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The Comparison of Iterative and Filtered Back Projection Method for Gamma-ray CT

Jong Bum Kim, Sung Hee Jung, Jin Sup Kim
Korea Atomic Energy Research Institute, P.O.Box 105, Yusong, DaeJon, Korea,305-600, jong@kaeri.re.kr

1. Introduction

There are two categories for an image reconstruction, the transform based reconstruction and the iterative reconstruction technique. The transform based reconstruction is based on an inverse radon transform theory. Filtered Back Projection (FBP) method is a frequently used algorithm based on radon model. In FBP, it is assumed that the measured data consist of line integrals of the object distribution. Iterative reconstruction technique is the method in which the estimated image is progressively refined in a repetitive calculation. For X-ray CT, FBP has been the most powerful technique because it has the sufficient number of total ray-sums. Unlike the X-ray CT, there are situations where it is not possible to measure a large number of projections for the industrial gamma-ray CT. In addition to aforementioned factors, there are many different characteristics between the gamma-ray and X-ray. To get a precise image from gamma-ray CT, the adequate image reconstruction algorithm should be adopted. To evaluate the algorithm suitable for gamma-ray CT, comparison of iterative and FBP method result from the gamma-ray CT is introduced.

2. The image reconstruction methods

2.1 Filtered back projection process

FPB method is a frequently used algorithm for a reconstruction in a commercial CT. FPB includes a filtering process in the algorithm as in Fig.1.[1].

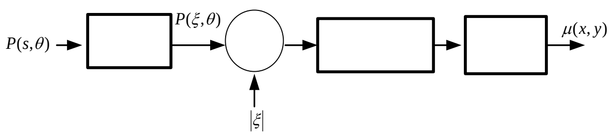

Figure 1. Filtered back projection process.

2.2 Iterative reconstruction techique

Iterative reconstruction technique solves the unknown pixels information by assuming that the cross section consists of an array of unknowns, and setting up an algebraic equation for the unknowns in terms of the measured ray-sum data as in equation(1). In equation, H is the M×N matrix called the system matrix, which describes the imaging process and can represent an attenuation coefficient.

$$\begin{bmatrix} h_{11} & h_{12} & h_{13} & . & . & h_{1N} \\ h_{21} & h_{22} & h_{23} & . & . & h_{2N} \\ . & . & . & . & . & . \\ h_{i1} & . & . & h_{ij} & . & h_{iN} \\ . & . & . & . & . & . \\ h_{M1} & h_{M2} & h_{M3} & . & . & h_{MN} \end{bmatrix} \begin{bmatrix} f_1 \\ f_2 \\ . \\ . \\ . \\ f_N \end{bmatrix} = \begin{bmatrix} g_1 \\ g_2 \\ . \\ . \\ . \\ g_M \end{bmatrix} \quad (1)$$

i=1~M, M is total number of ray-sums
j=1~N, N is total number of pixels

There are Algebraic Reconstruction Technique (ART), its variation and Expectation Maximization (EM) in iterative techniques. Many different ART's variations have been proposed, but they share some common features. Among these algorithm, SIRT and EM are outlined briefly in the following section

2.3 Simultaneous Iterative Reconstruction Technique

Simultaneous iterative reconstruction technique (SIRT) is a variation of ART. In SIRT, the projections are all performed simultaneously and then averaged.

$$f_j^{(n+1)} = f_j^{(n)} + \delta \sum_{i=1}^{M} h_{ij} \frac{(g_i - \sum_{k=1}^{N} h_{ik} f_k^{(n)})}{\sum_{k=1}^{N} h^2{}_{jk}} \quad (2)[7]$$

2.4 Expectation Maximization algorithm

The Expectation Maximization algorithm has been widely used in a medical emission CT such as a single photon emission tomography (SPECT) and a positron emission tomography (PET) [7]. It is also useful for a gamma transmission tomography [7][3].

$$f_j^{(n+1)} = \frac{f_j^{(n)}}{\sum_{i=1}^{M} h_{ij}} \sum_{i=1}^{M} h_{ij} \frac{g_i}{\sum_{k=1}^{N} h_{ik} f_k^{(n)}} \quad (3)$$

2.4 Phantom

In the petrochemical industry the most frequently encountered final or interim products are oil and its side products. A phantom simulating a packed bed reactor with air voids was designed on the basis of an example at the Chemical Reaction Engineering Laboratory, Washington University ST. Louis as shown in Fig. 2. The phantom is filled with polypropylene (PP) grains and the outer shield of the phantom is made of a 5mm thick acryl plate.

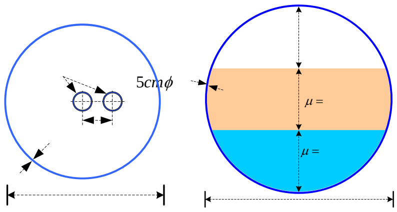

Figure 2. The design of phantomS

To estimate the contrast for a water-oil, a phantom shown in Fig. 2 was designed. Linear attenuation coefficient of liquid water is known as 0.0862cm^{-1}. The light oil whose density is 0.815 and linear attenuation coefficient is 0.0702cm^{-1} is filled into the middle layer of the phantom.

3. Result and conclusion

Reconstructed PP phantom images by FBP, SIRT and EM respectively are shown in Fig.3. Each ray-sum is measured at the conditions of Table 1.

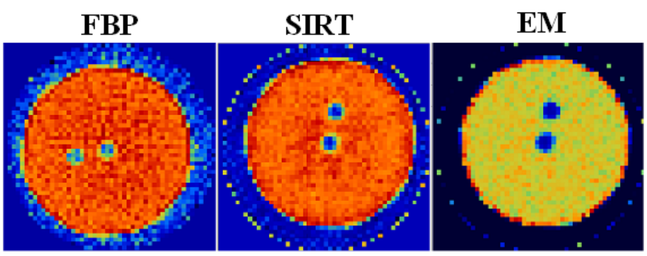

Figure 3. Result from PP phantom

SIRT shows less noise when it is compared to FBP and EM. This phenomenon can be explained by the fact that FBP uses a lamp filter in its algorithm which amplifies the noise and EM algorithm has the shortcoming of a noise amplification [7]. In spite of the noise, EM shows the better contrast image than the others in Fig.2.

Table 1

Gamma-ray source	^{137}Cs (0.662keV)
Threshold	31keV
Maximum count	10300
Detector collimator aperture	10mm
Total number of ray-sum	1632 (32K×51N)
Radiation detector	1 inch NaI(Tl)

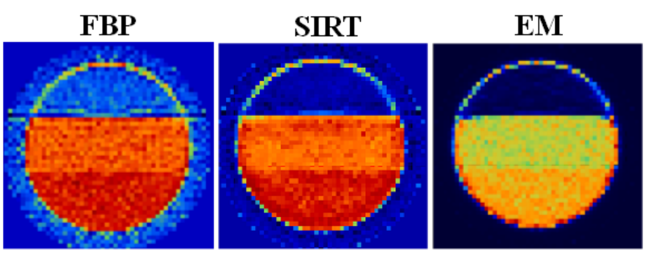

Figure 4. Result from water oil air mixture phantom

Fig.4 shows the results from the air/oil/water mixture phantom. The measurement condition is summarized in Table 2.

Table 2

Gamma-ray source	^{137}Cs (0.662keV)
Threshold	500keV
Maximum count	8,000
Detector collimator aperture	10mm
Total number of ray-sums	1632 (32K×51N)
Radiation detector	1 inch NaI(Tl)

Because each component is not mixed with the others and homogenous, their reconstruction results should have a uniform density in each component. Fig.4 shows that the EM result is the closest to the original image.

Table 3

	Algorithm
Less noise	SIRT
Better contrast	EM
Less artifact	EM

By the result, we can conclude that iterative method is more suitable than FBP for Gamma-ray CT which has fewer ray-sums. It can be reconfirmed by the fact that iterative methods can produce good result even if their data have much statistical noise and less ray-sums [1][7].

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