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Classification and Retrieval of Medical Images in an Integrated Healthcare Environment

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Abstract – **This work presents a new approach for classification and retrieval of echocardiographic images from textual information of the anatomical structures and diagnosis features. These textual attributes will be acquired from the electronic medical report generated in an integrated healthcare environment. The medical report is provided by a specialist in the area during the analysis of the medical image stored in a PACS environment. Such innovation guarantees a more accurate classifier and a better optimization of the medical work, since the medical report and the attributes for the medical image classifier will be created at the same time. The system is being developed in the University Hospital of the University of Brasilia.**

I. Introduction

The use of digital systems has become more present in moderns healthcare centers. Nowadays, it is common to use a triad of systems in these centers, as illustrated in Fig.1, to create a concept that is known as integrated healthcare environment (IHE). The hospital information system (HIS) is responsible for the administrative process, such as the patients' administration and financial control, or the administrative functions of the healthcare center. The electronic patient record (EPR) gives the institution a much more accurate control of each patient record [1]. The PACS (Picture Archive and Communication System) supplies the necessary structure for the storage and communication of the different types of medical images generated during all kinds of medical process. DICOM is the standard model used by the medical equipment manufacturers and by their users, offering a detailed specification for coding, communication and storage of medical images and associated information. Therefore, it is unfeasible to make any modification in the standard in order to insert new search criteria [2]. Actually, the only field in the DICOM model for representation of semantics of the image is a non-structured free text field. Images in the DICOM standard can be retrieved using as keywords the entities associated with information such as patient, study and series. The attributes of the DICOM standard do not allow the retrieval of an image based on its inherent content.

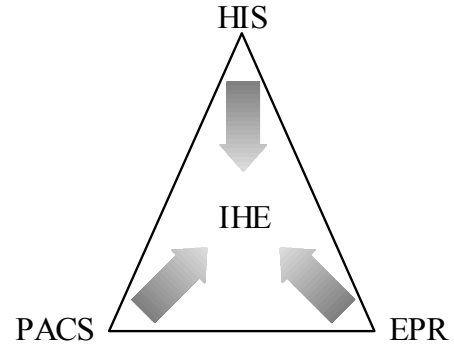

Fig. 1. A triad of digital systems in a healthcare center.

Therefore, due to the great number of images stored in a PACS environment, it is important to create alternative ways to search this information. In the majority of the cases, the process of searching an image is performed in a system for which there was a previous classification of the information, which is used for its retrieval, thus leading to a better performance of the search process. In this context, there are several works related to the pre-processing of medical images through automated processes after its acquisition and classification [3] [4] [5] [6]. There are search algorithms that carry out the retrieval of images based on their content. One example is the use of the histogram of the image intensity [7]. Another example is the method for extraction of image characteristics called metric histogram. These histograms allow the comparison of images of different sizes by mapping them into different bands of quantization [8]. There is another work where echocardiographic images in the DICOM standard can be retrieved using the anatomical structures and characteristics as search keywords [2], [9] and

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[10]. In this way, it is easier to recover ultrasound images of patients based on image characteristics. Araujo *et al.* [11] presented an algorithm that applies a distance function to measure the similarity of images. In [12], a technique based on the comparison of image texture is presented. However, automatic classifications of images do not result in completely reliable information, but they provide a margin of error for the process.

In a IHE system, the image classification process can be made right after an essential step in the medical procedure: the creation of the electronic medical report. Thus, we propose a generic architecture where it is possible to create a relationship between the information provided by the specialist, during the elaboration of the medical report, and the image stored in the database, while maintaining consistency with the DICOM standard. This approach will make it possible to refine searches, improving the study and research based on medical images.

II. Materials and Methods

The use of standard vocabulary in all the computer-based components of the IHE makes it possible to think about the classification of images using medical attributes that occur naturally in this environment. All the modalities of medical images are evaluated by a specialist in the area before the generation of the electronic report. The report is generated based on a set of medical attributes of the image on which it was based. Using the medical attributes it is possible to create a computational model capable of dealing with a great variety of medical reports.

Fig. 2 shows the proposed architecture. The database of Modalities of Medical Reports represents a set of some of the types of reports that can be manipulated by the system. For example, there can be reports related to X-Ray, Echocardiography etc. The Medical Report module is responsible for presenting to the user a graphical interface that allows the insertion of information. After the confirmation of the report, whenever possible, a classification according to the international classification of diseases (CID) is generated. Then, the report module codes its content in XML, so that it can have its attributes extracted and added to the Classification of Images database. After that, a link between the image in the PACS and its classification is created.

In this work, some records for echocardiographic images were initially processed. This phase of the project required constant interaction with cardiologists, which performed the detailed analysis of anatomical and functional structures and substructures that are important during an echocardiographic investigation. One example is the anatomical structure named left atrium. This structure is initially classified as normal or abnormal. If it is abnormal, it is necessary to describe the type of abnormality. An example of description would be "light, moderate or severe increase of size". An example of substructure is the atrial septum or other walls that can present abnormalities, such as an aneurism, a thrombus or a tumor. Typical values for the structure sizes can be found in [13] [14].

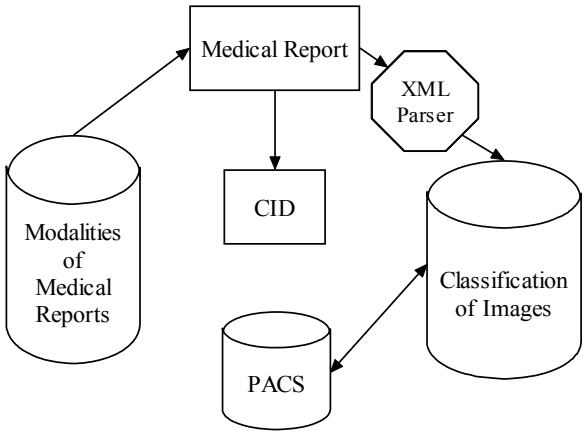

Fig. 2. System for classification of images.

With the previous definition of elementary anatomical structures that are routinely examined in echocardiographic investigations, it is possible to define keywords, also called attributes. With the use of these attributes, the reports can follow a standard. Thus, the images will be classified using a more homogeneous approach for definition of its semantics.

Any information that is added by a specialist to the report must first be classified according to the options in the combo-box items. Whenever the options do not satisfy the requirements of the specialist, he can use an option where he can add comments to the report. However these comments will not be part of the image classification scheme.

Initially, the database was created using an object-relational model, where the relations between report, anatomical structures and substructures contain a functional description and/or anatomical description. The relations between these descriptions can define a diagnosis that may or may not be associated with an entrance in the CID, as shown in Fig. 3.

For echocardiographic images, a single report is usually related to a set of images that, in the terminology of standard DICOM, is named study. Thus, the study will receive the classification that was obtained through the XML from the medical report.

The assembling of the XML of the medical report is based on the method presented in [9]. Since the XML code is structured, it is easy to perform the insertion of the content of tags in the database as attributes or to process it with other information system. The information semantics of the report can now be transferred to the database and be associated with the image. Fig. 4 shows a small model illustrating how the XML file is structured.

The architecture was developed for use in the WEB environment, and the JAVA language was adopted. The TomCat (JSP) server for dynamic pages was used, and the PostgreSQL was chosen for database management.

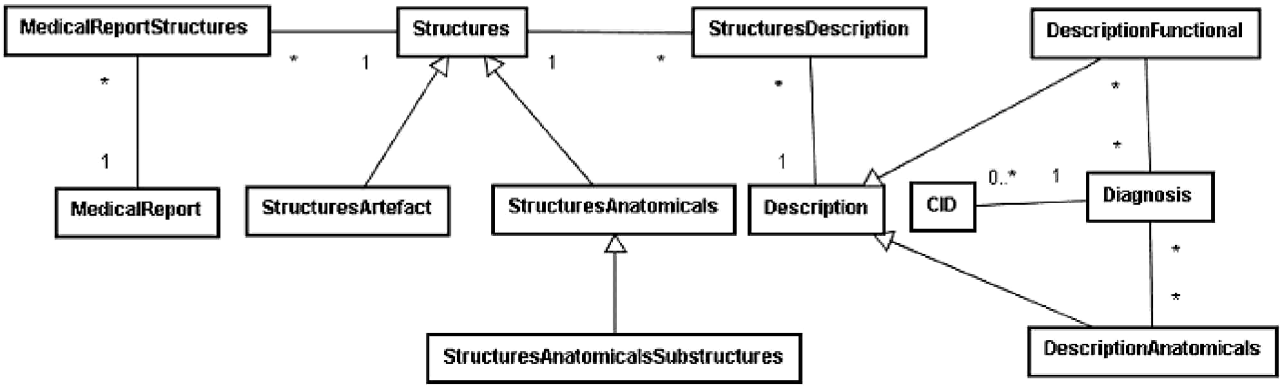

Fig. 3. Class diagram.

The HTML language was used in conjunction with the Javascript for the creation of the WEB interface with the user, in order to guarantee a better interaction of the user with the system (usability). Depending on the choices made by the user, in the selection boxes, new options related to the previous choice are made available. For example, if the user selects the left atrium as the anatomical structure of interest, then the system will show only options related with that structure.

```
<relation>
        <structure Anatomical>
                Left Ventricle
                <anatomical Description>
                        Increased severe degree
                </anatomicalDescription>
                <functional Description>
                        Contractile decrese severe
                        degree
                </functional Description>
    </structure Anatomica l>
</relation>
```

Fig. 4. Model of the XML file.

III. Results

The prototype described possesses an interface for supplying data related to the functional and structural parameters of the echocardiogram. After this initial data entry, it is possible to perform a preliminary classification of some structures, based on previously established normal values. After this stage, the physician responsible for the report is directed to a new page with the options for classification of the structures and substructures. After that, the report is confirmed and the information is used for the classification of the images. In this test phase, five studies were generated. Each one has twenty images. All the images were correctly classified and retrieved.

The retrieval of an image, that has already been classified, can be made through the interface shown in Fig. 5. The user can open the interface and perform a search using the anatomical structures, a logical condition and a keyword. After the search, a list of all the images that satisfy the search criterion is shown, so the user can select the image for visualization.

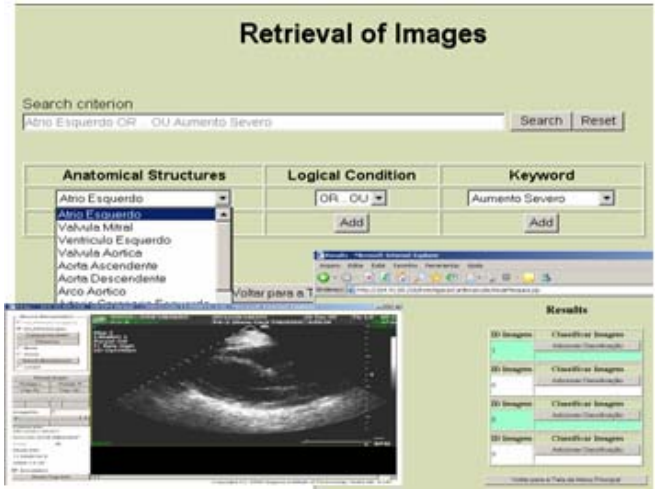

Fig. 5. Software interface for medical image retrieval through the selection of a search criterion (textual medical attribute). The list of images that meet the criterion is displayed and an image is selected for visualization.

IV. Discussion and Conclusion

This work described the development and the implementation of a generic architecture capable of relating the creation of medical reports with the classification of the images. The use of a database to store attributes and links for the images in the PACS made the association of semantic information with the images possible. This association is

performed during the elaboration of the electronic medical report in an integrated healthcare environment that is being used in the University Hospital of the University of Brasilia.

With this system, it is possible to use the information in the medical report for the semantic classification of the images, unlike others techniques, where the classification of the image by a specialist is part of a separate process, consuming more time. Another aspect is the fact that the attributes must be defined by a specialist, who should use a specific format, and not by an automated classifier. This approach guarantees a good level of reliability in the classification of the images.

At this point, we have developed a system for medical image retrieval through an image classifier based on medical attributes (text information) extracted from the medical report. The next step consists in implementing a set of tests in order to measure parameters such as accuracy, speed and ease of use. Another goal is to implement a content-based image retrieval system in order to automatically classify the images that were not analyzed by a doctor and consequently do not have a medical report.

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