L1-ESPIRiT Reconstruction for Accelerating 3D UTE and Denoising

Wenwen Jiang[1], Frank Ong[2], Roland Henry[3], Michael Lustig[2], and Peder E.Z. Larson[3]
[1]*Bioengineering, UC Berkeley/UCSF, Berkeley, CA - California, United States,* [2]*EECS, UC Berkeley, Berkeley, California, United States,* [3]*Radiology and Biomedical Imaging, UCSF, San Francisco, CA - California, United States*

Target audience: reconstruction methods engineers, UTE application radiologists

Purpose: Ultrashort echo time (UTE) imaging has shown promise as a technique for imaging tissues with T2 values of a few milliseconds or less. Theoretically, to fulfill the Nyquist sampling criteria, a 3D radial trajectory requires π times the number of phase-encodings as its Cartesian counterpart. Practically, ~π times undersampling is often used for radial trajectory acceleration without noticeable streaking aliasing artifacts using direct gridding reconstruction methods. However, the undersampling-induced aliasing is transformed into noise-like artifacts, which degrade the SNR and the depiction of fine anatomical structures. With parallel imaging, the undersampling resulted aliasing can be resolved given appropriate coil sensitivities. Additionally, the variable density of radial trajectories makes it a natural fit for auto-calibration parallel imaging method, as the center is usually oversampled. ESPIRiT [1] is a novel and general auto-calibration parallel imaging method, which was implemented into 3D radial pulmonary imaging. [2] Using multiple sets of sensitivity maps, ESPIRiT provides robust and flexible reconstruction properties. Compressed sensing [3] can also be applied owing to the incoherent aliasing distribution of the radial trajectory. The purpose of this study is to evaluate whether L1-ESPIRiT reconstruction is beneficial to 3D UTE and implement the method for brain imaging to detect ultrashort-T2 components in myelin.[4]

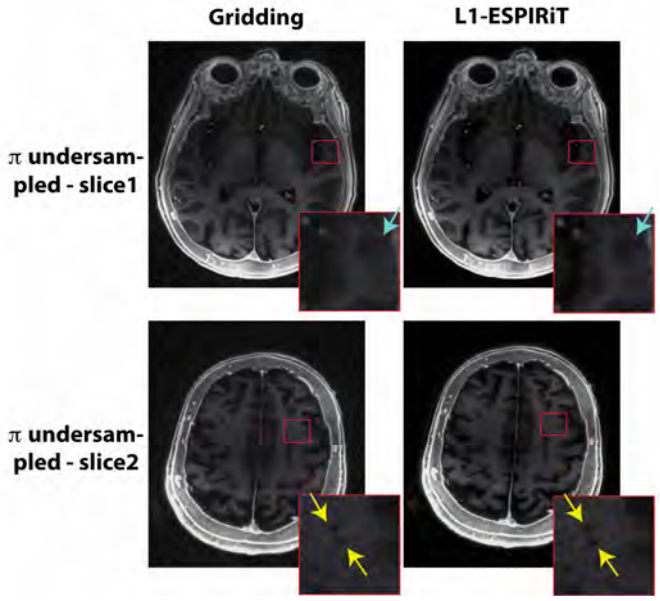

Fig.1. Comparison of gridding and L1-ESPIRiT on π-undersampled data: (left) Gridding reconstruction; (right) L1-ESPIRiT reconstruction. Yellow arrows show the suspicious MS lesions and blue arrow shows the fine

Methods: 3D UTE brain images of Multiple Sclerosis (MS) patients were acquired at 7T (GE Healthcare, Waukesha, WI) with an anisotropic field of view (FOV) [5] of 14×11×12.32 cm^3, depending on the head size, and with a 0.8×0.8×0.8 mm^3 isotropic resolution. Data were sampled with a 3D radial trajectory using a 32-channel-receive head coil. The data was prospectively undersampled by a factor of π, with respect to Nyquist sampling rate. Images were reconstructed using gridding algorithm. [6] We also used L1-ESPIRiT algorithm to perform parallel imaging reconstruction and compared the results with just gridding. Then, we retrospectively undersampled the data by an additional factor of 4 and used L1-ESPIRiT to evaluate the performance of additional acceleration. The images were acquired with a spoiled sequence with TE = 80 μs, TR = 2 ms and sampling bandwidth = ±250 kHz. The brain images used a 4° flip angle, 78752 spokes and 256 samples per spoke. Other L1-ESPIRiT reconstruction parameters include: 24×24×24 auto-calibration area, 2 sets of sensitivity maps and 20 iterations.

All the above reconstructions, including gridding and parallel imaging, were performed with the available open toolbox - Berkeley Advanced Reconstruction Toolbox. [7]

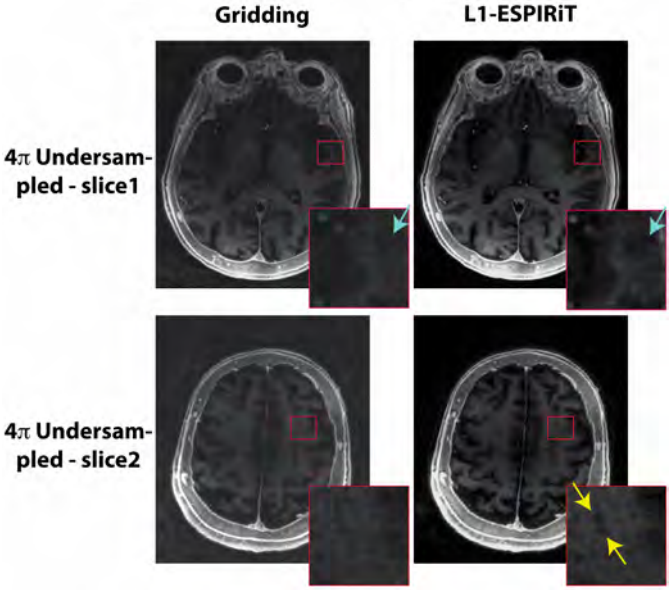

Fig.2. Comparison of gridding and L1-ESPIRiT on 4π-undersampled data: (left) Gridding reconstruction; (right) L1-ESPIRiT reconstruction.

Results: Fig. 1 shows comparison between direct gridding and L1-ESPIRiT reconstruction results on π-undersampled data of representative slices. Both gridding and L1-ESPIRiT exhibit no obvious streak artifacts with comparable image quality to show suspicious lesions (yellow arrows shown in slice2). However, the fine structures (as the blue arrows show in the zoomed-in red boxes) can only be resolved by L1-ESPIRiT (in slice1). Fig. 2 shows the comparison results on 4π-undersampled data of the same slices. The fine structure was still preserved by L1-ESPIRiT while it was blurred by direct gridding reconstruction as the arrows show (in both slice1 and slice2). In both reconstructions, SNR is sacrificed due to undersampling, but L1-ESPIRiT removes any noise-like aliasing artifacts greatly improving the image quality.

Conclusion: Using L1-ESPIRiT for 3D UTE allows for high acceleration factors without image quality degradation by removing both streaking and noise-like aliasing artifacts.

References: [1] Uecker M, et al. MRM 2014; 71:990–1001. [2] Bauman G, et al. ISMRM 2014, # 0295. [3] Lustig M, et al. MRM 2007 Dec;58(6):1182-95. [4] Du et al. Neuroimage 2014; 87: 32-41. [5] P.E.Z.Larson et al. IEEE Trans Med Imag 2008; 27(1): 47-57. [6] P. J. Beatty, et al. IEEE Trans. Med. Imag. 2005; 24(6):799–808. [7] bart: doi:10.5281/zenodo.12495.