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Development of intelligent systems based on Bayesian regularization network and neuro-fuzzy models for mass detection in mammograms: A comparative analysis

*Hela Mahersia**, *Hela Boulehmi*, *Kamel Hamrouni*

LR – Signal, Images et technologies de l'information, Ecole Nationale d'Ingnieurs de Tunis, Universit Tunis El Manar, BP37, 1002 Tunis, Tunisia

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A B S T R A C T

Female breast cancer is the second most common cancer in the world. Several efforts in artificial intelligence have been made to help improving the diagnostic accuracy at earlier stages. However, the identification of breast abnormalities, like masses, on mammographic images is not a trivial task, especially for dense breasts.

In this paper we describe our novel mass detection process that includes three successive steps of enhancement, characterization and classification. The proposed enhancement system is based mainly on the analysis of the breast texture. First of all, a filtering step with morphological operators and soft thresholding is achieved. Then, we remove from the filtered breast region, all the details that may interfere with the eventual masses, including pectoral muscle and galactophorous tree. The pixels belonging to this tree will be interpolated and replaced by the average of the neighborhood. In the characterization process, measurement of the Gaussian density in the wavelet domain allows the segmentation of the masses. Finally, a comparative classification mechanism based on the Bayesian regularization back-propagation networks and ANFIS techniques is proposed. The tests were conducted on the MIAS database. The results showed the robustness of the proposed enhancement method.

1. Introduction

Breast cancer is the second most common cancer in the world, and, by far, the most frequent form of malignancy affecting women worldwide with 1.67 million new cases diagnosed in 2012 (25% of all cancers). According to the world health organization's report, GLOBOCAN 2012, the estimated incidence rates vary across the world regions, with rates ranging from 27 per 100.000 in Middle Africa and Eastern Asia to 96 in Western Europe [19]. Fortunately, earlier detection and more effective treatments have contributed to maintain relatively constant rates of the breast cancer mortality during the last decades.

* *Corresponding author.* Tel.: +216 55354049.
E-mail addresses: helamahersia@enit.rnu.tn (H. Mahersia), hela.boulahmi@yahoo.fr (H. Boulehmi), kamelhamrouni@enit.rnu.tn (K. Hamrouni).

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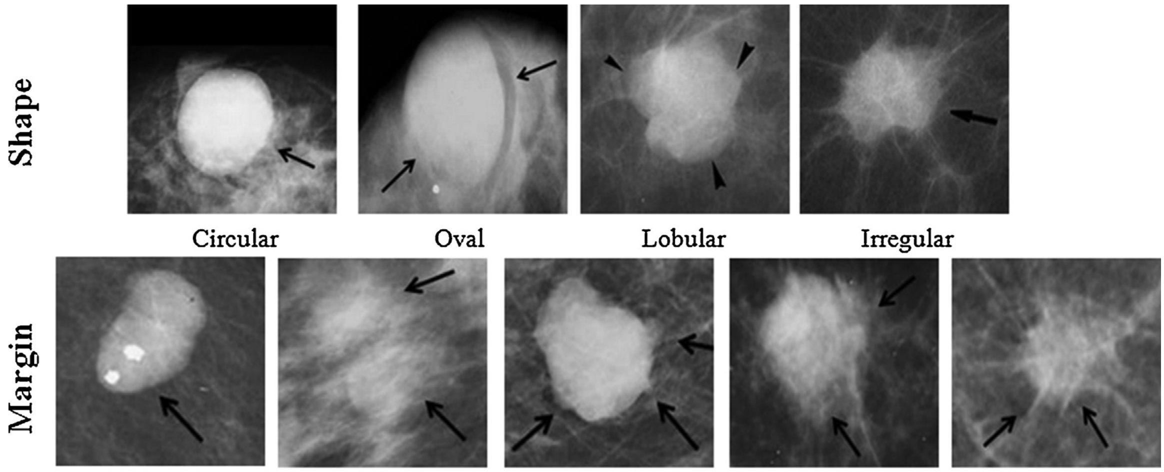

Fig. 1 – Terminology used to describe masses.

Early detection imposes that postmenopausal women and women with family antecedent must be subjected to a regular mammography every two years. Mammographic screening is the most popular method at present for breast cancer detection. It provides adequate evidence of abnormality and can detect between 85% and 90% of all nodules corresponding to breast cancer [55]. Vacek et al. show in [55] that the proportion of breast tumors that were detected by screening mammography in Vermont [58], increased from 2% between 1974 and 1984 to 36% between 1995 and 1999.

There are several forms of abnormality that may affect breast tissue. These abnormalities are often classified into two families: the masses and the micro-calcifications. Nevertheless, it is generally accepted that mass detection is a more challenging problem than the detection of micro-calcifications, not only for the large variation in size and shape in which masses can appear in a mammogram but also because masses often exhibit poor image contrast. Breast masses are then more difficult to identify and mass detection continues to challenge both radiologists and researchers [1,53].

A breast mass, also called opacity, is a localized sign of breast cancer and defined as a space-occupying lesion seen in at least two different projections [57]. Masses are often characterized by their size, shape, margin, and associated features (architectural distortion, contrast). The most significant features that indicate whether a mass is benign or malignant are its shape and margins. Generally, the shape can be round, oval, lobular, or irregular. Circumscribed oval and round masses are usually benign. An irregular shape suggests a greater likelihood of malignancy.

The margins can be described as circumscribed, microlobulated, obscured (partially hidden by adjacent tissue), indistinct (ill-defined), or spiculated (characterized by lines radiating from the mass). Typical examples of benign circumscribed masses are cysts and fibroadenomas [3]. Fig. 1 shows different masses according to their shapes and margins. Usually, the malignant mass will appear whiter than any tissue surrounding it. According to Basset et al., masses with irregular shapes and indistinct or spiculated margins have a higher likelihood of malignancy. Nonetheless, a small number of cancers may exhibit a round shape and relatively circumscribed margins [3].

Different studies have demonstrated that Computer Aided Diagnosis (CAD) of breast cancer can improve the detection rate from 80% to 90% compared to radiologists whose judgments depend on training, experience, and subjective criteria.

It is not surprising that even well-trained experts may have an inter-observer variation rate of 65–75%. In [44], the authors confirm that 65–90% of the biopsies of suspected cancer turned out to be benign. Hence, it is extremely important to combine CAD schemes and experts' knowledge to improve the detection accuracy and avoid unnecessary biopsies. Various CAD systems have been proposed for improving the breast cancer diagnosis. A review of existing literature in this area is presented in Section 2.

2. Related works

The main objective of CAD systems is to assist the radiologist in different analysis steps, such as the detection of lesion's boundary, the extraction of robust features, the classification into different types of abnormalities, the visualization, the storage, the database management, etc. [12,13,18,6]. Researchers are then becoming more and more concerned with the elaboration of automated CAD systems for breast abnormalities. Thus, several studies have been carried out about breast cancer and different recognition systems using image processing, and including, different intelligent techniques for mass segmentation have been proposed.

In this context, segmentation techniques used in literature can be divided into unsupervised and supervised approaches.

Unsupervised segmentation partitions an image into a set of regions which are distinct and uniform with respect to homogeneous properties (such as texture, gray level or color). Classical approaches to solving unsupervised segmentation