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A System for Classification of Skin Lesions in Dermoscopic Images

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***Abstract*—** Melanoma is a leading cause of skin cancer. It spreads through metastasis in the body and can affect the whole skin surface. Most of the skin cancers initiate with the formation of skin lesions on the skin surface. If the type of skin lesion is diagnosed properly at an early stage, then the chances of survival can be increased. This project aims at classifying the skin lesion into benign and melanoma.

***Keywords*—**Melanoma; Best-fit ellipse; Active contour

I. INTRODUCTION

Skin cancer has been identified today as one of the leading causes of death. Melanoma is considered as one of the most hazardous type. The early stage diagnosis of melanoma is important since it proves to be fatal if detected at higher stages. Early intervention is required for the cure of melanoma. This disorder is characterized by the development of skin lesions that vary in shape, size, color and texture. For a clinician, to diagnose the features, patterns and type of lesion using non-invasive methods requires extensive training. Invasive methods such as biopsy of the lesion are widely used for the diagnosis purposes. Analyzing the skin lesion with the naked eye is a challenging task for the clinicians. The method used in this project being non-invasive can benefit the clinicians as well as patients for diagnosing the type of skin lesion and increasing the survival rate.

In section II of the paper a brief literature review of different methods used till now for analysis of skin lesion is presented. Section III deals with the methodology used in the project work in which the pre-processing of the original image, segmentation of the image, feature extraction from the image and the classification based on the features extracted are discussed. In section IV, experimental results are discussed. The paper concludes in section V.

II. LITERATURE REVIEW

The classification of skin lesion involves four steps; pre-processing, segmentation, feature extraction and classification. In the literature, different methods are used for implementing each of these steps. For pre-processing; bilinear interpolation, in-painting based on partial differential equation, fast marching scheme, directional filters, median filtering, radial search algorithm, Gaussian smoothing, gamma correction are used [1,2,3,4,5]. The fast marching scheme is based on non-iterative partial differential equation and gives better results but, the lesions with characteristics similar to hair pixels cannot be detected. The ability of directional filters to detect and extract lines from pigment network is unique. For segmentation, the different methods used are; eight connectivity criteria, Otsu's method, gradient vector flow, k-means clustering based on colors, region growing method, adaptive thresholding, adaptive snake, expectation-maximization level set [2,4,6,7].

The eight connectivity criterion gives good result but, the manually segmented results provided by an expert are wider. Otsu's method also provides better result than eight connectivity criterion but, it has got less execution speed. Region growing method provides good result for some type of melanomas. The features extracted are; pigment network area and lesion characteristics ratio, number of holes in the pigment network, ABCD parameter is widely used which includes asymmetry, border irregularity, color variation and diameter, texture features, color features, RGB histogram, geometric features [2,4,5,6]. In the ABCD criterion, fractal dimension which is a sub-feature of border irregularity gives good results but using this criterion, the lesion sizes can hardly be estimated. The parameters used need to be scaled. Geometric features give better result than the ABCD criterion but, the biggest blob in the lesion has to be determined manually. For classification; support vector machine and K-nearest neighbor classifiers are used in the literature [4].

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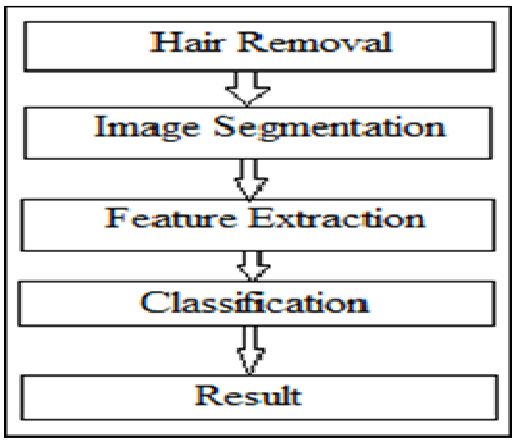

Figure.1. Flowchart of the proposed methodology

III. METHODOLOGY

A. *Pre-Processing*

The flowchart for the proposed methodology is shown in Fig.1. For hair removal, the median filtering and bottom-hat filtering is used. The median filter works by moving over the image pixel by pixel. It arranges the pixels in numeric order, calculates the median by considering the neighboring pixels and goes on replacing the current pixel with the value of median. Median filter removes noise while preserving the edges. It also makes the image smooth and is efficient in removing salt and pepper noise.

$$\text{Median} = \frac{1}{2}(X(k) + X(k+1)) \quad k = 1, \ldots, N \qquad (1)$$

Where, N is the number of pixels in the image, X(k) is the value of a particular pixel.

The bottom-hat filter highlights dark spots on a light background. It works by subtracting the morphological close of the image from the image. By doing this it removes holes and joins nearby objects. Fig. 2 (b) shows the image after hair removal.

$$I_{th} = I_g - (I_g \,.\, B) \qquad (2)$$

Where I_{th} is the image after applying bottom-hat filter, I_g is the smoothened version of the original image and $I_g \,.\, B$ is its morphological close. B is the structuring element.

B. *Segmentation*

Segmentation of the lesion from its background is important task in dermoscopic image analysis as it will provide proper feature extraction strategy in successive image processing module. Segmentation is difficult since the lesions vary in shape, size and color. In some lesions there is a smooth transition between lesion and the skin surface. The segmentation of the skin lesion is carried out in following steps;

1) Thresholding: It is applied for minimizing the intra-class variance between foreground (lesion) and background pixels. The white corners of the image are replaced by black pixels.

2) Morphological operations: Due to thresholding, the edges of the image become irregular. For this the morphological closing operation is done. It smoothens the edges of the image. The morphological opening operation is then done which smoothens the contour and breaks linkages.

3) Hole filling: Holes are a set of background pixels that cannot be reached by filling the image from its edges. So the hole filling operation is done.

4) Active-contour segmentation: It is used for segmenting the image into foreground (lesion) and background. It stops the evolution of the contour if the current contour position is same as that of the recent five iterations.

5) Area opening: The small connected components are determined. The area of the components is calculated and the components which have less number of pixels are removed. This is done using area-opening operation.

6) Morphological operations: The morphological opening and morphological closing operations are done again for smoothing the contour and the edges respectively. Fig. 2 (c) shows the result of segmentation.

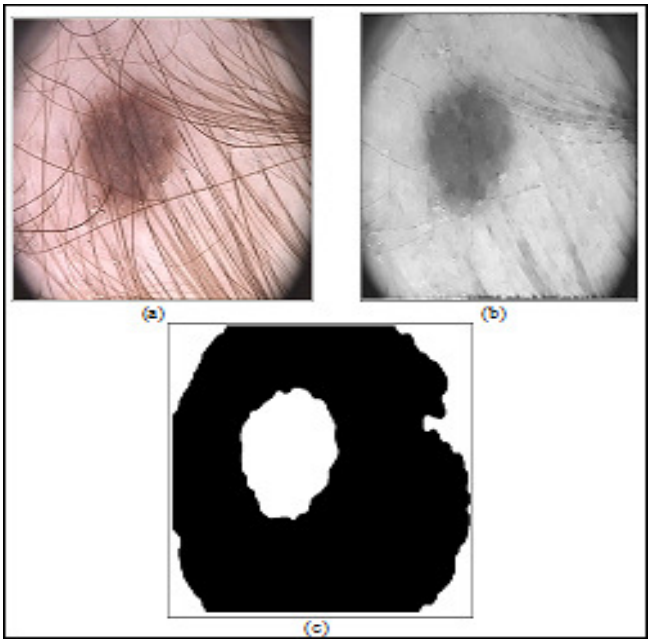

Figure.2. (a) Original image (b) Image after hair removal (c) Image after segmentation

C. *Feature Extraction*

1) Color feature set: Melanoma has tendency to change color. Hence, the color features can describe the lesion. For extracting the color features, first the image is converted into Lab color model. The histograms of the three components of the model are computed. The components in the illumination axis are accumulated. It gives color bins. Each color bin is considered as a feature.

2) Pigment network feature set: Pigment network is an important aspect of dermoscopic images. Pigment network is observed in skin lesion as dark network of thin lines over a diffused light brown background. The dense network is due the projections of rete edges. The holes in the network are due to projections of the dermal pappilae. For extracting pigment network features, steergauss filter is used here. Five features are extracted which are defined as follows.

a) Pigment network area and lesion area ratio (f1): This feature compares the area of the pigment network (A(PN)) with the area of the lesion (A(L)).

$$f1 = \frac{A(PN)}{A(L)} \tag{3}$$

b) Pigment network area and filled network area ratio (f2):This feature compares the total pigment network area in the lesion and the total filled network area (A(FN)).

$$f2 = \frac{A(PN)}{A(FN)} \tag{4}$$

c) Total number of holes in the pigment network (f3):

$$f3 = \sum H \tag{5}$$

Where, H represents a hole in the network.

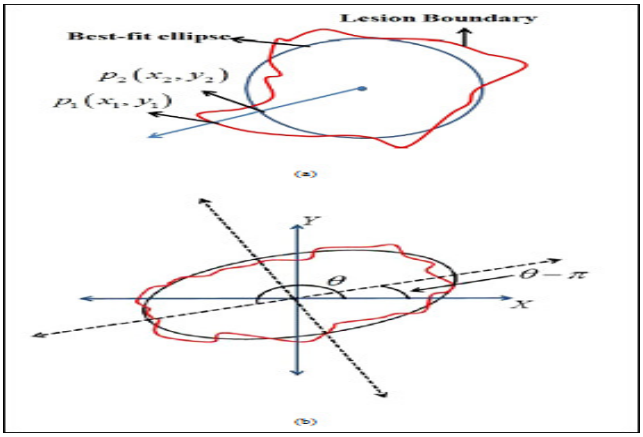

Figure.3. Best-fit ellipse (a) Lesion shape estimation (b) Lesion orientation estimation

d) Total number of holes in the network and lesion area ratio (f4): This ratio compares total number of holes and the total lesion area.

$$f4 = \frac{\sum H}{A(L)} \tag{6}$$

e) Total number of holes in the network and filled network area ratio (f5):

$$f5 = \frac{\sum H}{A(FN)} \tag{7}$$

3) Lesion characteristics feature set: Skin lesion has different shapes, orientations, margin, intensity of pixels it consists of and variation pattern. Thus, the feature set consists of five features.

a) Shape (L(S)): Most of the skin lesions have irregular shapes. This feature calculates the degree of irregularity of the lesion. The best-fit ellipse is used for this purpose [8]. As shown in the Fig. 3 (a), the best-fit ellipse is inscribed over the lesion. A line originating from the centre of the ellipse intersects the ellipse and lesion at two points, $p_2(x_2, y_2)$ and $p_1(x_1, y_1)$ respectively. The distance between these points is calculated as,

$$D(p) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{8}$$

All such distances between pixels are calculated and the lesion shape feature is given by,

$$L(S) = \frac{\sum D(P)}{LB_N} \tag{9}$$

Where, LB_N is the total number of pixels on the lesion boundary.

b) Orientation (L(O)): The range of orientation of the lesion is calculated in this feature [8]. The measure of angle θ made by the main axis of the best fit ellipse is used for this feature as shown in Fig. 3 (b).

$$\begin{aligned} L(O) &= \theta \text{ if } 0 \le \theta \le \frac{\pi}{2} \\ &= \pi - \theta \text{ if } \frac{\pi}{2} < \theta \le \pi \\ &= \theta - \pi \text{ if } \pi < \theta \le \frac{3\pi}{2} \\ &= 2\pi - \theta \text{ if } \frac{3\pi}{2} < \theta \le 2\pi \end{aligned} \tag{10}$$

c) Margin (D(P)): The distance map is used to measure the undulation and the angular characteristics of

the lesion's margin. For a pixel P(x, y) in the region of interest, its eight neighbors are defined as the following,

$$N_8(P) = \{(x-1,y-1),(x,y-1),(x+1,y-1),(x-1,y),(x+1,y),(x-1,y+1),(x,y+1),(x+1,y+1)\} \quad (11)$$

The distance from P to the lesion boundary is defined by,

$$D(P) = \mathrm{Min}\{D(N_8(P))\} + 1 \quad (12)$$

Where, $\mathrm{Min}\{D(N_8(P))\}$ denotes the minimum distance between P's eight neighbors.

d) Intensity Pattern (L(IP)): The average gray intensity of the lesion is used for representing the intensity pattern feature. The average gray intensity is defined as,

$$L(IP) = \frac{\sum_{P \in ROI} I(P)}{N_{ROI}} \quad (13)$$

Where, I(P) is the gray intensity of pixel P of the lesion and N_{ROI} represents the total number of lesion pixels.

e) Variation Pattern (L(VP)): The variation on pixel P is estimated by the gradient magnitude. According to the definition of neighbors , the Sobel gradients on x-direction and y-direction of pixel P(x, y) are respectively defined as,

$$G_x(P) = I(x-1,y-1) + 2I(x-1,y) + I(x-1,y+1) - I(x+1,y-1) - 2I(x+1,y) - I(x+1,y+1) \quad (14)$$

$$G_y(P) = I(x-1,y-1) + 2I(x,y-1) + I(x+1,y-1) - I(x-1,y+1) - 2I(x,y+1) - I(x+1,y+1) \quad (15)$$

The magnitude of gradient on P is defined as,

$$G(P) = \sqrt{G_x(P)^2 + G_y(P)^2} \quad (16)$$

Finally, the average variation is calculated as,

$$L(VP) = \frac{\sum_{P \in ROI} G(P)}{N_{ROI}} \quad (17)$$

D. *Classification*

Support vector machine (SVM) is used for classification. It is based on structural risk minimization. It aims finding a classifier for minimizing the limits of expected errors. It searches for a maximum margin that separates the hyper-plane and the nearest valued point of the training set between two sections of data. The support vector machine is used here as a bi-classifier for classifying skin lesions into benign lesion or melanoma lesion.

IV. Experimental Results

The PH2 dermoscopic image database is used for the evaluation of experimental results. It has 80 benign and 40 melanoma images. All are bitmap images with 768*560 pixel resolution. Fig. 4 and Fig. 5 show the results of benign and melanoma lesions respectively. The images in database are all RGB images. The feature vector produced is fed to the SVM classifier. For training the SVM classifier, 10 benign and 10 melanoma lesions are taken. Both are labeled with a certain class number and then the tests are performed for different images of lesion

V. Conclusion

The cases of skin cancers are increasing rapidly. The primary mark on the body surface in most of the skin cancers are the skin lesions. The skin lesions have to be analyzed at an early stage for preventing the possibility of occurrence of skin cancer. Current techniques for detection of type of skin lesion include biopsy which is an invasive method. For this, first the surgical excision of the skin lesion is done and then the type is determined. It is an obvious complex technique. In this paper, an approach for determining the type of skin lesion is presented. The hair removal which is obligatory as far as skin is concerned is taken into account so that the further procedures of automated recognition do not get obstructed. Here, two filters namely median and bottom-hat are applied for hair removal. The result obtained is a gray scale image. Segmentation is obtained using active contour and morphological operations primarily and gives good results for improvisation in feature extraction module. The output of segmentation stage is a binary image where the foreground (lesion) is white and the background is black. The features extracted are typically suited to the lesion and can be used to differentiate between different lesions. The feature vector produced includes color, pigment network and lesion characteristics features. Classification is obtained using support vector machine (SVM) for bi-classification of the lesions. The benign lesions are classified with an accuracy of 81.42% and melanoma lesions are classified with an accuracy of 85%. Thus, the proposed work can provide a helping hand to medical diagnostic techniques for determining the type of lesion non-invasively.

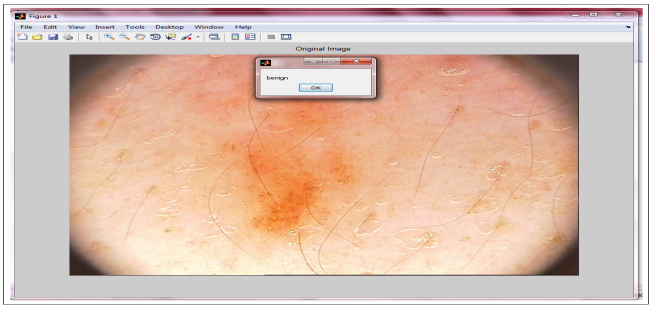

Figure.4. Result of a benign lesion

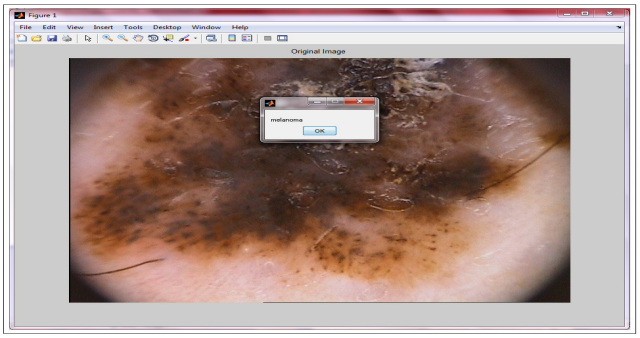

Figure.5. Result of a melanoma lesion

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