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Reliable and accurate psoriasis disease classification in dermatology images using comprehensive feature space in machine learning paradigm

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ABSTRACT

Classification reliability and accuracy are important components for any computer-aided diagnostic system. This paper presents a dermatology CADx system to automatically classify dermatology images into psoriatic lesion and healthy skin using an online system. The novelty of the system is an exploration of the unique and comprehensive feature space combined with classification in support vector machine (SVM) paradigm. The unique feature space consists of grayscale space, color space and aggressiveness of psoriatic disease such as redness and chaoticness.

The proposed CADx framework is conventional in paradigm that it has offline and online components. The offline system trains using unique integrated feature space and apriori dermatologist derived ground truth. This training system yields machine learning parameters. The online system is applied on the incoming test images which get transformed by an online classifier utilizing the offline machine learning parameters. The accuracy of the system is evaluated using cross-validation procedure depending upon one of the three partition protocols such as (5-fold, 10-fold and Jack Knife).

The proposed CADx system shows the classification accuracy of 99.53%, 99.66% and 99.81% for 5-fold, 10-fold and Jack Knife protocols respectively for 15 optimal features. Further, our results show that, we can demonstrate the reliability and consistency factor by showing the monotonously rising accuracy with increase in data size. Our system is benchmarked against previous reported systems and outstands besides being unique and novel.

1. Introduction

Psoriasis is a chronic and irritating skin disease affects quality of life due to its embarrassing social appearance (Krueger et al., 2001; Langley, Krueger, & Griffiths, 2005; Leonardi et al., 2012). Generally, psoriasis appears on scalp, elbows, knees, and lower back but it may spread further to all parts of the bodies (Camisa, 2004, chap. 2). Psoriasis may grow further, gives secretion in wet lesions while cracks lead to bleeding in dry lesions. This further leads to psoriatic arthritis which gives inflammatory bended joints. Psoriasis does not appear similar in all patients, it has variety of forms with distinct characteristics namely plaque, guttate, inverse, pustular, and erythrodermic, of which plaque is most widely appearing in 80% of the cases (Morrow, 2004). Statistics show that 2%–3% of world's population is suffering from psoriasis disease (International Federation of Psoriasis Associations, Facts about Psoriasis, 2014; National Psoriasis Foundation, Statistics, 2014). In Europe, the prevalence of psoriasis varies from 0.6% to 6.5% whereas in USA it is 3.15% (Chandran & Raychaudhuri, 2010). Psoriasis affects about 3% of population in Malaysia according to the Dermatological Society of Malaysia (Persatuan Dermatologi Malaysia, Overview of Psoriasis in Malaysia, 2014) whereas it affects about 1.02% of Indian population (Dogra & Yadav, 2010). According to the report in Nestle and Conrad (2004), at least 30% of the psoriasis patients contemplate suicide. There is no permanent cure for psoriasis reported till date but it used to be controlled by prolonged and attentive treatment. The cause of psoriasis is still

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unidentified and researchers think of genetic fault as a cause of psoriasis, in which skin cells production is faster than normal (Henseler, 1998).

For diagnosis and analysis of skin diseased images, dermatologist requires skilled training to predict the severity and prescribe medication to control it. So, objective analysis is essential along with inefficient, unreliable and a laborious subjective analysis. Many researchers have proposed and still working tirelessly on computer-aided diagnosis (CADx) systems for classification of different skin diseased images. In past, an approach is proposed for the recognition of malignant melanoma versus dysplastic naevus (Maglogiannis & Zafiropoulos, 2004). A methodology proposed in Messadi, Bessaid, and Taleb-Ahmed (2009) shows the classification of skin tumor. In Celebi and Zornberg (2014), an automated quantification of clinically significant colors in dermoscopy images is proposed. The algorithms to correct the illumination variation problem in dermoscopy images are presented in Glaister, Amelard, Wong, and Clausi (2013) and Fidalgo Barata, Celebi, and Marques (2014) and improvement in classification performance is reported.

In the aforementioned methods, one of the limitations is not enough substance for feature selection process which is required to eliminate the redundant and noisy features. Another lacking section in the previous studies is the lack of demonstration of role of generalization as the population pool increased. These are the two primary key objectives of this paper: (i) from the 46 features which belong to texture, color, redness and chaotic features, we generate 46 set of feature combinations based on proposed feature selection process. (ii) demonstrates the effect of classification accuracy on the changing data size to further understands generalization vs. memorization of the training system. Along with these two novelties, three novel features, such as: aggressiveness of red to green, aggressiveness of red to blue and redness are introduced in this paper. Thus our comprehensive approach for classification and data analysis provides a complete understanding of machine learning paradigm.

In today's world, CADx system became a tool for doctors and therefore it is important to have reliable and accurate CADx system. For any machine learning system to be reliable and accurate, there is always a quest to search for feature space which can provide more power in training. This paper presents a comprehensive feature space with 46 features belong to texture, color, redness and chaotic features. Under the category of redness features, there are three novel features are introduced viz. aggressiveness of red to green, aggressiveness of red to blue and redness which prominently contribute to the system for higher classification accuracy. In addition to that, feature selection process is proposed to determine the optimal features which establishes a better training system and in turn gives an accuracy of above 99%. So, the results of first experiment with fixed data size shows that the system is accurate. The second experiment with changing data size shows the system is reliable, since the pattern of growth of accuracy is monotonously increasing with the increase of data size.

We characterize the CADx system in a training-based paradigm using cross-validation as accuracy measure along the lines as adapted by conventional training-based system (Suri, 2000). Thus, the CADx system has two components: online system which can report the classification results as lesion or healthy skin image and offline system which is used for generating the machine learning parameters which is utilized by the online system. The offline system accepts the training image data base while the online system accepts the test image database. Both components have classification system except that offline system is used for training and online system is used for testing. A total of 46 features are extracted which are categorized as texture, color, redness and chaotic features. A feature selection process based on mean values of features is adopted to determine the optimal features. Classification is performed for five different kernel functions i.e., linear kernel, radial basis function (RBF) kernel and polynomial kernel of order one, two and three. The kernel function which gives the best results is selected. The least square method is used to find the separating the hyper-plane. To generalize the SVM classification process, we evaluate our classification performance on $k = 5$-fold, $k = 10$-fold and $k = N$-fold (Jack Knife) methods. To demonstrate the accuracy of the system as part of experiment one, the CADx system runs on a fixed data size of $N = 540$ using varying kernel functions. This experiment shows the classification accuracy of 99.53%, 99.66% and 99.81% for 5-fold, 10-fold and Jack Knife protocols respectively with polynomial kernel function of order two. The classification results justify the features selected for psoriasis images. The second experiment demonstrates the reliability of the system by taking into consideration the changing data size. This CADx system demonstrates the stabilization of accuracy with the increase in data size leading to generalization from memorization.

The layout of the paper is as follows: Section 2 presents the data acquisition protocol and data preparation. The methodology of machine learning paradigm is presented in Section 3. Detailed experimental protocol is discussed in Section 4 while the results are presented in Section 5. The benchmarking and discussions are presented in Section 6 and the paper concludes in Section 7.

2. Data acquisition and preparation

The database of psoriasis images are collected from Psoriasis Clinic and Research Centre, Psoriatreat, Pune, Maharashtra, India. The data are obtained by digitally photographing the patients of Indian ethnic origin under the supervision of dermatologist. The data are taken from Sony NEX-5 camera with 22 mm lens and 350 dpi. The images are processed in Joint Photographic Expert Group (JPEG) format with color depth of 24 bits per pixel.

The preparation of database is done by manually cropping the healthy skin (normal) and psoriatic lesion (abnormal skin) from the images of each patient. The normal and abnormal skin samples are cropped freehand to capture any shape through MATLAB. In this way, a total of 270 samples of normal skin and 270 samples of abnormal skin are acquired from the images of 30 patients. These 540 (270 normal + 270 abnormal) image samples are then used for proposed diagnosis system. There are few samples which are fuzzy in nature i.e., considered as an abnormal sample but actually they belong to normal sample and vice versa. First three rows of Figs. 1 and 2 show the samples of abnormal and normal skin respectively and last row of Figs. 1 and 2 shows the fuzzy abnormal and normal samples respectively.

3. Methods

Our CADx system as shown in Fig. 3 adopts the machine learning paradigm. It contains two components as denoted by the dotted line. The left side characterizes the offline system while the right side characterizes the online system. Online system is used for new test patient image, hence termed as online. Both components have feature extraction process which consists of extraction of four set of feature categories: texture, color, redness and chaotic features. We have extracted a total of 46 features from these four categories. Feature exaction is the heart of the machine learning system followed by training classifier and testing classifier for the two components of machine learning CADx system. A feature selection process based on mean values of features is proposed to reduce the dimensionality of the feature space and computational time (Jain, Duin, & Mao, 2000). The offline classifier generates the machine learning parameters which are estimated using