Partial Fourier Partially Parallel Imaging

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Partially parallel imaging (PPI) and partial Fourier (PF) permit decreased acquisition times by reducing the amount of phase encoding needed to image an object. PPI can an provide almost unlimited reduction in acquisition time although suffers from excessive noise at higher speed-up factors. PF does not result in excessive noise amplification however it can lead to artefacts where the assumption of conjugate symmetry does not hold. This abstract investigates the role of PF when combined with PPI as a regularisation parameter.

Theory

The PPI techniques use coil sensitivity information to partially replace phase encoding. SENSE (1) can be written as a linear equation

$$\mathbf{s} = \mathbf{B}\boldsymbol{\rho} \qquad [1]$$

where $\mathbf{s}$ is a vector of acquired k-space samples, $\mathbf{B}$ is a sensitivity matrix and $\boldsymbol{\rho}$ is a vector of pixel values to be reconstructed. In the image domain, the PF requirement for conjugate symmetry translates into the object being pure real, ie. $\mathrm{Im}\{\boldsymbol{\rho}\}=0$ (2). This may be incorporated into Eq 1 by separating into real and imaginary parts and solving the constrained equation

$$\begin{bmatrix} \mathrm{Re}\{\mathbf{s}\} \\ \mathrm{Im}\{\mathbf{s}\} \\ \mathbf{0} \end{bmatrix} = \begin{bmatrix} \mathrm{Re}\{\mathbf{B}\} & \mathrm{Im}\{-\mathbf{B}\} \\ \mathrm{Im}\{\mathbf{B}\} & \mathrm{Re}\{\mathbf{B}\} \\ \mathbf{0} & \lambda\mathbf{I} \end{bmatrix} \begin{bmatrix} \mathrm{Re}\{\boldsymbol{\rho}\} \\ \mathrm{Im}\{\boldsymbol{\rho}\} \end{bmatrix} \qquad [2]$$

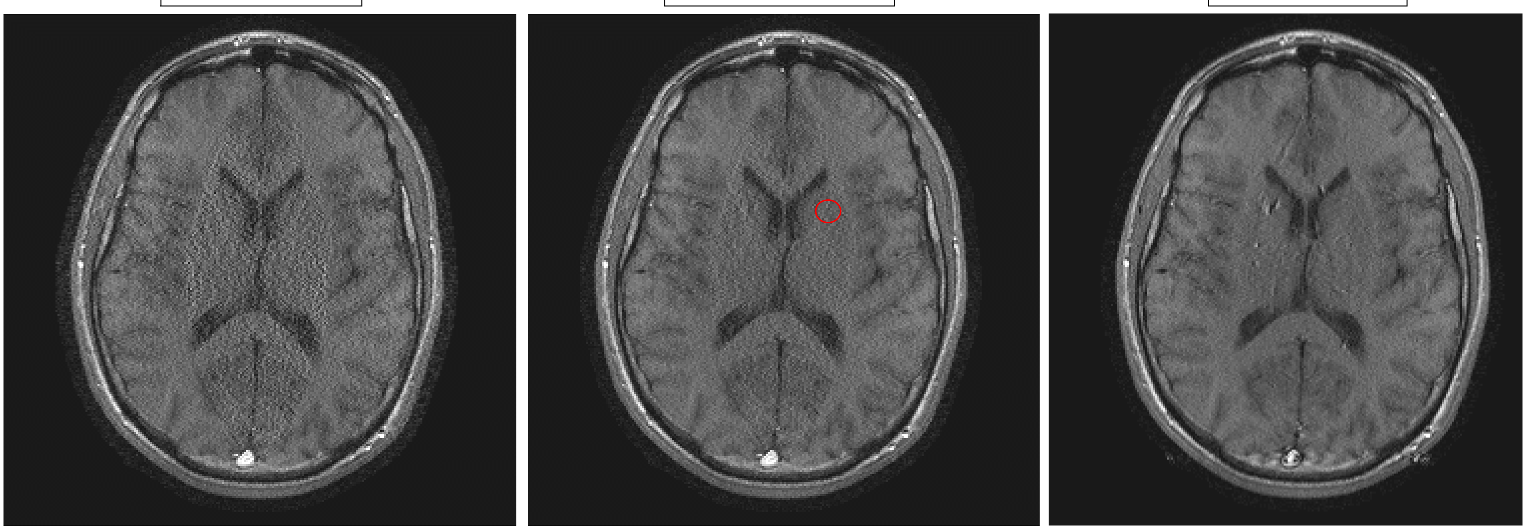
where $\mathbf{I}$ is the identity matrix and $\lambda \geq 0$ is a scalar to strengthen/weaken the constraint. Note that only the imaginary part of $\boldsymbol{\rho}$ is constrained. When λ is zero Eq 2 is identical to SENSE, which is prone to high noise at high speed-up factors. When λ is large the reconstruction can rely on conjugate symmetry as well as the coil sensitivities which gives a result more or less identical to (3) since $\mathrm{Im}\{\boldsymbol{\rho}\}$ becomes zero and may be excluded from the equation. The benefits are reduced noise and higher speed-up factors.

However, there is a price to pay for this gain and that is that conjugate symmetry never strictly holds in MR data so artefacts are introduced where there are fast phase variations in the image. Intermediate values of λ allow a trade-off between the noise of PPI and the phase artefacts of PF so that some of the noise can be reduced for a negligible increase in artefact.

Results

Data were acquired on a Siemens Sonata 1.5 T scanner using an MRI Devices 8-channel head array coil. Spin echo sequences (TR 500 ms, TE 14 ms, 256×256 resolution) were used with an auto-calibrating PPI sampling strategy: 48 central lines and an outer line spacing of 4 (100 lines in total). Images were reconstructed with a sum-of-squares coil modulation for several values of λ .

$\lambda = 0, \mathrm{SNR} = 4.6$ | $\lambda = 0.01, \mathrm{SNR} = 7.1$ | $\lambda = 1, \mathrm{SNR} = 9.9$



Conclusions

PPI and PF can be combined in a number of different ways (eg. 3,4). The present technique incorporates PF by regarding conjugate symmetry as a regularisation term in the PPI equation, which may be varied to alter the properties of the reconstructed image. Intermediate values appear to give the best compromise between noise and artefacts.

References

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