A Morphological Analysis of Pigmented Skin Lesions through Digital Image Processing

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Abstract— **Melanoma is the most malignant type of skin cancer due to its ability to metastasize. Since early detection is the best way to prevent it, many detection techniques have been developed, such as the ABCD rule, the Menzies method and the 7-point checklist. Digital image processing is nowadays a powerful and useful tool for the analysis of biomedical images, resulting in great help in the diagnosis of many diseases. Consequently, by using this tool it is possible to develop software capable of automatically recognizing different patterns of pigmented skin lesions. In this paper we propose an algorithm based on the morphological analysis of an image of a pigmented skin lesion in order to characterize and quantify its malignity according to the ABCD rule developed by Stolz in 1994. The proposed method includes image enhancement techniques, the segmentation of the injured area together with morphological algorithms to obtain the ABCD characteristics, and the calculation of the Total Dermoscopy Score (TDS), which will let us classify the lesion as benign, suspicious or malign. The results obtained show that the proposed algorithm is reliable and could help the medical professional in the diagnosis of melanoma.**

Key words— **Melanoma, ABCD Rule, Total Dermoscopy Score, Digital Image Processing.**

I. Introduction

Melanoma is a type of pigmented skin cancer of melanocytic origin. Despite the fact that melanoma accounts for only 2% of all skin cancer cases, it is of a major malignancy, due to its capacity to generate metastatic sites. An estimated 76,100 new cases of melanoma will be diagnosed in 2014 in the United States, and nearly 9,710 deaths will occur [1].

The single most effective mechanism to combat melanoma is an early detection. Thus professionals use different techniques to determine whether the pigmented lesion could possibly be a case of melanoma. This, together with complete removal, is essential, since melanoma evolves from localized skin lesions to very aggressive, treatment-resistant tumors [2].

The accurate perception and experience of the physician play a key role in diagnosing the lesion, for which there exist algorithms that facilitate an objective approach. Some of the most influential algorithms in literature are: Stolz's ABCD Rule, the Menzies method, and the 7-point checklist by Argenziano [3].

The ABCD Rule, put forth by Stolz et al. in 1994 [4], is based on the calculation of the Total Dermoscopy Score (TDS), which assesses four criteria regarding the lesion: asymmetry (A), border (B), color (C), and diameter (D) (Table 1).

Table 1: ABCD Rule [4]

Criterion	Score	Weight Factor
Asymmetry	0-2	1.3
Border	0-8	0.1
Color	0-6	0.5
Diameter	1-5	0.5

The Total Dermoscopy Score is calculated as follows [4]:

$$TDS = 1.3 * A + 0.1 * B + 0.5 * C + 0.5 * D \tag{1}$$

Depending on this value, the lesion is classified according to Table 2.

Table 2: Classification of Pigmented Lesion [4]

Total Dermoscopy Score	Classification
TDS<4.75	Benign
4.75<TDS<5.45	Inconclusive
TDS>5.45	Melanoma

Although there are a number of documents about this algorithm, they limit their scope to only one of the four mentioned criteria regarding the lesion [5][6]. This paper proposes a method through morphological treatment of images to obtain the TDS taking the four criteria into account.

II. Materials and Methods

A data base with 26 dermoscopy images of melanocytic pigmented lesions has been used. 21 of such images have been provided by the Private Center for Diagnostic

Imaging, Rio Cuarto, Córdoba; whereas the other 5 have been retrieved from an online data base of the University of Valencia, Spain [7]. The instrumentation used for the obtaining of such images was the epiluminescence microscopy.

The proposed methodology accounts for five stages:

1. Preprocessing
2. Segmentation
3. Assessment of criteria
4. Calculation of TDS
5. Classification of the lesion

The image shown in Fig. 1 will serve as an example to the method.

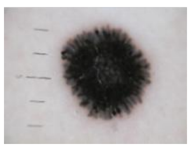


Fig. 1 Original Image

A. Preprocessing

The aim of this stage is to highlight the contrasts in the image and to eliminate noise, so as to facilitate the detection of the injured area and distinguish it from the surrounding skin. For this, the image will be converted to grayscale, and a 3x3 median filter will be applied [8]. In several images there are lines (inherent to the acquisition) or hair that introduce noise. In order to solve this, morphological openings and closings with a structuring element of radius 2 are applied. Finally, the histogram is adjusted, which emphasizes the contrast between the lesion and the surrounding area, and the preprocessed image is obtained. (Fig. 2).

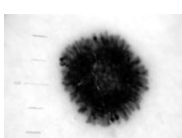
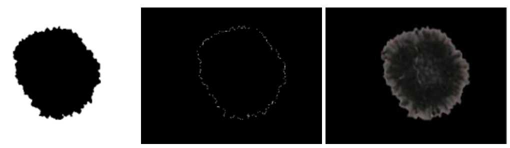


Fig. 2 Preprocessed Image

B. Segmentation

In order to make the distinction between the lesion and the rest of the skin, a correct selection of the process of segmentation is necessary. The combination of Otsu's method for image binarization (Fig. 3a), followed by the Canny algorithm for edge detection (Fig. 3b) has shown better results [8]. The edges detected are not always continuous. Therefore, dilations are applied with a disk of radius 2 to give continuity to the edge. Subsequently, the structures are refilled and eroded with a disk of the same radius to maintain the size of the segmented areas.

In some images, the process of segmentation detects zones that do not belong to the area of interest, such as small areas with a different pigmentation or illumination which have not been eliminated in the preprocessing. Since medical images expand the area corresponding to the lesion, in most cases the area of interest will be the one with a bigger structure. In this way, the smaller structures are eliminated through a process of comparing the areas which result in the segmented image (Fig. 3c).



a) b) c)

Fig. 3 Process of segmentation. a. Otsu's method for binarization. b. Edge detection. c. Area of interest.

C. Assessment of Criteria

Once the image segmentation has taken place, the characteristics of the lesion are to be analyzed according to the ABCD rule.

Asymmetry: it is to be considered in terms of form and color. It varies depending on the axes taken as reference, thus those that minimize the asymmetry in form will be selected. The major and minor axis of the smaller ellipse that encloses the lesion is the criteria of rotation. Fig. 4 shows the rotated image with the selected axes set vertically and horizontally to compare the upper portion with the lower one, and the right portion to the left one. Then, the two halves to compare are overlapped, the percentage of pixels which are left out is determined, and the average of such comparisons is calculated. Asymmetry in form is empirically determined if such percentage is above 17%.

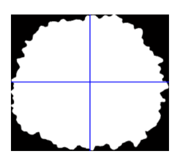


Fig. 4 Rotated image according to the selected axes.

To quantify asymmetry in color, grayscale normalized histograms of opposing halves are compared based on the calculation of 1-norm in the difference between both histograms.

$$\sum_{j=0}^{255} \left| h1_j - h2_j \right| \quad (2)$$

h1 and h2 represent the compared normalized histograms. The average of both comparisons is calculated and if the 1-norm is above the empirical value of 0.3, there is asymmetry in color.

If there is no asymmetry, then the criterion A equals 0, if there is asymmetry in form or color A=1, and if the asymmetry is in both form and color A=2. In the example, there is no asymmetry in form since %Pixels=10.32% and 1-Norm=0.14, then A=0.

Borders: the score of this criterion ranges from 0 to 8, for which it is necessary to analyze 8 portions of the image, and to study the irregularity in the borders of each portion separately. To this end, the same axes selected for criterion A are used, and other two in 45º are added as shown in Fig. 5.

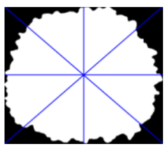


Fig. 5 Selected axes for border analysis.

For each portion, the distance from each pixel to the center of the lesion is calculated (the center being the one of the calculated ellipse).

$$D_i = \sqrt{(x_i - x_c)^2 + (y_i - y_c)^2} \quad (3)$$

Being (x_i, y_i) the coordinates of each pixel of the border and (x_c, y_c) the ones in the center. Once these distances are obtained, the average is calculated:

$$\overline{D} = \frac{1}{N} \sum_{i=1}^{N} D_i \quad (4)$$

Then, the standard deviation:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (D_i - \overline{D})^2} \quad (5)$$

One score is assigned for each portion of the border whose standard deviation surpasses the empirical value of σ=5. In the example, all borders are irregular, then B=8.

Color: this score is given on the basis of 6 different colors. Each of these is represented by a vector in the RGB space as shown in Table 3.

Table 3: Representation of colors of ABCD in RGB

Color	RGB	rgb
White	255,255,255	1.0,1.0,1.0
Black	0,0,0	0.0,0.0,0.0
Red	255,0,0	1.0,0.0,0.0
Light brown	205,133,63	0.80,0.52,0.25
Dark brown	101,67,33	0.40,0.26,0.13
Blue-gray	0,134,139	0.0,0.52,0.54

Next, using the segmented image in RGB, the Euclidean distance is calculated between each color and the color of each pixel in the lesion.

$$Euclidean = \sqrt{(r_i - r)^2 + (g_i - g)^2 + (b_i - b)^2} \quad (6)$$

Being (r_i,g_i,b_i) the components of red, green and blue of the pixels in the image, and (r,g,b) the components of each of the colors shown in Table 3.

The color tone whose Euclidean distance to the pixel is minor will be the one that better represents the color of such pixel, thus the pixel is considered to have that tone. If there is a sufficient percentage of pixels P=4%, the color is considered to be present in the lesion, and one score is assigned to criterion C for each existing color. In this case, two colors are detected: Black=58.43% and Dark brown=39.97% (Fig. 6), then C=2.

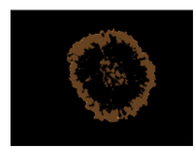


Fig. 6 Colors detected in the injured area.

Diameter: the average diameter in pixels is obtained. By knowing the pixels per millimeter in the image, it is possible to obtain the diameter in millimeters. To make this measurement effective, the images use a scale. In accordance with the ABCD rule, a lesion of 5mm or more has better probability of being melanoma, thus one score is assigned for each millimeter, and any lesion larger than 5mm will have a score of 5. In the example, D=3.77mm.

D. *TDS Calculation*

Once the A, B, C, and D criteria have been obtained, the Total Dermoscopy Score is calculated.

$$TDS = 1.3*0 + 0.1*8 + 0.5*2 + 0.5*3.77 \quad (7)$$
$$TDS = 3.69 \quad (8)$$

E. Classification

Based on the TDS, the lesion is classified according to the previously exposed in Table 2. In the example, TDS=3.69, which means the lesion is benign. This coincides with the physician's diagnosis, Nevus de Reed (benign melanocytic pigmented lesion).

III. Results

To evaluate the performance of the developed method, we used the presented database as input. The results obtained are shown in Table 4.

Table 4: Results

	Benign	Melanoma
Number of Images	15	11
Correctly detected	10	9
Detected as suspicious	2	1
Incorrectly detected	3	1

The measures used for the evaluation of the method are sensitivity, specificity and accuracy.

$$Sensitivity = \frac{TruePositive}{TruePositive + FalseNegative}\% \qquad (9)$$

$$Specificity = \frac{TrueNegative}{FalsePositive + TrueNegative}\% \qquad (10)$$

$$Accuracy = \frac{TruePositive + TrueNegative}{Positive + Negative}\% \qquad (11)$$

The experimental results revealed a sensitivity of 91%; specificity of 75% and accuracy of 73%.

IV. Discussion

The results obtained show that the morphological processing of skin images represents a reliable tool that can guide and assist the physician with the detection of melanoma. It does not pretend to replace the professional judgment, but it is one resource that can work as basis to support the diagnosis.

The high sensitivity suggests that the method is a strong warning system that can tell which lesions are more likely to be malign.

As future work, further development is proposed regarding algorithms following other methods, such as the Menzies method or the 7-point checklist by Argenziano. The development of an automatic algorithm combining such methods could represent a stronger tool, as it would improve the specificity and accuracy, and become a more reliable system.

Another proposal is the use of techniques based on fuzzy logic to quantify the parameters involved in the TDS.

V. Conclusions

The proposed method has revealed coherent and reliable results for the identification of images to diagnose melanoma, and it has the potential to become a useful instrument for physicians, since it is an objective and standardized system which follows international accepted rules.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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