A MULTI-SCALE APPROACH TO THE
COMPUTER-AIDED DETECTION OF
MICROCALCIFICATION CLUSTERS IN
DIGITAL MAMMOGRAMS

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Abstract
A computer-aided detection (CADe) system for the identification of microcalcification clusters in digital mammograms has been developed. It is mainly based on the application of wavelet transforms for image filtering and neural networks for both the feature extraction and the classification procedures. This CADe system is easily adaptable to different databases. We report and compare the FROC curves obtained on the private database we used for developing the CADe system and on the publicly available MIAS database. The results achieved on the two databases show the same trend, thus demonstrating the good generalization capability of the system.

1 Introduction
Microcalcifications appear as small bright circular or slightly elongated spots embedded in the complex normal breast tissue imaged in a mammogram. Especially when they are grouped in clusters, microcalcifications can be an important early indication of breast cancer. Computer-aided detection (CADe) systems can improve the radiologists’ accuracy in the interpretation of mammograms by alerting them to suspicious areas of the image containing possibly pathological signs.

The main problem one has to deal with, in developing a CADe system for mammography, is the strong dependence of the method, of the parameters and of the performances of the system on the dataset used in the set-up and testing procedures. The approach we adopted for our CADe system is mainly based on the exploitation of the properties of the wavelet analysis and the artificial neural networks. The use of wavelets in the pre-processing step, together with
the implementation of an automatic neural-based procedure for the feature extraction, allows for a plan generalization of the analysis scheme to databases characterized by different acquisition and storing parameters.

2 CADe scheme

The CADe scheme can be summarized in the following main steps:

- **INPUT**: digitized mammogram;

- **Pre-processing of the mammogram**: identification of the breast skin line and segmentation of the breast region with respect to the background; application of a wavelet-based filter in order to enhance the microcalcification signal;

- **Feature extraction**: decomposition of the breast region in several $N \times N$ pixel-wide sub-images to be processed each at a time; automatic extraction of the features from each sub-image;

- **Classification**: clustering of the processed sub-images into two classes, i.e. those containing microcalcification clusters and the normal tissue$^1$;

- **OUTPUT**: merging of contiguous or partially overlapping sub-images and visualization of the final output by superimposing rectangles indicating suspicious areas to the original image.

3 Tests and results

The CADe system was set up and tested on a private database of mammograms collected in the framework of the INFN (Istituto Nazionale di Fisica Nucleare)-founded CALMA (Computer-Assisted Library for MAmmography) project [1]. The digitized images are characterized by a 85$\mu$m pixel pitch and a 12-bit resolution, thus allowing up to 4096 gray levels. The dataset used for training the CADe consists of 305 mammograms containing microcalcification clusters and 540 normal mammograms. The system performances on a test set of 140 CALMA images (70 with microcalcification clusters and 70 normal images) have been evaluated in terms of the FROC analysis [2] as shown in fig. [1]. In particular, as shown in the figure, a sensitivity value of 88% is obtained at a rate of 2.15 FP/im.

$^1$In this paper the tissue not containing microcalcification clusters is referred as normal breast tissue, i.e. in our notation this class of tissue can even accommodate regions of mammograms affected by the presence of different pathologies, such as opacities, massive lesions, etc.
In order to test the generalization capability of the system, we evaluated the CADe performances on the publicly available MIAS database [3]. Being the MIAS mammograms characterized by a different pixel pitch (50 µm instead of 85 µm) and a less deep dynamical range (8 bit per pixel instead of 12) with respect to the CALMA mammograms, we had to define a tuning procedure for adapting the CADe system to the MIAS database characteristics. A scaling of the wavelet analysis parameters allows the CADe filter to generate very similar pre-processed images on both datasets. The remaining steps of the analysis, i.e. the characterization and the classification of the sub-images, have been directly imported from the CALMA CADe neural software. The performances the rescaled CADe achieves on the images of the MIAS database have been evaluated on a set of 42 mammograms (20 with microcalcification clusters and 22 normal) and are shown in fig. 1. As can be noticed, a sensitivity value of 88% is obtained at a rate of 2.18 FP/im.

4 Conclusions

The implementation of the wavelet transform in the preprocessing step of the analysis and the use of an auto-associative neural network for the automatic feature extraction make our CADe system tunable to different databases. The main advantage of this procedure is that this scalable CADe system can be tested even on very small databases, i.e. databases not allowing for the learning procedure of the neural networks to be properly carried out. The strong sim-
ilarity in the trends of the FROC curves obtained on the CALMA and on the MIAS databases provides a clear evidence that the CADe system we developed can be applied to different databases with no sensible decrease in the detection performance.

References

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