MCNPX-Polimi Simulation for Development of a Stereo Gamma Camera

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1. Introduction

In-situ localization of radiation source is of prime concern regarding decommissioning and de-contamination of nuclear facilities [1]. For this reason, many researchers are developing the gamma-camera [2]. There are two variations; the Compton camera and coded-aperture based gamma camera. Compared with Compton cameras, gamma cameras based on coded-aperture can have superior angular resolution, simultaneous multi-nuclide identification, a wider measurable energy range, dose linearity, and sensitivity [3]. Therefore, we developed Energetic Particle Sensor for the Identification and Localization of Originating Nuclei-Gamma (Epsilon-G) which is a gamma camera based on coded-aperture from the preceding study [3]. However, the two-dimensional (2-D) coordinates only provide information regarding the location of the radiation sources, without the depth information i.e., source-to-detector distance. If two stereo gamma cameras are placed at a certain distance, the depth can be estimated through *triangulation* [4]. In this study, Monte Carlo N-Particle eXtended (MCNPX)-Polimi was performed to derive the optimized distance between two gamma cameras. In addition, an estimate of the source to detector distance was calculated based on the simulation results.

2. Methods and Results

In this study, the distance between two gamma cameras is derived through MCNPX-Polimi considering the Epsilon-G parameters. Figure 1 shows the Epsilon-G. It is composed of detector module, data acquisition (DAQ) system, and MURA mask as shown the Fig. 1. The detector module is composed of 12 x 12 SiPM (ArrayC-30035-144P, On Semiconductor) coupled with 12 x 12 pixels GAGG(Ce) scintillator arrays [3].

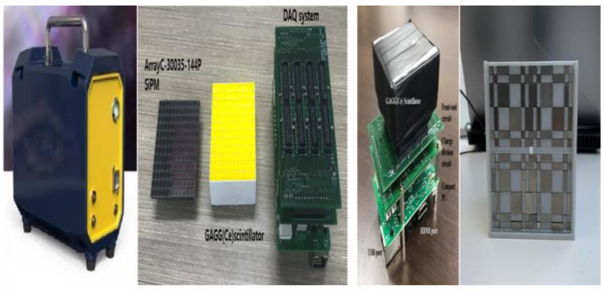

Fig. 1. Epsilon-G (left), components for the Epsilon-G based on 12 x 12 SiPM array (ArrayC-30035-144P, On semiconductor) coupled with 12 x 12 pixels GAGG(Ce) scintillator array, DAQ system center) and 21 x 21 MURA mask (right).

Data was collected from the detector and coded-aperture mask parameters input to MCNPX-Polimi for coded-aperture imaging (CAI) system simulation is shown in Table I. In this simulation, the source to detector distance is set as 1 meter.

Table I: Monte Carlo simulation conditions for the derive the distance between two gamma cameras.

Detector size	4.62 x 4.62cm^2
Scintillator size	4 x 4 x 20 mm^3
Mask pattern	Mosaic MURA
Rank	11
Mask material	Tungsten (ρ = 19.3g/cm^3)
Mask thickness	2cm
Mask pixel size	4.105 x 4.105mm^2

Triangulation is used to estimate the source-to-detector distance. To use *triangulation*, we optimize the distance between two gamma cameras to verify the accuracy at 1 meter. The equation used to estimate the source-to-detector distance for images acquired from gamma cameras on both the left and right is calculated by the following equations (1-5) [5].

$$A = \begin{bmatrix} x_{\gamma R} & y_{\gamma R} \\ x_{\gamma L} & y_{\gamma L} \end{bmatrix} \quad (1)$$

$$A = \left(\frac{n}{2} - A\right) \times \left(\frac{FoV}{n}\right) \quad (2)$$

$$x'_{\gamma R} = A \times x_{\gamma R} \quad (3)$$

$$x'_{\gamma L} = A \times x_{\gamma L} \quad (4)$$

$$Z = \frac{b\ d}{x'_{\gamma L} - x'_{\gamma R}} \quad (5)$$

where A is a matrix consisting of x and y coordinates of reconstructed images from left and right cameras, $x_{\gamma R}$, $x_{\gamma L}$, $y_{\gamma R}$, $y_{\gamma L}$ are x, y coordinates on each camera. And n is pixel number, Z is the source-to-detector distance, b is the distance between two gamma-cameras, and d is mask-to-detector distance.

An illustration of the geometry of gamma camera is shown in Fig. 2. And figure 3 shows reconstructed images acquired from both gamma-cameras.

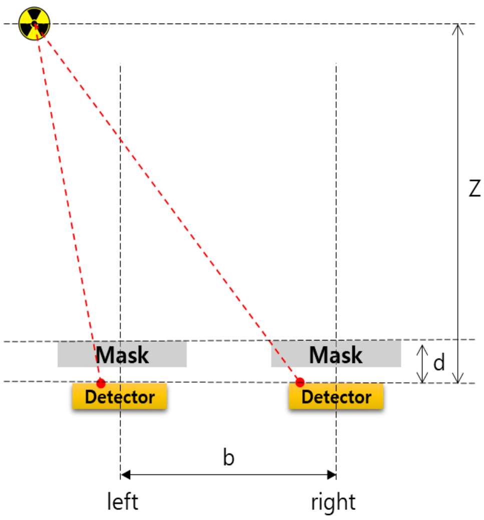

Fig. 2. Schematic of a radiation source reconstructed two gamma cameras.

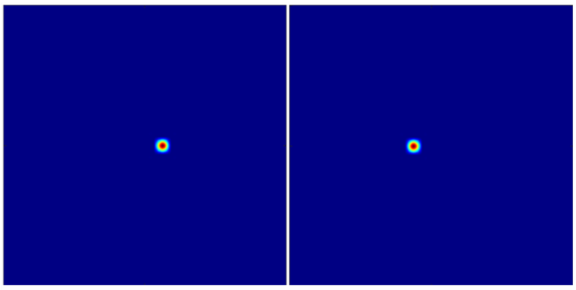

Fig. 3. The reconstructed images from each gamma camera when the source is placed at 1m away form the system.

As a result of the MCNPX-Polimi, when the distance between the two gamma cameras was 12.4cm, the error for the source-to-detector distance was minimized. Figure 4 shows the distance accuracy (Z value) versus incident angle of gamma ray, evaluated from two images taken by both gamma cameras.

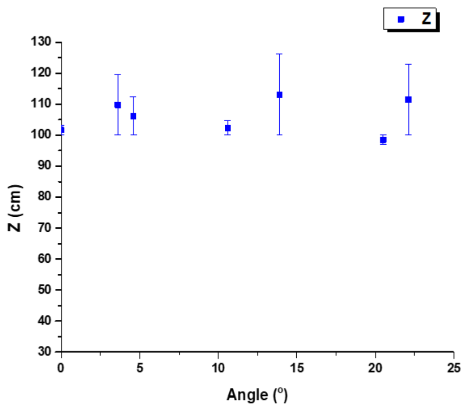

Fig. 4. Source-to-detector distance accuracy according to incidence angle.

Using the results for the optimized geometry condition for the stereo camera from the MCNPX-Polimi results, further data will be presented regarding the distance estimation accuracy and Field-of-View (FoV) after experimenting with two Epsilon-Gs in this conference.

3. Conclusions

In this study, we optimized the distance between two gamma cameras for the stereo camera that can provide the source-to-detector distance through *triangulation*. The MCNPX-Polimi simulation results show that the error rate between the actual distance and the estimated distance is about 6.59% when the distance between the two gamma cameras is 12.4 cm. And FoV was determined -22° and +22°.

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