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3D medical volume reconstruction using web services

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Abstract

We address the problem of 3D medical volume reconstruction using web services. The use of proposed web services is motivated by the fact that the problem of 3D medical volume reconstruction requires significant computer resources and human expertise in medical and computer science areas. Web services are implemented as an additional layer to a dataflow framework called data to knowledge. In the collaboration between UIC and NCSA, pre-processed input images at NCSA are made accessible to medical collaborators for registration. Every time UIC medical collaborators inspected images and selected corresponding features for registration, the web service at NCSA is contacted and the registration processing query is executed using the image to knowledge library of registration methods. Co-registered frames are returned for verification by medical collaborators in a new window. In this paper, we present 3D volume reconstruction problem requirements and the architecture of the developed prototype system at http://isda.ncsa.uiuc.edu/MedVolume. We also explain the tradeoffs of our system design and provide experimental data to support our system implementation. The prototype system has been used for multiple 3D volume reconstructions of blood vessels and vasculogenic mimicry patterns in histological sections of uveal melanoma studied by fluorescent confocal laser scanning microscope.

Keywords: Web services architecture; Workflow; Medical image analysis; Test case

1. Introduction

In general, web services attempt to solve many of the same problems related to running distributed software applications as the more mature, previous generation, middleware technologies, e.g., CORBA and DCOM/COM+ [1,2]. When deciding how a distributed software application should be implemented, web services should be considered since they offer new advantages over the previous middleware technologies.

One of the key advantages of web services is real system interoperability. The real system interoperability is made possible by XML based standards, such as the simple object access protocol (SOAP) and the web services description language (WSDL). SOAP and WSDL are simultaneously compatible with and independent of any particular programming language. Many distributed applications can tremendously benefit from using web services because there is a need to execute multiple processing algorithms on different operating systems and devices (potentially using grid computing). Furthermore, web services provide benefits when software algorithms have been written using different programming languages and originated from multiple vendors (software houses). Thus, web services can meet the objectives for designing distributed software applications, such as interoperability of multi-programming language bits of software, provided by independent vendors and running on several operating systems and devices. These objectives can be achieved at a very low cost by using publicly available web service development frameworks.

Another major advantage of web services is their orientation toward loosely coupled architectures. Web service clients (end user applications and other web services) can dynamically bind with web services to couple heterogeneous computer architectures at runtime. Thus, investigating real-life solutions using web services today will build the foundation of web service

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based cyber-infrastructure for the future [3], and enable creating complex composite workflow solutions. The objective of web service based workflows is to orchestrate runtime execution on multiple computer architectures by combining several algorithmic and workflow solutions.

The focus of this paper is on the web service based cyber-infrastructure system design to perform image registration, and specifically 3D medical volume reconstruction. The motivation for using web services is leveraged by the aforementioned advantages and described as follows. The technology of web services opens new opportunities for applications that have high demands on computational resources (storage and computation), require setting up sophisticated computer algorithms, and involve geographically distributed expertise from multiple disciplines [4]. We have found web services to be an especially attractive technology for academic research projects due to their open and interoperable nature that facilitates sharing, collaboration, and discovery. These characteristics of web services in a combination with the aforementioned advantages outweighed the risk of adopting current web service technologies [5].

Within the scope of cyber-infrastructure system design, our work aims at providing computational resources to end applications using web services, building tools for user interaction with images (e.g., image visualization, registration feature selection), and using web services for accessing sophisticated algorithms and for executing computationally intensive and memory demanding image processing queries. Our objective in this work is to provide either a set of developed software tools or the hardware resources at NCSA or both to scientific communities with the use of web services.

The remaining sections of this paper report on meeting the above objectives and on resolving the tradeoff issues related to building a prototype cyber-infrastructure system based on web services. To explain the prototype challenges, we provide a brief description of the data to knowledge (D2K) web service architecture, document the benefits of web services in the context of 3D medical volume reconstruction, formulate the problem of 3D volume reconstruction using image to knowledge (I2K) algorithms [6], and elaborate the system design issues when using web services.

2. Previous work

There exist commercial software packages that address the problems of image access and navigation with other than web service approaches. In the medical domain, these solutions are known as “virtual microscopes” and primarily owned by companies (like Bacus Laboratories, Inc. and Aperio Technologies). In the GIS domain, the solution for accessing all IKONOS aerial photos before 9/11 was developed by Microsoft (navigation capability without annotation or computation capability).

Among the most recent solutions using web services, we should mention a new suite of web service tools to facilitate multi-sensor investigations in Earth System Science that is sponsored by NASA [7], and the ArcWeb tools which are web services implemented for GIS data operations. The tools for NASA are developed based on a framework using grid workflows (known as SciFlo) [8]. Other workflow frameworks, like Kepler [9,10], have not been used for applications using web services. The ArcWeb services are proprietary, and focus primarily on accessing images with the size in the terabytes, and reducing data storage and maintenance costs.

In contrast to the previous work, the presented work is based on the data flow framework called D2K [11]. D2K is a visual programming environment and data flow execution engine developed at NCSA for data mining applications (prediction, discovery, and anomaly detection with data management and information visualization). The underlying 3D volume reconstruction algorithms came from a library of image analysis tools called I2K [6], also developed at NCSA. Our prototype system has been used in practice for 3D reconstruction of uveal melanoma tissues based on the NIH-funded collaboration between UIC and NCSA [12].

3. D2K web service architecture

D2K [11] is a flexible data mining and machine learning system that integrates analytical data mining methods for prediction, discovery, and deviation detection, with information visualization tools. It offers a visual programming environment that allows users to easily connect software modules together in a unique data flow environment. D2K supplies a set of software modules and application templates, along with a standard application programming interface (API) for software module development. The software modules are reusable components that facilitate collaboration among developers. These modules and the entire D2K environment are written in Java for maximum flexibility and portability.

Fig. 1 is a conceptual diagram of the many components that make up D2K. The three inner rings represent the core

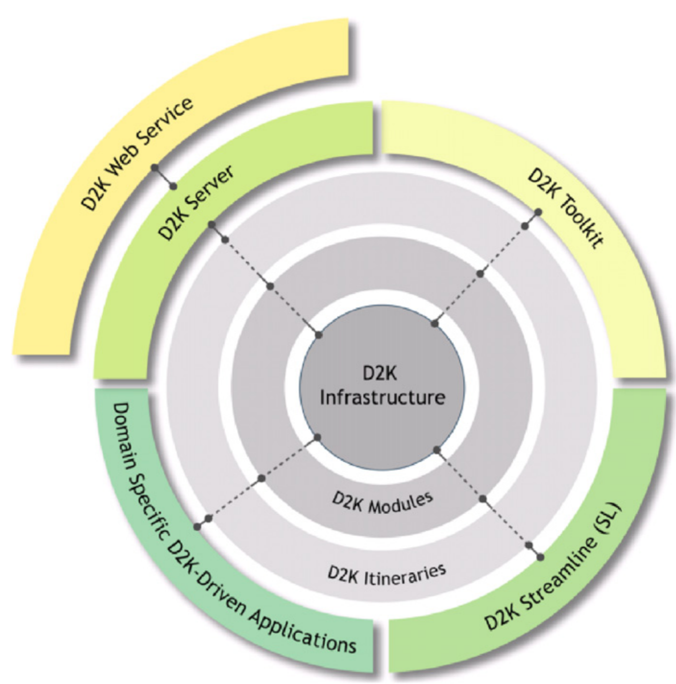

Fig. 1. D2K component architecture.