Automatic identification and segmentation of infarct lesions from diffusion weighted MR images and ADC maps

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Introduction

There has been considerable interest in the use of diffusion weighted imaging (DWI) to detect the site and size of ischemic lesions in acute stroke patients [1, 2]. This information assists in classifying the stroke age and may also be useful in predicting the clinical outcome [3]. The measurement of infarct volume has an important role to play in: (a) decision-making in acute stroke, and (b) assessment of stroke therapy response in clinical trials. Previous methods for infarct segmentation from DWI images had many false positives, as they did not use the complementary information from apparent diffusion coefficient (ADC) maps (free from T2-shine through and coil-shading effects) available with DWI images [4,5,8]. In the present work, we have combined the contrast information provided by DWI and physiological information provided by the ADC maps to segment the infarct core automatically. A T2 image is part of the standard DWI protocol and hence ADC map is available for use. Previous research [6,11,12] shows that ADC values of acute stroke lesions fall in a range and we use this to get rid of susceptibility artifacts and some of in-homogeneity artifacts, which may mimic acute stroke.

Methods

The algorithm was run on 22 data sets with cerebral stroke of which 15 subjects were imaged using GE Signa HDx 3T system and 7 with GE Signa Excite 1.5T system. DWI images were acquired using a spin-echo EPI sequence, with diffusion encoding applied (b-factor = 1000 s/mm^2) along the three principal axes and trace maps generated to remove the effect of anisotropy. In-plane resolution was either 0.9375 mm or 1.01 mm, slice thickness varied from 3.5 mm to 6 mm and spacing between slices varied from 0-1 mm. ADC images were calculated for each slice on pixel-by-pixel basis as: $ADC(x,y) = \ln\left(S_0(x,y) / S_{b_{1000}}(x,y)\right) / b_{1000}$. As shown in fig.1, the method primarily consists of four steps: skull stripping, automatic seed(s) selection, restricted region growing within a ROI around the seeds and refinement using level sets. A pixel is included as a seed if it and a critical size (>4 neighbors in 2D) of its neighbors have intensity greater than an adaptively generated threshold in the DWI image and is in the range of ADC value of acute infarct (0. 15 - 0.63 x10^{-3} mm^2/s) [6,11,12]. A region growing is performed restricting the growth in 2D and in a 5x5 ROI around the seeds. Region growing is also restricted within the ADC range (0. 15-0.63 x10^{-3} mm^2/s) of stroke lesion. Finally a geodesic active contour [7] is performed to refine the segmentation. Implementation was done within the ITK framework [9]. Manually traced volumes by a radiologist using ITK SNAP version 1.6.0.1, 2008 were considered to be the 'gold standard' to which automatic segmentation results were compared and calculated the DICE similarity coefficient.

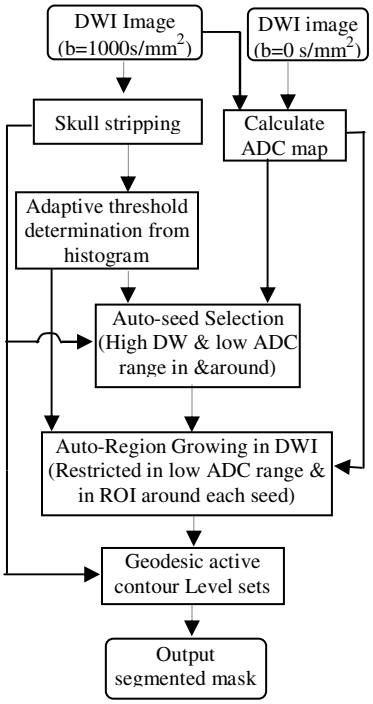
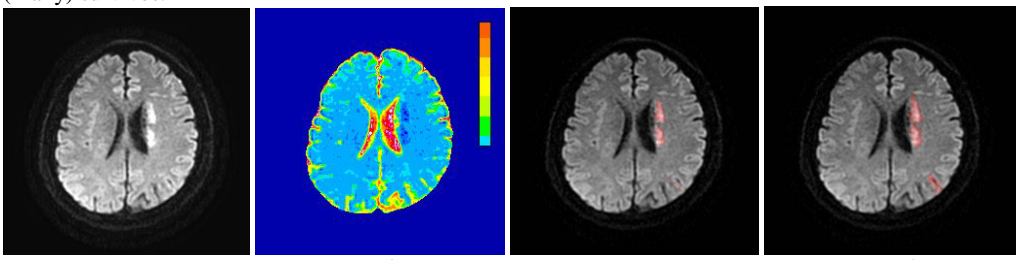


Fig. 1. Flow chart of the proposed automatic segmentation algorithm

Results

Average DICE similarity coefficient calculated with respect to the ground truth was 67.58±24.2 (ranged from 37.13 to 95.8) with the proposed algorithm. Fig. 2 shows DWI image, ADC image, the proposed algorithm output and ground truth for one of the images.

The algorithm worked very well in cases where the intensity range of infarct tissues were separated well from the normal tissues in DWI images. The high performance in these cases can be attributed to the fact that in these cases, the seed selection picks both the artifact as well infarct which are then further refined to eliminate all the artifact seeds (false positives). The problem arises when the infarct is almost in the same intensity range as the normal tissue and hyper intense intensity in homogeneity artifacts are present. This leads to a higher initial threshold value due to which only the most hyper-intensive core of the infarct tissue (if any) survives.



(a) (b) (c) (d)

Fig. 2(a) DWI image (b) ADC map (c) Auto segmentation output and (d) manual ground truth.

Discussion

An automatic MRI segmentation of stroke lesions was proposed. Preliminary experiments show promising results. Further algorithm refinements are required to obtain high level of overlap with ground truth and make our system clinically viable. Future work will focus on the use of Blood Supply Territories Atlas [10] as a priori information in the segmentation process, in fact, a stroke lesion is restricted to a specific blood territory, this anatomical information can therefore be used to constraint the segmentation process to be restricted to a specific territory.

References

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