Increasing Efficiency of Parallel Imaging by Using Information from Spatially Adjacent Slices

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Introduction

Autocalibrating parallel imaging methods such as GRAPPA [1] estimate coil sensitivity information using additionally acquired reference lines together with the under-sampled k-space data for each slice. While autocalibration makes parallel imaging robust against motion [2], it has the drawback of reduced acquisition efficiency due to the need for additional reference data. Here, two methods are presented which increase the efficiency of GRAPPA for 2D multi-slice acquisitions by including information from adjacent slices. Thus, extra acquisition of reference data is avoided or their amount is reduced significantly.

Methods

The TGRAPPA method [3] which is used in dynamic imaging, avoids the acquisition of additional reference lines. Instead k-spaces for adjacent time frames are acquired in an interleaved fashion and combined to form reference data for coil weight estimation for each time frame. This concept is transferred here to the spatial domain: k-spaces for each slice position are undersampled with a factor *R* and acquired such that k-space lines are shifted by one line for adjacent slice positions (Fig. 1, Step 1). Reference data are extracted for each slice by combining k-space lines from the current slice position and its R-1 left and right neighbors (Fig. 1, Step 2). Finally, coil weights computed from that data are applied at the current slice position (Fig. 1, Step 3). If multiple lines are available for one k-space position, they are averaged. At the edges of the acquired volume weights estimated for neighboring slice positions are used. No additional reference data are acquired for the proposed method, which is henceforth denoted as z-GRAPPA. The other presented approach to increase the efficiency of GRAPPA, denoted as i-GRAPPA here, samples additional reference lines only for every kth slice position. Coil weights for other slice positions are linearly interpolated between the weights estimated for the two closest slice positions where reference data is available.

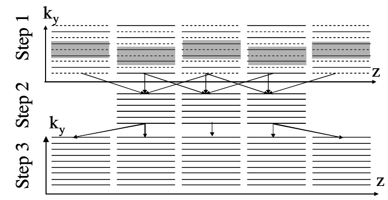

Fig. 1: Principle of z-GRAPPA for *R*=2.

Both methods were compared to conventional GRAPPA for a volume of 98 slices of a volunteer's head with 2.5mm slice distance and 4mm thickness acquired with a spin-echo sequence on a 1.5T scanner (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany). The volunteer's informed consent was obtained prior to the experiment. Standard head and neck coil arrays were used providing data from 16 channels. K-spaces were fully sampled for each slice and k-space lines were retrospectively removed for the application of conventional GRAPPA, z-GRAPPA and i-GRAPPA with *R*=2. Coil weights were estimated from 32 lines around the k-space center. For conventional GRAPPA these lines were used as well for actual image reconstruction. Experiments with z-GRAPPA were conducted for slice distances of 2.5mm, 5mm and 7.5mm. The latter two distances were simulated by removing slices from the complete volume appropriately. The slice positions of the images reconstructed with i-GRAPPA were located exactly in the middle between two slices for which reference data was available.

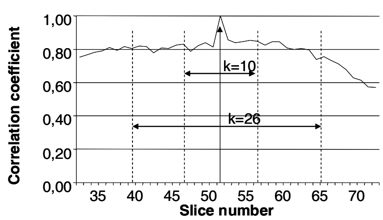

Fig. 3: Correlation coefficient between weights for slice 52 and neighboring slices for one coil. Dashed lines indicate slices which contribute weights for i-GRAPPA with k=10 and k=26.

Results

Fig. 2 shows images reconstructed with GRAPPA, z-GRAPPA and i-GRAPPA for one slice position. No difference in image quality can be seen between the z-GRAPPA reconstruction for a slice distance of 2.5mm (Fig. 2a) and the conventional GRAPPA reconstruction (Fig. 2d). For slice distances of 5mm (Fig. 2b) and 7.5mm (Fig. 2c) image quality of the z-GRAPPA reconstructions decreases, and for a slice distance of 7.5mm artifacts become visible in the image background. If i-GRAPPA is applied with a value of *k*=10, i.e. weights are estimated at positions 12.5mm left and right of the current slice, there is no visible degradation in the image quality (Fig. 2e) compared to the conventional GRAPPA reconstruction. A further increase of *k* leads to artifacts with increased intensity. For *k* = 26 they can clearly be seen in the image (Fig. 2f). For a coil which substantially contributes signal to the slice shown in Fig. 2 (slice number 52), correlation coefficients between the weights estimated for that slice position and neighboring slices are plotted in Fig. 3. Weights which are combined for i-GRAPPA with *k*=10 for application at slice 52 are well correlated with the weights estimated on reference data from that slice. Correlations drop (at least at the right side of slice 52), if *k* is increased to 26.

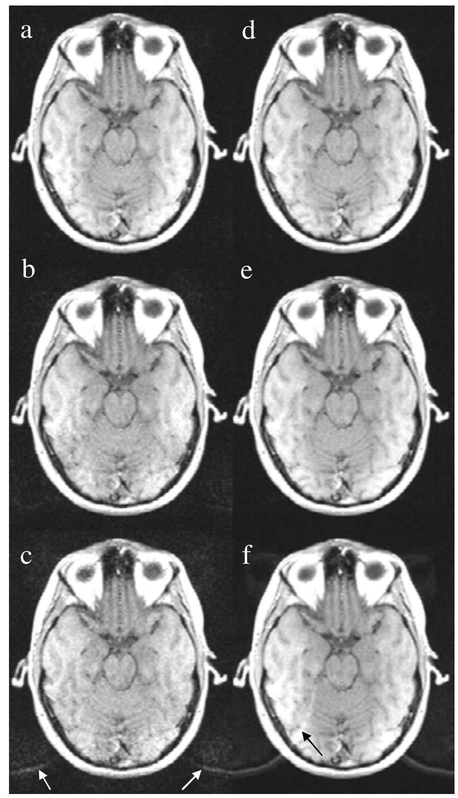

Fig. 2: Images reconstructed with different variants of GRAPPA for one slice. a-c: z-GRAPPA with slice distances of 2.5mm, 5mm and 7.5mm, d: conventional GRAPPA, e-f: i-GRAPPA with *k*=10 and *k*=26. Artifacts are indicated by the arrows.

Discussion

Information from spatially adjacent slices can be used for parallel imaging to reduce the amount of required reference data, thereby increasing acquisition efficiency. z-GRAPPA does not require any reference data at all, but computes weights on data combined from adjacent slices which are inconsistent with respect to anatomy and coil sensitivities. Good quality images can therefore be obtained for very small slice distances only. For higher reduction factors a larger range of slices must be considered which might further increase inconsistencies in the reference data. i-GRAPPA acquires reference lines for each kth slice, such that weights are always computed on inherently consistent data, but applied at a position with different coil sensitivity distribution. For larger slice distances, it produces less artifacts than z-GRAPPA, which suggests that the GRAPPA algorithm is sensitive against inconsistencies during weight computation (as in z-GRAPPA), but robust against inconsistencies during weight application (as in i-GRAPPA). The finding that coil sensitivity information represented by the weights is very similar for a large range of slices (Fig. 3) confirms the robustness of z-GRAPPA. Applications of z-GRAPPA are restricted to very small slice distances. For example, z-GRAPPA can be used, if a given volume has to be acquired rapidly with a high resolution in the slice direction. In other applications i-GRAPPA seems to be the preferable way to increase acquisition efficiency.

Besides increasing efficiency, information from adjacent slices can be used as well to increase robustness of parallel imaging. If reference data at the current slice position is corrupted due to motion for example, coil sensitivity information can be approximated by combining coil weights or reference data from adjacent slice positions.

References

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