

An Extensible Framework for Sharing Clinical Guidelines and Services

Fei Xiong, Kefei Cao, Zhifeng Wang, James Ford, Fillia S. Makedon¹, Justin D. Pearlman²

¹Department of Computer Science, Dartmouth College, Hanover NH 03755, USA

²Advanced Imaging Center, Dartmouth Hitchcock Medical Center, Lebanon NH 03756, USA

Abstract— Accurate and descriptive information from clinical studies guides improvements in health care. Clinical guidelines established by authoritative medical organizations provide such information in a standard form for medical professionals' reference. Previous work on electronically sharing clinical guidelines focuses on the idea of building unified clinical terminologies and sharing resources through centralized data repositories. In this paper we propose a novel five-layer framework called the Extensible Clinical Guidelines and Services Sharing Architecture (ECGSSA). This framework provides for clinical guideline sharing among autonomous service providers over a distributed architecture. Requests for exchange of guidelines are disseminated through Web Services through a registry mechanism. Currently we have adopted the Guideline Interchange Format (GLIF) from InterMed as the representation format and use the Open Grid Services Architecture (OGSA) to attain virtual organization of shared guideline and service resources. This approach will allow more flexibility for medical professionals to exchange their practice guidelines in an effort to improve quality of health care. Also, it extends the possibility of solving clinic-related computational problems through collaborative sharing of analytical services. A sample scenario is presented to explain the application of ECGSSA in distributed task assignment and service matching in medical image processing.

Keywords— Clinical Guideline Sharing, Analytical Service Sharing, Grid Architecture, Web Services

I. INTRODUCTION

Clinical guidelines are recommendations for the care of individuals by health care professionals; they are based on the best available evidence [1]. Electronic guidelines help clinicians to encode their knowledge and skills in easy-to-access format and serve as an important decision basis for others by sharing of guidelines. Two important issues to be resolved in the sharing problem are: the need for a standardized format to express a guideline and the need for computer-interpretable guidelines. Formats and models based on ontologies, which can be defined as explicit specifications of a domain conceptualization [2], have become the basis of guideline sharing for central service providers such as government agencies or authoritative medical organizations, but these do not yet support the large number of potential local guideline providers (such as municipal health institutions).

Central providers currently use guidelines as references rather than for the sharing of clinical knowledge through the exchange of guidelines. This is because of obstacles due to

differences in administration and network protocols. Recently, the Grid architecture, which is a concept related to but distinct from Grid computing, has been used for sharing data and Web Services over distributed heterogeneous networks. In this paper, the aim is to extend this work in order to enable the sharing of clinical guidelines on a large scale. For this purpose, we introduce a new framework based on the Open Grid Services Infrastructure (OGSI) standard [3], thus also supporting the sharing among smaller-scale guideline providers. Our framework also supports sharing of analytical services, including decision support analysis and exchange of computer programs, and is extensible. In complicated computing tasks, such as medical image processing or data mining, individuals may benefit from outside assistance; therefore, we envision a model where a complex application problem can be reduced to simpler sub-problems that will be accomplished by service providers on a Grid infrastructure. To support this vision, we provide a preliminary strategy using ontologies to divide tasks and locate qualified service providers.

II. RELATED WORK

Work on the exchange and analysis of biomedical data has focused on the representation of domain knowledge. GALEN [4] is an approach to medical coding that is designed to support medical concepts in a unified, computer interpretable representation. The Unified Medical Language System[®] (UMLS[®]) [5] develops a meta-thesaurus to hold multi-purpose biomedical knowledge bases and distributes associated lexical programs for clinical language processing. The Guideline Interchange Format (GLIF) [6] is a simpler and more practical approach that provides a structured language for representing practice guidelines. Similar efforts (with references in [6]) include Arden, EON, PRODIGY, and PRESTIGE. The Guideline Element Model (GEM) uses XML to represent heterogeneous knowledge contained in guidelines; it could be integrated with GLIF by supplying the fundamental terminology [7]. As a clinical standard, GLIF aims at facilitating public communication and includes features for additional expressivity. It supports discussion of disease control cases at three levels of abstraction, defined as “the conceptual level, the computable level, and the implementation level”.

Work on sharing of network services has centered on allowing tasks to be conducted locally or remotely by collaborating autonomous parties. Grid technology [8] is a

developing approach that allows large-scale sharing of network services. The Open Grid Services Architecture (OGSA) [3] was proposed to address fundamental issues such as service creation, description, and discovery. It integrated Grid and Web Services technologies effectively and soon became the de facto standard for data and service sharing in dynamic, distributed “virtual organizations” (VOs) [9]. Here “Services” are defined as computational resources, storage resources, networks, programs, and databases that could be organized by OGSA for universal access. The Globus ToolKit [10] provides an open source implementation for building OGSA applications.

The Web Services framework is an XML-based distributed object/service component system. Common Web Services protocols include SOAP [11], WSDL [12], WSIL [13]. Web Services are based on the existing web standards and have a similar structure to dynamic web resources used by humans, but are designed to be invoked transparently by computer programs in order to provide a platform and programming language independent distributed invocation system. Compared to earlier approaches such as DCE, CORBA, and Java RMI in distributed computing, Web Services are less developed as a paradigm to address the high demand for versatile Internet-based network computing. Nevertheless, the development of OGSA has benefited a lot from the fast evolution of web services technologies, which provide significant support to Grid-based virtual organizations at the cost of minor changes to the core infrastructure.

III. SYSTEM ARCHITECTURE

In this paper we propose a five layer framework for clinical guideline sharing over a Grid architecture.

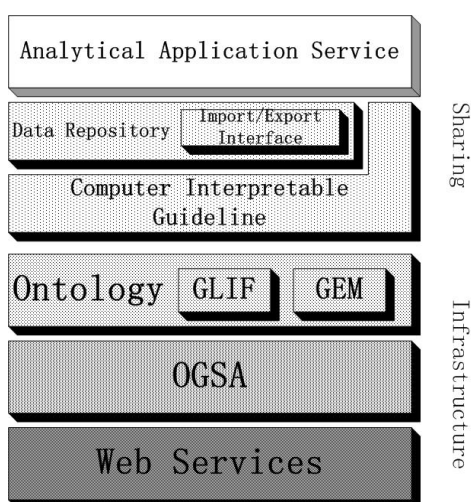


Figure 1. Extensible Clinical Guidelines and Services Sharing Architecture (ECGSSA)

Figure 1 shows the composition of the five layers. The foundation is a Web Services layer interface, designated as

layer 1. The Web Services layer specifies a standard port for native computer programs to use in sending requests of service sharing. In our application, exchanges are of clinical guidelines described in a standard format so as to be platform and programming language neutral. Clients such as hospitals or institutes that have local clinical guidelines available could publish their resources for sharing by employing the WSDL (Web Services Definition Language) protocol to tell others how to invoke a service. The actual exchange of data objects could be conducted using SOAP (which originally stood for “Simple Object Access Protocol”), which defines a message format for exchanging structured, typed information; requests for data/service sharing would then be encoded with SOAP and carried over HTTP or SMTP for message transport. To search for a feasible Web Services definition over layer 1, WSIL (Web Services Inspection Language) could be applied as a mechanism for automatic discovery and location of resources.

A Grid can be defined as a system that “coordinates resources that are not subject to centralized control; that uses standard, open, general-purpose protocols and interfaces; and that delivers nontrivial qualities of service” [3]. In conjunction with Web Services, the OGSA layer (layer 2) coordinates the mapping of requests sent by end users to specific service providers over the grid while keeping the intermediate steps transparent. A service-oriented view simplifies abstraction, allowing diverse implementations of service support to be hidden behind a common interface regardless of their physical instantiations and what combination of them might be required to satisfy a request. This structure also allows service providers to handle requests at multiple levels: for example, service providers can decide whether to accept a request based both on their capability for meeting it and on the requestor’s offer of compensation.

Layer 3 is the Ontology layer that includes the terminology and methodology used to describe guidelines. In our framework, Ontology is based on GLIF + GEM. GLIF provides a robust model for guideline representation, namely the methodology part. GEM supplies a universal terminology, allowing ambiguities in local uses of clinical terms and potential resulting discrepancies between guideline definitions to be minimized. In contrast with the Web Services layer or the OGSA layer, where no domain knowledge is needed, this layer supplies necessary information about guideline format, organization, and specifications. Requests for guideline sharing are encapsulated in an XML data structure, translated into human/computer interpretable commands, and then matched to an appropriate category of clinical guidelines. A version control tool provides for adapting local rules for other repositories while maintaining local flexibility by recording the rationale and timestamp associated with any changes.

In Layer 4 concrete clinical guideline information is shared. Guidelines provide an objective reference for

analyzing clinical and biomedical data (in the data repository), and thus play a key role in clinical decision support systems (DSS) in which guidelines are typically mapped to an advisory decision tree. The existence and distribution of computer-interpretable guidelines based on domain ontologies will promote guideline sharing, though standards still need to be further established for the two important areas of guideline representation and guideline sharing. The former requires a decision on details of ontology-based representations, while the latter requires support of network-level architectures. In previous paragraphs, we have discussed possible solutions to such problems by supplying Ontology + Grid Architecture + Web Services as the lower level infrastructure. Using this approach, a guideline sharing system could support (1) access to various guidelines through a universal interface and (2) use of guidelines at different locations concurrently and associatively. Meanwhile, Layer 4 can make use of existing tools, such as the commercial clinical information systems, for data import and export.

The mechanisms for guideline sharing in layer 4 support the sharing of services in layer 5, where multiple client-side applications exist for users' common analytical tasks. Requests are generated in this layer and then transferred to the lower layers for further processing. There are several applications of this layer. In a difficult clinical session, a physician may wish to make use of the Grid-based service sharing architecture to get advice from others with appropriate expertise. Clinicians or medical researchers may also have the need to analyze data from medical tests using advanced computational methods that they do not have expertise in. For example, in an angiogenesis study CT images of human legs could be processed with an algorithm called elastic subtraction [14] to distinguish microvessels from nearby bones. This work may not be feasible for a clinician without image processing knowledge to attempt alone, but could be made possible by requests over ECGSSA that result in responses from qualified service providers.

In general, this architecture presents an open and efficient framework for the sharing of clinical guidelines and analytical services across heterogeneous networks. The sophisticated request transformations, service location, and network communications it enables can be completely invisible to end users, while supporting quality assurance, standardization, and flexibility.

IV. EXTENDING THE NOTION OF GUIDELINES

Medicine today is highly dependent on computational processing, in part because of the proliferation of data from imaging hardware. To recognize the importance of computational tasks in medical practice, we propose to incorporate them into guidelines. If we view a guideline as a decision tree, a computational task is a node—and based on

the result of the computation, the decision tree branches. Extending guidelines in this way makes them more powerful but introduces some complexities.

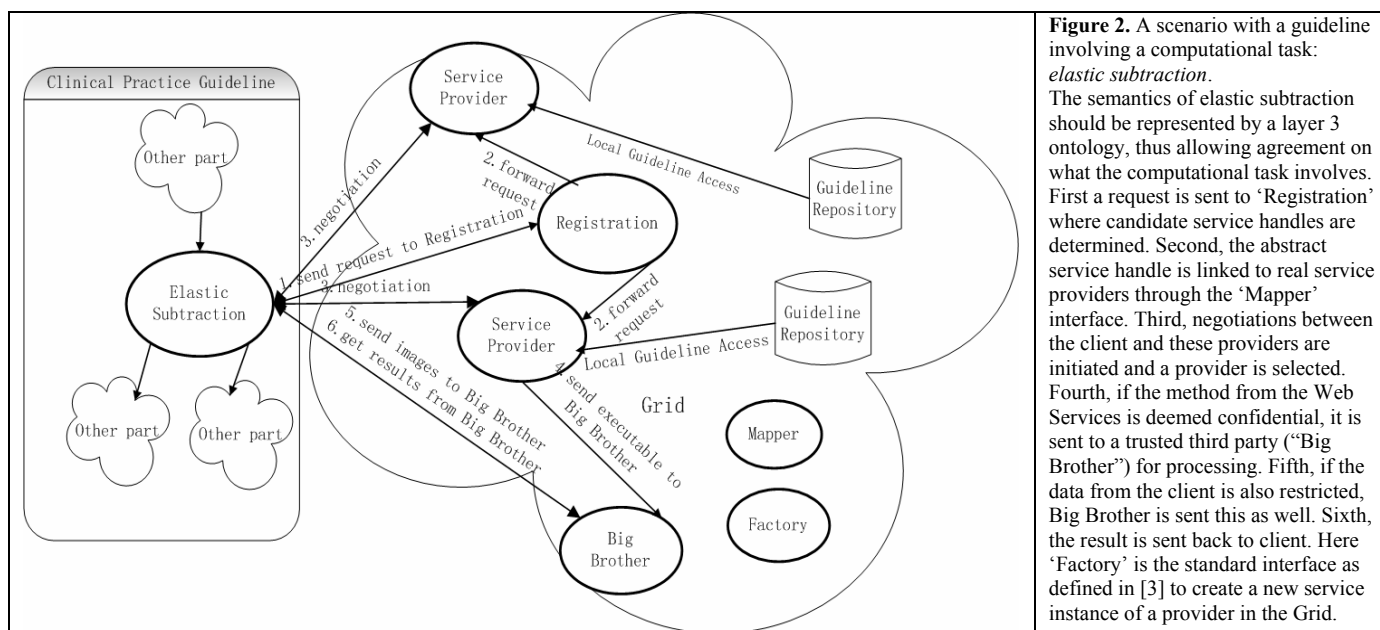
The first, and most important, complexity is in extending GLIF to accommodate computations. This extension may be possible using the same approach GLIF uses for clinical practice guidelines: introducing meta-concepts, *e.g.* of medical image processing, describing other concepts in terms of meta-concepts using some structure, and introducing a methodology to decide if two concepts under different names are really the same (or if two concepts under the same name are actually different).

A second complexity is providing for agreement on the characteristics and output of computational tasks, which may require negotiating on details beyond the scope of the guideline itself, such as requirements related to confidentiality or the quality of results that are to be delivered. For example, in every computational task it must be determined who will actually carry out the computation: the client (if the guideline for the task is not restricted), the service provider (if the client data is not restricted), or a trusted intermediate server (for cases when both data from the client and service provider are restricted). Negotiation could also be useful to specify a measure of success, either one that is subjective—an image registration task could be deemed a success if experts agree—or objective, such as a mean squared error measure. Providing support for negotiation should also facilitate service provider selection, to choose among multiple service providers who would like to provide the same service. In Figure 2, we portray such a scenario in which the Grid architecture mediates negotiation between service requestors and service providers. There has been some recent work on this problem [15].

Finally, a third complexity is handling the complex nature of many computational tasks, which may result in a situation where no single service provider can satisfy a client's request. A solution to this potential problem is task division: if some service providers know that a proposed task can be divided into a series of sub-tasks which they can support, then those service providers could either return a feasible task division to the client or request guidelines for the required sub-tasks on behalf of the client and return a combined guideline.

V. CONCLUSION AND FUTURE WORK

In this paper, we propose an extensible clinical guidelines and services sharing architecture (ECGSSA) to facilitate collaboration among autonomous, heterogeneous service providers. In ECGSSA, a request for application service generated at the top layer of our proposed protocol stack will first be translated into computer interpretable format through an abstraction of guideline sharing mapped at layer 4. Corresponding medical terminology and semantic libraries are provided by the ontology structure at layer 3.



In the lower layers, requests for services will be disseminated over a grid of distributed computers allowing candidate service providers to respond. Each autonomous service provider resides in a local network cluster and communicates with the outside world through a standard Web Services interface. This proposed clinical guideline sharing approach unifies existing work related to clinical guidelines, and has also identified numerous functionality issues not solved by currently available products. Compared to existing frameworks, our work benefits from incorporating a Grid architecture to coordinate resource sharing and allow problem solving in dynamic, multi-institutional virtual organizations. This paper also proposes a related extension to current guidelines to allow representation of computational processes and discusses three resulting issues and their possible solutions.

In the future, we will further explore the possibility of Grid-based guideline sharing with the goal of supporting multiple protocols (e.g. using lifetime protocol to track the activities of a stateful service provider in layer 2). We will also consider how security and access control rules can be taken into consideration, particularly in the case of computational tasks involving sensitive patient data. We believe extending the current GLIF standard will be complicated, and therefore we plan to investigate whether a new framework can be developed to allow new features while supporting convenient modification and maintenance of existing guideline repositories

ACKNOWLEDGMENT

The work in this paper was supported by a grant from the Flight Attendant Medical Research Institute (FAMRI).

REFERENCES

- [1] National Institute for Clinical Excellence, UK., *Introduction to Clinical Guidelines*. 2004, <http://www.nice.org.uk/cat.asp?c=34454>.
- [2] Gruber, T.R., *A translation approach to portable ontologies*. Knowledge Acquisition, 1993. 5(2): p. 199-220.
- [3] Foster, I., Kesselman, C., Nick, J., and Tuecke, S. *The Physiology of the Grid: An Open Grid Services Architecture for Distributed System Integration*. in *Open Grid Service Infrastructure WG, Global Grid Forum*. 2002. Toronto, Canada.
- [4] Robbe, P.d.V., *OpenGALen: Making the impossible very difficult [Web site]*, <http://www.opengalen.org/>.
- [5] National Library of Medicine, *Unified Medical Language System® (UMLS®) [Web site]*. 2004, <http://www.nlm.nih.gov/research/umls/>.
- [6] Peleg, M., Boxwala, A., Ogunyemi, O., et al. *GLIF3: The Evolution of a Guideline Representation Format*. in *AMIA Annual Symposium*. 2000. p. 645-649.
- [7] Shiffman, R.N., Karras, B.T., Agrawal, A., Chen, R., Marengo, L., and Nath, S., *GEM: A proposal for a more comprehensive guideline document model using XML*. *Journal of American Medical Information Association*, 2000. 7(5): p. 488-498.
- [8] Foster, I. and C. Kesselman, eds. *The Grid: Blueprint for a future computing infrastructure*. 1999, Morgan Kaufmann.
- [9] Foster, I., Kesselman, C., and Tuecke, S., *The Anatomy of the Grid: Enabling Scalable Virtual Organizations*. *International Journal of High Performance Computing Applications*, 2001. 15(3): p. 200-222.
- [10] Foster, I. and C. Kesselman, *Globus: A Metacomputing Infrastructure Toolkit*. *International Journal of Supercomputer Applications*, 1997. 11(2): p. 115-128.
- [11] W3C, *SOAP Version 1.2 Specification*. 2002, <http://www.w3.org/TR/soap12>.
- [12] Christensen, E., Curbera, F., Meredith, G., and Weerawarana, S., *Web Services Description Language (WSDL) 1.1*. 2001, <http://www.w3.org/TR/wsdl>.
- [13] Brittenham, P., *An overview of the Web Services Inspection Language*. 2002, <http://www-106.ibm.com/developerworks/webservices/library/ws-wsiloover/>.
- [14] Meijering, E.H.W., Zuiderveld, K. J., Viergever, M. A., *Image Registration for Digital Subtraction Angiography*. *International Journal of Computer Vision*, 1999. 31(2/3): p. 227-246.
- [15] Ye, S., et al. *SCENS: A system for the mediated sharing of sensitive data*. in *Third ACM/IEEE Joint Conference on Digital Libraries (JCDL)*. 2003. Houston, TX.