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Performance of 2½D Simultaneous Multislice Reconstruction from Fourier-Rebinned PET Data

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Introduction

True 3D reconstruction from fully 3D PET data has only a limited clinical use, because of its large computational burden. Rebinning of the fully 3D data into a set of 2D sinogram data reduces the 3D reconstruction into 2D reconstructions of decoupled 2D image slices, and thereby substantially reduces the computational demand, even if the 2D reconstructions are performed by an iterative reconstruction algorithm. On the other hand, the approximations involved in rebinning combined with the decoupling of the image slices cause a certain reduction of image quality, especially when the signal-to-noise ratio is low.

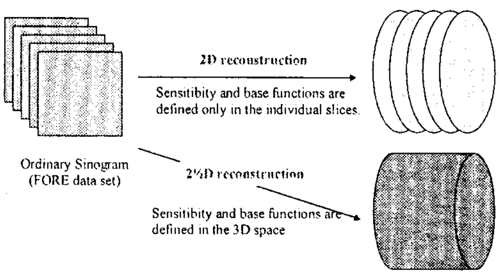

Figure 1. Concept of the proposed method

In the current paper, we are proposing a 2½D Simultaneous Multislice Reconstruction approach, which takes advantage of the time reduction due to the use of the FORE[1] data instead of the original fully 3D data, but at the same time uses a 3D iterative reconstruction approach with 3D basis functions. We compare the performance of the standard 2D iterative approach and of the proposed 2½D iterative approach. The results are evaluated based on several clinically-motivated image-quality measures. We also present a performance comparison of two 2½D iterative reconstruction methods differing in mathematical derivation; namely, an Algebraic Reconstruction Technique (ART) [2] and the Row Action Maximum Likelihood Algorithm (RAMLA) [3].

Reconstruction algorithms

The new 2½D approach proposed in this paper is based on the discrete mathematical model used by iterative reconstruction techniques. Our approach is discussed in [4], in which an image is represented as a linear combination of smooth and rotationally-symmetric bell-shaped basis functions, called blobs. For the standard 2D reconstruction from rebinned data, the blobs are defined as 2D functions located within the image slices and the reconstruction calculations are done in each image slice independently. In the true 3D reconstruction, the blobs are defined as 3D functions and the reconstruction is done in the whole 3D volume simultaneously. In the proposed 2½D approach, we use the true 3D iterative reconstruction technique (treating image slices as being coupled one to another), but employing only the rebinned data.

In our study, the data were rebinned by the FORE technique. The reconstruction techniques employed were ART and RAMLA, which are two inherently different techniques belonging to the class of the so-called row-action algorithms which update the reconstruction measurement-by-measurement (i.e., row-by-row of the system matrix).

Training of the reconstruction algorithms

As we implemented them, both ART and RAMLA have two free parameters: the number of times they cycle through the data and a relaxation parameter. The choice of these influence the resolution and noise properties of the resulting reconstructions. For optimal performance, as given by a particular image-quality measure or clinical task, a search (called the training of the algorithm) for the optimal parameter values has to be performed.

In the first stage of our experimental study, we randomly generated four head phantoms and the corresponding fully 3D projection data, simulating the data collection of the HEAD PENN-PET scanner. The performance of the algorithms was evaluated using four Figures of Merit (FOMs) [5], designed to measure different aspects of the discrepancy between the reconstructed image and the phantom. We train the reconstruction algorithms to maximize each of these FOMs individually, giving us four optimal parameters for each of the studied methods.

Results

Figure 2 and 3 show for comparison the resolution of of the 2½D and 2D ART reconstruction using the standard blob. The major difference between the methods can be seen in the radial and tangential direction. FWHM of 2½D ART resolution don't change with the radius and it is about 30% better than the 2D ART. However the method have comparable resolution in axial direction and resolution deteriorates with the radius, influenced dominantly by the FORE approximation effects.

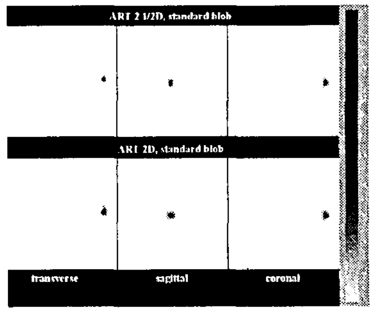

Figure 2. Reconstructed images. Point source is located at axial center (z=0mm) but at large radius (r=100mm).

Statistical analysis of the results of the reconstructions was performed using the one-tailed t-test for paired data. The evaluation results confirmed the 2½D approach is better than the 2D one according to all FOMs. Comparisons of the RAMLA reconstructions were essentially identical. And also we confirmed the decision to use the proposed approach for FORE data is more important than the particular choice of the iterative reconstruction algorithm.

Conclusion and future work

We have proposed a new reconstruction approach for PET reconstruction from rebinned data. Our experimental studies confirm that this approach provides a considerable improvement in reconstruction quality as compared to the standard 2D approaches, while the reconstruction time is of the same order as that of the 2D approaches (and, hence, it is clinically practical).

Our future work will include incorporation of this information into the iterative reconstruction algorithms combined with the 2½D approach.

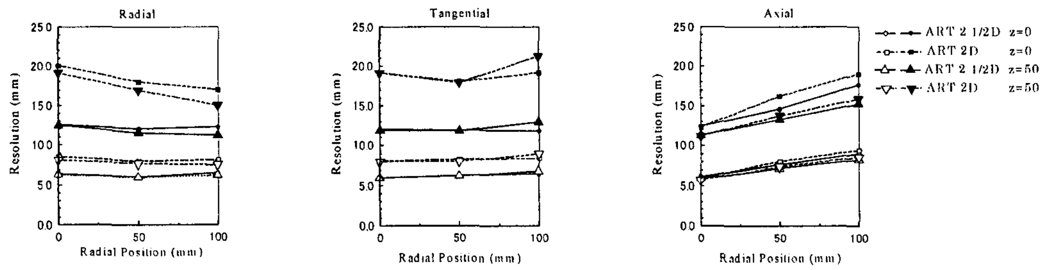

Figure 3. FWHM(open symbols) and FWTM(closed symbols) of the 2½D and 2D ART reconstruction using the standard blob at the different radial locations in center slice (z = 0mm) and a half position of the axial field of view boundary (z=50mm). Relaxation parameter is selected the optimal value for structural accuracy.

Acknowledgment

This research was partially supported by the Japanese Ministry of Education, Science, Sports and Culture (Grant-in-Aid for Encouragement of Young Scientists 10780529), the Whitaker Foundation and the National Institutes of Health (grants CA54356 and HL28438).

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