An analysis on segmentation methods for skin lesions

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The medical diagnosis from images aided by computational solutions has become frequent in the last years, being the automatic extraction of contours, for example, very important to assist the diagnosis of skin lesions. Commonly, some skin lesions are not detected by the clinicians by visual inspection, because they are very small, or sometimes, the clinicians are tired and have some difficulties in their identification. This work presents a study on methods to automatically segment skin lesions from images that can be considered to aware the clinicians' attention on the location of possible skin lesions in images. Moreover, it is presented the comparison of two methods of the most promising ones, analyzing their main characteristics, advantages and disadvantaged.

Key Words: image segmentation, skin lesions, growing and merge regions, edges detection, anisotropic diffusion, contours detection.

1 Introduction

The segmentation of images is one of the most important topics in image processing and analysis, because it allows the extraction of regions of interest from the input images, so they can be post-processed and characterized, (Gonzalez et al. 2003). Tasks of image segmentation and characterization are applied in several domains, such as natural and life sciences, engineering and industry. This paper focus on the analysis of techniques to accomplish the segmentation (extraction) of skin lesions from images.

Much research work has been developed in Computer Vision to assist clinicians in the diagnosis of lesions in the human body from images (Chung and Sapiro 2000), based on the extraction of the lesions' contours.

Here, two methods to segment skin lesions from images that present relevant results are analyzed and compared. One method uses a partial differential equation based on the gradient to smooth the original image and remove the noise presented, and then apply the Canny's edges detector, obtaining the lesions' contours, (Pires and Barcelos 2007). The other method applies a filter (in this case a median filter) to remove the noise from the original image, followed by the application of a segmentation method based on the growing of uniform regions, and at the end applies a merge (union) method to refine the segmentation results, (Celebi et al. 2005).

This paper is organized as follows: the following section introduces some common techniques used for the segmentation of skin lesions from images. The sections 3 and 4 describe the methods of segmentation based on regions growing and on anisotropic diffusion, respectively. The experimental results obtained by each method and their analysis are presented in section 5. Finally, section 6 presents the main conclusions of the work described.

2 Related works

The high rate of skin lesions due to different reasons and their consequences to patients, with the high possibility of some of them become skin cancers, makes their early detection extremely important so the most appropriate treatment plan can be fruitfully followed. Some physical inherent characteristics, such as shape, texture and color, can help in the early diagnostic of such lesions (Claridge et al. 1998).

A research developed by Morris-Smith (Morris-Smith. 1996) demonstrated that clinicians emphasize the irregularity of the lesions' shapes, mainly by analyzing their contours, when describing them. Morris-Smith also showed that clinicians have common difficulties in the visual evaluation of the irregularity of the lesions' contour and that changes in the lesions' position (i.e. rotation and reflection) can, sometimes, affect the diagnosis.

Therefore, an efficient and accurate process of image segmentation can assist clinicians in the early detection and diagnosis of skin lesions. In this computer aided diagnosis, the accuracy of the lesions' contours automatically extracted is crucial for the successfully of the following steps of lesions' analysis and classification.

The automated detection of skin lesions' contours in images is a complex task, mainly due to the usually low contrast between the possible injury area and its surround, complex and irregular shapes, cases of reflection, occlusion and shadow, because of inadequate lighting conditions, interferences from, for example, skin bubbles or hairs, and variations of the inner color of the lesions (Celebi et al. 2005).

The segmentation of images containing skin lesions consists in the separation of unwell and healthy tissues. Claridge and Orun (Claridge and Orun 2002) developed a segmentation method that determines an initial contour for a lesion from the analysis of the associated histogram. In the attempt to get an accurate contour, the initial contour is refined considering:

$$\rho(r, A, T, s) = \frac{A}{(1 + s(r - T))}, \tag{1}$$

where *r* is the radial distance from the center of the lesion, *A* is the amplitude, s is the factor of sharpen and *T* is the center of the contour.

Rajab, Woolfson and Morgan (Rajab et al. 2004) proposed an iterative method to segment skin lesions based on the detection of regions and contours by using a neural network. The iterative segmentation consists of applying a mapping function highlighting the features of the contour, then a threshold is set and the outline of the lesion is obtained. However, this method is inaccurate when the original images are noisy.

Chung and Sapiro (Chung and Sapiro 2000) proposed a more efficient method for the segmentation of skin lesions based on active contour models. These models are characterized by the motion of a closed curve along the image plane with the final goal to fit this curve to the lesions' contours by minimizing the energy functional given by:

$$\int_{\mathcal{C}} g(|\nabla I|)ds, \tag{2}$$

where *ds* is the curve of the arc $\left(|\frac{\partial \mathcal{C}}{\partial s}| = 1\right)$, $\mathcal{C}$ is the deformation of the curve, *I* is the original image to be segmented and *g* is a function of smoothing, such that *g (r)* $\longrightarrow$ *0* where *r* $\longrightarrow \infty$.

The minimization of the energy functional is performed calculating a path with minimum distance (geodesic curve) with weight *g (.)* given by:

$$\frac{\partial \mathcal{C}}{\partial t} = gkN - (\nabla g.N)N, \tag{3}$$

where *k* is the Euclidean curvature and *N* is the Euclidean norm.

To refine the contours extracted from nosy images and eliminate the false contours, Chung and Sapiro changed their original method in order to capture some key points defined by the user on the desired lesions' contours, and then minimize the energy functional (equation 2) connecting these points.

The results of this improved method are satisfactory both for images with reduced or considerable noise. However, this procedure is not fully automatic as it requires the user intervention.

Celebi, Aslandogan and Bergstresser (Celebi et al. 2005) proposed a method of skin lesions' segmentation more efficient based on the technique of regions growing. Pires and Barcelos (Pires and Barcelos 2007) developed a more robust procedure based on anisotropic diffusion and the Canny's edges detector. These two methods have special attention in this work and are presented in the next sections, because they are able to extract the skin lesions' contours from the input images automatically, even when they are nosy. One designated the method based on region growing as CAB and the one based on anisotropic diffusion as PB.

3 Segmentation of Skin Lesions by Growing Region and Merge Methods

The CAB is a procedure to automatically segment skin lesions based on the growing of homogenous regions. The pre-processing, segmentation and post-processing steps of this procedure are described in the following.

3.1 Pre-processing

This step of the CAB method aims to facilitate the detection of edges of the lesions with reduction of the noise and color space of the image.

Smoothing: the images of skin lesions often contain features that complicate the detection of the contours presented, such as skin bubbles, hairs and variation of the inner color of the lesions. Several filters are able to reduce these artifacts. The CAB method uses the median filter (Gonzalez et al. 2003) to smooth the original images.

Color Quantization: with this step, the authors intend to eliminate the low representative colors for the differentiation of neighboring regions of the image. After the execution of this step, the original image is represented by a set of 20 colors, being this number determined by tests done in order to find the enough number of colors for a precise quantization, in other words, so the internal and external parts of the lesions can be distinct.

3.2 Spatial Segmentation

The new colors of the image, labeled by the algorithm of quantization used, made a set of classes called *map of classes*. This map can be seen as a composition of texture. The distance between different classes is called *local values*. In figure 1 one can see a diagram of the segmentation algorithm considered in the CAB method (adapted from (Celebi et al. 2005)).

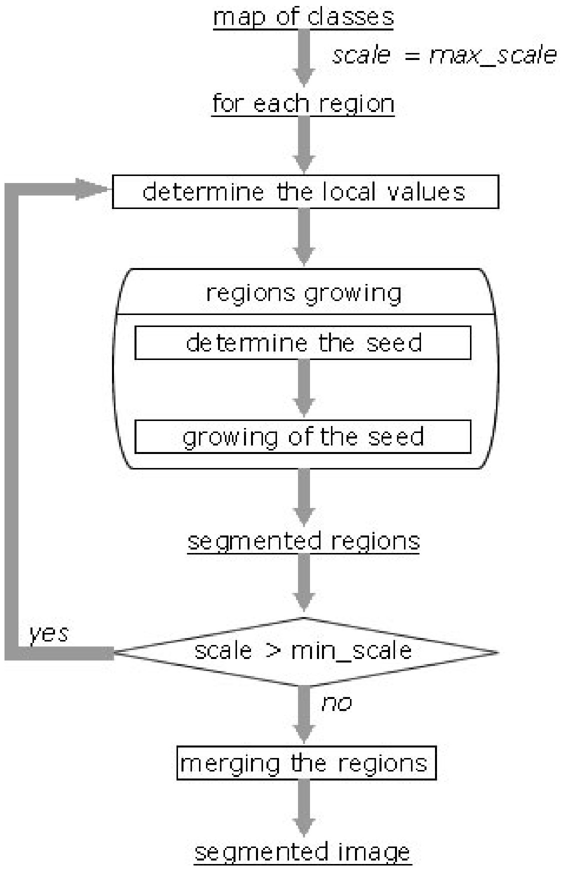

Figure 1: Outline of the CAB method.

According to the diagram presented in figure 1, the input image is scanned using local values and its pixels are clustered into regions according to local windows defined by a scale factor. As larger as the scale factor, bigger is the associated local window. The first iteration of the regions growing method is performed with the largest scale. In this case, parts of healthy skin tissue are fused with lesions' tissues.

To refine the results, the regions growing method is repeated considering smaller scales, always using as input the segmented image considering the previous higher scale. The segmented image is composed of several regions, where some involve healthy tissue and others limited parts of lesions' tissues. To merge the regions of unwell tissue, Celebi and collaborators (Celebi et al. 2005) perform a merging method, described in the following section.

The initial and final scales are defined according to the spatial resolution of the original images, as indicated in table 1.

n (pixels)	Max Scale	Min Scale	Scales
$>$ 512 x 512	4	3	2
$>$ 256 x 256	3	2	2
$>$ 128 x 128	2	2	1
$>$ 64 x 64	1	1	1

Table 1: Initial and last scales corresponding to different sizes of images.

3.3 Post-processing

To detach healthy and unwell regions, the color intensity of healthy skin tissue is considered a squared sub-image of 100 $pixels^2$ located in each corner of the original image and calculated the mean color in the Luv space of the sub-images. This average value is associated to healthy tissue because the skin lesions are usually focused in the center of the input images.

The regions in which the difference between its average color and the average color of healthy tissue is less than a certain threshold are considered as external to the skin lesion and discarded. This process is called merge and, by using it, the unwell regions are merged into bigger regions, which are the desired skin lesions' areas.

4 Segmentation of Skin Lesions using Anisotropic Diffusion

The PB method extracts the contours in images of skin lesions using anisotropic diffusion to make the smoothing of the input image and applying the Canny's edges detector to extract the lesions' contours. The anisotropic diffusion smoothes the input images, regarding the smoothing effect on the edges presented.

In anisotropic diffusion, the control of the diffusion intensity is accomplished through an edges stopping function, according to the gradient on the point that should undertake the diffusion. This stopping function uses a scale parameter σ that indicates if the diffusion should be strong or weak. The space of non-linear anisotropic scale defined by Perona and Malik (Perona and Malik 1988) is given by equation 4, where $\|\nabla F_t(x,y)\|$ is the magnitude of the gradient of F_t and g an edges stopping function:

$$\begin{array}{c} \frac{\partial F_t(x,y)}{\partial t} = div[g(\|\nabla F_t(x,y)\|)\nabla F_t(x,y)] \\ F_0(x,y) = f(x,y). \end{array} \tag{4}$$

The spatial and temporal discretization of the equation 4 made by Perona and Malik is:

$$I_{(s,t+1)} = I_{(s,t)} + \frac{\lambda}{|\eta_s|} \sum g(|\nabla I_{s,p}(t)|) \nabla I_{s,p}(t), \quad (5)$$

where,

- *I (s, t)* is the discretized image;
- *s* is the position of the pixel in a discrete two-dimensional grid;
- *t* is the discrete time step (or number of iterations);
- λ is a constant that determines the speed of diffusion;
- η_s is the set of spatial neighboring of *s*; usually, are considered the east, west, north and south neighbors;
- $\nabla I_{s,p}(t)$ is the magnitude of the gradient of *I* at the point *s* and in the direction *(s, p)*.

In the anisotropic diffusion, the correct choice of the stopping function *(g)* and of the scale is crucial to define how the discontinuities will be preserved. During last years, several methods of image segmentation were modified and adapted the equation of Perona and Malik. One of the main methods was proposed by Pires and Barcelos (Pires and Barcelos 2007) that is discussed in the next section.

4.1 Pre-processing

To make a selective smoothing of the input image, the authors of the PB method used partial differential equations, discarding the elements of less interest, such as elements of low contrast and noise. The equation 6, defined by Barcelos, Boaventura and Silva (Barcelos et al. 2003) is applied on each point of the input image, eliminating the noise and emphasizing the lesions' contours:

$$u = g|\nabla u| div(\frac{\nabla u}{|\nabla u|}) - \lambda(1-g)(u-I). \quad (6)$$

The new terms in equation 6 relating to the equation proposed by Perona and Malik are:

- *u* = F_t (x, y);
- *I* is the original image;
- λ is a parameter that determines the speed of diffusion;
- *(u - I)* is the forcing term defined by Nordström (Nordström 1990) to reduce the degenerative effects of diffusion;
- *(1 - g)* is the moderation selector of the diffusion process, forcing the image smoothed to preserve the contours' positions.

The adequate selector makes that the diffusion is done in a reasonable manner, allowing the identification of different regions of the input image and, consequently, allowing a more smoothing in the homogeneous regions than in the lesions' contours. This is an important feature of the adopted equation that makes attractive their use in pre-processing methods of contours extraction from noisy images.

4.2 Segmentation using Canny's Edges Detector

After the smoothing of the input images using the anisotropic diffusion equation, the PB method applies the Canny's edges detector to extract the contours of the skin lesions. The Canny operator was chosen because it very efficient and extracts the images' edges and makes also their refinement, eliminating fragments located on the lesions' contours. Therefore, the post-processing is embedded in the segmentation step.

5 Tests and Results

The two methods of segmentation previously presented, reveal to be promising. The results show that the contours of the skin lesions are extracted preserving some of its main features. For example, in Figure 2 one can see the results of the segmentation methods discussed applied to the same skin lesions. The contours extracted by the methods are drawn in white, superimposed to the original skin lesions that are located in the first column of the same figure. The experimental tests were performed on a set of images obtained from the Skin Cancer Guide, which is an online open source with information about treatment of skin cancer (Guide 2009).

For the skin lesions presented in the first line of Figure 2, one have the anisotropic diffusion in the second column, where can be find the presence of some double edges in the upper part of the lesions, and a discontinuity at the bottom and a portion of the lesion not successfully detected on the right part. In the third column, where one used the method of regions growing, the results were of superior quality, detecting the contours more precisely and leaving only a small part not detected on the right side of the input image.

In the second line, the results of the methods had dissimilar behavior. The pre-processing made using the anisotropic diffusion in the second column provided the extraction of an contour maintaining its original irregularity, approaching to the ideal solution, and the method by regions growing in the third column, returned an contour less accurate, leaving a small part in the left side of the lesion unsuccessfully detected.

In the third row and second column, the pre-processing done by using the anisotropic diffusion caused an excessive smoothing in the left part of the lesion, while it was not enough to eliminate the inner noise presented in the correspondent right part. In the third column, the results obtained by the regions growing method were better, detecting even a small smudge on the top right of the image that has an appearance approximately equal to some parts of the lesion, as can be seen in more detailed in Figure 3, where the small smudge is indicated by an arrow.

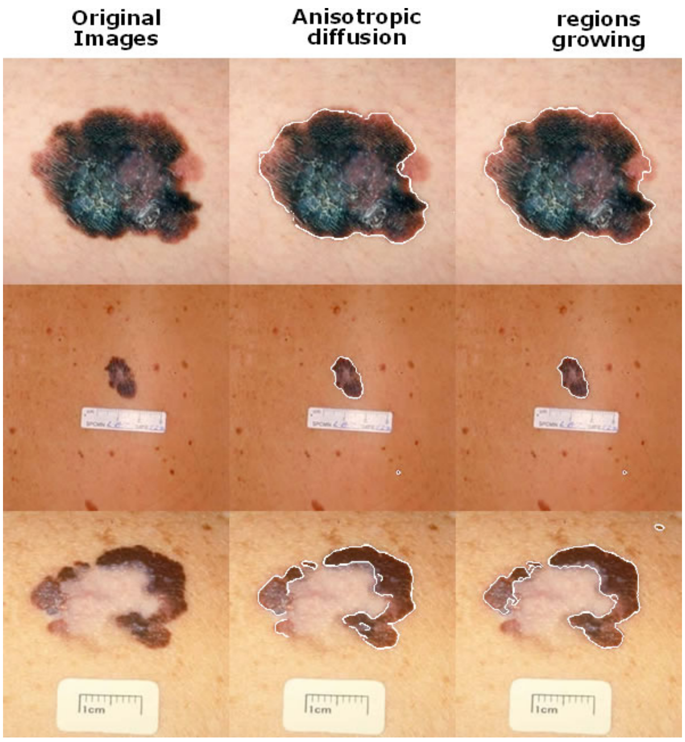

Figure 2: example of results obtained using the CAB and PB methods in melanomas.

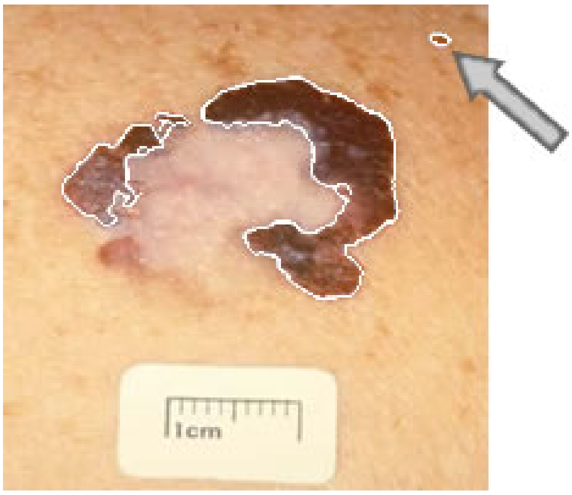

Figure 3: Detail of a small lesion found by the method of regions growing.

The method of image segmentation by regions growing cannot extract successfully contours from images in gray scale. Additionally, for images of skin with hairs and considerable noise, the median filter applied in the pre-processing phase to smooth them must have a convolution mask of large dimensions, which originates a deformation on the fine contours' details (as irregularities), which makes this segmentation method inaccurate to be applied on images with considerably noise.

The method based on anisotropic diffusion for smoothing the input images is efficient in the segmentation of color and grayscale images, but it is of more complex implementation. In the experimental tests performed, the images were smoothed by accomplishing 100 iterations of this method. The number of iterations done influences the smoothing obtained. As more as iterations are done, more the input image is smoothing are more probable is some smooth effect on the original irregularity of the lesions' contours. Thus, if the input image presents small skin lesions, they can be confused with noise and eliminated. This is the cause why the PB method does not find the little smudge similar to a skin lesion that was detected by the CAB method.

6 Conclusions

The two methods here described for the segmentation of skin lesions from images revealed to be very promising. The CAB and PB methods have the capacity to find and extract the contours of the skin lesions automatically from the input images.

The PB method is efficient on the removal of the noise presented in the input images, but too many iterations tend to affect the original irregularities of the lesions' contours. This number varies from one image to another, depending on the amount of noise presented in them, and can be calculated from the standard deviation if the image is quantized, since this not presents a very large variation of colors. The CAB method could detect the minor lesions presented, showing to be more efficient in the extraction of the contours, but the pre-processing done by using the median filter is not efficient on images with considerable noise, because the contours presented are very affected by smoothing done.

Although these methods can detect the skin lesions presented in images successfully, they cannot always assure the original irregularities of the contours, returning imprecise contours from some images. The ideal segmentation method of skin lesions from images should return contours that keep all of their original irregularities, regardless the size and shape of the lesions involved, to assist accurately the clinicians in their diagnosis so further developments should be addressed in this medical imaging area.

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