Accelerating Acquisition in Spiral Imaging

A. Devaraj[1], and J. Pipe[1]
[1]Keller Center for Imaging Innovation, St. Joseph's Hospital and Medical Center, Phoenix, AZ, United States

INTRODUCTION: Spiral trajectory is a means to achieve rapid k-space coverage. Rapid coverage is particularly desirable in 3D imaging. 3D trajectories based on spirals like Spiral Projection Imaging (SPI) [1] have been developed. Regardless of the rapid k-space coverage achieved with spirals, applications like 3D PC-MRA and true 3D fMRI can still significantly benefit with further shortening of scan time. Reduced acquisition time also increases tolerance to motion (another important concern in 3D imaging). All these factors necessitate non-cartesian parallel imaging.

Computational complexity and obscure aliasing pattern in i-space make non-cartesian parallel imaging demanding. Partially parallel Imaging with Localized Sensitivities (PILS) [2] (scissors [3]) with its trajectory independent and mathematically simple algorithm is a natural first step. Presented here is a modified PILS algorithm for multi-coil reconstruction of spiral data.

METHOD: The crucial factor in a practical implementation of PILS is the localization of the coil sensitivities. Weighting each coil image with the corresponding coil sensitivity is an effective way to enhance the localization. A low resolution coil image is a good estimate of the coil sensitivity. Spiral trajectory can be designed to fully sample a small central region to permit a low-pass filtered version of the coil image to serve as a coil sensitivity estimate. To further suppress aliasing the weighted coil images are thresholded to generate a mask which is applied to both the weighted coil image and the coil sensitivity.

The coil sub-images are now summed together and for an even signal intensity across the final image the result is de-weighted with the sum-of-squares (SOS) result of the coil sensitivities. Mathematically

$$I_f = \sum_i R_i I_i \Big/ \sqrt{\sum_i R_i^2}$$

Here I_f is the final image, I_i is the i[th] coil image and R_i is the low-pass filtered version of I_i. But $I_i = c_i I$, $R_i \approx c_i R$ and $c_1^2 + \cdots + c_n^2 = 1$ (I is the original image, R is the low-pass filtered version of I and c_i is the i[th] coil sensitivity). Thus

$$I_f = \left(c_1^2 + \cdots + c_n^2\right) RI \Big/ \sqrt{\left(c_1^2 + \cdots + c_n^2\right) R^2} = RI/R = I\ .$$

RESULTS: The experiments were carried out on a 3T GE Signa Excite 14x scanner with an 8 channel bird-cage receiver. The spiral trajectory was designed for 24cm FOV, 1mm X 1mm resolution, receiver bandwidth of 250kHz and 16 interleaves. The interleave spacing was increased to achieve a 36% reduction in ADC time. The results are shown below.

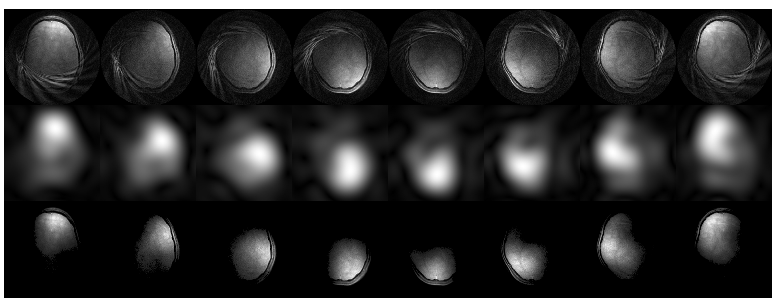

Fig 1. The raw coil images (top row), the low resolution coil sensitivity estimates (middle row) and the weighted coil images with the mask applied (bottom row). The images are arranged from left to right according to their coil numbers.

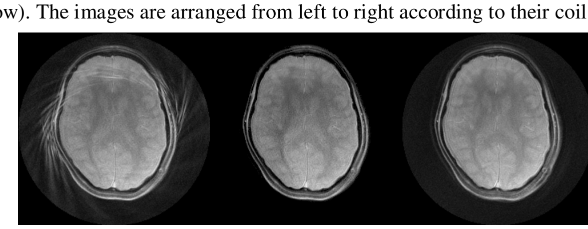

Fig 2. The final image (middle) in comparison to the SOS image (left) and a fully sampled image (right).

DISCUSSION: While a separate low resolution scan is a straight forward coil sensitivity estimate [4] the increased scan time is not practical. Under-sampling along the spiral read-out direction [5] can also accelerate the acquisition. While this has the added advantage of controlling blurring it requires modification to the present day scanner hardware. The coil sensitivity information can also be estimated applying an appropriate window to each coil image [6]. All of these implementations [4, 5, 6] are for cardiac imaging and use surface coils. As PILS is trajectory independent the presented algorithm can also be used for other arbitrary trajectories.

The experimental results demonstrate the efficacy of the proposed algorithm to reconstruct multi-coil SPI data with acceleration factors less than 2. Work is progress to develop algorithms to generalize the choice of the threshold limit (presently it is chosen in an ad hoc manner). Extension of this approach to 3D parallel imaging is also being investigated.

REFERENCES: **[1]** Pipe *et. al.*, ISMRM 13 (2005), 2402 **[2]** Griswold *et. al.*, MRM 44 (2000), 602-609 **[3]** Madore *et. al.*, MRM 45 (2001), 1103-1111 **[4]** Eggers *et. al.*, ISMRM 9 (2001), 1772 **[5]** Lee *et. al.*, MRM 54 (2005), 669-676 **[6]** Hu *et. al.*, ISMRM 14 (2006), 371