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ITERATIVE RECONSTRUCTION OF TRUNCATED FAN BEAM TRANSMISSION DATA

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To accurately quantify radiotracer uptake in the heart, photon attenuation maps of the thorax are necessary to correct cardiac SPECT data for tissue attenuation. A line source with a converging, fanbeam collimator offers increased sensitivity and resolution compared to a sheet source and parallel hole collimation for performing transmission computed tomography. However, due to the magnification of the fanbeam collimator, parts of the body will be outside the field of view which results in truncated projection data. Because reconstruction with conventional filtered backprojection does not "fill in" truncated information and produces ring artifacts, iterative reconstruction algorithms are required to accurately estimate attenuation maps from truncated transmission data.

In this work, we investigated the suitability of two iterative weighted least squares minimization algorithms, conjugate gradient (CG) and penalized, iterative coordinate descent (ICD), for reconstructing truncated transmission data. For a 1M event, simulated transmission scan (20min scan with a 150mCi Am-241 source), the ICD algorithm better estimated the truncated information than CG. In addition, increased iterations of CG degraded image quality while ICD image estimates improved with additional iterations. This behavior results from the smoothness penalty term in the ICD objective function which serves to regularize neighboring pixels. Measured truncated transmission data demonstrated similar findings. Based on these results, we consider the ICD algorithm to be better suited than non-regularized least squares methods for the reconstruction of transmission projection data.

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To accurately quantify radiotracer uptake in the heart, photon attenuation maps of the thorax are necessary to correct cardiac SPECT data for tissue attenuation. A photon emitting line source with a converging, fanbeam collimator offers increased sensitivity and resolution compared to a sheet source and parallel hole collimation for performing transmission computed tomography. However, due to the magnification of the fanbeam collimator, parts of the body will be outside the camera field of view (FOV) which results in truncated projection data. Because reconstruction with conventional filtered backprojection does not "fill in" truncated information and produces ring artifacts, iterative reconstruction algorithms are required to accurately estimate attenuation maps from truncated transmission data.

In this work, we investigated the suitability of two iterative, weighted least squares, minimization algorithms, conjugate gradient (CG) and penalized, iterative coordinate descent (ICD), for reconstructing truncated transmission data. The CG algorithm minimizes the objective function

$$\Phi_{CG}(\mathrm{x}) = \frac{1}{2}(\mathrm{y} - \mathrm{A}\mu(\mathrm{x}))'\mathrm{Diag}\left\{\sigma_i^{-2}\right\}(\mathrm{y} - \mathrm{A}\mu(\mathrm{x})) \tag{1}$$

where y_i is the log of the measured ratio of blank to transmitted counts for pixel i, σ_i^{-2} is the inverse variance of y_i, A is the system response matrix, and μ_i is the linear attenuation coefficient to be determined for pixel i. The ICD algorithm minimizes the following objective function

$$\Phi_{ICD}(\mathrm{x}) = \frac{1}{2}(\mathrm{y} - \mathrm{A}\mu(\mathrm{x}))'\mathrm{Diag}\left\{\sigma_i^{-2}\right\}(\mathrm{y} - \mathrm{A}\mu(\mathrm{x})) + 2^{\beta}\frac{1}{2}\sum_j \sum_{k \in N_j} w_{jk}\frac{1}{2}(\mu_j - \mu_k)^2 \tag{2}$$

subject to a nonnegativity constraint on μ_i. The second term in (2) acts as a smoothing penalty (β is user defined) which regularizes the ill-posed reconstruction. The weights w_{jk} are 1 for horizontal and vertical neighbors and $1/\sqrt{2}$ for diagonal neighbors. Both algorithms were judged on the quality of the reconstructed image and the average *rms* error per pixel in non-truncated and truncated regions of the image.

Transmission measurements of the thorax, using a 150mCi Am-241 (60 keV photons) line source with a 65cm focal length fanbeam collimator, were simulated using a digitized, midventricular CT tomograph with measured attenuation coefficients at 60 keV assigned to the lung, tissue, and bone. The detector radius of rotation was 23cm which provided a non-truncated FOV with a radius of 12.9cm. The elliptical axis dimensions of the torso outline were 35cm x 20cm. The transmission sinogram data (128x60, 360° orbit, 40cm FOV) consisted of 1M events to simulate a 20min transmission scan.

After 10 iterations of the CG algorithm, the calculated *rms* values were 0.021/cm and 0.047/cm for the non-truncated and truncated regions, respectively. Further iterations degraded image quality and *rms* values. The reconstructed image from 10 CG iterations was used as an initial estimate for the ICD algorithm. After 35 ICD iterations, the reconstruction was stopped because image quality and *rms* error marginally improved with additional iterations. The *rms* values from the reconstructed image were 0.019/cm and 0.033/cm for the non-truncated and truncated regions, respectively. This represented a decrease in error compared to CG by 9.5% and 29.8% in the non-truncated and truncated regions, respectively. Qualitatively, the truncated regions in the ICD image were better defined with no noticeable streaking as was apparent in the CG images. In addition, image quality and *rms* values improved with increasing ICD iterations making this algorithm more stable than CG.

The algorithms have also been tested using measured transmission data, and the ICD algorithm has consistently performed better than CG in estimating attenuation in truncated regions. Based on these results, we consider the ICD algorithm to be better suited than CG for the reconstruction of transmission projection data. The improved performance of the ICD algorithm is attributed to the incorporation of a smoothness penalty and nonnegativity constraint.