AQTR 2004 (THETA 14)
2004 IEEE-TTTC - International Conference on Automation, Quality and Testing, Robotics
May 13 – 15, 2004, Cluj-Napoca, Romania

Tools and Methodology for DICOM SR in Echocardiography

S. Nedevschi[1], D. Olinic[2], I. Popa[1], F Rusu[1], A. Smeu[1], A. Vancea[1], C.Homorodean[2]
[1] *Technical University of Cluj-Napoca,*
[2] *University of Medicine and Pharmacy of Cluj-Napoca*
Sergiu.Nedevschi@cs.utcluj.ro

Structured reporting is a modality of information representation according to some patterns that define the structure and the content of documents. DICOM standard has defined a method for structured reporting in the field of medicine. This method focuses on the use of coded term dictionaries for the definition of the main standard elements: context groups and templates. Medical reports are generated using these key elements. Their representation and remote communication is specified by the standard.

We have developed a structuring methodology of the medical information in the field of echocardiography. The aim is to fully systematize an area of medicine laying the foundation for computer assisted diagnosis, research, and education. An environment consisting of a set of powerful software tools was implemented to assist physicians in applying the methodology.

The tools are being created in collaboration with physicians and designed to respond to their demands while maintaining the conformance to the DICOM standard. The structured reporting environment is currently being used in a clinical research program. Over one hundred contexts and dozens of templates concerning echocardiography have been created. Studies conducted on real cases were translated into reports that are now useful in the medical instruction activity.

Keywords: structured reporting, DICOM, echocardiography

1 INTRODUCTION

It is a known fact that computers deal better with the information represented as structured data. Hence, the necessity appeared for representing information in a more suitable manner for computer processing. One solution is structured reporting, a modality of information representation according to some patterns that define the structure and the content of documents.

DICOM standard has defined a method for structured reporting in the field of medicine [1]. The DICOM solution is based on the exclusive use of controlled and encoded terminologies of medical concepts. In order to impose precise requirements on the structure and content of medical reports, the standard introduced two basic elements that rely on the use of concepts. They are context groups and templates. Medical reports are generated using these basic elements and their representation and remote communication is specified by the standard.

Until recently, medical reports created using the findings in medical images contained only free text, which made unfeasible their semantic processing because of both lack of structure and the large number of possibilities to express the same medical aspects. We present here a methodology for structuring the information from echocardiography according to DICOM standard specifications. The application of this methodology facilitates the systematic description of medical images and the structural-oriented

retrieval of medical reports.

As part of our long-term attempt to build a software environment for echocardiography image acquisition, processing, storing, communication, and reporting, an advanced DICOM compliant structured reporting environment was designed and has been implemented.

2 DICOM SR STANDARD

The structure of DICOM medical reports is specified through templates. They define the items of information [2] a report can contain and the possible relationships between these items. An item of information or content item is a concept name-value pair. Concept names are always coded medical terms. In order to exclude semantic ambiguity that can be generated by the use of a coded concept in different contexts, DICOM standard introduced the context group element. Actual values of a content item can be of various types (e.g. text, numerical value with measurement units, coded term, date, time, image reference). Figure 1 contains an extract from a DICOM report showing the content items and some of the seven DICOM predefined relationships.

2.1 *Coded concepts*

Although the standard specifies the coded terms that should be used, there is an important impediment: the concepts specified are from a various number of dictionaries, each having its own structure and coding scheme. For an effective use of the specified coded terms, we designed a flexible ontology having a SNOMED-like structure and containing concepts from different medical dictionaries. We mapped the structure of the included coded dictionaries to our ontology structure, thus permitting directional navigation and search. The backward compatibility is also maintained, as well as the coding scheme of the transformed ontology. We applied these transformations to different coded dictionaries, some of them being CTV3 and LOINC.

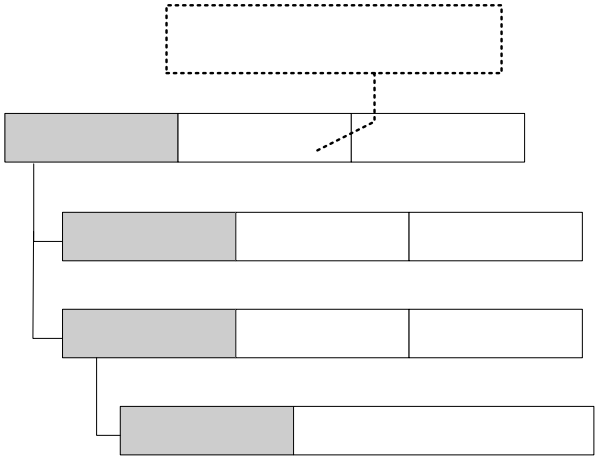

Figure 1. Report content items and relationships.

2.2 *Context groups*

Context groups impose restrictions regarding the information reports can contain. They include a set of coded concepts and, possibly, references to other context groups. The concepts that form a context are semantically linked and can pertain to different coded dictionaries. Every concept that is part of a context group has associated with it a description that must be used when the concept appears in the corresponding semantic context. Only one concept can be selected from a context group and it can act as a concept name or as a content item value, under specific circumstances. Context groups help to focus the physician's attention within a huge set of available coded terms that would otherwise be infeasible to work with.

2.3 *Templates*

Templates offer structural guidance in report construction. Report templates are patterns of structured document content that suggest or constrain concept names, value types, value sets, and/or relationship types for a particular kind of report. Templates have a hierarchical structure, content items being organized into a tree. However, by the use of additional elements, this hierarchical structure can be extended to an acyclic graph. Tree nodes are linked by means of relationships that specify the semantic connection between content items. The complexity of a template may vary from simple patterns used to describe the properties of a mass (size, shape, margin) to large sets of constraints covering an entire structured report document tree.

3 STRUCTURING METHODOLOGY

Our approach tries to extend the DICOM echocardiography procedure report [3], dealing not only with numerical findings, but also with the non-numerical medical diagnosis knowledge. Templates and context groups presented by DICOM supplements cover the numerical findings. We propose a structuring methodology involving systematic investigation of the heart diseases and aiming to extend the set of contexts and templates with those corresponding to non-numerical findings [4]. In order to achieve this, the following approach was adopted:

- exhaustive description of the diseases investigated by echocardiography, in terms of anatomical and functional findings, etiological and pathogenic findings, and disease severity assessment
- comparison of the disease descriptions for identifying the common contexts and templates
- proposal of a consistent set of concepts, context groups, and templates.

Our main objectives in designing the structure of echocardiography reports were to match the physician's way of thinking and to achieve an exhaustive yet practical coverage of the domain. Based on the proposed structuring methodology an extension of the existing set of templates and contexts was proposed and experimented. The aim was the extension of the standard's procedure so that it includes, besides general scores and measurements, sections corresponding to the reason of examination, description of the anatomical regions of interest that are visible on the images, and physician's conclusions and diagnosis.

The experimentation of this methodology required the development of a suite of software tools for coded concepts, context groups, templates and reports editing.

4 ENVIRONMENT ARCHITECTURE

We have designed a distributed layered environment that is reliable and very flexible. Its architecture is presented in Figure 2. It is a three-tier architecture composed of a server layer, a framework layer and the application layer. The server layer consists of many modules which deal with report data storage and communication and whose basic purpose is to respond to application requests. The application layer interacts directly with the user and enhances structured report editing, management and visualisation. For increasing the independence between servers and end-applications, an extra-layer – the framework – was added. Its role is to connect the services supplied by servers with associated user actions.

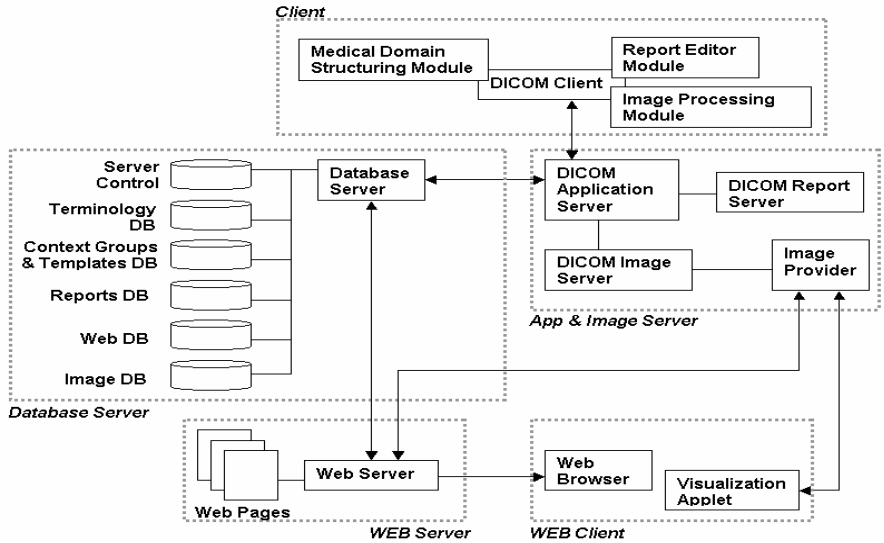

Figure 2. Environment architecture.

4.1 *Medical domain structuring module*

This module contains a set of tools used to manage DICOM primitives for structured reporting – coded concepts, context groups and templates – stored in corresponding databases. The main purpose of the module is to realise independence of continuous standard modifications and to enable specialists with powerful tools for extending the standard. Concept Builder is the application that works with our SNOMED CT-like ontology and has text, language, position and code retrieval capabilities. Template Builder is the other tool in this module and it manages context groups and templates, elements that define the structure and the content of medical reports. The underlining characteristic of these end-applications is their user-friendliness.

4.2 *Report editor module*

This module and the associated servers – DICOM Report Server, DICOM Image Server and Web Server – support the tasks related to reports – editing, management, rendering and communication.

The report editing process uses a template that specifies the structure and the type of report content items. Simply put, editing a report is equivalent with the traversal of template hierarchical structure and the instantiation of each content item with a corresponding value. Unfortunately, this scenario is complicated by the presence of some standard elements – row multiplicity, requirement type and condition, template parameters – that imply a continuous report structure evaluation during editing. Our solution consists of an interpreter that evaluates syntactic expressions for presence conditions and template parameters passing. The recognised syntax contains arithmetical and logical operations, references to other report rows, and template parameters. The allowed expressions incorporate symbolic representations of concepts and contexts. Delegation is used as a primary method in our object-oriented interpreter. As the user advances through the process of report editing, the interpreter evaluates its input and updates the structure such that it satisfies all the constraints. At any point, user choices maintain the partial report in a consistent state. The user is unaware of the interpreter presence and all she/he has to do is just selecting the desired items and supply them with the necessary information through a set of context sensitive dialogs that match the type of data.

We chose to store report-objects in a relational database and thus using the advantages of such an engine. For that, we had implemented a module at the framework level that realises the database transfer in both directions. Benefits of using a relational database consist in greater access and lookup speed, higher reliability and in the enormous number of possible interrogations. We exploited that feature at report retrieval. The report editor module implements three different methods for locating medical reports. The first method uses patient name or identifier as interrogation key. A more complicated method takes as input parameters concept name – coded value pairs and returns the reports that contain such pairs. The last and most powerful retrieval method we propose locates medical reports that satisfy specified content structure constraints. It is a search focused on biological structures that can be used in medical research and education. What results in the process of retrieval is a set of reports that satisfy the imposed constraints, but also the attached data to reports – images, waveforms. Thus, we could interpret the retrieval method based on content structure as a way of finding images that are defining for some specified concepts.

The possibility of storing partial reports and updating them, as the necessary data becomes available, gives flexibility to the report editing process that can extend now over a long period of time and can involve the participation of more persons.

Intuitive rendering of report contents is an important feature that eases the human understanding and interpretation of data. A modality of describing the synthetic elements of DICOM standard, such as relationships and value types, into an easy-to-read form that hides the standard's details was needed. We have decided to use XML for this purpose because of its extensibility and its large utilisation. XSD and XSLT technologies are used to enhance the graphical aspect of medical reports. Viewing and printing are possible by using ActiveX modules for a variety of web browsers. Rendering of the attached information – images, waveforms – is done by simply selecting a link to invoke an applet that extracts them from the DICOM Image Server for interactive visualization on the client host.

Remote communication of DICOM medical structured reports has two aspects. One is specified by the standard as a set of services a DICOM compliant environment has to assure and involves entities that implement these specifications. The other type of communication is web-oriented. Our environment supports them both as services of DICOM Report Server.

DICOM communication implies standard file format and transmission syntax. Unfortunately, the file format is defined in a way that makes the recovery of the structure that generated the report difficult. In order to import structured reports into our framework representation and to include them in the retrieval mechanism, we had to make some extensions to the standard file format. DICOM transmission syntax defines classes of services – C-FIND, C-GET, and C-STORE – which operate with standard reports. Web communication permits remote visualisation of reports and their associated data. HTML pages are generated from the XML representation of reports and transmitted by our Web Server that manages the HTTP connections for DICOM Report Server.

5 RESULTS

An example presenting the application of the structuring methodology to a cardiac structure, specifically mitral valve, is presented in Figure 3. The concepts, contexts and templates were processed using the designed and implemented software environment and the structured reporting was experimented.

NL	Relation with Parent	VT	Concept Name	Value Set Constraint
		CT	(EV, Anatomic and Functional Findings)	
>	CONTAINS	CT	(EV, Mitral Leaflets)	
>>	CONTAINS	CT	(EV, Thickness)	
>>>	CONTAINS	INC	TID301 Echo Section	$MeasType = (EV, Leaflet Thickness)
>>>	HAS PROP	CODE	(EV, Appearance)	(CX, Appearances)
>>>>	HAS PROP	CODE	(EV, Severity)	(CX, Severities)
>>>	HAS PROP	NUM	(EV, Score)	
>>	CONTAINS	CT	(EV, Opening)	
			.....	
>>	CONTAINS	CT	(EV, Calcification)	
			.....	
>>	CONTAINS	CT	(EV, Closure)	
			.....	
>	CONTAINS	CT	(EV, Mitral Ring)	
			.....	
>	CONTAINS	CT	(EV, Mitral Cordages)	
			.....	
>	CONTAINS	NUM	(EV, Wilkins Score)	
>	CONTAINS	CT	(EV, Mitral Hemodinamics)	
>>	CONTAINS	INC	TID301 Echo Section	$MeasType = (CX, Mitral Valve)
		CODE	(EV, Diagnosis)	(CX, Diagnosis)
		CODE	(EV, Ethiopathogeny)	(CX, Mechanisms)
		CODE	(EV, Severity)	(CX, Grades)

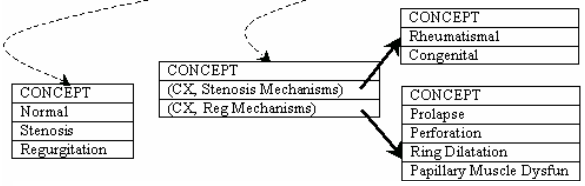

Figure 3. Mitral valve template.

6 CONCLUSIONS

The structured reporting environment is currently being used in a clinical research program. Over one hundred contexts and dozens of templates concerning echocardiography have been created using the implemented applications as an attempt to fully systematise the information from this medical field. The Report Editor module was used to construct a number of significant reports from studies conducted on real cases. Advantages that emerge from this structured approach include DICOM compliant report storage and powerful retrieval capabilities that enable education and research activities in the echocardiography field.

This paper presents an environment for structured reporting as specified in the DICOM standard. We had to combine two requirements: standard specifications and the demands imposed by physicians. The solution we arrived to realises both of them. In the future, we propose to find even better modalities for integrating the physicians' viewpoint into the reporting environment.

REFERENCES

[1] {2003} DICOM Part 16: Content Mapping Resource. National Electrical Manufacturers Association, Rosslyn, Virginia, USA.

[2] Clunie DA. {2000} DICOM Structured Reporting. PixelMed Publishing, Bangor, Pennsylvania, USA.

[3] {2003} DICOM Supplement 72: Echocardiography Procedure Reports. DICOM Standards Committee, Rosslyn, Virginia, USA.

[4] S. Nedevschi, D, Olinic, R. Popovici, F. Rusu, A. Smeu, C. Homorodean. {2003} DICOM Compliant Environment for Structured Reporting in Echocardiography. *Computers in Cardiology 2003* pp. 24-28.