Debiasing incorporated into reconstruction of low-rank modelled dynamic MRI data

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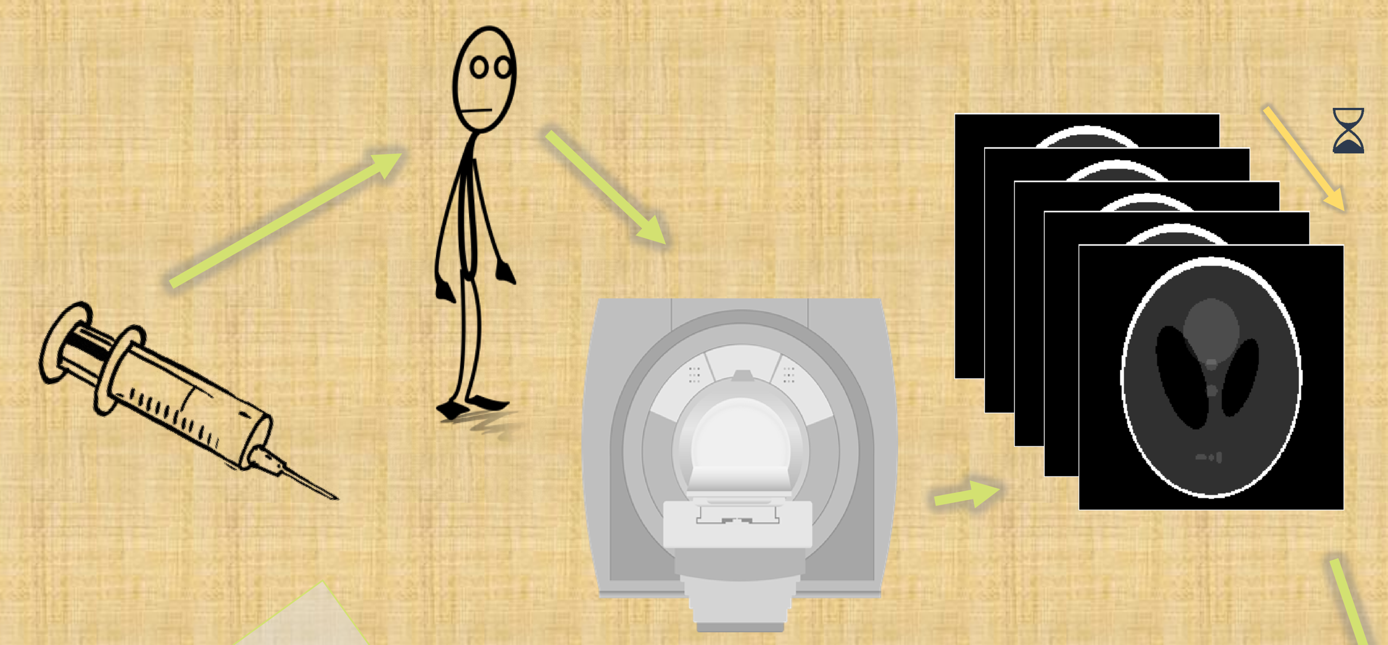
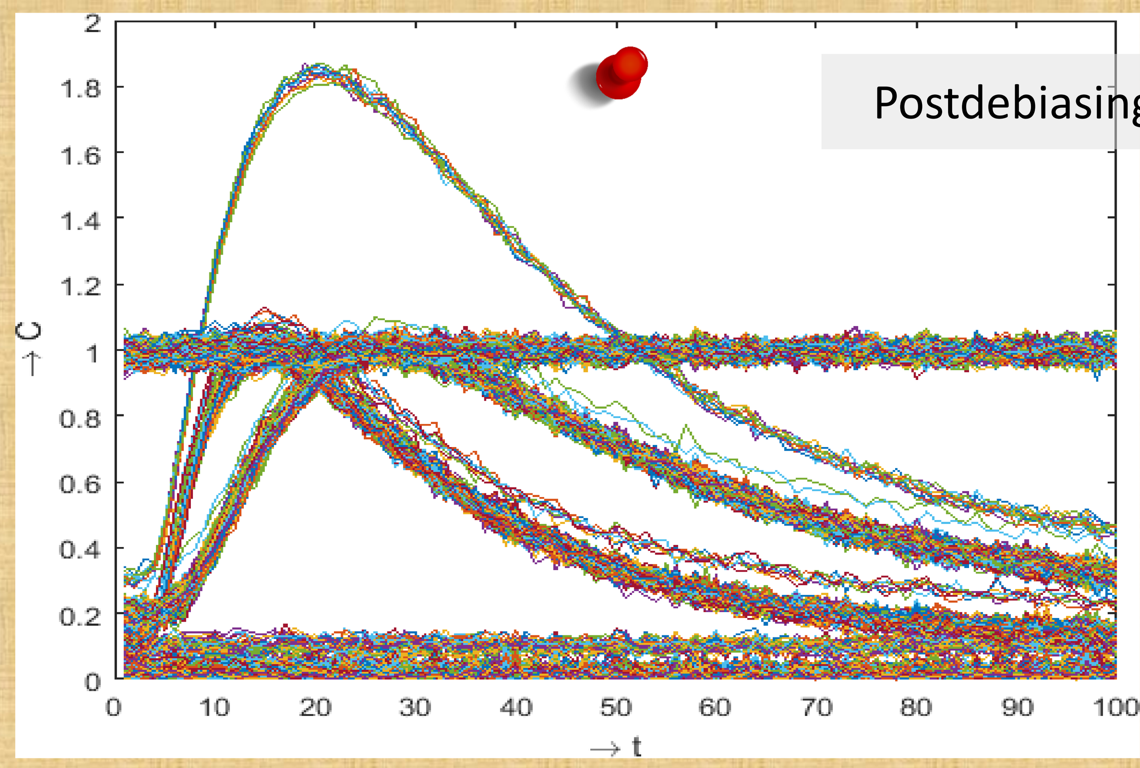
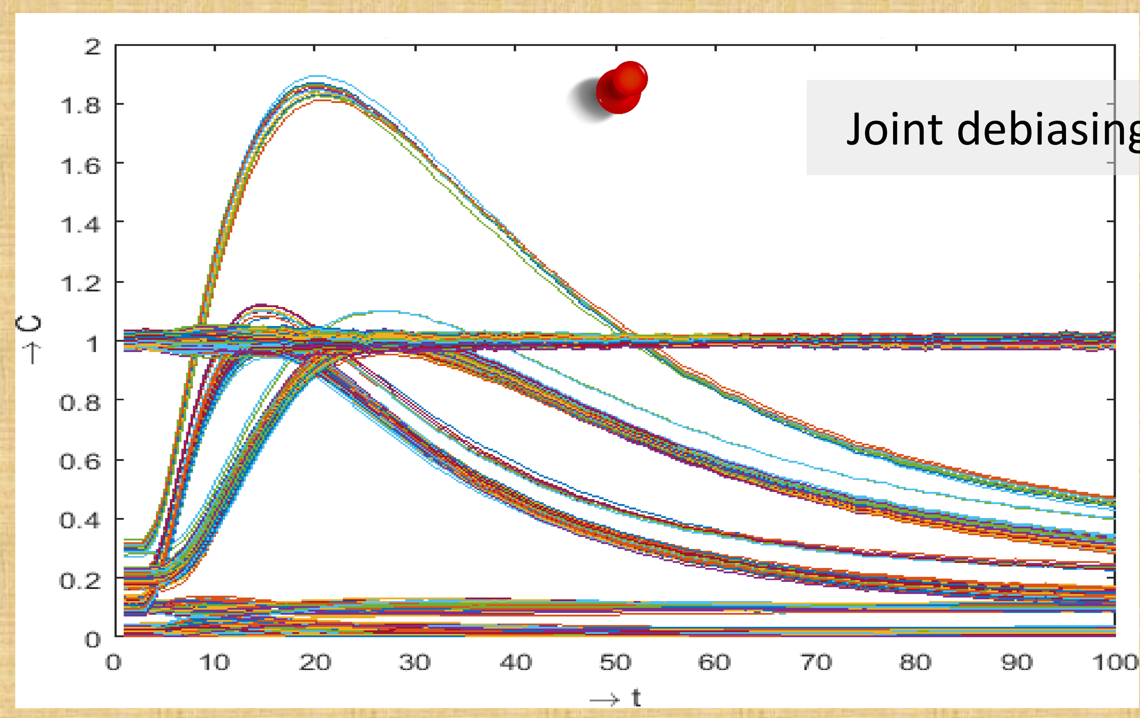


Introduction

- Perfusion is diagnostic method in medicine
- Reconstruction treated often as optimization problem (compressed sensing, CS)
- It gives biased estimates





Method

First step

Perfusion DCE-MRI reconstruction L

$$\arg\min_{\mathbf{L}} \frac{1}{2}\|\mathbf{Y} - E(\mathbf{L})\|_F^2 + \lambda\|\mathbf{L}\|_* \quad (1)$$

- Y is the matricized k-t-space data
- E is the respective subsampled Fourier transform
- Computed using proximal gradient algorithm
- After each iteration, SVD of $\mathbf{L}^{(k)}$ is known:

$$\mathbf{L}^{(k)} = \mathbf{U}^{(k)} \cdot \mathrm{diag}(\sigma_1^{(k)}, \sigma_2^{(k)}, \ldots, \sigma_r^{(k)}) \cdot \mathbf{V}^{(k)*}$$

Second step

Debiasing

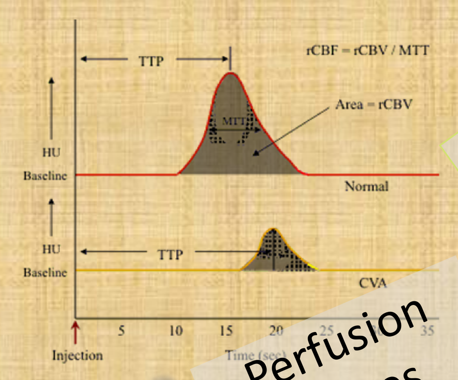
$$\arg\min_{\substack{\sigma_1,\sigma_2,\ldots,\sigma_r > 0 \\ \sigma_i \in \mathbb{R}}} \left\|\mathbf{Y} - E(\mathbf{U}_r^{(k)} \cdot \mathrm{diag}(\sigma_1, \sigma_2, \ldots, \sigma_r) \cdot \mathbf{V}_r^{(k)*})\right\|_F^2 \quad (2)$$

- Solved by repeating several times: gradient step w.r.t. σ_i and projecting result to real, non-negative values

Biased

Reconstruction using CS

Debiasing can help



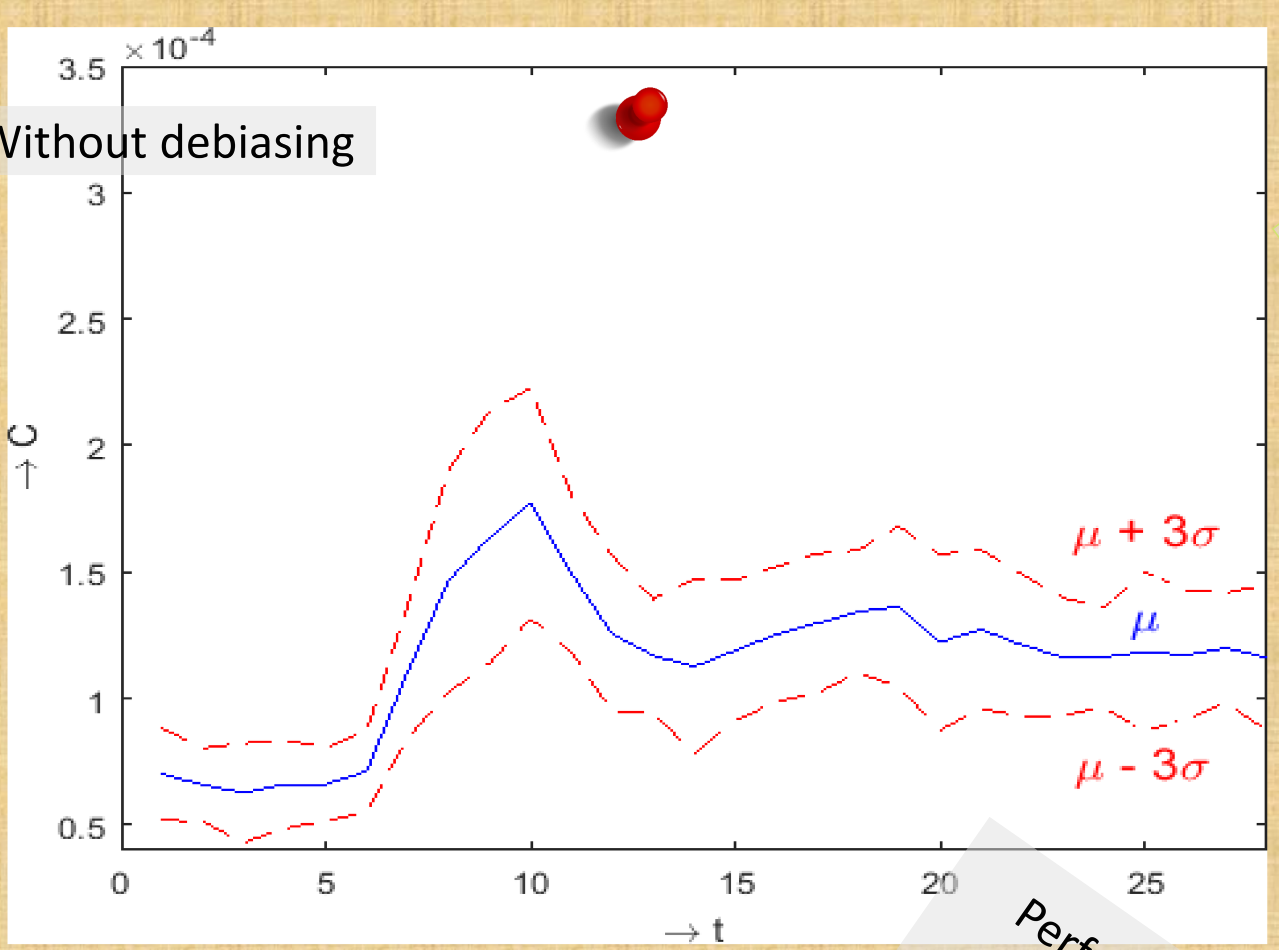
Perfusion curves

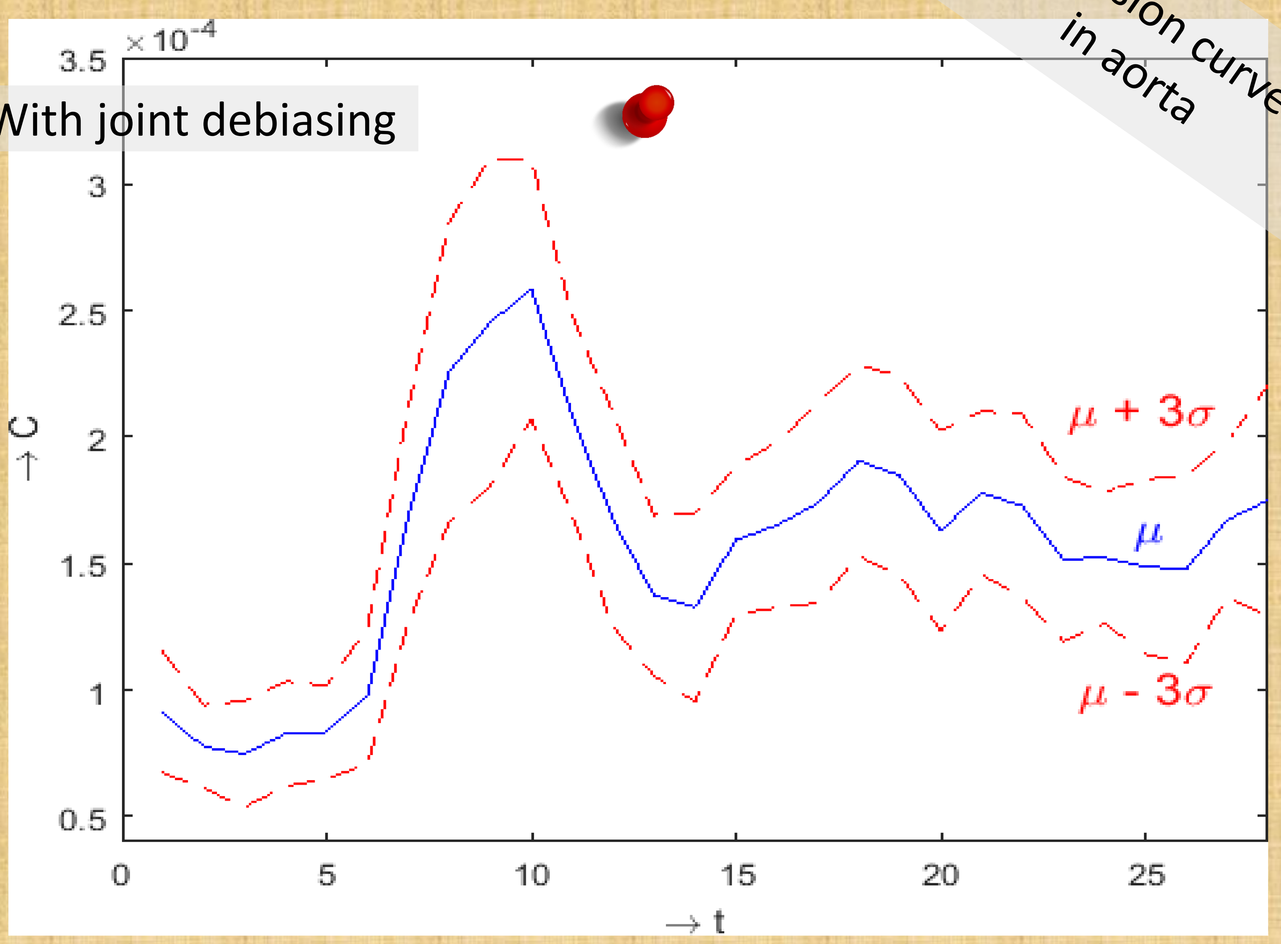
Diagnosis

Oncological and cardiovascular diseases

Simulation

- First evaluated on a Shepp-Logan modified to simulate perfusion [1] using Matlab
- Phantom of 100 × 100 px × 100 time points in size
- Perturbed by additive Gaussian noise with standard deviation 0.05
- Used 100 radials per frame with random slopes of spokes
- Using (1) with postdebiasing (2) led to worse reconstruction than joint debiasing algorithm

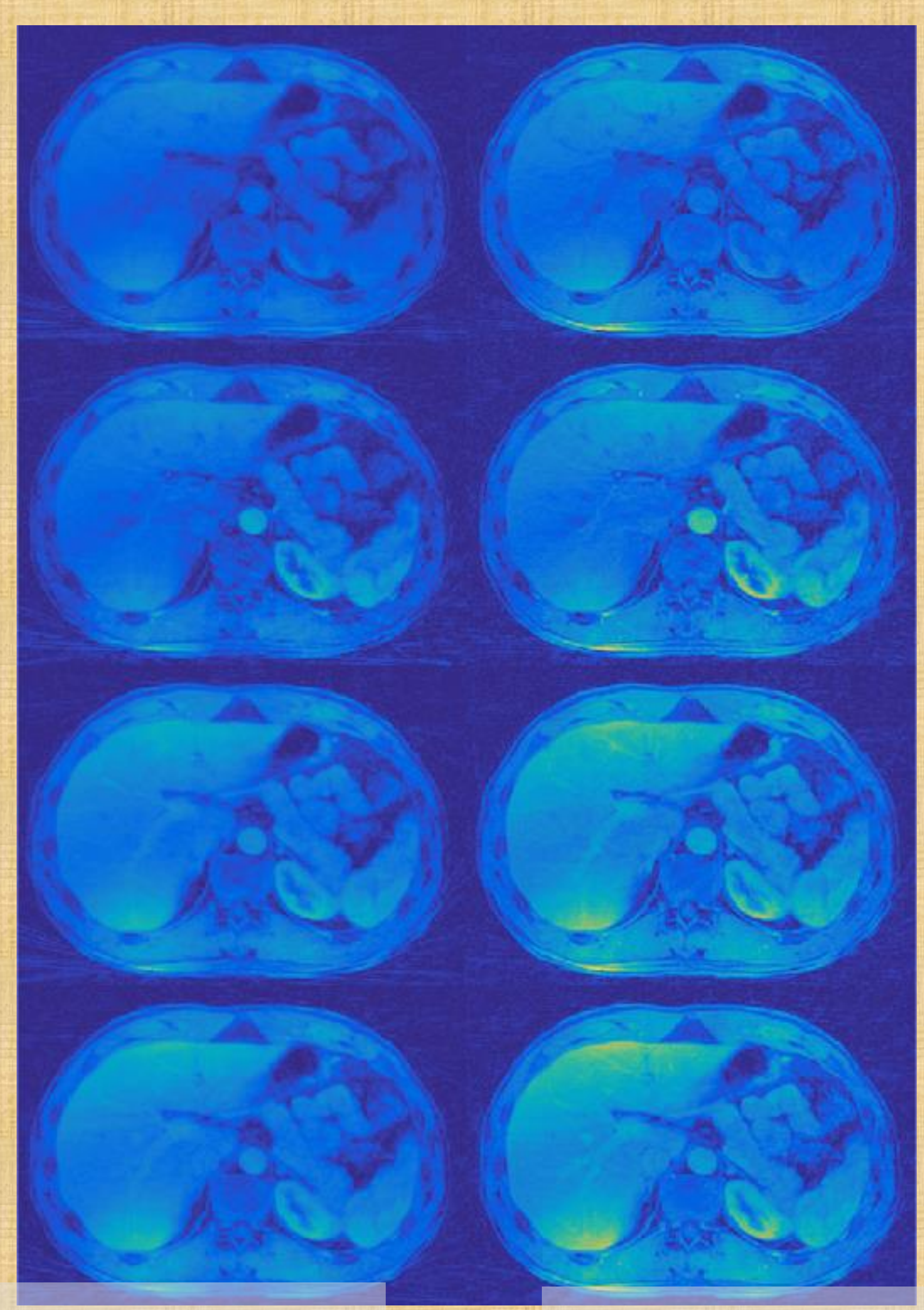




Perfusion curves in aorta

Real data

- Free-breathing abdominal DCE-MRI data [3]
- The acquisition used golden-angle scheme with a 12-element receiver coil array
- 21 golden-angle radial trajectories per frame were used
- With joint debiasing, perfusion curves enjoy higher initial peak and the second peak is more readable



Without debiasing — With joint debiasing

References

[1] Daňková, M.; Rajmic, P.; Jiřík, R.: Acceleration of Perfusion MRI Using Locally Low-Rank Plus Sparse Model. In Latent Variable Analysis and Signal Separation. Liberec: Springer, 2015.

[2] Ma, S.: Algorithms for Sparse and Low-Rank Optimization: Convergence, Complexity and Applications, Disertation thesis, Columbia University, 2011.

[3] Otazo, R., Candes, E., Sodickson, D.K. Low-rank plus sparse matrix decomposition for accelerated dynamic MRI with separation of background and dynamic components. Magnetic Resonance in Medicine, 73(3), 2015.