

Automated multi-atlas segmentation of anatomical brain MR images from elderly subjects.

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Introduction:

An increasing number of studies use brain MR imaging to assess volumetric changes due to neurodegenerative diseases in the elderly. Crucial to these studies is segmentation of anatomical brain MRI data. Multi-atlas segmentation is one of the approaches used for automated labeling [1]; however the performance of this method in subjects with age-related atrophy has not been thoroughly investigated. The purpose of this work was to compare the performance of multi-atlas segmentation to that of FreeSurfer segmentation in data from elderly subjects (>80 years of age).

Materials & Methods:

Data & Segmentation: High-resolution T1-weighted MPRAGE data from 7 elderly subjects (88.4 ± 1.5 years of age) was collected on a 1.5T GE MRI scanner. All datasets were segmented using both a) multi-atlas and b) FreeSurfer (<http://surfer.nmr.mgh.harvard.edu>) segmentation. The atlases used for multi-atlas segmentation consisted of T1-weighted MPRAGE data from 25 subjects, previously divided into 85 regions using FreeSurfer. The atlases were selected to have the same age distribution as the 7 elderly subjects, and no history of dementia or other neurologic diseases. The 7 datasets were not included in the 25 atlases. After brain extraction using BET (FSL, Oxford, UK), all atlases were registered to each of the 7 datasets in two steps: affine (FLIRT, FSL, 12 degrees of freedom) and non-rigid registration (Automated Registration Toolbox, ART). The resulting transformation matrices were then applied to the corresponding label volumes, thereby propagating 25 label volumes to each dataset's space. The final segmentation of each dataset was conducted using a vote rule based on the maximum frequency of appearance of a label. In each voxel where vote rule resulted in a non-unique outcome, a label was chosen randomly from the labels with maximum frequency in that voxel. The result was further improved by applying tissue probability maps obtained using FAST (FSL, Oxford, UK).

Multi-atlas vs. FreeSurfer Segmentation: The performance of multi-atlas segmentation was compared to that of FreeSurfer in terms of the location and volume of labeled regions. For the assessment of agreement in terms of the location of labels across methods, a stereology-type validation study was performed. For each subject, 2000 voxels restricted to the brain tissue and ventricles were randomly selected and classified based on the segmentation results of the two methods. Cohen's κ coefficient was calculated from the co-occurrence table [2]. For the assessment of agreement in terms of the volume of the labels across methods, linear regression analysis was used ($P < 0.01$).

Results & Discussion:

Figure 1 illustrates the co-occurrence map for the agreement in terms of the location of labels obtained with the two segmentation methods, for a single subject. Cohen's coefficient was $\kappa = 0.89$. According to published literature κ values higher than 0.81 illustrate an "almost perfect agreement" [3]. Similar results were obtained for all 7 subjects ($\kappa > 0.85$). Figure 2 shows a plot of the volumes of the 85 regions segmented in all subjects with multi-atlas vs. FreeSurfer segmentation. A significant linear relationship described by the equation $y=0.9812x$, ($R^2 = 0.9487$, $P < 10^{-20}$), was detected between the volumes obtained with multi-atlas and FreeSurfer segmentation. Linear regression analysis suggested that the volumes of the different regions were very similar across segmentation methods.

In conclusion, the results of this study suggest that multi-atlas and FreeSurfer segmentation provide similar results for brain MRI data from elderly human subjects. The number of studies investigating volumetric changes due to neurodegenerative diseases in the elderly is increasing. FreeSurfer segmentation often requires manual corrections. The present work suggests that, for data from elderly human subjects, multi-atlas segmentation provides results that are similar to those of FreeSurfer, in a fully automated manner.

References:

- [1] Heckemann R.A., et al., NeuroImage 2006;33:115-126
- [2] Cohen J., Educ. Psychol. Meas. 1960;20:37-46.
- [3] Landis J.R et al., Biometrics 1977;33:159-174.

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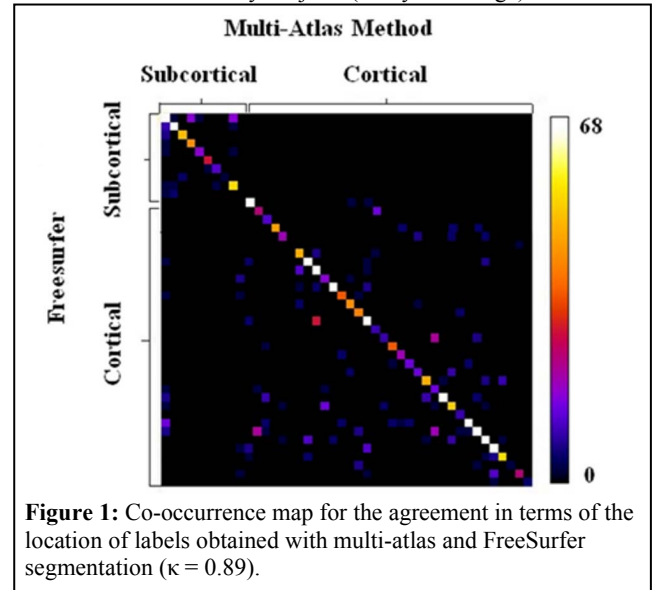


Figure 1: Co-occurrence map for the agreement in terms of the location of labels obtained with multi-atlas and FreeSurfer segmentation ($\kappa = 0.89$).

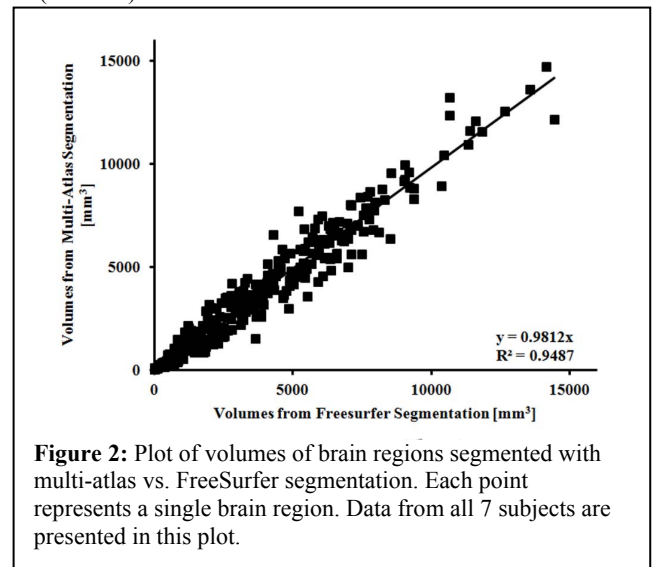


Figure 2: Plot of volumes of brain regions segmented with multi-atlas vs. FreeSurfer segmentation. Each point represents a single brain region. Data from all 7 subjects are presented in this plot.