Unified Segmentation at 7T

Yosef A Berlow[1], Lisa Karstens Vingara[1], Manoj K Sammi[1], Laura E McMahon[1], Ian Tagge[1], Brendan Moloney[1], John W. Grinstead[2], and William D Rooney[1]
[1]*Advanced Imaging Research Center, Oregon Health & Science University, Portland, Oregon, United States,* [2]*Siemens Healthcare, Portland, OR, United States*

Introduction: At 7 Tesla (T), the magnitude of B_1 inhomogeneities can cause problems for many brain imaging post processing steps, including brain extraction and segmentation. To address these challenges, we previously developed an iterative approach to signal intensity bias correction, brain extraction and segmentation using tools from FMRIB Software Library (FSL, FMRIB, Oxford, UK.).[1] While this initial approach was robust and effective, it required multiple processing steps and the acquisition and registration of additional MR images. To simplify and improve on this process, we have begun to utilize SPM8's Unified Segmentation (New Segment) (SPM8, Wellcome Trust Centre for Neuroimaging, London, UK.) to classify brain tissue using 7T MPRAGE images. Here, we report our initial results using Unified Segmentation in a large dataset of high resolution MPRAGE images acquired at 7T.

Methods: We identified multiple 7T MPRAGE images from 88 healthy control subjects (53 women; 35 men; age range 18-75, mean age 36) who participated in Institutional Review Board approved studies at the Advanced Imaging Research Center at Oregon Health and Science University. All MR data acquisitions were performed on a whole-body 7T Siemens MAGNETOM system using singly-tuned RF coils (X) using an eight-channel phased-array ^{1}H RF coil (Rapid Biomedical). Subjects were positioned in the RF coil and referenced in the magnetic field direction (z) using laser fiducial beams. After B_0 shimming and RF pulse calibration, high resolution 3D data sets with Magnetization Prepared Rapid Gradient Echo (MPRAGE) (TR = 2.3 s, TI = 1.05 s, flip angle = 6^0, isotropic resolution of 0.8 mm, data matrix: 320 x 320 x 208, TA = 10.8 min) were acquired. Echo times (TE) varied very slightly, (TE=2.75 ms, 33 subjects; TE=3.07 ms, 41 subjects; TE=3.12 ms, 8 subjects, the remainder had intermediate values).
Image Analysis: Unified Segmentation was run in parallel on a grid engine using the New Segment command through a Nipype interface (http://nipy.sourceforge.net/). Non-default options included setting the bias FWHM cutoff to 30mm and saving the intermediate images files in both warped and native space. Brain voxels were edited by adding the volume classes representing gray matter (GM), white matter (WM) and cerebrospinal fluid (csf) into a single mask and thresholding this mask at 0.5 with a minimum cluster size of 500 to remove any voxels representing small partial volume effects outside of the skull. Resulting volumes were quantified in native space and analyzed as both absolute volumes and volume fractions(fGM, fWM, fCSF). Ten of the subjects were identified with multiple MPRAGE scans within a short time frame (< 14 months) and were used in coefficient of variation (CV) measures.

Results and Discussion: The Unified Segmentation process resulted in significant correction of the RF bias, robust and accurate brain identification and segmentation in all subjects (**Figure 1**). Average volumetric measures for men and women are shown in Table 1. CV values were 0.011, 0.015, and 0.036 for GM, WM and CSF, respectively. Linear models adjusting for age and sex detected significant age and sex effect in fGM (Age: $F(1,85)=57.5$, $p<0.0001$; Sex: $F(1,85)=4.12$, $p=0.045$) and fCSF (Age: $F(1,85)=41.7$, $p<0.0001$; Sex: $F(1,85)=4.25$, $p=0.042$) with increasing age associated with decreasing fGM and increasing fCSF and women having larger fGM and lower fCSF compared to men. This preliminary study demonstrates the feasibility and effectiveness of the Unified Segmentation process for volumetric analysis of 7T images.

Acknowledgements: This work was supported by F30-DA033094, T32-AG023477, T32-GM067549

References:

1. Berlow YA, Sammi MK, Selzer AH, Bourdette D, and Rooney WD. Quantitative Volumetrics of Multiple Sclerosis Brain from 7T MRI. Proceedings of the International Society for Magnetic Resonance in Medicine. 21:4692 (2013)
2. Ashburner J, Friston KJ. Unified segmentation. Neuroimage. 2005 Jul 1;26(3):839-51.

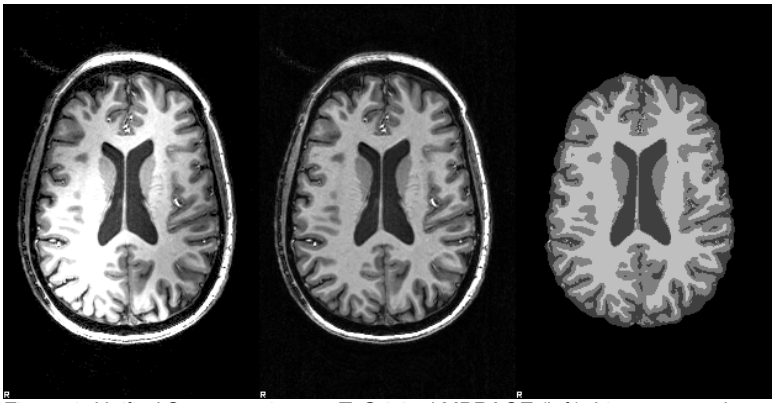

Figure 1: Unified Segmentation at 7T. Original MPRAGE (left), bias corrected image (middle) and brain extracted and segmented image (right).

	Women	Men
n	52	36
Age	34.6±13	37.5±13
Gray Matter (cm^3)	680±48	758±74
White Matter (cm^3)	484±39	543±56
CSF (cm^3)	231±22	269±31
Gray Matter (%)	48.73±0.90	48.28±0.95
White Matter (%)	34.67±0.88	34.57±0.97
CSF (%)	16.59±0.98	17.15±1.30

Table 1: Segmented Volumes and Volume Fractions from 88 healthy volunteers.