Motion compensated reconstruction for free breathing dynamic constrast-enhanced MRI

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INTRODUCTION:

In contrast-enhanced MRI, medical diagnosis is often compromised by the motion, the need for registration and the difficulty of sustaining a breath-hold. A previously published motion correction algorithm GRICS (Generalized Reconstruction by Inversion of Coupled Systems) [1] has proven to correct for motion artefacts successfully in images acquired with a wide set of sequences, though restrained to images without global or local contrast change. Dynamic contrast-enhancement (DCE) GRICS generalizes GRICS with the purpose of taking into account local contrast changes and performing free-breathing motion correction in contrast-enhanced MRI.

METHODS:

Given in entry the raw data (complete k-space, NEX>1, multi-coil system) and physiological respiratory signals, GRICS reconstructs the wanted image corrected for motion artefacts and yields in addition spatial distortion maps u_x and u_y (eq. 2) . The equations set and solved by GRICS (eq.1) assume the intensity of the true image ρ_0 does not change in time.

In order to overcome this restriction, the true image ρ_0 is replaced by a linear dynamic contrast model (eq. 3) analogously to the motion model (eq. 2), where $S_i(t)$ are ideally independent functions of time, strongly correlated with different local contrast changes in the image. Introducing this model, all the equations and approximations used and derived in GRICS are satisfied and equally true.

In order to validate this approach, the contrast change model was simplified by taking two basic functions, $S_1(t)=1$ and $S_2(t)=\Theta(t-t_0)$, assuming that there is no contrast change during the acquisition of one image. This model was applied to an experiment imitating dynamic contrast-enhancing series of both kidney and cardiac images. Images were acquired on a 1.5T scanner (Signa HDx, General Electric, Milwaukee, WI) on two healthy volunteers. In the first experiment an SSFP sequence was used to acquire free-breathing images of kidneys with and without tubes of various T1 attached to the stomach. In the 2nd experiment the same procedure was carried out on long heart axis with ECG-gated DIR-FSE sequence. Physiological respiratory signals from 2 bellows were acquired in both experiments. The reconstruction was accomplished using a set of 4 full k-space data, two with tubes before t_0 and two without tubes after t_0 . Since the requirements for temporal and spatial resolution in DCE-MRI are quite high in clinical settings, a full NEX=2 acquisition could be inappropriate. Therefore, a reconstruction with simulated undersampled data set was performed, aiming at reducing the acquisition time: for both the image with and without tubes one complete and one incomplete k-space was taken (NEX=1.5, NEX=1.125 etc.).

$$\begin{cases} s = E(\alpha)\rho_0 \\ \varepsilon(\rho_0,\alpha,\delta\alpha) = R(\rho_0,\alpha)\delta\alpha \end{cases} \quad \text{(eq.1)} \qquad \begin{cases} u_x = \sum_k \alpha_{xk} S_k(t) \\ u_y = \sum_k \alpha_{yk} S_k(t) \end{cases} \quad \text{(eq.2)}$$

$$\rho_0 = \sum_i \beta_i S_i(t) \quad \text{(eq.3)}$$

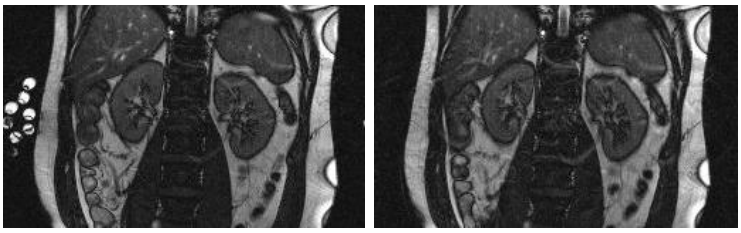

Fig 1: Conventional reconstruction of the DCE test series

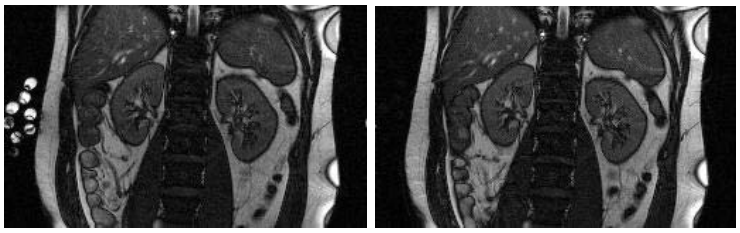

Fig 2: DCE-GRICS reconstruction of the test series

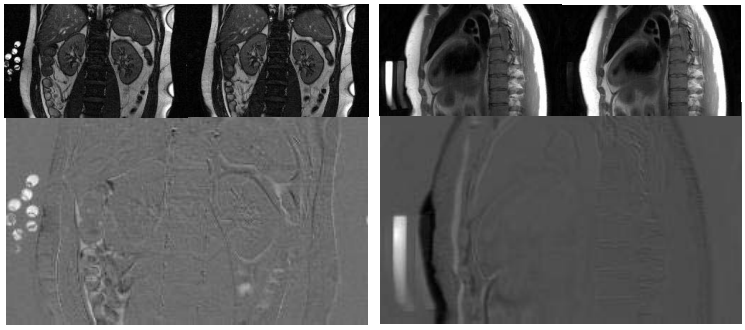

Fig 3: Substraction of the DCE-GRICS reconstructed kidney (left below) long axis cardiac images (right below) with and without tubes - contrast change map

RESULTS:

Both kidney and cardiac images reconstruction performed motion artefact correction and yielded in addition to distortion maps a contrast change map, which enables the reconstruction of both the image with and without external tubes. The conventional reconstruction of the 4 full k-space series of contrast-changing kidney images (Fig 1) presents slight blurring and motion artefacts, mostly kidney replicas. The series reconstructed with our method (Fig 2) is much sharper and motion artefacts almost completely disappeared. The contrast change map (Fig 3 a)) shows important changes in tubes and in intestines area (peristaltic intestine motion causes out-of-slice phenomenon). The experiments with k-space undersampling accomplished similar results for NEX=1.5, whereas stronger undersampling produced worse results.

DISCUSSION:

An immediate application of the presented method could be in substraction imaging, where the reconstruction of images acquired before and after contrast agent injection would result in images with no motion artefacts automatically registered to the mean physiological position. The promising results with more frequent acquisition of central k-space lines opens possibilities for combination with different sampling schemes (k-t, TRICKS, etc.), in order to optimize abdominal and cardiac perfusion imaging, taking into account the need for high temporal and spatial resolution in DCE-MRI. Following applications are multiple: 1) reconstruction of a whole DCE sequence using this method in a sliding window manner, 2) creation of a generalized contrast change model comprising $S_i(t)$ correlated with contrast change over a long DCE-MRI sequence, opening possibilities for an automatic extraction of $S_i(t)$ and subsequently for the segmentation of differently enhancing compartments, the main goal being motion artefact correction in 2D and 3D dynamic contrast-enhanced MRI.

REFERENCES: 1. Odille *et al.*[2008] MRM. 60:146-157 **2.**Tsao *et al.* [2003] MRM. 50:1031-1042