Improved Gradient Field Distortion Correction in Continously Moving Table Acquisitions Using GIRAFFE

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Introduction: Whole-body images can efficiently be acquired by continuously moving the patient table (CMT) (1). Unfortunately, B_0, gradient and B_1 field imperfections can all result in data inconsistency and lead to image artifacts (2,3). To reduce artifacts at source, it is common to limit the extent of the acquisition volume, and to traverse k-space in a linear fashion maximizing consistency between adjacent k-space lines (3). Small acquisition volumes reduce scanning efficiency and linear k-space ordering limits the choice of sequences and therefore contrasts attainable. Building on the reconstruction method proposed by Kruger et al. (4), an approach has been suggested by Polzin et al. (5) to correct for the effect of gradient non-linearities. We show here that although this reconstruction method is accurate enough when k-space is sampled in a linear way, its performance is poorer for segmented acquisitions. In both cases improved reconstructions can be obtained using instead the recently introduced GIRAFFE method (Generalised Image Reconstruction Accounting For Field Effects) (6) which uses an iterative reconstruction enforcing data consistency.

Methods: To compare the Polzin method (5) with GIRAFFE (6), simulations were performed by introducing a non-rigid image transformation to a gold standard simulated data set mimicking image distortion due to gradient non-linearities. Multi-slice coronal CMT acquisitions with both linear and segmented sampling schemes were simulated, with frequency encoding along the direction of motion. Using the Polzin approach, data corresponding to a single phase encoding (PE) step is firstly corrected for sub-pixel motion. This is followed by zero-filling and a 2D Fourier transformation. The resulting image is corrected for distortion and subsequently for integer pixel motion. The process is repeated for all PEs and the intermediate complex images are added together (5). With GIRAFFE, a forward model g is constructed which represents all steps leading from the unknown object s_0 to the collected k-space data S (S=g s_0). The model can include all a-priori knowledge of any field imperfections. The images are reconstructed using an iterative approach (conjugate gradient) which requires only the functional equivalents to each intermediate step to be known (and their hermitian conjugate - inverse image transformation in the case of gradient distortions) – (6).

Results: Reconstructions of the simulated data are shown in Figure 1. The performance of both methods was similar when a linear sampling scheme was employed (upper row Figure 1- c) to k)), with GIRAFFE performing slightly better with lower residuals – Figure 1 – i) and k). However, GIRAFFE's reconstruction was clearly superior for the segmented acquisition (lower row Figure 1 - d) to l)) as confirmed by comparing the residuals in both cases - Figure 1 - j) and l) - scaling consistent for the two methods, but different for the two sampling schemes.

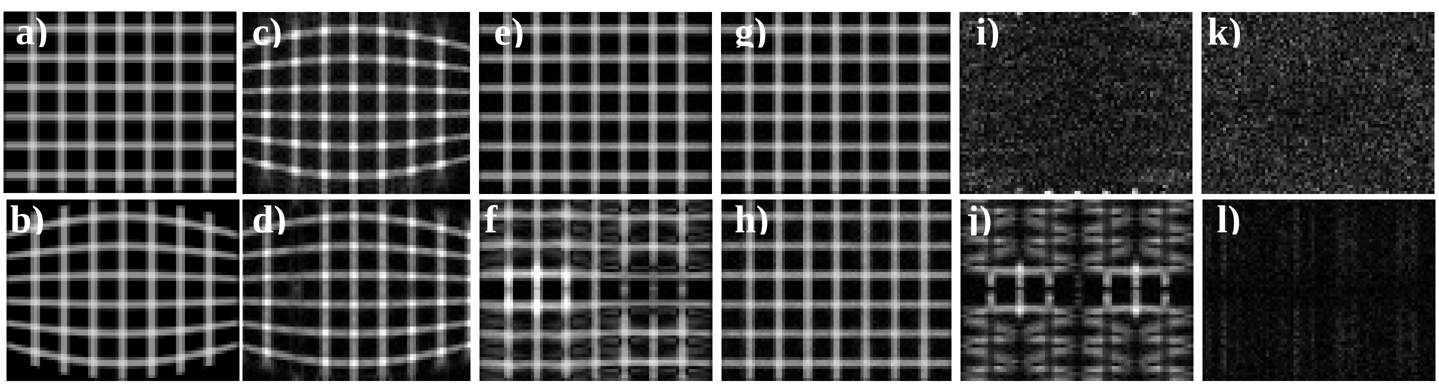

Figure 1- CMT in the presence of phase errors (linear variation of π along FOV_{read}) and gradient field distortions – a) gold standard; b) distorted image. Motion and readout directions left to right. c)-k) linear sampling order; d)-l) interleaved (2 segments); c),d) uncorrected; e),f) corrected using the Polzin approach; g),h) corrected with GIRAFFE; i),j) absolute residuals corresponding to e) and f); k),l) absolute residuals for GIRAFFE reconstruction.

Discussion and Conclusions: The performance of two reconstruction methods designed to correct for the effect of gradient non-linearities in CMT acquisitions was compared. They were shown to have a similar behavior when k-space was traversed in a linear order. However, GIRAFFE produces less reconstruction artefact in the case of segmented acquisitions, demonstrating that the use of an appropriate mathematical framework is essential to fully account for field effects in CMT acquisitions. Using GIRAFFE should allow higher levels of field imperfections be tolerated, leading to increased scanning efficiency and more sequence design flexibility.

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References: (1) O Dietrich et al, ISMRM 1653 (1999); (2) DG Kruger et al, MRM 54:712 (2005); (3) Aldefeld B et al., ISMRM, 102 (2004); (4) DG Kruger et al, MRM 47:224 (2002); (5) Polzin JA et al., 2004, MRM, 52:181; (6) Nunes RG et al., ISMRM, 975 (2007); (7) http://fsl.fmrib.ox.ac.uk/fsl/fnirt.