

### 3D Free-breathing Abdominal MRI using Robust Navigator Processing with Coil Clustering

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**Purpose:** 3D free-breathing abdominal MRI is often limited by respiratory motion. Various motion compensation (MC) methods have been proposed to reduce motion artifacts. Accurate motion tracking is crucial to achieve effective MC for any method. Some acquisition trajectories, such as modified Cartesian (Butterfly) and radial, can provide self-navigating signals during data acquisition [1-2]. This enables retrospective MC. With phased array coils, individual navigators can be acquired for each coil element. The averaged navigator from all coils is often used for MC. However, since navigators from different coil elements track motion in local regions that can vary significantly, averaging all navigators sometimes yields inaccurate respiration estimation, and therefore ineffective MC. The ideal approach is to select the navigators that track respiration for MC, but it usually cannot be achieved automatically. Here, a robust navigator processing technique using coil clustering is described to automatically create a composite navigator for respiratory MC from coil arrays.

**Methods:** To illustrate the concept of coil clustering, the Butterfly navigator [2] is used for the rest of this work. An example of a multi-coil MR Urography (MRU) dataset is shown in Fig 1. Navigators from different coil elements vary significantly (Fig 1a). To select the subset of coils whose navigators best represent respiration, we assume: (1) respiration is the dominant motion and is measured by multiple coils; (2) navigators from those coils are highly correlated. Then the problem of finding respiratory motion can be equivalently formulated as finding the largest coil cluster, within which navigators from every two coils are highly correlated:

$$\max_{S \subseteq \{1, 2, \dots, N\}} |S|, \text{ subject to } |\rho(d_i, d_j)| > t, \forall i, j \in S$$

where  $|S|$  is the number of coils within the coil subset (coil cluster)  $S$ ,  $N$  is the total number of coils,  $d_i$  and  $d_j$  are navigators from coil  $i$  and  $j$ ,  $\rho(d_i, d_j)$  is their correlation coefficient, and  $t$  is a threshold (e.g., 0.9). To solve this problem, a spectral clustering method with the following steps is developed:

1. Calculate the navigator correlation matrix  $C$  (Fig 1b), where  $C(i, j) = \rho(d_i, d_j)$
2. Construct correlation graph  $G$  (Fig 1c) by thresholding, such that:  
 $G(i, j) = 1$ , if  $|C(i, j)| > t$ ;  $G(i, j) = 0$ , otherwise.
3. Perform eigen-decomposition of  $G$ :  $G = USU^T$
4. Coil clustering based on the first eigenvector:  
 $i \in S$ , if  $|u_1(i)| > t_2$ ;  $i \notin S$ , otherwise.

where  $u_1$  is the eigenvector corresponding to the largest eigenvalue, and  $t_2$  is another threshold (e.g., 0.1).

The estimated correlation graph after coil clustering is shown in Fig 1d. The navigators within the coil cluster represent the respiratory motion.

**Results:** The proposed method has been validated on a MRU dataset shown in Fig 2. The individual navigators from all coils are plotted in Fig 2a and the selected navigators within the coil cluster are highlighted. The average navigators from all coils and within the coil cluster are shown in Fig 2b. Coil clustering can achieve more robust respiratory motion estimation. MC using soft-gating [3-6] with the proposed method achieved better image quality compared to no soft-gating and soft-gating with the averaged navigator from all coil elements (Fig 2c).

**Discussion:** When navigators along multiple axes are acquired, coil clustering should be individually performed on each axis. The averaged navigators within the coil cluster along each axis can be combined using square root of sum of squares for MC.

**Conclusion:** Robust navigator processing using coil clustering has been proposed in this work. The proposed method can achieve better motion compensation for abdominal MRI with coil arrays.

**References:** [1]. L Feng, et al. ISMRM 2013, p606. [2] J Cheng, et al. Magn Reson Med 2012; 68:1785-1797. [3] K Johnson, et al. Magn Reson Med 2012; 67:1600-1608. [4] J Cheng, et al. J Magn Reson Imaging 2014. DOI: 10.1002/jmri.24785. [5] T Zhang, et al. J Magn Reson Imaging 2014. DOI:10.1002/jmri.24551. [6] C Forman, et al. Magn Reson Med 2014. DOI: 10.1002/mrm.25321.

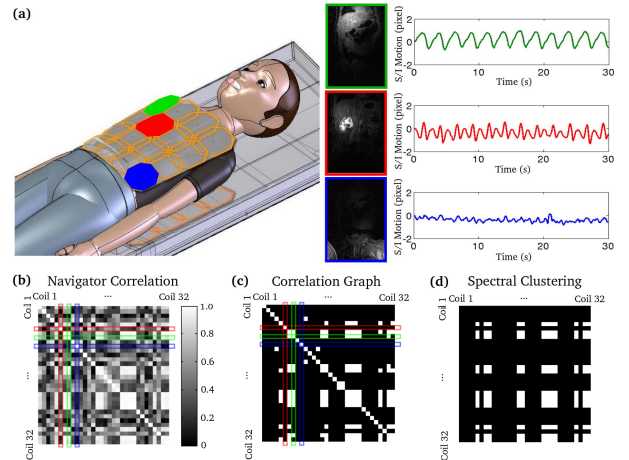


Fig 1. Demonstration of robust navigator processing with coil clustering: (a) 32ch coil array with Butterfly navigators from three representative coil elements, only one of which tracks respiratory motion well; (b) navigator correlation matrix of the 32ch coil array; (c) correlation graph formed by thresholding the correlation matrix; (d) correlation graph after spectral clustering. Selected coils in the cluster are highly correlated with each other, formulating an all-ones sub-matrix.

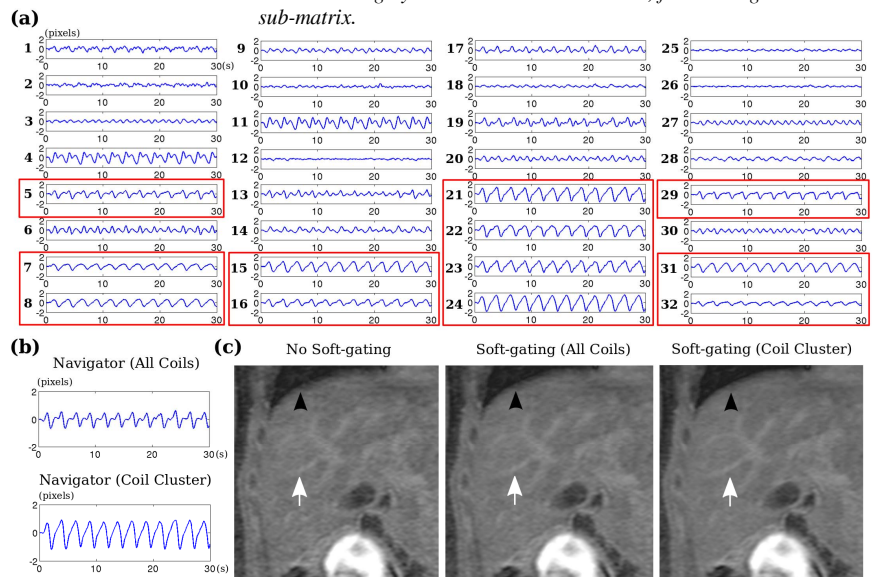


Fig 2. Example of robust navigator processing with coil clustering: (a) individual Butterfly navigators of a 32ch coil array. Selected navigators after coil clustering are highlighted; (b) averaged S/I navigator signals of all coils (top) and within the coil cluster (bottom); (c) locally low-rank parallel imaging reconstruction [5] of a MRU dataset without soft-gating (left), with soft-gating using the averaged navigator from all coils (middle) and within the coil cluster (right). Improved motion compensation has been achieved using robust navigator processing – note diaphragm (arrow heads) and branch portal veins (white arrows).