Internet Technologies for the Distribution of DICOM Structured Reports Within Healthcare Intranets

Andreas Delistamatis & Eleni Kaldoudi
School of Medicine, Democritus University of Thrace,
I. Kaviri 6, Alexandroupolis, Greece 68100

Abstract

DICOM, the ubiquitous standard for medical image distribution, has recently been augmented with a Structured Reporting (SR) extension, an information model for describing the findings contained in medical images. We have employed SOAP (Simple Object Access Protocol), XML (eXtensible Markup Language) and the related Web technologies to create a Web service that supports query of different DICOM-SR servers, to retrieve (as well as store) DICOM Structured Reports and related image data using Internet technologies. The proposed Web Service can support integration of conventional DICOM-SR sources through general purpose Web technologies with other Web service enabled applications such as authoring tools, general purpose image processing environments, and clinical Web servers.

Key Words: Digital Imaging and Communications in Medicine (DICOM), Structured Reporting, eXtensible Markup Language (XML), Simple Object Access Protocol (SOAP), Web services

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Introduction

The DICOM protocol has become the predominant standard for the communication of medical images and related data within the Radiology Intranet (DICOM, 2004). Recently, the standard has been augmented with the DICOM Structured Reporting (SR) extension, a powerful and expressive mechanism for representing hierarchically structured clinical findings including links to the source diagnostic data, e.g. images, waveforms, etc.(DICOM, 2004a & Clunie, 2000).

When integration with other clinical information systems is considered, the DICOM Structured Report is usually one of the most important pieces of information that needs to be retrieved and communicated. Software developers of such third-party applications have to go through the rather cumbersome task of adapting the DICOM communication model and implementing the DICOM protocol. Recently, the widespread adoption of eXtensible Markup Language (XML) technologies (W3C, 2004) has made a notable step towards easier integration of clinical information within the Healthcare enterprise. For example, HL7 is currently developing its Clinical Document Architecture (CDA) for exchange of healthcare documents based on XML technologies (Dolin *et al.*, 2001).

The need to translate DICOM SR documents in XML format has been noted by several researchers in the field, e.g. (Lee & Hu, 2002) and (Cohen *et al.*, 2002), mainly for the following reasons:

- exchange radiology reports and related data easily across the healthcare enterprise, especially as other clinical information systems and relevant standardization bodies

✉ **Corresponding Author:**
Eleni Kaldoudi
Assistant Professor, School of Medicine, Democritus University of Thrace
I. Kaviri 6, Alexandroupolis, Greece 68100
Tel: +30 2551 030329
e-mail: kaldoudi@med.duth.gr

begin to adopt XML technologies
- make radiology reports machine processable
- communicate with general purpose research and academic tools (e.g. to create easily searchable clinical data repositories to support research, teaching and data mining for administrative and clinical protocol planning, budget control, etc)

So far, attempts to transform DICOM SR documents into XML format address only the report itself but do not support mechanisms to query DICOM servers and/or retrieve the image data that is referenced in the report. Although XML addresses the problem of data integration, it does not support control integration among disparate information systems. Recently, the XML Web Services programming paradigm (W3C, 2004a) has made effective system integration much easier to achieve through commonplace Internet technologies.

Web Services are self-describing, self-contained applications that are accessible over the Internet. Web services are based on open Internet standards: build on the HTTP transport protocol, they use XML for data presentation while messaging is described in Simple Object Access Protocol (SOAP). Web services describe themselves through a standardized Web Service Description Language (WSDL) document (W3C, 2004a, & Ferris & Farrell, 2003). A whole suite of additional standards are currently being developed to formally address issues such as security, reliability, transactions, etc. The Web Services paradigm has already gained broad industry support and is currently starting to be employed in biology and healthcare applications. For example, Web Services have been used for supporting integration of biology sequence data banks (Sugawara & Miyazaki, 2003), for managing mammography data in international research networks (Estrella *et al.*, 2004), as well as in cancer informatics (Covitz *et al.*, 2003).

This paper presents the DICOM Image Management (DIM) Web Service which acts as a façade for conventional DICOM sources allowing DICOM image data and related information, such as Structured Reports, to be transformed into XML documents encapsulated in SOAP messages, enabling integration at the application level within the health care enterprise, and with external partners, through general purpose standardized Web technologies.

DIM Web Service Architecture Overview

The process of engaging the DIM web service as well as a schematic overview of its architecture is given in Figure 1. The web service accepts queries from a client application about a DICOM image server in SOAP/XML form, transforms them into the equivalent DICOM protocol services, communicates with the DICOM image server using the

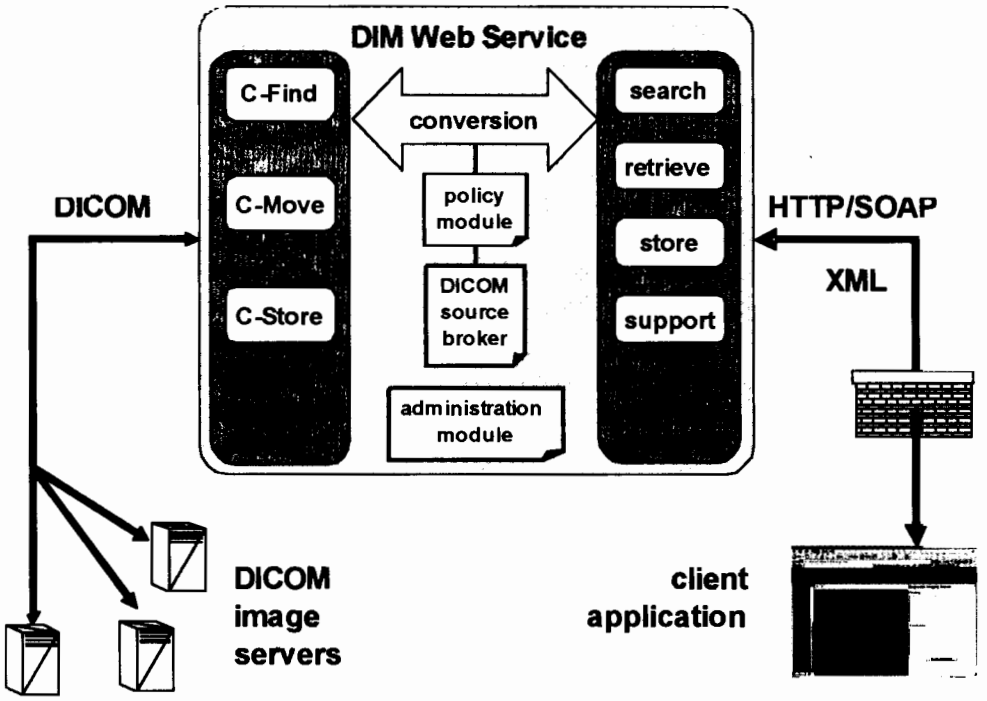

FIGURE 1
The DIM Web Service Architecture Overview.

DICOM protocol, and transforms the results back into XML documents, encapsulated in SOAP messages. Any conventional DICOM source can use the proposed Web Service to expose the principal DICOM operations of store, query, and retrieve over the Web, using XML documents communicated via SOAP messages.

Functional and information organization in the DIM web service is based on the DICOM information model, which in short organizes information related to a medical image using a logical structure of information entities and their relationship. Basically, the standard specifies the entities involved in radiological operations, such as patients, visits, studies, images, structured reports, other data objects, etc. Each entity is characterized by a collection of attributes, which carry all information related to the particular entity. The 'study' information entity defines the characteristics of a medical study performed on a patient, and is a collection of one or more series of medical images, presentation states, structured reports documents, overlays and/or curves that are logically related for the purpose of diagnosing a patient and are collectively referred to as data objects. Every instance of study, series and data object in DICOM is assigned a unique number as an identifier (unique identifier, or UID).

The DIM Web service implements the basic functionalities supported by the DICOM protocol for searching a DICOM image server and retrieving images, structured reports and other data objects, as well as storing files in a DICOM archive. User authentication is provided via a login mechanism. Different access privileges are supported via a policy module which takes into account administrative information about the user (either client application or end-user of the client application) and the target DICOM repository. Finally, data anonymization can either be requested at method call, or be imposed by the Web Service itself following preset policies that take into account several factors such as the target DICOM server, the client application, the end user of the client application, etc.

The web service exposes several methods that support searching at various levels of the DICOM information model. All search methods implement the C-Find Service Object Pair (SOP) of the DICOM protocol. The functionality of the various search methods exposed by the DIM web service is briefly described below:

- *FindPatients:* searches for patients and retrieves patient-related data from a DICOM archive.
- *FindStudies:* searches and retrieves studies and related data from a DICOM archive.
- *FindSeries:* retrieves series information, within a particular study.
- *FindObjects:* retrieves information about images or other objects within a given series (objects can be various types of images, waveforms, structured reports, and a number of other information objects generated and stored as part of the DICOM image file).

The Retrieve Facility supports the retrieval of DICOM objects (data and related meta-information). The internal implementation of the methods that realize this facility is based on the C-MOVE SOP of the DICOM protocol. Currently, the web service exposes a generic retrieve method for all types of DICOM data objects and related meta-information. Additionally, emphasis is placed on image retrieval which is especially handled by a dedicated retrieve method. The functionality of the various retrieve methods exposed by the DIM web service is briefly described below:

- *RetrieveObject:* retrieves a generic DICOM data object from a DICOM repository.
- *RetrieveImage:* retrieves an image object from the specified DICOM Database. (depending on the optional input parameter concerning image returned type, the result of the method is either the requested data stream or a link to the requested image file).

Image and related data can be stored in a DICOM archive over the web using the Store Facility of the DIM web service. Methods of this facility internally implement the C-STORE SOP of the DICOM protocol. Their functionality is briefly described below:

- *StoreDicomFile:* uploads a DICOM file into a DICOM repository.
- *StoreImage:* combines a non-DICOM image (e.g. BMP, JPEG, TIFF) and related attributes to create a DICOM file and stores it into a DICOM repository.

Managing Structured Reports

The DIM Web Service queries a DICOM server and retrieves information about a Structured Report using the generic methods of the Search Facility as described above. It also exposes two additional methods for specifically handling Structured Reports:

- *RetrieveSRDocument:* retrieves a DICOM SR document from a DICOM repository. The input parameters are the DICOM related unique identifiers of the study, series and data object – in this case the Structured Report document. The result is the requested SR document in XML format as well as the related data object meta-information.
- *StoreSRDocument:* creates an SR document and stores it in the DICOM repository. The method accepts as input an SR document in XML format as well as related infor-

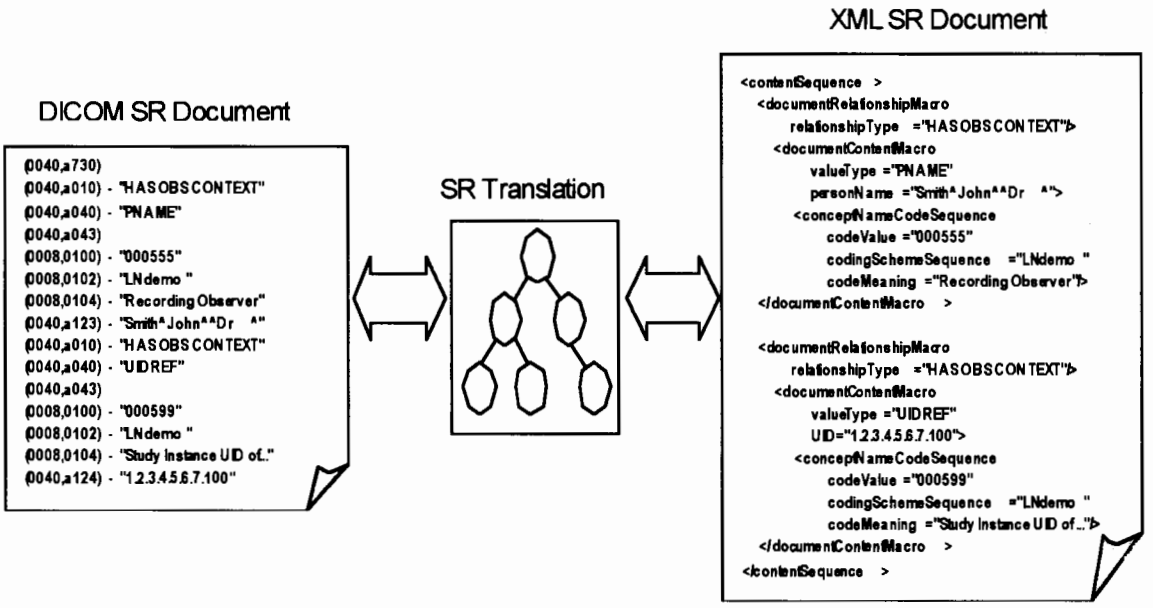

FIGURE 2
Translating DICOM SR to XML and Vice Versa in the DIM Web Service.

mation needed to construct the DICOM file (patient, study, series, and object meta-information as specified by the DICOM standard).

Whenever the above methods are employed, the Web Service performs a translation of the Structured Report from its DICOM format into an XML document, and vice versa. This translation process is based on a look-up table of XML element/attribute names and their respective DICOM tags as used in the DICOM SR document. When retrieving the DICOM SR document, the tag is mapped to the respective element/attribute. This process is performed for all DICOM tags and the result is an XML document. Similarly, when creating an SR document, each XML element/attribute of the received document is mapped to the respective tag so that a DICOM SR document is created and stored in the target DICOM repository. An example of this translation process is shown in Figure 2.

Currently, the DIM web service is using a proprietary XML schema for describing DICOM tags. This schema was created with simplicity in mind, to be used by developers not familiar with the DICOM standard. Once a standardized XML schema for DICOM is available, the DIM web service can be easily enhanced to support it.

Implementation Issues

The web service has been developed in C# using the MS. Net Framework 1.1 (Microsoft, Redmond, USA) and uses the DICOM library DicomObjects 4.1 (Medical Connections, Reynoldston, UK). System requirements at runtime include the MS Internet Information Server >5.x, MS .Net Framework 1.1, and MS SQL Server 2000 Desktop Engine (Microsoft, Redmond, USA). Basic security is achieved through the Secure Sockets Layer encryption mechanism for data transmission, as provided by the Internet Information Server, and this is enhanced by user authorization process. An asynchronous communication pattern is used to enhance the scalability & reliability of the Web Service and enable long running operations.

Discussion

Concluding, we have built a web service to support communication and integration of DICOM image sources with other applications using internet standards, and enable the seamless distribution of DICOM images and structured reports using commonplace Internet technologies. Examples of such applications, that do not necessarily implement DICOM, could include Internet based medical e-learning environments, medical research support tools, medical expert systems and other healthcare information systems. We strongly believe that this current implementation only scratches the surface of the potential capabilities Web Services might have for radiology and other healthcare information systems.

This work is part of our efforts to seamlessly integrate clinical data into a generic Internet based generic e-learning environment that will support undergraduate medical ed-

ucation in Democritus University of Thrace, Greece. Currently we are working towards a cluster of collaborating Web Services for advanced radiology services over the Internet, that will include complex PACS searches and data mining, and will enhance academic and research work.

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