Geometric-decomposition Coil Compression for Real-time Simultaneous MultiSlice EPI reconstruction at high MultiBand factors

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TARGET AUDIENCE: Neuroimaging scientists and clinicians interested in image reconstruction for SMS-EPI protocols with high levels of slice-acceleration.

PURPOSE: Simultaneous MultiSlice (SMS) EPI acquisition significantly increases the temporal efficiency for both diffusion-weighted imaging and functional MRI [1-6]. With the Blipped-CAIPI modification [6] and a large channel-count receive coil array, high resolution (<2mm) whole brain images can now be obtained in sub-second with little SNR penalty and artifact level. However, this acquisition breakthrough poses a challenge for the rapid or real-time reconstruction of these large datasets; a critical criteria for high patient throughput in clinical and research settings. We develop the Geometric-decomposition Coil Compression (GCC) method [7] to speed-up accurate reconstruction of SMS-EPI acquisitions with high MultiBand (MB) factors to real-time using standard vendor's computational hardware.

METHOD: The GCC coil compression method is applied within the Split Slice-GRAPPA (Sp-SG) formulation [8] for SMS-EPI reconstruction. Coil compression is imbedded as part of the Sp-SG kernel fitting/application process. The fully sampled Sp-SG training data, acquired at the beginning of the SMS-EPI scan, is used to train coil compression mapping at each read-out position, using a sliding window of 5 neighboring hybrid-space columns. The coil compression mappings are then applied to the Sp-SG training data prior to performing the Sp-SG kernel fitting across the reduced number of channels. Finally, the coil compression mappings are applied to all collapsed volumes prior to slice un-aliasing. To examine the performance of GCC coil compression, *in vivo* SMS GE-EPI data of a healthy volunteer was acquired on a 3T Siemens Skyra scanner using the following protocol: 72 slices, 2mm^3 resolution, FOV = 196 x 196 x 144 mm^3, MB=8, TR=900ms, TE=30ms, Partial Fourier 6/8. Blipped-CAIPI FOV/3 shift was used along with a custom 64-channel head array coil [9] and 5x5 Sp-SG kernel. We compared: i) Full 64 ch., ii) 16 ch. standard SVD compression [10], and iii) 16 ch. GCC compression. Comparisons were made with respect to reconstruction time, g-factor penalty, and reconstruction error. Pseudo multiple replica [11] was used to calculate the g-factor maps.

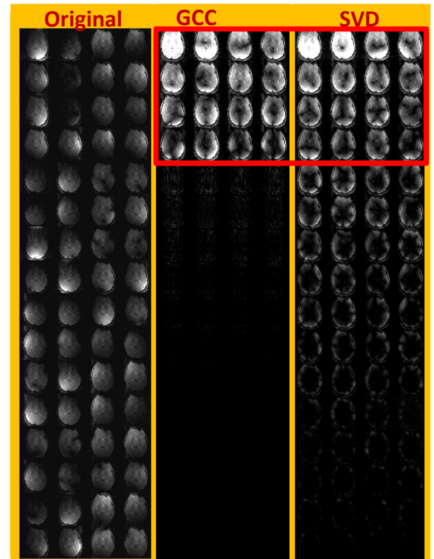

Fig 1. Coil sensitivities for channel compression.

RESULTS: Fig. 1 shows the retained sensitivity observed for the GCC method and the SVD for one of the imaging slices. With the GCC method, the coil compression was performed only along slice and PE directions; capturing most information with 16 channels; significant coil information is lost with 16 SVD channels. Using vendor's CPU hardware, the 64 channel reconstruction time for a 10-minute MB=8 acquisition suitable for a typical resting-state study is ~32 minutes and this time is reduced to 10 minutes and 30 seconds for the 16 channel GCC. Figs. 2 and 3 show differences in the sum-of-square image error and retained SNR (1/g-factor) for the three methods. The reconstruction error is very low with full 64 channels and increases only slightly with GCC; the error for the SVD method is much higher. Note that Fig. 2 only shows the parallel imaging error, i.e. it does not include the loss in sensitivity due to compression, which is significant for the SVD (Fig. 1). The retained SNR for 64-channel and GCC reconstructions are nearly identical with the maximum SNR penalty of 30% occurring in the center region of the brain. With SVD reconstruction, the mean and minimum retained SNR decreased by 15% and 14.3% respectively.

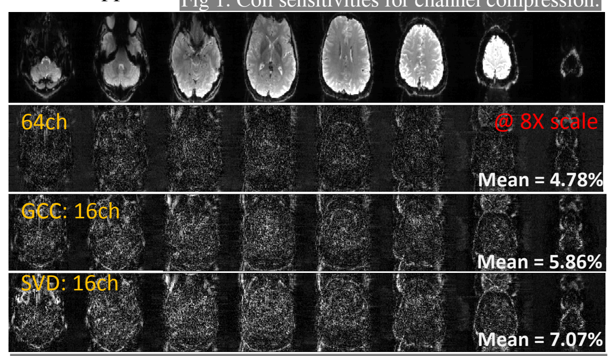

Fig 2. Mean artifact level for MB=8 with channel compression.

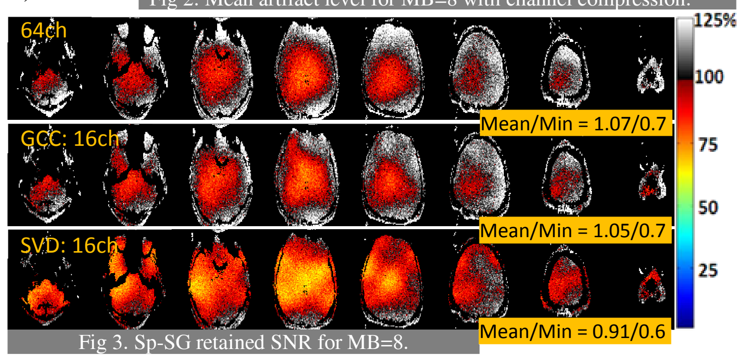

Fig 3. Sp-SG retained SNR for MB=8.

DISCUSSION: GCC compression enables clinically relevant SMS reconstruction of high resolution, MB=8, 64-channel data. The GCC method captures most of the coil sensitivity variations (along the y-z directions) using 16 effective channels and has negligible change in g-factor penalty compared to the full 64 channels. Minor increases in reconstruction error for GCC are likely due to the reduction (kernel size x #ch.) in fitting variables for Sp-SG. Increasing the Sp-SG kernel size should aid in reducing this relatively low error.

CONCLUSION: We use GCC coil compression to ameliorate the computational challenges associated with SMS-EPI acquisitions at high MB factors. This enables real-time reconstruction of large datasets using vendor's provided computational hardware. The reconstruction is shown to provide a high level of retained SNR and low artifacts and should allow for high patient throughput scanning in clinical and research settings.

REFERENCES: [1] Larkman et al, JMRI, 2001; [2] Feinberg et al, MRM 2002; [3] Breuer et al, MRM, 2005; [4] Moeller et al., MRM 2010; [5] Feinberg et al., PLoS One 2011; [6] Setsompop, MRM 2012; [7] Zhang et al, MRM 2013; [8] Cauley et al., MRM 2013; [9] Keil et al., MRM 2012; [10] Huang et al., MRM 2008 [11] Robson et al. , MRM 2008; **SUPPORT:** NIBIB R00EB012107, R01EB006847, NCRR P41RR14075, NIH U01MH093765, Sloan Research Fellowship.