FatNavs: Exploiting the Natural Sparsity of Head Fat Images for High-Resolution Motion-Navigation at Very High Acceleration Factors

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Purpose. Involuntary motion of the subject is a major source of artifact in MRI. For neuroimaging a number of techniques have been proposed to attempt to monitor and correct for this motion, either prospectively, retrospectively or a combination of the two [1]. Methods capable of tracking motion at high spatial resolution typically rely on external hardware as MRI navigator methods tend to require excessive time spent on navigator acquisition to achieve the desired sensitivity to motion and can have detrimental effects on the SNR and contrast in the host sequence. In this work we aim to demonstrate the feasibility of using a fat excitation for the motion navigator acquisition. The fat signal in the head is inherently very sparse, lending itself well to highly accelerated compressed sensing, thereby allowing high sensitivity to motion in a short scan time. Additionally, the magnetization of the water will experience negligible perturbation from the fat acquisition – allowing the insertion into existing sequences without loss of SNR efficiency or altered contrast in the host sequence.

Methods. All imaging was performed on a 7T head-only Siemens MR scanner with a 32-Ch RF coil (Nova Medical Inc.). For this proof-of-concept study we collected 2 whole-head volumes (34s per GRE volume, one with 3° binomial fat excitation, one with 3° water excitation, 2mm isotropic, 88x128x128 matrix, TE/TR 1.35/3.0 ms) at 3 time-points throughout a scan session of ~40 mins (at least 10 minutes between volume pairs) in 6 healthy young adults who were instructed not to move during the experiment. We assumed negligible motion within the volume pairs, and that any motion between the pairs should reflect the typical small motion of healthy compliant subjects during extended scan sessions. The water images were brain-extracted using BET [2] and co-registered (6 DOF rigid-body) to the first volume per subject using SPM [3] re-align and re-slice tools, and the extracted motion parameters were considered the gold standard for the motion between time-points. For the fat volumes the signals from the 10 lower RF channels (towards the foot direction) were discarded to minimize contamination from non-rigid motion regions. To verify that the fat images also allow accurate motion estimation, the fully-sampled fat volumes were registered to the first fat volume and the resulting motion parameters compared against the gold standard. A highly-accelerated 3D radial acquisition was then simulated from the data by only retaining k-space data on the Cartesian points closest to 250 spokes evenly distributed across the sphere. These data were then reconstructed using non-Cartesian SENSE [4] (with RF coil sensitivities estimated from the first water volume) regularized with an L1 penalty on the image itself [5] in Matlab (The Mathworks Inc.). This should give similar image quality to what could be expected from an acquisition of ~750 ms duration – with an effective acceleration factor of approximately R≅50 (actual R depends on the definition, [N Cartesian phase-encodes]/[N pseudo-readouts] = 45, [N voxels, pseudo-radial Cartesian]/[N voxels, fully sampled Cartesian] = 54).

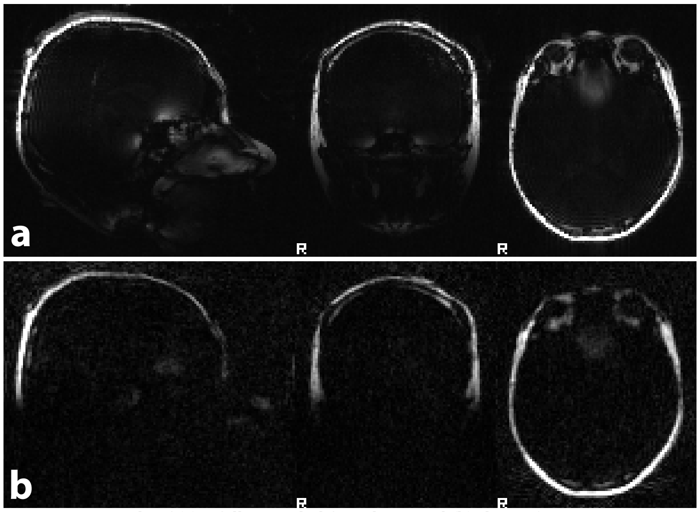

Fig. 1. Example of (a) a fully sampled fat volume and (b) the R=50 reconstruction

Results and Discussion. An example fully-sampled fat image is shown in Fig. 1 along with the reconstructed R≅50 fat image, which still shows clear high-resolution delineation of the main structural features of the scalp. The estimated motion parameters from time point 1 to time points 2 and 3 are shown in Fig. 2 for both the full-fat data and the R≅50 fat data, plotted against those from the water images as a reference. There is a tendency for both the translations and the rotations to be underestimated from the fat data, more so in the accelerated case. It is not clear what is the cause of this discrepancy, but non-linearities of the short gradient system are likely to be a major factor – with the fat in the scalp more affected that the brain. Tight cushioning against the head may also compress the skin slightly, affecting the assumption of pure rigid-body motion. However, the consistency of the estimates from the fat data implies that further work to improve the registration step should be able to remove this bias. The close agreement of the R≅50 fat data and the fully sampled data also confirm the hypothesis that high-resolution fat data can be acquired with very high acceleration factors.

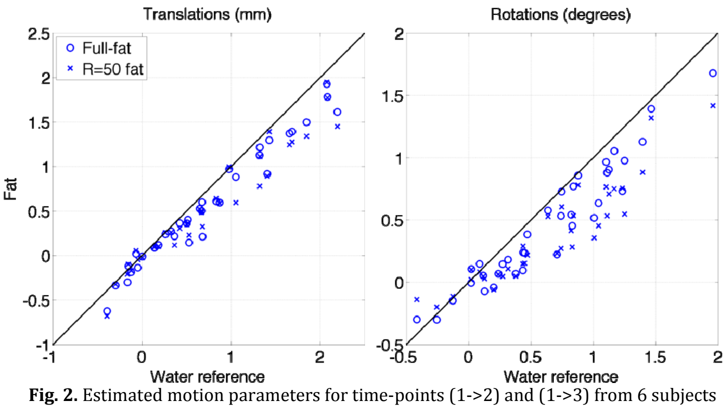

Fig. 2. Estimated motion parameters for time-points (1->2) and (1->3) from 6 subjects (no intentional motion) from the fully sampled fat data (circles) and the R≅50 fat data (crosses) against the parameters from the fully-sampled water data as a reference.

Conclusion. This preliminary study demonstrates that the fat signal in the head has the potential to be used as a high-resolution motion-navigator acquired at very high acceleration factors. In the longer term we expect this to be easily integrated into high-resolution protocols, especially where gaps already exist (e.g. MP-RAGE and 3D-TSE), conferring the additional advantage of a negligible influence on the water signal for the host sequence.

References. [1] J. Maclaren et al, MRM (Early View online); [2] S.M. Smith, HBM (2002) 17:143; [3] www.fil.ion.ucl.ac.uk/spm; [4] K. Pruessmann et al, MRM (2001) 46:638; [5] M. Lustig et al, MRM (2007) 58:1182;
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