Suppression of Residual Noise and Artifact in Parallel Imaging by Iterative Noquist

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INTRODUCTION: A fast imaging method, PINOT[1,2] (Parallel Imaging and NOquist in Tandem), was proposed earlier to combine SPACE-RIP[3] parallel imaging and the Noquist[4] reduced field of view (rFOV) method. PINOT was demonstrated[5] to preserve full spatiotemporal resolution and retain edge information better than comparable methods. However, even though use of an iterative Conjugate Gradient implementation with a fast initial estimate[6] alleviates the computational cost, PINOT reconstruction is still time-consuming compared with other methods. Here we present a simplified variant of PINOT which combines parallel imaging and iterative Noquist[7] sequentially to significantly accelerate the reconstruction speed.

METHOD: Parallel imaging methods (e.g. SENSE[8],SPACE-RIP) eliminate the aliasing artifacts that result from data undersampling in acquisitions with multiple receiver coils, provided each coil contributes independent additional spatial image information. Noquist exploits spatiotemporal redundancy in dynamic imaging if parts of the field of view (FOV) are relatively static over time. PINOT, as a combination of these two methods, achieves higher acceleration factors and/or improves suppression of aliasing artifacts. Unlike the integrated PINOT which uses a single inversion to perform Noquist and SPACE-RIP simultaneously, the method we propose here applies SPACE-RIP (*k*-space implementation of SENSE) and iterative Noquist (iNoquist) sequentially. Following reconstruction of reduced-sampled *k*-space data by SPACE-RIP initially, iNoquist begins the first iteration reconstruction using SENSE estimated results, iteratively applies temporal band-limitation constraints for (nearly) static regions in the image sequence to improve the estimation of the *k*-space views omitted during acquisition.

EXPERIMENTS: Data were used from a GE 1.5T TwinSpeed scanner (R12M4) using an 8-element cardiac coil. A FIESTA/FastCARD cine SSFP sequence was used for a cine MRI scan of a 2-chamber view of the heart, with slice thickness = 8 mm, TR = 4.4 ms, TE = 1.5 ms, flip angle 45°, 192 phase encodings, 224 frequency encodings, and 12 temporal frames. All reconstructions were computed with MATLAB on a Pentium 2.80GHz with 4GB of RAM. We compare SENSE, SENSE with iNoquist and PINOT with reduction factor R=4 on the real MRI dataset. A common subset sampling scheme for SENSE/SPACE-RIP is used, simply acquiring every fourth phase encoding line.

RESULTS AND DISCUSSION: Fig. 1 shows a comparison of SPACE-RIP, SPACE-RIP with iNoquist, and original PINOT with all reduction factors R = 4. Diastolic and systolic reconstructions demonstrate that SPACE-RIP with iNoquist provides a greater suppression of noise levels compared with SENSE, but retains a higher noise level than integrated PINOT. Higher sampling rate/reduction factor for parallel imaging is desired but usually limited due to higher noise level and even hot spots in the reconstructed images. Our proposed method shows that successive application of iNoquist after SENSE reconstruction leads to further noise suppression, while retaining image resolution. Compared with integrated PINOT, SPACE-RIP with the same reduction factor is less well-conditioned. This explains why the integrated PINOT performs better than the proposed method. However, for the same reason, due to the much lower matrix inversion burden in successively applied SPACE-RIP and iNoquist, image reconstruction is much faster than by PINOT. Respective reconstruction times for SPACE-RIP, SPACE-RIP with iNoquist, and PINOT are 2 min 18 sec, 3 min 21 sec, and 24 min 41 sec respectively.

CONCLUSIONS: Our proposed method, successive combination of SENSE with iNoquist demonstrates successful reconstruction. Compared with parallel imaging alone with the same reduction factor, this approach suppresses the noise level and residual artifacts. Compared with integrated PINOT, it has the advantage of alleviating computational burden, even though it does not achieve the same overall image quality. Furthermore, although illustrated here only for SPACE-RIP, we note that iNoquist can be used as a post processing method following any parallel imaging methods to suppress residual noise and artifacts.

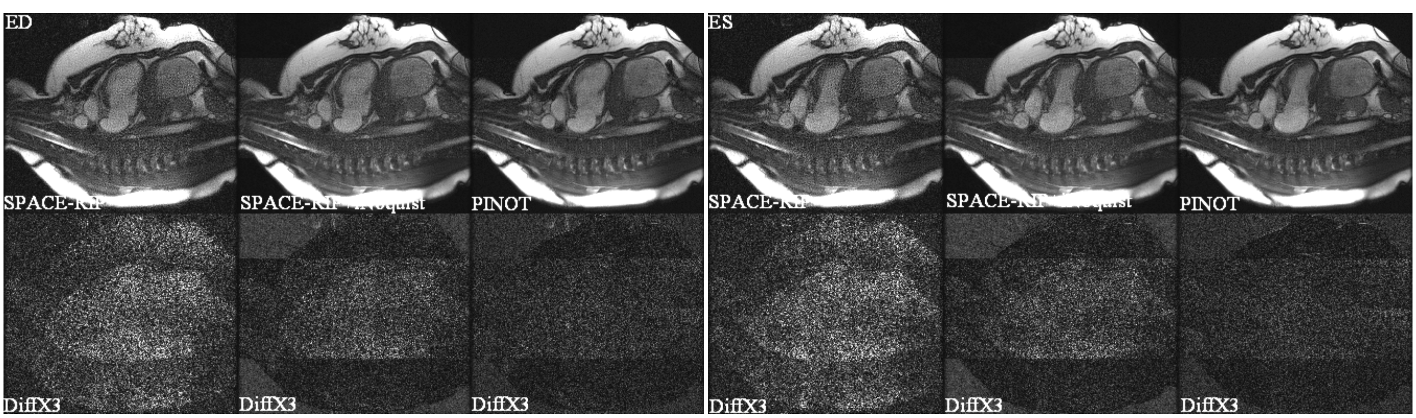

Fig. 1 shows (left to right) SPACE-RIP (R=4), SPACE-RIP with iNoquist(R=4), and PINOT (R=4) reconstructions of end diastole (frame 1) and systole (frame 6). The bottom row shows differences from truth (i.e., a full-grid reconstruction), amplified by a factor of 3 to see the details.

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