Parallel Magnetic Resonance Imaging: New Methods, New Insights

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Parallel imaging can be formulated as an inverse problem using a signal model which predicts multi-channel k-space from magnetization image and coil sensitivities (SENSE). Extending this approach to autocalibration leads to the nonlinear inverse problem of jointly estimating image and sensitivities,[1] which is similar to blind multi-channel deconvolution. A second approach to parallel imaging uses linear prediction of the missing samples from a local neighbourhood in k-space. Using shift-invariance, the reconstruction weights can be learned from correlations in a fully-sampled calibration area (GRAPPA). This can be formulated using a so-called calibration matrix, a concept which also appears in singular spectrum analysis. It has low-rank, *i.e.* a signal and a noise subspace. This fact can be exploited for calibrationless parallel imaging using structured low-rank matrix completion.[2] Linking the different approaches yields new insights. Starting from the signal model, it is possible to identify the subspace of physical k-space signals as a reproducing kernel Hilbert space and to derive a reconstruction formula and error bounds in k-space using approximation theory.[3] Coming from the other direction, the ESPIRiT method computes the coil sensitivities from the signal subspace of the calibration matrix and uses them in extended SENSE-based reconstructions which are as robust as GRAPPA and as efficient and flexible as SENSE.[4]

References:

1. Uecker *et al.*, Magn Reson Med 2008;60:674-682

2. Shin *et al.*, Magn Reson Med 2013; Epub

3. Athalye *et al.*, arXiv:1310.7489 [physics.med-ph]

4. Uecker *et al.*, Magn Reson Med 2014;71:990-1001