Prior-regularized GRAPPA Reconstruction

F-H. Lin[1]

[1]Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, MA, United States

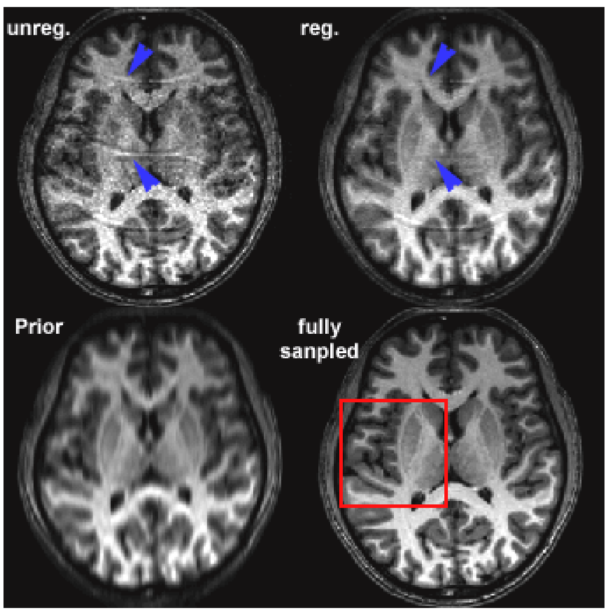
Introduction

An auto-calibration scan (ACS) can help to improve the reconstructions in k-space based parallel MRI, such as GRAPPA [1]. Usually ACS is acquired at the center of k-space for higher SNR, thus constituting of full-FOV low-resolution prior images in the channels of an RF coil array. Previously, we have demonstrated the incorporation of prior information in SENSE imaging reconstruction to reduce noise amplification in both anatomical and functional scans [2, 3]. Based on a similar rationale, the incorporation of credible prior information may also improve GRAPPA reconstruction. Here we derive a robust prior-informed GRAPPA reconstruction based on the prior obtained from ACS. Formulated as Tikhonov regularization, the prior-informed GRAPPA is demonstrated to provide reduced aliasing artifact and noise level in the reconstruction compared with an unregularized one.

Methods

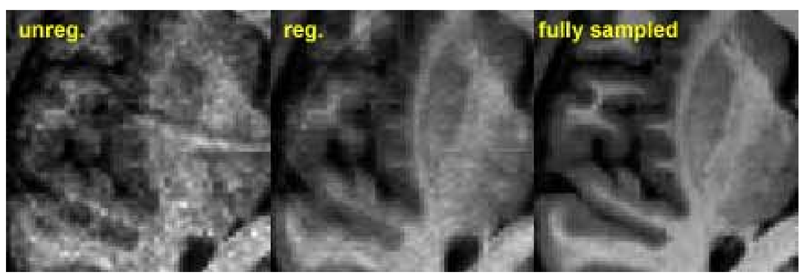
GRAPPA reconstruction can be formulated as a two-step algorithm. First the reconstruction coefficient $\boldsymbol{\beta}$ is solved using auto-calibration scan data ($\mathbf{y}_{acs}$) and actual acceleration data ($\mathbf{Y}_{acc}$), where $\mathbf{y}_{acs}=\mathbf{Y}_{acc}\boldsymbol{\beta}$. Second, based on the least-square fits for $\boldsymbol{\beta}$ and the actual accelerated data, the reconstruction of skipped data ($\mathbf{y}_{GRAPPA}$) is estimated: $\mathbf{y}_{GRAPPA}=\mathbf{Y}_{acc}\boldsymbol{\beta}$. In fact, the GRAPPA reconstruction can be regarded as applying a data-driven "inverse operator" $\mathbf{Y}_{acc}$ on $\boldsymbol{\beta}$. This corresponds to a forward problem of $\mathbf{A}\,\mathbf{y}_{GRAPPA}=\boldsymbol{\beta}$, where $\mathbf{A}=(\mathbf{Y}_{acc})^{+}$. Given this forward problem, we can apply Tikhonov regularization to solve the prior-informed GRAPPA by minimizing the following cost function: $|\mathbf{A}\,\mathbf{y}_{GRAPPA} - \boldsymbol{\beta}|^2+\lambda|\mathbf{y}_{GRAPPA} - \mathbf{y}_{GRAPPA}^0|2$, where $\mathbf{y}_{GRAPPA}^0$ is the prior and λ is the regularization parameter.

In vivo anatomical images were acquired using a 3T scanner (Siemens Medical Solution, Erlangen, Germany) with an 8-channel phased array coil. We used a 3D MPRAGE sequence on a healthy subject after the approval from the Institutional Review Board and informed consent. Parameters of the MPRAGE sequence were TR=500 ms, TE=3.9 ms, flip angle=20 deg, slice thickness=3 mm with 1.5 mm gap, 48 slices, FOV=210 mm x 210 mm, image matrix=256 X 256. The same scan was repeated with the reduced number of phase encoding by 4-fold with 32 ACS lines. We calculated both regularized an unregularized GRAPPA images to compare the quality of the reconstructions.



Results and Discussion

The figure at left shows the fully sampled data and the low-resolution prior image with 32 ACS lines acquired from the center of k-space (effective acceleration: 2.91). It also shows both the unregularized and regularized reconstructions. Note that using regularization, the residual aliasing was reduced compared with the unregularized reconstruction (indicated by the blue arrows). The figure below shows the magnified temporal lobe (area indicated by the red box) for regularized and unregularized reconstruction. We found that the noise level was reduced in the deep brain areas, where coil information is less independent among channels. Quantitatively, the mean sum-of-square error for unregularized and regularized GRAPPA reconstructions with respect to the fully sampled data was 2.4% and 2.2%, respectively.



Here we demonstrated the improved GRAPPA reconstruction using prior information. Even though not shown in this abstract, this approach can be further generalized in *k-t* space and thus to provide priors of identical spatial resolution without compromising temporal acceleration. We will further investigate prior-informed GRAPPA in functional brain imaging with large-*N* coil arrays.

Acknowledgements

This project is supported by NIDA 1 R01 DA14178-0, NIH R01 HD040712, NIH R01 NS037462, NIH P41 RR14075 and the MIND Institute.

References

1. Griswold, M.A., et al., Magn Reson Med, 2002. **47**(6): p. 1202-10.
2. Lin, F.H., et al., Magn Reson Med, 2004. **51**(3): p. 559-67.
3. Lin, F.H., et al., Magn Reson Med, 2005. **54**(2): p. 343-353.