

Linear Interpolation in K-space

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Introduction

Due to both high speed and accuracy, GRAPPA [1] has become a leading reconstruction algorithm among techniques not utilizing sensitivity maps. In GRAPPA, additional lines in the center are used as ACS lines, which according to reference [2] may contain less detail information than outer lines. Hence much acquired data at high frequency makes no contribution to the calculation of the interpolation weights. This leads to the main idea of LIKE: application of all acquired data to the calculation of the weights.

GRAPPA uses information from neighbors of missing points corresponding to each coil but in the same column (as the particular missing point) to interpolate the value of the missing point. It is thus natural to consider that the interpolation might be improved by also utilizing neighbors in other columns. This leads to the second idea of LIKE: interpolate the missing data also utilizing neighbors in other columns.

Methods

There are two steps in LIKE. The first step is to obtain an initial guess of the weights and missing lines by using the additional (ACS) lines, the second step is to use all the acquired data to calibrate the initial guess. The basic idea of the **first step** is to apply GRAPPA to fit weighted linear combinations of neighbors to the ACS line. This fit gives the weights, which then are used to generate the missing lines from a given coil. The definitions of Column neighbors and Row neighbors are shown in Fig 1. Column neighbors and Row neighbors are used separately to interpolate the missing data, resulting in two reconstructions for each line. These lines are then averaged to form the final reconstructed line. Unlike GRAPPA however, this step uses information not only from acquired data in the same column but also from data in other columns. The **second step** is based on the idea that if we use the same weights that interpolate the non-acquired lines to interpolate the acquired lines, then the interpolated results should be same as the acquired data. Since an initial guess for all the missing lines is now available, any line can be used as ACS line. In this step, all acquired lines are used as ACS lines, the previous step is then re-applied in order to recalculate the weights. This process is repeated until convergence. This approach has the advantage that it utilizes high frequency K-space data without sacrificing SNR. In most of our experiments, convergence was achieved in 2 to 5 iterations during the calibration step. So the reconstruction time necessary for LIKE is 5-10 times longer than that of GRAPPA.

Results

Figure 2 shows the result for a Coronal Phantom collected by a 1.5 T GE system (FOV 480 mm, matrix 256x256, TR 500 ms, TE 13.64 ms, flip angle 90°, Slice thickness 3 mm) with the 8-channel Neurovascular Array coil (MRI Devices Corporation, Waukesha, WI, USA). The reduce factor of K-space is 2 in the experiment. Reference image was reconstructed with full K-space.

Discussion

A reconstruction algorithm, LIKE, for the partially parallel acquisition (PPA) method is presented. This algorithm can be viewed as an improved version of GRAPPA. LIKE has all the advantages of GRAPPA, such as easy implementation and no need for the use of sensitivity maps. And in our experiments with same number of extra lines, the results of LIKE have much smaller ghost ratios than those of GRAPPA. With a single extra line, the ghost ratio for images generated with LIKE are 26% to 50% that of GRAPPA. To reconstruct an image with a ghost ratio less than 8%, 1 to 5 extra lines are sufficient using LIKE. Even though the time consumed for reconstruction by LIKE is 5-10 times that of GRAPPA, the speed of image reconstruction is still quite reasonable.

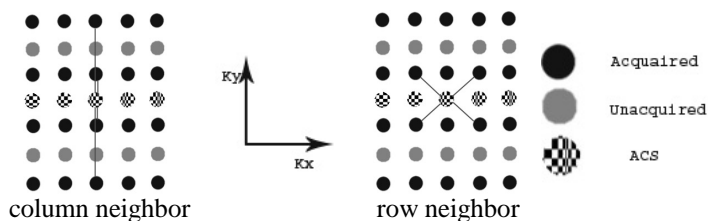


Fig. 1 Neighbors in the K-space of one coil. This figure shows the definition of neighbors in one coil for LIKE. This is the K-space of one coil. The black lines are the acquired lines. The gray lines are the un-acquired lines. The patterned lines are the ACS lines. Those black points, which are connected with the middle patterned point, are neighbors of that patterned point in the K-space of one coil. The left neighbor image is called the column neighbor. The right neighbor image is called the row neighbor.

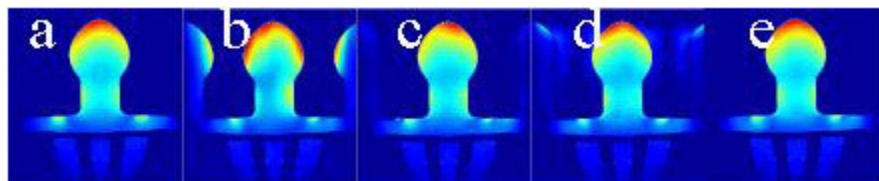


Fig 2. Results for Coronal Phantom a) Reference Image b) Reconstructed image by GRAPPA with 1 extra line c) Reconstructed image by LIKE with 1 extra line e) Reconstructed image by GRAPPA with 2 extra lines f) Reconstructed image by LIKE with 2 extra lines.

References

[1] Griswold, M.A., et al., Magn Reson Med 47:1202-1210, 2002.

[2] You Z., et al., 11th ISMRM Proceedings, p. 2332, 2003