Segmentation of Brain MR Image Using Template Matching and Hierarchical Fuzzy C-means Algorithm

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Abstract: In brain magnetic resonance (MR) images, segmentation and 3D visualization of brain are useful to diagnose abnormalities. The fuzzy c-means algorithm (FCM) has been widely used for segmentation of brain MR images. However, FCM does not yield sufficient results under RF nonuniformity. We propose a segmentation method composed of template matching to extract the cerebrum and a hierarchical FCM to segment the cerebrum into white matter, gray matter, and cerebrospinal fluid without any parameter setting and heavy computation. The proposed method shows good segmentation results from T_1-weighted image under RF nonuniformity.

Introduction: Segmentation of brain MR image makes it possible to diagnose abnormalities through 3D visualizing and quantifying the interesting parts. Among many algorithms, the FCM has been successfully used for segmentation [1][2]. However, the FCM itself does not solve RF nonuniformity of MR images. Some segmentation algorithms have addressed the RF nonuniformity that results in spatial variation of image intensity [3][4]. They require manual setting of parameters and heavy computation load. In addition, pre-processing is needed under operator supervision in order to reduce noise and extract cerebrum [1][5]. In this study, we extract cerebrum by template matching and segment the cerebrum into white matter (WM), gray matter (GM), and cerebralspinal fluid (CSF) by a hierarchical FCM (HFCM) in brain MR image.

Material and methods: Figure 1 shows overall block diagram of the proposed segmentation method. T_1-weighted image is smoothed by 2D median filtering to remove noise. The pre-constructed Talairach templates of right cerebrum, left cerebrum, and cerebellum [6] are registered into image coordinates based on 10 reference points (CA, CP, AP, PP, SP, IP, RP, LP, ML1, and ML2) by affine transformation. The transformed templates are deformed to the image using active contour model [7]. The external force is the potential force like balloon [8] and the midline force, which is the strong force at the midline in the image to prevent over-deformation to other part of the cerebrum. The resultant right and left cerebrums are obtained by subtracting the deformed cerebellum template from the deformed right and left cerebrum templates, respectively. The initial centroids and the degrees of membership of HFCM are calculated from the cerebrum in advance. The 3D data is divided into small volumes, and the divided volumes are divided into smaller volumes hierarchically until size of the volume is 8×8×8 (figure 2). In small volume, the image characteristics can be approximated to be homogeneous, and the FCM in this small volume is successfully used. As the hierarchical level increases, the volumes become smaller and the number of voxels in a volume is not enough for reliable estimation of degrees of membership and centroids. Therefore, the membership values from every level are averaged with different weights according to the level, and normalized.

Results and Discussions:

Brain MR images were obtained from 3 Tesla MRI system at the KAIST fMRI center, Korea. Figure 3 shows the (a) image, (b) the extracted cerebrum, the segmented (c) WM, (d) GM, and (e) CSF. The cerebrum is extracted by template matching, and WM, GM, and CSF are well segmented by HFCM although the image is distorted by RF nonuniformity. Computation cost of HFCM is 8 times as much as FCM, however, its segmentation performance is much better than the FCM.

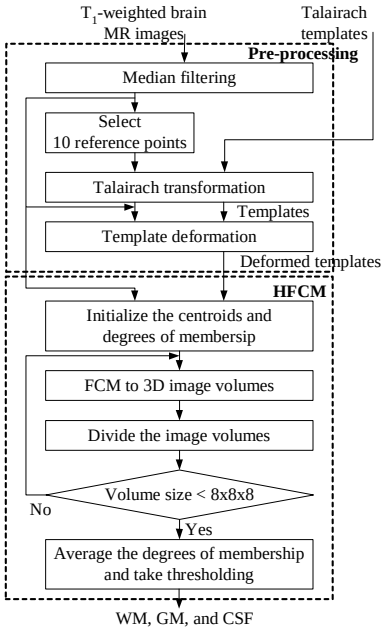

Figure 1. The proposed algorithm

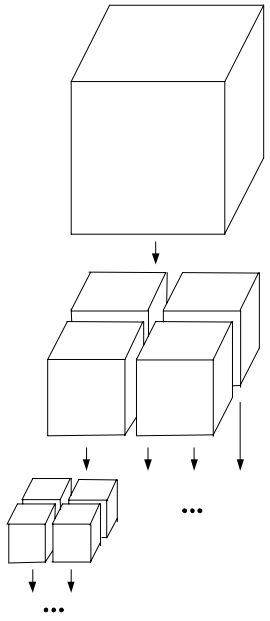

Figure 2. Hierarchical division of volume

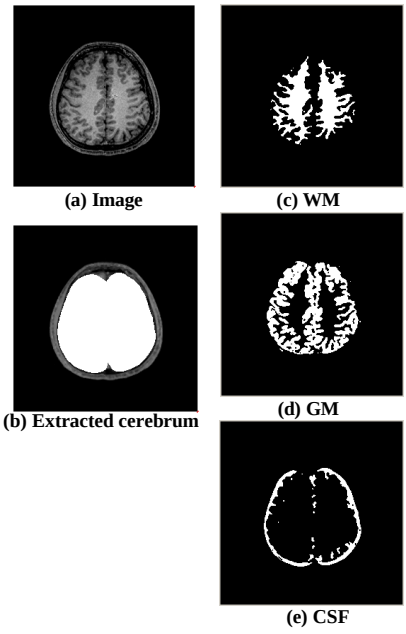

Figure 3. The experimental results

Conclusions: The proposed method by template matching and HFCM provides the convenient and robust segmentation results in brain MR image. For the automated segmentation, it is desirable to select 10 reference points automatically.

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