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Fuzzy cluster based neural network classifier for classifying breast tumors in ultrasound images

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ABSTRACT

The performance of supervised classification algorithms is highly dependent on the quality of training data. Ambiguous training patterns may misguide the classifier leading to poor classification performance. Further, the manual exploration of class labels is an expensive and time consuming process. An automatic method is needed to identify noisy samples in the training data to improve the decision making process. This article presents a new classification technique by combining an unsupervised learning technique (i.e. fuzzy c-means clustering (FCM)) and supervised learning technique (i.e. back-propagation artificial neural network (BPANN)) to categorize benign and malignant tumors in breast ultrasound images. Unsupervised learning is employed to identify ambiguous examples in the training data. Experiments were conducted on 178 B-mode breast ultrasound images containing 88 benign and 90 malignant cases on MATLAB® software platform. A total of 457 features were extracted from ultrasound images followed by feature selection to determine the most significant features. Accuracy, sensitivity, specificity, area under the receiver operating characteristic curve (AUC) and Mathew's correlation coefficient (MCC) were used to access the performance of different classifiers. The result shows that the proposed approach achieves classification accuracy of 95.862% when all the 457 features were used for classification. However, the accuracy is reduced to 94.138% when only 19 most relevant features selected by multi-criterion feature selection approach were used for classification. The results were discussed in light of some recently reported studies. The empirical results suggest that eliminating doubtful training examples can improve the decision making performance of expert systems. The proposed approach show promising results and need further evaluation in other applications of expert and intelligent systems.

1. Introduction

Breast cancer is one of the major causes of cancer deaths in women worldwide, accounting for greater than 1.6% of the total deaths (Tata Memorial Centre, Breast Cancer Information, 2015). Mammography and Ultrasound are the most common screening methods that are used to detect breast cancer at early stages. In this study, ultrasound images are used since it has no radiation or compression unlike mammography. The images obtained from the ultrasound machine suffers from major shortcomings such as low resolution, low contrast and blurred edges due to the presence of speckle noise and acoustic shadowing. Therefore, the interpretation and diagnosis of breast tumors in ultrasound image is very difficult and highly operator dependent. At present, biopsy is the only pathological test which is used to determine whether the tumor is cancerous or not. However, it is time consuming, tiresome and painful procedure.

1.1. Origin of the problem

Computer Aided Diagnosis (CAD) systems have been coming out as a second choice for automatic classification of breast cancer that can reduce the effect of the operator dependent nature intrinsic in ultrasound imaging (Tang, Agaian, & Thompson, 2014). Appropriate choice of classifier is of important concern in any CAD system. It should be sturdy and capable of tolerating ambiguities. Its performance is highly dependent on the quality of training set. In real time scenario, the training data may contain some doubtful class labels arising due to overlapping of benign and malignant tissues in ultrasound images, human judgment, intra class variations, diagnostic errors, etc. Such situations may result in the non separability of benign and malignant tumors. Thus, in order to improve

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the classification performance, the training samples with doubtful class labels should be automatically identified and ignored in the training phase of the classifier. To address this challenge, a new approach to classify benign and malignant breast tumors in ultrasound images is proposed in this paper. The proposed approach uses a combination of fuzzy c-means clustering (FCM) and back-propagation artificial neural network (BPANN) to classify the breast tumor. The performance of the proposed technique is compared with that of BPANN and support vector machine (SVM) as well as with some of the recently reported studies.

1.2. Related work

This section reviews some of the recent works reported in the related area. A CAD system for classifying malignant and benign breast tumors using 19 morphological features is proposed in Huang et al. (2008). The ultrasound image dataset consisting of 34 malignant and 84 benign cases was used in the experiments. Principal component analysis (PCA) was used to select relevant features and SVM with 10-fold cross validation was used for classification. In Yap, Edirisinghe, Bez and Pluim (2009)), a comparative study of PCA, two dimensional linear discriminant analysis (LDA) and SVM in classifying breast ultrasound image is conducted. Area to perimeter ratio, solidity, convexity, elongation, extent, aspect ratio, compactness, roundness, form factor, max/min radii, texture features and edge descriptors were used as features. The results demonstrated that SVM outperformed other classification techniques with respect to different performance measures.

A technique to find the most pertinent morphometric features for classifying breast tumors in ultrasound images is reported in Pereira, Alvarenga and Infantosi (2010). The database consisting of 177 malignant and 69 benign tumors were used in experiments. Tumor contour was approximated by semi-automatic contour based on morphological operators. LDA, step wise LDA and mutual information were used to rank features and determine the most significant features. The individual features were evaluated using area under receiver operating characteristics (ROC). The results indicated that normalized residual mean square error and circularity are the most significant features in distinguishing malignant from benign tumors.

A classification technique based on fuzzy SVM to characterize masses in breast ultrasound images is proposed in Shi, Cheng, Hu, Ju and Tian (2010). A small dataset of 36 malignant and 51 benign cases was used. Raw images were first enhanced using multi-peak generalized histogram equalization. Then segmentation was carried out using Markov random field (MRF) / Gibbs random field (GRF). Texture, fractal and histogram based features were used to classify breast masses using fuzzy SVM. The proposed approach achieved an area under ROC of 0.964. Classification of breast tumors using SVM with radial basis function (RBF) kernel and texture features is reported in Liu et al. (2010).

In Chen, Huang and Lin (2011), image retrieval techniques based on Euclidean distance are used to classify the breast tumor. Measures of variance and roughness along with features from 2-dimensional normalized auto-covariance coefficients, spatial gray level dependence matrices, gray level difference matrix and neighborhood gray tone difference matrix were extracted. PCA was used for vector dimension reduction. Proposed system was evaluated using k-fold cross validation method. Area under the ROC was used as a performance measure. Its value was found to be 0.925.

An unsupervised classifier for automatic detection and classification of breast tumors in ultrasonic images using texture and morphological features was developed in Su, Wang, Jiao and Guo (2011). Analysis and evaluation of co-occurrence texture statistics as a function of gray level quantization for classifying breast ultrasound using Fisher linear discriminant analysis (FLDA) is conducted in Gomez, Pereira and Infantosi (2012). A combination of genetic algorithm and SVM for classification of breast tumors in ultrasound images using texture and morphological features is proposed in Wu, Lin and Moon (2012). A computer aided lesion diagnosis in automated 3-D breast ultrasound using coronal speculation is proposed in Tan et al. (2012). In Zhou, Shi, Zhu, Cai and Wang (2013) a method to extract texture feature descriptors by shearlet transform for classification of breast tumors is proposed. SVM and AdaBoost classifiers were used to evaluate the consistency of texture features. A multi cluster feature selection approach to determine most relevant features for classification of benign and malignant tumors using the sparse representation classifier is reported in Nayeem, Joadder and Shetu (2014).

In Kim et al. (2014) SVM classifier is used to classify 89 (20 cysts, 42 benign and 27 malignant lesions), 2-dimensional breast ultrasound images. Otsu's threshold method was used for lesion detection. Eighteen features were used to determine whether the detected mass was benign or malignant. A novel CAD method for the classification of benign and malignant breast lesions using biclustering learning technique is reported in Zhang, Chang, Liu, Li and Huang (2014). In this technique, biclusters obtained from biclustering learning were used as a training set for k-nearest neighbour classifier (k-NN classifier). A comparative study of SVM and bootstrap aggregating (bagging) in classifying benign and malignant breast masses using ultrasound images is reported in Wahdan, Saad and Shoukry (2014). Sixteen texture features were extracted from 107 ultrasound images. PCA was used for eliminating unimportant features and dimensionality reduction of feature space. The reduced set of features was then used to classify breast tumors using SVM and bootstrap aggregating.

The following limitations are found in aforementioned studies: (1) the performance of classification algorithms is highly dependent on features extracted from breast patterns since they are used to train the classifier model. Further, large number of features present redundant information to the classifiers which in turn increases the computational complexity. The majority of the reported works relies on one or two evaluation criteria for feature selection that has shown restricted capability in decision support system due to their biases towards single criterion. Hence, multiple criteria have been adopted in this study to select the optimal set of features; (2) none of the reported works have discussed about handling of ambiguous samples in the training data. Ambiguous samples may affect the training performance adversely thereby decreasing the diagnostic accuracy. Thus, the classifier adopted should be able to identify and eliminate such doubtful training samples before building the classifier model. Further, it should be able to reduce false positives and false negatives in classification. Therefore, a combination of FCM and BPANN is employed in this study; (3) there is no way to compare new methodologies due to lack of open access to the reported datasets or benchmark. From literature review, it is found that SVM is most frequently used classifier for classification of breast tumors in ultrasound images. Thus, we compared the performance of proposed approach with that of SVM and traditional BPANN. Further, we also compare the performance of proposed approach with that of some recently reported studies.

1.3. Contribution and Outline of the paper

The major contribution of this paper is to develop a method to identify and eliminate doubtful training samples to improve performance of the classifier. The proposed approach demonstrates significant improvement in classification accuracy as compared to conventional methods. Additionally, we review and demonstrate the performance of state of art feature selection techniques in determining relevant features for breast tumor classification. The pa-