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# Scatter correction in cone-beam CT using a wavelet transform

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## INTRODUCTION

A cone-beam CT can take a 3D structure of a patient in short time. The scattered radiation may deteriorate the reconstructed image in x-ray CT. Particularly, in cone-beam CT, the scattered radiation may have much larger effects on the reconstructed image than in current 2D CT, because the detecting size is wide. We intended to improve the image of cone-beam CT to remove the scattered radiation from the projected image.

Because each of the projection is inputed as a digital image into a computer, we proposed the method of removing the scattered radiation using the digital processing. We developed a Monte Carlo simulation model of cone-beam CT to take the spatial intensity distribution of both primary and scattered radiations. We investigated the behavior of the scattered radiation both in the space and frequency domain in the simulation, and removed the scattered component using a wavelet transform. To use the simulation result, then, we tried removing the scattered radiation from the projection image taken with the cone-beam CT scanner. We will report the method of removing the scattered radiation and the results with the simulation and the measurement.

## METHOD

We decomposed the projected image at different scales using a wavelet transform. The decomposition is along the direction perpendicular to the rotation axis.

The function $f$ can be represented by the arbitrary function $\psi$ as following,

$$f(x) \sim \sum_j \sum_k d_k^j \psi(2^{-j}x - k). \tag{1}$$

$\psi$ is the wavelet function. If the part of the eq.(1) is exchanged for

$$g_j(x) = \sum_k d_k^j \psi(2^{-j}x - k), \tag{2}$$

the original function $f_0(x)$, which includes primary and scatter components is represented as

$$f_0(x) = \sum_{j=1}^{M} g_j(x) + f_M(x), \tag{3}$$

where the function $g_j(x)$ has a detailed character of $f_0(x)$ with a level $j$, and the function $f_M(x)$ has a smoothed character of $f_0(x)$ with a level $M$.

The projected image including the scattered intensity essentially differed from the primary image in $g_j(x)$ and $f_M(x)$ in low frequency ragions. We multiplied these $g_j(x)$ and $f_M(x)$ by the factors of $w_j^g$ and $w_M^f$ respectively,

$$\hat{f}_0(x) = \sum_{j=1}^{M} w_j^g g_j(x) + w_M^f f_M(x) \tag{4}$$

where $f_0(x)$ is the function without the scattered component, and $w_j^g$ and $w_M^f$ are weighting factors to remove the scatter component. We estimated the suitable value of $w_j^g$ and $w_M^f$ and removed the scatter components from the projected image including the scattered intensity.

## RESULTS

The geometry of the phantom taken with cone-beam CT is shown by fig.1. Figure.2 is the reconstructed image of the phantom. In the original image(fig.2(a)), the CT number of No.3 position was higher than that of the outside of the phantom, though the both CT numbers should be equal. This problem is influence of the scattered radiation.

The image from which the scatter components were removed using a wavelet transform is shown by fig.2(b). Then, the CT number of No.3 position agreed with that of the outside of the phantom. This result showed improvements of contrast and linearity in reconstructed image.

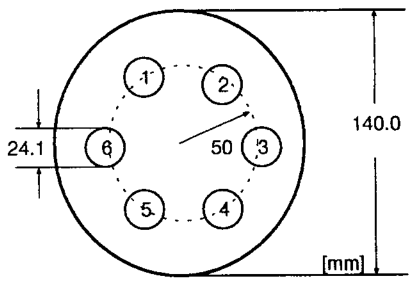
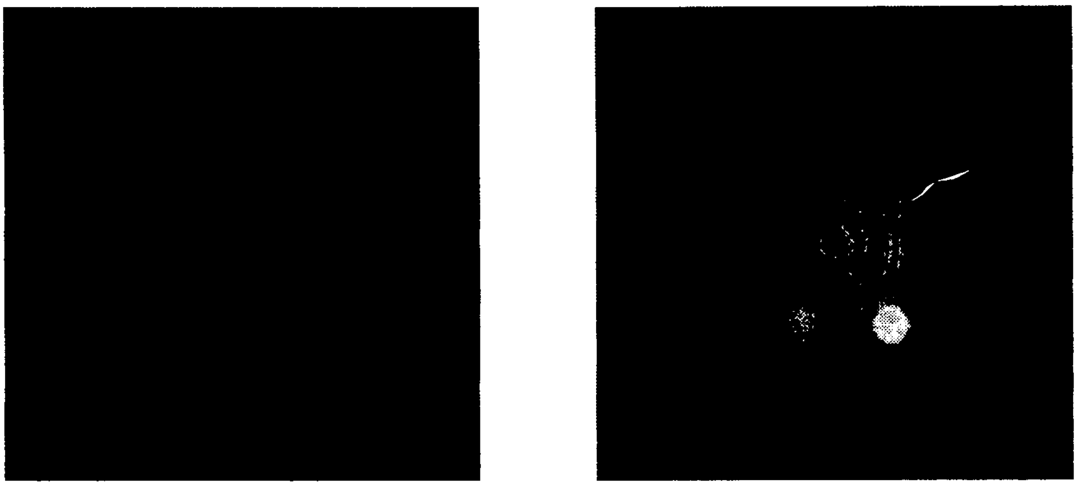



Figure 1: The geometry of the phantom

Table 1: CT number of each components

| position | component | CT number |
|---|---|---|
| 1 | contrast medium 4 | 121 |
| 2 | water | 0 |
| 3 | air | -1000 |
| 4 | contrast medium 1 | 950 |
| 5 | contrast medium 2 | 500 |
| 6 | contrast medium 3 | 260 |
| center | acrylic | 120 |



(a)The original image (b)The image removed the scatter components

Figure 2: The reconstructed image of the phantom