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Research Paper

Optimal selection of features using wavelet fractal descriptors and automatic correlation bias reduction for classifying skin lesions

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ABSTRACT

The non-invasive computerized image analysis techniques have a great impact on accurate and uniform evaluation of skin abnormalities. The paper reports a method for the texture and morphological feature extraction from skin lesion images to differentiate common melanoma from benign nevi. In this work, a 2D wavelet packet decomposition (WPD) based fractal texture analysis has been proposed to extract the irregular texture pattern of the skin lesion area. On the whole 6214 features have been extracted from each of the 4094 skin lesion images, by analyzing the textural pattern and morphological structure of the lesion area. For the identification of the most efficient feature set, an improved correlation bias reduction method has been introduced in combination with support vector machine recursive feature elimination (SVM-RFE). An automatic selection of correlation threshold value has been introduced in this proposed work to eliminate the correlation bias problem associated with SVM-RFE algorithm. With these selected features, the support vector machine (SVM) classifier with radial basis function is found to achieve the classification performance of 97.63% sensitivity, 100% specificity and 98.28% identification accuracy. The results show that the scheme presented in this paper surpasses the performance of the other state-of-the art techniques for the differentiation of melanoma from other skin abnormalities.

1. Introduction

Among the most frequent types of cancer, the incidence of skin cancer has increased dramatically over the last few decades. Computer aided diagnostic (CAD) system has played an important role in the field of medical diagnosis and further decision making for early detection and prevention of skin cancers. Melanoma or malignant melanoma, usually developed from pigment-containing cells (melanocytes), has been contemplated as most deadly variety among all types of skin cancers [1]. In the detection of melanoma, a gold standard non-invasive imaging technique known as dermoscopy has been widely accepted by the medical personnel for in-depth visualization of morphological structures, forms and colors that cannot be assessed by visual inspections only [2,3]. To quantify the dermoscopic findings and effectively distinguish melanoma from other skin diseases, different algorithms have been extensively used by expert dermatologists. Development and utilization of some powerful methods for the identification of geometrical, structural, texture and color properties of skin lesions, such as ABCD rule of dermoscopy [4], 7-point checklist [5], Menzies method [6] etc. have improved the diagnostic accuracy in comparison with the simple visual inspection, by 5–30%. Despite the introduction of dermoscopy, the melanoma diagnostic accuracy is still not greater than about 85% for experienced dermatologist [7]. Examples of dermoscopic images for atypical nevus and common melanocytic skin lesion have been shown in Fig. 1.

To increase the accuracy of diagnosis of skin diseases by providing a second opinion to the expert dermatologists, a number of methodical approaches have been proposed in the literature using image processing techniques in the area of computer-aided diagnosis. Aiming at classification of skin diseases, most of the CAD systems consist of four steps: image segmentation, border detection, feature extraction and finally the feature selection followed by image classification.

The standard approach for morphological feature extraction and structural analysis is to extract the lesions area from the skin lesion images using efficient segmentation method. The wide variety of lesions in terms of structural shape and size with irregular nature makes it very difficult to segment and identify the border irregularity from dermoscopic images. To address this problem, numerous

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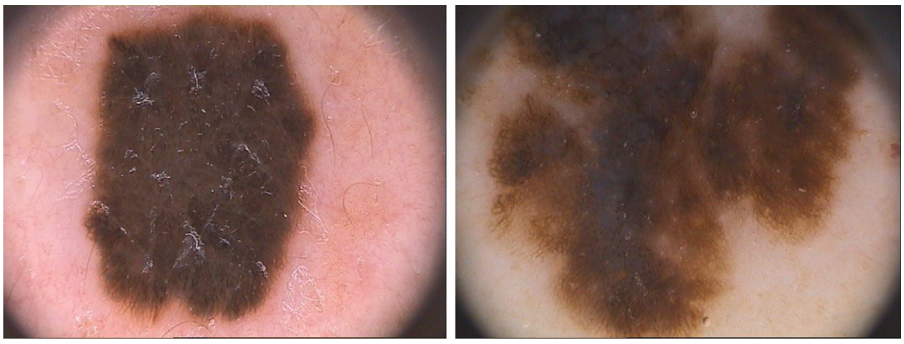

Fig. 1. Typical examples of dermoscopic images (a) atypical nevus and (b) melanoma.

segmentation and border detection techniques have been proposed in the literature [8–10]. In the work presented in this paper, our recently proposed mathematical morphology based segmentation and border detection technique [11], has been applied for the accurate identification of skin lesion area and the pixel locations along the lesion border.

For the accurate characterization of skin abnormalities, the use of feature extraction techniques for the quantification of visual interpretation of dermatologists, followed by segmentation and border detection plays an important role. In the literature, different methods for the extraction of features related to shape, border, texture and color from dermoscopic images have been reported.

Differentiation of melanoma from dysplastic nevi has been done with a sensitivity of 98% and specificity of 70% by Rastgoo et al. [12] using different shape, texture and color related feature extraction techniques, from global and local regions of dermoscopic images.

Shimizu et al. [13] have proposed a layered model for the classification of four different types of skin diseases and a flat model as a classification performance baseline. Different statistical color features with geometrical distribution of the color along the lesion area and GLCM based texture features have been extracted from each of the images.

In [14], Maglogiannis et al. have achieved a classification accuracy of 90.38% by extracting globules and dot related morphological features in dermoscopic images. Among all of the demarcating features of melanoma, such as asymmetry, border irregularity, atypical structures and colors, the textural pattern is the most subjective in nature. It is very difficult to characterize the textural pattern of the skin lesion by visual inspection only.

Garnavi et al. [15] have proposed a wavelet based texture analysis technique and boundary-series analysis for the diagnosis of melanoma with an accuracy of 91.26%. In literature, several other significant feature extraction and classification algorithms have been proposed in literature for the characterization of different biomedical images, [16–21].

In the work reported here, a systematic strategy has been formulated for the extraction of morphological and texture features of skin lesions. A set of well-known and important morphological features have been extracted from each of the segmented images. For the estimation of the irregular nature of the lesion border, wavelet based fractal dimension measurement technique has been proposed.

For the extraction of texture related features, most of the works employ different state-of-the-art techniques involving Gray-level Co-occurrence Matrices (GLCM) [22], Gabor- wavelets [23], Local Binary Pattern [24] etc, to describe the intensity distribution in the region of interest. However a more thorough approach is necessary for the estimation of the textural pattern of the skin lesion area. Here, we focus on the fractal descriptor approach based on wavelet packet decomposition to compute the fractality of the skin texture in the wavelet space. Fractal descriptor expresses the complexity at different wavelet decomposed levels within the texture and gives a detailed representation of the analyzed images.

From a wide range of extracted features, selection of the most demarcating features between different classes ensures the accurate classification of the images. Some of the important reported feature selection methods in this domain include genetic algorithm [25], principal component analysis [26], etc. In the present work, prior to the classification, recursive feature elimination (RFE) method combined with correlation bias reduction (CBR) technique [27], has been used for the selection of most appropriate and informative set of features. After the efficient feature selection step, melanoma and dysplastic nevi have been classified from the dermoscopic image datasets.

Hence, the contributions of the present work can be summarized as follows.

- A wavelet fractal descriptor has been introduced for the characterization of textural pattern of the skin lesion area. The original skin lesion images have been decomposed into different levels using wavelet packet decomposition technique and a fractal descriptor has been used for the extraction of textural distribution on the skin lesion area.
- For the border irregularity measurement, a border series has been obtained after calculating the pixel distance from central location to each of the border pixel locations. The border series, as a 1-D signal has been decomposed using three level wavelet decomposition technique, and Higuchi and Katz fractal dimension have been calculated from each of decomposed signals for the estimation of border irregularity.
- A classification algorithm by deploying automatic selection of correlation threshold value for SVM-RFE with CBR feature selection technique has been introduced in this proposed work, which may be considered as another novelty of the work.

This research paper is organized as follows. A brief introduction on fractal geometry has been given in Section 2. The image segmentation and border detection technique have been briefed in Section 3. The proposed wavelet packet fractal texture analysis followed by the border irregularity measurement technique has been described in Sections 4 and 5 respectively. The feature selection method together with the classification technique has been discussed in Section 6 followed by the results and discussion in Section 7. Finally, the paper has been concluded along with the future scope of the work in Section 8.

2. Fractal geometry

Fractals describe objects having unusual and high degree of complex properties with irregular shapes. The fundamental con-