CARDIO-RESPIRATORY MOTION ESTIMATION FOR COMPRESSED SENSING RECONSTRUCTION OF FREE-BREATHING 2D CINE MRI

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Respiratory motion is still an issue in MRI of the heart despite the introduction of Compressed Sensing (CS) techniques, which significantly accelerate acquisition [1]. Recently [2], a *double-binning* scheme was introduced in which k-space data is split according both to the cardiac and respiratory phases (Fig. 1); at reconstruction, sparsity along both dimensions is exploited. Other methods introduce motion estimation and compensation in CS (MC-CS) either to correct the respiratory motion [3] or to promote sparsity for reconstruction improvement [4]. In this work, we propose a technique to jointly estimate the respiratory and cardiac motions within a *double-binning* scheme, enabling the MC-CS reconstruction of respiratory resolved free-breathing 2D CINE MRI. Preliminary results on synthetic, highly undersampled (x16) Cartesian setup are shown.

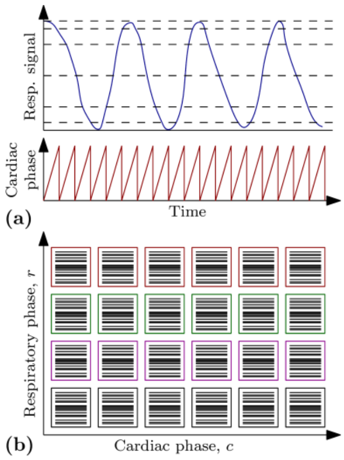

Fig 1. Respiratory and cardiac signals (a) are used to bin the acquired data (b).

Motion estimation: We model the cardio-respiratory motion as the composition of two spatial deformations, $\Phi^{R,C}_{r,c} = \Phi^{R}_{r} \circ \Phi^{C}_{c}$, where Φ^{R}_{r} stands for the respiratory deformation at the respiratory state r and Φ^{C}_{c} for the cardiac motion at the cardiac phase c [5]. Both models are based on free-form deformations and a groupwise registration procedure [4]. We define the MC operator $\Phi^{R,C}$ that, when applied to the dynamic image $\mathbf{m}$, deforms it to a common cardio-respiratory configuration.

Reconstruction: We introduce $\Phi^{R,C}$ in the MC-CS reconstruction problem and solve:

$$\underset{\mathbf{m}}{\text{minimize}} \frac{1}{2} \|\mathbf{y} - \mathbf{E}\mathbf{m}\|_2^2 + \lambda \|\nabla_{RC} \Phi^{R,C} \mathbf{m}\|_1$$

where $\mathbf{y}$ is the acquired data, $\mathbf{E}$ the encoding operator and ∇_{RC} for the temporal total variation, computed along the respiratory and cardiac dimensions after MC.

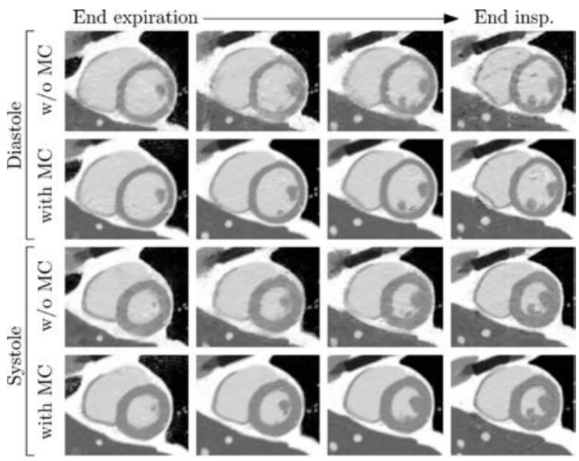

Fig 2. Results with and w/o the proposed MC for four respiratory states (left to right) at diastole (top) and systole (bottom).

Results: Figure 2 shows the results obtained both without MC and with the proposed method. Recovered motion is more realistic with MC and contours are sharper even though some artifacts are visible; they can be easily eliminated with additional spatial regularization [6]. Extension to 3D can also get rid of through-plane artifacts observed, and enable its application to whole heart coronary MR angiography [7].

References: [1] Lustig et al. MRM 2007, [2] Feng et al. MRM 2015, [3] Usman et al. MRM 2013. [4] Royuela-del-Val et al. MRM 2015. [5] Jantsh et al. ISBI 2013. [6] Royuela-del-Val et al. MRM 2016. [7] Piccini et al. MRM 2016.