High Temporal Resolution Radial Motion Correction with GROWL

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Introduction

Radial imaging, or projection reconstruction (PR), is a powerful technique to deal with motion artifacts. The oversampling of central k-space region provides a "self-navigating" property, which has been exploited in several existing methods, such as data-consistency [1], self-gating [2], and correction of both rigid-body motion [3] and non-rigid deformation [4].

However, there is always a tradeoff between temporal resolution and robustness for radial motion correction. More radial views provides more information allowing for the correction of more complex motion (e.g. deformation), but also results in a lower temporal resolution for the correction. In this work, a recently proposed rapid radial paralleling imaging technique, GRAPPA operator for wider radial bands (GROWL) [5], is used to significantly improve the temporal resolution for motion correction in multi-coil radial imaging applications. *In vivo* experiments demonstrated correction of rotation/translation with a high temporal resolution (8 radial views) using an 8-channel coil.

Methods

A simulation experiment was first carried out to examine the minimal number of radial views required for robust rotation/translation detection using GROWL. A noise-free T_1-weighted Cartesian brain MR dataset was downloaded from a simulated brain database (http://www.bic.mni.mcgill.ca/brainweb/). The complex sensitivity profile of a head coil array with 8 coil elements equally spaced around a cylinder was computed using an analytic Biot-Savart integration. The k-space data for each individual channel was then derived using the Fourier Transform (FT) and inverse gridding. GROWL reconstruction was then carried out using 8, 16, 32 and 64 views. In GROWL, GRAPPA operator is used to expand each acquired radial line into a band consisting of several parallel lines, therefore enlarging the central k-space region where the Nyquist criterion is satisfied (Fig. 1). To examine the accuracy for motion detection, the k-space data generated from GROWL reconstructions with different sampling patterns were rotated to various angles, followed by a 2D correlation in the image-space. The maximal correlation then yields both detected rotation and translation.

For the in vivo motion correction experiment, a healthy volunteer was scanned on a 3.0T Achieva scanner (Philips, Best, Netherlands), using an eight-channel head coil (Invivo, Gainesville, FL) and a multi-slice 2D radial gradient echo sequence. A bit-reversed scheme [6] was used for view-angle ordering, which provides flexibility in choosing an appropriate temporal resolution retrospectively. Scan parameters: FOV 230x230 mm^2, slice thickness 5mm, matrix size 256 (readout) x 256 (view no.), TR/TE=250/6.9 ms, flip angle = 80^0. For motion-corrupted dataset, the subject was asked to shake his head several times during the scan. Data was grouped into interleaves based on the acquisition order, and GROWL reconstruction was carried out for each interleaf. One interleaf with the lowest image entropy value was chosen as the reference, and the 2D rotation/translation was detected using the image correlation method. The detected rotation was then used to modify the radial trajectories, while translational motion was corrected by applying the corresponding linear phase term.

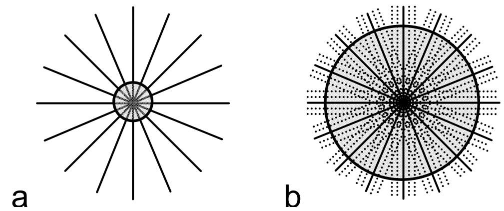

Fig. 1 GROWL reconstruction scheme. (a) The original undersampled dataset with a small Nyquist circle. (b) After each radial view is widened into a band using a GRAPPA operator, the Nyquist circle is enlarged.

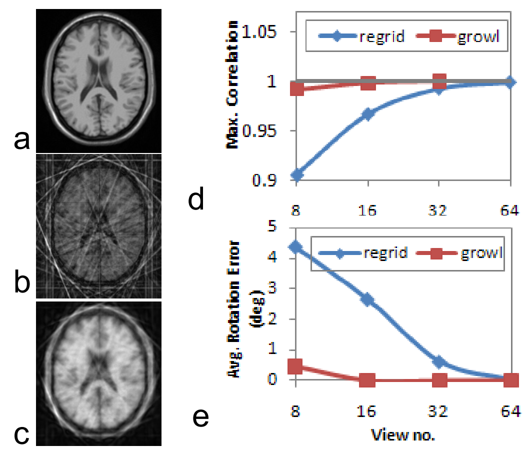

Fig. 2 Simulation results demonstrating the motion detection accuracy of GROWL recon. (a)-(c): Reference image (a, 256x256), reconstruction using 8 radial lines with regridding (b) and GROWL (c). (d)-(e): Maximal correlation (d) and average rotational errors (e) with different no. of views.

Results and Discussions

Figure 2 shows the simulation results investigating the temporal resolution that motion correction can achieve with GROWL reconstruction and 2D image correlation. With only 8 radial lines, GROWL reconstruction (Fig. 2c) significantly reduces streaking artifacts and improves image quality over conventional regridding (Fig. 2b). This results in a much higher image correlation values (Fig. 2c) and negligible error for rotational motion detection (Fig. 2d). Error for translation is also negligible. Figure 3a-c shows images from the *in vivo* experiment, where the image blurring caused by the motion (Fig. 3b) was significantly reduced after the correction (Fig. 3c). Motion trajectory detected from the 2D image correlation shows both continuous and abrupt components, with a rotation range of 5.5^o and a translation range of 5 pixels. The entire motion detection and correction procedure takes about 20 seconds.

When compared with PROPELLER [7], the proposed method provides a flexibility to select an appropriate temporal resolution for motion detection and correction retrospectively. The proposed method can also be expanded to detect and correct for through-plane motion and non-rigid deformation, if a regional image correlation and correction is carried out [4].

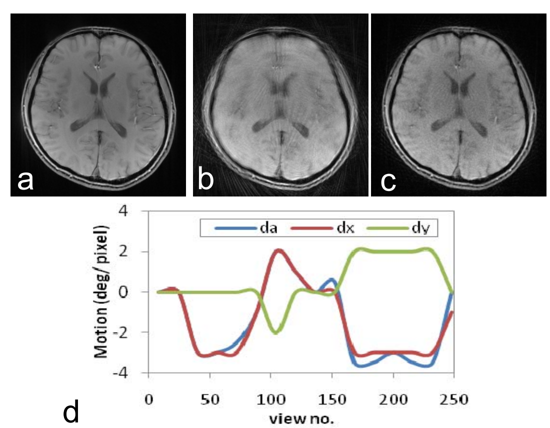

Fig. 3 In vivo experiments results, showing motion-free (a), motion-corrupted (b), motion-corrected (c) images and the detected in-plane rotation (da) and translation (dx, dy) (d).

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