ABSTRACT

In the medical field, digital images are becoming more and more important for diagnostics and therapy of the patients. At the same time, the development of new technologies has increased the amount of image data produced in a hospital. This creates a demand for access methods that offer more than text-based queries for retrieval of the information. In this paper is proposed a framework for the retrieval of medical images that allows the use of different algorithms for the search of medical images by similarity. The framework also enables the search for textual information from an associated medical report and DICOM header information. The proposed system can be used for support of clinical decision making and is intended to be integrated with an open source picture, archiving and communication systems (PACS). The BIRAM has the following advantages: (i) Can receive several types of algorithms for image similarity search; (ii) Allows the codification of the report according to a medical dictionary, improving the indexing of the information and retrieval; (iii) The algorithms can be selectively applied to images with the appropriated characteristics, for instance, only in magnetic resonance images. The framework was implemented in Java language using a MS Access 97 database. The proposed framework can still be improved, by the use of regions of interest (ROI), indexing with slim-trees and integration with a PACS Server.

Keywords: CBIR, medical image, information retrieval

1. INTRODUCTION

In the medical field, digital images are becoming increasingly important for diagnostics and therapy of the patients. At the same time, the development of new technologies has increased the amount of image data produced in the hospital. The Hearth Institute (InCor) of Sao Paulo Medical School, for example, produced in 2005 around 23,500 medical image studies of different modalities, corresponding to approximately 2.5 TBytes of data. This volume will increase in 2006 with the inclusion of twelve ultrasound rooms to InCor’s PACS (Picture, Archiving and Communications System) plus the normal increase in production. Although there is a huge amount of medical images being produced, the retrieval of the images is still made based on textual searches such as Patient ID, Study ID and modality. This creates a demand for access methods that offer more than text-based queries for retrieval of the information. Content Based Image Retrieval (CBIR) systems allow the retrieval of images by similarity, using intrinsic characteristics of the image such as color, texture and shape and can play an important role in medical training, research and diagnostic. The development of a CBIR is useful for a variety of operations and is especially interesting for medical school hospitals as InCor. The BIRAM is a project for the development of a CBIR system that can support different types of algorithms for feature extraction and similarity measure. An important part of the project is also the possibility of integrating the system with a PACS system, enabling its use in medical routine.

The general diagram of the BIRAM is shown at Figure 1 and is composed of a RMI interface with access by a standalone Java client; a WEB interface for remote access by any Web Browser; and a DICOM (Digital Imaging and Communications in Medicine) interface to the integration with a PACS system (C-Store). The DICOM interface will come from the MiniWEBPACS project also developed at InCor. Currently, only the modules inside the dashed line have been implemented.

The development of a framework for CBIR with the characteristics of the BIRAM is interesting for several reasons: it is possible to rapidly test different algorithms using the same set of medical images, evaluating the relevance of the feature

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extractor; it is possible to create a reference database for teaching purposes; once integrated with DICOM, it will be able to fit in medical routine; the use of a codified report associated with the image improves the indexing of the information and its retrieval.

The development of CBIR is still a challenge\(^8\) so it is necessary to be able to test new algorithms and provide an architecture to bring the advantages of CBIR systems inside the clinical practice. Some efforts have been done toward an integration of PACS with CBIR capabilities\(^13\), but few systems have been evaluated in practice\(^8\). The most well succeeded projects in CBIR for medical images seem to be the IRMA\(^14\) and ASSERT projects\(^8\). A very good review of the state of art in CBIR for medical images is presented by Müller\(^8\) while a extensive review about generic CBIR is given by Smeulders\(^9\).

In this paper is proposed a framework for the retrieval of medical images based on its intrinsic characteristics and on textual information from a report and DICOM header. The system has been developed for being a medical image case database and to support the use of several algorithms for search by similarity. The image case database can be used for the support of clinical decision making and deal with the increasing amount of digital images produced in the hospitals by the new equipments of image acquisition.

2. METHODOLOGY

The BIRAM was implemented in Java language with an MS Access 97 database. The JDBC interface makes it possible to change the database to Postgres or MySQL without many changes in the code. The implementation uses specific features of the Java language such as serialization, remote method invocation (RMI) and dynamic instantiation.

The BIRAM works in the following way: an implementation of the Algorithm class (Figure 1) is sent to the server as a JAR file. The server then, saves the JAR file in its classpath. After saved, the Algorithm is instantiated and stored in the database (see Figure 2, Algorithm table) using the information provided by the class (calling the get\(\text{...}\) methods). Based on the Algorithm meta-information (modality that it can be applied to, number of bits and body part) the algorithm is applied to the stored images (calling the process\(\text{...}\) method). The result of applying the algorithm is a Descriptor instance that is serialized and stored in the database (table ALG_X_IMG in Figure 2 that relates an algorithm with an image
instance). Once all the Descriptors are stored, the database is ready to be searched with the provided algorithm. When a client request the search for similarity the *Algorithm* is applied to the template image producing a *Descriptor*. The *Descriptor* is then compared with the stored *Descriptors* in the database (calling the method `calculateDistance()`, see Figure 1), finding the most similar images.

The advantage of this approach is that the type of *Algorithm* used can be abstracted, supporting the implementation of different feature extraction algorithms. It also offers the possibility of working with meta-information about the algorithm and image. One example is the possibility of automatic selection of the similarity algorithm used for the search, based on the DICOM header and on the algorithm meta-information. Also it is possible to combine several algorithms for the search and create a ranking based on different algorithms12.

The BIRAM also supports the association of a free text report (table *REPORT*) with the study (table *STUDY*) and the use of a coded element from a medical dictionary (*DICTIONARY* table) to codify the conclusion of the medical report (table *CONCLUSION*). The actual implementation only supports the ICD-10 (International Classification of Disease - 10th version) codification, but the framework supports the use of other dictionaries. The user interface for the input of the report is shown in Figure 3.

The tables are described following the DICOM standard, divided in the levels of Patient, Study, Series and Image with a relationship of one-to-many between them. The Report is associated with the Study level (one-to-one) and each Report is associated with a medical Dictionary and a Report has a Conclusion composed of one or more coded elements from the dictionary. The access to a medical Dictionary is done using meta-information contained in the table Dictionary. For example, the field `DIC_SELECT_DESC` for the ICD-10 dictionary is “SELECT ICD_DESCRIPTION FROM ICD_10 WHERE ICD_CODE = ‘?’”. In a different dictionary the select would be different, but without changing the Dictionary table or the Java code.

![Figure 2 – UML diagram of the BIRAM server](image-url)
The Image table is associated with two ROIs (Region Of Interest), one for the report and other for the algorithm. The ROI_Report table is only to associate the report with a region in the image, in a similar way to the DICOM SR. The ROI_Algorithm is used to associate a region in the image with a feature extraction (ALG_X_IMG.AXI_ROI_ID). This association is predicted in the model but has not been implemented yet. The idea is to be able to apply the algorithm only to a region that is more descriptive of the content of the image (e.g., the contour of a lung).

One relevant point that is missing in the BIRAM is the indexing of the image database. The current implementation searches the entire collection of Descriptors to find the most similar. This can be surpassed by the use of an indexing tree such as a slim-tree\textsuperscript{15,16} and by enforcing the use of a distance that satisfies the three rules of a metric space (symmetry, non-negativity and triangle inequality) in the implementation of the \textit{Descriptor}. Then, it is possible to create an indexing tree that optimizes the access time to the most similar images. The indexing can be independent of the implemented algorithm if it obeys the rules of metric space. There is currently a library, called XXL\textsuperscript{17,18} that implements several indexing structures in Java and can be used to improve the speed in the retrieval of the images.

3. RESULTS

The BIRAM has been partially implemented as highlighted in Figure 1. The Java standalone client (Figure 4 and Figure 6) was implemented, with the capability of sending to the server DICOM medical images by RMI (Remote Method Invocation), the client can also associate the image with medical reports using ICD-10 coding medical dictionary and is able to search similar images using different algorithms. The server was implemented and is capable of receiving new algorithms, store DICOM images in the database, associate medical reports to studies and apply different algorithms to the stored DICOM images. Some simple algorithms were also implemented for the image retrieval such as momentum, histogram, metrical histogram\textsuperscript{19} and center of mass (Figure 5).
Figure 4 – Report association with image for fast indexing and retrieval of the medical images.

On the right is shown a report conclusion coded in ICD-10.

```java
public Result process(Imagem img) {
    double intensityTotal = 0.0;
    double eixoX = 0.0;
    double eixoY = 0.0;
    if (img.bitsAlocados == 8) {
        for (int j = 0; j < img.height; j++) {
            for (int i = 0; i < img.width; i++) {
                byte val = img.img_byte[i + j * img.width];
                intensityTotal += val;
                eixoX += i*val;
                eixoY += j*val;
            }
        }
    } else if (img.bitsAlocados == 16) {
        for (int j = 0; j < img.height; j++) {
            for (int i = 0; i < img.width; i++) {
                short val = img.img_short[i + j * img.width];
                intensityTotal += val;
                eixoX += i*val;
                eixoY += j*val;
            }
        }
    }
    double centroX = eixoX/intensityTotal;
    double centroY = eixoY/intensityTotal;
    return new ResultCentroMassa(centroX, centroY);
}
```

Figure 5 – Mass center Algorithm interface partial implementation
4. DISCUSSION AND CONCLUSIONS

The current implementation of BIRAM is very promising, but there are still some issues that must be better explored.

- Although the DICOM protocol provides the means of using textual information to help retrieving medical images, there is a problem with the quality of data. It was demonstrated that only one out of four examined modalities included the correct digital imaging and communication in medicine DICOM Header information and even in this case the information was incorrect in 15.5% of the examined cases\textsuperscript{20}, including the field anatomical region (BODY\_PART) that is used for the matching of the images. This can hinder the use of meta-information for the retrieval of information, so it is necessary to place some restriction on the images that can be stored in the database;

- Keysers et al\textsuperscript{20} advert that “common CBIR systems have only a rudimentary understanding of image content, with little or no distinction between important and negligible features or between different anatomical or biological objects in the image. But queries of diagnostic relevance include searching for organs, their relative locations, and other distinct features such as morphological appearances. Therefore, common CBIR systems cannot guarantee a meaningful query completion when used in a medical context”. So it may be necessary, when applied to clinical practice, to include a more complex model of the image and algorithm to the model.
The proposed architecture is extensible and powerful, and is intended to solve the problems of retrieving valuable information from the increasing volume of information generated at InCor medical school hospital. The BIRAM has the following advantages: (i) Can receive several types of algorithms for image similarity search; (ii) Allows the codification of the report according to a medical dictionary, improving the indexing of the information and retrieval; (iii) The algorithms can be applied only to images with the appropriated characteristics, for instance, only in magnetic resonance images.

The proposed framework can still be improved, by the use of regions of interest (ROI), indexing with slim-trees and integration with a PACS Server.

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