Nonlinear smoothing of skin lesions images driven by derivative filters

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1. ABSTRACT

Image segmentation is an important step to suitable extraction of features of objects from images. However, the presence of noise interferes in segmentation quality; for example, by generating the detection of false edges (or false borders). To diminish the problems caused by the presence of noise in images, various smoothing techniques have been proposed to pre-process the original images. Those methods reduce the noise presented in input images, but they can also strongly affect the borders of the objects, leading to the loss of important details, such as the original roughness of the contours or the elimination of the borders of small objects. Among the existing smoothing techniques, one of the most promising is based on the use of anisotropic diffusion, which allows a selective smoothing that decreases the undesirable effects caused by noise presented in the input image and preserves the edges of the objects. However, the success of this smoothing method is strongly reliant on the number of iterations performed that depends on the input image. In this work, we propose the use of derivative filters for the definition of the appropriate number of iterations adopted by the smoothing method based on anisotropic diffusion, when it is applied for the removal of noise usually present in images of skin lesions. The experimental results demonstrate that the developed solution is promising, being able to determine the adequate number of iterations for smoothing the input images avoiding the excessive loss of details of the borders of the lesions presented in images.

2. INTRODUCTION

The segmentation process permits the extraction of interesting regions present in images that are to be post-processed and characterized [1]. This is a complex and important step of image processing and analysis, which is applied in various fields, such as in medical, agricultural and satellite images. Usually, systems of image acquisition, image

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processing and transmission suffer from different interferences that may lead to the existence of noise in the images to be segmented. This noise may affect the superior identification of the borders of the objects presented in such images, which can lead to the loss of important information about their contours [2].

A suitable computational process of image segmentation can assist the automatic detection of the borders of objects presented in images. However, this task is frequently difficult to be attained due to complex and irregular borders, light changes, occlusions, presence of noise and variations in the surfaces of the objects [3].

In an attempt to diminish the problems caused by the noise presented in the images to be segmented, various smoothing techniques have been proposed. For example, Barcelos et al. have presented a smoothing method based on anisotropic diffusion [4, 5]. On the other hand, Camarena et al. [6] and Morillas et al. [7] used fuzzy filters for noise removal, and Chai, Zhao and Wang [2] have suggested a smoothing technique based on multi-scale morphology [8-11].

The nonlinear smoothing techniques, such as the anisotropic diffusion, have been a topic of huge interest for researchers working on image processing and analysis. In fact, the recursive use of anisotropic diffusion on the intensity matrix of an image has shown to be an efficient approach for selective smoothing. This technique is based on the idea of modifying the intensities of the pixels of the input image, using a nonlinear function of the intensity of the neighborhood pixels and generating a new value that better represents the local structures presented [12]. Thus, it allows the nonlinear removal of noise, delaying the degenerative effects caused by the smoothing method on the neighborhood of the borders of the objects.

A common problem of the methods for image smoothing based on the anisotropic diffusion technique is that frequently the noise and the borders presented in the input images have characteristics that are equally associated with the high frequencies [1]. Thereby, even making a nonlinear removal of the noise, the objects' borders, especially of the small ones, can be affected by the smoothing process when too many iterations are considered for the anisotropic diffusion. Therefore, the adequate estimation of the number of iterations is important in order to obtain satisfactory results, particularly in applications that require a reliable extraction of the borders presented in the input images. In an attempt to obtain an automatic approximation of the number of iterations to be used in the smoothing of images of skin lesions, we propose the application of two derivative filters on the original image: One filter more sensitive to the noise presented and another one that is less sensitive to the same noise. Then, the relation between the contours detected by each filter is used to define the suitable number of iterations for the anisotropic diffusion in order to remove the noise presented in the input images while preserving the borders of the objects in the same images.

This paper is organized as follows: In the next section, we describe the proposed approach to calculate the number of iterations for the anisotropic diffusion. In section 4, we present some experimental results. Finally, in the last section, we present the conclusions.

3. AUTOMATIC ESTIMATION OF THE NUMBER OF ITERATIONS FOR THE ANISOTROPIC DIFFUSION

In an attempt to automate the smoothing method based on anisotropic diffusion for images of skin lesions, we propose the application of two derivative filters (i.e. image operators) on the original image. Thus, the number of iterations to be used during the anisotropic diffusion is defined from the difference on the borders obtained by those filters. The operators we used were Prewitt's and Roberts' filters [1]. This choice was due to the dissimilarity of behavior shown by these filters in the presence of noisy in the input image. As it can be observed in from Fig. 1, as bigger is the presence of noise, as larger is the difference between the border points detected by the two filters. In this figure, the blue curve represents the growth of the border points detected by Roberts' filter, and the pink curve represents the outcome of Prewitt's filter, when both were applied to images with growing intensities of noise.

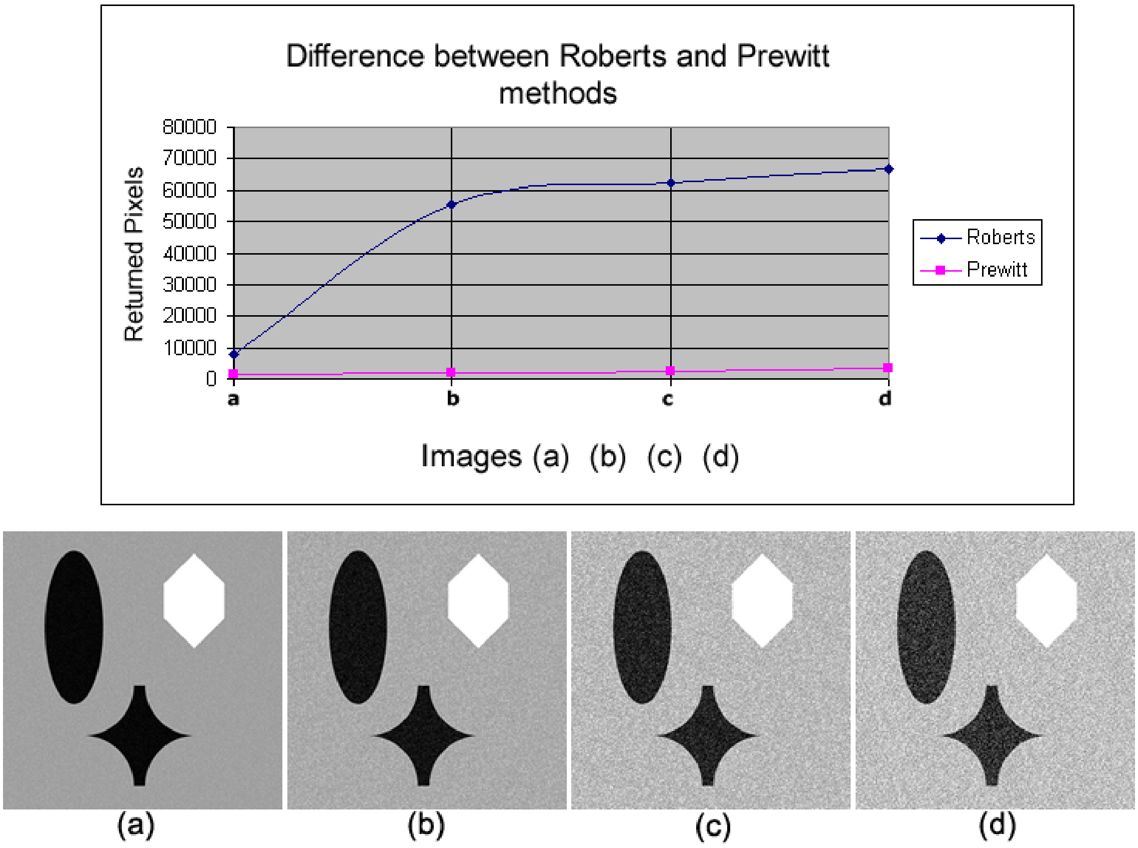

Fig. 1: Number of border points (i.e. pixels) returned by Roberts' and Prewitt's filters when applied to images with growing intensities of noise ((a), (b), (c) and (d)).

The increasing difference between the number of border points resulting from the two gradient operators when applied to images with growing amount of noise, is due to the convolution masks used by each one. The Roberts' filter calculates the difference of intensity values along directions multiple of 45º, using convolution masks as the ones shown in Fig. 2a. On the other hand, Prewitt's operator uses masks with bigger dimensions, as shown in Fig. 2b, that performs a small image smoothing along the horizontal and vertical directions, decreasing the negative effects of the presence of noise in the input images.

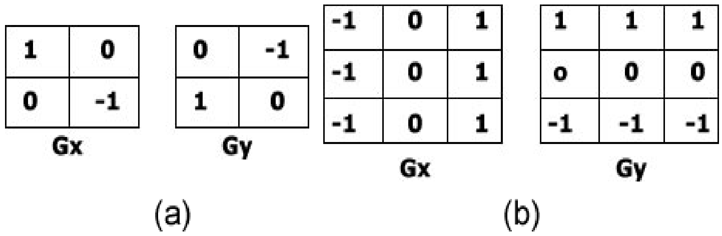

Fig. 2: Masks used by Roberts's (a) and Prewitt's (b) filters.

When smoothing an image using anisotropic diffusion, the number of iterations to consider should be determined according to the amount of noise present: as higher is the level of noise, more iterations must be performed. When the difference between the border points returned by Roberts' and Prewitt's filters is analyzed, it can be concluded that it increases with the growth of the level of noise in the input images. Therefore, we propose an estimation for the number of iterations for anisotropic diffusion, *n*, based on the difference between the border points returned by the two filters:

$$n = \frac{[N_P(I) - N_R(I)]^2}{r\ c}, \qquad (1)$$

where:

- I is the original image;
- rc is the total number of pixels of I;
- N_P is the number of border points returned by Prewitt's filter and,
- N_R is the number of border points returned by Roberts' filter.

Thereby, more noisy images are smoothed with a bigger number of iterations for anisotropic diffusion, while less noisy images require a smaller number of iterations to be satisfactory smoothed.

4. EXPERIMENTAL RESULTS

A group of 4 skin lesions images, from the image database Dermatlas (Dermatology image atlas) [13], managed by Johns Hopkins University on Baltimore in United States of America, were used for the experimental tests considered here. The images are colored with 256x256 pixels of dimension, Figs. 3a – 3d. The results of the application of the non-linear smoothing, based on our approach to estimate the number of iterations for anisotropic diffusion, on these images are presented in Figs. 3e – 3h. These images were smoothed using 142, 114, 173 and 289 iterations, respectively. From these images, it could be verified that much of the noise present, both externally and internally to the regions of lesions, were effectively removed, preserving the original characteristics of the lesions’ contours. It is important to notice that the smoothing process was applied on a matrix of the three color components of the RGB (Red, Green, Blue) system.

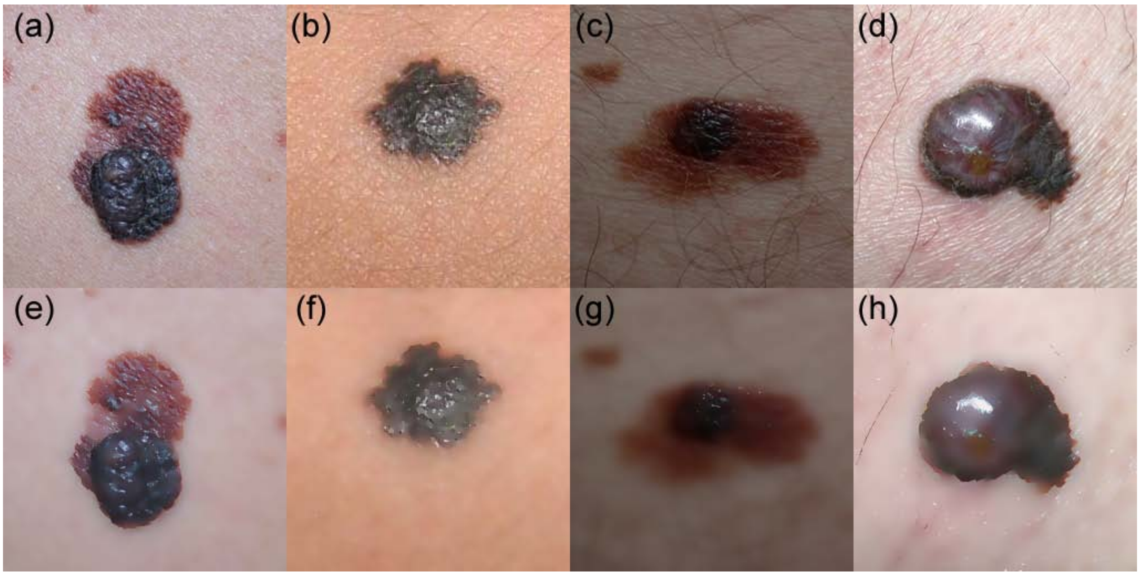

Fig. 3: Four original images of skin lesions (top) and the correspondent smoothed images obtained by anisotropic diffusion with the number of iterations estimated by the approach proposed (bottom).

From the experimental results obtained, some presented in this paper, one can conclude that the smoothing process based on the anisotropic diffusion equation proposed by Barcelos et al. [4] with the number of iterations estimated by our approach is very promising, in particularly for images of skin lesions.

5. CONCLUSIONS

The estimation of the number of iterations for anisotropic diffusion proposed, based on the difference between the border points returned by Prewitt's and Roberts' filters, has allowed the automatic and reliable smoothing of images of skin lesions. The experimental tests conducted during this work allow us to conclude that much of the noise presented in the input images was successfully eliminated. The external and internal regions of the lesions presented in these input images were efficiently smoothed, preserving the borders of the existing lesions and increasing the contrast between the healthy and unhealthy tissues. This behavior is awfully important as turns easier the posterior detection of the transitions between lesioned and healthy tissues in images.

ACKNOWLEDGMENTS

The authors are thankful to CAPES – Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil and FAPESP – Fundação de Amparo à Pesquisa do Estado de São Paulo – Brazil – reference 2009/13000709-2 by the financial support.

The first author would like to thank his PhD grant, with reference SFRH/BD/61983/2009, from FCT - Fundação para a Ciência e a Tecnologia in Portugal.

This work was partially done in the scope of projects “Methodologies to Analyze Organs from Complex Medical Images – Applications to Female Pelvic Cavity”, “Aberrant Crypt Foci and Human Colorectal Polyps: Mathematical Modelling and Endoscopic Image Processing” and “Cardiovascular Imaging Modeling and Simulation - SIMCARD”, with references PTDC/EEA-CRO/103320/2008, UTAustin/MAT/0009/2008 and UTAustin/CA/0047/2008, respectively, financially supported by FCT.

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