Achieving Greater SPEED with Iterations between Object and K-space

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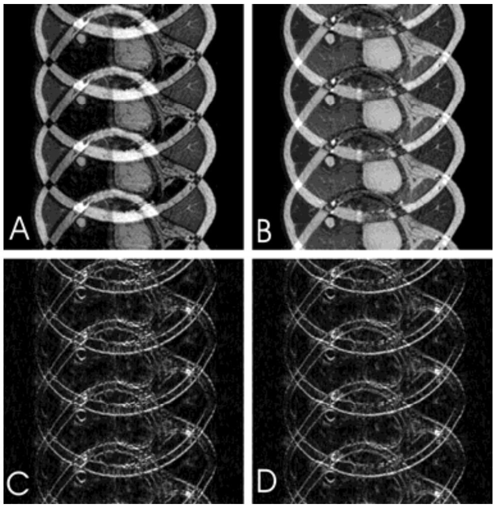
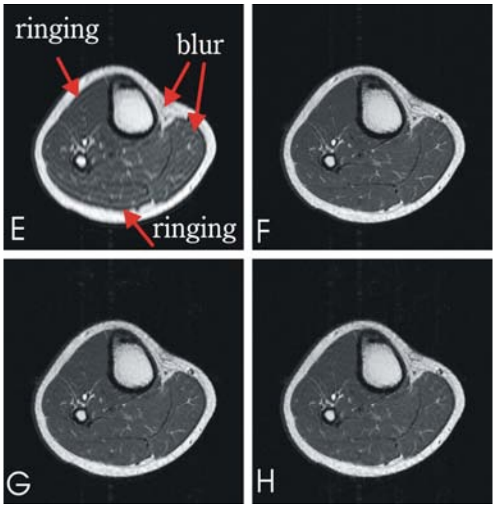


Target audience: Researchers and clinicians interested in fast MRI and its applications, or novel data acquisition and reconstruction strategies.

Purpose: MRI can be accelerated even with a single coil by using signal sparsity. Examples include Compressed Sensing [1] and Skipped Phase Encoding and Edge Deghosting (SPEED) [2]. The original SPEED acquired 3 skipped datasets along PE with interleaved offsets, and resolved aliasing ghosts by solving linear equations for individual pixels [2]. In this study, a significant enhancement of SPEED is achieved, with a greater acceleration power and a more straightforward processing that takes advantage of intrinsic data properties between object and K-space.

Methods: Consider two magnitude images, acquired on a human calf with same PE skip size $N=4$ but different PE offsets, shown as figures A and B. In general, their contrasts are different depending on the particular phase relationships among the overlapping ghosts. However, if these data are high-pass filtered to yield edge maps, they will have remarkable similarity, as shown in figures C and D. This is due to the fact that edges are considerably sparser, with much less chance of signal overlapping. Therefore, for all N possible sparsely sampled datasets with skip size N, their aliased edge maps have approximately equal magnitude. This intrinsic data property can be robustly used as partial knowledge in object domain.

In this work, only one skipped dataset is sampled completely. The rest $N-1$ datasets are incomplete, covering only the central K-space where the lower spatial-frequency data capture most energy. This sampling pattern is actually quite similar to that used in the better known method of GRAPPA [3]. The unsampled data are extrapolated by using iterations between object and K-space (iOK) as described in the following steps.



(1) Apply high-pass filtering along PE as an "edge enhancer" [2].
(2) For each incomplete dataset, do FT to obtain aliased edges in object space.
(3) Without changing phase, update magnitude with the mean value between the current value and that of the complete dataset.
(4) Inverse FT to get back to K-space.
(5) Update with the sampled central data, and known zeroes at skipped locations (only a small K-space portion needs to be found, and thus not updated now).
(6) Repeat (2) to (5) till convergence is reached for all incomplete datasets.
(7) Merge all datasets together, followed by an inverse filtering [2], and FT to reconstruct final output image.

Results: Fig.E is from direct FT of the central K-space, with blur and ringing (arrows). Fig.F is a gold-standard from full data. Fig.G is from SPEED with iOK. Relevant imaging parameters are matrix 256x256, skip size $N=4$, fully sampled central k-space lines $L=64$, corresponding to a fractional scan time of $f = 0.4375$. Another case is shown in Fig.H with $N=8$, $L=64$, leading to an $f = 0.34375$, or a nearly 3 times faster scan. Visually, artifact is hardly noticeable in both cases. Satisfactory results were similarly obtained from other MRI scans covering various anatomical regions.

Discussion: Unlike algorithms that work either in K-space [3] or object domain [4], SPEED with iOK progressively approaches a global solution by imposing partial knowledge in both Fourier domains. The constraints are so tight that iOK converges quickly in just few (~10 or less) iterations with strong noise immunity. The principle behind iOK may also find applications for accelerated MRI using multiple receiver coils.

Conclusion: Using only a single receiver coil, SPEED with iOK is able to accelerate MRI in a manner similar to GRAPPA, namely with K-space center sampled fully but periphery sampled every Nth line sparsely, with satisfactory image quality.

References:

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