Is parallel MRI without a priori information possible?

M. Blaimer[1], F. Breuer[1], R. M. Heidemann[1], M. Müller[1], M. A. Griswold[1], P. M. Jakob[1]
[1]Physikalisches Institut, Universität Würzburg, Würzburg, Germany

Introduction:

Parallel MRI methods allow one to significantly reduce scan time in an elegant way by using the spatial information inherent in a multiple receiver coil array with dedicated reconstruction algorithms. In general, all these reconstruction algorithms are based on *a priori* information for coil sensitivity calibration. This information can be obtained before or after the accelerated scan by an additional experiment or during the accelerated scan if a variable density (VD) acquisition scheme is used. Therefore additional scan time is necessary to obtain this *a priori* information. In this abstract it is shown that it is feasible to extract the information for coil sensitivity calibration directly from the undersampled data set, using the GRAPPA-Operator formalism [1] essentially without any *a priori* information.

Theory:

In the GRAPPA-Operator formalism, the collected signal $S_j(k)$ in each coil $j=1\ldots N$ at position k in k-space can be shifted to position $k+1$ using an appropriate set of coil weights G^1:

$$S_j(k+1) = G^1 S_j(k).$$

For a shift to position $k+2$, another set of weights G^2 is used, which can be expressed by the weights G^1:

$$S_j(k+2) = G^2 S_j(k) = G^1 S_j(k+1) = G^1 G^1 S_j(k).$$

This implies the following conditions:

$$G^2 = G^1 G^1 = (G^1)^2 \qquad \text{and also} \qquad G^1 = (G^2)^{1/2}.$$

Therefore, once G^1 is known, G^2 can be calculated by the square of G^1. Furthermore, once G^2 is known, the set of weights G^1 for a shift to position $k+1$ can be determined by calculating the square root of G^2.

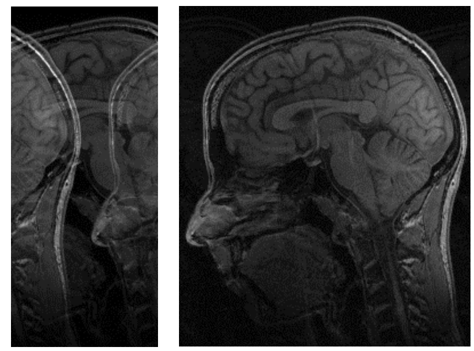

Figure. (Left) Folded image (reduction factor of 2). (Right) Image reconstructed with a set of coil weights derived directly from the undersampled data set.

For an undersampled data set reduced by a factor of $R = 2$ in phase encoding direction, G^2 can be calculated by fitting one k-space line $S(k)$ at position k to its adjacent normally acquired line $S(k+2)$ at position $k+2$. The weights set G^1 for the $k+1$ shift, which is necessary for the reconstruction of the missing k-space lines, can directly be determined by calculating the square root of G^2 and therefore no *a priori* information would be necessary for image reconstruction.
This calculation is not trivial, due to the fact that the (N x N) matrix G^2 provides 2^N possible non-unique square roots [2]. In other words, the square root of G^2 provides 2^N solutions, but only one solution for each coil contains the appropriate set of coil weights for an artifact-free reconstruction. At the moment this solution has to be found empirically by searching through all solutions for the best result.

Results:

Evaluation of this concept was performed using a data set acquired with a head coil array with $N = 8$ elements (MRI Devices, Waukesha, WI). Every second phase encoding line was removed, resulting in a reduction factor of $R = 2$. G^2 was extracted from the undersampled data by fitting the line $S_j(k)$ of a single coil to its adjacent line $S_i(k+2)$ of all coils in the array. In total, $2^N = 256$ solutions G^1 of the square root of G^2 were calculated. For every single coil, the best reconstruction was used for the final image, which is the sum-of-squares image of the single coil reconstructions (see Figure).

Discussion:

Small residual artifacts can be seen in the reconstructed image, resulting from a poor fit. However, in general the reconstruction is quite reasonable considering that no *a priori* information was used. For the future, the calculation of G^2 has to be improved, for example by using a sliding block reconstruction as in normal GRAPPA [3]. Furthermore a reliable method has to be found to extract the appropriate coil weights G^1 out of the multiple solutions. One possibility could be the acquisition of one additional k-space line $S(k+1)$ to compare this line with the reconstructed line $G^1 S(k)$. On the other hand, this would again incorporate *a priori* information. However, a single extra line would result in only a small time penalty compared to normal GRAPPA acquisitions.

Conclusions:

In this work it was shown, that in principle it is feasible to use the GRAPPA-Operator formalism, to derive the reconstruction parameters directly from the undersampled data set. Compared to other parallel MRI implementations no *a priori* information is necessary, resulting in more relaxed requirements.

Acknowledgements: This work was funded by the DFG JA 827/4-1.

References:
[1] Griswold MA, et al. Proc ISMRM 2003 (Toronto), p 2348.
[2] Kim HM. Thesis, University of Manchester, Manchester, p 17 (1997).
[3] Griswold MA, et al. MRM 47:1202-1210 (2002).