Fast Parallel Image Reconstructions for Spiral Trajectories

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INTRODUCTION:

The primary limitation in non-Cartesian spiral imaging is blurring from off-resonance effects. Blurring, however, scales with the readout duration and can be greatly reduced by the use of parallel MRI (pMRI) methods. Unfortunately pMRI reconstructions are non-trivial in the case of spiral trajectories [1-3]. In this study, we have focused on the implementation of a fast reconstruction algorithm for parallel imaging with spiral trajectories, which enables single-shot spiral pMRI. As in other recent approaches [4,5] for parallel imaging of non-Cartesian k-space sampling by means of the GeneRalized Autocalibrating Partially Parallel Acquisitions (GRAPPA) algorithm [6], the proposed algorithm works completely in k-space leading to significantly reduced reconstruction times.

METHOD AND RESULTS:

The pMRI process for spiral data can be greatly simplified by using k-space reconstructions with relative shift operations [4]. In particular, constant-angular-velocity spiral trajectories, which have a similar symmetry to radial trajectories, are suitable for this approach. The pMRI reconstruction in k-space allows one to exploit the high symmetry of these spiral trajectories. Here, the acquisition is performed with a constant-linear-velocity spiral to benefit from the SNR advantage of this trajectory, while the pMRI reconstruction is performed with the data interpolated onto a constant-angular-velocity spiral using a simple 1D interpolation in the time dimension. After interpolation, the data is reordered to exploit the high symmetry in the reconstruction process. As shown in Fig. 1, the data can be reordered into a new hybrid space with new pseudo-Cartesian coordinates windings (w) and projection angle (Φ). After reordering of the data, a segmented GRAPPA [6] reconstruction is applied to reconstruct missing data. All images were obtained on a 3.0 T MR scanner (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany). For signal reception, an eight channel product head coil array (MRI Devices, Waukesha, USA) was used. The following spiral MR imaging protocol was used for the images shown in Fig. 2: TR = 2500 ms, TE = 30 ms, alpha = 75°, slice thickness 4 mm, FOV 240 x 240, matrix = 192 x 192.

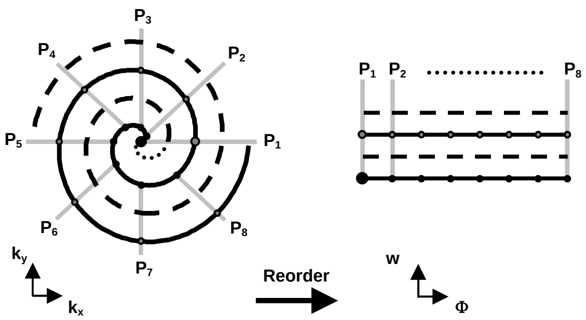

Fig.1: Schematic depiction of the reordering: The data points are collected in pseudo-projections P1 to P8 (left) and reordered in a new hybrid space with coordinates windings and projection angle (right).

DISCUSSION:

Our method enables high resolution single-shot spiral pMRI, which intrinsically minimizes off-resonance effects and blurring, the most important short-comings in spiral imaging. As can be seen in Fig. 2a, the conventional single-shot spiral acquisition suffers from severe off-resonance artifacts. The multi-shot acquisition with 4 interleaves (see Fig. 2b) reduces these effects, but it requires 4 times longer scan time and is more sensitive to flow and motion. The single-shot spiral pMRI acquisition reduces blurring, which is clearly visible by comparing the conventional acquisition (Fig. 1a) and the pMRI acquisition with an acceleration factor of 4 (Fig. 1c). Compared to the multi-shot acquisition artifacts from physiological effects (e.g. respiration) are reduced in the pMRI images. In conclusion, the proposed fast pMRI spiral reconstruction enables good quality high resolution single shot applications even for T2* weighted fMRI images at high fields.

Further gains in image quality in spiral pMRI can be achieved by going to higher acceleration factors, which can be seen in the 8x accelerated image in Fig. 1d. Our results indicate that the artifact behavior in parallel imaging with spiral trajectories is less degrading than respective artifacts in Cartesian parallel imaging methods, which can be used to achieve higher acceleration factors. Notably, the pMRI reconstruction with an acceleration factor of eight (see Fig. 2d) was obtained with an eight element coil array. In general, the reduced off-resonance effects in spiral pMRIs and the related smoother artifact appearance opens new perspectives for spiral imaging and may give new inspiration for further implementations of this promising technique.

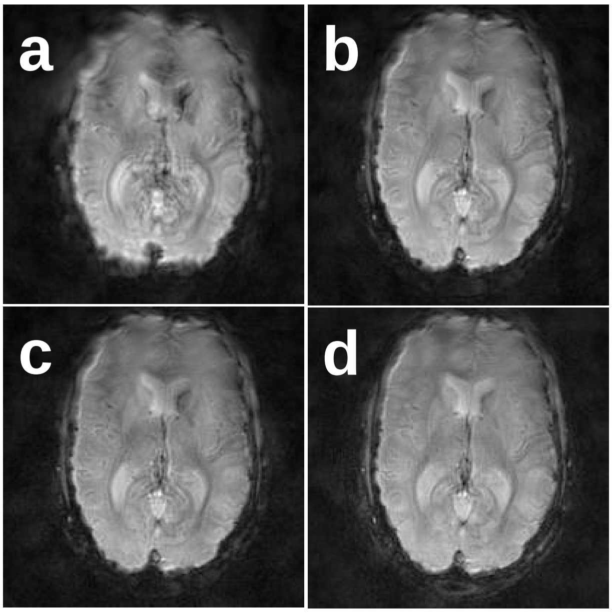

Figure 2: Conventional versus pMRI single-shot spiral imaging: The conventional 192x192 single-shot spiral image (a) suffers from off-resonance artifacts, which can be reduced by 4x multi-shot acquisitions (b). (right) The pMRI single-shot reconstruction with acceleration factor of four (c) and acceleration factor of eight (d) shows significantly improved image quality.

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