Maximum-Likelihood Expectation-Maximization Algorithm for Improved Clinical SPECT Scintimammography

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Abstract— **Conventional MLEM and OSEM algorithms used in SPECT Tc-99m sestamibi scintimammography produce hot spot artifacts (HSA). We investigated a suitable modification of MLEM and OSEM algorithms needed to reduce HSA. Patients with suspicious breast lesions were administered 10 mCi of Tc-99m sestamibi and SPECT scans with patients in prone position with uncompressed breasts were acquired. In addition, to simulate breast lesions, some patients were imaged with a number of breast skin markers each containing 1 μCi of Tc-99m. We modified MLEM and OSEM algorithms by removing from the backprojection step the rays that traverse the periphery of the support region on the way to a detector bin when their path length trough this region is shorter than some preset critical length. Such very short paths result in a very low projection counts contributed to the detector bin and this in turn gives rise to a overestimation of the activity in the peripheral voxels in the backprojection step, thus creating HSA. We analyzed the breast-lesion contrast and suppression of HSA in the images reconstructed using conventional and modified MLEM and OSEM algorithms vs. critical path length (CPL). For CPL ≥ 0.01 pixel size, we observed improved breast-lesion contrast and lower noise in the images reconstructed, and a very significant reduction of HSA in the maximum intensity projection (MIP) images**

Manuscript received November 12, 2004.

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I. Introduction

Tc-99m sestamibi scintimammography is a useful tool for reducing the number of breast biopsies due to its very high negative predictive value (NPV) of 95% [1], as compared to screening x-ray mammography with positive predictive value (PPV) in the 15–40% range. Whereas scintimammography is usually performed in a planar acquisition mode, we explore here the application of a tomographic approach (SPECT) to scintimammography.

II. Materials and Methods

Patients with suspicious breast lesions were administered 10 mCi of Tc-99m sestamibi. SPECT Tc-99m sestamibi scintimammography (90 views, 30 sec/view, parallel-hole high-resolution collimator) was acquired on a dual-head gamma camera (E.Cam, Siemens). In addition, in order to simulate hot breast lesions, some patients were imaged with a number of breast skin markers each containing 1 μCi of Tc-99m.

The images were reconstructed using a maximum-likelihood expectation-maximization (MLEM) algorithm [2-3] in its ordered subset version [4-5]. We performed fully-3D reconstruction with resolution and attenuation modeling. We used our of version of an MLEM algorithm [6]:

$$\lambda_k^{n+1} = \lambda_k^n \frac{1}{\sum_{i\in S_0} c_{ik}} \sum_{i\in S_0} c_{ik}\cdot\gamma_{iJ_i} \frac{Y_i}{\sum_{m\in P_i} \lambda_m^n \cdot c_{im}\cdot\gamma_{iJ_i}} + c_{ik}(1-\gamma_{iJ_i}) \quad . \qquad (1)$$

The symbols are as follows:

i projection subscript

J_i number of pixels in the ray I

j pixel subscript ($j < J_i$)

P_i set of pixels contributing to projection i

S_0 subset of the projection bins corresponding to a particular set of views

R_{k0} subset of projections that belongs to S_0 to which pixel k contributes

Y_i total (random) number of photons recorded by the detector bin i

λ^n_j current estimate of source intensity of pixel j (*i.e.* the mean number of photons emitted by pixel j)

μ_j linear attenuation coefficient of pixel j

l_{ij} the length of intersection of the pixel j, *i.e.* the fraction of the ray orignated from the center of detector bin i intercepted by pixel j

γ_{iJ} probability of surviving attenuation between the source in the pixel j for the photon heading towards the detector bin i

c_{ij} known probability (corrected for the decay rate and the time interval of *ith* projection) that photon leaving pixel j is directed toward detector bin i.

The summation in (1) is performed over a subset S_0 of the projection bins corresponding to a particular set of views. The images are updated after a user-specified number of projection views (OS size) that form the subset S_0. The OS size may vary from unity (the smallest possible) to the number of acquired views (the largest possible).

III. RESULTS

An example of conventional MLEM reconstruction of SPECT data obtained for a patient with skin markers simulating breast lesions is shown in Fig. 1.

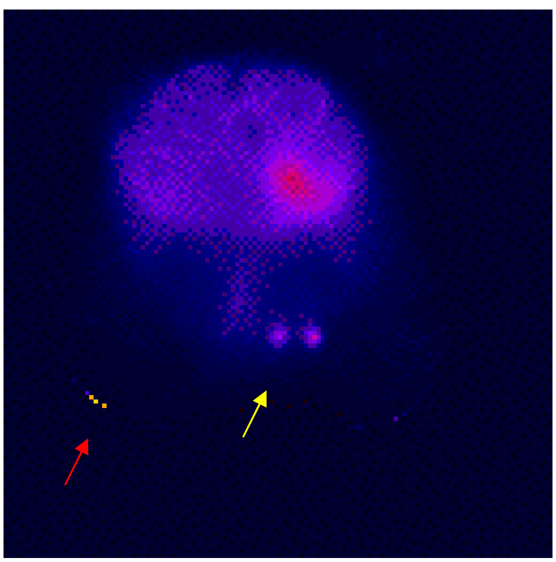


Fig. 1. OS1, iteration=70, slice 65; reconstructed using conventional MLEM algorithm. Yellow arrow indicates location of simulated breast lesions. Red arrow indicates location of hot spot artifacts at the edge of support.

The result of a reconstruction of the same data but using OSEM algorithm (OS=5) is shown in Fig. 2

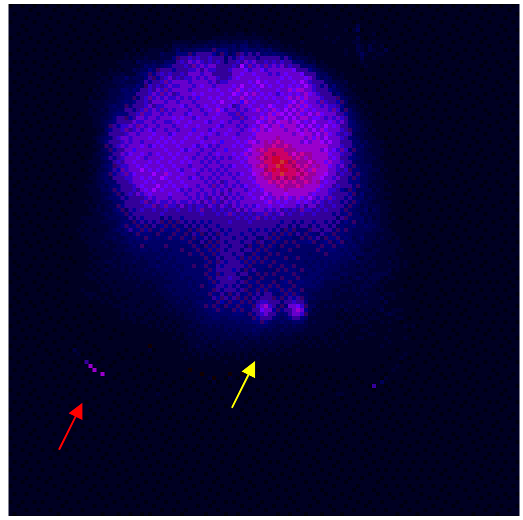


Fig. 2. OS5, iteration=10, slice 65; reconstructed using conventional OSEM algorithm. Yellow arrow indicates location of simulated breast lesions. Red arrow indicates location of hot spot artifacts at the edge of support.

We observe hot spot artifacts present at the edge of the support region. By analyzing the components of (1) we have established that, when the ray path through the support is very short (Fig. 3)—as is likely for rays traversing the periphery of the support region on the way to a detector bin—it results in very low projection counts contributed to the bin, and this in turn gives rise to a significant overestimation of the activity in the peripheral voxels in the backprojection step, thus creating hot spot artifacts.

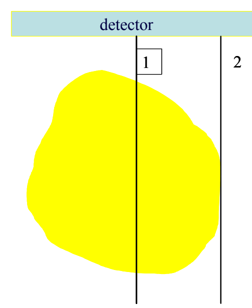


Fig.3. 1: Ray passing through the bulk of the reconstructed object 2: Ray passing through the periphery of the reconstructed object.

To rectify this problem, we modified the MLEM and OSEM reconstruction algorithms by removing from the backprojection step the rays that traverse the periphery of the support region when their path length through this region is shorter than some preset critical length. For a critical path length equal to 0.01 pixel size, we have observed empirically a very significant reduction of the hot spot artifacts (Fig. 4).

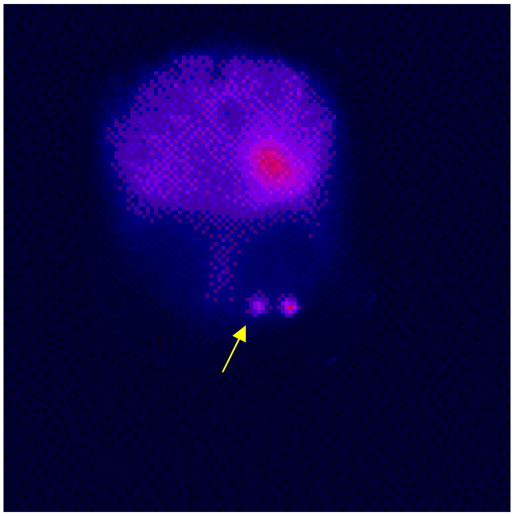


Fig. 4. OS5, iteration=10, slice 65; reconstructed using modified OSEM algorithm modified for hot spot reduction; critical length = 0.01 pixel size. Yellow arrow indicates location of simulated breast lesions.

The modified OSEM resulted in improved breast lesion contrast and lower noise (Fig. 5), as well as in a very significant reduction of "hot spot" artifacts in the MIP images (Fig. 6).

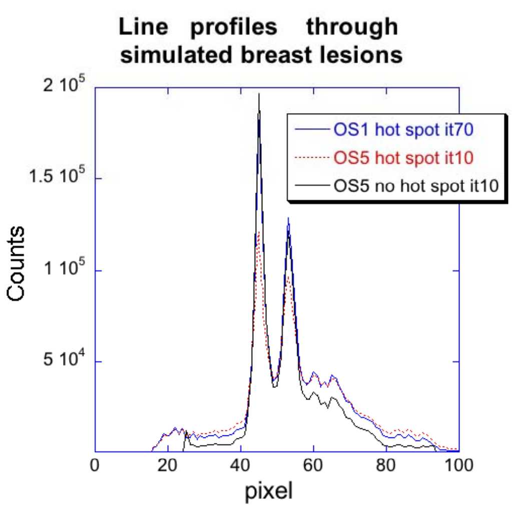
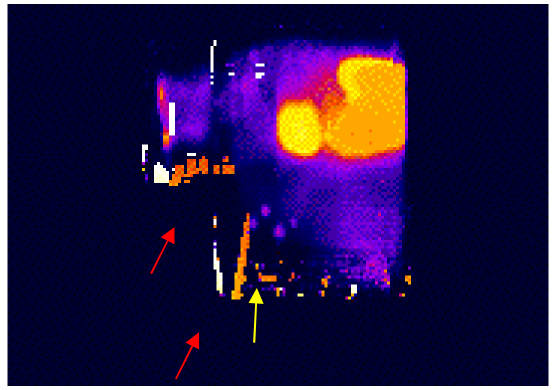
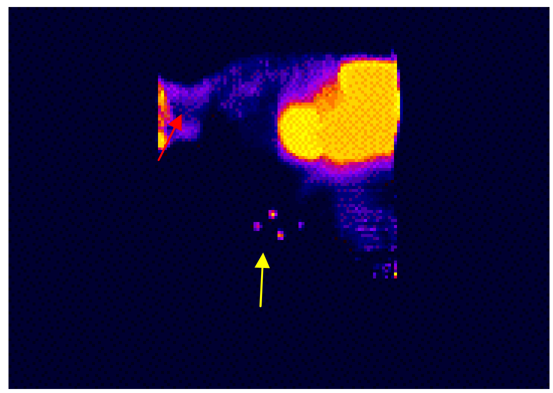


Fig. 5. Line profiles through simulated breast lesions shown in Fig. 2. Solid blue line: OS1, iteration=70, without hot spot reduction; dotted line: OS5, iteration=10 without hot spot reduction; solid black line: OS5, iteration=10, with hot spot reduction; critical length= 0.1 pixel size.



A. OS1, iteration=70, no hot spot reduction, MIP at 98°.



B. OS5, iteration=10, with hot spot reduction, MIP at 98°.

Fig. 6. MIP at 98°of the reconstructed patient data with simulated breast lesions (see text). Yellow arrows indicate location of simulated breast lesions. Red arrows indicate location of hot spot artifacts at the edge of support.

IV. Conclusions

A modified MLEM or OSEM algorithm should be used to improve sensitivity for breast-lesion detection in clinical SPECT Tc-99m sestamibi scintimammography and to remove hot-spot artifacts from breast images.

V. References

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