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Detection and classification of masses in mammographic images in a multi-kernel approach

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ABSTRACT

Background and Objective: According to the World Health Organization, breast cancer is the main cause of cancer death among adult women in the world. Although breast cancer occurs indiscriminately in countries with several degrees of social and economic development, among developing and underdevelopment countries mortality rates are still high due to low availability of early detection technologies. From the clinical point of view, mammography is still the most effective diagnostic technology, given the wide diffusion of the use and interpretation of these images.

Methods: Herein this work we propose a method to detect and classify mammographic lesions using the regions of interest of images. Our proposal consists in decomposing each image using multi-resolution wavelets. Zernike moments are extracted from each wavelet component. Using this approach, we can combine both texture and shape features, which can be applied both to the detection and classification of mammary lesions. We used 355 images of fatty breast tissue of IRMA database, with 233 normal instances (no lesion), 72 benign, and 83 malignant cases.

Results: Classification was performed by using SVM and ELM networks with modified kernels in order to optimize accuracy rates, reaching 94.11%. Considering both accuracy rates and training times, we defined the ration between average percentage accuracy and average training time in a reverse order. Our proposal was 50 times higher than the ratio obtained using state-of-the-art approaches.

Conclusions: As our proposed model can combine high accuracy rate with low learning time, whenever a new data is received, our work will be able to save a lot of time, hours, in learning process in relation to the best method of the state-of-the-art.

1. Introduction

Breast cancer is the leading cause of cancer death of women around the world, both in developed and underdevelopment countries [1]. According to the World Health organization (WHO), in 2012, about 1.7 million new cases of breast cancer emerged in the world [1]. Additionally, breast cancer is the most common type of cancer in 140 countries of a total of 182 evaluated nations [1]. The incidence of breast cancer increased 20% between the years 2008 and 2012, as well as mortality rates augmented by around 14% [1].

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According to Brazil's National Institute of Cancer, approximately 30% of cases of breast cancer could be prevented with simple measures such as the adoption of a balanced diet, regular physical activity, and maintenance of the ideal weight [2]. However, the industrial way of life has been contributing for unhealthy lifestyles and obesity increasing, especially in urban and industrialized countries, which is intrinsically related to increasing breast cancer incidence rates in the next decades [1].

Although the amount of breast cancer cases in economically developed regions is increasing, mortality is decreasing due to the availability of early detection technologies, from self-examination campaigns to image-based diagnostic technologies, especially mammography [1].

In underdevelopment countries, however, the increasing incidence of breast cancer has been accompanied by the augment of the mortality rates. In East Africa, the incidence is 30 new cases per 100 women per year, while in Western Europe and industrialized, economically developed regions of the world, the incidence of breast cancer has reached more than 90 new cases for each group of 100 women per year [1]. The mortality rates, however, are almost identical in these two regions, about 15 per 100 women [1]. One of the causes is that patients from East Africa do not have easy access to image diagnosis. Therefore, breast cancer is usually detected in advanced stages. Additionally, this fact may lead to the need of mastectomies, mutilating surgeries in which the suspicious mammary tissue is completely removed [3]. Consequently, in order to promote early detection of breast cancer, self-examination by touch is not sufficient: availability of imaging diagnosis technologies is fundamental once, in some cases, tumors take about 10 years to become palpable [3].

By the importance of breast imaging techniques, professional radiologist experience assumes a crucial role at finding and interpreting clinical data and developing accurate diagnosis. This is a particularly complex task due to the wide variability of cases, where many do not accurately fit in classical models and descriptions [4].

Particularly, there is a large difficulty about interpreting masses in noisy images such as those resulting from a mammography acquisition [5,6]. Furthermore, several studies indicate that over than 70% of breast cancer biopsy surgeries returns benign findings [7–9]. In order to turn diagnosis less susceptible to errors, several decision support systems have been developed to aid at the detection and classification of mammary lesions by analyzing mammographic images, once mammography is still the most effective clinical method for the early detection of breast cancer [3]. Decision support systems can be important allies of health professionals in order to perform accurate diagnostic decision making.

The task of detect and classify mammary lesions using mammograms is highly dependent on the feature extraction stage, in which the regions of interest, clinically determined by using specialist knowledge, are pre-processed, and moments, statistics, and other measures are extracted. In breast cancer applications, the use of texture descriptors combined with segmentation methods is very common. However, more complex pre-processing approaches have being used in order to reach higher classification rates by modifying feature dimensionality. One of the most successful techniques is the series of wavelets: each image of region of interest is decomposed by a series of details images with different resolutions and a reduced and simplified version of the original image [10]. Features are extracted from these image components. Several works point this multi-resolution approach as able to detect mammary lesions and, in some cases, classify them as benign or malignant findings, with successful differentiation of the suspicious lesion and the mammary tissue [10].

Zernike moments have been widely used to perform mass shape analysis [11,12]. The lesion shape is essential for the determination of the malignancy degree of mammary lesions [13].

Herein this work, we propose a methodology to detect and classify mammographic images by using multi-resolution wavelets decomposition and Zernike moments, without the needing of manual segmentation or adjustment, in the feature extractor stage, and kernel-based neural networks, namely Support Vector Machines (SVM) [14] and Extreme Learning Machines (ELM) [15], in the classification stage. We investigated the use of the more widespread wavelets and how they could affect detection and classification performance, particularly the classification rate and the training time. We varied neural networks kernels as well. We claim that the combination of multi-resolution wavelets and Zernike moments can mix texture and shape features, improving image representation for the classification stage. We also claim that the use of SVM and ELM furnish accurate classifiers just varying the kernels of the hidden layer neurons in order to optimize classification accuracy.

For the experiments, we used the classification criteria for mammographic images defined according to the American College of Radiology, described on BIRADS (Breast Imaging Reporting and Data) [13]. The goal of BIRADS is to group the cases into three classes: normal (i.e. without cancer), benign and malignant lesion. We used 355 images of fatty breast tissue of IRMA database [16], with 233 normal instances, 72 benign, and 83 malignant cases. We generated synthetic instances of benign and malignant cases using linear combinations with random weights in order to balance our database, getting a final amount of 699 instances, with 233 instances for each class. Classification was performed using SVM and ELM networks with modified kernels in order to optimize accuracy rates, reaching 94.11%.

Learning is usually a time consuming affair as it may involve many iterations through the training data [17], involving cross-validation combining with different random initial conditions, testing different modified kernels (learning functions), and different initial weights of layers neurons when neural networks are employed as learning technique. Also, whenever a new data is received, batch learning uses the past data concatenated with the new data and performs a retraining, thus consuming a lot of time [17]. Furthermore, long time is necessary in order to process the new image cases on the feature extraction stage. A solution in order to reduce the training time is the online learning which is only necessary to processing and training the new data (images) without retraining the past data. Online learning, however, shows lower accuracy results than batch learning in all studied cases [17].

Our proposed model can combine high accuracy rate with low learning time in a batch learning approach. Considering both accuracy rates and training times, we defined the ration between average percentage accuracy and average training time