Accelerated MR Parametric Mapping for Tissue Characterization

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I. HEADING—MR parametric mapping is an important application in diagnostic imaging and biomedical research which quantitatively measures intrinsic tissue properties. However, its practical utility is often hampered by long data acquisition times. Recently emerged sparse sampling theory has shown great potential for accelerating MR data acquisition [1, 2]. In this abstract, we propose a new method based on joint partial separability (PS) and sparsity constraints to accelerate MR parametric mapping, and we demonstrate its efficacy through T_1 mapping via ultrashort echo time (UTE) MRI and T_2 mapping via spin echo (SE) MRI.

II. THEORY AND METHOD —To exploit spatiotemporal correlation and sparsity in a T_1- or T_2-weighted image sequence $\boldsymbol{\rho}$, we propose joint partial separability and sparsity constraints to constrain image reconstruction from highly undersampled data $\mathbf{d}$. Denoting imaging operator $\mathbf{E}$, spatial coefficients $\{u_\ell(\mathbf{r})\}$, and temporal basis functions $\{v_\ell(t)\}$, the problem is formulated as

$$\widehat{\boldsymbol{\rho}} = \arg\min_{\boldsymbol{\rho}\in\{\sum_{\ell=1}^{L} u_\ell(\mathbf{r})v_\ell(t)\}} \|\mathbf{d} - \mathbf{E}\boldsymbol{\rho}\|_2^2 + \lambda \sum_{\ell=1}^{L} \mathrm{TV}\big(u_\ell(\mathbf{r})\big), \qquad (1)$$

where the decomposition $\rho(\mathbf{r},t) = \sum_{\ell=1}^{L} u_\ell(\mathbf{r})v_\ell(t)$ represents the PS constraint, and $\mathrm{TV}(\cdot)$ represents the total variation constraint enforcing spatial transform sparsity. We use a specialized data acquisition scheme (e.g., the sampling pattern in [4]) to allow direct PCA determination of $\{v_\ell(t)\}$ from navigator data. Then, Eq. (1) can be efficiently solved by half-quadratic regularization with a continuation procedure [3]. Finally, contrast parameters of interest are determined from reconstructed contrast-weighted image sequences by a nonlinear least squares fitting procedure such as the Levenberg-Marquardt algorithm.

III. APPLICATION EXAMPLES —We first illustrate the effectiveness of the proposed method in accelerating T_1 mapping via UTE MRI of an *ex vivo* imaged rat heart. We performed retrospective undersampling and image reconstruction using the proposed method. Fig. 1 shows the T_1 maps estimated from 15 fully sampled flip angles (i.e., 15 time points), 2 fully sampled flip angles, and from the proposed method with 15 highly undersampled flip angles with data size equivalent to 2 fully acquired flip angles. The T_1 map from the proposed method shows much higher accuracy and SNR than the map from 2 flip angles.

We also evaluated the performance of the proposed method on accelerated T_2 mapping via multi-echo SE brain MRI. Fig. 2 shows the T_2 maps estimated from fully acquired data with 32 echoes (i.e., 32 time points), fully acquired data with 3 echoes, and from the proposed method using highly undersampled 32-echo data with data size equivalent to 3 echoes. Consistent with the previous case, the results demonstrate the superior performance of the proposed method for accelerating T_2 mapping.

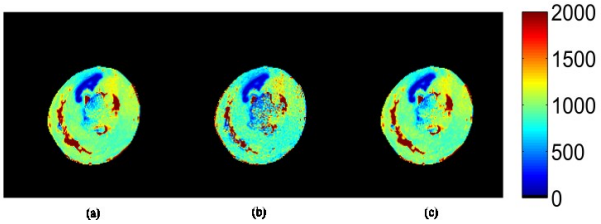

Fig. 1: T_1 maps via UTE MRI, estimated from (a) 15 fully sampled flip angles, (b) 2 fully sampled flip angles, and (c) the proposed method with 15 highly undersampled flip angles (7.5x acceleration).

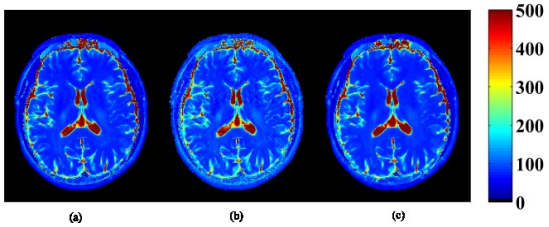

Fig. 2: T_2 maps via SE MRI, estimated from (a) fully sampled 32-echo data, (b) fully sampled 3-echo data, and (c) the proposed method with highly undersampled 32-echo data (10.7x acceleration).

IV. CONCLUSION—We have proposed a method for highly accelerated MR parametric mapping and illustrated its superior performance in two application examples. It should prove useful for a range of parametric imaging applications.

References

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This work was supported in part by the research grants: NIH-P41-EB001977, NIH-P41-RR023953, and NIH-R01-EB013695. B. Zhao (e-mail:bozhao1@illinois.edu), A. G. Christodoulou, W. Lu, and Z.-P. Liang are with the Beckman Institute of Advanced Science and Technology, University of Illinois at Urbana-Champaign. T. K. Hitchens, Y. L. Wu and C. Ho are with the Pittsburgh NMR Center for Biomedical Research and the Department of Biological Sciences, Carnegie Mellon University.