Combined cone-beam and parallel-beam approach to SPECT

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Purpose: To improve sensitivity of SPECT.
Materials and methods: A combined cone-beam (CBC) and a parallel-beam collimator (PBC) performance were investigated. The advantage of CBC is its enhanced sensitivity; the disadvantage is its limited field-of-view, possibly resulting in truncation artifacts. We investigated performance of simultaneous CBC/PBC STSM acquisition on a simulated and experimental data obtained with Defriese phantom. We have investigated the performance of simultaneous CBC/PBC STSM acquisition on simulated data sets and on SPECT data obtained using a triple-head gamma camera (Triad, Trionix) equipped with one high-resolution CBC with focal length f=100 cm and two ultra-high-resolution PBCs. An OSEM algorithm for simultaneous CBC/PBC reconstruction was used with CBC and PBC estimates obtained separately at the first iteration and the subsequent CBC estimates obtained as a linear combination of previous CBC and PBC estimates.
Results: The image quality, suppression of truncation artifacts as well as noise characteristics and optimal scaling factors between PBC and CBC in the reconstruction were analyzed. We observe overall better imaging performance of the combined CBC/PBC STCM, as compared to CBC- or PBC-only acquisition.
Conclusion: The combined CBC/PBC SPECT may afford a useful clinical tool and is a promising alternative to a conventional SPECT.

Combined Cone-Beam and Parallel-Beam Approach to SPECT

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We have investigated the performance of simultaneous combined cone-beam (CBC) and a parallel-beam collimator (PBC) SPECT acquisition on simulated data sets and on SPECT data obtained using a triple-head gamma camera (Triad, Trionix) equipped with one high-resolution CBC with focal length f=100 cm and two ultra-high-resolution PBCs. A modified OSEM algorithm for simultaneous CBC/PBC reconstruction is described below. The simulated data set is shown in Fig. 1. The experimentally obtained SPECT data using a triple-head gamma camera (Triad, Trionix) equipped with one high-resolution CBC with focal length f=100 cm and two ultra-high-resolution PBCs is shown in Fig. 2.

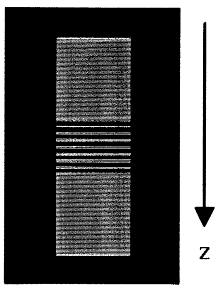

Fig. 1a.
A synthetic semi-Defrise phantom.

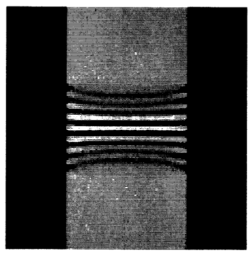

Fig. 1b.
An example of a simulated cone-beam projection image obtained for the semi-Defrise phantom shown in Fig. 1a.

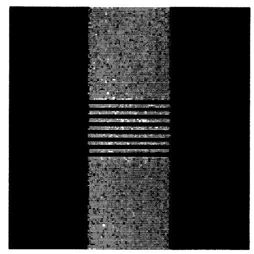

Fig. 1c.
An example of a simulated parallel-beam projection image obtained for the semi-Defrise phantom shown in Fig. 1a.

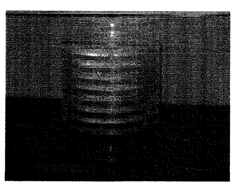

Fig. 2a.
A physical Defrise phantom.

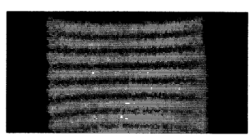

Fig. 2b.
A cone-beam projection image obtained for the physical Defrise phantom shown in Fig. 2a.

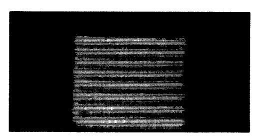

Fig. 2c.
A parallel-beam projection image obtained for the physical Defrise phantom shown in Fig. 2a.

A modified OSEM algorithm[1] for simultaneous CBC/PBC reconstruction uses separately obtained estimates of CBC and PBC at the first iteration; the subsequent CBC estimates are obtained as a linear combination of previous CBC and PBC estimates, as follows:

$$\lambda_{CBC}^{n} = \alpha \cdot \lambda_{PBC}^{n-1} + (1-\alpha) \cdot \lambda_{CBC}^{n-1} \qquad \text{with} \qquad 0 \le \alpha \le 1 \tag{1}$$

$$\lambda_k^n = \lambda_k^{n-1} \frac{1}{\sum_{i\in S_0} c_{ik}} \sum_{i\in S_0} \left\{ c_{ik}\cdot \gamma^n_{ikJ_i} \frac{Y_i}{\sum_{m\in P_i} \lambda_m^n \cdot c_{im} \cdot \gamma^n_{imJ_i}} + c_{ik}(1-\gamma^n_{ikJ_i}) \right\} \qquad (2)$$

The meaning of used symbols is as follows: i is a projection subscript; J_i is the number of pixels in the ray i; j is a pixel subscript ($j < J_i$); P_i is the set of pixels contributing to projection I; S_0 is the subset of the projection bins corresponding to a particular set of views; Y_i is the total (random) number of photons recorded by the detector bin i; λ^n_j is the current estimate of the mean number of photons emitted by pixel j; γ^n_{ijm} is probability of surviving attenuation between the source in the center of pixel j and the boundary of pixel m for the photon heading towards the detector bin i, evaluated using the current vector of parameter estimates μ^n; and c_{ij} is the known probability that photon leaving pixel j is directed toward detector bin i.

The image quality, suppression of truncation artifacts, as well as noise characteristics and optimal scaling factors between PBC and CBC in the reconstruction were analyzed. The z-profile (refer to Fig. 1) and the signal-to-noise ratio along the z-axis for α =0.5 of the reconstructed simulated semi-Defriese phantom are shown in Figs. 3 and 4.

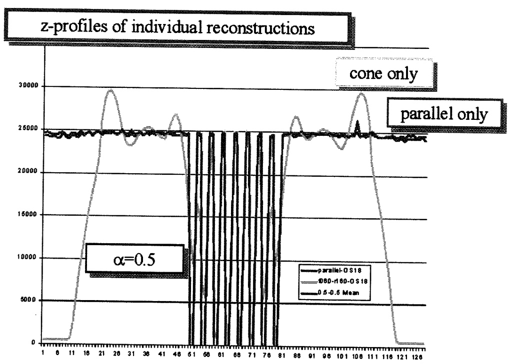

Fig. 3.
The z-profiles obtained for combined CBC and PBC reconstruction (heavy line) of the semi-Defrise phantom with α =0.5. For comparison, the z-profiles obtained for separate CBC and PBC reconstructions are shown.

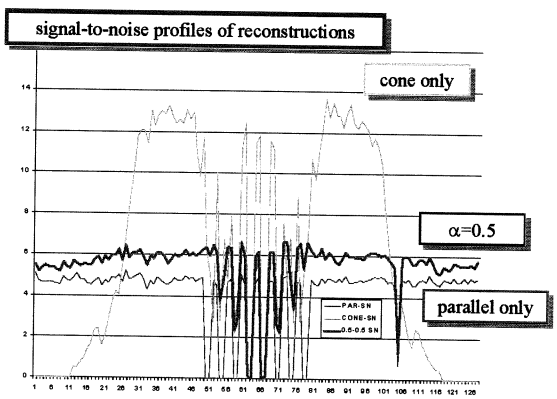

Fig. 4.
The signal-to-noise ratio along the z-axis obtained for combined CBC and PBC reconstruction (heavy line) of the semi-Defrise phantom with α =0.5. For comparison, the signal-to-noise ratio obtained for separate CBC and PBC reconstructions are shown.

We observe good recovery from truncation artifacts present in the CBC-only reconstruction, resulting in a more uniform z-profile, as well as a higher signal-to-noise ratio within common field-of-view of the combined CBC/PBC SPECT reconstruction, as compared to the PBC-only SPECT.

[1] A. Krol, J.E. Bowsher, S.H. Manglos, D.H Feiglin, and F.D. Thomas, "An EM algorithm for estimating SPECT emission and transmission parameters from emission data only", IEEE Transactions on Medical Imaging **20**, 218-232 (2001).