4548

Iterative Residual Based Deconvolution Partial Volume Correction for Brain PET- MRI

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Target Audience:

Researchers and clinicians interest in PET and MRI image fusion and lesion contrast enhancement.

Purpose:

PET is a practical medical imaging technique for early tumor diagnosis. However, the relatively low spatial resolution of PET system limits its capability to detect small lesion in human brain. Partial Volume Effect (PVE) is one of the causes for low resolution of PET system which is usually defined as a convolution of real radioactivity concentration map with PVE kernel [1]. A small lesion will be obscured after it be blurred by PVE. Traditional Partial Volume Correction (PVC) methods like Region Based Voxel wised (RBV) [2] usually assume that the distribution of radioactivity within each tissue is uniform. However, the small lesions have a different radioactivity concentration compared with surrounding tissues, and traditional methods would overlook those small lesions. In this work, we used the residual of corrected image to iteratively correct PVE, and enhanced the lesion contrast.

Theory:

Mathematical Concept: Acquired PET images are generally defined as a convolution of actual distribution with the Point Spread Function (PSF) of PET system [3].

$$I_{obs} = I_{real} \otimes h$$

After traditional RBV correction, the difference between the actual distribution and corrected RBV image is defined as residual.

$$I_{corrected} - I_{real} = I_{residual}$$

Residual of PVE corrected image is therefore:

$$I_{residual} \otimes h = I_{corrected} \otimes h - I_{real} \otimes h = I_{corrected} \otimes h - I_{obs}$$

Then, the residual can be calculated by deconvolution:

$$I_{residual} = D(I_{corrected} \otimes h - I_{obs})$$

where D stands for deconvolution operator. The actual image is then restored by the following equation:

$$I_{real} \approx I_{corrected} - I_{residual}$$

Phantom Simulation: A brain MRI image and PET image were acquired simultaneously by a Simens mMR in *General Hospital, Beijing* (Figure 2). A simulated brain PET image was generated by segmenting MRI image and reassigning radioactivity values according to the segmentation. Since the acquired PET image did not have a reference, simulation phantom was used to validate our correction method. The MRI image was segmented into *12* parts by *Freeserver*. A 4*mm x 4mm x 4mm* cold lesion was added to evaluate the lesion recovery. To emulate the PVEs, the brain was convoluted by a PSF which obeys Gaussian function with *5.5mm* of radial and *6.0mm* of axial Full Width Half Maximum (FWHM).

Iterative residual deconvolution method (IRD): After Region-based voxel-wise (RBV) correction, a feedback network is applied to correct the lesions region. The algorithm flow chart is shown in Fig.1 with following steps:

1. Get an initialization RBV corrected image by conducting RBV correction on the simulated PET image.
2. Convolute the image with the PSF to get a blurred image
3. Calculate the difference (residual) between the blurred image and the simulated PET image which contained the PVE effect.
4. Subtract the initial image by the residual.

Repeat from step 2 until the RMSE convert to a target threshold.

Results:

Corrected simulation results and their error maps are shown in Figure.3. Low cubic lesion (high light Green cubic in Figure 3, zoom-in view included) is well recovered by IRD. Root Mean Square Error (RMSE) of the overall region and Region Of Interests region (ROI) which is 8 mm x 8mm x 8mm around the lesion is calculated in Table 1. It shows that IRD has lower RMSE in both overall and ROI region. Line Profile along x axis crossing the lesion is plotted in Plot 1. IRD corrected line profile fits the reference PET better. A clinical result is shown in Figure 4. An artificial added 4 x 4 x 4 mm lesion is well corrected (lesion region zoom-in).

Conclusion and Discussion:

In this work, we proposed an iterative PVC method based on the residual of PVC corrected image. Simulation PET results demonstrate that the proposed method has a better performance in detail feature recovery and lesion contrast enhancement. Clinical result shows better performance in lesion recovery while overall performance is hard to evaluate without the reference. Further study could be carried out on brain phantom experiment and a more noise-insensitive algorithm development.

Reference:

[1] Yang J, et al. IEEE Transactions, 1996.
[2]Thomas B A, et al. EJNMMI, 2011.
[3] Muller G, et al. J Ceeb Blood Flow Metab, 1992.

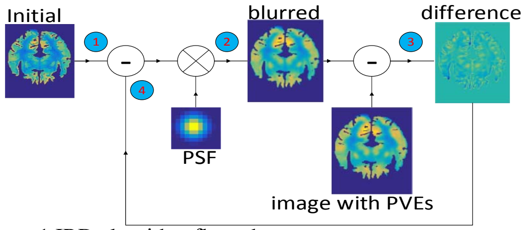


Figure 1 IRD algorithm flow chart

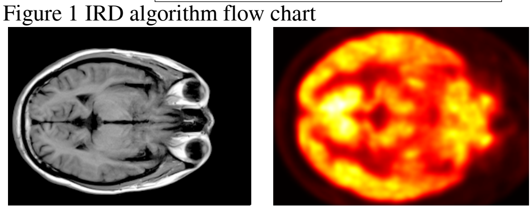


Figure 2 Simultaneous acquired MRI and PET image

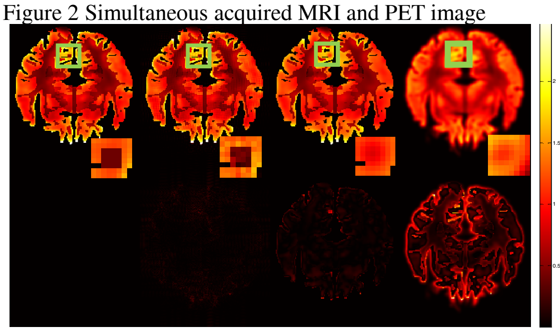
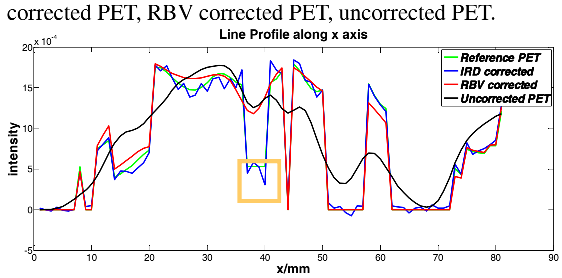


Figure 3 First row is corrected images and second row is their error maps. From left to right: Reference PET, IRD corrected PET, RBV corrected PET, uncorrected PET.



Plot 1 Line Profile. Lesion is highlighted by orange square.

	PVE	RBV	IRD
Overall	0.191	0.039	0.012
ROI	0.4137	0.2750	0.0872

Table 1 RMSE of PVE blurred, RBV corrected and IRD corrected PET in overall and ROI region

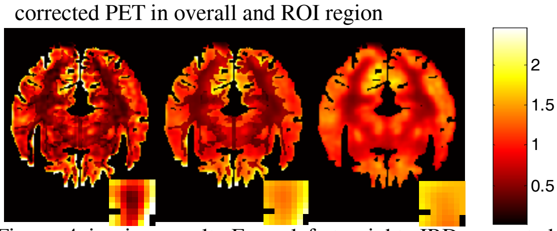


Figure 4 in-vivo result. From left to right, IRD corrected, RBV corrected, Uncorrected PET.