AUTOMATIC LESION SEGMENTATION FOR MELANOMA DIAGNOSTICS IN MACROSCOPIC IMAGES

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ABSTRACT

Detailed segmentation of pigmented skin lesions is an important requirement in computer aided applications for melanoma assessment. In particular, accurate segmentation is necessary for image-guided evaluation of skin lesions characteristics. In this paper, we present a new approach of histogram thresholding for detailed segmentation of skin lesions based on histogram analysis of the saturation color component in the hue-saturation-value (HSV) color space. The proposed technique is specifically developed with the aim to handle the complex variability of features for macroscopic color images taken in uncontrolled environment. A dataset of 30 cases with manual segmentation was used for evaluation. We compare our results with two of most important existing segmentation techniques. For similarity report between automatic and manual segmentation we used dice similarity coefficient (DSC), the true detection rate (TDR), and the false positive rate (FPR). Experimental results show that the proposed method has high precision and low computational complexity.

Index Terms— lesion, segmentation, saturation, skin cancer.

1. INTRODUCTION

Melanoma rate of disease is increasing globally. A report from the Skin Cancer Foundation lists a number of alarming facts [1]: one person dies of melanoma every 57 minutes, an estimated of 73,870 new cases of invasive melanoma will be diagnosed in the year 2015 only in the US, an estimated of 9,940 people will die of melanoma in 2015, melanoma accounts for less than two percent of skin cancer cases, but the vast majority of skin cancer deaths. Nevertheless, melanoma can be treated easily and cured in most cases if detected at an early stage. Given these antagonistic features two important conclusions can be drawn: for malignant melanoma prevention is the key word; people's access to melanoma screening is vital.

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Medical diagnosis of melanoma is performed by trained dermatologists using a specialized device called dermoscope. This hand held optical device is used to differentiate malignant skin lesions from nonmalignant skin lesions. The main clinical criteria used by dermatologist for diagnosis of cutaneous melanoma are known as ABCDE rule: A (Asymmetry) – the shape of the skin lesion is asymmetrical; B (Border) –the edges are irregular and poorly defined; C (Color) – the color is uneven; D (Diameter) – the dimensions are larger than 6mm; E (Evolution) – any change in size, shape, color, or other feature, is a sign of potential danger. Based on the ABCDE rule it is obvious that the most important diagnostic indicators used in the clinical assessment of melanoma are related to the size, the shape, and the color of the lesions.

This work represents a part of a research project that aims to provide an easy to use image based diagnosis tool for skin lesion assessment. The project aims at developing low complexity image processing techniques that will allow the identification of suspicions skin lesions from a macroscopic color image alone.

The first step in image-guided evaluation of skin lesions is the automatic segmentation of the lesions from macroscopic images. The segmentation is very challenging due to factors such as illumination variations, irregular structural, and color variations, the presence of hair, as well as the existence of multiple lesions in the skin [2].

There are a wide range of approaches in the existing literature for skin lesions segmentation for macroscopic images [3], [4], [5], [6], [7], [8], [9], [10], [11] and [12].

A popular class of approaches [3] – [5] is based on snakes, also known as active contours. A snake is an energy-minimizing curve guided by internal forces that preserve its characteristics, and external forces that pull it toward image features such as lines and edges [3]. In the case of lesion segmentation the curve is evolved toward the boundaries of the skin lesion regions. Active contour approaches are robust at handling noise, artifacts, and variations in illumination and color, but can face difficulties in situations characterized by multiple lesions or weak contrast between the skin lesions and the surrounding skin regions [5]. Furthermore, the methods in this class have the disadvantage of relatively high computational complexity.

A more simple class of methods for lesion segmentation is thresholding [6] – [12]. Thresholding is very effi-

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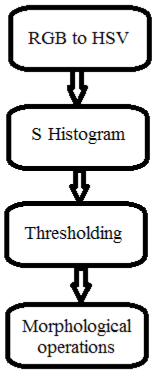
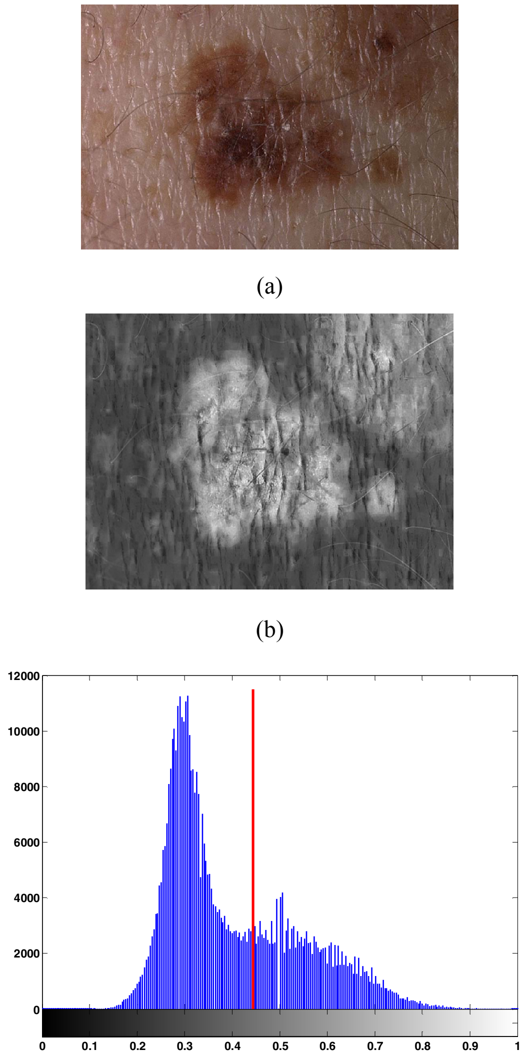


Fig. 1. Overview of segmentation approach.



(a)

(b)

(c)

Fig. 2. a) Macroscopic image for lesion segmentation. b) Saturation component for HSV representation of (a). c) Image histogram of (b) and Otsu threshold value.

cient in segmenting macroscopic lesion images, even in situations involving multiple regions, if the skin regions are homogeneous in nature and the lesions have consistent features. However, most of these approaches face difficulties when the images have variations of illumination and when body hair is present.

The goal of this paper is to address the issue of automated skin lesion segmentation for macroscopic images. The proposed thresholding method operating in the hue saturation value (HSV) color space offers good results in the presence of hair and illumination variations, and is efficient in the case of multiple lesion regions. To the best of the authors' knowledge, an HSV thresholding skin lesion segmentation method has not been previously proposed.

This paper is organized as follows. In Section II, the proposed method is described. Section III presents the experimental results using real macroscopic images. Finally, conclusions are drawn and future work is discussed in Section IV.

2. SKIN LESION SEGMENTATION

The goal of image segmentation is the extraction of distinct objects (regions) from the original image. The objects are usually described by some uniformity criterion defined according to the specific field of application. In this particular application we are interested in the segmentation of the pigmentary skin lesions from macroscopic images. The theory behind the proposed automatic lesion segmentation approach is described in the following sections.

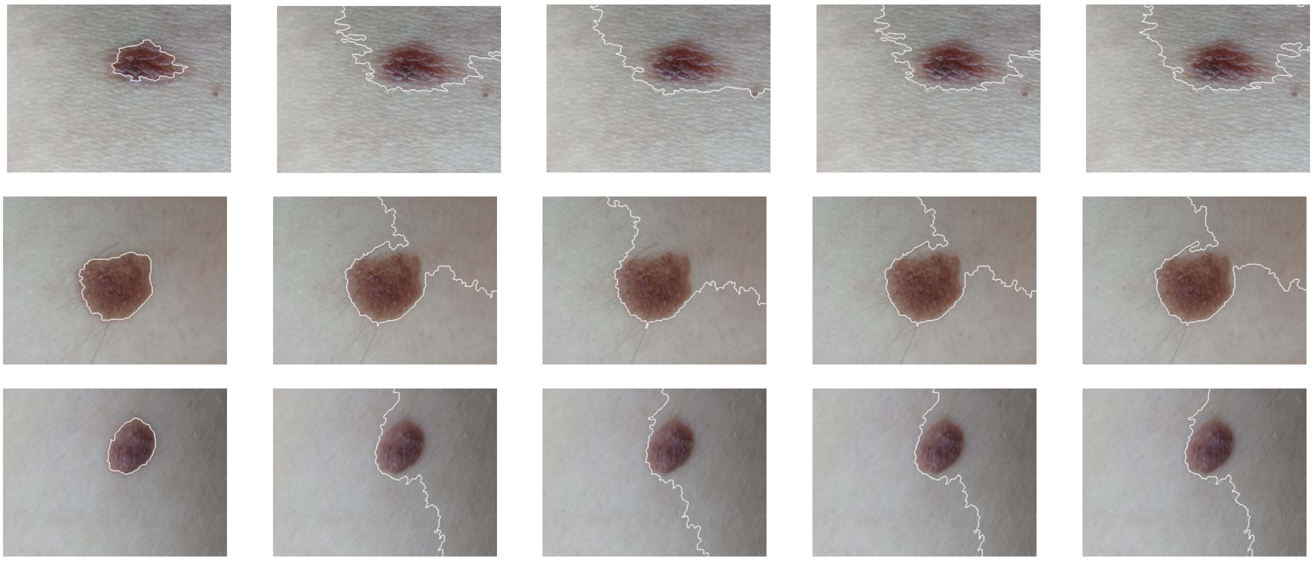
2.1. Method

A general overview of the segmentation method used for skin lesion estimation is shown in Fig. 1. First the image is converted from the red-green-blue (RGB) representation into HSV representation. Second, the image histogram of the saturation (S) image component is computed over 255 bins. Third, the threshold value is selected based on the histogram analysis and the binary mask is determined. Finally, morphological operations are used for holes filling and small regions removal. These operations are: selection of the largest areas of the binary mask, areas with more than 1000 pixels, morphological closing and morphological opening with a 5 pixel radius disk structuring element, and filing the holes of the resulting mask.

2.2. Histogram and Otsu thresholding

The proposed method is based on the experimentally found observation that the saturation component in the HSV representation offers the best discrimination between lesions and skin for most lesion types. This observation is explainable by the fact that the melanoma suspicious lesions are developed through mutations by the same pigment producing cells that give the skin tone.

Thresholding is a simple segmentation technique used for segmenting a digital image into mutually exclusive regions. Initially developed for segmenting grayscale images into 2 major regions, background and foreground, thresholding is successfully used also for color image



(a) (b) (c) (d) (e)

Fig. 3. Segmentation results of (a) proposed, (b) grayscale, (c) red channel, (d) green channel, and (e) blue channel.

segmentation [13], [14]. A threshold algorithm returns a binary map of a grayscale or color image by comparing each of the image's pixels to a given value named threshold. The most important advantages of thresholding segmentation methods are simplicity and low computational complexity. The basic problem of any thresholding algorithm is finding the most fitting threshold value.

One approach to threshold value determination is based on the image histogram. Peaks in image histograms are proofs of different tonal regions, so that a minimum value between two peaks can be used as threshold for region segmentation. Many times image histograms have poor defined maximums and minimums. In this case, finding the appropriate threshold value for skin lesion segmentation can be done using Otsu's method.

Otsu's method [15] is used to automatically perform clustering-based image thresholding. The Otsu algorithm is based on the assumption that the image contains two classes of pixels, background and foreground, and calculates the optimum threshold separating the two classes so that their combined intra-class variance is minimal.

An illustrative example of the image histogram based on the saturation component and the threshold value determined using Otsu's algorithm is presented in Fig. 2.

3. EXPERIMENTS AND RESULTS

The proposed method was implemented in MATLAB on an Intel Dual Core Pentium 3.3 GHz computer with 4 GB of RAM.

To evaluate the effectiveness of the proposed method, we compared the results with the thresholding method using Otsu's algorithm for the grayscale images and with a state of the art active contour segmentation method based on Chan–Vese model [16].

We used for testing 40 macroscopic images containing malignant and benign melanoma cases. Ten of the images are malignant melanoma cases and 30 images are benign lesions.

Method	DICE[%]	TDR[%]	FPR[%]
Red Otsu	64.53	97.65	7.73
Green Otsu	68.02	99.43	6.48
Blue Otsu	67.46	99.63	6.52
Proposed	98.49	98.26	1.36

Table 1. Performance evaluation of Otsu segmentation for red, green, and blue channels, and proposed segmentation method.

The 30 benign images were captured using a smartphone camera at a resolution of 1920x1080 pixels and resized to 800x600 for reducing simulation time in the case of Chan-Vese method. For 10 of the images we have evaluated the segmentation methods for different resolutions. The results showed that the resize of the images has a very small effect on the resulting segmented regions.

For the 10 melanoma images the results are similar but we have not included as a reprinting approval was not yet obtained from the source site [17].

For similarity report between automatic and manual segmentation we used dice similarity coefficient (DICE), the true detection rate (TDR), and the false positive rate (FPR).

The Dice index between the experimentally determined segmentation DS and the ground truth segmentation GT is computed as:

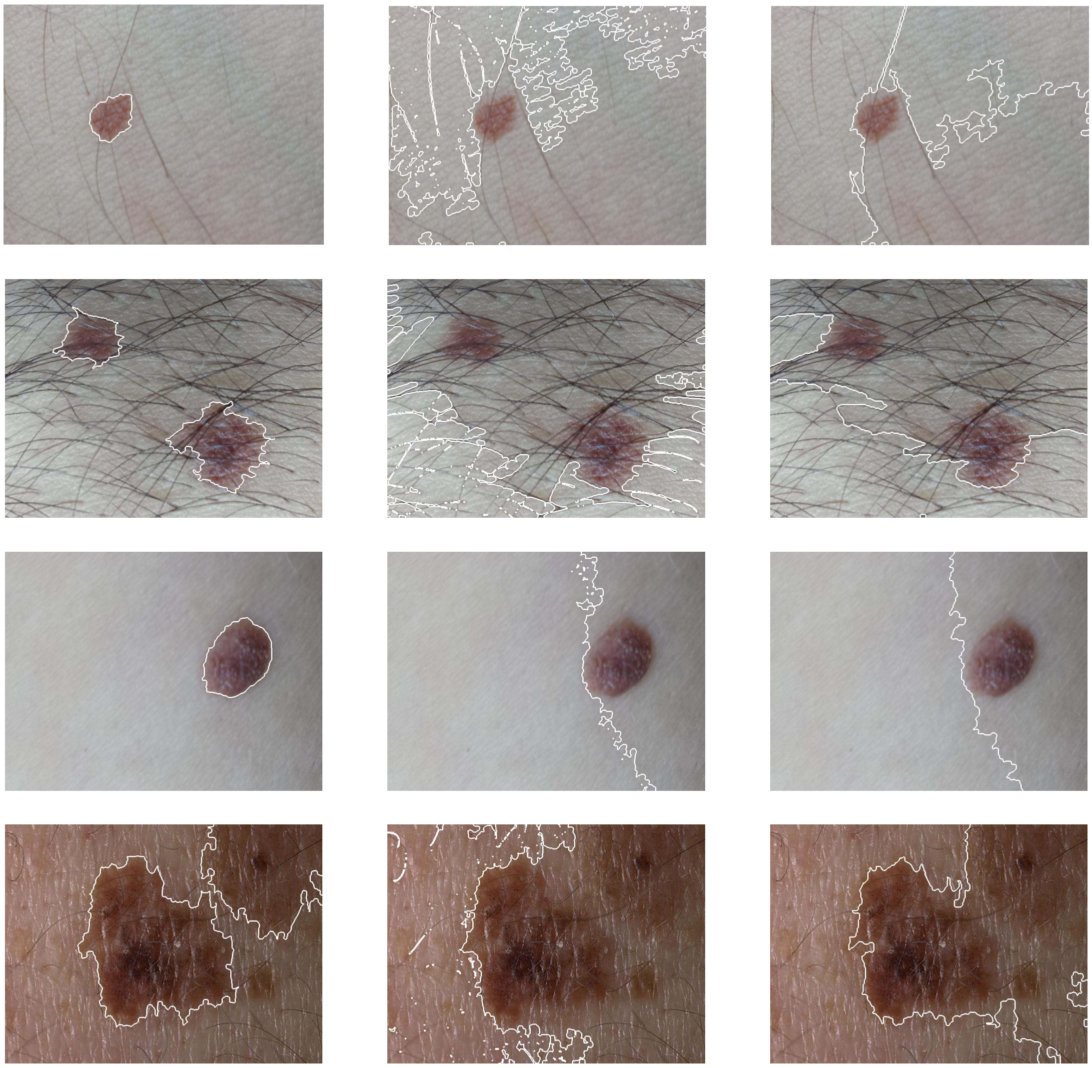
$$DICE = \frac{2 \cdot Area(DS \cap GT)}{Area(DS) + Area(GT)} \cdot 100[\%] \quad (1)$$

The true detection rate (TDR) is computed as:

$$TDR = \frac{Area(DS \cap GT)}{Area(GT)} \cdot 100[\%] \quad (2)$$

The false positive rate (FPR) is computed as:

$$FPR = \frac{Area(DS \cap \overline{GT})}{Area(GT)} \cdot 100[\%] \quad (3)$$



(a) (b) (c)

Fig. 4. Segmentation results of (a) proposed, (b) grayscale Otsu, and (c) Chan-Vese.

3.1. Comparison with Otsu thresholding

In order to prove the validity of our approach, the first comparison we've done is to the same thresholding method used in the grayscale representation of the images and on the red, blue, and green components of the color RGB representation.

As we expected in this case, the computational complexity is similar since the methods are similar. In terms of segmentation accuracy, the grayscale and RGB thresholding algorithms gave inaccurate results for real life macroscopic images characterized by the presence of hair, noise, illumination variations, and weak boundaries between skin and lesions.

From the results presented in Table 1 we conclude that the saturation thresholding method offers significantly better results, thus showing robustness to the listed conditions. An example of segmentation results using these compared methods is shown in Fig. 3.

3.2. Comparison with active contours Chan-Vese

To evaluate the effectiveness of the proposed method we compared the results with a state of the art active contour segmentation method based on Chan-Vese model [16].

The Chan-Vese model is an important segmentation model based on techniques of curve evolution, Mumford-Shah model, and level sets. We used the Chan-Vese model for vector-valued images implemented also in Matlab.

Method	DICE[%]	TDR[%]	FPR[%]
Grayscale Otsu	65.52	99.48	6.48
Chan-Vese	79.81	99.82	2.97
Proposed	98.49	98.26	1.36

Table 2. Best values of performance metrics.

Because it is clear that active contours methods have higher rates in computational complexity that the thresholding based methods, the comparison, in computational time, between the implemented methods is not included in this paper.

In Fig. 4, three examples of segmentation results of the tested macroscopic images are represented. By visual comparison it can be clearly seen that the proposed segmentation method offers higher segmentation precision than the active contours Chan-Vese model.

In terms of performance metrics we had difficulties in computing representative average values for DICE, TDR, and FPR for grayscale Otsu and Chan-Vese due to the high difference in area size between GT and DS. For this reason the values shown in Table 1, are the best values for grayscale Otsu and Chan-Vese, and the mean values for our approach. The segmentation results of the proposed method exemplified in Fig. 3 and Fig. 4, and the mean values for DICE, TDR, and FDR presented in Table 2, validate the feasibility of using the saturation component for skin lesion segmentation.

The proposed method achieves the highest DICE index, which indicates that it has a better overall performance when compared to grayscale Otsu method and active contour Chan-Vese method. The key advantage of the proposed method is its robustness to hair presence and illumination variations.

So far, the only limitations of the proposed method are for images captured using flash.

4. CONCLUSIONS AND FUTURE WORK

This paper proposed an automatic segmentation method for skin lesion identification defined for macroscopic digital images. The novelty of the proposed method consists in using only the saturation component from the HSV representation of the image. Experimentally we discovered that using the saturation image component for skin lesion segmentation two unwanted skin image characteristics, illumination variations and body hair, are addressed.

The idea of using only the saturation component for skin segmentation can be extended for other segmentation algorithms.

5. ACKNOWLEDGEMENTS

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