Determination of Border Irregularity in Dermoscopic Color Images of Pigmented Skin Lesions

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***Abstract*—Malignant melanoma, which is the most dangerous type of skin cancer, is commonly diagnosed in all people, regardless of age, gender, or race. In the last several years an increasing melanoma incidence and mortality rate has been observed worldwide. In this research we present a new approach to the detection and classification of border irregularity, one of the major parameter in a widely used diagnostic algorithm ABCD rule of dermoscopy. Accurate assessment of irregular borders is clinically important due to a significantly different occurrence in benign and malignant skin lesions. In this paper we describe a complex algorithm containing following steps: image enhancement, lesion segmentation, border irregularity detection as well as classification. The algorithm has been tested on 300 dermoscopic images and achieved a detection of 79% and classification accuracy of 90%. Compared to state-of-the-art, we obtain improved classification accuracy.**

I. INTRODUCTION

Malignant melanoma (Latin: *melanoma malignum*) originates in pigment producing cells called melanocytes, which derive from neural crest. Melanomas are fast-growing and highly malignant tumors often spreading to nearby lymph nodes, lungs and brain. In the last several years increasing melanoma incidence has been observed worldwide and the diagnoses and deaths are increasing faster than those of any other skin cancer [1]. Malignant melanoma becomes a most frequent type of cancer with over 100 000 deaths each year [2]. Malignant melanoma is predicted to become one of the most common malignant tumors in the future, with even a ten times higher incidence rate. One of the major contributors to the development of melanoma is ultraviolet radiation (long-term sun exposure and sun-burn) that causes damage to the cell DNA. Also the negative influence of quality of life is of great importance. Due to high skin cancer incidence, dermatologic oncology has become a quickly developing branch of medicine. One of the main tasks of modern dermatology is the detection of melanoma in its early stage of development, because the survival rate after identification of less than 0.75 mm thick melanomas is near 100 % [1, 3, 4]. In the light of the above data, prevention and early diagnosis of melanoma become an extremely important issues.

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The examination of small moles is possible through a digital epiluminescence microscopy (ELM, also dermoscopy or dermatoscopy) which is a non-invasive, in vivo technique that, by employing the optical phenomenon of oil immersion, makes subsurface structures of the skin accessible for examination (Fig. 1). The dermoscopic diagnosis of pigmented skin lesion is based on the assessment of the presence or absence of different global and local features. Various analytic methods and algorithms have been set forth in the last 25 years. The most important and widely used are: Pattern analysis, ABCD rule of dermoscopy, 7-point checklist and Menzies method [1, 5].

Figure 1. Lesion observed with the naked eye in comparison to the dermoscopy examination. The global and local features become visible (based on [1]).

This paper is organized in 5 chapters as follows. Chapter 2 presents the diagnostic algorithm and the importance of border irregularity. Chapter 3 describes the image processing algorithm, including preprocessing step, segmentation method, and the detection and classification of border irregularity. major and minor axes determination. In chapter 4 the conducted tests and results are described. Chapter 5 closes the paper with conclusions, discuss the results and highlights future directions.

II. CLINICAL DEFINITION AND RELATED WORKS

A. ABCD rule of dermoscopy

ABCD rule of dermoscopy is one of the first diagnostic algorithms and is one of the most commonly used methods for the evaluation of melanocytic lesions also by Polish dermatologists. The ABCD rule was originally proposed in 1994 by Stolz and coworker [6]. In 1994, Nachbar et al. proved the reliability of the ABCD rule in a prospective study. For 172 melanocytic lesions (69 melanomas and 103 melanocytic nevi) specificity was 90.3% and sensitivity was 92.8% [7]. For calculating the ABCD score the 'asymmetry, **border irregularity**, color, and differential structure' criteria have to be assessed semiquantitatively.

B. *Border irregularity*

The most important warning sign for melanoma is a change in size and shape of a mole or other skin growth. One of the main warnings is border irregularity. Border irregularity is a ragged, notched, or blurred edge at the periphery of the skin lesion (Fig. 2). For semiquantitative evaluation, the lesion is divided into eight similar parts and a sharp, abrupt cut-off in each part has a score of 1. So, if the whole border is irregular the maximum border score is 8. If the mole is round with no ragged borders the score is 0. As a rule the border score in nevi is very low and in melanomas is between 4 and 8 [1].

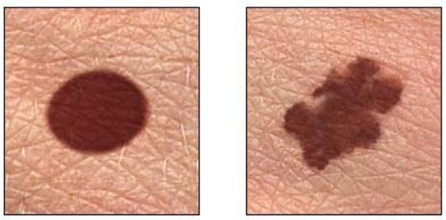

Figure 2. Border irregularity [17].

III. RELATED WORKS AND BACKGROUND

Different groups are developing diagnostic systems and improving the detection algorithm to provide distinction between benign and malignant melanocytic lesions [8]. To the best of our knowledge, only a few studies have focused on border irregularity detection and classification. The most successful detection and classification method is presented in [9]. Different parameters are being estimated including: compactness index [3], solidity [10], fractal dimensions [11] and indentation irregularity index [12]. Many papers analyze the radial distance between the center of the mass and the border (Fig. 3). This approach is of great interest but still causes many errors.

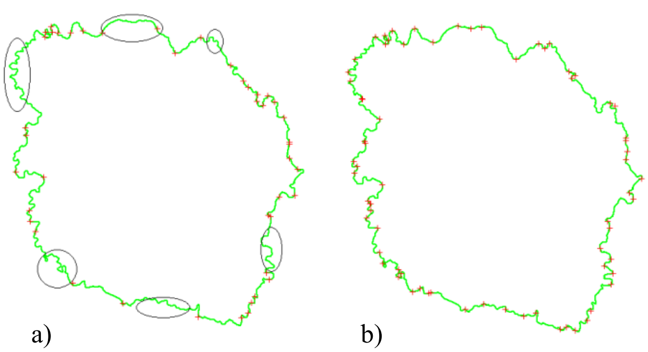

Figure 3. Border irregularity measured for the same skin lesion a) with the radial distance b) with proposed method.

IV. MATERIALS AND METHODS

For the detection and classification of border irregularity in skin lesions a special image processing system has been designed. The overview of the algorithm is presented in Fig. 4.

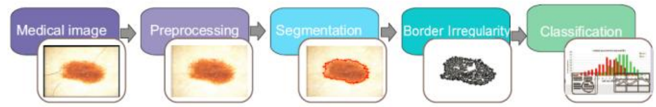

Figure 4. System overview.

The system is divided into four stages: preprocessing (image enhancement), segmentation, border irregularity detection and classification. Since the main aim of this research is to present the border irregularity detection and classification step, the preprocessing and segmentation stage will be described shortly. A detailed description of this steps can be found in our works [13, 14].

A. *Preprocessing*

For dermoscopy images the preprocessing step is obligatory, because of extraneous artifacts such as skin lines, air bubbles and hairs which appear in most every image. The preprocessing stage consists of three parts: black frame removal, smoothing and black hair inpainting. The black frame is introduced during the digitization process. In order to determine the darkness of a pixel with (R;G;B) coordinates, the lightness component of the HSL color space are calculated [13, 15, 16]. The smoothing filter (Gaussian filter) helps to reduce the influence of skin lines, air bubbles and light, thin hairs. The last stage is the black hair detection and inpainting. For removing black and thick hairs we chose the white top-hat transform. Hair line pixels are replaced with values calculated on the basis of the neighborhood pixels (Fig. 5b).

B. *Segmentation*

The last step before border irregularity detection is the segmentation process. The aim of the image segmentation stage is to extract the lesion area from the healthy skin. In our case the most important information will be the border line. The applied segmentation algorithm for the skin lesion extraction is based on seeded region-growing algorithm. For the skin lesion segmentation we select one seed which is located in the left corner of the image (Fig. 5c). It gives us the certitude that we will segment the homogeneous background [14].

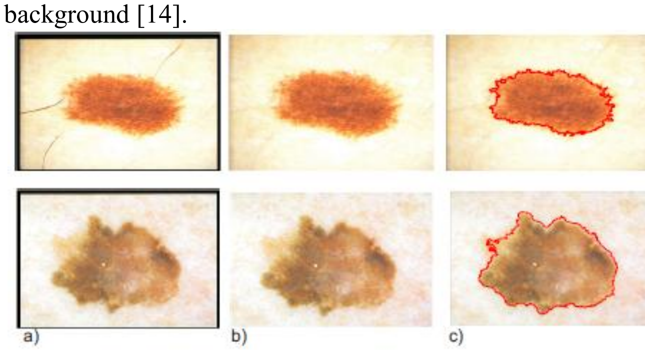

Figure 5. Algorithm steps: a) dermosopic image, b) preprocessing, c) segmentation.

C. Border irregularity detection

In our research we propose to translate the border into a function with peaks indicating the border irregularity. For solving this problem we have implemented a four step algorithm. Firstly, we compute a bounding box of the segmented skin lesion. Secondly, we find the boundary pixels lying on the lines connecting the center of the mass with the vertices as shown in Fig. 6.

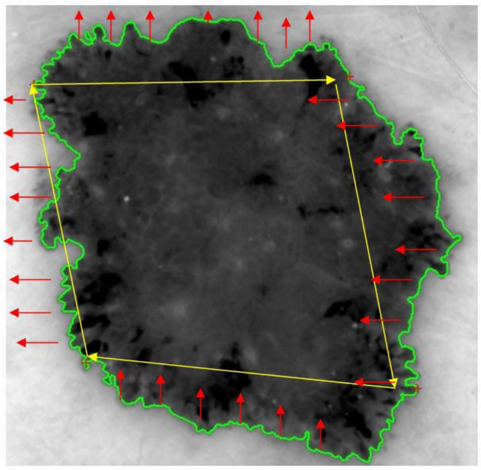

Figure 6. Results after preprocessing and segmentation

In the next step we calculate the distance between the border and the image edge, presented in Fig. 6 with red arrows. As a result of the calculation we obtain a function with an exact reflection of the border irregularities.

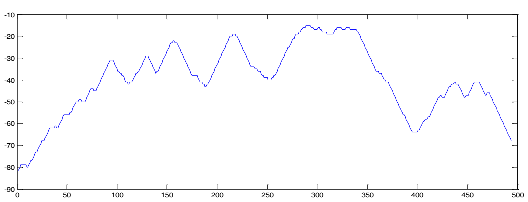

Figure 7. Function of the first part of the border line.

For the determination of the ragged edges we smooth the signal with Gaussian filter (1).

$$w(n) = e^{-\frac{1}{2}\left(\alpha\cdot\frac{n}{N/2}\right)^2} \tag{1}$$

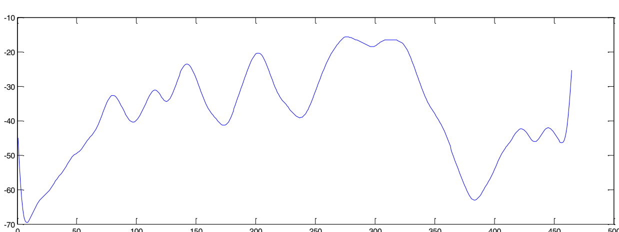

Figure 8. Results after smoothing for the first part of the border.

After the smoothing filter (Fig. 8) we calculate the derivative to find local maximum points of the function. The local maximum is detected when the function crosses the zero point and the slope changes form + to -.

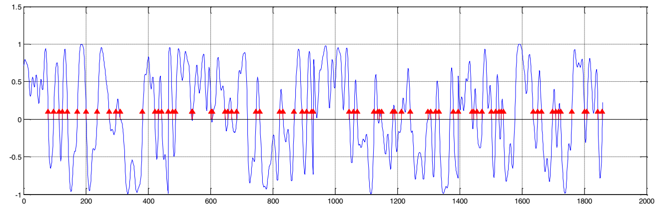

Figure 9. Detected border irregularities.

Fig. 9 presents the detected border irregularities with red arrows.

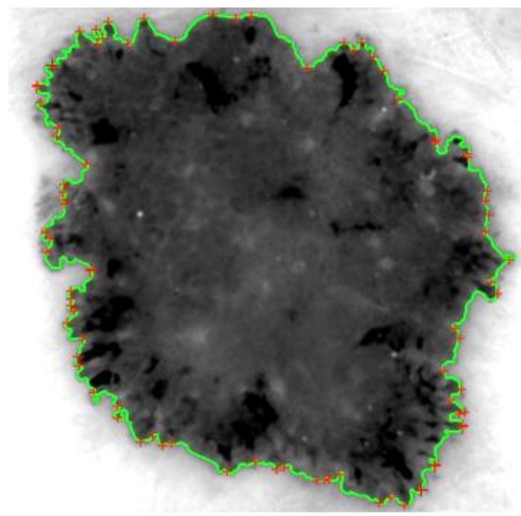

Figure 10. Border irregularities on the skin border line.

In Fig. 10 the detected border irregularities are marked with red crosses on the skin border line.

D. Border irregularity classification

Finally, after the border irregularity detection the border score has to be obtained. The lesions border are divided into eighth parts and an abrupt cut-off of pigment pattern at the periphery within one eighth has a score of 1. The maximum border score is 8, and the minimum score is 0. The final score is one of four parameters in the diagnostic algorithm ABCD rule of dermoscopy.

In Fig. 11 we present the outcome for 4 skin lesions with different border irregularity score.

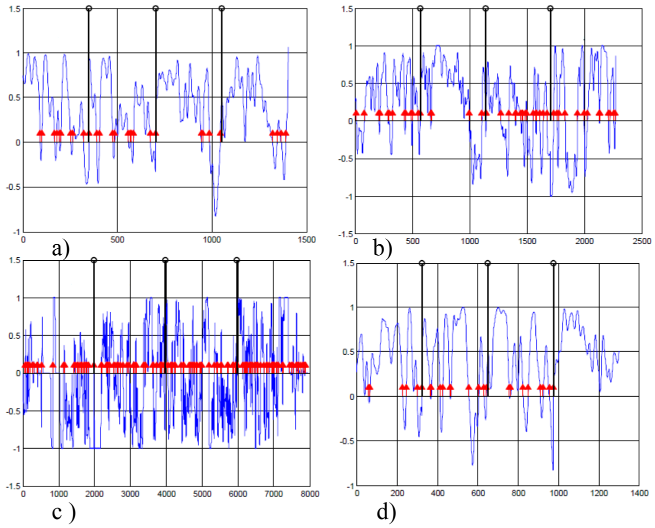

Figure 11. Function of the border line with detected irregularities.

V. RESULTS

The implemented algorithm for the detection and classification of irregular borders has been tested on a set of 300 high quality clinical and matching dermoscopic images taken from the Interactive Atlas of Dermoscopy [1]. The experts assessed every image in terms of the border irregularity. The database contains: 120 cases with border irregularity less than 3 and 180 skin lesions with border irregularity above 4. The preprocessing step (black frame removal and hair removal) as well as the segmentation step (border error less than 6%) did not affect the further research.

The border irregularity detection is in many cases hard to assess. We only checked the border irregularities that were obvious for the physician. We achieved accuracy of 79%. The final medical score for border irregularity is based only on correct identification of only one cut-off in every region. For this reason the final score is higher than the achieved accuracy. For skin lesion with score over 6 the accuracy is 94%. For skin lesion with score between 3 and 5 the accuracy is 81%. For skin lesion with score between below 3 the accuracy is 93%. In most cases the errors have been product of the own subjectivity in the appreciation.

VI. CONCLUSION AND FUTURE PLANS

We propose a new approach to the detection and classification of the border irregularity. The results obtained within this study indicate that the proposed algorithm can be used for the diagnosis of the border irregularity in the diagnostic algorithm ABCD rule of dermoscopy. Due to the difficulty and subjectivity of human interpretation, the computerized image analysis techniques have become important tools in this research area. Despite the fact, that the results are satisfactory, the proposed algorithm will still be the subject of development. To begin with, the border irregularity will be compared with local structures like streaks. Secondly, the classification process will include more parameters, such as the changes of the thickness of the border and the size of the cut-off. To sum up, the algorithm meets the expectations and satisfactory. The results of tests show that computer-based image processing has the potential of providing the better evaluation of changes.

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