Accelerated Variable Flip Angle T1 Mapping via View Sharing of Pseudo-Random Sampled Higher Order K-Space

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Introduction: Variable flip angle T1 mapping (VFA) is a quantitative imaging method in which a series of spoiled gradient echo scans are performed in quick succession [1]. The T1 relaxation times of tissue are extracted by fitting signal vs. flip angle curves for each voxel in the images. T1 mapping can be time-consuming because it requires collection of many angles for accuracy across the range of T1 values in tissue. We sought to accelerate VFA by using a view sharing scheme, variations of which have seen applications in MR angiography [2] and DCE-MRI [3]. In our scheme, the outer regions of k-space are pseudo-randomly undersampled and missing k-space data is filled in by sharing samples from adjacent flip angle frames in the collected sequence. The center of k-space remains fully-sampled because it is responsible for most of the contrast in the image. The accuracy and precision of the T1 maps produced by these 2.3x accelerated composites were studied.

Methods: Scans were collected from a healthy volunteer using a 3T MR scanner (GE Signa MR750, GE Healthcare, Waukesha, WI) with a 32-channel head RF coil (Nova Medical, Wilmington, MA). The following parameters were used for the VFA collection: FOV = 22cm, matrix = 110x110, slice thickness = 5mm; SPGR parameters: TE/TR = 1.5/4.5ms, $\alpha = \{13$ uniformly spaced angles up to $18\}°$. The total imaging time was ~5min. The view sharing undersampling scheme (Fig. 1) was used to synthesize composites in Matlab from the raw data after the acquisition. The outer 84% of k-space was undersampled by a factor of 3 but the center 16% of k-space was fully sampled, resulting in a net acceleration of about 2.3x. Three patterns, each with the same total number of points, were designed so that when interleaved, all outer k-space points would be covered without overlap. Points were chosen in a pseudo-random fashion so that the resulting image artifacts would be incoherent. For each flip angle, outer k-space data was mixed in from its two closest flip angle neighbors. For example, the first angle used data from the second and third angles, while the second angle borrowed from the first and third. When mixing data, careful attention was paid to avoid large jumps in k-space values caused by the overall signal level changing due to flip angle. A scale factor correction was applied to the mixed-in data. The scale factor was the ratio between the average magnitudes in the center region of k-space for the target angle and the borrowed angles. For each flip angle, the result was a view-shared composite facsimile of the original for each. Brain extraction and image registration were accomplished with FSL. Finally, T1 was extracted in the conventional manner: by linearizing the collected image data according to the SPGR signal equation and computing a linear regression [1,4].

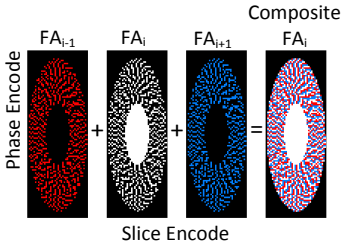

Fig. 1 View sharing sampling scheme. Outer k-space data is mixed in from neighboring flip angles to create the composite image.

Results: Without scale correction, the composite images were corrupted by artifacts, especially at the lower angles where the image contrast is changing rapidly with flip angle. With scale correction, the resulting images were essentially indistinguishable from the fully sampled originals; the same was true for the derived T1 maps (Fig. 2). The percent difference error between the view-shared and fully-sampled T1 maps is shown in Fig. 3. The distribution has a median percent error of 0.104% and 5-to-95 percentile range of -5.216% to 5.192%. This is improved over the case with no scale correction where the median and range were 0.993% and -6.866% to 10.537%, respectively (images omitted). We therefore achieved 2.3x accelerated T1 mapping without significant loss of accuracy or precision. There seems to be a slight net underestimation of T1 in CSF in the view-shared map, which may be due to the loss of high-frequency information at the sharp signal transition between parenchyma and CSF.

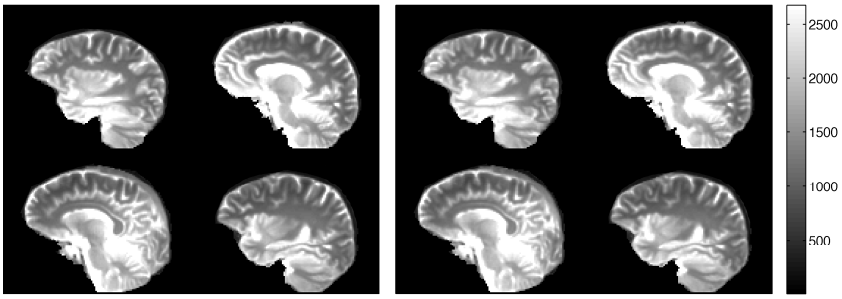

Fig. 2 Sagittal slices of T1 maps in milliseconds derived from the fully sampled images (left) and the view shared composites (right)

Conclusion: View sharing with scaling correction provides a simple method to reliably accelerate the acquisition of VFA T1 maps. A 2.3x acceleration was reliably and simply achieved. The addition of a scaling correction to the mixed data dramatically improved the fidelity of the reconstructed composite images. The gains here are also directly relevant to other lengthier flip angle based mapping techniques like DESPOT2 and mcDESPOT. The method is compatible with existing parallel imaging techniques. In this case, outer k-space samples would be chosen from the undersampled SENSE or GRAPPA matrix and mixing would occur before the parallel imaging reconstruction. This could easily provide greater than 8-fold speed up with a modest 2x2 parallel imaging acceleration factor, yet with no decrease in SNR due to the view-shared acceleration. Adding more peripheral regions with greater undersampling, may allow for time reductions greater than 3x. Compressed sensing reconstruction could also be used to reconstruct each angle without the need for mixing.

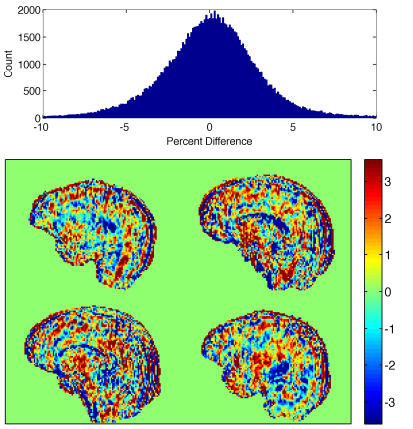

Fig. 3 Percent difference between the T1 maps derived from view shared composites and fully sampled images.

References: [1] Fram et al., Magn Reson Med. 1987;5(3):201-208. [2] Korosec et al., Magn Reson Med. 1996;36(3):345-351.[3] Saranathan et al. Proc ISMRM p2941 (2011). [4] Deoni et al., Magn Reson Med. 2003 Mar;49(3):515-26.

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