Instrumentation and Data Analysis: SPECT I: Reconstruction Algorithms

10:30–12:00 **Session 5** **Room 202**

No. 24

A FAST ITERATIVE RECONSTRUCTION METHOD BASED ON FUNCTIONAL REGIONS. Y. Zhang, N. H. Clinthorne, J. A. Fessler, W. L. Rogers. Division of Nuclear Medicine, University of Michigan, Ann Arbor, MI.

Iterative reconstruction methods offer the potential for improved quantitative accuracy over filtered backprojection because they accurately model the tomograph response and Poisson counting noise as well as allowing the use of spatially-varying side-information derived from MRI or CT images. However, because of their heavy computational burden and sometimes slow convergence rate, they are not yet practical in a clinical setting—especially in 3D where the number of voxels can easily exceed a quarter million.

To decrease the computational overhead we have developed a dual-grid iterative reconstruction method where the first pixel-grid is based on segmenting the reconstruction volume into regions over which the activity is potentially smoothly varying. These "functional-pixels" can be determined by mapping organ and region boundary data obtained from MRI or CT data into the ECT data. Reconstruction is performed first using an un-regularized solution objective on the coarse grid. When coarse-grid convergence is attained the reconstruction is mapped, *without smoothing*, onto a conventional fine grid of square pixels and further reconstruction is performed using a regularized solution criterion. If the boundaries of the functional regions have been determined accurately, the convergence rate will be greatly enhanced. Inaccuracies in region boundaries can be accounted for with some loss in convergence rate.

Evaluations of the method in 1D and 2D simulations with noiseless data have demonstrated that for approximately the same amount of computation, residuals from the dual-grid method are up to a factor of eight lower than those using the conventional, fine-grid-only method at 50 iterations. These performance advantages are likely to further increase in 3D because the functional-pixel to fine-grid-pixel ratio will generally be much smaller than in 1D or 2D.

The dual-grid method has the potential for greatly reducing the amount of computation in 3D iterative reconstruction, is easy to implement, and can be applied to both least-squares and maximum-likelihood solution objectives.

No. 25

discrete SVD?

A RECONSTRUCTION ALGORITHM USING SINGULAR VALUE DECOMPOSITION TO COMPENSATE FOR CONSTANT ATTENUATION IN SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY. G.T. Gullberg and G.L. Zeng. The University of Utah, Salt Lake City, UT.

The development of reconstruction algorithms to correct for constant attenuation has important application in SPECT imaging of the brain. Previously, a convolution reconstruction algorithm was developed which mathematically can be shown to be an accurate reconstruction of projections of emission sources within a constant attenuating media. The major problem with the algorithm is the severe noise amplification. The algorithm was derived based upon being able to represent the projection data as projections of the exponential Radon transform and uses an exponential backprojector after applying a reconstruction filter to the modified projection data. Due to the exponential backprojector, the point spread function of the backprojection has a hyperbolic cosine factor, which makes the point spread function non local and noise amplifying. Even if window functions are applied to the filters to try to remedy the noise amplification, the window functions do not help very much to improve the image quality in a noisy reconstruction. The new algorithm is derived from the singular value decomposition (SVD) of the exponential Radon transform. Using SVD to reconstruct an image, the projection data is first backprojected using the standard tomographic backprojection without the exponential term. The point spread function of the backprojection is local and easy to regularize. Using the SVD approach, regularization is accomplished by truncating the terms with small singular values. Computer simulations show an improvement in the SVD method over the convolution backprojection method when the projection data is corrupted with noise.

No. 26

LEAST SQUARES ALGORITHM FOR REGION-OF-INTEREST EVALUATION IN EMISSION TOMOGRAPHY. A.R. Formiconi, A. Passeri. University of Florence, Italy.

See PMB, 1989

The performances of the least squares (LS) algorithm applied to region-of-interest (ROI) evaluation were studied by means of simulations and phantom studies. The LS algorithm is a direct algorithm which does not require any iterative computation scheme and also provides estimates of statistical uncertainties of the ROI values (covariance matrix). A model of physical factors, such as system resolution, attenuation and scatter, can be specified in the algorithm. In this paper an accurate model of the nonstationary geometrical response of a camera-collimator system was considered. The algorithm was compared with three others which are specialized for ROI evaluation, as well as with the conventional method of summing the reconstructed quantity over the ROI. For the latter method, two algorithms were used for image reconstruction: filtered backprojection and conjugate gradients with the model of nonstationary geometrical response. For noise-free data and for ROI of accurate shape LS estimates were unbiased within roundoff errors. For noisy data, estimates were still unbiased and the precision worsened slightly for ROI smaller than resolution: with a typical statistics of brain perfusion studies performed with a collimated camera, the estimated standard deviation for a 1 cm square ROI was 10% with an ultra high resolution collimator and 7 % with a low energy all purpose collimator. Using conventional ROI estimates with the conjugate gradient iterative algorithm and the model of nonstationary geometrical response, bias of estimates decreased on increasing the number of iterations, but precision worsened heavily thus achieving an estimated standard deviation of more than 25 % for the same 1 cm ROI. These results show that the LS algorithm with accurate modelling of physical factors applied to ROI evaluation allows to recover resolution effects with limited amplification of statistical fluctuations in comparison with techniques where image reconstruction is involved. → bias - variance tradeoff

Shows bias for small coarse-ROI ML estimates! (50 its).

No. 27

CARDIAC SPECT RECONSTRUCTIONS WITH TRUNCATED PROJECTIONS IN DIFFERENT SPECT SYSTEM DESIGNS. B.M.W. Tsui, X.D. Zhao, P. Vernon*, D. Nowak*, J.R. Perry and W.H. McCartney. University of North Carolina at Chapel Hill, Chapel Hill, NC and *General Electric Medical Systems, Milwaukee, WI.

Truncated projections are found in cardiac SPECT acquisitions when imaging large patients and when using SPECT systems with the smaller detector sizes now commercially available. We studied the effects of truncated projections on cardiac SPECT images obtained from three rotating camera SPECT system designs. The first and second system designs had the camera(s) positioned centered and off-centered with respect to the axis-of-rotation, respectively. The third design consisted of two camera heads connected at a right angle and rotating around the patient as a single unit. Three camera sizes of 30, 35 and 40 cm were used in the study. Reconstruction methods included the conventional filtered backprojection (FBP) algorithm and iterative methods which provided improved image quality and quantitative accuracy. A simulation study was conducted using the three system designs and a realistic cardiac-chest phantom derived from CT scan of a normal size patient. The effects of the non-uniform attenuation in the chest region was included in the simulation. Transmission and emission projections from 180^{0} and 360^{0} acquisitions using the three system designs were first reconstructed using the FBP algorithm. In general, image artifacts and distortions were found in regions with missing projection data due to truncated projections and these were increased in 180^{0} when compared with 360^{0} reconstructions. The affected region was near the edge of the reconstructed image and away from the heart even for the smallest size camera. The artifacts and distortions could be reduced by extrapolating the projection data. Iterative reconstruction methods such as those using the maximum likelihood-expectation maximization (ML-EM) algorithm with attenuation compensation were found to provide the best image quality in terms of reduced image artifacts and distortions, and improved quantitative accuracy. We conclude that truncated projections can be effectively used in cardiac SPECT imaging as long as the heart stayed within the region with non-truncated projections and corrective reconstruction methods are used.

Noise free?

No. 28

MULTI-ENERGY MAXIMUM-LIKELIHOOD RECONSTRUCTION ALGORITHMS FOR SPECT AND PET. N.H. Clinthorne, X. Wang, J.A. Fessler, Division of Nuclear Medicine, The University of Michigan, Ann Arbor, MI.

Projection data acquired in multiple energy-windows can potentially be used to correct for Compton-scattering thereby improving quantita-

Look at ratio of contrast to noise.