A Method for Reducing the Convolution Kernel Size Used in k-Space Channel Combination for Non-Cartesian Acquisitions

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TARGET AUDIENCE: MR physicists who are interested in faster reconstruction for multi-channel non-Cartesian imaging.

PURPOSE: k-Space channel combination permits multi-channel non-Cartesian data to be deposited onto a single k-space grid per echo/temporal phase. This greatly reduces the computer memory required compared to standard image space channel combination [1], which requires a separate grid for each channel. Depositing the data onto the grid can be performed during data acquisition; using k-space channel combination, only a single transform from k-space to images space needs to be computed per echo/temporal phase. This greatly reduces the reconstruction time compared to image space channel combination methods, which must perform a transform for each channel. k-Space channel combination using the Direct Virtual Coil (DVC) [2] method has been previously proposed for non-Cartesian imaging [3]. The previously proposed method convolved a standard gridding kernel with DVC channel combination kernels, which resulted in large (8x8) combined channel combination/gridding kernels. In this work, we propose a new method of creating combined channel combination/gridding kernels that results in significantly smaller (4x4) kernels --- comparable in size to a standard gridding kernel.

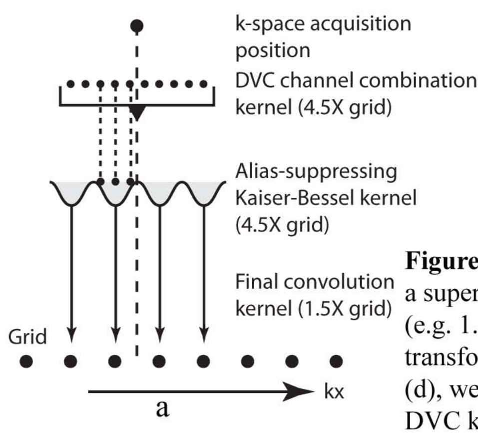
METHODS: The proposed method was implemented using a combination of C++ and Python code. As illustrated in Fig. 1, for the proposed method gridding and DVC channel combination kernels are created using a super-oversampled sample spacing. Moreover, the pass-band of the gridding kernel is designed significantly wider than usual (3X in our experiments). To compensate for this, the DVC channel combination kernels are designed to optimize channel combination SNR as well as suppress aliasing signal at potential aliasing locations within the (now wider) gridding kernel pass-band. When these new kernels are convolved together, the result is a significantly smaller kernel that still has good channel combination and aliasing suppression properties. To demonstrate the method, an 8-channel spiral acquisition of an ACR-NEMA phantom was reconstructed twice. The first reconstruction used channel-by-channel gridding with image space sum-of-squares (SoS) channel combination and the second reconstruction used the proposed k-space channel combination method. A difference image was computed to assess the impact of the proposed method on image quality.

RESULTS: Figure 2 shows the results of our experiment. The proposed method achieved nearly identical image quality to the channel-by-channel with image space channel combination reconstruction.

DISCUSSION: For non-Cartesian imaging, our results indicate that k-space channel combination can be performed with smaller kernels than previously proposed. In fact, kernels of similar size to those used for standard gridding reconstructions can achieve good image quality.

CONCLUSION: With reduced kernel size, k-space channel combination holds great promise for speeding up multi-channel non-Cartesian image reconstruction. This is especially relevant to multi-phase view-sharing imaging, where a high frame rate is desired and multi-phase/echo 3D non-Cartesian imaging, where computer memory becomes an issue with high channel-count arrays. Future work will include demonstrating the method with 3D data sets and evaluating the compute performance.

REFERENCES: [1] Roemer et al., MRM 1990 16:192-225. [2] Beatty et al., MRM doi: 10.1002/mrm.24883 [3] Beatty et al., ISMRM 2011, p2858.



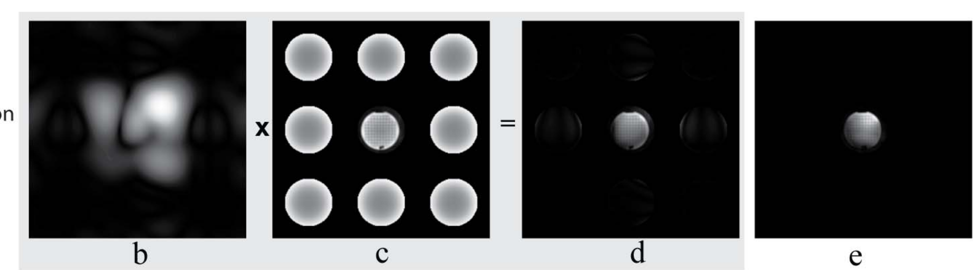


Figure 1 (a) DVC channel combination and Kaiser-Bessel (gridding) kernels are designed with a super-oversampled sample spacing. The resulting kernel is then downsampled onto a standard (e.g. 1.5X) oversampled grid. This super-oversampling enables the gridding kernel (Fourier transform shown in b) to suppress regions of potential aliasing (shown in c). After suppression, (d), we are close to our target effect (e). By sharing the job of aliasing suppression between the DVC kernel and the gridding kernel, it is possible to achieve a smaller combined kernel.

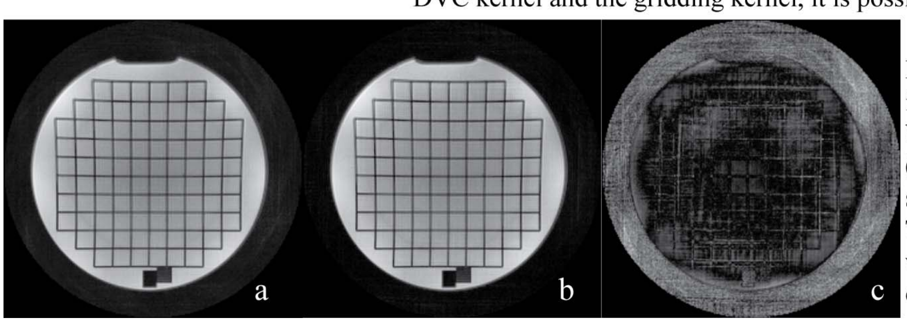


Figure 2 Results for an 8-channel spiral data set imaging the ACR NEMA phantom. (a) Channel-by-channel sum-of-squares (SoS) reconstruction; (b) DVC k-space channel combination reconstruction; (c) difference image (brightened 10X). The largest differences are seen in the regions without signal, where the SoS reconstruction coherently adds the noise across channels.