Evaluation of Boundary Extraction on Ultrasonic Images

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Boundary extraction is the partition of an image into a set of nonoverlapping regions whose union is the entire image. The image is decomposed into meaningful parts which are uniform with respect to certain characteristics. We propose a methodology for evaluating medical boundary extraction algorithm. In this case, the boundary extraction algorithm can be evaluated by integration of separability and gradient, which can be calculated by linear discriminant analysis. We illustrate the use of this methodology on different applications in ultrasound imaging.

Keywords: ultrasonic image, boundary extraction, separability, integrated evaluation

1. Introduction

Researchers in the area of medical image analysis have long sought to extract boundaries of different body organs and tissue from medical images. Gunn⁽¹⁾ has used a snake implementation to extract and evaluate the boundary by using an internal and external energy which must be previously fixed manually. We believe that objective evaluation of the medical boundary extraction algorithms is one of the important steps toward establishing validity and clinical applicability of an algorithm. However, very few medical boundary extraction researchers have carried out such an evaluation of their algorithms. This paper proposes a methodology for evaluating medical boundary extraction algorithm. The boundary extraction algorithm is evaluated by integration of separability and gradient, which can be calculated by linear discriminant analysis.

2. Method

2.1 Separability Each neighborhood of pixel is investigated by separability⁽³⁾ which depends on the shape of the edge. Separability E_s can be calculated by linear discriminant analysis using information from 2 regions,

$$E_s = \frac{\sigma_b^2}{\sigma_T^2} \dots\dots\dots (1)$$

$$\sigma_b^2 = \frac{n_1(\bar{P}_1 - \bar{P}_m)^2 + n_2(\bar{P}_2 - \bar{P}_m)^2}{N}$$

$$\sigma_T^2 = \frac{1}{N} \sum_{i=1}^N (P_i - \bar{P}_m)^2$$

n_1 and n_2 are the number of pixels in region 1 and 2, respectively. $N = n_1 + n_2$. σ_T^2 is the variance of the total image features. $\bar{P}_m$ is the average of features. $\bar{P}_1$ and $\bar{P}_2$ are the averages of the image features in region 1 and 2, respectively. Separability will be $0 \leq E_s \leq 1.0$.

2.2 Gradient As the ultrasonic images have the complex boundary such as the roof type, the incline of the density value in the local, named gradient, is supposed necessarily to be calculated in order to evaluate the boundary more accurately and faithfully. The gradient of the boundary is calculated⁽²⁾ as

$$E_g = \frac{1}{E_{g_{max}} \times (J - 1) \times I}$$

$$\times \sum_{i=-\frac{J-1}{2}}^{\frac{J-1}{2}} \sum_{j=-\frac{J-1}{2}}^{\frac{J-1}{2}} \left(Z \times \left| \frac{M_{i,0} - M_{i,j}}{j} \right| \right); (0 \leq E_g \leq 1) \quad (2)$$

M is the density value which is in the neighborhood of the pixel. Z is a variable of the distance which is viewed from the investigated pixel, and can be calculated by the distribution as

$$Z = \exp \left\{ - \left(\frac{\sqrt{i^2 + j^2}}{(J-1)/2} \right)^2 \right\} \dots\dots\dots (3)$$

2.3 Integrated Evaluation By having integration of separability and gradient, the poor value of separability can be reflected by gradient in order to make value higher. Consider that separability as E_s and gradient as E_g , that integration (E_i) defines as

$$E_i = \sqrt{\frac{(E_s)^2 + (E_g)^2}{2}}; \quad (0 \leq E_i \leq 1) \dots\dots\dots (4)$$

2.4 Algorithm In order to evaluate the boundary extraction with connection to the intensity and direction from a given image for pixel i , our method uses a set of multiple masks. Fig. 1 shows an example configuration which consists of four masks. The main steps are outlined below.

- (1) Set the four masks at a pixel i .
- (2) Calculate the E_s value for each mask using formula (1), then take the maximal value from them.
- (3) Calculate the E_g value for each mask using formula (2), then take the maximal value from them.
- (4) Integrate the E_s value and the E_g value using formula (4).
- (5) Move the four masks to the next pixel (Fig. 1).

3. Experiment

We investigate the performance of methodology for

Fig. 1. Calculation for evaluation of boundary extraction with mask configuration.

Fig.2. Original image.

Fig.3. Speckle reduction.

Fig.4. Boundary extraction.

evaluating medical boundary extraction algorithm by testing an ultrasonic phantom image which is modeled as an organism and an ultrasonic image application, named mammary which is provided by Cancer Research Institute Hospital. Both of the images are reconstructed by digital processing to be 128×128, 256 gray level, and are shown in Fig. 2 (a) and (b), respectively.

The images whose speckle have been reduced by fuzzy morphology speckle reduction (FMSR)⁽⁴⁾ are shown in Fig. 3. The boundary extraction which is also extracted by fuzzy morphology⁽³⁾ is shown in the Fig. 4.

As a methodology for evaluation, the characteristic of each of position is necessary to be calculated. For the benefit of it, separability is calculated. Fig. 5 shows the separabilities of the original images. The value of the separabilites is poor, so the boundary is hard to be separated.

Fig. 6 and Fig. 7 show the separabilities of the images of which speckle have been reduced and the separabilites of the images of which boundaries are extracted, respectively. According to Fig. 3, the the images of which speckle have been reduced still have some levels. That is the reason why the values of separabilities in the Fig. 6 are not so high. Here, by doing the boundary extraction, the values of separabilites become higher.

However, the value of boundary characteristic in the each of position is not surely high. For the reference, see point X in the Fig. 7. The lower value of boundary characteristic describes that the extracted boundary is not faithfully extracted, and vice verse. Here, to make better for the value of boundary characteristic, the gradient in the each of position is necessary to be calculated also. Then, by integrating separability and gradient of each position, the faithful boundary is considering to be attained. Fig. 8 shows the integration of separability

Table 1. Numerical evaluation.

	phantom	mammary
original image	0.127	0.192
speckle reduction	0.423	0.354
boundary extraction	0.882	0.852
integrated evaluation	0.886	0.859

Fig.5. Separabilities of the original image.

Fig.6. Separabilities of images of which speckle have been reduced.

Fig.7. Separabilities of images of which boundaries are extracted.

Fig.8. Integrated evaluation of extracted boundary.

and gradient as for the boundary characteristic. The value in the point X becomes higher. It causes that the distribution of the density in the point X is complicated so the separability does not become higher. But, it will be reflected by gradient. So the integration of its separability and its gradient makes the value become higher. In another word, it can be considered that the boundary is more faithfully extracted.

Table 1 shows the numerical evaluation which is defined as

$$E_{ave} = \frac{1}{i} \sum_{i=0}^{i-1} E_{\bullet} ; \quad E_{\bullet} \neq 0 \dots\dots\dots (5)$$

Here $E_{\bullet}$ is the value of each evaluation.

4. Conclusion

We have presented a methodology for evaluating medical boundary extraction algorithm by integration of separability and gradient. The algorithm was shown to be useful in the ultrasonic images of which speckle have been reduced.

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