

Learning SPECT detector response for Monte-Carlo simulations

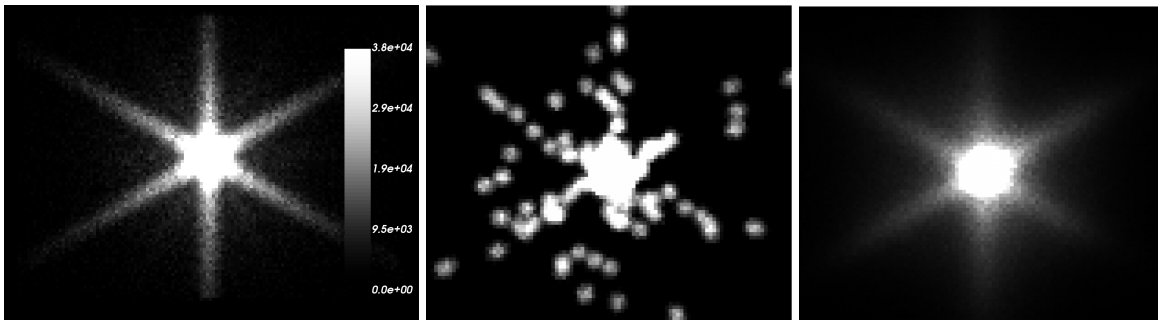
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Introduction. The use of Artificial Neural Networks (ANN) was investigated to learn detector response in Monte-Carlo (MC) simulation of imaging systems in order to replace computationally costly particle tracking in the detector. The proposed method is applied to speed-up simulation of collimator-detector systems with Angular Response Function (ARF) for SPECT imaging.

Method. In SPECT MC simulation, the collimator-detector response function (CDRF), which combines the accumulated effects of all interactions in the imaging head, may be approximated with the ARF method [1,2,3]. It replaces photon tracking inside the imaging head by a tabulated model of the CDRF, build with a histogram (denoted histo-arf) computed from a training simulation. This approach has previously been shown to be efficient and provides variance reduction that greatly speeds up the simulation. One limitation is that computing the tabulated functions is a time-consuming process: about 10^{11} emitted primary photons are required to obtain good statistical uncertainty. We replaced ARF tables with ANN, trained with data obtained from MC simulations. Russian-Roulette was used to decrease data size. Once trained, the nn-arf was used like the histo-arf to estimate the probability of a photon with given incident angles and energy to be detected in each energy window. All development was performed with the open-source Gate/Geant4 platform and will be available in the next release.

Results. The normalised mean absolute error (MAE) between the reference MC simulation and ARF-based simulation, averaged over all image pixels, was compared for various sizes of the training dataset and binning of the histo-arf. Larger datasets ($> 10^9$) were needed for histo-arf to reach the same precision as nn-arf in all studied test cases. Efficiency distributions of all voxels in the image were computed and showed similar results for both methods, with an average around 2 to 3 orders of magnitude faster than analog MC (tracking particles inside the detector, but not the phantom).



Typical star effect of the HEGP collimator for high energy gamma, clearly visible with the analog Monte-Carlo simulation (2×10^{10} particles, top image), visible with ARF-nn (10^7 particles, bottom right) and not visible with ARF-histo (10^7 particles, bottom left). Colorscale is saturated and is the same for all three images.

Conclusion. The proposed ANN-based approach builds ARF tables from less data than conventional methods. It produced results as accurate as histo-arf with slightly better overall efficiency. No binning parameters are required, contrary to histo-arf where results vary depending on such choice. Learning Monte-Carlo detector response with ANN is feasible. The proposed approach is generic and may be used for other types of detectors.

References

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