Multicontrast 3D Structural Imaging to Improve Automatic Brain Extraction and Segmentation

B. P. Sutton[1,2], and A. T. Van[3]
[1]Bioengineering, University of Illinois, Urbana, IL, United States, [2]Beckman Institute, University of Illinois, Urbana, IL, United States, [3]Electrical and Computer Engineering, University of Illinois, Urbana, IL, United States

Introduction: Structural neuroimaging studies rely on T1-weighted images to provide gray/white matter contrast for image segmentation. As an initial step in a morphological study, brain extraction is performed to remove from consideration all non-brain tissues. However, some regions lack sufficiently distinctive T1 contrast between brain matter and adjacent soft tissues and bone, making brain extraction difficult [1]. These difficulties can interfere with automatic segmentation in several regions including: separating the eyes [2] or other connected non-brain matter; the base of the cerebellum and temporal poles, where fatty tissue and dura mater frequently are incorrectly preserved as brain tissue [3]. Acquisition of a multiparametric data set, with additional T2-weighting, may improve the performance of automatic segmentation methods by providing increased contrast between brain and non-brain regions, taking advantage of T2 contrast differences between brain and dura mater, for example. In this work, we use a previously proposed multiparametric 3D structural imaging sequence [4] that provides several volumes with varying contrast in a multi-echo acquisition to assist in automatic brain segmentation. Two 3D volumes (one T1-weighted and one T2-weighted) with 1.2 isotropic resolution and a low resolution 3D field map were obtained simultaneously within **6.5 minutes.** Improvement in brain extraction utilizing the additional contrast was observed.

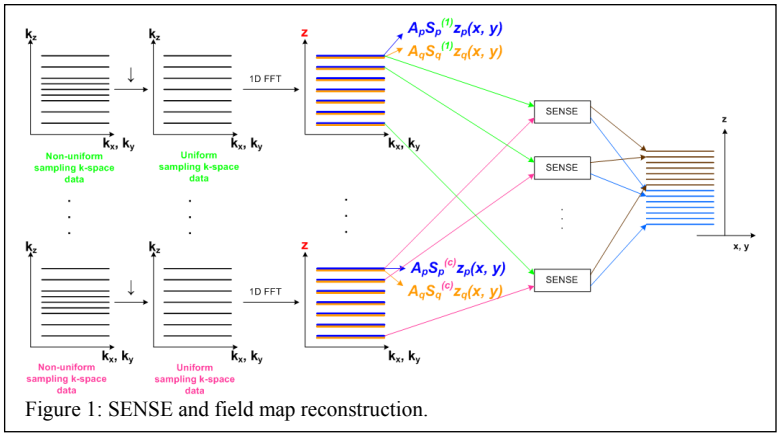

Figure 1: SENSE and field map reconstruction.

Method: *Multi parametric acquisition:* The multiecho acquisitions include a short echo time (2.2 ms) gradient echo high resolution spiral-out (GRE, T1-weighted), a low resolution spiral-in/spiral-out centered around spin echo time of 48 ms for field map data (FM), and a high resolution spiral-in/spiral-out centered around spin echo time of 96 ms (SE, T2-weighted). After corrected for eddy-current induced gradient delays, the spiral-in and spiral-out images around the last spin echo are averaged to improve signal-to-noise ratio (SNR). To speed up the acquisition, parallel imaging was used. Center portion of the 3D k-space is fully sampled for sensitivity maps estimation. To reduce the memory requirement in the reconstruction, Cartesian SENSE [5] in combination with field map correction [6] was used. *K*-space data were resampled to get a uniform sampling pattern in the k_z direction. After taking 1D FFT through-plane on the resampled data, SENSE and field map correction was performed simultaneously in (k_x, k_y, z) space for the final images. Figure 1 gives the description of the SENSE reconstruction and field map correction algorithm [4]. In Figure 1, S_p, and S_q are the sensitivity maps at slice position p, and q, respectively. A_p, and A_q are the system matrices for SENSE and field map reconstruction at slice location p and q, respectively and have the form

$$A_p(m,n) = e^{-j2\pi\left(k_x(m)x(n)+k_y(m)y(n)\right)} e^{-j\omega_p(x(n),y(n))t(m)}$$

where (k_x, k_y) is the in-plane spiral *k*-space trajectory, $\omega_p(x,y)$ is the field map (estimated from the second echo) value at position (x,y,z) in image space, and t is the acquisition time of each *k*-space location.

Brain extraction: Brain extraction is perform using BET tool from FSL [7] to the GRE*SE image [8]. The multiplication of GRE*SE was performed based on the observation that the non-brain regions in SE are greatly reduced in intensity due to shorter T2 values in the surrounding tissues.

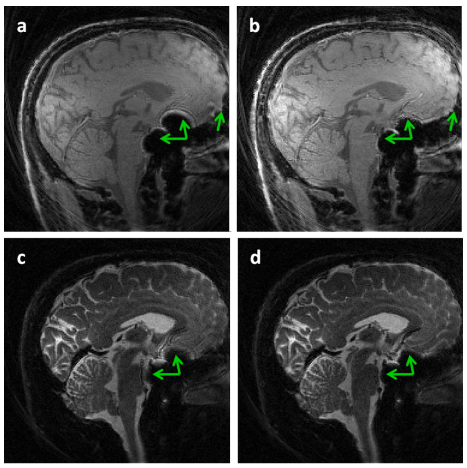

Figure 2: Reconstruction images (a,c) without, (b,d) with field map correction.

Results and Discussion: *In vivo* data were acquired using a 3D stack of 10-shot constant density spirals trajectory [9] with a 190x190x160 matrix size, 1.2 mm isotropic resolution, and TR 350 ms. Multishot spiral is chosen to reduce field inhomogeneity effects. Data were acquired on a Siemens 3 T Trio scanner with a 32 channel head coil in accordance to the institutional review board. Non uniform under sampling was employed in the stack direction (k_z) with average under sampling factor of 1.42. Total acquisition time is **6.5 minutes**. Figure 2 shows the improvement of GRE and SE (less signal loss and distortion) after applying field inhomogeneity correction using the field map (FM) obtained from the second echo. To determine the utility of the acquisition in terms of automatic brain extraction, Figure 3 shows images with the extraction results using the T1 image (GRE) (transparent red brain mask) and the improvement by using the GRE*SE image (transparent green brain mask).

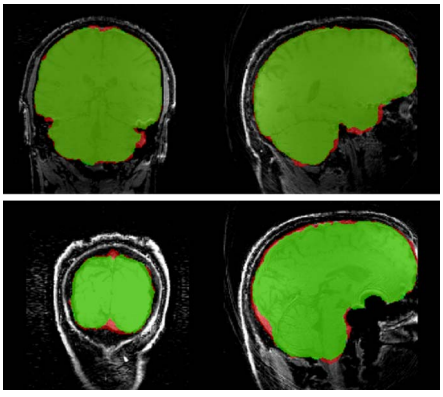
Figure 3: Brain extraction results.

T1-weighted contrast in GRE was similar to that in the MPRAGE anatomical sequence typically used at our site. The additional information from the T2 image provides valuable information for brain extraction using BET, especially in separating connected non-brain tissues. In addition to the extraction benefits, multiparametric segmentation methods, such as mFAST [10] may be able to take advantage of the additional contrast from the multi-echo acquisition, aiding segmentations especially in determining partial volumes of CSF. More advanced hybrid methods for segmenting T1-weighted brains, such as the hybrid watershed and deformable surface method (HWAT), a part of Freesurfer [3], may already help segment regions where connections are made between brain and non-brain tissue leaving mainly the problem of dura mater. The ability of the proposed sequence to separate temporal dura mater may be impaired by a close match in both the T1 and T2 contrast in this region and further analysis is necessary to quantify the contribution of this sequence to this problematic area.

Conclusion: By incorporating information from T1-weighted and T2-weighted images, we obtained improvement in automatic brain extraction. T1-weighted, and T2-weighted images were acquired simultaneously using a novel multiparametric acquisition strategy.

References: [1] Fennema-Notestine et al, HBM. 27: 99-113, 2006; [2] Atkins et al, IEEE TMI. 17: 98-107, 1998; [3] Segonne et al, Neuroimage. 22: 1060-1075, 2004; [4] Sutton et al, ISMRM Image Reconstruction Workshop, 2009; [5] Pruessmann et al, MRM. 42: 952-962, 1999; [6] Sutton et al, IEEE TMI. 22: 178-188, 2003; [7] Smith, HBM. 17: 143-155, 2002; [8] Zagorodnov et al, HBM, 2008; [9] Glover, MRM. 42: 412-415, 1999; [10] Zhang et al, IEEE TMI. 20: 45-57, 2001.