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Method of differentiation of benign and malignant masses in digital mammograms using texture analysis based on phylogenetic diversity☆

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ABSTRACT

Breast cancer is a disease resulting from the multiplication of abnormal breast cells, which form masses. Every year, breast cancer kills more than 500,000 women around the world. In 2015, 570,000 women died of breast cancer. When detected early, the five-year survival rate for breast cancer exceeds 80% of cases. Early diagnosis of breast cancer is critical for the survival of the patient. Screening by mammography is the most promising means for early diagnosis. This article presents a method of classifying malignant and benign breast tissue using digital mammography exams. This method employs texture descriptors from all image regions, including to the inner regions. This approach enables a more detailed texture description of the analyzed region of interest. The feature extraction is based on phylogenetic indexes. Then, classification is conducted using multiple classifiers. Experiments are performed to verify the performance of the proposed method. Results show that the method achieves 99.73% accuracy, 99.41% sensitivity, 99.84% specificity, and a receiver operating characteristic (ROC) curve with a value of one when using images of the Digital Database for Screening Mammography. An accuracy of 100% is achieved when using the Mammography Imaging Analysis Society image database. The use of phylogenetic indexes to describe patterns in regions of mammography images in both external and internal areas is thus effective in the categorization of malignant and benign tumors, thereby making the proposed method a robust tool for specialists.

1. Introduction

Cancer is a group of more than 100 diseases that have in common the uncontrolled growth of cells that invade tissues and organs. Breast cancer alone accounts for 30% of all new cancer diagnoses in women. It is formed by the disordered multiplication of cells, which form a malignant or benign tumor. The malignant tumor is a cluster of cancer cells that can invade adjacent tissues or spread to other parts of the body. One of the main risk factors of breast cancer is aging. This cancer is most often detected in women of menopause age. Early detection of breast cancer can increase the chances of treatment and curing in most cases. The detection is

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enabled by digital mammography performed on patients who do not have signs or symptoms of the disease. With the use of digital mammography for breast cancer detection, a reduction in mortality rates is observed [1].

Several factors may influence the exam sensitivity and affect the image quality. These factors can result in possible diagnostic errors by the radiologist in 10%–30% of cases [2]. In the medical field, the use of imaging is an essential resource for the diagnosis of anomalies. Studies on digital image processing have evaluated requirements for extracting technical information, thereby improving the parameters needed for more accurate diagnosis. Accordingly, the interpretation of mammography images can be improved.

To advance medical diagnostics through imaging, several computer-aided detection (CADe) and computer-aided diagnosis (CADx) systems have been developed. Image analysis manually performed by a specialist is very complicated and mainly involves use of low-contrast digital mammography. The possibility exists that some structures will remain masked in the image on account of visual fatigue by the specialist [3]. CADe and CADx systems are therefore crucial for cases in which detection is very difficult to the human eye.

In most CADx methodologies, the feature extraction step is based on 1) shape, which characterizes the geometry of objects; and 2) texture To characterize the breast tissue, we only use texture descriptors. Only texture characteristics are used for several reasons. For one, texture analysis is a complex task, even for the expert, since small differences in contrast in some tissues may be unobserved by human eyes. Secondly, texture analysis is essential for digital images because it enables exploration of image regions that have the same characteristic patterns. For this task, we use phylogenetic diversity indexes, that are, 1) pure diversity or phylogenetic diversity; 2) the sum of the phylogenetic distances; 3) the mean nearest neighbor distance; 4) the phylogenetic species variability; and 5) the phylogenetic species richness.

In summary, this work contributes to several areas. For the medical field, we provide a developed automatic breast tissue diagnosis system through texture analysis of the whole region of the image, starting from the external regions of the image and extending to the inner regions. For the field of computer science, we contribute the use of texture measures based on phylogenetic analysis, as well as the use of phylogenetic trees for characterization of breast tissue.

The remainder of this paper is organized as follows. In Section 2, we present related works. In Section 3, we describe the proposed method that is used to classify malignant and benign breast tissues. In Section 4, the results, discussion, and comparisons with other works are provided. Finally, the conclusions presented in Section 5.

2. Related works

Several studies have been conducted to increase the accuracy rates of CADx systems in determining if breast tissue is malignant or benign for the diagnosis of breast cancer. Table 1 we present the summaries of related works.

The problem thus remains of improving the diagnosis technique, such as making it more efficient for use in CADx systems, which can help reduce the interpretation variability. The use of CAD systems in medicine have improved decision-making based on medical experience. CADe and CADx systems have shown a positive impact on the early detection of breast cancer [14]. The development of techniques for extracting texture characteristics in images can thus aid experts in making more accurate diagnoses. The present work, therefore, is intended to classify masses as malignant or benign based on the behaviors of species within a community, such as a relationship between species and their richness, i.e., how many pixels a particular species has.

Table 1
Summary of related works.

Work	Descriptors, techniques and classifier	Sample
[4]	The features are extracted using the gray-level co-occurrence matrix (GLCM) and Zernike moments. The classification is made with artificial neural networks.	51
[5]	Presented a method for feature extraction of grayscale texture from the mammographic patch. The classification is made using the support vector machine (SVM) classifier.	137
[6]	Features extracted with a discriminating texton are used for both the central region and edge region of the mass. The classification is performed using the k-nearest-neighbor classifier.	130
[7]	Features are extracted by the region of interest (ROI) identification with irregular shapes using a sparse matrix. Classification is conducted using a multi-SVM.	322
[8]	A method is presented that uses texture characteristics of radial local ternary patterns (RLTPs). The classification is performed using an ANN, SVM and random forest (RF).	376
[9]	Geometric, border, and texture characteristics are used to classify the masses. The classification is performed using different classifiers.	332
[10]	Use the discriminative robust local binary pattern and discriminative robust local ternary pattern for texture feature extraction. The classification is performed by the Fisher linear discriminant analysis method.	58
[11]	The resource extraction method is intended to capture the characteristics defined for each margin type. Images are retrieved from reference cases using a set of SVMs that can assess the edge probability and pathology type in the input samples.	400
[12]	Evaluates image similarity measures. CADe was developed for content-based retrieval and mass screening for screening of mammograms. The study showed that measures of similarity fit into one of two categories.	1820
[13]	Exclusively utilizes texture analysis to describe mass characteristics in digitized mammograms. To increase the efficiency of texture feature extraction the ability of the diversity index is used to detect co-occurrence patterns of species. For this, the Gleason and Menhinick indices are used.	300
Our work	**Texture descriptors based on phylogenetic diversity and multiple classifiers.**	**1,155**

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