Motion correction technique for segmented acquisition using parallel imaging reconstruction and image based correlation

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PURPOSE

Patient movement and physiological motion can substantially degrade diagnostic image quality. Image-based motion self-correction techniques have shown potential in correcting these motions. However, most of these techniques[1-6] rely on trajectories that pass through the center of k-space in each acquisition segment to produce a low resolution image that is used for motion comparision between various segments. The precision of motion detection and correction is therefore limited by the resolution of the under-sampled segment. Moreover, these techniques are restricted to radial or spiral based acquisitions that might present additional artifacts. To overcome these short comings, we propose an image-based motion self-correction method that utilizes parallel recontruction and image-based registration to provide subpixel precision in motion correction for 2D cartesian interleaved acquisitions.

THEORY

In any 2D segmented acquisition, each segment, consisting of multiple phase encoding lines, is acquired progressively in time. If motion occurs during the acquisition, some of the k-space segments will be corrupted by a linear phase shift or a rotation (for rigid body translation or rotation, respectively). If the segmentation is interleaved, each segment represents an under-sampled k-space in the phase encoding direction, and can be unaliased and reconstructed into sub-images using various parallel imaging reconstruction techniques. Each of the sub-images will show the position of the object. Comparing each of these sub-images (i=1..N) with the reference sub-image (i=1), the relative displacement of each sub-image can be determined and corrected by applying the appropriate linear phase shift in k-space (where N=total number of segments). In our feasibility study, we used SENSE reconstruction to demonstrate the concept and the algorithm (Fig 1.). The method can be summarized as follows:

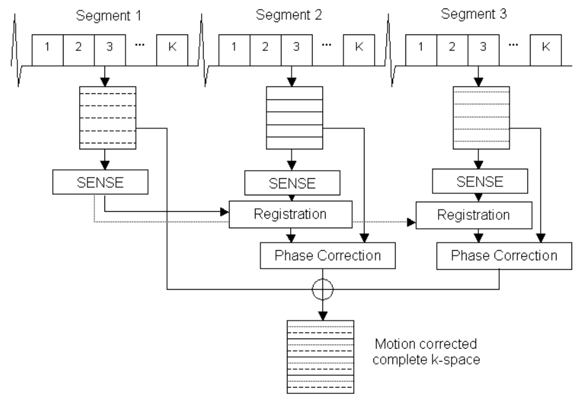

Figure 1 Image-based motion correction algorithm applied to one of the K cardiac phases to produce a motion corrected image.

1. Apply SENSE reconstruction to each interleaved k-space segment to yield an unaliased full resolution sub-image of the object.
2. Determine the relative motion between various segments by comparing a square ROI (128x128) in each sub image with that of the reference sub-image using 2D least squares error technique.
3. To achieve sub-pixel precision while minimizing processing time, once the first level motion estimate is found, upsample the comparison region and repeat the motion comparison within a smaller motion range with higher spatial resolution.
4. Apply a linear phase correction to the k-space data of each segment individually in frequency and phase encoding directions.
5. Combine the corrected k-space segments into a single complete k-space data set and reconstruct into a motion-suppressed image.

METHOD

In our feasibility study, we acquired data from a water phantom using a 2D SSFP CINE sequence in a GE HD 1.5T scanner (GE Healthcare, Milwaukee, WI, USA) with an 8 channel cardiac coil. A continuous S/I sinusoidal table motion of 3mm was applied to simulate respiratory motion. Each complete k-space of each cardiac phase was acquired in 4 segments in an interleaved manner. The image acquisition parameters were TR = 3.4 ms, TE = 1.5 ms, flip angle = 60^o, 256x256, views per segment = 64, 1 NEX, 4mm slice thickness). The acquired data was then processed offline in MATLAB with the proposed algorithm.

RESULTS & DISCUSSION

Fig 2. showed the reconstructed image acquired and processed with and without the proposed motion correction algorithm. The uncorrected image (Fig2a) showed motion artifacts (ghosting) in the phase encoding direction and blurring in the frequency encoding direction. The motion artifacts were significantly reduced with the proposed retrospective motion correction algorithm (Fig2b). The total number of segments N allowed by this algorithm is restricted by the SENSE reconstruction algorithm. As N increased, the signal to noise ratio (SNR) of the resulting SENSE reconstructed sub-image decreased. If the SNR of the segment image was too low, image registration would not be able to provide an accurate displacement result. N= 4 was the maximum segmentation feasible on an 8 channel system. With the use of higher channel system, N can be increased such that the views per segment can be further reduced. This decreases the length of the segment acquisition window and thus reduces the amount of motion that occurs within a segment. Residual smearing artifact caused by such motion can therefore be minimized.

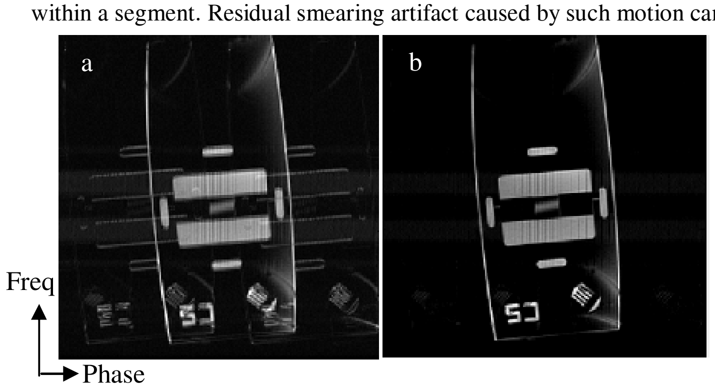

Figure 2 a) Uncorrected image acquired during a continuous sinusoidal table S/I movement of 3mm. b) Data from the same acquisition processed with the proposed motion self-correction algorithm. Note the reduction in ghosting in the image with motion correction. Motion occurred during the segment acquisition window was not corrected in this approach and might result in minor residual smearing artifact in the motion corrected image.

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