

Feature Based Retrieval of Echocardiographic Images Using DICOM Structured Reporting

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Abstract

Structured descriptions attached to medical image series conforming to the DICOM standard make possible to fit the collections of existing digitized images into an educational and research framework. This paper presents the milestones in our work to provide a simple yet robust structured reporting method for echocardiographic investigations. Our initial reporting solution and the underlying healthcare information system are introduced first, and the results of the system's use in a clinical environment are also pointed out. Latest development in the domain of DICOM structured reporting norms is outlined next. Accordingly, our recent improvements are covered then: the upgraded structured reporting method is introduced and several new or modified components of the system are brought into view. The paper concludes by summarizing similarities and differences between the old and the new approach, highlighting future development tracks.

1. Introduction

In order to conduct research and education relying on digital ultrasound images it is necessary to access a large number of relevant cases represented by images and their description and interpretation. Hence, a key characteristic of the underlying information system should be the possibility to retrieve images based on features of anatomic structures and of the medical diagnosis. Feature-based retrieval requires the definition of a structured and standardized way to describe the ultrasound images and their interpretation.

The goal of our project was the development of an echocardiographic image database that complies with the DICOM (Digital Imaging and Communications in Medicine) standard and provides query/retrieve services based on features of the visible anatomic structures and features of the diagnosis. Thus, important objectives were: to define a simple but robust structured reporting (SR) method for DICOM echocardiographic images and, at the same time, to contribute to the adoption of a unified domain terminology.

2. Initial SR solution

2.1. Basic reporting method

A first version of our medical information system was built around a structured reporting method that matches the physician's way of thinking. The method introduces four levels of structuring [1].

Echocardiographic investigations are categorized according to investigation context. The following investigation types were considered: transesophageal echocardiography, transthoracic echocardiography, cervical and upper limbs arteries ultrasonography, lower limbs arteries ultrasonography, and venous ultrasonography.

A medical description and diagnosis pattern is available for each type of echocardiographic investigation. The pattern, which is the next level of structuring, consists of a set of compulsory keywords corresponding to the visible anatomic structures and the rules for describing these structures.

Description is made by means of free attributes and their qualifiers, representing the last two levels of structuring. Attributes are used to specify various properties of the anatomic structures or of the diagnosis. Such attributes may have one or more qualifiers and may be linked to one or more relevant images.

In case of the basic structured reporting method, the set of keywords is predefined, while the attributes and qualifiers may be freely specified by the physician, according to his own usual terminology.

The reports are generated starting from the free medical description of anatomic structures. The next steps consist of marking attributes and qualifiers and entering references to images. All these yield the structured description. Figure 1 captures through an example how the transition from traditional to structured description takes place.

2.2. System architecture and features

Initially, a DICOM archiving system and a DICOM client application were designed and developed at our university. Their conformance to the DICOM standard is

achieved both by using the imposed image file content structuring and by implementing the DICOM network communication protocol. Furthermore, the organization of data based on patients, studies, and series, which is characteristic to the DICOM standard, is maintained.

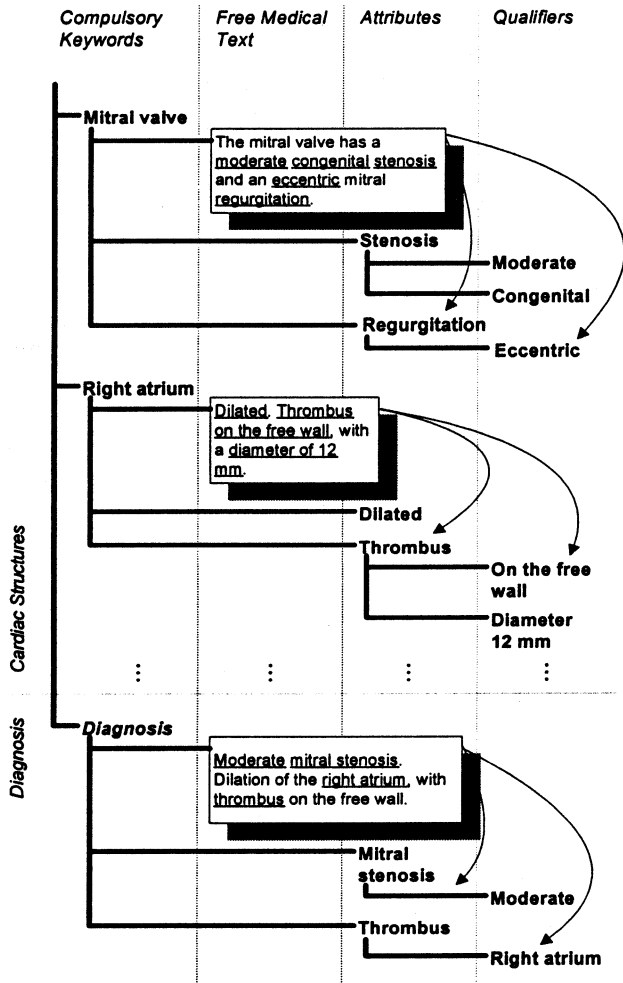


Figure 1. Example of free medical description structuring.

The archiving system is made up of two components: (1) an image and application server responsible for image file archiving and DICOM-compliant communication, respectively; (2) a database server that manages textual information associated with images. The following DICOM services are implemented: multi-modality image storage (C-STORE), patient, study, series query (C-FIND) and retrieve (C-MOVE). The database contains not only information regarding patients, studies, series, and images but structured reporting data, too.

The DICOM client makes possible to acquire, visualize, process single- and multi-frame images, and convert them to and from DICOM format. It provides DICOM-based access to the archiving system for storing,

looking up, and retrieving images and related information. Two of its modules deal with structured reporting.

A diagnostic module implements the basic structured reporting method, making possible to generate structured descriptions starting from traditional ones. Powerful query/retrieve operations can be performed by means of complex interrogation phrases. Such phrases can be built for each investigation type based on the available dictionary. Phrases consist of associations of keywords, attributes, and qualifiers. The result set for a query contains all the reports from the database that contain all items of the query phrases. Series and images associated with the reports can be retrieved then.

A dictionary maintenance module provides a way to insert, delete, and order dictionary items and to declare terms with similar semantics equivalent.

Recently, we provided by means of a web interface an alternative method to access DICOM medical image databases. The web interface implements both query/retrieve methods available in the client-server system, i.e. patient, study, series query/retrieve; and query/retrieve based on structured medical report items. It is possible the platform-independent visualization of stored DICOM images. The information in the database is protected by session-level authentication and secure communication mechanisms. Database contents cannot be modified through the web interface.

Figure 2 is an overview of the main components of the archiving system, client application, and web interface.

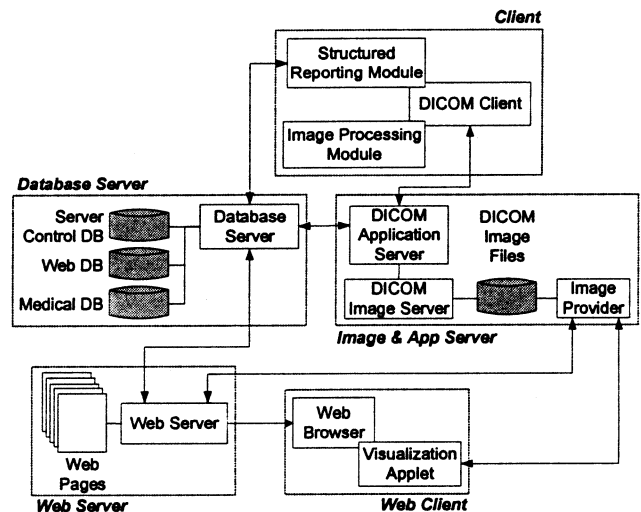


Figure 2. Information system components.

2.3. Results

The archiving system, client application, and web interface were deployed at Medical Clinic no. 1, University of Medicine and Pharmacy of Cluj-Napoca.

Up to now more than seventy DICOM image series

representing transesophageal and transthoracic echocardiographic investigations were introduced in our database.

Structured reports were attached to each of the image series using our basic structured reporting method. The dictionary that resulted from this process is fairly rich, covering a large spectrum of cardiac diseases (valvular, congenital, thromboembolic, etc.).

The database has been successfully used as a source of relevant examples in medical training.

Based on the gained experience, a controlled domain terminology has been sketched and contexts—covering possible sets of: attributes for keywords and qualifiers for attributes—have been identified.

3. Latest DICOM SR norms

The DICOM standard provides two levels of reporting.

The higher level of reporting foreseen by the initial DICOM standard is associated with patient studies [2]. It consists of an initial report and amendments in free text format.

The lower level is associated with patient series and was introduced by DICOM Supplement 23 [3]. Structured Report Information Objects can be attached to each Series. These are foreseen to be “databaseable documents,” which: provide unambiguous “semantic” documentation of the diagnosis; provide context; link text with images, waveforms, and measurements; contain coded entries based on standardized or private lexicons [4].

A DICOM structured report is made up of content items with well-defined relationships among them. Content items are name/value pairs: names encode in a standard way the concept conveyed by the item (e.g. concept: person observer name, code: 121008, coding scheme: DICOM); the existence of more than a dozen value types confer flexibility to the representation of actual values. For instance, information can be stored in free text format or coded according to a coding scheme such as SNOMED (Systematized Nomenclature for Human and Veterinary Medicine). Most frequently used relationships are: contains, has observation/acquisition context, has properties, has concept modifier, selected from, inferred from. For instance, these relationships make possible to build up a structured report tree or to include references to significant images or image regions. Content items and relationships represent building blocks for structuring medical reports; the structure of a specific report depends on the medical field it applies to.

Several issues branched out from the problem of structured reporting, one of them being the need for a domain specific controlled terminology. Controlled terminology is required to enable the interchange of patient records. The DICOM SR supplement organizes the collections of domain-specific notions by introducing context-sensitive controlled terminologies for various

clinical specialties that perform or depend on diagnostic imaging procedures. Correspondingly, a context can be attached to each report item, conveying the set of all possibly related items as well as the types of relationships that might appear. DICOM Supplement 53 provides such contexts for several possible report items related to various domains of medicine [5].

4. Improved SR solution

4.1. Advanced reporting method

The track of improvements we followed is one that makes possible to conform to the latest DICOM SR norms and maintain, at the same time, our way of structuring the echocardiographic reports. In the new method the four levels of structuring are preserved, but the report is made up of standard DICOM “brick and mortar:” content items and relationships. As seen in Figure 3, free text elements were removed and the concept of qualifier was refined by introducing qualification categories (e.g. etiology, severity).

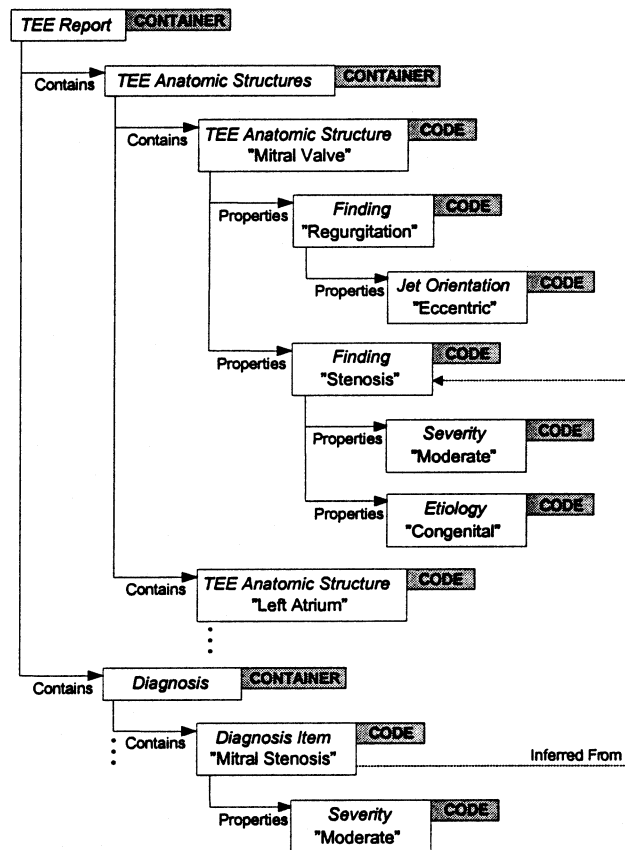


Figure 3. Structured DICOM echocardiographic report.

The new echocardiographic reports rely on the emerging controlled domain terminology. Thus, a transition takes place: the physician’s usual terminology

is replaced by a controlled one. In order to use a controlled domain terminology, it is essential to define the contexts for each item of the structured report. Our work of defining contexts for echocardiographic report items is based on the information extracted from the medical database that was created using the initial structured reporting method. Parts of the contexts associated with the transesophageal echocardiographic investigation of the mitral valve are shown in Figure 4.

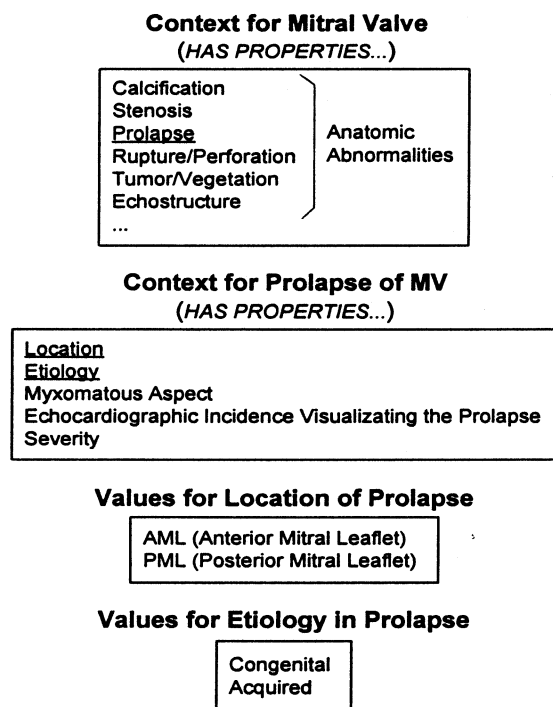


Figure 4. Contexts for structured report items.

The improvements make our new structured reporting method easier to use than the basic one: instead of extracting and structuring relevant items from a free text description, the physician only has to look up and select the items from the available contexts in order to create a structured report.

4.2. New or modified system components

A new structured reporting module for the client application is currently being implemented. The new module's query/retrieve engine provides the same expressiveness as its predecessor. It also includes a novel user interface that helps to directly build structured descriptions based on contexts and controlled terminology. The key idea is that for each report item the corresponding context, which covers all possible directions of extension, is automatically displayed. Thus, free text is avoided and the report results from a simple selection process.

A completely redefined, more complex database

structure is introduced that: makes possible to capture various relationships and structured report item types; can handle references within the report; and eases the storage of contexts for content items.

The program code dealing with the storage and retrieval of structured reports to and from DICOM or XML files or the database is also being rewritten.

5. Conclusions

Structuring the medical report is not an easy task. Our approach takes into account the physician's algorithm of describing the pathologic findings of each cardiac structure first and formulating the diagnosis next.

In case of our initial structured reporting method, the reporting cardiologist has the freedom to define new attributes and qualifiers that describe well the keywords. The main drawbacks of this solution are that structuring a free text description may be problematical and that merging dictionaries becomes an arduous task.

Our improved structured reporting proposal eliminates the shortcomings of the first method, while it fits the requirements of the latest standards. The improved proposal introduces DICOM content items, relationships, controlled terminology, and contexts, preserving at the same time the structuring levels of the initial method. The experience obtained from using the initial method and the large volume of medical data already collected acted as catalysts during the development of the new method.

We are currently elaborating the contexts for all content items of echocardiographic investigation reports. The new or modified software components are in development or test phase.

References

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