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Vector Based Classification of Dermoscopic Images Using SURF

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Abstract

Detection of melanocytic skin lesion at an early stage increases the probability of being cured. Dermoscopy is a widely used diagnostic tool that aids the diagnosis of skin lesions and is proven to increase the accuracy of melanoma diagnosis. In this paper, vector based pattern analysis and classification approach for dermoscopic images are proposed. Feature plays a vital role in pattern recognition system. The various features include color, texture and shape features. Texture is considered as a dominant feature. In this paper lesion is segmented using region based Statistical Region Merging (SRM) algorithm. Scale invariant based Speeded up Robust Features (SURF) technique is used for feature point detection and descriptions under texture analysis. SURF uses Hessian matrix approximation for feature point detection, haar- wavelet response for feature descriptions. It uses l*a*b color space for describing color intensities. The patterns so detected are classified using multi-SVM classifier. The proposed system provides the cla3ssification accuracy of 86.37% and sensitivity, specificity rates as 86.53% and 96.42% respectively.

Keywords: Dermoscopy, melanoma, Speeded up Robust Features(SURF), Statistical Region Merging (SRM),texture

INTRODUCTION

Skin cancer is a common and locally destructive cancerous growth of the skin. Melanoma is the rarest, but the most dangerous form of skin cancers. Moreover, at an early stage, skin cancer is very economical to treat, while at an later stage cancerous lesion generally result in near fatal consequences and extremely high costs associated with a necessary treatement So, there is a need to detect lesion at an early stage [2] . The pigmented lesions are diagnosed by dermatologists using the technique called dermoscopy. Dermoscopy is a non-invasive diagnosis technique for the in vivo observation of pigmented skin lesions used in dermatology [3]. Eventhough the detection of melanoma using dermoscopy is higher than unaided observation based detection, its diagnostic accuracy based on the intelligence and training of the dermatologist [4]. Skin cancers are of three types namely: basal-cell cancer (BCC), squamous-cellcancer (SCC) and melanoma [1]. When melanoma occurs, it affects the melanocytic cells thereby increasing the synthesis of melanin. The disorder is characterized by skin lesion development and it varies in shape, size, color and texture [5]. Skin Cancer Detection System is the system to identify and recognize skin cancer symptoms and diagnose melanoma in early stages by analyzing feature variations [6]. There are four main diagnosis methods for dermoscopic images: ABCD rule, pattern analysis, Menzies method, and seven-point checklist. Pattern analysis, considered as the classic approach for diagnosis in dermoscopic images, was deemed superior to the other algorithms [7]. Currently, it is the method most commonly used for providing diagnosis accuracy for cutaneous melanoma [8]. Differentiate melanocytic lesion into clark nevus, Spitz nevus, blue nevus and malignant melanoma. But this paper focuses on textural pattern associated with the lesion [9]. The main textural patterns appeared on the melanocytic lesion are: Globular pattern, Cobblestone pattern, Reticular pattern, Homogeneous pattern, parallel pattern, Starburst pattern, and Multicomponent pattern. They are associated with the predominant local features: Globular pattern with globules, Cobblestone pattern with globules, Reticular pattern with pigment network, Homogeneous pattern with pigmentation, Parallel pattern with furrows and ridges, Starburst pattern with streak, and Multicomponent pattern with a combination of three or more above patterns. These patterns present in the lesion with an irregular/regular or atypical/ typical nature, implying its malignancy level. The technique proposed in this system focuses on automatic identification of local features and recognizes the pattern. As the aim is to find textural pattern, the system uses SURF technique to find Region of interest (ROI) and its descriptors. SURF uses scale and invariant based Hessian matrix approximation for feature point detection and follows integral images concept for the fast computation of convolution filters. Multi-SVM classifier is one of the learning techniques used for pattern classification. It analyses and recognizes the image and data patterns used in image processing. The advantage of SVM is that in high dimensional spaces it works effectively and also it uses a subset of training points in the decision function provide memory efficient technique.

RELATED WORKS

Various skin lesion classifications have proposed in the literature. Most of the papers focuses to identify that the lesion is malignant are not. Papers that focus pattern classification use global methods to classify the pattern. Global methods consider color, shape and texture features [8]-[12]. The standard approach in automatic dermoscopic image analysis has usually three stages: 1) image segmentation; 2) feature extraction and feature selection; and 3) lesion classification.

The paper [13] compares two strategies for melanoma detection such as global and local methods. Global method characterizes color, texture and shape based global features. Local method describes local patches. The performance of the classifier for each feature was evaluated with different combination of parameters. Classification process uses Ada-boost, KNN and SVM classifiers. The evaluation result showed that color feature dominate texture feature and local features with BoF provides slightly better results.

In paper [14], ABCD rule is used to characterize geometric and structural lesion properties. It uses Geodesic Active Contour, a contour detection technique for segmenting lesion. This notified two issues that causes misclassification includes, bad contour detection and inability to detect structures. This implementation follows lesion malignancy but not patterns.

Tanaka *et al.* [15] presented an extraction of 110 texture features to classify a pattern into three categories: homogeneous, globular and reticular. The statistical differences in features and co-occurrence matrices that are used for texture analysis. Since the system is not invariant to scale and shape, the contours of the skin are not effectively extracted, if the shape is irregular and extremely small.

Gola *et al.* [16] presented a method based on edge detection, mathematical morphology, and color analysis to detect three global patterns (reticular, globular, and homogeneous), but based on the predominant local pattern identification: globules, pigment network, and blue pigmentation.

This paper uses vector based SURF approach for feature extraction and texture analysis. It uses integral images for each feature point and uses haar-wavelet response for feature descriptors. Region based Statistical Region Merging (SRM) technique is used for segmenting the lesion from the skin .It uses Multi-SVM for pattern classification.

The organization of this paper is as follows: Section II describes aim and objectives of the paper. In Section III, the overall system frame work is analyzed. Section IV discusses the methodology adopted. The experimental results are evaluated in Section V and Section VI concludes the result and expresses its future scope.

RESEARCH AIM AND OBJECTIVES

The purpose of the study is to design and develop a system on melanoma pattern recognition area that focuses on early detection of the malignancy level and patterns associated with skin cancers cells and also have less dependency on medical experts or dermatologists.

The objective of the paper includes:

i) To develop an algorithm for the efficient extraction, texture analysis and classification of skin patterns in the melanoma skin datasets.

ii) To ease and early treatment of skin cancer, our system proposes the melanoma pattern recognition system to identify the distribution of patterns at an earlier stage and find their malignancy level of the skin cancer cells.

SYSTEM FRAMEWORK

The analysis and classification of patterns on melanocytic skin lesion is an object recognition system with specific lesion properties. Several approaches have been carried out by different authors considering global features like color and gradient histogram. These systems will not produce optimum results if the shape, border and color features of the lesion are not easily found on the object [15]. Moreover, numerous works have focused on the malignancy of the lesion type but not analyses the patterns. The methodology that has been developed relies on extracting and analyzing information features by selecting interest points that discriminates the pattern features. The following figure depicts the overall design of the SURF based dermoscopic skin lesion pattern classification system.

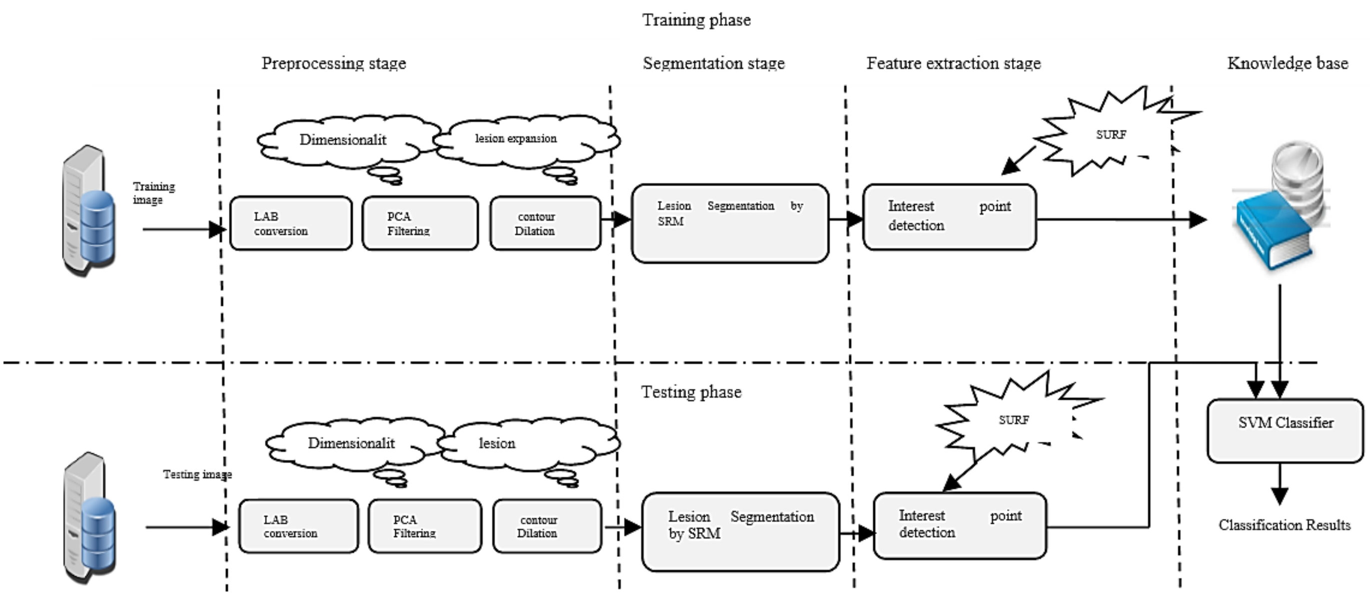

Figure 1. Overview of vector based approach for Melanoma pattern classification

METHODOLOGY

Differentiating the melanoma patterns from the skin lesion needs effective preprocessing, segmentation, feature extraction and classification techniques. The following section focuses on the description of methods used in the melanoma pattern recognition system.

A. Pre-processing

Image pre-processing is an essential step for dermoscopic images which eliminates noises, leads to increasing accuracy level of the pattern recognition system. It has been observed that dermoscopy images often contain undesirable elements such as uneven illumination, black frames, dermoscopic gel, air bubbles, ink markings, rulers and intrinsic cutaneous features that can affect border features such as blood vessels, hairs, and skin lines and texture. These elements may complicate the detection procedure and the accuracy as well . Thus, it requires some preprocessing techniques for image enhancement and restoration. Since Color information plays a significant role in the analysis of dermoscopic image, the input image here in RGB color space is directly transformed into a LAB color space. It is easy to visualize by the human perception. And also has the following advantages: (i) reducing the number of channels, (ii) decoupling luminance and chromaticity information, (iii) Ensuring approximate perceptual uniformity, and (iv) Achieving invariance to different imaging conditions such as viewing direction, illumination intensity, and highlights [19]. The advantage of using Lab color space is that it yields uniform color space since Lab is perceptually linear and also the luminance factor L for all pixels is constant. This will reduce the data size and computation time.

The second step is to remove the artifacts from the image. This has been achieved by applying PCA filter on the image database followed by image expansion using contour dilation technique. PCA is used for dimensionality reduction of color and texture space [20].

B. Region based Lesion Segmentation using SRM

Segmentation is the most important step for analyzing the image property since it affects the accuracy of the subsequent steps. It allows to identify various global morphological features to the lesion and provides a confined region for segmentation of various local clinical features at a later stage [21]. Though number of segmentation techniques was proposed, the system uses region based segmentation method. It partitions an image into region or group of pixels having similar property.

The SRM algorithm used in [22], [23] is proposed as segmentation method. The idea is to start with one region per pixel and merge the region if the region possesses common homogeneity property.

Inside any statistical region and given any color channel ∈ {R, G, B}. the statistical pixels have the same expectation for this color channel.

Nielsen and Nock consider a sort function *f* defined as follows:

$$f(P,P')=\max|P_a'-P_a| \quad (1)$$

Where, P_a', P_a, stand for pixel values of a pair of adjacent pixels. Nielsen and Nock define the merging predicate as follows.

$$P(R,\ R') = \begin{cases} true\ if |\bar{R}' - \bar{R}| \le \sqrt{b^2(R)+b^2(R')} \\ false \qquad otherwise \end{cases} \quad (2)$$

Any regions (R, R') from the image I and whose merging is tested should satisfy $|(\bar{R}-\ \bar{R}')| \le b(\bar{R}-\ \bar{R}')$. Since $b(R,R') \le \sqrt{b^2(R)+b^2(R)}$ and the merging predicate authorize the merging of $\bar{A}$ and $\bar{A}'$. Here, $\bar{R}a$ denotes the observed average for color level channel a in region R.

C. Melanoma Pattern observation by ROI selection and distribution using SURF

As the main objective of the paper is melanoma pattern recognition, it is considerably important to select the region of interest (ROI) in the image and texture distribution. Texture property describes image patterns, each having property of homogeneity. The patterns in the melanocytic lesion includes: Pigment network, Dots/globules, Streaks, Blue-whitish veil pigmentation, Hypo pigmentation, Regression structures, and vascular structures. These patterns present in the lesion with an irregular/regular or atypical/typical nature, implying malignancy or not [5]. The technique proposed in this system focuses on automatic identification of local features and recognizes the pattern. This can be achieved by identifying the Region of interest (ROI) using SURF technique.

SURF uses scale and invariant based Hessian matrix approximation for feature point detection and follows integral images concept for the fast computation of convolution filters. Integral image I(x) at a location x represents the sum of all pixels in the image I within the rectangular region formed by the origin and x.

$$I(x) = \sum_{i=0}^{i\le x} \sum_{j=0}^{j\le y} i(i,j) \quad (3)$$

Given a point X(x,y) in an image I , the hessian matrix H(x, σ) in X at scale σ is defined as

$$H(x,\sigma) = \begin{bmatrix} L_{xx}(x,\sigma) & L_{xy}(x,\sigma) \\ L_{xy}(x,\sigma) & L_{yy}(x,\sigma) \end{bmatrix} \quad (4)$$

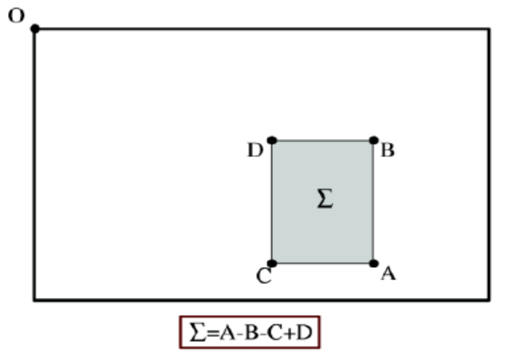

Figure 2. Integral Image and its coordinates

Once get the interest points, we have to identify their distributions. For that, SURF uses interest point descriptor. It represents the distribution of small scale features within the interest point neighborhood [24]. In this, it first calculate the Haar wavelet response in x and y direction within the circular radius of interest point.

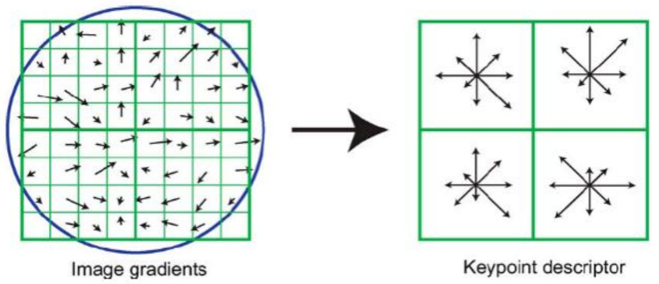

Figure 3. Interest point orientation

SURF features are then matched with minimum distance with descriptors considered for feature matching pair.

D. Classification

Even if the analysts were using number of classification techniques for melanoma prediction like ANN classifier, Ada-boost classifier, K-NN classifier and SVM classifier, the experiments show better results for SVM classifier. Since the patterns to classify include globular pattern, Reticular pattern, Homogeneous pattern and Multi-component pattern, this paper uses multi-class SVM for classification.

EXPERIMENTAL RESULTS AND EVALUATION

A. Experimental data

The experiment is carried out with 611dermoscopic images taken from Interactive dermatology atlas, opticomdataresearch of four classes (Globular, Homogenous, reticular, multi-component).The images are in JPEG formats and the images are resized into 256x256 pixels. The system is validated by leave one out approach.

For evaluating the results, MATLAB R2012a software was used and sample data inputs as follows in Fig 4.

The performance of the results is analyzed in terms of accuracy, sensitivity and specificity metrics. These three terms are defined as follows:

Sensitivity

It defines the proportion of patterns correctly identified as such.

$$\text{Sensitivity}=\frac{TP}{TP+\ FN} \qquad (5)$$

Specificity

It defines the proportion of actual negative patterns which are correctly identified as such.$\frac{TN}{TN+FP}$ (21)

$$\text{Specificity}=\ \frac{TN}{TN+FP} \qquad (6)$$

Accuracy

It is the probability that the diagnostic test is performed correctly.

$$\text{Accuracy}=\frac{TP+TN}{TP+TN+FP+FN} \qquad (7)$$

B. Experimental setup

To evaluate the performance of the system, every skin images in the dataset undergoes image preprocessing techniques. It is used to correct illumination, remove small spots & noise and enhance the contour and contrast of the images without degrading the lesion features. This can be achieved here by applying filters and contour dilations. PCA in the preprocessing stage used for dimensionality reduction. For better visualization it takes a cloud of data points and rotates it to visualize maximum data variables. After preprocessing the lesion is extracted by Statistical Region Merging (SRM) technique. In this border detection technique, the variable k is adjusted to 4 to reduce the border error and set the maximum intensity distance to 0.2.After detection; the features are extracted by SURF feature extraction technique. SURF selects 20 strongest features and their neighborhood orientation. The selected features are undergone classification process which uses Multi-class SVM. By analyzing the features, the lesion may be classified as homogenous, reticular, globular or multi-component. The classification rate is compared and evaluated with other techniques. This paper also includes sensitivity and specificity measures. The following figure depicts the output the system got on each stage.

Figure 4. Sample input data images

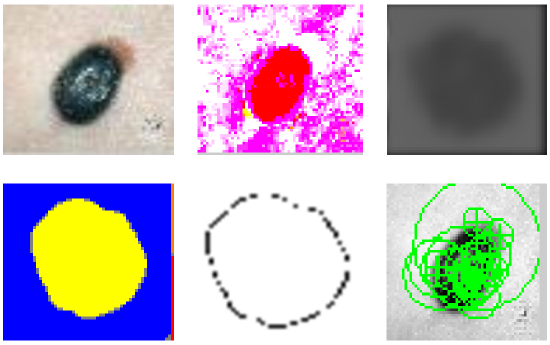

Figure 5. Output produced on each step

C. Discussion

To examine the superiority of the proposed method, qualitative measures are made to compare with the methods used by the existing authors.

In this paper, 20 feature points and their distributions are selected. So, texture feature computed for 12220 small integral images. Higher the no of pattern feature sets, higher will be the recognition accuracy. Feature extraction technique used in the paper [25] showed that 46 features recognize only two patterns and there is a need of 64 features to recognize three patterns. The sensitivity and specificity measures are not considered and also the recognition rate decreases for increasing number of patterns. The above system is not invariant to scale, blur and the presence of hyperpigmentation. The color model used in [26] CIECAM02 JCh and Steerable Pyramid Transform based texture model produces 89% sensitivity and 94% specificity rates. But, it is sensitive to artifacts and increases false positives. The method used in[27] l*a*b color space following Markov random field(MRF) extended Finite Symmetric Conditional Model(FSCM) provides 86% accuracy on an average and considered color intensities. The paper [10] provided 87% sensitivity and 92% specificity rates which uses ABCD and ELM algorithm.

From all the above discussions, the proposed system provides considerable result for pigmented lesion for four classes such as homogenous, reticular, globular and multi-component patterns. It is scale invariant, not sensitive to any artifacts and even produces better result for large database. Table I describes the performance of the proposed pattern classification system of different dermoscopic structures with 611 data images

Table I: Qualitative Parameters of all Patterns

Pattern detectors classes	Classification Accuracy (%)	Sensitivity (%)	Specificity (%)
Globular	89.599	90.405	95.564
Homogenous	84.317	82.838	95.468
Reticular	80.070	86.761	97.390
Multi-component	91.51	86.090	97.280
Average	86.374	86.523	96.425

CONCLUSION AND FUTURE SCOPE

The proposed early detection of the lesion pattern recognition system using vector based SURF approach provides better results when compared to the existing techniques. Most of the authors focus on the lesion malignancy. But, this pattern recognition system is used to find the melanoma types. In order to find the types, lesion is segmented by the region merging technique. After detection, this system finds 20 most salient feature points and their texture distributions. Since the point of interests are scale invariant, SURF uses scale and Invariant based hessian matrix approximation for feature point detection. The unique and robust distribution of interest points are calculated by the haar- wavelet response of the integral image. Finally, the features so found are classified using multi-svm classifier. The performance of the existing methods shows that they provide better results for less pattern types and for less data elements. i.e) the database size and no of pattern types affects the system accuracy and sensitivity and specificity rates. This system provides 86.37% accuracy, 86.53% sensitivity and 96.42% specificity rates on an average for four classes and the database of 611 data elements.

This system only uses the texture feature of the patterns. In future, the system aims to enhance the qualitative rates by considering color and geometric features. This can achieve by normalizing the feature sets.

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