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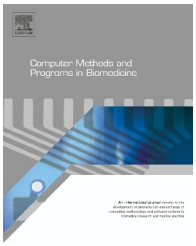

Computer-aided diagnosis of psoriasis skin images with HOS, texture and color features: A first comparative study of its kind

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ABSTRACT

Psoriasis is an autoimmune skin disease with red and scaly plaques on skin and affecting about 125 million people worldwide. Currently, dermatologist use visual and haptic methods for diagnosis the disease severity. This does not help them in stratification and risk assessment of the lesion stage and grade. Further, current methods add complexity during monitoring and follow-up phase. The current diagnostic tools lead to subjectivity in decision making and are unreliable and laborious.

This paper presents a first comparative performance study of its kind using principal component analysis (PCA) based CADx system for psoriasis risk stratification and image classification utilizing: (i) 11 higher order spectra (HOS) features, (ii) 60 texture features, and (iii) 86 color feature sets and their seven combinations. Aggregate 540 image samples (270 healthy and 270 diseased) from 30 psoriasis patients of Indian ethnic origin are used in our database. Machine learning using PCA is used for dominant feature selection which is then fed to support vector machine classifier (SVM) to obtain optimized performance. Three different protocols are implemented using three kinds of feature sets. Reliability index of the CADx is computed.

Among all feature combinations, the CADx system shows optimal performance of 100% accuracy, 100% sensitivity and specificity, when all three sets of feature are combined. Further, our experimental result with increasing data size shows that all feature combinations yield high reliability index throughout the PCA-cutoffs except color feature set and combination of color and texture feature sets. HOS features are powerful in psoriasis disease classification and stratification. Even though, independently, all three set of features HOS, texture, and color perform competitively, but when combined, the machine learning system performs the best. The system is fully automated, reliable and accurate.

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1. Introduction

Psoriasis is a chronic skin disease affecting about 125 million people worldwide [1]. The prevalence of psoriasis in different geographical regions such as Europe, USA, Malaysia and India is about 0.6–6.5% [2], 3.15% [2], 3% [3] and 1.02% [4], respectively. It can influence the patients' quality of life due to its embarrassing physical appearance [5]. This results in increased risk of contemplating suicide (~30%) which makes it an equally dangerous disease at par with depression, heart disease and diabetes [6]. Psoriasis appears in a variety of forms namely plaque, guttate, inverse, pustular, and erythrodermic. For 80% of the cases, plaque is found to be the most common form of psoriasis [7] and thus the work presented in this paper is focused on plaque type psoriasis.

Dermatologists generally follow visual examination and sense of touch to predict the severity which requires skilled training for better diagnosis and analysis. Still the subjective assessment is inefficient, unreliable and a laborious process. Hence, a computer-aided diagnosis (CADx) system could be useful in clinical applications.

Over the years, researchers developed many CADx systems for classification of various skin diseased images. The authors presented a review on CADx system for psoriasis severity risk stratification [8]. A psoriasis CADx system has been proposed in [9] to automatically classify images into psoriatic lesion and healthy skin utilizing color and texture features in SVM framework.

In the current study, the objective is to analyze the performance of psoriasis CADx (pCAD) system using different feature sets i.e., 11 higher order spectra (HOS), 60 texture, 86 color and their combinations. Overall, we have formed seven sets of feature combinations: (i) HOS by itself (FC1); (ii) Texture by itself (FC2); (iii) Color by itself (FC3); (iv) HOS + Texture (FC4); (v) HOS + Color (FC5); (vi) Texture + Color (FC6); (vii) HOS + Texture + Color (FC7). Along with the aforementioned objective, the paper brings following novelties: (i) to the best of our knowledge, first time HOS features have been extracted for psoriasis images. The random distribution of pixels of psoriatic lesions and nonlinear behavior among the frequency components, innovates us to use HOS features; (ii) optimization procedure to estimate the set of radon angles for optimization of HOS features; (iii) largest set of mathematical features ever computed in psoriasis skin disease framework consisting of 157 features including HOS, texture and color; (iv) comparative analysis of systems with different feature sets in changing data size framework; (v) understanding the reliability analysis of the CADx system while switching between combinations sets.

Three sets of experiments are performed for all the aforementioned feature combinations. (i) optimization of the SVM kernel type in PCA-based feature selection paradigm while keeping the data size (N) fixed. Classification is performed for four different kernel functions, where kernel function of polynomial of order two showed the best results for FC2–FC7 and polynomial kernel of order one for FC1. (ii) Compare and contrast the effect of feature sets in psoriasis disease classification with fixed data size (N). The highest classification accuracy of 100% with sensitivity and specificity both of 100% have been achieved using FC7 (HOS + Texture + Color) at PCA-cutoff of 0.94. (iii) The last and third experiment presents the effect of change in data size on the machine learning paradigm for all seven sets of feature combinations while computing the reliability of the system. Our experimental results conclude that all feature combination yield high reliability index throughout the PCA-cutoffs except FC3 (Color alone) and FC6 (Texture + Color). Therefore, our observations on experiments performed using different feature combinations clearly shows the dominant behavior of HOS features.

2. Data acquisition and preparation

The psoriasis image data required for this study were collected from Psoriasis Clinic and Research Centre, Psoriatreat, Pune, Maharashtra, India. Images of Indian ethnic origin patients were acquired by digitally photographing using Sony NEX-5 camera with 22 mm lens and 350 dpi under the supervision of dermatologist. The images were processed in Joint Photographic Expert Group (JPEG) format with color depth of 24 bits per pixel. The ethics approval was generated for the dataset and the image dataset were anonymized.

For this work, a total of 540 subjects (270 healthy skins and 270 diseased skins) were acquired from the images of 30 patients. The preparation of database was done by manually cropping the healthy and diseased skins freehand to capture any shape through MATLAB from the images of each patient. First row of Fig. 1 shows the samples of diseased skin while second row shows healthy skin samples.

3. Methodology

The objective of the paper is to compare the performance of the pCAD system using different feature sets i.e., HOS, texture, color and their combinations. Our pCAD utilizes the machine learning paradigm in PCA-based SVM framework shown in Fig. 2. The spirit of this machine learning framework and risk stratification comes from methods developed by Suri and his team [10–13]. Our pCAD has two components as shown by the dotted line. The left side reflects the offline system while the right side reflects the online system. In the offline system, HOS, texture and color features were extracted. The dominant features were selected using PCA in order to reduce the dimensionality of the extracted feature set and to select only unique and highly discriminating features without altering the original values of the features. The dominant feature set and a priori physician classified labels (ground truth) are used as inputs to the offline classifier in order to determine the machine learning parameters. The dominant features generated in offline system were extracted from the test images. Subsequently, the machine learning parameters from the offline system and dominant features of test images were used to determine the class label of the test images.

3.1. *HOS features*

Higher order spectra-based features are used to analyze the nonlinear and dynamic nature of the given signal [14]. The

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