Image Reconstruction in Lower Extremities Perfusion Imaging: Combined Low-Rank Matrix-Completion and Image Segmentation

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INTRODUCTION

- Accurate measurement of lower leg perfusion is desired for assessing peripheral arterial disease.
- First-pass dynamic contrast enhancement (DCE) imaging is challenging:
  - **Large volumetric coverage** (30×15×32 cm^3, resol. 2.5×2.5×8 cm^3)
  - **High temporal resolution** (< 2 second)
- Low-rank matrix completion reconstruction combined with segmentation and parallel imaging enables highly accelerated 3DFT perfusion imaging.

METHODS

Propose to recover low-rank matrix X as [1-4]:

$$\text{argmin}_X \; \mu \sum_i \|X_{Si}\|_* + \|PFSX - y\|^2$$

X: reformatted image series, # of pixels by # of time frames S: coil sensitivity map
F: Fourier transform operator P: undersampling operator y: measured k-space data
$\|X_{Si}\|_*$: nuclear norm of X_{Si} (segmented images of X)

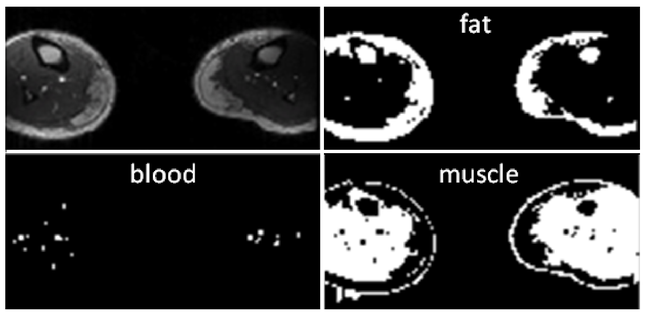

Figure 1. Segmentation map.

The segmentation is based on different dynamic behaviors: (1) blood: signal amplitude overshoot; (2) muscle: signal increasing with time; (3) fat: signal remaining static over time (Fig. 1). Mean-shift clustering and hierarchy clustering algorithm are used.

Segmentation improves low-rank property and avoids temporal blurring between different dynamic behavior, improving reconstruction accuracy.

The coil sensitivity is a constraint between the true image and the acquired data. Several time frames are fully sampled at the beginning and end of scan, from which the coil sensitivity map can be estimated. Higher acceleration factor can be achieved with combination of parallel imaging.

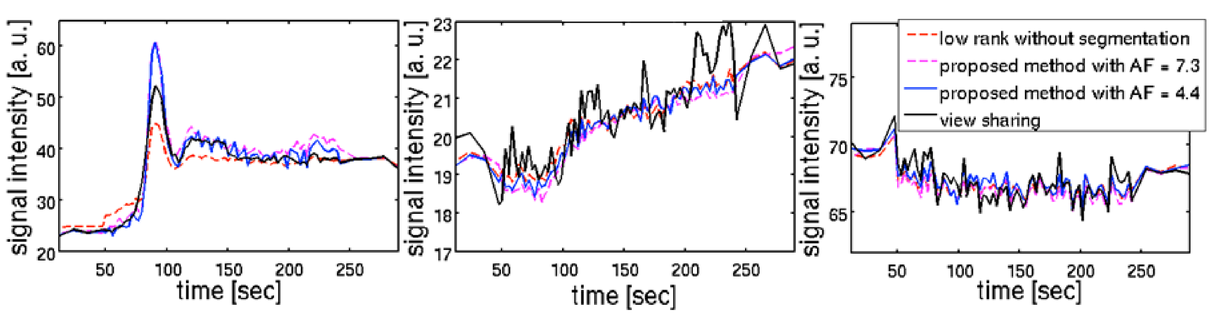

Figure 2. Time curves reconstructed with different methods [7] (single pixel in arterial, muscle and fat). The proposed method shows the least temporal blurring. Reconstruction with AF = 7.3 also agrees well with AF = 4.4, showing potential higher acceleration factor.

IN VIVO STUDIES

DCE images were acquired on a GE 1.5T scanner with a uniformly random undersampled 3DFT SPGR sequence with an 8-channel cardiac coil and the following parameters: TR/TE = 4.4/1.7ms, flip angle = 20, FOV = 36×18×32 cm^3, acceleration factor (AF) = 4.4, temporal resolution = 2.7 s. The dynamics of various tissues are clearly captured (Fig. 3 (b) (b)). As a semi-quantitative analysis, the maximum slope of signal rise and the Fermi impulse response [8] are shown in Fig. 3 (c) (d).

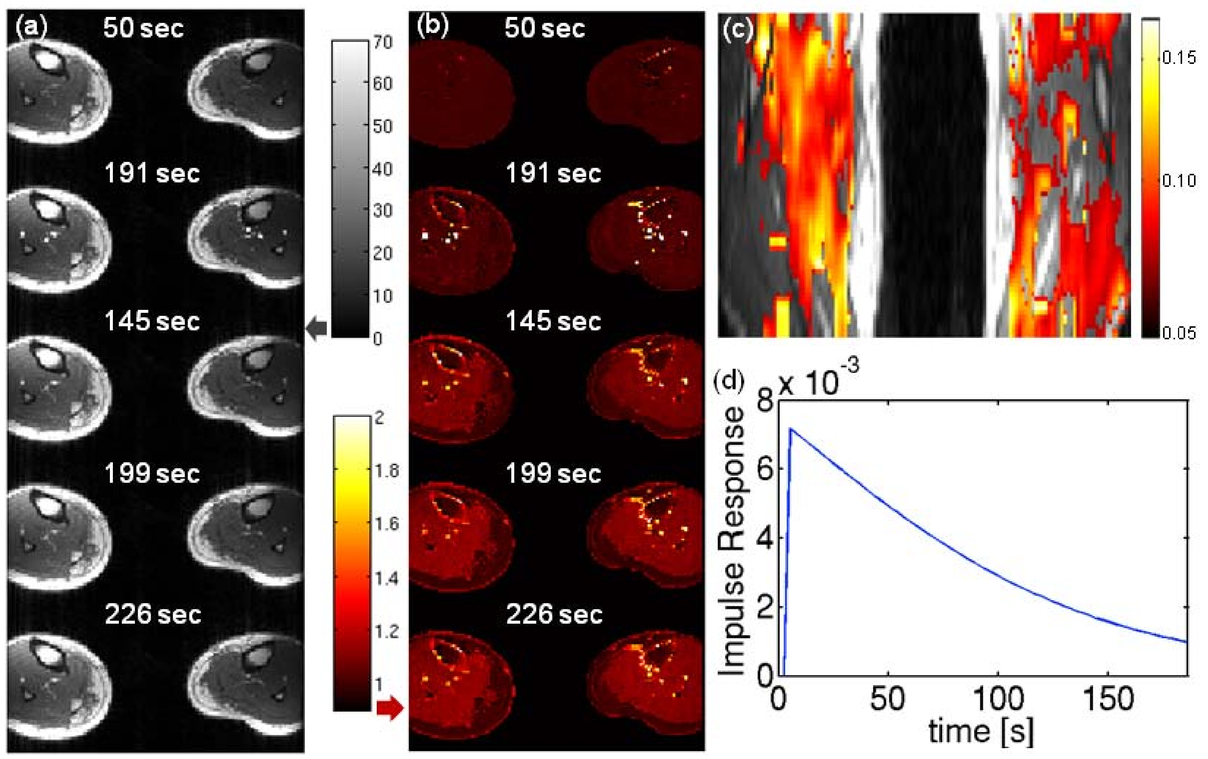

Figure 3. (a) Perfusion images of the center axial slice at different time. (b) Images normalized to average of 5th to 7th time frames (80 time frames in total). (c) Maximum slope (5×5 pixels^2 ROI) overlaid in the coronal image. (b) Impulse response estimated by Fermi deconvolution of normalized muscle signal intensity (5×5 pixels^2 ROI) with normalized arterial input.

CONCLUSION

Combined with **image-based segmentation** and **parallel imaging**, the low-rank matrix-completion method can achieve **better reconstruction accuracy** and **higher acceleration factors**. The proposed method can recover perfusion dynamics with less temporal blurring, and is promising for quantitative perfusion imaging in the lower extremities.

REFERENCES

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