Iterative Reconstruction Concepts for Magnetic Resonance Imaging

Kai Tobias Block [1], Martin Uecker [2], and Jens Frahm [2]

[1] Siemens Healthcare MR, Erlangen, [2] Biomedizinische NMR Forschungs GmbH, Göttingen

Iterative reconstruction is a relatively new concept for the calculation of medical images, which is based on formulating the reconstruction process mathematically as an inverse problem and solving it with a numerical optimization method. Driven by recent success for dose reduction in CT, iterative reconstruction is currently receiving strong interest also in the MRI community. The first part of the talk will give a step-by-step introduction to the iterative reconstruction scheme and demonstrate how the technique can be applied for magnetic resonance imaging.

The second part will present four applications to illustrate that the concept can be exploited either for significantly reducing the scan time or for improving the image quality relative to a conventional reconstruction. These advantages arise from two main components that inherently compensate for incompletely sampled data: First, the incorporation of prior knowledge about the solution and, second, the use of an extended modelling of the MRI signal.

In the first example, it is shown that the higher sampling requirement for radial k-space acquisitions can be ameliorated with a constraint on the solution’s total variation (TV), based on the assumption that most objects are piece-wise constant to some degree. Because radial undersampling creates streaking artifacts that increase the TV value relative to the true object, the artifacts can be suppressed by penalizing the TV in addition to enforcing consistency with the sampled data. Further, by extending the signal model to include the locally varying sensitivity of the receive coil, all receive elements can be processed simultaneously in a parallel imaging manner, which enables reconstructions from very limited data. In example 2, the concept is adapted for radial fast spin-echo imaging. This sequence acquires spokes with increasing T2 weighting along the echo train, which conventionally results in an averaged image contrast. When adding a spatial relaxation component to the signal model, the iterative approach copes with the contrast inconsistencies and renders separated proton-density and relaxivity maps. These maps are estimated directly from k-space and allow for fast T2 quantification from a single dataset. In example 3, the signal model is extended for improved parallel-imaging reconstructions where the coil sensitivities are calculated jointly with the image content. Because in this way all sampled data is used for profile estimation instead of only few reference lines, the method yields artifact-free images even in conditions where conventional parallel-imaging approaches fail, which is particularly relevant for modern high-density coils. The last example combines the idea with a temporal constraint on serially acquired time frames. For measurements with an optimized radial real-time sequence, the technique achieves temporal resolutions of up to 20 ms and reveals a novel cinematic insight into the human body.