Tracking Brain Ventricle Expansion in Alzheimer Disease Using Combined Intensity and Shape-based Segmentation

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Introduction

Brain ventricles (Figure 1, [1]) are fluid-filled cavities in the brain that increase in size at different rates in people aging normally, those with mild cognitive impairment (MCI) or those with Alzheimer disease [2]. Such pathological changes can be measured from repeated high resolution magnetic resonance imaging (MRI) of the brain.

Our overall goal is to develop and implement advanced algorithms that adapt and combine several segmentation approaches to increase the accuracy and precision of brain ventricle volume measurements.

The goal of the present study was to fully automate segmentation of the lateral ventricles.

Limitations of Existing Methods

- Current automated ventricle segmentation methods do not consistently identify the temporal horns in all subjects.
- Automated segmentation algorithms have previously used deformable registration to map ventricle volumes between an atlas and a subject, but such indirect segmentation can lead to inaccuracies [3].
- Segmentation methods performed directly on images require user interaction to make corrections, decreasing speed and leading to bias.

Algorithm: General

- Seed points are identified by automatically mapping predefined points from within the ventricles of a brain atlas to the ventricles in individual subjects.
- This mapping utilizes a deformation field obtained from a deformable registration that warps the brains of the subjects into the brain atlas.
- Using the mapped seeds points, intensity-based fuzzy connectedness segmentation [4] is used to generate an initial segmentation, followed by a refinement of the segmentation using shape-based expectation-maximization (EM) [5].

Software Validation

A polycarbonate ventricle phantom in a brain mold of agar solution was created to validate accuracy of the software [11].

- T₁-weighted MR images from the Alzheimer Disease Neuroimaging Initiative (ADNI) were used to test and validate software including Normal Elderly Controls (NEC), subjects with Mild Cognitive Impairment (MCI), and subjects with Alzheimer Disease (AD) at baseline and at 24 months.

Results

- The phantom was segmented using fuzzy connectedness to within 0.8% of its true volume [11]. Figure 2 shows an MRI image of the phantom and a visualization of the ventricle segmentation.

Conclusions

- Deformable registration was successfully used to map seed points.
- A novel texture-based fuzzy connectedness algorithm was implemented that uses mapped seeds and works well on capturing the ventricle body.
- A shape based refinement was implemented using expectation-maximization that works well on capturing horn details.
- Future enhancements include automated cropping and partial volume correction using a mesh and mixture models.

References

[10] Slicer is an open-source program at http://www.slicer.org

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Figure 1: Illustration of Ventrices in the Brain [1]

Figure 2: Brain Ventricle Phantom

Figure 3: Warping and Seed Mapping (a) Original Atlas with 4 seeds, (b) Original Subject with 4 mapped seeds.

Figure 4: Ventricle segmentation of a subject with Alzheimer disease at baseline (left) and at 24 months (right).