Multiple-region affine motion correction using localized coil sensitivities

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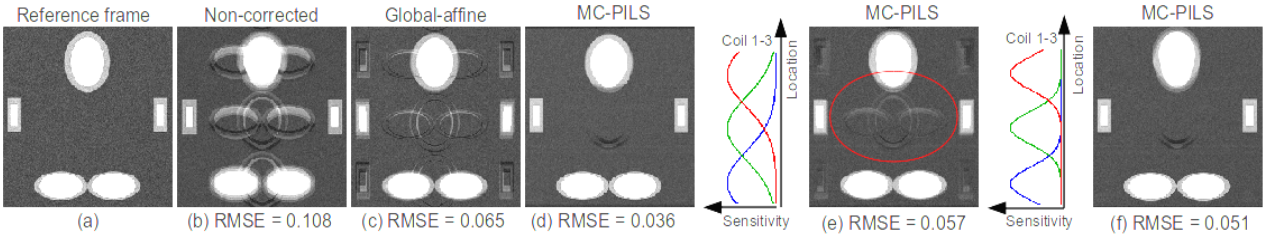
Introduction: Respiratory motion compensation is still a major challenge in cardiac and abdominal MRI. It has been shown that the respiratory motion of the heart can be approximated by an affine transformation, allowing a direct correction in k-space [1]. However, the field-of-view (FOV) must be restricted to the heart only to avoid artefacts coming from surrounding tissues, which cannot be described by the same affine transformation. The use of localized coil sensitivities has been proposed for a simple parallel imaging approach (PILS) to speed up image acquisition [2]. In our work, we used the localized coil sensitivities of a 32-channel coil array for multiple affine-based corrections. This approach has been called motion compensated PILS (MC-PILS). MC-PILS was validated in simulations and the feasibility was tested on a healthy volunteer.

Methods: MC-PILS combines localized reconstruction with k-space based affine correction, by applying the following steps: 1) Localized coil sensitivities of a coil array are used to select regions of the FOV. 2) Affine motion estimation is performed in each region. 3) Affine motion correction is performed in each corresponding k-space by applying a shifting in phase and magnitude, plus a rotation and scaling of the k-space grid. 4) After applying a FFT on the regridded data, a sum-of-square reconstruction of the localized motion corrected images is performed and the final multiple-region affine corrected image is obtained.
a) Simulations: A numerical phantom comprising different regions with pre-defined motion was created. Three dynamic image frames were used to study motion artefacts and the influence of two corrections: global-affine and multiple-region affine. Three different regions were selected by simulated Gaussian sensitivity profiles of varying locations and widths. The efficiency of motion correction was quantified from the difference images between the reference frame and the reconstructed images by calculating the root mean square error (RMSE).
b) In-vivo experiment: The feasibility of the MC-PILS approach was tested on abdominal images obtained from a healthy volunteer. For this, several single breath-hold 3D SSFP acquisitions (FOV=400x262x384mm, TR/TE=3.2/1.61ms, 30° flip angle) were performed on a 1.5T Philips Achieva scanner with a 32-channel coil. Coil sensitive maps were estimated from an extra reference scan and used to select 4 different regions in the FOV. The motion parameters were extracted from an intensity-based local affine registration algorithm [3] using the sum-of-squared differences as similarity measure.



(a) (b) RMSE = 0.108 (c) RMSE = 0.065 (d) RMSE = 0.036 (e) RMSE = 0.057 (f) RMSE = 0.051

Fig. 1: Comparison between: (a) reference frame, (b) non-corrected reconstruction, (c) global-affine corrected reconstruction and (d) MC-PILS. (e-f) MC-PILS reconstructed image for different degrees of selectivity in the simulated coil sensitivity profiles. Broader selectivity tends to generate more residual artefacts in overlapping sensitivity regions (circled in red).

Results: Figure 1 shows the simulation results, with (a) the reference frame and (b) the non-corrected image. (d-f) MC-PILS clearly improves image quality (RMSE < 0.06) in comparison to (c) the globally-affine corrected image (RMSE = 0.065), by reducing the amount of ghosting. In (d), correction was performed with the pre-defined motion parameters resulting in higher image quality, whereas in (e-f), motion estimation was performed, which results in some inaccuracy. However, this is less than for the non-corrected and globally-affine approach. Furthermore, the performance of the MC-PILS correction depends on how selective the coil sensitivities are within the regions of different motion, as is shown for two different coil configurations in (e-f). In areas where sensitivities overlap, motion may not be described by a single affine transformation resulting in residual artefacts (circled in Fig. 1e).
Figure 2 shows the results of the different corrections for in-vivo data. (a) Reference and (b) non-corrected images are displayed for visual comparison. Global affine parameters were extracted from the registration of a single-coil weighted FOV covering the liver. Although global-affine reconstruction does successfully recover the liver (c), significant amount of ghosting arising from static fat tissues is visible (see arrows). (d) MC-PILS reconstruction further reduces these artefacts at the expense of some blurring on the regions where the sensitivity profiles overlap (see circled region).

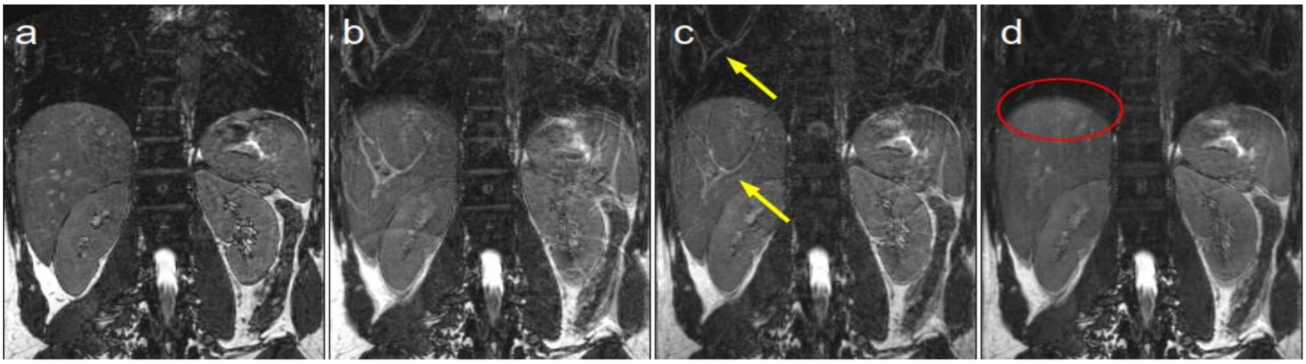


Fig 2: (a) Coronal slice from abdominal scan reconstructed (b) without motion correction, (c) with global-affine correction and (d) with multiple-region affine correction.

Conclusion: A novel reconstruction technique combining parallel imaging and k-space based motion correction has been proposed. Multiple region-affine motion compensations reduce the motion artefacts in the reconstructed image. Besides, we expect image quality improvement to depend on the selectivity of the coil-sensitivities, with regard to regions of motion. Further work will focus on porting this technique to SENSE reconstruction using the full potential of the 32-channel coil-array.

References: [1] Nehrke and Bornert, MRM 2005, [2] Griswold et al., MRM 2000, [3] Buerger et al., ISBI 2010