THESIS DEFENSE

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IMAGE RECONSTRUCTION FOR A HIGH RESOLUTION PET-INSERT SCANNER

Positron emission tomography (PET) is widely used in clinical diagnosis as it provides metabolic and functional information about an organ of interest or the whole body. We are developing novel insert devices for existing PET scanners to achieve higher resolution in selected regions of interest such as the head, neck, breast, or abdomen. In this work, the insert is a ring of high-resolution detectors placed concentrically inside a scanner. Adding the insert inside the scanner leads to three different types of coincidence data: insert-insert, insert-scanner, and scanner-scanner. The insert-scanner coincidences have an unconventional geometry and hence a novel image reconstruction method is developed. The two-dimensional model of the system matrix is developed for a full-ring insert and is based on the intersection of a fan with a pixel and the same approach is extended in three-dimensions. This model is further modified to better describe a new geometry for a half-ring PET-insert system and improvement in the accuracy of the model is demonstrated using a point source simulation study.

A filtered back-projection (FBP) algorithm is developed in two-dimensions based on the novel idea of using a fan-beam geometry for the coincidences. This FBP algorithm yields images with significantly reduced artifacts compared to traditional FBP reconstruction on the insert-scanner data using parallel-beam geometry. A penalized maximum likelihood expectation-maximization (PML-EM) algorithm is developed to jointly estimate the activity distribution from all three datasets. The PML-EM algorithm is demonstrated to have a better resolution-noise tradeoff than the FBP algorithm. Factors such as attenuation from the insert, crystal detection efficiency are not modeled in the system matrix computation. Instead, they are included in a component-based normalization correction. Corrections for attenuation from the body and accidental coincidences are also discussed.

Phantoms and animals are imaged in a fully functional prototype insert system attached to a microPET F220 (Siemens Inc., Knoxville) scanner to validate the reconstruction algorithm. The resolution of the images reconstructed using all three types of coincidence data are demonstrated to have improved resolution compared to images reconstructed using coincidence data of type SS, which is close to the resolution of the original microPET F220.

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