INTEGRATED MEDICAL IMAGING ENVIRONMENT

Sergiu Nedevschi, Radu Teodorescu, Zoltán Gyöngyi, Sergiu Nedevschi jr., Antonia Leuca, Dan Olinic*

Technical University of Cluj-Napoca
E-mail: Sergiu.Nedevschi@cs.utcluj.ro
**University of Medicine and Pharmacy, Cluj-Napoca*

ABSTRACT

Powerful tools for image and data handling play an important role in the advance of modern medicine. This paper gives an overview of a distributed medical environment that allows the acquisition, processing, storage, and retrieval of digital images and data. The architecture and main features of the dedicated DICOM-compliant client-server system are introduced first. The following part outlines our structured reporting method and the supporting software. Next, an integrated image processing module is presented. The interface for web access to medical image databases is described then. Results of the system's current use in clinical environment are pointed out, underlining at the same time its applicability in medical practice, research, and education. The paper concludes with summarizing the main achievements of the research and highlights the possible future developments.

Key words: DICOM, image archiving system, image processing, web interface, feature-based retrieval

1. INTRODUCTION

The progress in information technologies has a spectacular impact on the domain of health care. In the case of medical imaging, traditional solutions are gradually being replaced by digital imaging techniques. This transition sets an ever-increasing need for integrated medical imaging environments.

In this context, DICOM (Digital Imaging and Communications in Medicine) has been developed and now it is a widely recognized and used standard for the communication of digital medical images and associated information.

This paper presents a DICOM-compliant medical information system that supports the acquisition, processing, communication, archiving, and retrieval of single- and multi-frame ultrasound images and various associated data items. The system covers a large domain of applications by offering a wide variety of functions for medical image databases.

Because an important deployment field of the system is medical research and education, one of its key characteristics is 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.

2. SYSTEM ARCHITECTURE AND FEATURES

2.1. Archiving System

The archiving system was built around the open-source CTN kernel available by courtesy of Mallinckrodt Institute of Radiology [1]. It 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 former component is a Windows application written in C/C++ while the latter one is a Microsoft SQL Server.

Image and application servers are aware of each other and can transmit information from one to another based on the DICOM communication protocol. This makes possible to build up a distributed archiving system around one common database and a group of image and application servers. Clients can access all the data residing in the distributed system as if it were stored on a single server.

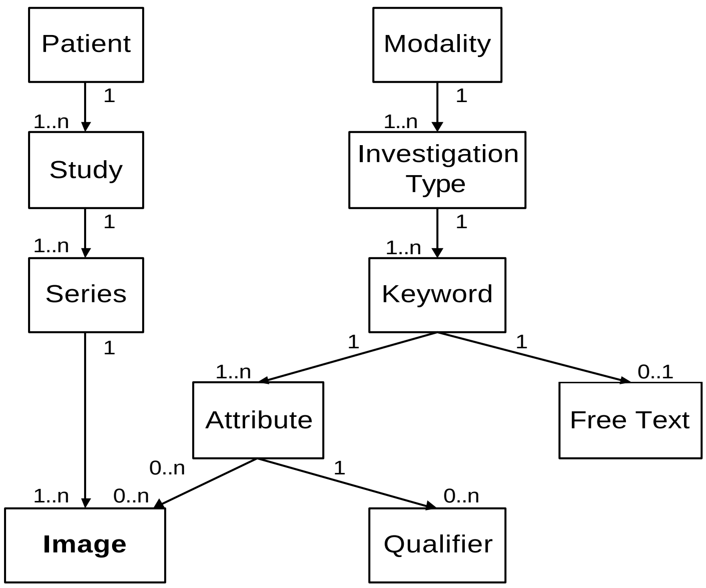

Figure 1. Simplified database model

As presented in Figure 1, the database contains not only information regarding patients, studies, series, and images but structured reporting data, too.

In conferring structure to medical reports, we started from the premise that a description and diagnosis pattern corresponds to each investigation type. Such a pattern consists of a set of compulsory keywords related to the visible anatomic structures and the rules for describing these structures. Description is made by means of free text and attributes with their qualifiers [2].

2.2. Client Application

The client is a Windows application written in C/C++. It is built up of several coupled modules.

Two modules deal with image file opening and saving, real-time playback, and conversion. The AVI processor provides these services for BMP and AVI files, while the DICOM processor handles single- and multi-frame image files in DICOM format. In addition, the AVI processor makes possible to acquire images from non-DICOM medical imaging devices on computers with video capture cards. The DICOM processor is responsible for converting images to DICOM format and for communicating them over the network. Both modules rely on DICOM libraries for file encoding/decoding and communication.

Figure 2 is an overview of the client application's modules. Figure 3 presents how parts of the archiving system and client application interact.

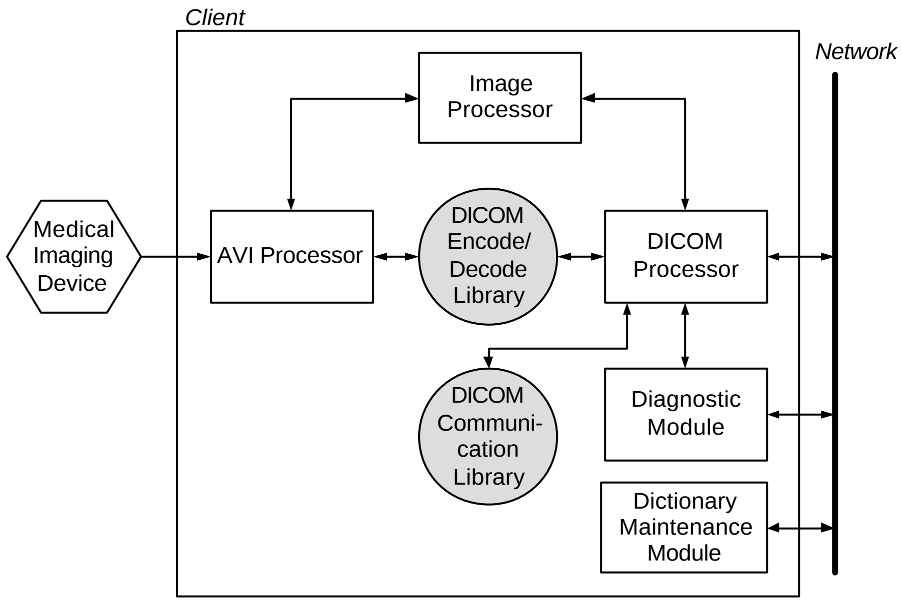

Figure 2. Modules of the client application

2.3. Structured Reporting Module

A module for structured medical reporting is integrated in the client application making possible to generate structured descriptions starting from traditional (free text) ones. Powerful query/retrieve operations can be performed on the database of stored reports 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 phrase. Series and images associated with the reports can be retrieved then.

Echocardiographic investigations are categorized according to the investigation context. 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.

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

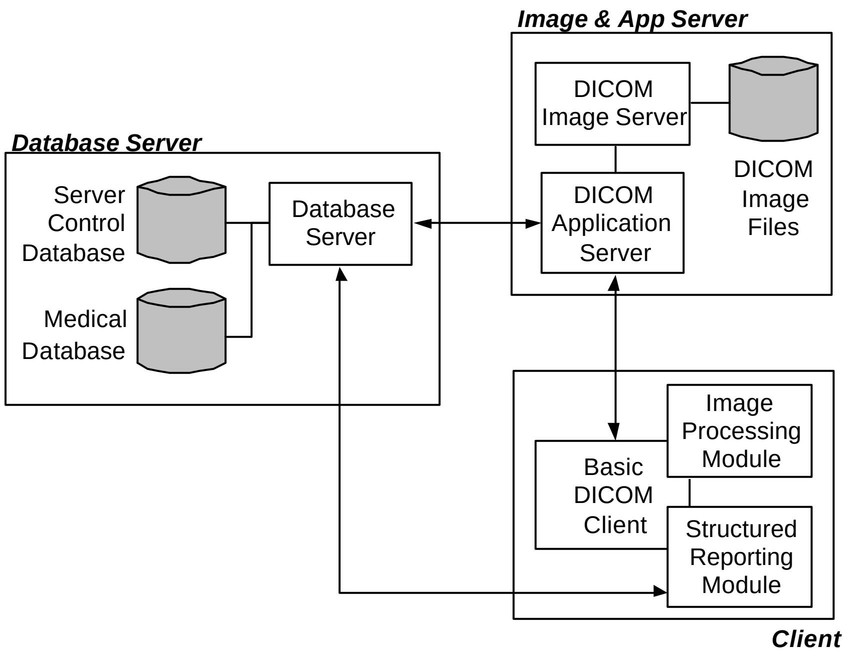

Figure 3. Components of the client-server system

2.4. Image Processing Module

The reason for including an image processing module in the client application lies within the need for specific tools for enhancing the quality of the medical images and also for performing various measurements and investigations.

The module permits the processing of single and multi-frame images allowing the modifications applied to one frame to be repeated for several selected frames or an entire video. A list of processings can be defined in order to automate frequently used sequences of operations. The system allows the definition of a so-called region of interest that can be rectangular, freeform, or echocardiography specific, allowing different operations to be applied only to specific image areas.

Tools for angle, distance, and area measurements using custom scales were included. A number of statistics like RGB and grayscale average or dispersion measurements are possible. High quality scaling from a factor of 2 to a factor of 5 was implemented with an algorithm of bipolar interpolation. A tool for area evolution tracking was designed to record the progress of a user-specified region from a multi-frame image.

Several functions that allow intensity or contrast modification, color inversion, histogram modeling, and geometric operations (flip, rotate) were implemented. Also a number of filters—like median or low-pass—were used for noise elimination. Others like high-pass, Laplace, and derivative (Roberts, Sobel, Prewitt) can be utilized for contour enhancement and edge detection that are useful in the identification and isolation of various anatomical or pathological structures.

2.5. Web Interface

An alternative method to access a DICOM medical image database is provided by means of a web interface.

The web interface features 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. The platform-independent visualization of stored DICOM images is possible. The information in the database is protected by means of a session-level authentication and secure communication mechanisms. Database contents cannot be modified through the current version of the web interface.

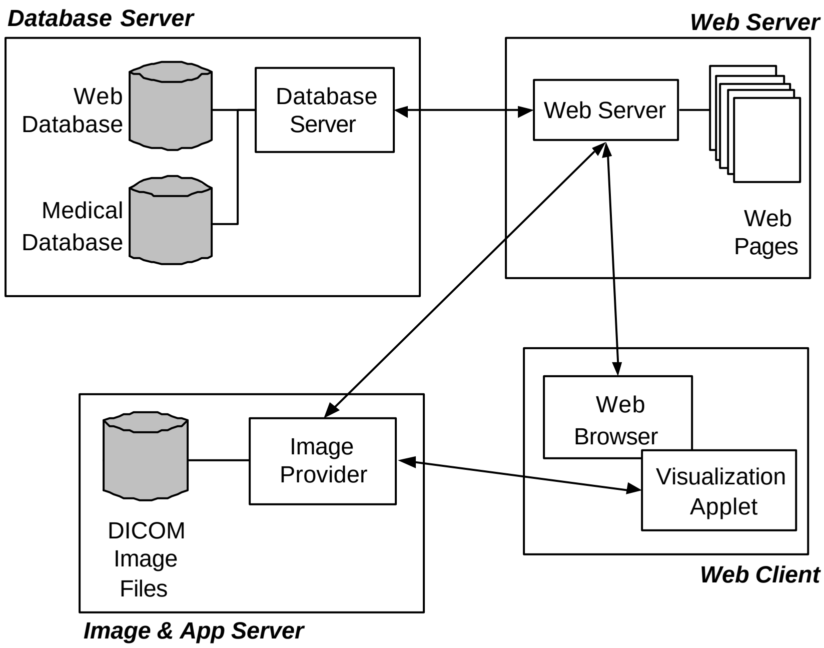

Figure 4. Components of the web interface

Figure 4 presents the important components that interact to provide the functionality of the web interface.

The medical database is the one also used by the archiving system. An additional web database contains configuration data and web user account information. Our web site is built on JavaServer Page technology. A downloadable multi-threaded Java applet performs image retrieval and visualization. Images are retrieved directly from the computers on which they are stored, without overburdening the web server's communication lines. A key element of such retrieve operations is an image provider application, written in C++ that runs on each image server. At the request of a visualization applet, the image provider extracts data items from locally stored DICOM files and communicates them to the client. Each image frame is sent as a JPEG file.

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. Until now more than seventy single- and multi-frame DICOM image series representing transesophageal and transthoracic echocardiographic investigations were introduced in the database. Many of them were acquired from non-DICOM modalities and converted to DICOM format using the client application.

Structured reports were attached to each of the image series. The dictionary that resulted from this process is fairly rich, covering a large spectrum of cardiac diseases.

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

4. FUTURE EXTENSIONS

The entire system undergoes a continuous process of extension and upgrading.

We defined an improved reporting method [3] that is being implemented in a new module of the client application. This module conforms to the latest DICOM structured reporting recommendations [4, 5]. Its user interface makes possible to directly build structured descriptions based on content item contexts (that convey the set of all possibly related items and relationships that might appear) and controlled domain terminology. A flexible database structure captures various relationships and report item types, makes possible to handle references within and outside the report, and facilitates the storage of contexts for content items. An important track of our activities focuses on delimiting relevant subsets of current nomenclatures of medical terminology and building up the content item contexts.

5. CONCLUSIONS

The major achievement of this project is that an integrated medical image processing environment was created. The system exhibits a modular, extensible, and scalable architecture that makes possible to adapt it to various requirements. It integrates acquisition, processing, storage, and retrieval functions that together with the original structured reporting methods for echocardiographic investigations have helped our applications to become useful tools in the domain's practice, research, and education.

6. REFERENCES

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