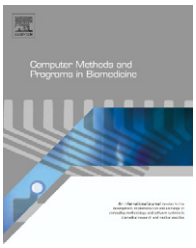
COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 106 (2012) 234–248

journal homepage: www.intl.elsevierhealth.com/journals/cmpb



Mammogram retrieval on similar mass lesions

Chia-Hung Wei[a,*], *Sherry Y. Chen*[b], *Xiaohui Liu*[b]

[a] *Department of Information Management, Ching Yun University, Taiwan*
[b] *School of Information Systems, Computing and Mathematics, Brunel University, UK*

ARTICLE INFO

Article history:
Received 4 January 2010
Received in revised form
3 August 2010
Accepted 3 September 2010

Keywords:
Content-based image retrieval
Breast cancer
Mammography

ABSTRACT

Enormous numbers of digital mammograms have been produced in hospitals and breast screening centers. To exploit those valuable resources in aiding diagnoses and research, content-based mammogram retrieval systems are required to effectively access the mammogram databases. This paper presents a content-based mammogram retrieval system, which allows medical professionals to seek mass lesions that are pathologically similar to a given example. In this retrieval system, shape and margin features of mass lesions are extracted to represent the characteristics of mammographic lesions. To compare the similarity between the query example and any lesion within the databases, this study proposes a similarity measure scheme which involves the hierarchical arrangement of mammographic features and a weighting distance measure. This makes similarity measure of the retrieval system consistent with the way radiologists observe mass lesions. This study used the DDSM dataset to evaluate the effectiveness of the extracted shape feature and margin feature, respectively. Experimental results demonstrate that, when Zernike moments are used, round-shape masses are the most discriminative among four types of shape; the circumscribed-margin masses can be effectively discriminated among the four types of margins. Moreover, the result also shows that, when retrieving round-shape and circumscribed margin masses, this retrieval system can achieve the highest precision among all mass lesion types.

1. Introduction

Breast cancer is the most common cancer among women. In the UK breast cancer accounts for 30% of all female cancer patients and approximately 1 in 9 women may suffer from breast cancer sometime during their life [1]. Although breast cancer is fatal if left untreated, patients do have high chance of survival if malignancy is detected at early stage. As a result, women over the age of 40 are recommended to receive regular mammography screening, which is a reliable method for the detection of breast cancer [2]. This makes enormous the number of digital mammograms have been produced in hospitals and breast screening centers. To exploit those valuable resources in aiding diagnoses and research, content-based mammogram retrieval systems are required to effectively access the mammogram databases. In clinical practice, an image retrieval system should be able to support the usual comparisons made on images by physicians, answering similarity queries over the images stored in the database. In addition to diagnosis, there are other medical or clinical contexts that would require the retrieval of similar cases from medical image databases, and need image retrieval systems to perform those search tasks. The aim of this paper is to propose a content-based mammogram retrieval system, which allows medical professionals to seek images that are patho-

* *Corresponding author*. Tel.: +886 3 4581196x7319.
E-mail address: roger773wei@yahoo.com (C.-H. Wei).
0169-2607/$ – see front matter © 2010 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.cmpb.2010.09.002

logically similar to a given example. The main contributions of this paper are summarized below:

(1) A set of methods are proposed for preprocessing mammograms and extracting mass features based on the definitions of BI-RADS standards. Those features represent mammographic meanings for describing the characteristics of mass lesions.
(2) A similarity measure scheme including the hierarchical arrangement of mammographic features and a weighting distance measure is proposed, which incorporates the manner of human vision for image matching and takes medical meanings of features into considerations.

2. Literature review

2.1. Existing CBIR mammogram systems

Although content-based image retrieval (CBIR) has frequently been proposed for use in medical image management, only a few content-based retrieval systems have been developed specifically for medical images, such as the ASSERT system [3,4] and NHANES II project [5,6]. These research-oriented systems are usually constructed in research institutes and continue to be improved, developed, and evaluated over time.

Qi and Snyder [7] highlighted the drawbacks existing in traditional textual-based retrieval and addressed the importance of image retrieval in PACS. As a result, a simple system framework embedded in a digital mammogram database was proposed to illustrate the idea of CBIR based on object shape, size, and brightness histogram of masses. However, this study did not provide further discussions on the proposed system's architecture and mammographic descriptors in details. Kinoshita et al. [8] developed a mammogram retrieval system, which is used to measure the similarity of breast density patterns based upon the anatomical size and shape of the breast region, structural characteristics and distributions of density of the fibroglandular tissue. Mammographic features related to shape, size, and texture were applied, as well as less-explored features based in the Radon domain and granulometric measures. The Kohonen self-organizing map was then used to perform the retrieval operation. Although many features were extracted to represent the visual properties in mammograms, the proposed system measures all those features altogether without taking the importance of medical meanings into account. Such a measure structure is likely to result in a great disadvantage that a particular characteristic represented by a greater number of features will dominate other characteristics described by only a few number of features.

Another study by Alto et al. [9] investigates the use of the shape, edge sharpness, and texture features for retrieving images with similar masses. The features were evaluated with linear discriminant analysis, logistic regression, and Mahalanobis distance for their individual effectiveness in classifying the masses as benign or malignant. Linear discriminant analysis resulted in the highest sensitivity of 100% and specificity of 97%. Muramatsu et al. [10] investigated a psychophysical similarity measure for comparing images similar to those of unknown masses on mammograms. In this study five radiologists were asked to assess 60 pairs of masses based on subjective similarity ratings, which were marked on a continuous rating scale and quantified between 0 and 1. In addition, the Euclidean distances between extracted features were also investigated in advance. The psychophysical similarity measure is obtained using an artificial neural network to learn the relationship between radiologists' subjective similarity ratings and their corresponding Euclidean distances in the feature space. The major drawback is that a large amount of data is required to train an artificial neural network in the machine learning process.

There are common drawbacks existing in these aforementioned studies: (1) although those studies propose methods on specific topics and specific lesions, such as relevance feedback learning for retrieving similar masses, the methodology of designing a complete content-based image retrieval system has not been proposed, which involves preprocessing, lesion detection and segmentation, feature extraction, similarity matching, and even relevance feedback learning; (2) the features extracted in those studies are based on visual perception of the system designers, rather than formal definitions on lesion evaluation of mammographic standards. As a result, those studies do not indicate the criteria of similarity matching from radiologists' view, and explain the physical meanings of the extracted features in terms of mammography.

2.2. Features of mammographic masses

One of the most important issues in developing a mammogram retrieval system is that those extracted features have to be discriminative enough to represent different kinds of lesion characteristics. The rest of this section presents a review of various mammographic features which are used to characterize mammographic masses from content-based mammogram studies. Those studies and proposed features regarding content-based mammogram retrieval have been tabulated in Table 1.

A breast mass is a space occupying lesion found in two different projections (X-ray points of view) [11]. Alto et al. characterized breast masses using shape features, texture features, and margin sharpness measures [9]. Those shape features used for content-based mammogram retrieval include compactness, fractional concavity, and speculation index. Compactness, a measure of shape complexity, is computed as $1-(4\pi a/p^2)$, where a is the area and p is the perimeter of the contour of the mass [9]. Fractional concavity represents the ratio of the cumulative length of the concave portions of the contour to the total length of the contour. Spicularity, which represents the degree of spicularity of a mass contour, can be computed as (the detected number of perimeter pixels)^2/the mass area [12]. A greater spicularity value indicates that greater spiculate are detected along the mass contour.

The texture contains parts of the mass region of interest and the mass margin for each of the masses. Texture features were computed using 14 texture measures of Haralick's gray level co-occurrence matrix, which represents the co-occurrence probability of textural features [13]. Texture features which can be extracted from grey level co-occurrence