A CADx Scheme in Mammography: Considerations on a Novel Approach

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***Abstract*—This paper describes a prototype of a complete CADx system developed in the last years in our research groupp. Its basic structure consists of pre-processing corrections based on the image acquisition and digitization procedures (FFDM, CR or film + scanner), a segmentation tool to detect clustered microcalcifications and suspect masses and a classification scheme, which evaluates the presence of microcalcifications clusters and possible malignant nodules based on their contour. The aim is to provide enough information not only on the detected structures but also a pre-report with a BI-RADS classification. At this time, the system is still lacking an interface integrating all the modules. Despite this, it is partially functional, as a prototype for testing.**

Keywords-Mammography; Mammographic CAD; Microcalcification Detection; Nodule Detection; Nodule Classification; Image Analysis.

I. Introduction

Since all women over the age of 40 are recommended to perform mammographic exams every two years, the demands on radiologists to evaluate mammographic images in short periods of time has increased considerably. As a tool to improve quality and accelerate analysis, CADe/Dx (computer-aided detection/diagnostic) systems are being researched, but very few complete CADe/Dx systems have been developed and most are restricted to detection and not diagnosis. The existent ones [1] [2] are associated to specific mammographic equipment (usually Digital Radiology), which makes them very expensive.

Computer-aided Diagnosis (CAD) schemes are addressed to accelerate and ease the evaluation of medical images, sometimes serving as a second opinion. In mammography, the lack of trained professionals makes the careful evaluation of each image of each exam expensive and restrictively time consuming, especially for second opinions. Thus, several CAD schemes are being developed focusing on mammography. However, the breast tissue is commonly very difficult for analysis, which makes the few CAD schemes approved by the American Food and Drug Administration (FDA) highly expensive, in addition to be only designed for detection (CADe) – indicating suspected signals without classifying them.

Our research group has been developing in the past years some processing schemes for both detection and classification of signals regarding mammographic images. These schemes include special attention to pre-processing enhancements based on imaging acquisition quality characteristics evaluation [3] [4] [5], detection of clustered microcalcifications [6] [7] and detection and classification of suspected masses [8] [9] [10] [11].

The purpose of this paper is to present the ensemble of several years of research in this CADx scheme prototype, including the results obtained individually by each module (as well as joined at all) and to discuss the further developments of this system in the near future. The scheme corresponds to an automatic CADx system being developed for free use and, in the future, to be connected to an online image database [12] to aid in the medical reports.

This following paper contains a Methods section, where the prototype system is described; this section is subdivided by the function of the module described. The next section is Results, where the results obtained so far with the prototype are described. Lastly, the Conclusion section discuss the future of the project.

II. Methods

This CADx scheme is divided in 3 major structures: Pre-processing, CADx processing and Comparison to database. A detailed diagram is presented in Figure 1. Each division is described as following:

A. Pre-processing

Once the digital images are obtained, they are submitted to pre-processing techniques for enhancement based on imaging intrinsic parameters, determined by quality assurance procedures. This process is composed of:

A.1 Breast and pectoral muscle segmentation

Initially, the digital image is segmented to remove tags and as much as possible of the background, reducing the size of the image and, consequently, reducing the computational cost of the following procedures. In this step, the pectoral muscle is also segmented to be used in step B.B.4.

This method consists of a logarithm contrast enlargement [13] [14] followed by a segmentation using Pun’s global threshold [15]. With this, the breast itself is segmented from the background. The techniques used in this step are fully detailed in [16].

A.2. Scanner/CR corrections

Another source of errors in this process is the image conversion in digital format. The aim in this step is "to correct" the final image according to the errors or distortions due to the digitization process, from a film digitizer or other electronic device in Computed Radiography (CR) or even Digital Radiology (DR) systems [5]. The procedure essentially transforms the image intensity according to the ideal relation between the optical density (or the beam intensity) and pixel gray scale. This is particularly important in film scanning, due to the relation between the film sensitometric curve and the digitizer characteristic transfer curve.

The technique used in this stage was previously described. For its use, knowing the characteristic curve of the scanner or CR/DR system is a requirement.

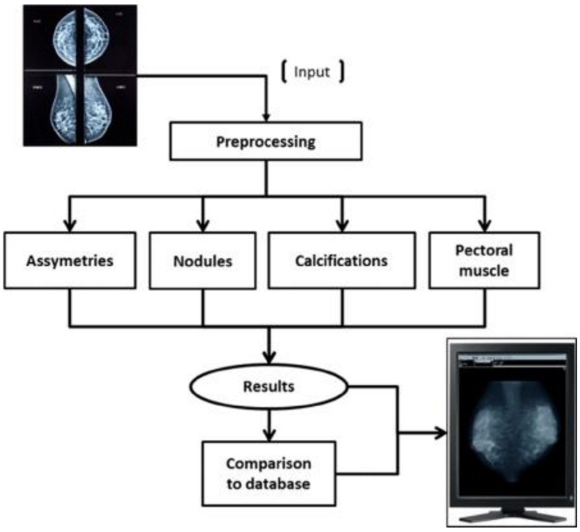

Figure 1. CADx diagram

B. CADx processing

Once the image is digitized and transformed according to the pre-processing techniques, the image is processed in the 4 distinct modules below:

B.1 Density

In this module, the breast image has its density evaluated, according to BIRADS [16] [17] classifications. This evaluation is performed based on the average gray scale intensity for the entire breast. Also, in this module, both breasts are compared in each orientation (Mediolateral-Oblique - MLO and Cranio-Caudal - CC) and analyzed for density differences between breasts, characterizing an asymmetry. If an asymmetry is detected, it is evaluated as a nodule detection in step B.2.

The results of this system are of an average sensitivity of 94.6% with a false-positive rate of 26.35%. Comparing to a well-recognized work in the field [18] - with a sensitivity of 90.38% and 32.12% false-positives rate - the proposed module has better results.

B.2Nodules

This module is designed to detect and classify nodules. First, the complete image is evaluated using neural network techniques to detect Regions of Interest (RoIs), which contain nodules [16]. The detected RoIs are then segmented in order to separate the nodule itself from the background using EICAMM [19]. Once the nodule is segmented, an evaluation of the contour, texture and density is used to classify the nodule between benign or malignant [19].

Early testing with this module presented the following results: the detection scheme of this module yielded 74% of sensitivity with 3.5 false positives per image; the segmentation scheme matches 65.8% against a specialist response and the classification process reached a sensitivity of 81.28% with 20.28% false positive rate. More tests are needed before a full comparison can be drawn to other similar systems.

B.3Calcifications

This module uses a series of convolution filters derived from Chan [20] and Schiabel [21] to detect, in the given image, the location of clustered microcalcifications. The filter is designed to match the format of a calcification, increasing the signal when a match occurs and removing most of the background. This filter is a reworking of Chan's filter for images of variable size.

This system has been shown to have good results with different types of images specially using FFDM [22]. On average, the system has 89% of sensitivity with 6.9 false-positives per image. When evaluating only FFDM images, the false positive rates are reduced to 1.4 per image. As a comparison, the commercially available ImageChecker [1] has 91% of sensitivity with 1.5 false-positives per image and it is restricted to images produced by its own digitizer system.

B.4 Pectoral muscle

This module takes the segmented pectoral muscle from step A.1 and searches for nodules [16]. In the current design, nodules are only detected, since, in most cases, they will be linfonodes. The demarcation of them facilitates the evaluation of spreading cancer by the radiologist.

This system simply finds the regional maximum intensity of the previously segmented pectoral muscle. These points are usually linfonodes.

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The results of this module have shown 74.9% of sensitivity and 3.5 false positives per image.

B.5 BI-RADS classification

The system is designed to present a BI-RADS© classification based on all the information obtained in the previous modules. The final purpose is that the results shown by this CADx system constitute a pre-report, so that a radiologist can confirm or change as fit.

C. Comparison to database

Another step in the future development of this CADx system includes integration with BancoWeb [12] database, allowing the radiologist to see example of similar results to those found in the image evaluated.

III. RESULTS

Currently, the CADx scheme is almost fully developed, but has not yet been integrated into a single system. For example, the microcalcification module is fully functional, but it was developed in MATLAB© and has not been converted to JAVA© yet.

Hence, all results shown in this work are direct tests with the different modules, not considering the pre-processing step in the complete system.

The last two modules in the section above are not yet completely developed (BI-RADS classification and Comparison to database), since these two modules require the rest of the program to be fully integrated for development.

When all modules are working and tested the last step in the development will be the interface itself, which will be developed in association with experienced radiologists to add as much useful functionality as possible.

Once the program is complete the validation will occur in two formats. The first will be a comparison to the DDSM database [23] that has over 2600 cases with complete medical and pathological reports. This will be a direct comparison between the program report versus the official medical and pathological report.

The second form will be a comparison between the program and trained radiologists with at least 10 years' experience. This set of tests will compare the system results to a trained radiologist and also the changes in results when the radiologist has access to the results of the CADx system before making his final call.

If the CADx improves the statistical results of the radiologists, it can be considered useful as a second opinion.

IV. CONCLUSION AND FUTURE WORK

The main purpose of this paper was to present a CADx system that has been shown promising results as a prototype. Once the interface is ready and all tools of the system can work automatically, this will be one of the few CADx systems available for general use.

Each tool has been showing promising results, at least equivalent to others reported in the literature. For the future, it is intended to be established in three formats: downloadable software, an internet system integrated to the BancoWeb database and a library in JAVA with all the tools used to develop the system.

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