

Field Strength and B_1 Influence on Kernel Support Selection for Highly Accelerated GRAPPA Reconstruction

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INTRODUCTION Parallel imaging (PI) in high magnetic field (~ 7 Tesla) is steadily growing. High magnetic field can provide an improvement of signal-to-noise ratio (SNR) in the MR images but creates more serious B_1 inhomogeneity [1], which on the other hand further improves the PI performance. Although the field strength (3T and 7T) influence on PI g-factor measures [2] has been recently studied for GRAPPA reconstruction [3], its influence on k-space signals structure that affects kernel support selection remains unclear. Very commonly, an isotropic shape kernel is used in diffuse applications and field strengths. In this paper, we study k-space signals anisotropy in 3T and 7T MR phantom data sets, and compared our proposed anisotropic kernel to isotropic kernel for highly accelerated GRAPPA reconstruction. Experimental results showed that k-space signals anisotropy is correlated to B_1 inhomogeneity, and anisotropic kernel is preferred over isotropic kernel for highly accelerated GRAPPA reconstruction, particularly in 7T MR data set.

THEORY AND METHODS In theory, k-space data is the convolution product of imaged object and coil sensitivity. Coil sensitivity oftentimes is inhomogeneous and the imaged object usually has prominent oriented structures. Hence, the k-space is always anisotropic. And coil sensitivity inhomogeneity is directly correlated to B_1 inhomogeneity. This anisotropic pattern is recognized by high power signals in the low frequency region of k-space. The high signal bands are often not identical in all directions at the DC component. Although complex pattern may be observable, we characterize k-space anisotropy with a bivariate Gaussian function. Experiences with MR data suggest that this simplified modeling is sufficient to demonstrate k-space anisotropy. The bivariate function is capable of modeling the spread of high power signals along the PE and FE directions. Its correlation parameter, ρ , provides us quantitation of isotropy; the absolute value of ρ ranges from 0 to 1 having 0 denotes isotropy. Any value deviates from 0 suggests anisotropy. From the spatial analysis theory [4], an anisotropic shape kernel should be used to describe anisotropic spatial pattern. Thus a kernel with a specific anisotropic shape should be considered. We derive such kernel from the fitted Gaussian function. This kernel is constructed by thresholding the bivariate function. Pixels having values higher than the threshold that cover the every other AF lines are the kernel elements. In order to investigate k-space signals anisotropy and the performance of corresponding anisotropic kernels, three MR phantom data sets acquired at different field strengths were tested. They are Dataset 1 acquired by a 3T Siemens scanner (Erlanger, Germany) using a 4-channel head coil, Dataset 2 acquired by a 3T Philips scanner (Best, the Netherlands) using an 8-channel head coil, and Dataset 3 acquired by a 7T Philips scanner (Best, the Netherlands) using an 11-channel head coil. Dataset 1 has close-to-homogeneous B_1 field and Datasets 2-3 have inhomogeneous B_1 field.

RESULTS All MR images were reconstructed without ACS integration into the final reconstructions. A fixed kernel size of 30 elements, an acceleration factor (AF) of 8, and ACS size of 20% full data were used in the study. Experimental results showed that GRAPPA with anisotropic kernel gave reconstruction with significantly better image quality than the one with rectangular kernel (6×5 elements), as demonstrated in Figure. This is because at high AF the rectangular kernel covers a larger scope making the anisotropy more prominent. The absolute rhos of the 3 data sets are 0.08 ± 0.05 , 0.42 ± 0.07 , and 0.12 ± 0.07 , respectively. These absolute correlation parameters to a certain extent are deviated from 0 in the later two data sets. This suggests k-space signal anisotropy is indeed correlated to B_1 inhomogeneity, and the anisotropy is in the direct proportion to the field strength.

CONCLUSION K-space signals anisotropy indeed exists and it is correlated to B_1 inhomogeneity. As a rule of thumb for highly accelerated GRAPPA imaging, anisotropic kernel should be used when B_1 field is inhomogeneous, particularly in high magnetic field.

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REFERENCES [1] Adriani et al., MRM 2005 [2] Banerjee et al., MRM 2008 [3] Griswold et al., MRM 2002 [4] Fortin et al., Cambridge University Press

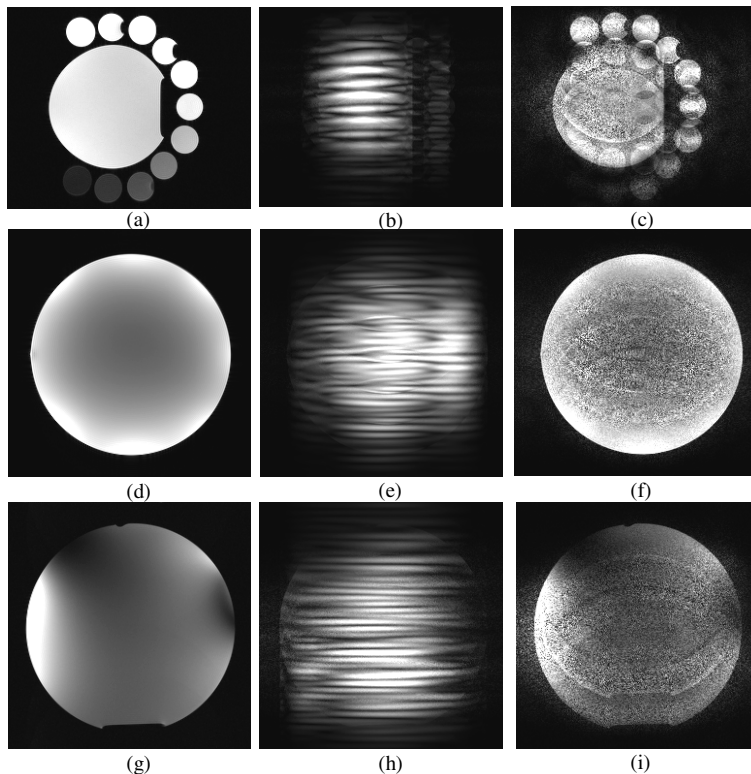


Figure (a), (d) and (g) are reference images for Datasets 1-3, respectively. (b), (e) and (f) are the corresponding images reconstructed by GRAPPA with rectangular kernel at AF = 8 and ACS of 20% full data. (c), (f) and (i) are the corresponding images reconstructed by GRAPPA with anisotropic kernel at the same under-sampling conditions. There are significant image quality improvements in images reconstructed by GRAPPA with anisotropic kernel.