Functional MRI using Spiral GRAPPA Parallel Imaging

Y. Kim[1], D. C. Noll[1]
[1]Biomedical Engineering, University of Michigan, Ann Arbor, MI, United States

Introduction

Parallel imaging has the potential to improve image quality in function MRI by reducing the length of readout gradients to reduce susceptibility induced image distortions. Multishot MRI acquisition can also accomplish this, but this reduces the temporal resolution and makes the acquisition more sensitive to physiological noise and motion artifact. In this work, we investigate the use of the GRAPPA method [1] for spiral functional MRI acquisition. Recently, Heidmann [2] described the interpolation of data from the experimental actual spiral trajectory to a constant-angular-velocity spiral trajectory. This transformation allows GRAPPA to be applied in the radial direction to reconstruct unsampled spiral data. In our approach, an initial time point is acquired using a two-shot acquisition from which GRAPPA coefficients are calculated and then these are used for the remainder of the fMRI time course using only one of two shots. This method results in the efficient computation of images with reduced susceptibility artifacts while still using a single-shot acquisition.

Method

To implement the GRAPPA in spiral trajectory, we interpolate the original constant-linear-velocity spiral trajectory to get constant-angular-velocity spiral trajectory [2]. Then we divide the new trajectory into some number of groups in angular direction. In each group, the method of Cartesian GRAPPA is applied, but due to the acquisition of a fully sampled data set, we are able to estimate the GRAPPA coefficients over a broader range of radial positions. The number of groups and the number of neighbors in radial direction to estimate GRAPPA coefficient were determined as the ones that produce the estimated k-space with the smallest least squares errors. Once determined, the GRAPPA coefficients are then used to reconstruct the images for the entire functional MRI time series. Here, there is an implicit assumption that the sensitivity maps do not change much over time, which is likely valid unless there is substantial head motion.

In order to evaluate the proposed method, a functional MRI experiment was performed on a 3T GE scanner using a 4-channel array coil with 2-shot spiral trajectory (TR = 2s, FOV = 20cm , TE = 20 ms, 64×64 matrix). The task was a finger tapping task of 20 s tapping/20 s rest, repeated 4 times for a task period of 10 time points with 40 total time points. GRAPPA coefficients were calculated using both shots of the first time point, and for all subsequent time points, images were reconstructed for only one of the shots using the described GRAPPA method above. The second shot was used to determine error measures by comparing the GRAPPA generated data for the second shot to acquired data. Activation maps were determined by calculated the correlation coefficient with a sinusoidal reference waveform, lagged from the task by 8 seconds.

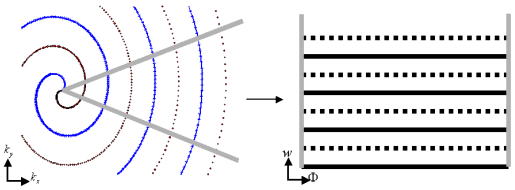

Fig 1. Description of transforming the interpolated spiral trajectory into Cartesian trajectory for each group of spiral trajectory .

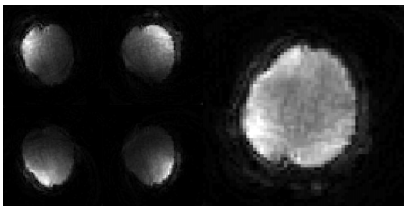

Fig 2. Reconstructed images using proposed method(R=2). (left) reconstructed images from each coil. (right) combined image

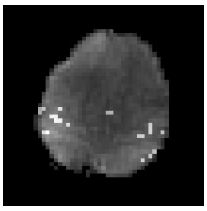

Fig 3. Activation map

Results and Discussion

For these particular acquisition parameters, our investigation of GRAPPA coefficients showed that a neighborhood of 2 samples in the radial direction and groups of 6 angular directions (≈11.25 degrees) provided the reconstruction error (normalized RMS error) of 6.29% over the entire time series. A representative image reconstructed using the GRAPPA method is shown for a slice through motor cortex in Figure 2 and the thresholded ($\rho > 0.56$) activation map for this slice is shown in Figure 3.

Several modifications of this method can also be considered. These activation maps were calculated using only the first of the two interleaves in the multishot acquisition. In practice, either the first shot could be acquired repeatedly or the shots can be alternated. The former case should have reduced variability over the time series, but the latter case would allow the GRAPPA coefficients to be periodically updated and improved, which might be particularly useful for long time series in where there is substantial head movement. In this case, variability introduced by changing shots might be reduced through the use of methods similar to TSENSE[3].

References

[1]Griswold et al. MRM 2002; 47:1202-1210
[2]Heidemann et al. In Proc. 2nd Parallel, MRI, 2004, p27
[3]Kellman et al. MRM 2001; 45:846-952
Acknowledgement: This work is supported by NIH Grants R01 DA15410 and R01 EB002683.