Generalized Density Weighted Imaging

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Introduction: Sequences like RARE (FSE, TSE), EPI and single shot inversion and saturation recovery sequences suffer from blurring and an unfavorable spatial response function (SRF) because of the evolving magnetization while image data acquisition. Filtering can be used in the reconstruction to improve the SRF or to enhance the signal to noise ratio (SNR). However, in general, an SNR optimizing filter does not result in a favorable SRF and a filter that improves the SRF worsens the SNR. Non – Cartesian density weighted (DW) imaging [1] has proven to be able to generate desired SRFs during data acquisition for sequences with constant magnetization. Purpose of this work was to generalize the idea of density weighted data acquisition to sequences with non – constant magnetization to optimize simultaneously SNR and SRF.

Material and Methods: The basic idea of generalized density weighted imaging is to choose the sampling density in such a way that an SNR optimized filtering of the data results in a predetermined SRF. As for an optimized SNR every sampled data point has to be weighted (filtered) by its own SNR and the SRF defines the k-space weight function (Fourier transform of the SRF) the sampling density in generalized density weigted imaging is determined. Generalized DW is illustrated in Fig. 1 for the example of a single shot saturation recovery (SR) sequence sampled in reverse centric order. In SR sequences the consecutively acquired echoes are weighted by an exponential function, which can be approximated by a linear function for acquisition times short compare to T1. For a Cartesian sampling (Fig. 1a, left) of the phase encoding steps the k-space shows a triangular shape (Fig. 1b, left) and gets quadratic after application of a SNR optimizing filter (Fig. 1c, left). The resulting SRF is blurred (Fig. 1d, left). In generalized DW imaging the phase-encoding steps (Fig. 1a, right) are positioned in k-space in such a way that for the linear signal increase and application of a linear, SNR optimizing filter the k – space weighting results in the same SRF as for unfiltered Cartesian imaging. The non – Cartesian sampling density was calculated analytically in analogy to the method proposed by Greiser [1]. In a phantom study, using a Cartesian sampling without filtering and the optimized generalized DW scheme the SRF and SNR in the images were determined. Because of the varying sampling density DW imaging suffers from undersamling artifacts in images reconstructed using gridding. Parallel acquisition by effective density weighted imaging (PLANED) [2] combines DW with parallel image reconstruction in order to suppress these undersampling artifacts. Therefore the non – Cartesian sampled data were not only reconstructed using gridding but additionally with a PLANED reconstruction, i.e. a non – Cartesian GRAPPA algorithm. The generalized DW imaging was also applied to an in – vivo first pass myocardial perfusion study.

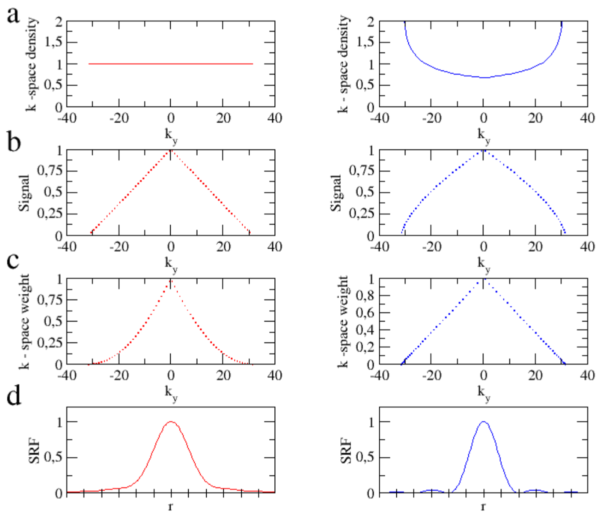

Figure 1: Comparison between the SNR optimized Cartesian sampled (left) and the generalized density weighted (right) SR – sequence.

Results: Fig. 2 shows the images of the phantom studies. The experimentally determined SRFs (not shown here) of the Cartesian and generalized DW images, are, as expected, identical within the experimental errors. The effective FOV is visibly reduced (Fig. 2b) for the DW sampled data reconstructed by gridding. Fig. 2c demonstrates that PLANED imaging is able to eliminate these undersampling artifacts. The experimental SNR comparison between the Cartesian and the generalized DW weighted images (for both reconstruction schemes) showed a SNR gain of 13% for the density weighted images. This is in good agreement with the theoretically predicted value of 15%. The increased SNR and the contamination reduced SRF in the in-vivo images of a myocardial perfusion study result in a high image quality.

Discussion: This work presents a method that simultaneously optimizes the SNR and the SRF for sequences with non – constant magnetization during data acquisition. The concept and application of generalized DW to a SR-sequence has been illustrated. The results indicate that the transfer of generalized density imaging to other sequences like EPI or RARE is promissing.

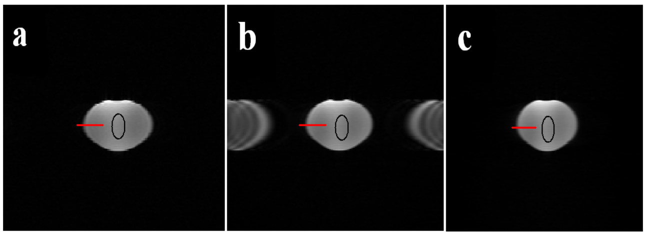

Figure 2: Images of the phantom study

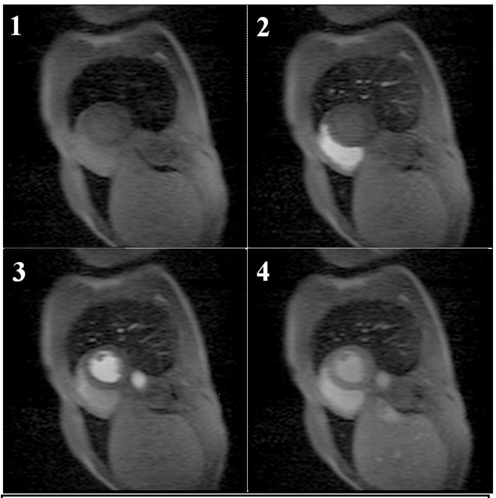

Figure 3: Images of an in-vivo study using generalized DW imaging

References: 1. Greiser et al. MRM 50(6), 1266-1275, 2003
2. Geier et al. MAGMA **20**, 19-25, 2007