Iterative GRAPPA (iGRAPPA) for Dynamic Parallel Imaging

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Introduction

In iGRAPPA (1), an initial kernel estimated from a few calibration lines is used to interpolate the missing lines which are also used to predict the acquired lines leading to a new estimate of the kernel. This procedure is repeated until convergence in the estimated kernel is reached. In this work, iGRAPPA is extended to real time non-gated non-breath-hold cardiac imaging in which the auto-calibrating lines for GRAPPA reconstruction (2) are acquired only during the first time frame. The weights determined from the first time frame are iteratively updated based on data acquired at other frames in order to track the relative change in coil sensitivities. An acquisition scheme in which only a very limited number of calibration lines are acquired for each time frame is also considered. Because iGRAPPA exploits all lines in addition to the initial estimate of the weights in deriving the GRAPPA interpolation weights, it is expected to force sensitivity consistency between acquired lines within a given frame and therefore reduce sensitivity to motion. The performance of the reconstruction is demonstrated with *in vivo* data.

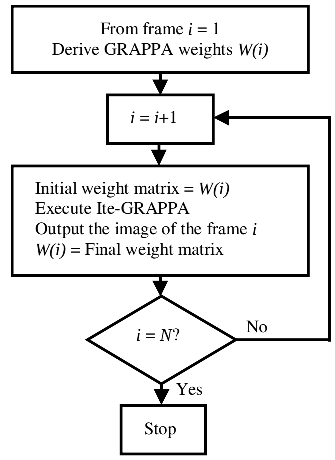

Fig. 1. Implementation procedure of iterative reconstruction of data acquired according to *strategy2*

Materials and methods

All experiments were performed on a 1.5T Siemens Avanto scanner (Siemens Medical Solutions, Malvern, PA) with an 8-channel cardiac coil combined with a 4-channel spine coil for reception and the body coil for transmission. Two acquisition schemes of real-time non-gated non-breath-hold cardiac data were utilized in healthy subjects using a trueFISP sequence. In the first acquisition strategy (referred to as *strategy1*), a short axis view reference data was fully acquired at the first time frame and subsequent time frame data were truly accelerated at rates R = 2 and R = 3. In the second acquisition strategy (referred to as *strategy2*), each accelerated four chamber view time frame data included internal auto-calibrating lines. With strategy 2, a nominal reduction of R = 2 with 3 ACS lines and that with R = 3 with 6 ACS lines were used.

The reconstruction procedure of the accelerated data acquired using *strategy1* is summarized in Fig. 1. The GRAPPA weights are derived from the fully acquired data of time frame #1 and then used as initial weights for the iterative reconstruction (1) of the accelerated data of time frame #2. This process is repeated such that the final GRAPPA weights obtained for time frame #*n*-1 are used as initial weights for the iterative reconstruction of the accelerated data of the time frame #*n*. The iteratively reconstructed images were compared to those reconstructed by a normal GRAPPA procedure that uses solely the weights derived from the first time frame for all other time frame data. The reconstruction of the accelerated data acquired using *strategy2* is performed frame by frame and the initial GRAPPA weights for each time frame is obtained from the available ACS lines as described in (1). The reconstructed images are compared to those reconstructed by a normal GRAPPA that uses only the available ACS lines for each time frame.

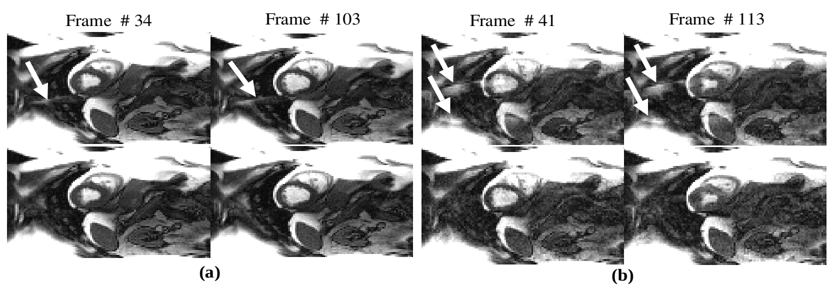

Fig. 2. Comparison between normal (top row) and iterative (bottom raw) GRAPPA reconstructions for data acquired according to *strategy1*: (a) R = 2 (temporal resolution of 96 ms) and (b) R = 3 (temporal resolution of 63 ms). The white arrows indicate the aliasing artifacts present on the top row images

Results and Discussion

Figure 2 shows the reconstruction results of data acquired using *strategy1*. The iteratively reconstructed images (bottom rows) are displayed against the images reconstructed (top rows) using standard GRAPPA with reduction factors 2 (Fig. 2a) and 3 (Fig. 2b). The presence of aliasing artifacts in the top row images indicates the change in the coil sensitivities that occur after the fully sampled first frame is acquired. The virtually artifact-free bottom row images demonstrate the ability of iterative GRAPPA to track the change in coil sensitivities that occurs in time from the weights derived from the first time frame data. Because coil motion caused by respiratory motion occurs more slowly than the actual frame rates, the initial estimate of the weights for a given frame is close enough to the solution to allow the iteration to converge in few steps. Similar observations regarding image qualities can be made in Fig. 3 which shows the reconstruction results of data acquired using *strategy2,* presented in the same manner as in Fig. 2. In this case, the inability of normal GRAPPA to reconstruct artifact-free images may be due to either the reduced number of ACS lines used or the sensitivity mismatch due to motion between calibration lines and other lines in the data. iGRAPPA inherently ensures sensitivity consistency between these lines and thereby generated virtually artifact-free images

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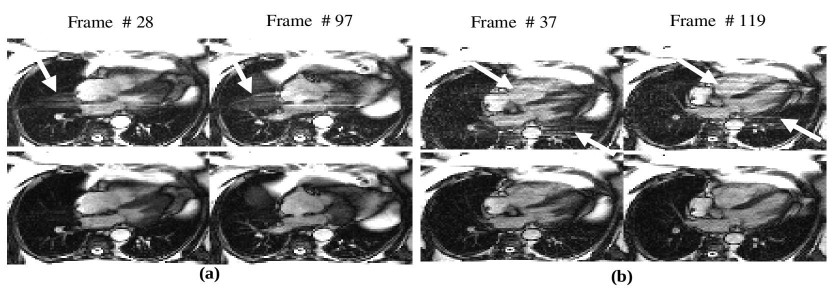

Fig. 3. Comparison between normal (top row) and iterative (bottom raw) GRAPPA reconstructions for data acquired according to *strategy2*: (a) R = 2 (temporal resolution of 105 ms) and (b) R = 3 (temporal resolution of 85 ms). The white arrows indicate the aliasing artifacts present on the top row images

Conclusion

The results presented here suggest that iGRAPPA is a possible method for real-time imaging, but without the possible temporal blurring effects due to data sharing in parallel reconstruction (3, 4). The two acquisition strategies employed in this study are commonly used in cardiac acquisition under the constraints of gating and/or breath holding. iGRAPPA can alleviate these constraints and therefore extend the range of applications of these acquisition strategies.

Reference:

1. T. Zhao et al. ISMRM 2007; p 1744
2. Mark A. Griswold, *et al.*, MRM 2002(6); 47:1202-1210
3. Felix A. Breuer *et al.,* MRM 2005; 53(6): 981-985.
4. P. Kellman *et al.,* 2001; 45(5): 846-852.

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