Joint Reconstruction of Simultaneous PET/MR Imaging with Motion Correction Using a B-spline Motion Model

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Introduction

- PET/MRI provides the opportunity for simultaneous data acquisition from different modalities
- Try to reach the full potential of PET/MRI by integrating their information.
- Joint reconstruction (JR) of PET and MRI exploiting inherent similarity between different modalities
  - Structural similarity [1]
  - Joint sparsity under the same sparsifying transformation [2]
- One of the most significant causes of image blurring in whole-body PET/MRI
- Our method tries to extend structural similarity to similarity in motion between images of PET and MRI
  - Flexible model
  - Joint reconstruction with motion correction

Methods

Optimization problem

- Minimize the cost function

$$J = \sum_t \left\{ \sum_j \left[(AM(x,\omega_t))_j - f_{j,t} \log (AM(x,\omega_t))_j \right] + \frac{1}{2\sigma^2} \| BM(y,\omega_t) - k_t \|_2^2 \right\} + \alpha U(x,y) + \beta V(\omega)$$

- x, y : PET and MRI images in the reference frame respectively
- f, k : PET and MRI raw data
- A, B : PET and MRI imaging operator which can include geometric projection, attenuation correction and normalization
- M : Motion transformation operator parameterized by ω
- σ : standard deviation of the noise of MRI data
- U : JTV (joint total variation) of PET and MRI images [1]
- V : Laplace regularization

Motion model

- B-spline free deformation model is used in this study.
- ω is the control point grid of B-spline

Results

- To validate the proposed JRMC method, we performed both simulation and patient studies.
- Simulation studies were performed using an XCAT phantom [3], with respiratory motion. The simulation data were equivalent to a 9-min PET scan with 0.5 mCi injection dose. The simultaneous MRI simulation was performed with standard GRE sequence (TR = 9.56 ms, TE = 2.4 ms, flip angle = 12° and x3 acceleration). Fig1 (a) and (b) show the result of simulation studies.
- A patient study was performed on a whole-body simultaneous PET/MR scanner (Biograph mMR, Siemens Medical Systems, Erlangen, Germany). 7.38 mCi 18F-FDG was injected. First, an attenuation map for PET reconstruction was acquired using Dixon sequence and segmentation-based method. This was followed by a 9.5-min simultaneous PET/MRI scan. A golden angle Radial VIBE data set was acquired with TR = 4.01 ms, TE = 1.94 ms and flip angle = 12°. PET list-mode data were acquired in the meantime. Fig1 (c) and (d) show the result of the patient study.
- The proposed method, allow motion correction in joint reconstruction. The results show that the proposed method can reduce the blurring caused by motion in PET and MR images. In addition, the proposed model is flexible, for it is suitable for various MRI trajectories and different motion models.

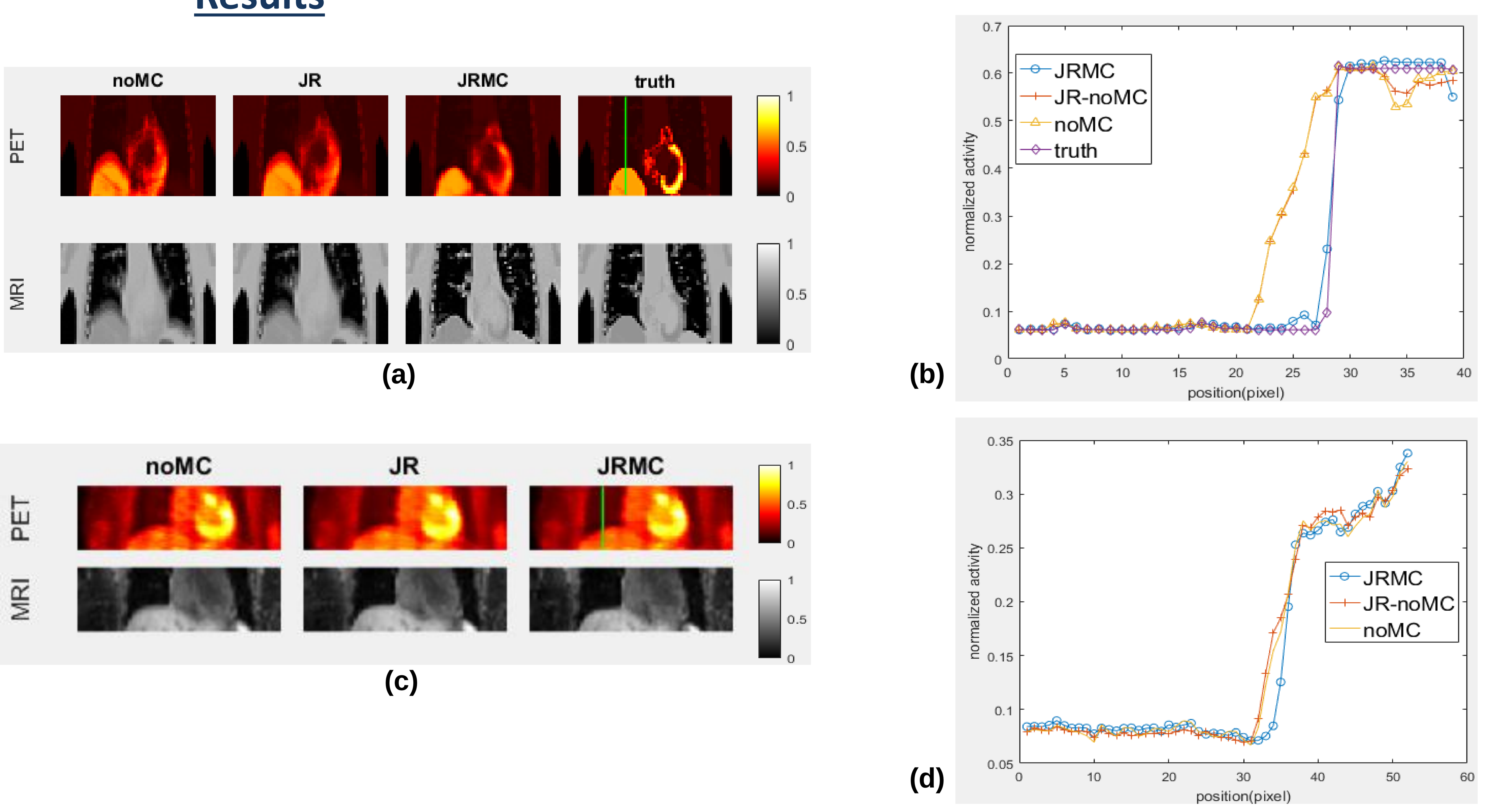

Fig 1: (a):PET and MR images reconstructed with 3 different methods (noMC: OSEM + NUFFT without joint reconstruction and motion correction, JR: joint reconstruction without motion correction, JRMC: joint reconstruction with motion correction) and the ground truth. (b): The profiles for the three reconstructed PET images and the ground truth of the line shown in the top right panel of (a). (c): PET and MR images reconstructed from clinical data using 3 different methods. (d): The profiles for the three reconstructed PET images of the line shown in the top right panel of (c).

Conclusions

We present a flexible PET\MRI reconstruction method, allowing motion correction in joint reconstruction. The results show that the proposed method can reduce the blurring caused by motion in PET and MR images.

References

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