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Intelligent Brain Tumor Tissue Segmentation from Magnetic Resonance Image using forward and backward anisotropic diffusion

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ABSTRACT

Image Segmentation have a crucial role in medical imaging applications . It has become an active area of research in the field of medical science. Recently, the segmentation of the brain tissues from a normal Magnetic Resonance Image (MRI) has been given lot of attention. We present herein a novel image segmentation technique for effective and accurate segmentation of the brain tissue even if there are tumors in the brain . The proposed approach consists of three steps. Initially, a forward and backward anisotropic diffusion filter is used to process the MRI. Forward and backward anisotropic diffusion filter removes image noise and performs intraregion smoothing .It preserves and enhances image edges, lines and corners. Then, thresholding is done to detect the region between the skull and the brain tissue. In order to remove the unwanted edges directly, skeletonization algorithm is used by which the unwanted edges became the branches on the skeleton of the region. Ultimately, sequence of morphological and connected component operator is used to enclose the detected region. The enclosed region obtained is the completed brain tissue. The segmentation results of the 2D MRI shows the efficiency of the proposed approach.

Keywords : Magnetic Resonance Image, thresholding, skeletonization, Forward and backward anisotropic diffusion filter

1.Introduction

Diagnostic imaging is an invaluable tool in medicine. Magnetic resonance imaging (MRI), computed tomography (CT), digital mammography, and other imaging modalities provide an effective means for noninvasively mapping the anatomy of a subject. These technologies have greatly increased knowledge of normal and diseased anatomy for medical research and are a critical component in diagnosis and treatment planning.

In medical image segmentation, our work is focused on the predominant tissues of the brain: grey matter (GM), white matter (WM), and cerebrospinal fluid (CSF). The non-brain tissues such as skin, fat, skull and dura have a negative effort for extracting the predominant tissues. So it is necessary to remove the non-brain tissue.

Brain Segmentation is an area which has attracted researchers immensely. Brain segmentation has potential applications in diagnosing many ailments.

2.Methodology

Magnetic resonance imaging is a very useful medical imaging technique as it has proven its high resolution and discriminationof tissues. Usually, the linear spatial filter does reduce the amplitude of the noise fluctuation, but also degrades some sharp details such as lines or edges. Their anisotropic diffusion filtering technique is mathematically formulated as a diffusion process, and encourages intraregion smoothing in preference to smoothing across the boundaries. This process can be formulated mathematically as follows, assume the image defined in the two-dimensional space. The original image is I(x,y,0)=I(x,y).

$$\left\{ \begin{array}{c} \frac{\partial}{\partial t} I\,(x, y, t) = \mathrm{div}(c(x, y, t)\ \nabla I\,(x, y, t)) \\ I_0 = I\,(x, y, 0) \end{array} \right\} \quad (1)$$

where we indicate with div the divergence operator, and with Δ and respectively the gradient and Laplacian operators with respect to spatial variables. The variable t is the process ordering parameter. It is used to enumerate iteration steps. The diffusion strength is controlled by diffusion coefficient. The image is hoped to be smoothed within a moderately continuous region while not smoothed across sharp discontinuities.

So, the diffusion coefficient c(x,y,t) should be away from 0 in the homogeneous regions. Fortunately, the gradient of image intensity can used to distinguish the homogeneous and non-homogeneous regions. Perona and Malik provided such two diffusion coefficient in their model:

$$g_1(w) = \exp\left[-\left(\frac{w}{K}\right)^2\right]$$

$$g_2(w) = \frac{1}{1+\left[-\left(\frac{w}{K}\right)^{1+\alpha}\right]}\ \alpha > 0$$

1.1 Proposed Forward and Backward Anisotropic Diffusion

The conductance coefficients in the P-M process are chosen to be a decreasing function of the signal gradient. This operation selectively smoothes regions that do not contain large gradients. In the Forward-and-Backward diffusion (FAB), a different approach is taken. Mathematically, we can change the sign of the conductance coefficient to negative:

$$\frac{\partial}{\partial t}\mathbf{I}(x, y, t) = \nabla\left[-c(x, y, t)\,\nabla\,\mathbf{I}(x, y, t)\right],\ c(x, y, t) > 0.$$

The result of this analysis is that two forces of diffusion working simultaneously on the signal are needed – one backward force (at medium gradients, where singularities are expected), and the other, forward one, used for stabilizing oscillations and reducing noise. These two forces can actually be combined to one coupled forward-and-backward diffusion force with a conductance coefficient possessing both positive and negative values. In a conductivity function that controls the FAB diffusion process has been proposed.

$$c_{FAB}(g) = \begin{cases} 1-(g/k_f)^n, & 0 \le g \le k_f \\ \alpha\left[\left(\frac{g-k_b}{w}\right)^{2m}-1\right], & k_b-w \le g \le k_b+w \\ 0, & \text{otherwise} \end{cases}$$

where is an edge indicator (gradient magnitude or the

value of the gradient convolved with the Gaussian smoothing operator), k_f, k_b, w are design parameters and α=

$k_f/(2k_b)$, $(k_f \leq k_b)$controls the ratio between the forward and backward diffusion.

1.2 Morphological Processing

In order to solve the issues mentioned in the first paragraph of this section, we replace the step of boundaries detecting by threshold segmentation. Because the pixels in the part of background and CSF (cerebrospinal fluid) have lower gray values, while the others have higher gray values. The region between the skull and the brain tissue can be extracted by thresholding . But this region is not always closed; so we connect those discontinuous parts to make sure the brain region not connect with other tissues. The connected region is called ring in the following part which looks like a ring. The unwanted edges always attach themselves with the closed ring. It is difficult to remove those unwanted edges directly.

2.2.1Threshold Processing

In this step, the region between the skull and the brain tissue will be found out. And this region to be segmented has significantly different gray values with other tissues. So the threshold operation can meet our requirement.

The algorithm assumes that the image to be threshold contains two classes of pixels (e.g. foreground and background) then calculates the optimum threshold separating those two classes so that their combined spread (intra-class variance) is minimal.

But sometimes this region is not closed. So it is necessary to link the gap in the region. Here, we only consider the pixels with the gray value of 0, and compute the distance from these pixels to the nearest pixels with gray value of 1. If the distance is larger than a certain threshold, change the gray- value of 0 to 1. Or leave the gray value untouched. The gaps could be connected through above processing. Though the region has been widened, the location of the edge will not change after skeletonization.

2.2.2 Skeletonization and deburring

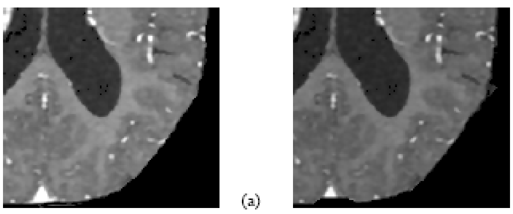
The goal of our modified method is remove that unwanted edges. In the figure 2b(4), there are many white spots attaching to the ring. These spots cause the pits in the surface of brain tissue. But it is difficult to remove these spots directly. Skeletonization and the removal of burrs is the key step in this method. The skeleton of the ring is shown in figure 2b(5). It is noticed that the spots are slimed as burrs. As long as these burrs removed, the desired results can be achieved.

The skeletonization cannot distort the shape of brain tissue. Because the goal of skeletonization is to preserve the homotopy of the region, i.e., the number of connected components and holes. The deburred image is shown in figure 2b(6).

2.2.3 Final Template Extraction

In the above step, we get only the skeleton of the ring but the final template. Fortunately, the region surrounded by the skeleton exactly is our wanted region. The template will be got after filling the region surrounded by the skeleton. But the template is slightly larger than actual brain tissue due to the skeletonization step. For this reason, we erode this template using the R structuring element to create a set the final template that will rightly cover nearly the entire brain region. The R is a round morphological element with a diameter of 6 pixels Finally, multiply the filtered image by the XD, our desired purpose can be achieved.

3.Experimental observation



(a) (b)

Figure1.The large version of the final images (a) the image processed by conventional method(b) the image processed by modified method

The white spots are completely preserved in the image processed by the modified method.

Experimental results for Input Image 1:

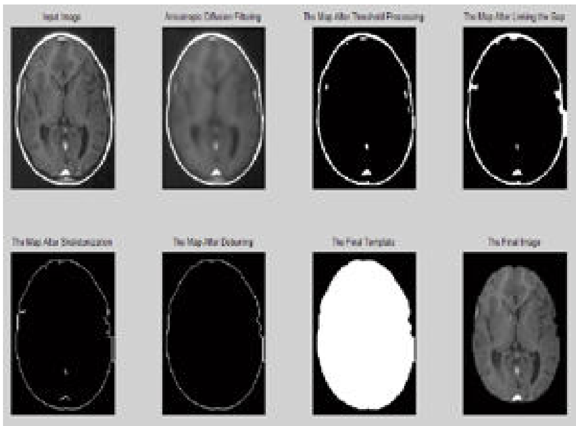


Figure2a.Existing method stages (1) Input Image(1) (2) anisotropic diffusion filtering (3) the map after threshold processing (4) the map after linking the gap (5) the map after skeletonization (6) the map after deburring (g) the final template (7) the final image

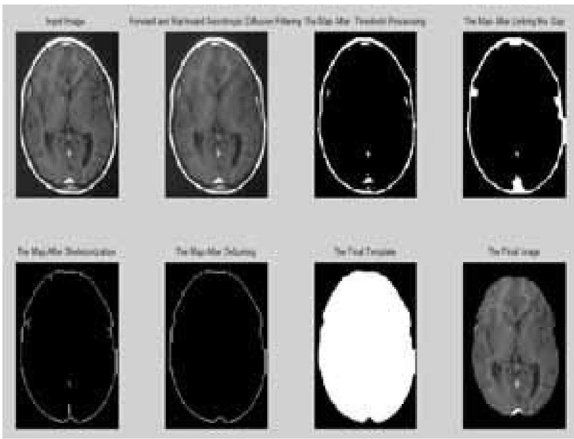


Figure2b.Proposed method stages (1) Input Image(1) (2) Forward and backward anisotropic diffusion filtering (3) the map after threshold processing (4) the map after linking the gap (5) the map after skeletonization (6) the map after deburring (g) the final template (7) the final image

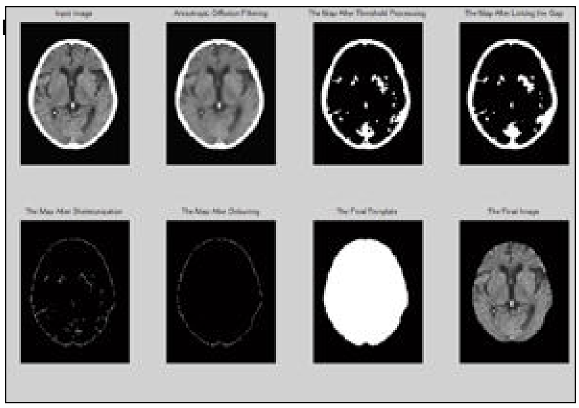


Figure3a.Existing method stages (1) Input Image(2) (2) anisotropic diffusion filtering (3) the map after threshold process-

ing (4) the map after linking the gap (5) the map after skeletonization (6) the map after deburring (g) the final template (7) the final image

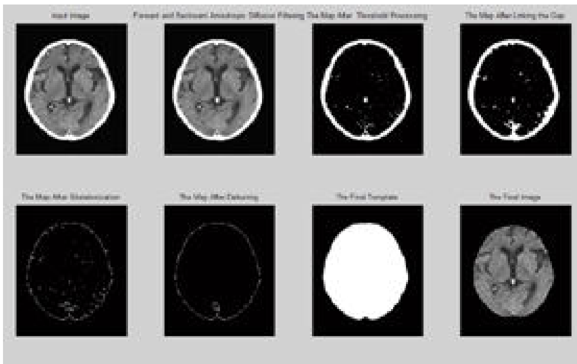


Figure3b.Proposed method stages (1) Input Image(2) (2) Forward and backward anisotropic diffusion filtering (3) the map after threshold processing (4) the map after linking the gap (5) the map after skeletonization (6) the map after deburring (g) the final template (7) the final image

Experimental results for Input Image 3:

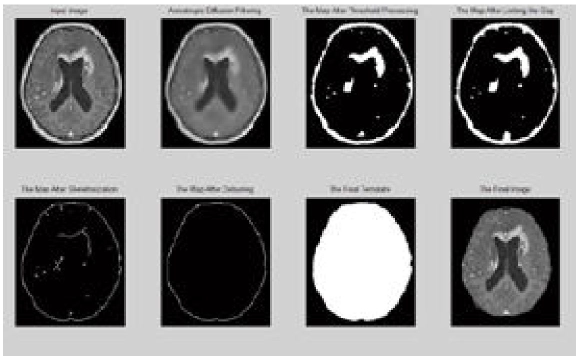


Figure4a.Existing method stages (1) Input Image(3) (2) anisotropic diffusion filtering (3) the map after threshold processing (4) the map after linking the gap (5) the map after skeletonization (6) the map after deburring (g) the final template (7) the final image

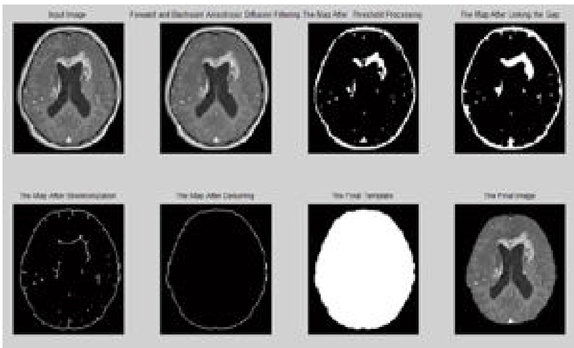


Figure4b.Proposed method stages (1) Input Image(3) (2) Forward and backward anisotropic diffusion filtering (3) the map after threshold processing (4) the map after linking the gap (5) the map after skeletonization (6) the map after deburring (g) the final template (7) the final image

4.Conclusion

A novel skill-stripping method is proposed in this approach. This method has several advantages when compared to the traditional methods. For the MR image with tumors, better results can be worked out using this modified method. The proposed approach uses forward and backward anisotropic diffusion filter which encourages intraregion smoothing. Moreover, thresholding technique is used to separate the region between brain and skull. The experimental results shows that the proposed approach provides better results

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