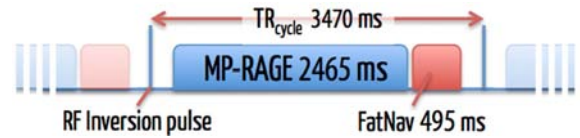


# Overproof GRAPPA: Exploiting the natural sparsity of fat images for 64-times accelerated motion navigators (FatNavs)

Daniel Gallichan<sup>1</sup>, José P Marques<sup>2</sup>, and Rolf Gruetter<sup>1,3</sup>

<sup>1</sup>CIBM-AIT, EPFL, Lausanne, VD, Switzerland, <sup>2</sup>Dept. of Radiology, University of Lausanne, VD, Switzerland, <sup>3</sup>Depts. of Radiology, Universities of Lausanne and Geneva, VD/GE, Switzerland

**Introduction:** We recently introduced the concept of exploiting the natural sparsity of volumes acquired with a fat excitation in the human head to achieve very high parallel acceleration factors, and proposed that this could be used as a motion-navigator for high-resolution imaging applications (FatNavs) [1]. Here we present the realization of this novel concept, using retrospective motion-correction for improved image quality in a 625  $\mu$ m isotropic MP-RAGE scan acquired at 7T in a compliant volunteer with no deliberate motion. We also demonstrate that when the image to be reconstructed is itself sparse, the conventional GRAPPA approach [2] is inherently able to exploit this sparsity – here giving sufficient image quality at 64-times acceleration using a 32-channel RF coil.



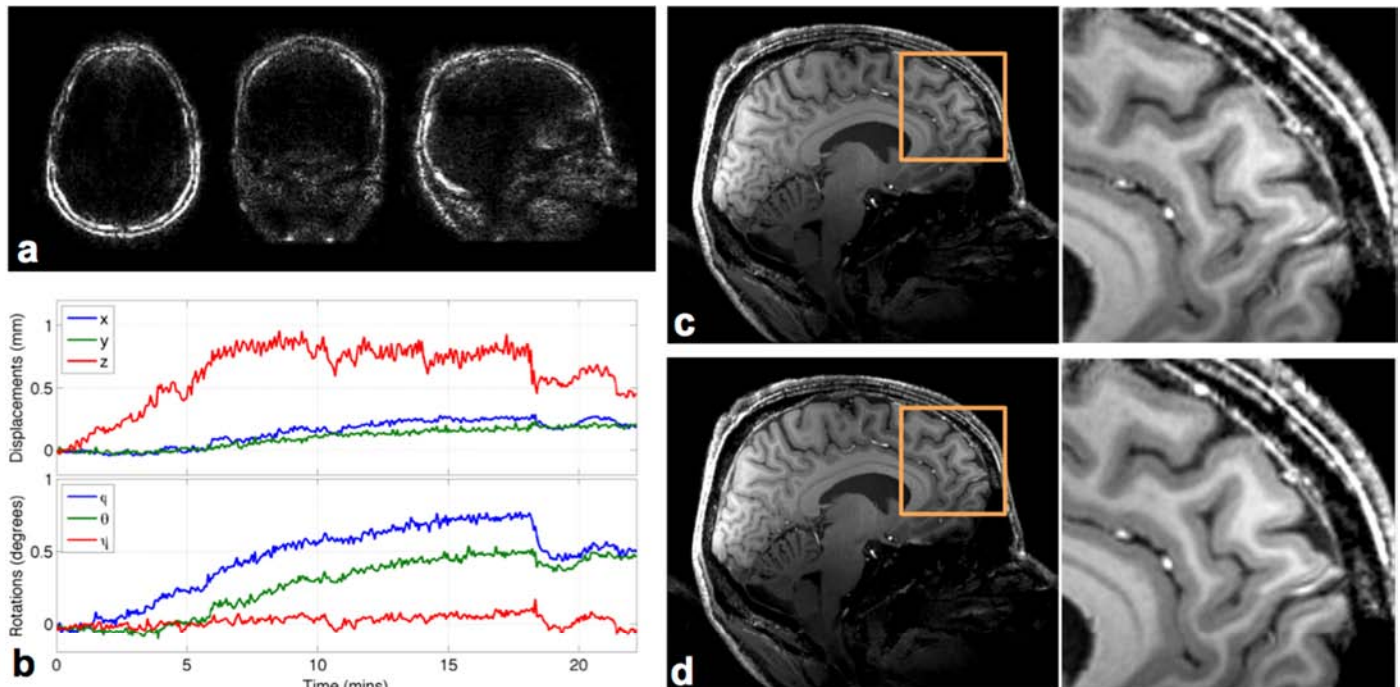
**Figure 1:** One  $TR_{cycle}$  of the pulse sequence, showing the relative timing of the FatNav motion navigator

**Method:** Imaging was performed on a 7T head-only Siemens MR scanner with a 32-channel RF coil (Nova Medical Inc.). A healthy adult volunteer accustomed to the scanner environment was instructed not to move during the scan. A high-resolution MP-RAGE volume (625  $\mu$ m isotropic, 288×384×384 matrix, TE/TI/TR = 2.94/1500/3470 ms, BW=140 Hz/Px, FA = 7°, total scan time = 22:12 mins) was acquired, with the insertion of a full 3D FatNav volume-navigator for motion correction after each MP-RAGE readout train. The FatNav was a 2mm isotropic 3D-GRE dataset acquired with 8×8 acceleration and a binomial RF pulse for fat excitation (88×128×128 matrix, TE/TR = 1.35/3.0 ms, BW = 1950 Hz/Px, FA = 7°) which could be acquired in 495 ms (relative timing shown in Fig. 1). In order for the GRAPPA kernel estimation to remain an overdetermined problem, a large number of ACS lines are required – we used the maximum offered by the system for this matrix size: 81×113. This introduces an additional 32 s pre-scan to the total scan time. After offline 2D GRAPPA reconstruction (following 1D FFT in readout direction), each of the FatNav volumes was co-registered (rigid-body) to the first using SPM *realign* [3]. The motion parameters obtained in this manner were then applied separately to the k-space data of each corresponding TR of the host MP-RAGE sequence to perform retrospective motion correction (3D gridding performed using *grid\_utils* [4]). Assuming small motion, no density compensation was applied.

**Results and Discussion:** Fig. 2a shows 3 orthogonal views of one 64-times accelerated 3D FatNav volume which, despite the extremely high acceleration factor, provided sufficient image quality for the co-registration step. Fig. 2b shows the estimated motion parameters from the FatNavs indicating total motion of less than 1 mm and 1°. As each FatNav was independently co-registered to the first, the small oscillations observed in these plots (~50  $\mu$ m or ~0.05°) give an indication of the precision obtainable by co-registration of the FatNavs. It should be noted that this does not indicate the accuracy, which future work still needs to address as currently no compensation has been made for distortions due to gradient non-linearities, or to attempt to mask regions of the image subject to non-rigid motion. Fig. 2c-d show the high-resolution MP-RAGE scan (c) before and (d) after application of the retrospective motion-correction where there is a clear improvement in image sharpness and contrast following the correction. The improvement is comparable to high-resolution examples of existing motion-correction methods which rely on external hardware [5,6]. Initial results have also recently been presented for high-resolution applications using an EPI-navigator for prospective motion correction [7], but the FatNavs offer the advantage of having a negligible effect on the signal of the host sequence. It would also be possible to use an EPI readout for the FatNavs to further shorten the time of each navigator, allowing easier incorporation into a variety of host sequences. There is also potential for using FatNavs for prospective motion correction, but this would be restricted by the reconstruction time of the highly accelerated 3D volume. As the application of the large GRAPPA kernel (here the kernel was 512×2106 for each of the 128 ‘slices’) is highly parallelizable, faster reconstructions are technically feasible.

**Conclusion:** We have successfully demonstrated the use of a very highly accelerated 3D volume as a high-resolution motion-navigator, capable of tracking small involuntary motion of a compliant subject over a 22 minute scan. This offers the potential to better exploit the SNR of ultra-high field to push the spatial resolution of MRI acquisitions without the need for additional hardware and with negligible impact on the signal of the host sequence.

[1] Gallichan et al, *proc. ISMRM 2013*, p309; [2] Griswold et al, *MRM (2002)* 47:1201-1210; [3] [www.fil.ion.ucl.ac.uk/spm/](http://www.fil.ion.ucl.ac.uk/spm/); [4] [www.ismrm.org/mri\\_unbound/](http://www.ismrm.org/mri_unbound/); [5] Maclaren et al, *PLoS one (2012)* 7:e48088; [6] Schulz et al, *MAGMA (2012)* 25:443-53; [7] Tisdall et al, *proc. ISMRM 2013*, p268; This work was supported by CIBM of the UNIL, UNIGE, HUG, CHUV, EPFL and the Leenaards and Jeantet Foundations



**Figure 2:** (a) Example of a single 2mm isotropic FatNav volume, 8×8=64 acceleration, acquired in 495 ms and reconstructed with GRAPPA. (b) Fitted motion parameters from FatNavs during MP-RAGE scan. MP-RAGE with no deliberate motion (c) before and (d) after retrospective motion-correction.