Iterative Motion Compensated Reconstruction

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Introduction:

Motion during data acquisition can seriously degrade image quality. Motion compensated reconstruction can restore image quality if the motion is measured with suitable navigator signals. We present a new scheme for motion compensated reconstruction which can be applied to segmented Cartesian acquisitions (e.g. TSE, TFE). It can be combined with parallel imaging and is fast because it works mainly in the spatial domain avoiding many Fourier-transforms between k-space and image space.

Methods:

To demonstrate the method we used a modified TSE sequence: the first spin echo in the TSE train is used as a navigator echo, the second and the following echoes are imaging echoes (see Fig. 1). We used an orbital navigator [1] to quantify 2D rigid body motion parameters. From the navigator data we determine shift and rotation of the object for each interleave (see Fig. 2). We assume that no motion occurs during acquisition of an interleave but only between interleaves. This is justified by the fact that TR is typically much longer than the time needed to acquire the data of one interleave.

The first step of the image reconstruction is to Fourier-transform the data of each interleave and each receive coil. This results in N*R images $Y_{n,r}$ with a strongly reduced field of view. Here, N is the number of interleaves used and R is the number of receive coils.

The image I is reconstructed iteratively by applying the following steps:

1. The image I is rotated and shifted according to the motion estimate for interleave n obtained from the navigator data.
2. For each receive coil r the rotated image is weighted with the r-th coil sensitivity and the reduced field of view images V_r are calculated.
3. Based on the difference between all V_r and the Fourier-transformed data $Y_{n,r}$ an image update U is calculated.
4. The image update U is rotated and shifted back to the reference position and added to I.

Steps 1-4 are performed for each interleave n and are repeated for a few iterations until the image I has converged. The iteration is initialized with I=0.

Results

As an example, we present the results of a volunteer head scan (TE=130 ms / TR=3000 ms, N=16, TSE factor = 16) acquired at 1.5 T using an 8 channel head coil (R=8). During the acquisition the head was moved twice, which is reflected in the motion parameters calculated from the navigator data (Fig. 2). The left image in Fig. 3 shows the result of a standard SENSE reconstruction which is heavily corrupted by motion artifacts. The right image in Fig. 3 shows the result of the proposed method after 5 iterations where no motion artifacts are visible.

Discussion

The proposed method is fast because it converges quickly and does not require repeated Fourier-transforms. It could also be used to speed-up auto-focus reconstruction [2].

GRAPPA-like methods [3] or gridding would be an alternative reconstruction method but the motion dependent sampling pattern makes the application of gridding difficult. Fig. 4 shows the k-space distribution of the acquired data: gaps and oversampled parts are distributed in a regular pattern over the whole k-space which is difficult to handle by gridding because the sampling density varies strongly and periodically. In addition to this, the sampling density compensation cannot be pre-computed because it depends on the motion pattern encountered.

Although the method can compensate only for in plane motion, through plane motion could at least be detected by a reduction of correlation between navigator profiles.

Conclusion

A new iterative image reconstruction method for Cartesian acquisitions is presented which can compensate for 2D rigid body motion and can be applied to parallel imaging. The motion is detected and quantified by adding an orbital navigator echo in front of the imaging echoes.

References: [1] Fu, et al., MRM 34: 746-753, 1995; [2] Atkinson, et al. MRM 41:163-170, 1999; [3] Lin, et al., Proc. ISMRM 17, 757, 2009

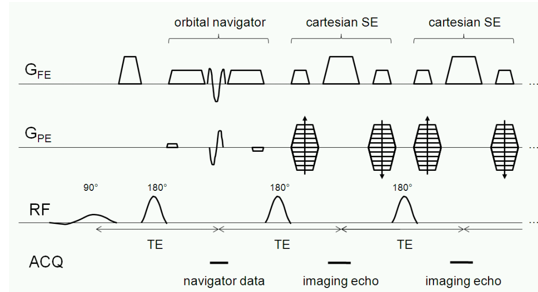

Fig. 1: Schematic representation of the TSE imaging sequence with the orbital navigator in front of the imaging echoes (the slice selection gradients are not shown). The navigator gradients are balanced so that the CPMG condition is fulfilled.

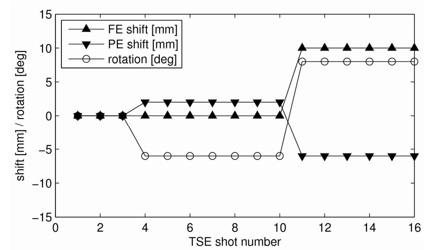

Fig. 2: Motion estimated from the orbital navigator data for a volunteer head scan. The head was moved twice during data acquisition.

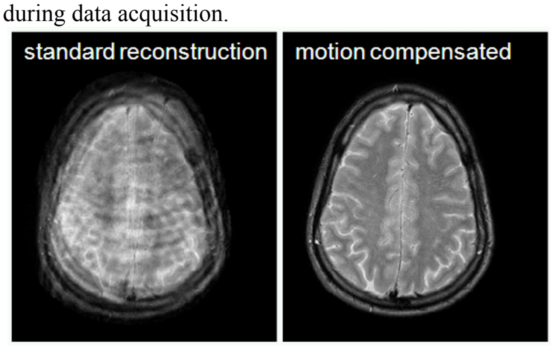

Fig. 3: Results of a standard SENSE reconstruction (left) and a motion compensated reconstruction (right) for the scan of Fig. 2. In contrast to the standard reconstruction the motion compensated reconstruction is free of artifacts.

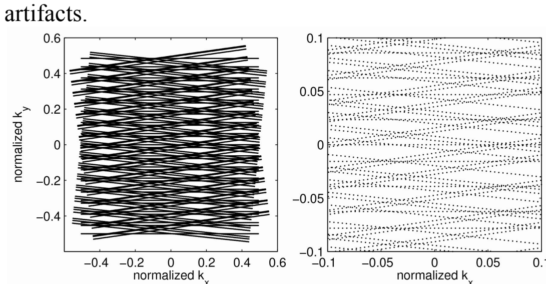

Fig. 4: Distribution of k-space samples for the example of Fig. 2/3 (left: full k-space, right: zoomed central part). Three different sets of parallel lines exist corresponding to the three rotation angles of the head. The areas where samples are overlapping or missing form a regular pattern over the whole k-space.