

A Universal Clinical Decision Support System using semantic web services

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Abstract. In this paper we propose the use of semantic web services to achieve a universal clinical decision support system (CDSS). Our goal is to develop a semi-automated approach to discover, select and compose CDSSs available as web services. Ontologies and tools support is necessary to achieve this goal. We describe similar efforts for ontologies and tools development and explain how our work is different from these efforts.

Keywords: Clinical decision support (CDS), Clinical Decision Support System (CDSS), Semantic web services, context model

1. Introduction

Actionable, computer-generated clinical decision support (CDS) provided automatically at the point of care significantly improved care quality in >90% of RCTs (Kawamoto et al., 2005). Different approaches have been used to deliver CDS e.g. standalone clinical decision support system (CDSS), integrated systems. The problem with standalone CDS is that they are not embedded in the workflow. Therefore a standalone CDSS user must switch between routine hospital systems and the CDSS. Isabel (Isabel, 2009) is an effort to integrate the CDS into the electronic medical record systems (EMR) and hospital information systems (HIS). Isabel is being used in primary care practices in UK and US. However, Isabel-like systems are tightly coupled with particular EMRs. A loosely coupled system is achievable using a service model (Duke, 2007). The premise for this paper is that clinical decision support could be improved in more modular and platform-independent manner using a service model.

Exploring the possibility of using web services in the clinical domain is not new. Catley et al. (2004) proposed a web services based infrastructure for CDSSs in order to support real-time clinicians' decision making for perinatal life cycle. These web services can be accessed from within the hospital information system and from authorized websites over the internet. This system also provides support for composition of different web services using a pre-defined composition template. Wright and Sittig (2008), developed a clinical decision support system, based on service-oriented architecture, called SANDS (Service-oriented architecture for NHIN Decision Support). SANDS is an example of how multi-dimensional CDS can be

provided at one terminal using service-oriented architecture. SANDS was tested for six use cases: drug interaction checking, syndrome surveillance, diagnostic decision support, inappropriate prescribing in older adults, information at the point of care and a simple personal health record. The system worked through one user interface to access disparate CDSSs.

OpenCDS (Kawamoto, 2011) is developed to encapsulate clinical knowledge in highly reusable components and to support multiple knowledge representations. It contains a terminology service which provides an interface to terminology standards e.g. SNOMED (IHTSDO, 2002), and a rules service which helps query knowledge bases connected to the system to extract information for decision support.

However, in the above mentioned cases, CDS services were previously known to the user and the services had been built for the system, i.e. they were not “plug and play”.

In this paper we first outline our vision with the help of scenarios, next we describe how web services are being used in CDS. Then we look into how existing ontologies are being used in different applications and how we visualize their use. Lastly, we describe some existing tools and tools we propose to develop, to advance the universal CDSS.

2. Vision

Following the trend in other domains (Wang Mingwei, 2011), we envisage that within a few years, there will be a plethora of CDS services over the internet: Ranging from diagnosis to prescription, test ordering to managing a dialogue with a clinician, targeted textual advice to mathematical reasoning on patient data. A healthcare information system of the future will incorporate up to date clinical decision support

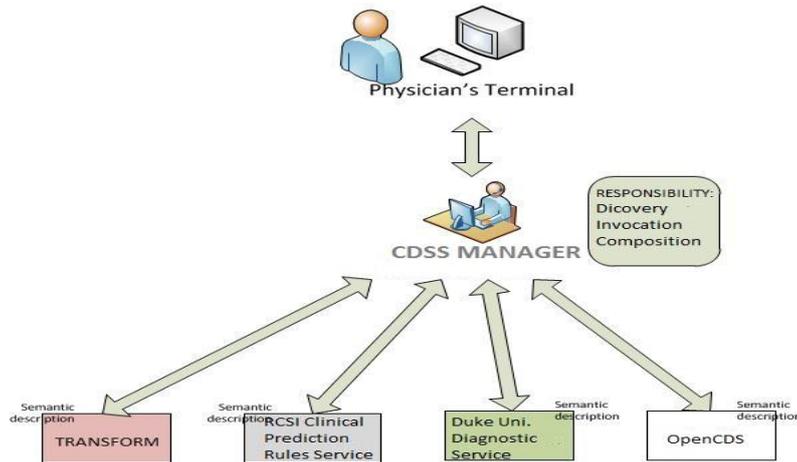


Fig.1. Semantically enabled CDSSs

components from multiple providers e.g. OpencCDS (Kawamoto, 2011) knowledge modules, DeGel (Shahar Y, 2003) executable guidelines, TRANSFORM

(TRANSFoRm, 2010) clinical prediction rules (CPRs), Archimedes Indigo (ArchimedesIndigo, 2011) diagnostic tools, etc. A healthcare organization (e.g. a hospital or primary care trust) will have a “CDSS manager”, whose role will be to constantly find, review and update CDS components which will meet the ever changing requirements of the healthcare provider in the organization. (See Figure 1)

Scenario 1: Suppose the endocrinology department of a hospital wishes to improve diagnosis of diabetes. The hospital will need to find potential diagnostic decision services that are available (service discovery), in conjunction with an endocrinologist, select one or more of those services that meet both clinical and system (i.e. ability to integrate with the existing information system) requirements, and then integrate that service(s) into the existing HIS.

Scenario 2: Suppose in a primary care center, a GP requires paediatric asthma management guidelines for prescription and test ordering. If a guideline based service issues recommendation based on a patient scenario, a decision support component is needed for carrying out those recommendations as well. We assume that suitable CDS components are available as web services. A CDSS manager will search for required services, select them and compose them for the clinician. For example, the CDSS manager uses Archimedes Indigo (ArchimedesIndigo, 2011) to identify guidelines for paediatric asthma management in primary care. While following some or all of these guidelines the GP requires prescription decision support. The CDSS manager selects Elsevier clinical decision support (Elsevier, 2011) drug reference module. The GP will also need test order support which is provided by another CDS component. The composition of guidelines, prescription and test ordering service is made available to the GP, who uses this system as one instead of three different services.

Scenario 3: Suppose in a renal diagnostic environment, a consultant needs some sort of mechanism to accurately diagnose with the help of measurements for chronic kidney disease (CKD). As shown in Fig.1. a clinician might be using Duke University’s diagnostic evidence service to diagnose. There might be a scenario where a consultant requires the CDSS manager to come up with a mechanism where diagnostic evidence from Duke University’s diagnostic service can be evaluated. The CDSS manager will look on the web for possible web services that provide the required mechanism. RCSI’s clinical prediction rules (CPR) service (Wallace et al., 2011) provides the rules that can help evaluate diagnostic evidence. The CDSS manager will invoke an evidence evaluation service to link both above mentioned services. The evidence evaluation service will help evaluate the diagnostic evidence of Duke University using RCSI’s CPR service. The consultant can access the output of the evidence evaluation service without knowing this service is composed of two disparate and distant services. This evidence evaluation service can be a dialogue-based or a mathematical service.

Discussion: The questions that arise are: How will the CDSS manager identify the CDS services that meet the needs of the decision makers? What criteria or features will affect the discovery and selection of services? How will these features be expressed? How can the CDSS manager be supported in the selection, discovery and composition of CDS services?

To discover, invoke and compose these CDS services in an efficient manner, semantic descriptions attached to these services can play a vital role. We envisage that

rich semantic descriptions of CDS services will be needed. Knowing only ‘what decision the service provides’ is not going to be sufficient. We need a relevant context in which the question is being asked e.g. primary care or secondary care. The context for clinical environment can be very extensive. We can classify this context into groups e.g. user, healthcare settings, information system etc. and their instances e.g. nurses, cardiology department, ED information system etc. For example, in scenario 2, primary care environment is the ‘healthcare settings’ of the CDSS manager. Therefore, the CDSS manager must look for services suitable for the primary care environment. So, a range of relevant and reusable ontologies will be used to describe the clinical domain, the decision task to be supported, terminologies used, the quality/strength of evidence, the context, integration requirements and other aspects to be identified as part of this work.

The complexity of the proposed system calls for human oversight throughout the workflow. Hence, we propose a semi-automatic approach to the service orchestration and a CDSS manager between physician and the underlying services.

3. Web services in clinical decision support

Web services are being widely used in business-to-business integration; however the promise of loose decoupling has not yet been fulfilled (Kerrigan et al., 2009). Tight coupling of CDS capabilities with specific institutions and health IT systems is one of the reasons why CDS is not so prevalent. Successful use of service-oriented architecture and related technologies offer the opportunity to develop loosely coupled services (Wang Mingwei, 2011) of which CDS services is of interest here.

SANDS (Wright and Sittig, 2008) came close to addressing the issue of discovering and invoking services located at distant places but SANDS is limited only to previously known services and their respective locations. We on the other hand propose a very loosely coupled solution where services can be found using semantics rather than through service registries already known to the CDS manager.

OpenCDS (Kawamoto, 2010) is addressing issues of composing and invoking services such as terminology services and rule services, but automated discovery and selection of CDS has not yet been addressed. Also, OpenCDS does not deal with discovery and invocation of geographically distant services. OpenCDS facilitates keywords to be attached to knowledge modules (clinical knowledge) To find a certain knowledge module (KM) connected to OpenCDS, a keyword based search is carried out and one or more of the KMs, matching the keywords, is pulled out from the KM repository.

Finding CDS services and using them cannot be realistically performed by only using syntactic technologies such as keywords. Semantic web services will empower the system to access service resources based on semantically rich metadata and discover, invoke and compose appropriate services efficiently.

4. Ontologies for clinical knowledge

Semantic-based discovery and composition requires use of shared ontologies. The shared ontologies are the basis for semantic annotation of web services that can be

used for discovery. The proposed universal CDSS must have the ability to construct queries to discover a certain web service using ontological concepts in a domain, in our case the clinical domain. This requires mapping concepts in web service description to the ontological concepts. In addition to domain model ontologies, we will need context model ontologies as well.

The Digital Electronic Guideline library (DeGel) (OpenClinical, 2001) provides a distributed web-based architecture which supports all of the design and run time tasks involved in guideline-based care. At the core of DeGel is a hybrid-meta ontology. The hybrid-meta ontology contains: source ontologies (classification, documentation and domain knowledge) and a target ontology such as Asbru guidelines ontology or GEM guidelines ontology. For the system we envisage, DeGel-like ontologies will need to be supplemented by context that will further specify the kind of services we will discover, invoke and compose.

The Semantic Automated Discovery and Integration (SADI) (Wikinson et al., 2011) approach is straight-forward and can be used as the basis of designing services based CDSS. While SADI is useful in discovering the right services and integrating them into our system but there is an interoperability issue that all the service providers must conform to the SADI conventions. Using OWL-S (Martin et al., 2004) with domain knowledge will be able to address this problem.

We will identify the ontologies that already exist or need to be developed to describe the aspects of CDS that need to be described.

5. Tools

To support universal CDSS management (finding, selecting and composing, etc.) we will develop a suite of tools for search, retrieval, browsing and annotating of CDS services and composing them in a way that covers the care providers' needs. The tools provided with the universal CDSS will help to search for CDS components meeting criteria across the range of ontologies identified as useful and to browse the annotations of retrieved components. Here, we describe some related work which will inform our research.

DeGel's IndexiGuide (OpenClinical, 2001) semantic classification of guidelines tool helps to index guidelines that in turn helps retrieval of these guidelines. The medical expert using IndexiGuide will annotate or associate metadata with a guideline. Any further search of the annotated guideline will be more efficient and accurate. This retrieval is somewhat similar to the opencCDS keyword match retrieval (See section 4). Vaidurya (OpenClinical, 2001) is another DeGel tool which helps a care provider to browse retrieved guidelines. Clinician can pick and choose from these guidelines.

Columbia University's InfoButton manager (Cimino et al., 2007) can be integrated into Web-based information systems fairly easily. InfoButton manager (IM) provides a bridge between context-sensitive Electronic Health Record (EHR) to a knowledge base. Hence helps clinical decision support. IM provides a set of tools which help its user locate knowledge resources using patients' context.

In our vision, universal CDSS will have multiple tools. One tool will help retrieve CDS services on the basis of metadata associated with the CDS service (semantic

matching) rather than keywords based retrieval. Of course that will require the service to be retrieved to have metadata associated with it.

We propose another tool that will help the CDSS manager to browse the relevant retrieved services. He can then use one or more of these services according to the clinicians' need.

In our vision, tools like Vaidurya and IM will be available as re-usable components i.e. web services which can be integrated through our system. Integration can be performed using tools as in Fig. 2a and Fig. 2b. Both these tools will be part of the package that will enable CDSS manager to perform the tasks of finding, selecting and composing services as required.

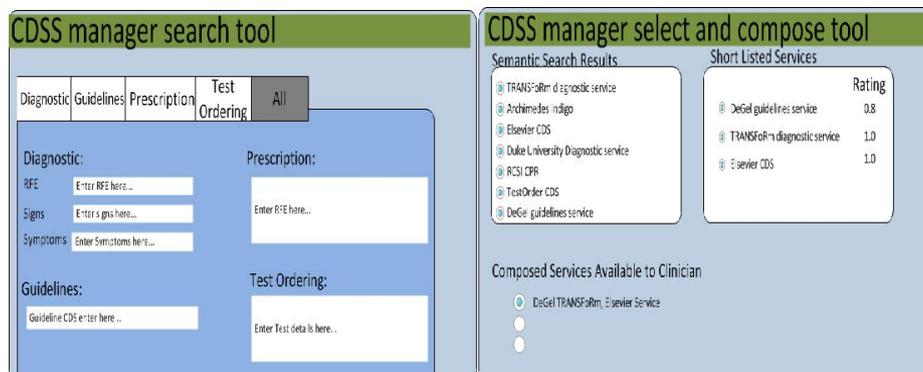


Fig.2a. CDSS manager search tool will let the CDSS manager to choose which type of CDS services are required. **Fig.2b.** Select and compose tool will let the service manager view the selected services and based on their rankings compose them for the clinician as one package

6. Future Work

This paper describes an early high level vision for how CDS will be deployed in the future. The next steps will be identifying the kinds of formalized semantics attached to the services that are useful in clinical and CDSS manager decision making. In the discussion of our vision, we identified what kinds of context should be considered. We will investigate the impact of context on decision making for clinicians and CDSS manager and investigate ways to incorporate that context. The focus for this identification process will be on existing reusable health domain ontologies. We will then design and develop the semantic web service discovery and integration framework for clinical decision support systems outlined here. This framework will be complemented by tools as described in section 5. These tools will enable service provider and service requestor to develop a semantically enabled clinical decision support system utilizing CDSSs available as web services.

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