Clustered microcalcification detection scheme for mammographic images

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Abstract: This paper describes a clustered microcalcification detection scheme for mammographic images improved from early designs by Chan et al (1) and Schiabel et al (2). This scheme includes a preprocessing segment in order to enhance the quality of the image without removing the smaller microcalcifications. The systems consist of a subtraction of a smoothed image from an image convoluted with a filter similar to a calcification in order to obtain an image with only the calcification-similar regions enhanced. The scheme was tested using DDSM (3) database (with a result of 89% sensitivity and 6.9 false positives per image) and INBreast (4) database (with a result of 89% sensitivity and 1.4 false positives per image).

Keywords: Mammography, Mammographic CAD, Microcalcification detection, Image Analysis

1. Introduction

In mammographic exams, calcifications are used as an indicator of malignancy. They are common in exams (around 50% of mammographic exams shows them), but when presented as clusters, there is 20 to 30% of chances of being a cancer signal (5). Unfortunately, although calcifications have a high density and opacity to X-rays, microcalcifications are smaller than 0.5 mm (6), having been found as small as 24µm (7). Due to its size the resulting contrast is low making them very hard to find. Another problem is that any noise can mask, or be mistaken for, a microcalcification.

In order to help the detection of microcalcifications this paper presents a microcalcification detection software. Unlike many other schemes for microcalcification detection (8) this one was designed to work with any type of image, considering different spatial and contrast resolutions, images from film-scanner systems and FFDM.

2. Materials and methods

The scheme described here was derived from a previous system from Schiabel et al (2). The flowchart in Figure 1 shows how it is structured.

Initially the system used a set of preprocessing methods before the detection. The first step crops the image to a rectangle close to the limits of the breast, removing a lot of background, tags and the white borders. This allows the system to work only in the breast area of the whole image, reducing the skew results of averages and border problems. This also reduces the size of the image to be processed (9).

If the digital image is yielded from a proper scanned mammographic film, a scanner correction is applied according to its characteristic curve (10). This process uses the digitizer characteristic curve to correct flaws on the image eventually caused by the digitization.
and to enhance the image quality as close as possible to a standard reference (10). This has been shown to reduce the false-positive rates of microcalcification detection. If the image is from a FFDM scanner this step is skipped.

Figure 1: System flowchart

Also a noise reduction algorithm using an Ascomb transform (11) is applied in order to remove the noise with minimal effect on the signal. The resulting image has fewer artifacts that can be confused with a microcalcification, without affecting the overall system sensitivity.

As shown in Figure 1, the preprocessed image is copied and each copy is separately processed by two different filters. One is a detection filter and the other a smoothing filter, as described below.

A detection technique based on a filter derived from Chan et al (1) and modified by Schiabel et al (2) starts with a convolution with a high pass filter used to enhance the calcifications. In this current technique, such a filter is changed to a function that can be scaled smoothly for different images sizes (Figure 2). This function is a Laplacian of a Gaussian function, also known as a Mexican hat function (1). It was chosen because of the visual similarities with the original filters when scaled down and the similarities with the microcalcifications being detected. The resulting filter is always used as a 35 by 35 square filter. The resulting image will be referred here as an enhanced image.

Figure 2: 2D cut of the center of the detection filter, (a) Chan (1), (b) Schiabel (2) and (c) New version

\[ F(x,y) = \left( \frac{2}{\sqrt{3\sigma_0}} \right) \left( 1 - \frac{x^2 + y^2}{\sigma^2} \right) e^{-\frac{(x^2+y^2)}{2\sigma^2}} \]  

(1)

Where \( \sigma \) is calculated based on image resolution (R) in microns, as shown in (2):

\[ \sigma = \frac{240}{R} \]  

(2)

Simultaneously the preprocessed image is smoothed using an average filter of size S also
based on the image spatial resolution, as shown in (3). The result will be referred here as a smoothed image.

\[ S = \frac{450}{R} \]  

(3)

The final size value is forced to always be an odd integer; thus, the result is rounded and, if even, 1 is added. The size was chosen so that to remove the microcalcifications and to leave only the background tissue of the breast.

The smoothed image is, then, subtracted from the enhanced image, removing the background and leaving only the enhanced signal and some noise. The strongest remaining signal is, for the most part, the microcalcification. The scheme raises a histogram from the result and selects a percentage of the brightest points (meaning the most probable calcifications) as valid detections. This percentage defines the sensitivity of the scheme and a FROC curve was constructed to evaluate the best cost-benefit for this percentage. This percentage will be referred here as the topmost percentage. In tests with a set of 60 images the best result found was of a percentage of 0.08% (as shown in the results section). The positive results are marked as white in a binary image.

In order to eliminate false positives signals and random calcifications, since the focus is the cluster of microcalcifications, the algorithm removes isolated detections. The following steps are considered with this aim.

Firstly an area-point transformation (12) is used to turn all detected signals into points. Next a square of size \( T \) pixels (4) is swept through the image. If there are 3 or more points inside the square a cluster is marked, otherwise the points in that region are ignored. The size of \( T \) was derived from tests by Schiabel et al (2). Remaining points represent clusters that are marked as positive results.

\[ T = \frac{5000}{R} \]  

(4)

Images used in our tests were acquired from 2 sources. The first set were 130 images from the DDSM Database (3), all scanned from mammographic films by using a Lumisys 200 digitizer (50µm of spatial resolution and 12-bits of contrast resolution). The second set was composed by 18 images from INBreast database (4), containing images from a MammoNovation Siemens FFDM (70µm of spatial resolution and 14-bits of contrast resolution).

3. Results

In order to evaluate the best topmost percentage to be used a FROC curve was determined using 60 images and a range from 0.03% to 0.15%, in 0.01% intervals. All images used for this test were from a Lumisys 200 laser scanner with a 50µm of spatial resolution from the DDSM database (3). The result can be seen in Figure 3.

![Figure 3: Evaluation of the system using FROC curve with DDSM database images](image-url)
As shown in Fig. 3 the best cost–benefit value was found at 89% of sensitivity with 6.9 false-positives detections per image. This translates to a topmost percentage of 0.08% for detection after subtraction.

It is important to notice that the evaluation considered only the demarcation by the DDSM database for reference in order to check the accuracy in results. The DDSM database is known to have some problems in relation to its demarcations (4), especially considering the size and format of a region containing a cluster of microcalcifications.

One frequent problem for our scheme is the fact that several images from DDSM database show a lead sphere used to mark skin moles or scars for the visual exams. These spheres are placed by the technician against the skin of the patient before image acquisition to be used as reference for the radiologist. All these spheres have such a strong contrast that there is usually considered as a positive detection. Although radiologists ignore such marks, these points were considered here as false-positive cases in order to evaluate with the best possible accuracy the current proposed scheme.

When using the 18 images from INBreast database (4) with marked clusters, the best results were obtained using topmost of 0.10%, with a sensitivity of 89% and a false-positive rate of only 1.4 per image. Since the set of images is limited this results could have been skewed.

Considering the complete set of images (DDSM and INBreast), a global sensitivity of 92% was registered with an average of 6.9 false positive per image, using a topmost of 0.10%.

4. Conclusion

The results show that the system is capable of detecting clustered microcalcifications in film-scanner settings with a sensitivity of 89%, considering an average of 6.9 false positive detections per image.

When the system was used in FFDM images from INBreast database the results were remarkably better with 89% of sensitivity and only 1.4 false-positive per image. This is associated with a better demarcation given by the database images, including isolated microcalcifications, and also better images quality. Unfortunately the INBreast database has few images determined with clustered microcalcifications (only 18 images) and lacking access to bigger databases with FFDM images limits to test with this type of mammography image as well as a more significant statistical evaluation.

Considering the complete set of images (both DDSM and INBreast) the sensitivity result is 92% and 6.9 false positive per image. The sensitivity value is comparable with ImageChecker (8), a commercial system with a sensitivity of 91% according to its manual.

The number of false-positives per image, on the other hand, is very large. ImageChecker has only 1.5 false-positives per image according to its manual.

In the presented scheme, most of these false-positives are caused by noise and natural breast structures that the system detects as calcifications. The difference in results shown by the set of images from DDSM and INBreast seems to represent that the improved image quality from a FFDM system seems to improve significantly our scheme performance, which is a promising result in this field.

It is important to point out that while the ImageChecker software was designed to work with a specific system developed together, our system was designed to work with any image acquisition hardware with little or even no changes in the system. Also, when using images with less noise (like FFDM images), it has shown results comparable to the best ones.
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References


