COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 112 (2013) 684–693

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

A coarse-to-fine approach for segmenting melanocytic skin lesions in standard camera images

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ARTICLE INFO

Article history:
Received 22 July 2012
Received in revised form
16 August 2013
Accepted 19 August 2013

Keywords:
Segmentation
Melanocytic skin lesion
Melanoma
Computer-aided diagnosis
Standard cameras

ABSTRACT

Melanoma is a type of malignant melanocytic skin lesion, and it is among the most life threatening existing cancers if not treated at an early stage. Computer-aided prescreening systems for melanocytic skin lesions is a recent trend to detect malignant melanocytic skin lesions in their early stages, and lesion segmentation is an important initial processing step. A good definition of the lesion area and its border is very important for discriminating between benign and malignant cases. In this paper, we propose to segment melanocytic skin lesions using a sequence of steps. We start by pre-segmenting the skin lesion, creating a new image representation (channel) where the lesion features are more evident. This new channel is thresholded, and the lesion border pre-detection is refined using an active-contours algorithm followed by morphological operations. Our experimental results based on a publicly available dataset suggest that our method potentially can be more accurate than comparable state-of-the-art methods proposed in literature.

1. Introduction

The efforts to develop reliable computer-based tools for pre-screening melanocytic skin lesions started nearly 30 years ago. Nowadays, it is possible to find in the literature: (a) tele-dermatology systems enabling an expert to receive images of suspicious lesions captured remotely, with a diagnosis indication to be confirmed by the expert; (b) computer-aided prescreening systems that pre-classify automatically an acquired skin lesion image; and (c) hybrid systems that use telemedicine and computer-aided prescreening in conjunction [1]. According to the World Health Organization [2], about 132,000 melanoma cases occur globally each year. Unfortunately, the incidence of malignant melanoma[1] still is high worldwide, which motivates new developments in this area.

Discriminating malignant (melanomas) and benign melanocytic skin lesions (e.g. nevi or moles) can be challenging. Usually, dermatologists screen each lesion with a dermoscope, a noninvasive tool that magnifies morphologic and vascular lesion structures. Therefore, many prescreening systems have been proposed to help physicians analyze dermoscopy images [3–5]. However, dermoscopes are specialized tools used by experts, and prescreening systems for images acquired with standard cameras (i.e. simple photographs) have been proposed in an attempt to provide an easy access to healthcare [6–8]. Even non-specialized systems running on

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[1] Malignant melanoma is a dangerous kind of melanocytic skin lesion.

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http://dx.doi.org/10.1016/j.cmpb.2013.08.010

mobile devices (e.g. smartphones) have been proposed as easy to use prescreening tools [9]. Although these non-specialized systems are not designed to replace the specialists, such tools can be helpful in the daily practice, for example for providing quick estimates of the severity of skin lesion cases, or as an accessible informed opinion, or yet for helping establish a priority in the assignment of skin lesion patients to specialists [9].

In general, a skin lesion prescreening system has four stages: (a) *preprocessing*, where the input image is processed so that its artifacts are eliminated to facilitate the segmentation step following immediately; (b) *segmentation*, for delimiting the lesion border; (c) *feature extraction*, where the segmented skin lesion is quantitatively described; and finally, (d) *classification*, that identifies the skin lesion as benign or malignant based on the lesion features extracted previously. As can be seen, it is a pipeline where each stage relies on the previous results. Understandably, the first two steps have been receiving ample attention in the literature, and also are the focus of this work.

For the segmentation of the melanocytic skin lesions, we propose three sequential steps: (1) initially, a quick pre-segmentation of the lesion image is obtained; (2) based on this pre-segmentation, a new channel is created trying to maximize the differences between lesion and **non-lesion** skin pixels; (3) after thresholding the lesion in this new channel, the segmentation is refined to better determine the lesion borders. All these steps of our proposed method are presented in Section 4. Before, we discuss the related approaches proposed in the literature in Section 2, and the pre-processing methodology used in Section 3. After the method description, we compare the results obtained by our approach and by state-of-art segmentation methods in Section 5. Finally, we present our conclusions in Section 6.

2. Related work

Considering standard camera images of melanocytic skin lesions, the most common preprocessing goal is to attenuate shading effects [7,8,10–12], since the segmentation step can be affected negatively by such imaging artifacts. Cavalcanti et al. [7,10] proposed a fully automatic shading attenuation method, which is image-adaptive and has been adopted in the preprocessing stage of this work, as detailed in Section 3. Elimination of other artifacts, like hair, also are common preprocessing goals. For example, hair elimination often relies on algorithms like DullRazor [13]). Nevertheless, hair also can be eliminated easily in the post-processing stage [7].

The segmentation of melanocytic skin lesions in standard camera images frequently use Otsu's thresholding method [14] because it is simple and fast. This thresholding method has been applied to grayscale images [8,15,16] and to the Red channel of melanocytic skin lesion images (i.e., R of the RGB color space) [17]. The method proposed by Tang [18] smooths the image with an adaptive anisotropic diffusion filter, and then uses a modification of the Gradient Vector Flow snake [19] to determine the lesion border. Cavalcanti and Scharcanski [7] use Otsu's thresholding method on a multi-channel image representation. Cavalcanti et al. [11] also proposed to use Independent Component Analysis (ICA) as an initialization, and then segment melanocytic skin lesions in standard camera images using the Chan-Vese active-contours method [20]. Moreover, all these segmentation methods includes a post-processing stage based on morphological operations to eliminate possible artifacts, and/or to refine the lesion border detection.

3. Skin lesion image preprocessing

As already mentioned in Section 2, shading effects are typical artifacts in standard camera images of melanocytic skin lesions. So, to suppress these artifacts, we apply a shading attenuation method recently proposed by Cavalcanti et al. [7,10], which is adaptive to the skin lesion image data. This method assumes that images are acquired in a way that the lesion appears in the image center, and it does not touch the image outer borders. The first step of the method is to convert the image from the original RGB color space to the HSV color space, and retain the Value channel V. This is justified by the fact that this channel presents the higher visibility of the shading effects. A region of 20×20 pixels is extracted from each V corner, and the union of these four sets define the pixel set S. This pixel set is used to adjust the following quadric function $z(x, y)$:

$$z(x, y) = P_1x^2 + P_2y^2 + P_3xy + P_4x + P_5y + P_6, \quad (1)$$

where the six quadric function parameters $P_i (i = 1, \ldots, 6)$ are chosen to minimize the error ϵ:

$$\epsilon = \sum_{j=1}^{N_s} \left[V(S_{j,x}, S_{j,y}) - z(S_{j,x}, S_{j,y})\right]^2, \quad (2)$$

where, $S_{j,x}$ and $S_{j,y}$ are the x and y coordinates of the jth element of the set S, respectively, and N_s is the total number of pixels of the four corners (in our case, $N_s = 1600$).

Calculating the quadric function $z(x, y)$ for each image spatial location (x, y), we have an estimate $z(x, y)$ of the local illumination intensity in the image $V(x, y)$. Dividing the original $V(x, y)$ channel by $z(x, y)$, we obtain a new Value channel where the shading effects have been attenuated. The final step is to replace the original Value channel by this new Value channel, and convert the image from the HSV color space to the original RGB color space. In Fig. 1, an example of applying this method to a skin lesion image is presented. The result is a color image that is easier to segment.

4. Proposed skin lesion image segmentation method

Our proposed segmentation method for melanocytic skin lesions in standard camera images is presented next. As can be seen in the following subsections, this method is based on sequential steps: initialization, processing and refinement. In the processing step, we create a projection of the original color image data, maximizing the difference between **lesion and non-lesion** pixels, in a way that facilitates the segmentation