Dynamic compressed sensing for multiband MRI

Huisu Yoon[1], Dong-wook Lee[1], Juyoung Lee[1], Seung Hong Choi[2], Sung-Hong Park[1], and Jong Chul Ye[1]
[1]Dept. of Bio and Brain Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Daejeon, Korea, [2]Dept. of Radiology, Seoul National University College of Medicine, Seoul, Korea

Purpose: The applications of dynamic compressed sensing MRI include cardiac imaging, fMRI, angiography, and perfusion imaging. Recently, by exploiting the diversities in coil sensitivity maps across the z-slice, simultaneous multislice imaging (SMS) or multi-band imaging (MB) have been extensively investigated for accelerated acquisition in brain imaging studies. By synergistically combining the two approaches, we propose a dynamic compressed sensing multi-band MR imaging technique for further acceleration in 3-D + t MR acquisition.

Theory: In this work, sparse set of phase encoding lines are obtained while retaining multiband RF acquisition. As shown in [1], the multi-band imaging can be interpreted as the lattice sampling pattern in z-direction of the corresponding 3-D volumes, and the trandititional MB imaging can be considered as sampling only the DC components. Accordingly, Fig 1(a) shows this k_z-k_y space sampling pattern with MB factor of 2 and spatio-temporal acceleration factor of 2. This results in two types of aliasing: one along spatio-temporal direction (k_y-t) and the other for slice direction (k_z). To resolve the aliasing artifacts, we can combine the PI algorithm to resolve the aliasing in the slice direction and dynamic CS algorithm[2] for spatio-temporal aliasing, respectively. More specifically, we reconstruct the slice direction aliased image after removing temporal directional aliasing using dynamic CS (Fig. 1(b)). For this, we use k-t FOCUSS[2]. After the temporal unaliasing, slice-GRAPPA[3] is used to separate the individual slices (Fig. 1(c)). To apply slice-GRAPPA, the undersampled pre-scan data also needs to be reconstructed k-t FOCUSS. By taking the same undersampling pattern for SMS and pre-scan data, the data acquisition time retains same so that temporal dynamics of the two datasets are maintained the same.

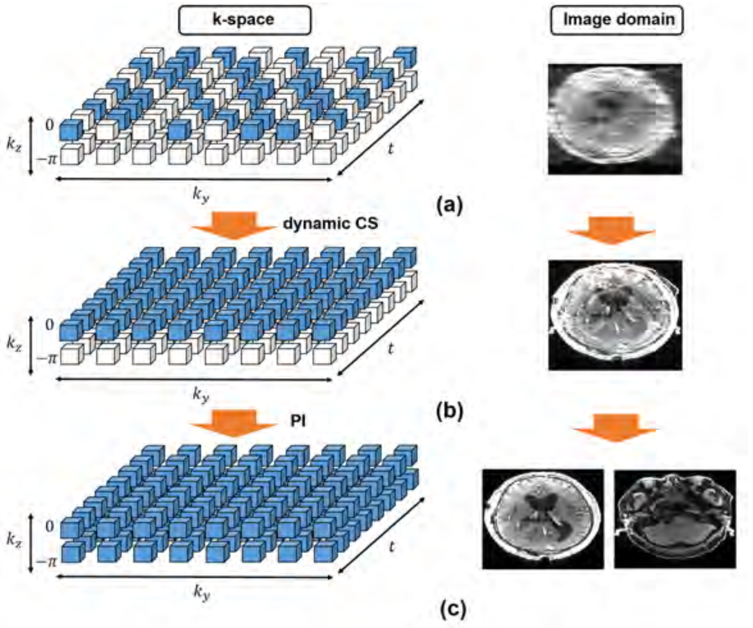

Fig. 1. (a) Sampling pattern in k-space with in-plane reduction factor of 2 and MB factor of 2. (b) CS is applied to fill the randomly skipped k-space samples. (c) PI separates the individual slices. The images corresponding to each k-space are shown on the right of the figures.

Results: 3D DCE data was acquired on a 32 coil Siemens 3T Verio scanner. Acquisition parameters are as follows: 192x252 matrix size, 40 partition encoding lines, TR/TE 2.81/1.04ms, slice thickness 3 mm, 32 channels and 60 time frames. This data is considered as fully sampled data, and retrospective downsampling was conducted for both slice and spatio-temporal directions. Downsampling rate along slice dimension was 2 (MB=2) and in-plane downsampling factor were 2, 4, and 8 (total of 4, 8, and 16). Fig.2 shows the reconstruction results using various methods. Here, for standard GRAPPA[4], each slice was downsampled with sampling rate of 6 and 32 ACS lines (total downsampling rate 3.69). This was used as reference. We confirmed that the proposed algorithm shows better result than normal GRAPPA algorithm for dynamic imaging. Even in the higher acceleration such as 8 and 16, the proposed algorithm shows much improved performance. Also, we observed that reconstruction order is critical for reconstruction quality. Specifically, when slice-GRAPPA is applied prior to CS, aliasing artifacts were not removed as shown in the second column of Fig.2. This is because removing spatio-temporal aliasing is critical to retain the performance of slice GRAPPA.

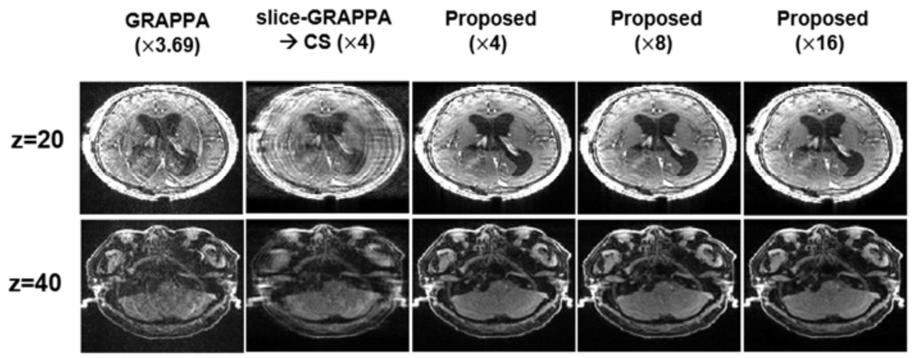

Fig.2. Reconstruction results of GRAPPA, slice-GRAPPA→ CS, and proposed algorithm with reduction factors of 4, 8 and 16 for 20th and 40th slices.

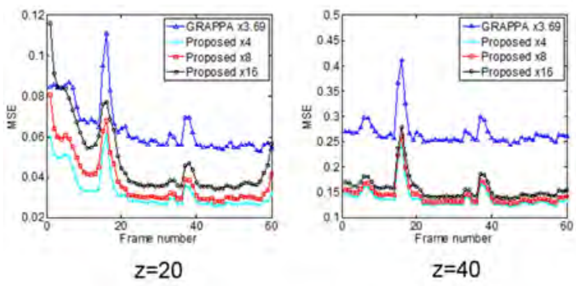

Fig. 3. MSE plots for the results in Fig.2

Conclusion: In this work, a novel reconstruction algorithm using compressed sensing and parallel imaging combination for dynamic simultaneous multislice imaging application was proposed. We investigated how to combine the multi-band imaging and compressed sensing reconstruction to further accelerate the acquisition. Our method can be used to distinguish images from different slices from measured data after the spatio-temporal aliasing is resolved using CS. Experimental results showed that the proposed method was effective for improved spatio-temporal resolution compared to the existing methods.

References: 1.Zahneisen Z, *et al*, MRM, 2014, p2071; 2.Jung H, *et al.* MRM, 2009, p103; 3.Setsompop K, *et al.* MRM, 2012, p1210; 4. Griswold M, *et al.* MRM, 2002, p1202;