Computer aided diagnosis for breast masses detection on a telemammography system

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Abstract

A Computer-Aided Diagnosis (CAD) scheme for breast masses detection has been developed and integrated as a part of a telemammography system. This work derives from the close cooperation between the Laboratory for Radiologic Image Research of the University of Santiago de Compostela (Spain) and the company Intelsis Sistemas Inteligentes (Santiago de Compostela, Spain). This cooperation has been supported by funds from different projects, mainly from the European Union, the Spanish Health Administration, and the Galician Public Health’s Service. As a result, a first prototype is ready to begin a demonstration project.

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1. Introduction

Breast cancer is a major cause of death among women in the world. Nevertheless, it is well known that an early detection of breast masses reduces this mortality. Therefore, mass screening programs are being performed, as long as they have proven to be an effective method for breast cancer detection at an early stage \cite{1}. Telemammography could provide widespread accessibility to breast screening programs because it allows high-quality mammographic interpretation at a distant location in areas where radiology coverage is deficient. Telemammography also facilitates other services as night or weekend coverage, radiologists on duty at home, or mobile units \cite{2}. Furthermore, telemammography reduce the likelihood that women refuse follow-up because of the distance to an accredited mammography center. Moreover, advances in the field of telecommunications have induced a supplementary interest in this new concept on the delivery of health care services.

Teleradiology systems operating in Integrated Standard Digital Network (ISDN), Ethernet and Asynchronous Transfer Mode (ATM) network connections have been developed \cite{3,4}. Images are usually transferred asynchronously in these systems, although this does not represent an important problem for real-time consultation. Telemammography has high-bandwidth requirements due to the large image file size, therefore ATM technology is more suitable \cite{5}. However, terrestrial means are not always available, in rural and low population areas fiberoptics networks are far from to exist. Because of this, satellite telemammography has been suggested, allowing near-real time diagnosis \cite{6}. Patients can receive screening results at the time of their screening visit.

However, it has been reported that mammograms may be incorrectly interpreted and masses may be missed. As a solution, independent double reading has been proposed to improve the detection rates. The enormous amount of mammograms produced by screening programs and the benefits of double reading have lead to consider computer-aided diagnosis (CAD) as an alternative.

Digital mammography presents promising advantages to improve the quality of mammographic diagnosis, and it is also suitable for the design of telemammography systems.

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One of the advantages of digital imaging is the separation between image storage and display, permitting contrast manipulation, image transmission, image processing and CAD. However, nowadays, several inconveniences have relegated mammography to remain in conventional film format [7]. Therefore, systems based on film digitization exhibiting adequate image quality have been explored [8].

On the other hand, CAD schemes have experimented an emerging interest reflected in the existence of commercially available systems. CAD schemes are being developed in many research centres and can indeed be integrated as a part of a telemammography system [9]. The ImageChecker System (R2 Technology Inc., Los Altos, CA, USA) was the first CAD system to receive approval from FDA for use in breast cancer screening, Second Look (CADx Medical Systems Inc., Quebec, Canada) also received recently approval, but many other schemes are under clinical evaluation, as MAMMEX TR™ (SCANIS Inc., Foster City, CA, USA).

The aim of this paper is to describe a CAD scheme for the detection of masses on digital mammograms, being part of a telemammography system. This project relies on the experience of both the Laboratory for Radiologic Image Research (LRIR) of the University of Santiago de Compostela on film based digital radiography and the company Intelsis Sistemas Inteligentes (Santiago de Compostela, Spain). Since 1987, the LRIR has undertaken several studies on image processing, CAD and PACS, and has conducted more than 15 research projects [10–20]. Moreover, Intelsis Sistemas Inteligentes has installed several teleradiology systems and has also carried out several telemedicine and teleconference projects among hospitals in Spain and in South America. The mentioned project was mainly supported by the European Union.

2. The telemammography system

2.1. System description

A limited PACS has been assembled at the LRIR (Fig. 1). This system is dedicated to address problems associated with digital techniques in a research environment.

The skeleton of the telemammography system (Fig. 2) is made of a Lumiscan 85 high-resolution laser scanner for mammogram digitization (Lumysis Inc., Sunnyvale, CA, USA), a UNIX Sun Workstation with a conventional monitor (Sun Microsystems, Inc., Mountain View, CA, USA), two high-resolution monitors MegaScan (Aydin Displays Inc., Horsham, PA, USA) controlled by a DOME onboard card (DOME Imaging Systems Inc., Waltham, MA, USA), and an AGFA IMPAX DRYSSTAR DICOM thermal printer providing hardcopy films (Agfa-Gevaert N.V., Mortsel, Belgium). As we quoted above, our telemammography system consists of a laser film digitizer. Although digital mammography is appropriate for telemammography, is not still widely used. Anyway, film digitizers may allow an acceptable image quality in the absence of a purpose-built digital mammography system [8].

2.2. Image acquisition

Conventional mammograms (four mammograms per patient, corresponding to left and right craniocaudal and
lateral views) are selected from the mammographic screening program that is currently underway at the sanitary area of Santiago de Compostela among women aged between 50 and 64 years old. These cases include normal that is, cases with no presence of pathology, and abnormal cases, containing biopsy proven masses. A Lumiscan 85 laser scanner is used to digitize the images. The scanner provides a resolution of 4096 × 5120 pixels, and 12 bits. Furthermore, some preliminary studies to evaluate this system with mammograms from public databases have been developed [21]. Mammograms are stored on a magnetic disk array Sun StorEDGE A5100, in a proprietary file format, which is converted to DICOM format to keep the system open to connections. Images can be transmitted to remote sites through the local network and printed by means of mouse click and drag operations. Patient information is also stored in a relational database based on Structured Query Language.

2.3. Soft copy visualization

Software for soft copy visualization has been developed at the LRIR based on the X window system and OSF/Motif libraries [19]. The visualization system consists of one conventional monitor and two high-resolution monitors (Fig. 2). The database interface is presented in the conventional monitor, while each high-resolution monitor depicts one mammographic study (current and previous studies). The control elements in the high-resolution monitors have been kept to a minimum presence. Image tools are available only from pop-up menus to reduce the presence of disturbing elements in the image area. The following manipulation tools that have been considered essential by the users (after the compilation of information from a standardized questionnaire) were incorporated into the system: magnifying glass, rotation, zoom and interactive modification of the grey-levels tasks. A drag and drop mechanism and a study map assist the radiologist in the arrangement of the images in the monitors.

2.4. CAD scheme

CAD Software for the detection of masses in mammograms has been developed at the LRIR [14]. This software is under continuous development in order to improve its performance. The preliminary versions, written in DT-IDL, have been translated to C language to obtain full portability of the code. Fig. 3 shows the schematics of the CAD scheme to detect masses.

In a first step, the breast border is automatically detected to segment the breast region from the original mammogram [12].

Regarding the detection of masses, an algorithm based on bilateral subtraction was initially employed. Once the points belonging to the breast border and the nipple position are established as reference points, images are aligned and compared. Asymmetries between mammograms, which could correspond with masses, are delimited by regional growing. False positives were reduced by means of size and eccentricity tests in conjunction with a back propagation neural network (BPNN) classifier that uses features extracted from these suspicious regions as coarseness, contrast, or maximum gray level value at 95% of the cumulative distributive law.

![Fig. 2. Telemammography system.](image)

![Fig. 3. Schematics of the CAD scheme for detection of masses.](image)
function [14]. An example of detection of breast masses is shown in Fig. 4.

A total number of 360 mammograms corresponding to craniocaudal and lateral views were analyzed to test the detection of masses. The system achieved a sensitivity of 80% at a false positive detection rate of 1.00.

3. Discussion

A telemammography system with a CAD tool for mass detection is currently in an advanced state of development. All the main requirements for a high-quality telemammography system are fulfilled, namely, acquisition of high-resolution mammograms, archive and retrieval of images, and acceptable greyscale display [22]. Data compression may be performed to facilitate transmission and storage, as the ACR states, and several techniques may be used, including irreversible methods, under the supervision of an expert radiologist [23]. Therefore, we are developing an efficient compression algorithm. Besides these technical requirements, demonstration projects are required to evaluate user acceptance of the telemammography system. In fact, we are currently initiating a demonstration project. It is very important to construct a telemammography system that works stable since an early stage for daily routine, as long as even small problems can influence the user acceptance [24], and a demonstration project may be a significant help. Furthermore, in spite of the considerations taken in the development of the system, the demonstration could be useful to determine if the system is so easy to use as it was planned. Studies of clinical relevance of telemammography and its benefits are needed. Additional work is also required covering important aspects as security of patient data and Computer-Supported Cooperative Work (CSCW).

Although the application of telemammography seems controversial, it is clear that it has an enormous potential. However, further efforts and investigation are needed to evaluate diagnostic accuracy and usefulness of telemammography. A potential advantage of the proposed system is the possibility of using CAD, allowing second opinion without the drawbacks of fatigue or intraobserver variation. The results obtained for the CAD scheme alone are very encouraging and suggest that the method could help radiologists in their daily work. Although it would be desirable to improve the true-positive rates of detection of masses, the low average number of false positives per image indicates that our method would not confuse the radiologists by suggesting normal regions as masses. We continue investigating methods to improve the overall performance of the detection of masses [20], and we are also developing other methods based on single-image segmentation, obtaining very encouraging preliminary results. We must bear in mind, anyway, that the method of bilateral subtraction may be useful in early breast cancer detection for automated interval change analysis [25]. We are also studying techniques to improve breast alignment as warping, like other researchers [25,26]. Possible benefits of this CAD tool could be its application to the breast cancer screening program currently underway in Galicia (Spain), and therefore, to any screening program. This software could help radiologists since increases the number of early detections, improves consistency, and reduces healthcare costs and patient trauma. Moreover, the telemammography system could allow high-quality mammographic interpretation in rural areas in which radiology coverage is deficient.

Finally, mammography technique has the highest demanding requirements, therefore, if the proposed objective is accomplished, the scheme could be applied to other radiographic techniques.

In conclusion, a CAD scheme has been developed and integrated in a telemammography system, and a prototype is ready to begin a demonstration project.

Fig. 4. The black arrows are the signs that the computer displays to indicate detections, the left one is a false positive and the right one is a malignant mass.
4. Summary

A CAD scheme for breast masses detection has been developed and integrated as a part of a telemammography system. This work derives from the close cooperation between the Laboratory for Radiologic Image Research of the University of Santiago de Compostela (Spain) and the company Intelsis Sistemas Inteligentes (Santiago de Compostela, Spain). The Department of Electronics and Computer Science of the University of Santiago de Compostela and the Complejo Hospitalario Universitario of Santiago de Compostela (CHUS) also collaborate in the project. This cooperation has been supported by funds from different projects, mainly from the European Union, the Spanish Health Administration, and the Galician Public Health’s Service. The aim of this work is to merge the knowledge and experience of the Department of Radiology on the field of Picture Archiving and Communication System (PACS), digital image processing, and CAD with the experience of Intelsis Sistemas Inteligentes on telemedicine systems. As a result, a first prototype is ready to begin a demonstration project.

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