for any other *KR* (knowledge representation) technologies, human readability and computer readability, standard, XML-based syntax as interchange format, smart navigation, subject-centric approach for *KR*, rapid information retrieval, source integration, open vocabulary, possibility to get different views of the same assertion. A presentation of how the *TM* technology can interact with *CDS* can be found in [19], where is explained the way in which the use of such a technology can improve *CDS*.

C. Other standards

Semantic Web technologies are used to create data stores on the Web, build vocabularies, and write rules for data handling. XML (Extensible Markup Language) and ontology (e.g., Web Ontology Language) are two components of the Semantic Web. In our case the XML is a *HL7 CDA* message in XML format. The *HL7 Clinical Document Architecture (CDA)* is a document markup standard that specifies the structure and semantics of clinical documents for the purpose of exchange. A *CDA* document is a defined and complete information object that can include text, images, sounds, and other multimedia content. *CDA* documents are encoded in Extensible Markup Language (XML). The clinical content of *CDA* documents is defined in the *RIM (Reference Information Model)* [20] [21].

The *Arden Syntax* is a clinical guideline formalism accepted as an official standard by *HL7* (textual language and intuitive). It is freely available, a mature and actively maintained open standard. This is the reason why *Arden Syntax* is used instead of other guideline formalisms as *Proforma, GLIF (GELLO), Asbru,* etc. [6] [22].

IV. System Components and Implementation of Different Standards

An overview of the CDS systems shows a large number of approaches (*Asbru*, *Proforma*, *GLARE*). Almost all CDS allow medical guidelines and protocols to be generated, edited, verified, executed (reasoning based on medical rules and medical databases) and visualized. In order to represent the medical knowledge there are used different technologies: rule based technology (*Arden Syntax*) or task network (*Asbru*, *Proforma*, *EON*), unique for all of them [3]. The various CDS depend very much on the medical local databases sometimes they being developed around them (databases). All of these approaches are usually hard to be deployed in different medical units, as stated in section two. In order to overcome these gaps we propose a system which brings the advantage of using well known standards (as main inputs) and also implements a very powerful knowledge representation technology (*Topic Maps*).

In this section, the main components of the system are presented.

A. Existing CDS

To obtain information from different database that can 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 made 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 inferring engine is based on Egadss open source solution [6] [22]. In order to have a standardized communication interface between databases and "recommendation generator" - *Egadss* has as inputs *HL7 CDA* (*Level 3*) standard messages as XML files, where the patient data is represented (XML retrieved from the *HL7 CDA Component*). Another standard used by *Egadss* is *Arden Syntax*, which is a clinical guideline formalism accepted as an official standard by *HL7* group, being used for the representation of medical rules. The result of the inference is *CDA Level 2* document, containing the medical recommendations [6] [22].

The communication between all the components of the *CDS* is based on web services, representing de *HL7 CDA Components*, decision making system or the interface. To manage the connection and the order in which the different web services are called, a *Data Manager* was developed. *Data Manage* has the roles to respond at different requests that come from the main components of the system (interface, medical data source, inference engine). In order to realize this, three communication channels are opened (see Figure 1), with: *Interface*, *HL7 CDA Component* and

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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; different alarms and they can insert feedback concerning the recommendations. The interface is implemented using *ASP.Net* platform with C#. A more detailed description can be found in [23]. Beside the use of *HL7 CDA documents* other sources can be added to the system through the *Data Manager*. One of these sources can be a *virtual Medical Record (vMR)* that implements the specifications from [10]. The *vMR* is implemented with the help of *Topic Maps*.

B. TM-vMR

The implementation of this module is based on the *vMR* data model and *Topic Maps* technology. The representation of the data model is realized with the help of the *Topincs* open source software.

Implementation steps:

- the strategy used to convert *vMR* terms into the *Topic Maps* constructs is to create a topic type for every *vMR* class within the *vMR DAM* atomic terms; the attributes of a class become occurrence types for the topic type corresponding to that class (Figure 2).
- to model all relationships within the *vMR DAM*
- populating the topic map can be done manually, but a tool for automatic data integration into the topic map is being to be developed.
- evaluate the results, by connecting the database with a *CDS*

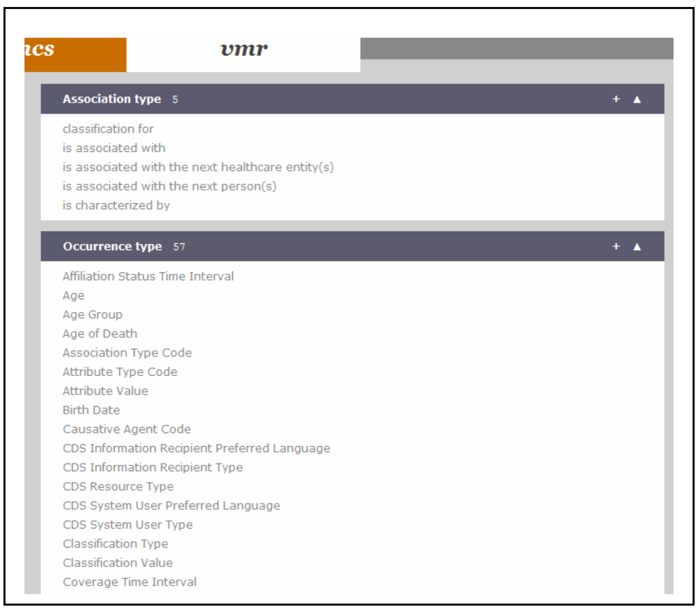

Figure 2. TM-vMR representation

To achieve the possibility of custom development of the *Topincs-based* application, the author of the topic map schema has to define the serialization names for all terms within the schema. In this way, a programming interface is automatically provided by the software, allowing the topic map author to use the exposed methods, in order to program the behavior of the application in such a way to get a better response to the requests of the project. To ease the rapid discovery of a topic map construct that a serialization name represent, a notation convention for serialization names was used. The exact form of the name of any *vMR* data model term was used for naming topic map types within the schema. Serialization name keeps the name but normalization was required:

- for topic types: all capital letters will be converted in lower-case, and the spaces between words will be replaced with minus sign "-";

- for any other topic map construct within the schema, the correspondent serialization name is created by adding a prefix which has the role to show what type it represents. (This convention was made for the further development of the project)

C. CDS connection to TM-vMR module

The connection between the existing system and the *TM-vMR* represented with the help of *Topincs* open source is realized with the help of the web services. 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.*

NuSOAP is the technology used for the development of web services in *PHP* for the access to the *TM-vMR* ontology. These services allow the work with the patient data that is represented in the *TM-vMR* ontology trough the help of a topic map objects which in "*Topincs*" is called "*tobject*". The *tobjects* allow the insertion, deletion, modification and many other types of special functions to work with patient data from the *TM-vMR*. The web services allow the connection of the model with the existing CDS trough the *Data Manager*. The *Data Manager* calls the web services from the *vMR*, based on the data needed for a certain patient (based on patient ID) for a set of medical rules in order to generate new medical recommendations.

Regarding privacy/integrity issues our system should achieve the *HIPAA* (Health Insurance Portability and Account-ability Act) requirements; the first step was implementing the communication over *HTTPS.*

V. CONCLUSIONS AND FUTURE WORK

Regarding the contribution the implementation of the different standards and the use of *Topic Maps* in the presented system lead to: integration of medical knowledge sources that are encoded in various technologies, extensibility for *vMR* data model and connection of any *vMR* compatible *CDS* to a medical web database.

This implementation allows an easier integration of the system (compared with systems that do not implement *HL7* standards) in different medical units allowing the connection with various types of data sources. With the help of the

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mentioned technologies the *vMR* was represented (Figure 2). Different web services are developed in order to have access to the different elements of the *TM-vMR*.

In this early stage of the development, the topic map can be used only for browsing through the elements of the schema (topic types, association types, constraint types).

Further developments of the system consist in: the implementation of other web services for a better interrogation and manipulation of the medical knowledge from *TM-vMR*; the development of an automatic way to integrate the medical sources in the *TM-vMR;* use of smart cards for the authentication of different actors (for data privacy).

The implementation of presented system will help the medical staff to increase the quality of medical care by: reducing the variation in medical practice, giving more efficient treatments and using new medical knowledge in current clinical practice.

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