3D Image Reconstruction for a Dual Plate Positron Emission Tomograph: Application to Mammography

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The Clear-PEM scanner is a compact, dedicated, dual plate positron emission tomography that is being developed for imaging the breast. This scanner has been designed to be a high sensitivity, high resolution instrument, able to detect small breast cancerous lesions at an early stage of the disease. The scanner will acquire data using two detector plates at two perpendicular angular positions around the breast. It will be able to measure the Depth-of-Interaction (DOI) of the photons within the detector crystal with a foreseen resolution of 2mm FWHM. The work presented in this thesis deals with 3D image reconstruction for the Clear-PEM scanner.

A number of issues such as the unconventional nature of the acquisition geometry, the incorporation of the DOI information in the reconstruction process, the large amount of data to be processed and the complexity of 3D image reconstruction were addressed in this thesis. The STIR library, an open-source image reconstruction library, originally developed for conventional Positron Emission Tomography ring scanners was used as the basis for 3D image reconstruction of the Clear-PEM scanner. The modular structure of the library allowed incorporating classes and methods adequate to the particular geometry under study.

The validation and optimization of the enhanced library was performed with geometrical phantom Monte Carlo and analytical simulated data and with the 3D OS-EM algorithm available in STIR. The results obtained indicate that, with the tuned 3D image reconstruction algorithm, the image spatial resolution is expected to be $1.3 \times 1.3 \times 1.3$ mm^3 in the Field-of-View (FOV) center and $1.5 \times 1.8 \times 2.0$ mm^3 at 4 cm from the FOV center. The ability to reconstruct data acquired in a realistic, clinical scenario was tested with

Monte Carlo simulated data of an anthropomorphic breast phantom. Images were reconstructed both with the OS-EM algorithm and with a Bayesian algorithm using the Median Root Prior. The results obtained show that the OS-EM algorithm allows obtaining high contrast images, albeit with low signal-to-noise ratio values in lesions located near the chest wall. The use of a Bayesian algorithm allows improving the signal-to-noise ratio, albeit resulting in lower contrast images. Globally, the results indicate the possibility of visualizing 3 mm diameter lesions in essentially fat tissue breasts and 5 mm diameter lesion in dense fibroglandular breasts.

Keywords: Breast Cancer; Positron Emission Tomography; Dual Plate Geometry Scanners in Nuclear Medicine; 3D Image Reconstruction; Iterative Statistical Algorithms.