HTGRAPPA: TGRAPPA BASED B1-WEIGHTED IMAGE DOMAIN RECONSTRUCTION FOR REAL-TIME MRI

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Introduction: TSENSE [1] based real-time reconstruction software for interventional applications has been previously described [2]. In this work, we present a parallel imaging algorithm based on TGRAPPA [3] for real-time MRI, called HTGRAPPA and its real-time, low latency implementation suitable for interventional MR applications. Our method calculates GRAPPA coefficients in k-space, but applies them in the image domain to avoid time-consuming convolution operations [4] allowing reconstruction fast enough for real-time imaging. In HTGRAPPA, image domain GRAPPA weights were combined into composite unmixing coefficients using adaptive B1-map estimates and optimal noise weighting to eliminate per coil reconstructions. That makes it possible to reconstruct images in the image domain by pixel-by-pixel multiplication and summing, instead of time-consuming convolution operations in k-space. Weight-sets were computed asynchronously to the image reconstruction, and updated quickly to adapt to changes in the image plane and coil sensitivity profiles. Our algorithm provides constant reconstruction performance, independent of the acceleration rate and GRAPPA kernel size. We evaluated our method using 30-coil, rate 4 dataset and compared it to TGRAPPA and TSENSE in performance and image quality. HTGRAPPA reconstruction algorithm was up to 265 times faster than TGRAPPA with no reduction in image quality. A frame rate exceeding 70 was reached on previously acquired data, which is more than sufficient for real-time data rates. Additionally, HTGRAPPA doesn't exhibit pre-folding artifacts when small FOV is used.

Methods: Real-time cardiac images from healthy individuals were acquired using a Siemens Magnetom Avanto 1.5T MRI scanner (Siemens Medical Solutions, Erlangen, Germany). Sequence parameters for the experiments were as follows: TR=3.06ms, flip angle=45º, and acquisition matrix of 192x108. Data were acquired using a 32-element array (Invivo Corporation), 16 elements on the chest, 16 elements under the spine The HTGRAPPA imaging technique was employed with acceleration factor *R*=4. Images were reconstructed and displayed in real-time.Weight-set calculation and reconstruction were computed in parallel in separate processing threads using 8 dual-core AMD Opteron 8220 processor (2.8 GHz) on Linux with SMP configuration, and weights were updated continuously and employed when available.

Results: The reconstruction performance of HTGRAPPA was compared to TGRAPPA using a 30-coil, rate 4 dataset acquired previously. Results showed that HTGRAPPA reconstruction was up to 265 times faster than TGRAPPA reconstruction. Figure 1 represents large (380mm) and small FOV (320mm) images (from top to bottom) reconstructed from 30 coils, rate 4 dataset using TSENSE, TGRAPPA and HTGRAPPA (from left to right). Figure 2 shows rate 4 images of the full cardiac cycle reconstructed in real-time using 30 receiver coils, with matrix size of 192x108, and ¾ partial phase Fourier acquisition (16 frames per second). Finally, Figure 3 represents reconstruction performance per image frame of HTGRAPPA on data acquired with different numbers of receiver coils. Weight set calculation was timed using 30 coils and 48 ACS lines, and the average times were 3.847 sec for 4x5 kernel, and 1.800 sec with 2x5 kernel.

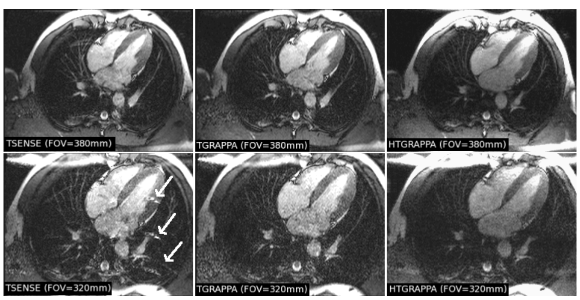

Figure 1. From left to right, TSENSE, TGRAPPA and HTGRAPPA reconstructed images for large (top) and small (bottom) FOV acquisitions.

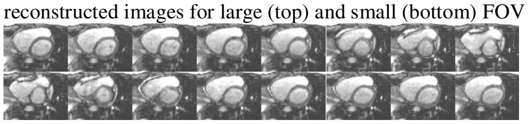

Figure 2. Full heart cycle reconstructed with HTGRAPPA in real-time using 30 coil acquisition with acceleration rate, R=4.

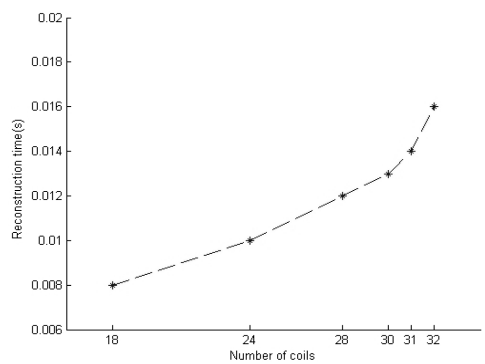

Figure 3. Reconstruction performances (in seconds) for one acquisition.

Discussion: HTGRAPPA allows reconstruction based on TGRAPPA to be performed in real-time. It replaces convolution operations with simple multiplication and summing, and it removes the block-size and acceleration rate dependency from the reconstruction. A drawback of our method is slightly slower weight-set calculation performance due to the image domain conversion of the GRAPPA weights. This increased the weight-set calculation time by 0.76 seconds on a 30-coil dataset, which should be reasonable for our application. As can be seen in Figure 1, both TGRAPPA and HTGRAPPA are free of pre-folding artifact when smaller FOV is used, which is not the case for TSENSE. Figure 2 shows that HTGRAPPA may be used across the cardiac cycle without aliasing artifacts or temporal blurring. Figure 3 indicates that HTGRAPPA is well suited for real-time interventional application as it can keep up the acquisition rate even with high acceleration rates and high numbers of receiver coils. Overall, our method is up to 265 times faster than TGRAPPA on a 30-coil, rate 4 dataset, and doesn't exhibit pre-folding artifacts when smaller FOV is used, as is the case for TSENSE.

References

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