More Optimal HYPR Reconstructions Using a Combination of HYPR and Conjugate-Gradient Minimization

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Introduction: Highly constrained projection reconstruction (HYPR) has recently been proposed as a way to dramatically accelerate MR acquisitions [1] while at the same time increasing SNR, especially in MR angiography. By constraining signal to only certain locations, much of the streaking artifact is eliminated. Unlike traditional reconstructions methods, the SNR in HYPR follows the composite image, which is collected over many frames, so that SNR per frame is no longer dependent just on the acquisition time of the individual frame, but also dependent on the total acquisition time. This can result in many orders of magnitude improvement in SNR. However, the temporal information in the original HYPR method is spatially low-resolution and this has been shown to be problematic for artery/vein separation. One solution is to use a sliding composite image [1]. However, user-guided selection of the temporal window for the composite image may still yield temporally inconsistent time courses and suffers from an SNR penalty relative to conventional HYPR.

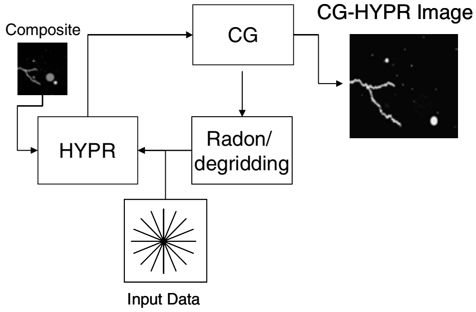

Figure 1; Schematic depiction CG-HYPR

In this abstract, we propose viewing the HYPR reconstruction as a constraint in a conjugate-gradient (CG) image reconstruction. CG processing has been previously proposed for parallel imaging reconstruction of non-Cartesian sampled data [2-3] and for reconstruction of bunched sampling trajectories [4]. The combined CG-HYPR method has been previously shown to result in significantly improved separation of temporal information while retaining much of the SNR advantages of HYPR in simulations [5]. In this abstract we compare normal backprojection, HYPR and CG-HYPR reconstructions for in vivo angiographic exams.

Theory: In the CG-HYPR reconstruction scheme shown in Fig 1, the raw projections are fed first to a HYPR reconstruction, which results in a high quality image, but one which potentially contains artifactual signal for closely spaced pixels with differing signal timecourses. This HYPR image is then fed to a CG processing unit which determines a correction image that optimizes the agreement between the acquired raw data and the reconstructed image. This correction factor is then transformed and fed back through the HYPR reconstruction to generate yet another correction image. This CG process iterates until convergence, at which time the difference between the reconstructed image and the collected data has been minimized. As opposed to the sliding window composite approach, all projections can be used in the composite image, since the CG processing corrects the temporal non-idealities of the composite input to HYPR processing. This scheme eliminates all user interaction and can result in an improved image reconstruction with higher SNR and temporal fidelity.

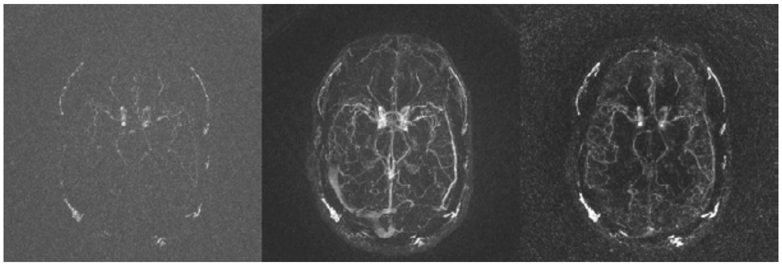

Figure 2: Left: Filtered backprojection image at peak arterial phase. (Middle) HYPR reconstruction of same timepoint. (Right) CG-HYPR Reconstruction. Note the improved artery-vein suppression in the CG-HYPR while still preserving the SNR advantage of HYPR.

Methods: An example angiographic exam is shown from a 1.5T Siemens Espree using a stack of spokes trajectory with 256 readout points, 32 partitions and 23 projections per volume. An asymptomatic human subject was scanned single dose Omniscan™ was injected at 2ml/s using a 250 mm^2 FOV and the standard 12 channel head coil, spatial resolution of 1x1x1.2 mm^3 and TR=7ms, TE=3ms for a temporal resolution of ~5s. Both HYPR and CG-HYPR reconstructions were performed offline. It was found experimentally that more stable results were achieved by slowing the convergence of the CG loop by about a factor of 3 so that each image required approximately 10 iterations to converge.

Results and Discussion: In comparison to backprojection, HYPR images show reduced streak artifact and significantly higher SNR, but significant residual temporal contamination in adjacent arteries and veins. This is especially clear in the large posterior venous structures. The CG-HYPR reconstruction retained the benefits of HYPR in terms of SNR but additionally resulted in more correct timecourses for all vessels. It is also clear that both HYPR and CG-HYPR represent huge gains in SNR compared to conventional backprojection methods.

Conclusion: HYPR is a change in paradigm for dynamic MRI. The simple change in SNR dependence from the time per frame to total imaging time will revolutionize dynamic scanning in MRI. Improved MR angiography will be the first result. We have confirmed that HYPR by itself can have problems distinguishing closely spaced pixels with different timecourses. The CG-HYPR method proposed here is a simple and effective way to achieve optimal temporal and spatial resolution while maintaining most of the SNR advantages seen in HYPR. In order to study the pure effects of HYPR, we have not applied any parallel imaging or echo sharing such as TRICKS or keyhole. Further significant gains in imaging speed should still be easily achievable in combination with these other methods.

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