Auto-Calibrated Parallel Imaging using Dual-Density Spirals

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INTRODUCTION: Interleaved spiral MR imaging is an effective and robust tool for ultra-fast high-resolution imaging. Advantages of segmentation include reduced image distortion, reduced hardware requirements and reduced physiological requirements, i.e. peripheral nerve stimulation limits (PNS). Essentially a multi-shot technique, segmentation limits the temporal resolution of applications such as functional BOLD imaging and cardiac imaging. Previously, spiral parallel imaging using SENSE has been demonstrated [1]. Also recently, the use of a "SMASH-like" reconstruction has been shown for spiral [2]. Advantages of the later technique include a non-iterative reconstruction process and lack of need for accurate sensitivity mapping. A limitation of the latter technique was a loss of sampling density in the low k-space at high reduction factors due to irregular sampling at the early stage of the spiral gradient. This work demonstrates an improved reconstruction by slightly increasing the sampling density in the low k-space using a dual-density spiral trajectory design [3]. Furthermore, this central over-sampling is used for calibrating the coil-weighting factors. This approach requires no pre-scan of missing segments. Single shot, high-resolution spiral imaging is presented in a phantom. *In vivo* human experiments using an fMRI paradigm will be presented at the meeting.

METHODS: All experiments are performed on a Siemens 3T Trio equipped with Sonata gradients capable of 40mT/m in 200us. Spiral gradients are generated numerically using an algorithm that implements variations in sampling density [3]. Gradient design parameters are for a 128 matrix, FOV 256mm, 4 segments, and a max risetime of 400us to avoid PNS limits. The readout duration is 20ms, is sampled at 200kHz and contains a 24x24 oversampled region in low k-space using dual-density spiral, as shown in Fig. 1. An 8 channel head array is used with a gradient echo sequence for single-shot acquisition in a simple phantom.

Only the first spiral segment is acquired while missing segments are considered virtual, as they are not acquired on the scanner and are used only in the reconstruction. Coil-weighting factors are calculated along radial lines as shown in Fig. 2 using the densely sampled region in central k-space. It is assumed that the coil-weighting factors are identical within a pie-shaped band of k-space, and that the coil-weighting factors calculated in the low k-space are consistent in the high k-space. Final reconstruction is by standard gridding and coil combination by sum of squares.

RESULTS AND DISCUSSION: Preliminary image results in a phantom are shown in Fig. 3. The leftmost panel contains the aliased phantom image obtained from the under-sampled data. The dual-density spiral compensates the reduced FOV for the coarse details, but the fine detail and edge information is lost as seen by the blurred edges of the phantom and an alias pattern in the center of the image. The parallel reconstruction image is shown in the center of Fig. 3. This image shows much finer detail in the edge information revealing that the high k-space, or high spatial frequency information has been restored. A difference image on the right of Fig. 3 shows the restoration more concretely. This scheme is highly relevant for pushing the spatial-temporal limits of event-related fMRI and cardiac imaging.
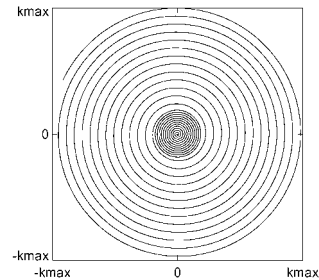

Figure 1: The dual density trajectory used in this work is generated using a 128x128 matrix with a 24x24 fully sampled navigator region and a segmentation factor of 4.
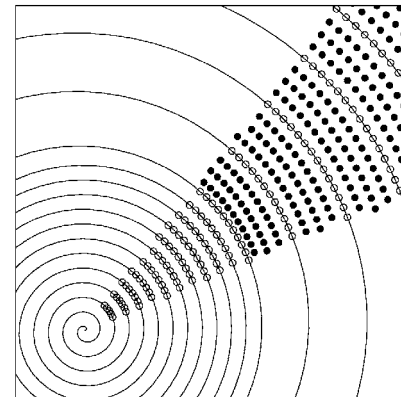
Figure 2: Coil-weighting factors are calibrated in the low k-space navigator area along radial lines using a two-point nearest neighbor approach. Fitted weights are assumed to be uniform within a pie-slice band of k-space. Open circles in the figure show the acquired data, whereas the closed circles show virtual spiral segments reconstructed with three sets of coil-weighting factors.
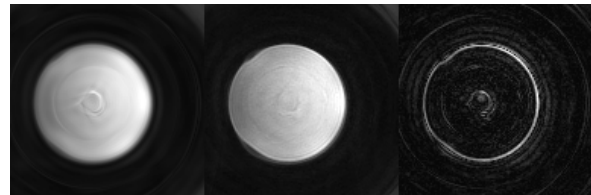
Figure 3: Phantom results showing reconstructions from under-sampled k-space trajectory (left), incorporation of virtual samples (center), and a difference image showing the alias removal and edge restoration (right).

REFERENCES:
[1] K. Pruessmann, et al, MRM 46(4):638-51, 2001. [2] K. Heberlein, et al, ISMRM 2004. [3] S. Sarkar, et al., MRI 20(10):743-57, 2002.