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Performance measurement of industrial SPECT

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1. Introduction

With the development of medical imaging, there has been an increasing interest in visualization of fluid flow for industrial processes. The case which the single photon emission computed tomography (SPECT) technique was applied to industrial field has been reported [1]. Originally the SPECT is widely used in hospitals to obtain the functional information of the human body. Although industrial SPECT is close to medical SPECT, here are significant differences. The main one stands in the range of the tracer energy that can be used. Due to the steel casing and/or refractory materials thickness, resort to relatively high energy is required. On the other hand, injection of extensive concentrations of tracer is more convenient in industrial uses.

As a part of the industrial process imaging technology, industrial SPECT system was developed to measure the cross-sectional distribution of the process fluid. To evaluate its performance, reconstructed images corresponding to the position of the radioisotope were analyzed. In addition, the Monte Carlo simulation data were compared with experimental results under same conditions as in the experiments.

2. Methods and Results

2.1 The image reconstruction methods

There are largely two categories of the analytic and the iterative methods for an image reconstruction. The analytic method is based on the inverse Radon transform theory. And the Filtered Back Projection (FBP) is the most representative algorithm using a Radon model [2]. FBP is the correct analytical solution to the Radon transform with no noise, which is only the case in transmission tomography. However, Emission Tomography (ET) has a significant level of noise and FBP becomes inaccurate in this case [3]. Due to the high amount of noise, a reconstruction algorithm for ET needs to compensate for the effects of its physics. The EM algorithm is one of the most suitable iterative methods for ET image reconstruction, because it contains imaging physics such as the geometry, non-uniform attenuation, scatter and so on. Parameters estimated with consideration of these imaging physics are components of a system matrix ($\boldsymbol{h_{ij}}$).

2.2 Expectation maximization algorithm

The expectation-maximization (EM) algorithm is used as an important statistic tool for finding the maximum likelihood estimates in an image reconstruction. This EM algorithm consists of two major steps which are called the expectation step and the maximization step, respectively. The expectation step concerns the unknown underlying variables, using the current estimates of the parameters and conditioned upon the observations. The maximization step then provides a new estimate of the parameter [4].

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

These two steps are repeated until a convergence. The EM algorithm is given by equation (1). Where, $\boldsymbol{f_k^{(n)}}$ is the estimated activity in pixel *k* for iteration *n*. The notation $\boldsymbol{h_{ij}}$ represents the probability that a photon emitted from voxel *j* will be recorded in data bin *i.* And notation $\boldsymbol{g_i}$ indicates the measurements in projection bin *i*. Because of the system matrix, the EM algorithm tends to reduce the statistical noise artifact over the FBP algorithm. The EM algorithm is especially useful in an industrial emission tomography, because it does not require the projection data to be equally spaced [5].

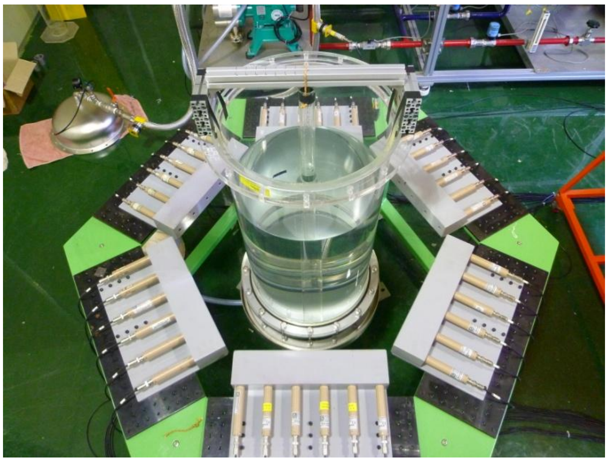

Fig. 1 Photograph of experimental set up

2.3 Experimental set up

In order to examine the spatial distribution of tracer, we used the radionuclides from the Ge/Ga generators for the emission tomographic tests with the industrial SPECT system. The industrial SPECT system consists of 36 detectors, 36 single channel analyzers and the DAQ system. The detectors are 0.5×1 inch NaI(Tl) scintillator coupled with PM-tube and shielded with lead collimator to minimize scattered radiation detection. The collimator was designed that has 10 cm of FWHM (full width at half maximum) at center of vessel. The measured counts in each detector were processed with the expectation maximization (EM) algorithm that reconstructs the cross-sectional image of the distribution of radiotracer in the vessel. The experiments were carried out for the static phantom. A cylindrical vessel was filled with water (Φ = 40cm) containing a cylindrical source. This cylindrical source was moved from the center to the wall of the vessel. In order to eliminate scattering radiation and electrical noise, photopeak was collected only with adjusting threshold. In order to confirm the reconstructed image, Monte Carlo simulation was performed with same geometry and conditions.

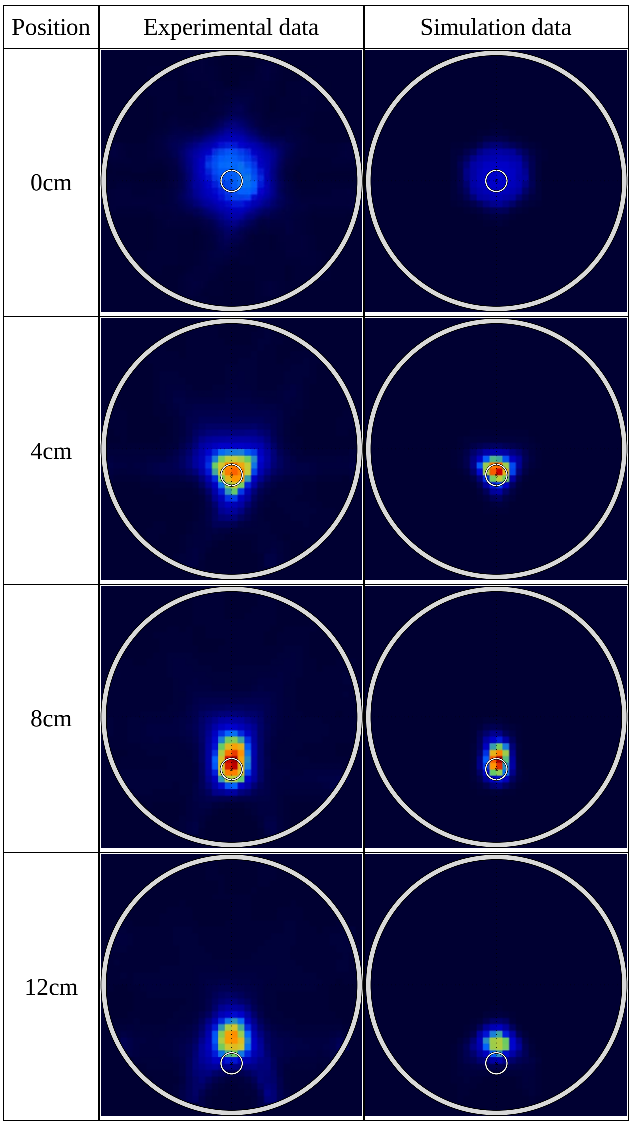

Fig. 2 Reconstruction image of experimental and Monte Carlo simulation data

2.3 Results

Fig. 2 shows the reconstructed image of experimental data and Monte Carlo simulation. To confirm the reliability of reconstructed image from experiments, the root mean square error between experimental and simulation data were calculated as shown table 1. When the static phantom remains the center of the vessel, the reconstructed images are blurred by low count rate of each detector regardless of the experimental and simulation data. As the static phantom was moved close to the wall, the position of the phantom was inaccurate.

Table 1. Root mean square error (RMSE) between simulations and experiments

Source position (cm)	0	2	4	6	8	10	12
RMSE	0.087	0.069	0.062	0.057	0.047	0.040	0.048

3. Conclusions

The industrial SPECT developed at KAERI can image the source distribution of a flow system. In order to evaluate the performance of the industrial SPECT, the reconstructed images depending on source position are obtained. To evaluate the reliability of the experimental results, the Monte Carlo simulation results are compared with experimental results also. Experimental data are in good agreement with the simulation data. And the positions of the reconstructed images reasonably agreed with their real positions. However, as the static phantom was moved close to the wall, the position of the phantom was inaccurate. It seems to be due to the inconsistent spatial resolution of the collimators according to the source position.

Acknowledgement

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