Monte Carlo Simulation Studies of Collimator Geometry in Nuclear Medicine Imaging using GATE

*Shantonu Sahoo[1,3], Ayan Paul[2], Amitabha Das[2], and Sarbajit Pal[1,3]
[1]*Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata-700064, India*
[2]*Jadavpur University, Kolkata -700098, India*
[3]*Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094, India*
** email: ssahoo@vecc.gov.in*

Introduction

Nuclear medicine imaging techniques are extensively popular these days for diagnosing cancer and other abnormalities in body. All the three imaging techniques of nuclear medicine (viz. Planar scintigraphy, SPECT and PET) uses one or more gamma camera heads to trace the gamma rays emitting from different body parts after a radioactive tracer is given to the patient. In planar scintigraphy and SPECT generally Tc-99m radiotracer is used which emits low energy gamma of 140 keV. The gamma camera head consists primarily of three parts i.e. collimator, scintillator and photon detector array. The basic figure of merit for a gamma camera is a good spatial resolution along with high geometric efficiency (or sensitivity). Clinically, the spatial resolution of a gamma camera is measured using quadrant bar phantom. Recently, Monte Carlo simulation using the Geant4 application for tomographic emission (GATE) is widely applied in the pre-clinical nuclear medicine field for modeling gamma cameras [1]. In our paper we have used GATE for simulation studies for determining spatial resolution of a gamma camera and choosing the correct collimator geometry for better image. Similarity analysis based on correlation coefficients and peak signal-to-noise (PSNR) ratios was performed to compare image qualities for various collimator geometries and source-to-collimator distances.

Detector Modelling

Geant4 is used extensively for modeling various kinds of detectors in nuclear physics. GATE has an application layer built over Geant4 core that provides macro-based scripting platform to users and is a useful tool for modeling new camera designs.

The detector model developed in GATE v9.1 (as shown in Fig. 1) consists of 51.2 X 51.2 mm of LYSO(Ce) scintillator with a thickness of 3 mm and a collimator with 128x128 parallel square holes. The collimator length and septal thickness has been varied from 4mm to 20mm and 0.03mm to 0.1mm respectively.

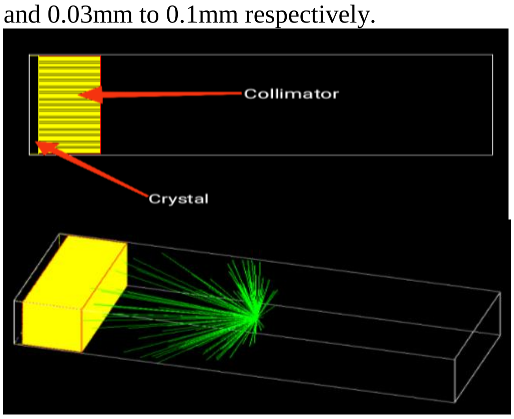

Fig. 1: Detector Model and Simulation in GATE

In this simulation, we have used two type of sources (a) point source and (b) quadrant bar source. For both the cases we have acquired 128x128 pixeled images with a 0.4 mm pixel size and 10% energy window of 140 keV (99mTc). The four quadrant bar shaped phantom consists of four group of bars with thicknesses 3.5mm, 3mm, 2.5mm and 2mm as shown in Fig. 2. These bars are separated by a distance equal to their thicknesses.

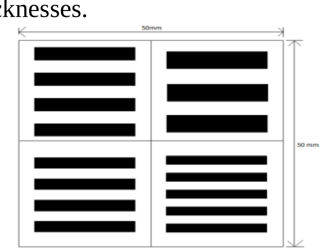

Fig. 2: Quadrant Bar Phantom Source

Results and discussion

i) <u>Septal thickness:</u>

For studying the effect of varying septal thickness, we have used point gamma source (140 keV) of activity 1MBq and 900s of acquisition time. Fig. 3 shows the images obtained for septal thickness of 0.03, 0.05 and 0.1 mm. Star artifact can be seen for the septal thickness of 0.03mm. Thus, for rest of the simulations 0.05mm is selected as the septal thickness. The reason for the formation of star artifacts is the penetration of gamma rays from one hole to another.

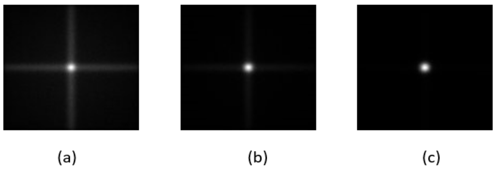

Fig. 3: Images acquired for point source with septal thickness of: (a)0.03 (b)0.05 (c)0.1mm

ii) <u>Collimator length:</u>

For studying the effect of collimator thickness and source-to-collimator distances, we have used the quadrant bar phantom gamma source (140 keV) of activity 1MBq for 200s of acquisition time. The Fig. 4 shows the images acquired for various collimator lengths (4 mm, 8 mm, 10 mm and 20 mm). Here, the source to collimator distance is kept constant at 4cm. Fig. 5 shows the results of similarity analysis based on correlation coefficients and PSNR for variation in collimator lengths.

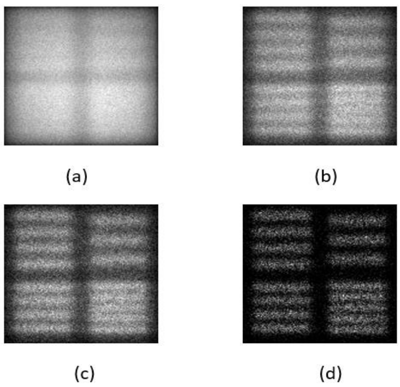

Fig. 4: Images acquired for bar phantom source with collimator length:(a)4 (b)8 (c)10 (d)20 mm

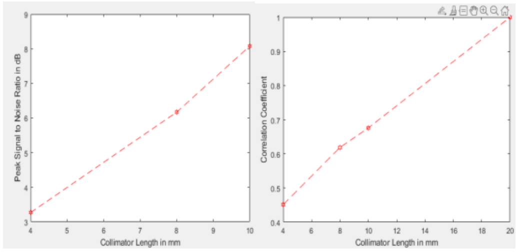

Fig. 5: Variation of correlation coefficients and PSNR with collimator length

iii) <u>Source to collimator distance:</u>

The Fig. 6 shows the images acquired for various source to collimator distances of 0cm, 2cm, 4cm, 6cm and 8cm keeping the collimator length of 10 mm. Fig. 7 shows the results of similarity analysis based on correlation coefficients and PSNR for variation in source to collimator distances.

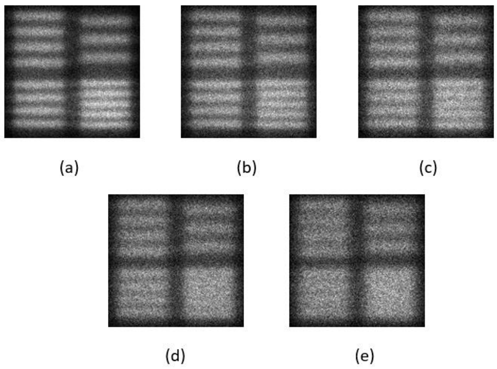

Fig. 6: Images acquired for bar phantom source with S-to-C distance: (a)0, (b)2, (c)4, (d)6, (e)8 mm

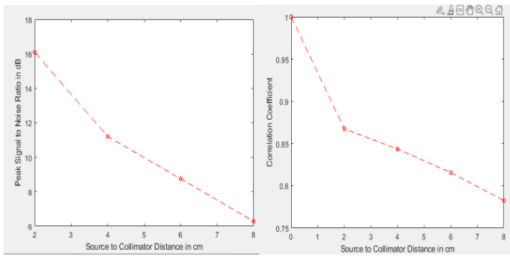

Fig. 7: Variation of correlation coefficients and PSNR with S-to-C distance

References

[1] Chan Rok Park, et.al, Nuclear Engineering and Technology, Volume 53, Issue 6,2021, Pages 1947-1954.