Gabor Filter for the Segmentation of Skin Lesions from Ultrasonographic Images

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Abstract. The present work applies Gabor filters bank for texture analysis of skin lesions images, obtained by ultrasound biomicroscopy. The regions affected by the lesions were differentiated from surrounding tissue in all the analyzed cases; however the accuracy of the traced borders showed some limitations in part of the images. Future steps are being contemplated, attempting to enhance the technique performance.

Keywords: Ultrasonic instrumentation and measurement techniques; Acoustic imaging, displays, pattern recognition, feature extraction; Medical diagnosis with acoustics.

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INTRODUCTION

In dermatology practice, before proceeding to the excision of some skin lesion, it is common to implement a previous evaluation of their limits by non-invasive imaging techniques. A number of them have been used with this purpose, presenting different image characteristics, and the most appropriated will depend on the particularities for each analysed case. Ultrasonic biomicroscopy (UBM) is a relatively recent technique, whose applications have been expanded in the last years, because of the benefits concerning the compromise between simplicity and performance.

UBM technique uses high-frequency acoustic waves for image generation, working in a similar way to B-mode ultrasonic equipment, but employing frequencies in the range of 20-50 MHz for most clinical applications. The resolutions achieved are of some tens of micrometres, which allows differentiating normal and atypical anatomic components (as epidermis, dermis, glands, tumour nests, nevus, and others); although, the visualization of cellular or sub-cellular structures remains yet not possible.

One limitation of the UBM technique as a diagnostic tool is that different structures can present similar grey-levels on images, which makes difficult lesions characterisation. Moreover, the border between structures can sometimes be diffuse, obscuring their delimitation. Attempting to improve the UBM potential in identifying different tissue regions, a quantitative method was implemented in this work based on image texture evaluation.

Different works have been implemented for the analysis of ultrasonic image textures using Gabor filters. Brunenberg et al. (2006) applied Gabor filters for texture features extraction of intravascular calcium and soft plaques images, generated by intravascular ultrasound, and followed by the application of pattern recognition algorithms; better segmentation results were observed for calcium than for soft plaques. Zhan and Shen (2006) considered shape and texture analysis using Gabor filters, to delimit prostatic tissue from adjacencies on 3D ultrasonic images; here better results were obtained than in studies with 2D images. Chen et al. (2010) used Gabor filters on 3D ultrasonic images from breast tumours attempting to classify malignant and benign tumours.

The objective of the present work is to evaluate the potential of Gabor filters to detect and delimit cutaneous lesions, based in the analysis of UBM image texture. A bank of Gabor filters was used with this purpose, and a number of fifteen tissue samples were studied.
MATERIALS AND METHODS

Tissue Samples

The images were acquired from ex vivo tissues obtained from volunteer patients. The samples corresponded to different skin lesions types, and the biopsies were performed with clinical purposes. Sample excision was made in the Dermatology Sector of the Gaffrée and Guinle University Hospital (HUGG), Rio de Janeiro. All procedures were approved by the HUGG Ethical Committee and by the National Committee for Ethics in Research.

After tissue extraction, the samples were conserved in formalin solution and then examined by UBM. Following, the samples were analysed by optic microscopy (OM) in the Pathology Anatomy Sector - HUGG, following the conventional procedure. The images obtained by UBM and OM for each sample were compared to evaluate the results.

A total of fifteen dermic lesion images were evaluated, consisting on basal cell carcinomas or BCC (10), Bowen disease (2), nevus (1), leprosy (1) and actinic keratosis (1).

UBM equipment

The acquisitions were made with a UBM equipment developed at the Laboratory of Ultrasound – Biomedical Engineering Program – Federal University of Rio de Janeiro, Rio de Janeiro. The equipment works at a central frequency of 45 MHz; provides axial and lateral resolutions of about 30 µm and 100 µm respectively and gives an image depth of about 5 mm. More system details are provided in (Petrella et al., 2010).

Algorithm for texture-based segmentation

The procedure for image segmentation consists basically on three steps. In the first one, it was performed a multichannel decomposition of the original ultrasonic image by using a bank of 2D Gabor filters. A single Gabor kernel consists of a sinusoidal function modulated by a Gaussian function with a specific frequency, orientation and scale, which is convolved with the ultrasound image, and its impulse response is defined as [5, 6]:

\[
g(x, y) = \exp \left(-\frac{\hat{x}^2 + \gamma^2 \hat{y}^2}{2\sigma^2}\right) \cos \left(2\pi \frac{\hat{x}}{\lambda}\right),
\]

where \(\gamma\) and \(\sigma\) are the aspect ratio and width, respectively, of Gaussian function, \(\lambda\) is the wavelength (defined as \(1/\omega\), where \(\omega\) is the frequency), and the pixel positions \(\hat{x} = x \cos \theta + y \sin \theta\) and \(\hat{y} = y \cos \theta - x \sin \theta\) where \(\theta\) is the orientation. In Table I, the parameters for tuning Gabor filters are summarized; these values were determined empirically and can be considered adequate for resembling all cases in our study. This method is based on the theory for processing visual information in the early stages of the human visual system, which decompose the retinal image into a number of filtered images, each of which containing intensity variations over a narrow range of frequency and orientation [5].

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect ratio (\gamma)</td>
<td>1</td>
</tr>
<tr>
<td>Orientation (\theta)</td>
<td>0, \pi/6, \pi/3, \pi/2, 2\pi/3, 5\pi/6, \pi, 7\pi/6, 4\pi/3, 3\pi/2, 5\pi/3, 11\pi/6,</td>
</tr>
<tr>
<td>Frequency (\omega)</td>
<td>(\sqrt{2} {1, 2, 4, 8, 16, \ldots, N / 4} / N), where (N) denotes image width.</td>
</tr>
<tr>
<td>Width (\sigma)</td>
<td>((\lambda / \pi)(\log 2/2^{2})^{2} + 1/2^{2} - 1)</td>
</tr>
<tr>
<td>Bandwidth (B)</td>
<td>2</td>
</tr>
</tbody>
</table>

The second step involves the feature extraction, being first performed the saturation of the filtered images by using a sigmoid function, and then regions with similar characteristics were smoothed with a Gaussian filter. Finally, the pixels presenting similar characteristics were clustered in a predefined number of groups, by using the \(k\)-means
technique. Therefore, textures with similar characteristics were classified as belonging to the same tissue type. The \( k \) parameter (number of textures to be segmented) varies with the tissue components and based on the analyzed image anatomy, values of 3 or 4 were considered adequate.

**RESULTS**

Herein, six of the fifteen analysed cases are presented, because they better represent the capabilities and limitations of the technique. In Figure 1a, one can observe a nevus case, and the corresponding segmented image is shown in Figure 1b; from the segmentation, the lesion (black) is well delimited from the adjacent tissue (white), except by some discontinuity at the bottom. This discontinuity can be due to an attenuation effect obscuring the deeper parts. A Hansen disease case is shown in Figure 1c, and the segmented regions in Figure 1d, where the nerves affected by the illness (white) were differentiated from dermis (black). Here, the border adjustments were poor and consequently anatomical details, which could help not just in delimiting the lesions, but also in diagnosing it, are lost. The third case, presented at Figure 1e, shown a Bowen disease, where the epidermis is enlarged by the tumour presence, and the subjacent inflamed region (superficial dermis) presents a hypoechoic aspect; in the corresponding segmented image (Figure 1f) it appears like a rather well delimited band (dark grey).

**FIGURE 1.** Skin images obtained by UBM, and their respective segmentations. (a) Nevus case showing a hypoechoic aspect; in the corresponding segmented image (b), the lesion (black) was well delimited from the surrounding skin (white), also a discontinuity in the segmentation is observed at bottom (arrow). (c) Hansen disease case, where the affected nervous structures are hypoechoic (arrows) when compared with the surrounding dermis; in the corresponding segmented image (d) these nervous structures (white) were differentiated from dermis (black), even the borders were not sharp. (e) Bowen disease case, where the superficial dermis affected by inflammatory infiltrate showed a hypoechoic aspect (arrows); (f) this region was well differentiated in the segmented image (dark grey). The white bars in UBM images have approximately 1 mm in height.

Three BCC cases with different anatomic characteristics are shown in Figure 2. In Figure 2a it is shown a BCC case containing ulceration; in the corresponding segmented image (Figure 2b), the region affected by the tumour (light grey and white) was well differentiated from surrounding epidermis (dark grey and black), and the presence of blood cells was also distinguished (black region in the centre). However, the stroma adjacent to the tumour nest was not differentiated. For the case presented at Figure 2c, the tumour nests are small and dispersed in the upper part of the dermis, and surrounded by other associated components like inflammatory cells. In this case, the UBM system resolution was insufficient to delimitate these tumour nests. Hence, all superficial dermic region affected by the tumour was segmented as being part of the lesion (light grey in Figure 2d). Finally, a nodular BCC is shown in Figure 2e, where the tumour nest is compact and well delimited from surrounding tissue; although a discontinuity is observed at the bottom (arrow in Figure 2f), similarly to the nevus case. For the other studied cases, whose images are not shown here, similar observations were obtained.

**DISCUSSION AND CONCLUSION**

Based on the results here obtained, the Gabor filters showed capability for segmentation of skin lesion images obtained by UBM. In all studied images, the tumours were differentiated from adjacent tissues. Hence, this tool could improve the planning of chirurgical procedures, helping in the evaluation of lesion dimensions. Nevertheless, some limitations were observed in the accuracy of the borders determined by segmentation. In some images,
boundaries were not completely delimited, probably due to the poor image definition at deeper layers, where the backscatter levels are reduced by attenuation. In this sense, the introduction of image pre-processing procedures could improve the results obtained from segmentation and consequently, the accuracy of borders delimitation. Moreover, the use of UBM systems that allow multiple focalizations at different depths, making it possible to get high quality images at both, upper and lower skin regions, would also improve the proposed segmentation method.

FIGURE 2. BCC images obtained by UBM, and their respective segmentations. (a) BCC case presenting ulceration, where the region occupied by tumour nest (white arrows) and stroma (grey arrow) is visualized with hypoechoic aspect, and the erythrocytes due to ulceration (at centre) showed a more echoic characteristic; in segmented image (b) the region corresponding to tumour nest and stroma (light grey and white) was not well depicted, nevertheless this region was well differentiated from surrounding dermis, and the ulcerated region was also identified (black arrow). (c) BCC case where numerous small tumour nests are distributed in the superficial dermis (not differentiated due to system resolution limitations), and mixture of inflammatory cells and stroma, gives a hypoechoic aspect (arrows); as segmentation result (d), all regions affected by tumour were rather well differentiated (light grey). Finally, in (e) it is presented a nodular BCC case where the tumour nest is compacted in a well delimited region (hypoechoic structure); (f) the tumour was well delimited (white), although a discontinuity is observed at bottom (arrow). The white bars in UBM images (on the left) have approximately 1 mm in height.

Up to now, the proposed method just segments anatomical components. Hence, as a next step, we intend to assess the contribution of texture parameters obtained from each tissue region to determine similarities and differences between them, which ultimately could help as a diagnostic tool. Concluding, we expect that texture analysis in skin lesions images obtained by UBM might improve the technique and provide a powerful tool for diagnostic and planning chirurgical procedures in a non-invasive way.

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