Reconstruction Efficiency and Accuracy Improvement in Real Time Dynamic Parallel Imaging through Explicit Tracking of Calibration Information

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Introduction

In parallel dynamic imaging such as TGRAPPA [1] and TSENSE [2], temporally adjacent frames acquired in a time-interleaved scheme are merged to form the fully encoded calibration dataset for reconstruction. In the TGRAPPA implementation, the reconstruction weights are determined for every time frame, leading to a high computation burden and possible errors due to data inconsistency. In applications such as free breathing cardiac and abdominal imaging, respiration induced coil sensitivity change is cyclic in time and multiple frames along the time course may have approximately the same calibration information. This paper presents a strategy that explicitly tracks the cyclic change of the calibration information to improve reconstruction in dynamic parallel imaging. From a consistency measure of the frame-to-frame calibration information obtained using cross-correlation between times frames, the reconstruction efficiency and accuracy is improved by allowing time frames to share calibration information and avoid using inconsistent calibrating frames. The method is demonstrated using *in vivo* cardiac imaging data.

Methods

Non-gated free breathing cardiac experiments were performed on a 1.5T Siemens Avanto with a 15-channel cardiac matrix coil using a trueFISP sequence. Fully sampled short-axis view cardiac data were acquired at a rate of 7.80 fps on healthy subjects (TR = 2.29 ms, TE = 1.15 ms, flip angle = 70°, slice thickness = 8 mm, FOV = 360 × 264.38 mm, matrix = 256 × 56 × 15) and later down-sampled in a time-interleaved phase-encoding scheme as previously described [1]. The reconstruction procedures were performed offline with programs written in MATLAB.

In our implementation of the frame-by-frame calibration information tracking procedure, the set of interleave-undersampled frames is divided into blocks, where a block consists of R (parallel imaging acceleration factor) consecutive frames with distinct sampling patterns, as shown in Fig. 1. Using one block as a reference, correlation coefficients between the reference and all other blocks are computed. By assuming that each correlation coefficient provides a measure of the sensitivity consistency between the reference block and the block under consideration, the change of the correlation coefficient as a function of block number reflects the change of the coil sensitivities in time and provides a basis for sorting the blocks. Assuming that the coil sensitivity changes smoothly in time and that the respiration rate is much smaller than the acquisition rate, the frames are given the correlation coefficient of their blocks and then divided into groups sharing the same reconstruction calibration information based on the correlation coefficients. The calibration frames of each group are then merged to derive the reconstruction weights which are subsequently used to reconstruct every frame in the group.

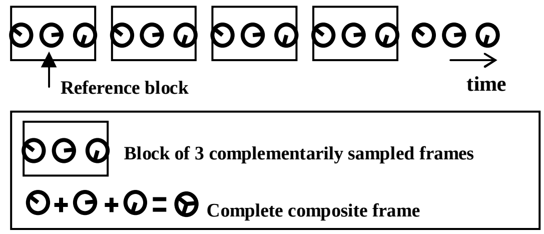

Fig.1 Formation of the blocks of frames to be examined by DCE for $R = 3$

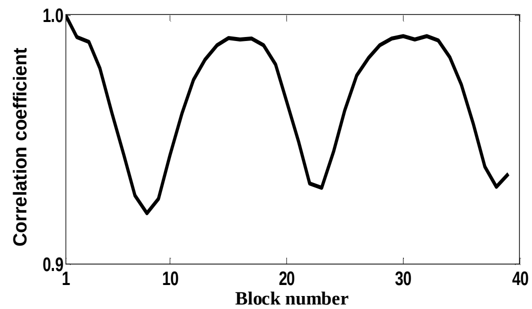

Fig.2 Correlation coefficient between the block number one and other blocks

Results and Discussion

Figure 2 presents the dependence of the correlation coefficients on the block number generated according to Fig. 1 for a parallel imaging acceleration factor of 3 (note that the first block was chosen as the reference block). The plot exhibits a cyclic pattern, indicative of respiration-induced changes. Nineteen groups of frame sharing approximately the same calibration information were identified in the dynamic dataset. Fig.3 compares the reconstruction of the original (b) and the modified (c) TGRAPPA for 3 representative frames of the same group. Below each reconstructed image, its absolute difference from the full-data reconstructed image (a) is displayed. The mean square error (MSE) between the images reconstructed from the under-sampled and fully sampled frames, respectively, were calculated for quantitative comparison between the two reconstructions (Fig 4). It is evident that the new method improves the reconstruction quality as compared to the original TGRAPPA. In addition, the new method considerably reduces the total reconstruction time as indicated in Table 1. The difference in reconstruction time between the two methods rapidly increases with increasing acceleration factor and/or number of time frames of a dataset.

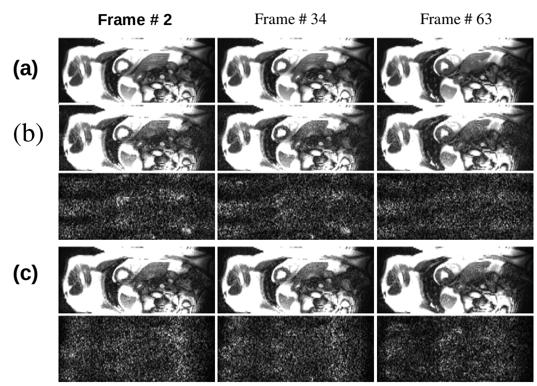

Fig. 3 cardiac results of original (b) vs. modified (c) TGRAPPA; (a) reference image

Conclusions

A new strategy that explicitly tracks the coil sensitivity changes in dynamic imaging to improve the reconstruction efficiency and accuracy in real-time parallel imaging with cyclic variation is introduced. The method was demonstrated using TGRAPPA with free-breathing cardiac MRI data. Compared to the original TGRAPPA, our method produces images with reduced artifacts and allows for faster reconstruction. The method is simple and robust and can be applied to other real-time parallel dynamic image reconstructions.

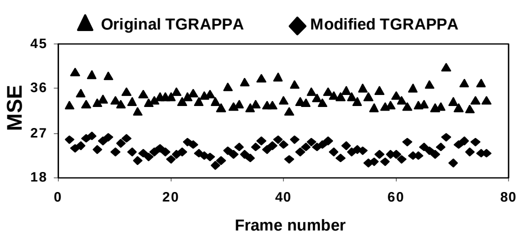

Fig. 4 MSE comparison between reconstructions

Table 1 Comparison between reconstruction times (sec)

	R = 2 107 frames	R = 3 128 frames	R = 4 128 frames
Original TGRAPPA	312	461	514
Optimized TGRAPPA	263	267	243

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References: [1] Breuer at al. MRM 2005; 53:981-985. [2] Kellmann et al. MRM 2001; 45:846-852.