PRELIMINARY STUDY ON MOTION CORRECTION IN MODEL-BASED MR THERMOMETRY

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Target Audience
Scientists and clinicians interested in MR Thermometry.

Purpose
Goal of this work is to correct intra-frame motion artifacts in model-based MR temperature mapping [1]. Compared with the prevalent PRF phase-mapping methods, the model-based method estimates temperature information from multi-echo signal model, thus eliminates the effects of field drifts and inhomogeneity, and is robust to inter-frame motion. However, the model-based method suffers a relatively long acquisition time and is therefore sensitive to intra-frame motion. We addressed this problem by introducing motion model into multi-echo image reconstruction to correct motion-induced phase distortion and image artifacts. Simulation results based on water-fat mixed phantom demonstrated the feasibility and efficiency of the proposed method.

Methods
Model of multi-echo acquisition: We model the acquisition of each echo as:
$$k_j^i = D_i F_s S_{i,j} T_i f \quad (1)$$
Where k_j^i is the acquired k-space by j^{th} coil at time $= i$, $S_{i,k}$ is the corresponding sensitivity map, D_i is down-sampling operator, F_s is spatial Fourier Transform, T_i is motion model. The full k-space k_j is a summation of k-space segments acquired at different time points:
$$k_j = \sum k_j^i = \sum_i D_i F_s S_{i,j} T_i f = e_j f \quad (2)$$
Stacking all the coils together, we get $\quad K = Ef \quad (3)$
Where $K = (k_1\ k_2\ ...\ k_{Ncoil})^T$, $E = (e_1\ e_2\ ...\ e_{Ncoil})^T$. E is a generalized encoding operator [2].
Image reconstruction and temperature estimation: Images of each echo are reconstructed by solving:
$$\hat{f} = argmin\ \|Ef - K\|_2^2 \quad (4)$$
Temperature of each voxel is then estimated through fitting to a multi-echo signal model [1].
The key assumption here is the motion is periodic, therefore we can acquire the motion models and sensitivity maps through a preparatory fast scan (e.g. true-FISP) prior to the multi-echo acquisition. The assumption is valid for abdominal imaging where respiratory motion is the dominant factor that impacts temperature mapping. Navigator information can be used to map the measured multi-echo k-spaces to their corresponding pre-acquired motion models.

Simulation setup: 16-echo data of water-fat mixed phantom [1] was acquired with mFFE sequence on a Philips 3T system (Philips Healthcare, Best, the Netherland) with an 8-channel head coil (Invivo Corp, Gainesville). Translational motion during acquisition was simulated via Matlab (MathWorks Inc., Natick, MA). Here we assumed that the full k-space was acquired with four interleaved subsets corresponding to the moving object, as shown in Fig. 1. Vertical and horizontal displacements (in pixels) of each subset are (0, 0), (3, 4), (4, -6), (6, 9). Motion models were acquired via affine registration.

Results
Fig.2 shows the results of simulation. The RMSE of estimated temperature maps are (from Fig. 2b to Fig. 2d) 66.03%, 55.92%, 4.67%. Severe distortions can be observed in direct Fourier reconstruction and SENSE without motion model, while the proposed method drastically removes the artifacts.

Discussion
Simulation results demonstrated the efficiency of proposed method. Compared to direct Fourier reconstruction and SENSE without motion model, the proposed method tremendously improves the accuracy of temperature estimation by incorporating motion models into reconstructoin. In-vivo experiments are under way to further investigate the effiency of proposed method in the context of respiratory motion.

Conclusion
We present a novel framework to correct motion induced errors in model-based MR temperature mapping.

References :
[1] Cheng Li et al., Magn Reson Med, 2009, 62(5):1251–1260. [2] Freddy Odille et al., Magn Reson Med, 2008, 60(1): 146-157.
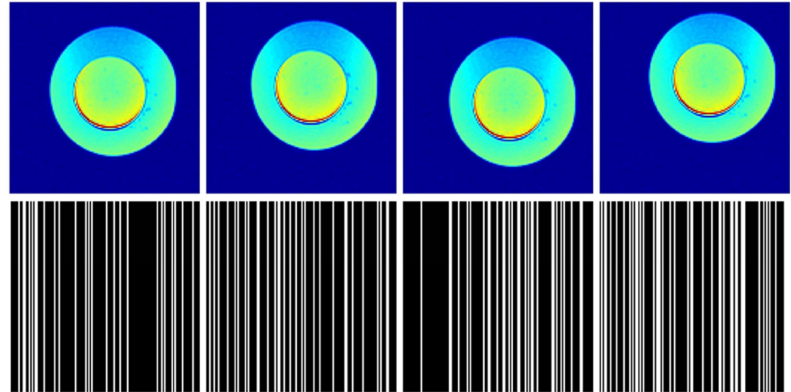
Figure 1. Simulated translational motion of water-fat mixed phantom and corresponding k-space samples.
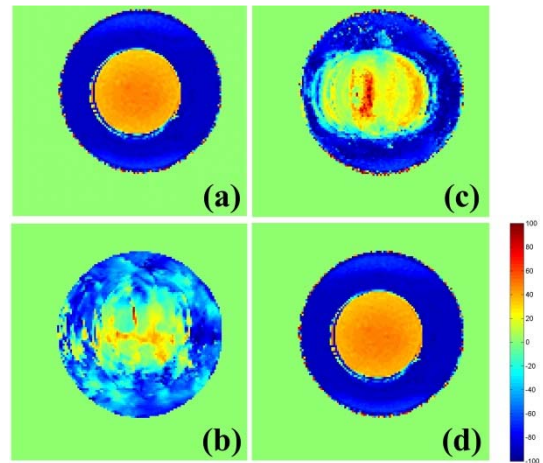

Figure 2. Estimated temperature maps in simulation: (a) reference; (b) direct Fourier reconstruction; (c) SENSE without motion model; (d) proposed method.