Ultrasound Breast Tumor Image Computer-Aided Diagnosis With Texture and Morphological Features[1]

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Rationale and Objectives. Computer-aided diagnosis (CAD) systems based on shape analysis have been proved to be highly accurate in evaluating breast tumors. However, it takes considerable time to train the classifier and diagnose breast tumors, because extracting morphologic features require a lot of computation. Hence, to develop a highly accurate and quick CAD system, we combined the texture and morphologic features of ultrasound breast tumor imaging to evaluate breast tumors in this study.

Materials and Methods. This study evaluated 210 ultrasound breast tumor images, including 120 benign tumors and 90 malignant tumors. The breast tumors were segmented automatically by the level set method. The autocovariance texture features and solidity morphologic feature were extracted, and a support vector machine was used to identify the tumor as benign or malignant.

Results. The accuracy of the proposed diagnostic system for classifying breast tumors was 92.86%, the sensitivity was 94.44%, the specificity was 91.67%, the positive predictive value was 89.47%, and the negative predictive value was 95.65%. In addition, the proposed system reduced the training time compared to systems based only on the morphologic analysis.

Conclusions. The CAD system based on texture and morphologic analysis can differentiate benign from malignant breast tumors with high accuracy and short training time. It is therefore clinically useful to reduce the number of biopsies of benign lesions and offer a second reading to assist inexperienced physicians in avoiding misdiagnosis.

Key Words. Ultrasound; breast tumors; texture analysis; morphologic analysis; SVM

Because of changing lifestyles and the polluted environment, the mortality rate for malignant tumors has had the highest rank of major causes of death in recent years. Breast cancer is the most common cancer in women. According to 2003 statistics, 211,300 women are expected to be diagnosed with this disease, and only lung cancer causes more death in women (1). Because of such a high incidence, breast cancer must be studied.

To reduce the mortality rate and extend patients' lives, early detection and prompt treatment for breast cancer are very important. Detection of breast cancer usually consists of physical examination, imaging, and biopsy (2). Although biopsy is the best way to accurately determine whether a tumor is benign or malignant, it is invasive and costs much more than other detection methodologies. Moreover, most biopsies are avoidable because the probability of positive findings at biopsy for cancer is very low, between 10 and 31% (3–5). To avoid unnecessary biopsy, many researchers have investigated computer-aided diagnosis (CAD) systems based on medical imaging (4–8). The aim of these CAD systems is to offer more objective evidence and increase the physician's diagnostic confidence.

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Ultrasound is the most popular technique in medical imaging due to its lower cost, high efficacy, and real-time scanning. It provides a convenient and radiation-free diagnostic method. However, there is a considerable overlap between benignancy and malignancy on ultrasonic images, and interpretation is subjective. In 1995, Stavros et al. (9) showed that the sensitivity of breast ultrasound for malignancy is 98.4%, the specificity is 67.8%, and the overall accuracy is 72.9%. These diagnostic results were achieved by experienced radiologists.

Many kinds of features of ultrasound breast tumor images have been presented to distinguish benign tumors from malignant ones, including texture (8,10), speckle (11), and shape (7,9). Texture and speckle features are extracted easily but are usually affected by the region of interest (ROI), which is drawn by physicians. In other words, the difference of the ROI in the same breast tumor image will produce different texture and speckle features. Shape features, which are also called morphologic features, are also effective features to evaluate breast tumors. Although they will be not affected by ROI, extracting morphologic features usually requires a lot of computation. Hence, training a CAD system will usually take a lot of time. Because texture and morphologic features can be used to evaluate breast tumors, we wanted to combine the two kinds of features to construct a quick and effective breast tumor CAD system in this study.

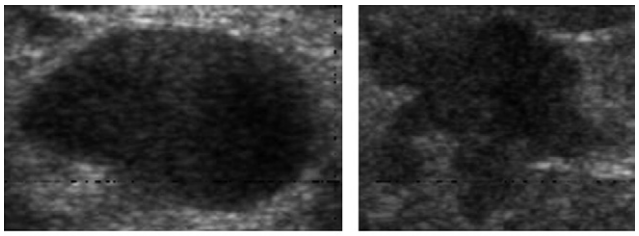
In this study, we first used some image preprocessing methods to remove noise and enhance the contrast of an ultrasound image. Second, a level set approach was used to segment a tumor, and then morphologic and texture features of the tumor were calculated to be the criteria of evaluation. Finally, a support vector machine (SVM) (11–15) was used to evaluate the breast masses.

MATERIALS AND METHODS

Data Acquisition

The ultrasound imaging system we used was the ATL HDI 3000 (Philips Medical Systems, Bothell, WA) with an L10-5 small part transducer. The L10-5 transducer is a linear-array transducer with a frequency of 5 to 10 MHz and a scan width of 38 mm. When acquiring images, patients were in supine position with arms extended overhead. No acoustic standoff pad was used with any of the cases.

There were a total of 210 ultrasound images of pathologically proven benign breast tumors from 110 patients as well as malignant tumors from 90 patients in our ultrasound image database for training and evaluation. All of the ultrasound images were supplied by one of the authors (W.K.M.) and were consecutively collected from August 1, 1999, through May 31, 2000. Patients' ages ranged from 18 to 64 years, and only one image for each patient was contained in the database.



a. **b.**

Figure 1. Two ultrasound breast tumor images: (**a**) benign tumor and (**b**) malignant tumor.

To simplify and speed up the process, we selected the small ROI that included the tumor. Then, the monochrome ultrasonic images were quantitized into 8 bits (ie, 256 gray levels), and the features were stored via magneto-optical (MO) disks, so that they could be read and analyzed on a personal computer and serve as our experimental data. Note that all solid nodules at ultrasonography were classified as C3 according to the American College of Radiology (ACR) Breast Imaging Reporting and Data System (BI-RADS), and all images were fed into the algorithm without selection bias.

Feature Extraction

Because texture and morphologic features can be used to distinguish benign from malignant tumors, we combined these two features to evaluate breast tumors in this study. Both the morphologic and texture features are discussed, respectively, in the following sections.

Morphologic Features

Figure 1 shows the ultrasound images of both benign and malignant tumors. Generally speaking, the shape of a benign tumor is smoother than the border of a malignant tumor. According to this observation, we evaluated breast tumors based on their shape. In Chang et al. (7), six morphologic features proved to be effective in classifying breast tumors. These features include factor, roundness, aspect ratio, convexity, solidity, and extent. However, extraction of these six morphologic features requires a lot of computation. In other words, it will take a lot of time