GARF : Gate Angular Response Function

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1 Learning ARF neural network

Four datasets have been simulated for the four radionuclides. Each simulation tracked 10^{10} primary photons, sampled from the energy distribution of the radionuclide. The simulation use one single SPECT head and record photon incoming at the collimator entrance. It lead to a dataset of about 2.3 GB of data. Russian Roulette factor is set to 100. It tooks around 6 days of computation (on a single core).

Neural networks for all four radionuclides were trained on those dataset with "config-nn-rr100-v4.json" parameter file : 3 layers, 400 neurons by layer, 500 epoch max, 5000 batch size, 200 batch by epoch. It tooks about 2 hours.

Rad	Collimator	E win	gam/decay
Tc99m	lehr	2 (sc, 140)	0.88
In111	megp	5 (sc 171 sc sc 245)	1.8
Lu177	megp	6 (sc 113 sc sc 208 sc)	0.17
I131	hegp	7 (sc 364 sc sc sc 637 722)	1.002

Table 1 – SPECT config

2 Evaluation with one example

The reference simulation was as follows. CT thorax image resampled to $4 \times 4 \times 4$ mm^3, with patient background removed (set to Air). The density tolerance for Gate was set to $1g/cm^3$ (very few material). Physics list was `emstandard_opt1`, cut was set to high values in order to not track electron, except in the SPECT crystal. The source was a voxelized source composed of 3 spheres of about 78, 24, 20 mm diameters, with activity of 1, 1.5, 3 (normalized). About 10^{10} decays was simulated for all radionuclides (and 10^{11} for Lu177), see table.

Reference analog simulation is long, more than 10 days for about 10^{10} decays. Because ARF simulation is a Variance Reduction Technique, less primary particles is needed to reach similar uncertainty. However, there is no simple rule to set this number. A rule of thumb is 10 times less (see efficiency in the next section). To compare to the analog reference simulation, image from ARF simulation must be scaled to the targeted number of primary.

Rad	Nb events	Time (days)
Tc99m	8,584,543,002	35.8
In111	17,918,903,766	68.5
Lu177	16,872,685,913	64.7
I131	9,623,522,427	35.7

Table 2 – Reference simulation

Rad	Nb events	Time (d)
Tc99m	884,971,913	4.05 days
In111	1,847,285,705	8.41 days
Lu177	1,721,704,624	7.6 days
I131	1,002,419,017	4.3 days

Table 3 – Time for ARF simulation (see efficiency speedup in next tables).

3 Results

Speed up have been computed as a mean on each slice, for all voxels with more than 10% max counts. Computation time is extracted from the stats.txt file and uncertainties were computed by voxel.

4 Conclusion

For high activity energy windows (primary peaks), speed up is between 16 to 50, and can reach up around 200 for low activity peaks. Speed up is better for low activity energy windows (scatter).

Tc99m	eff	Analog %	ARF %
channel 1 scatter	21.9	21.9 %	8.6 %
channel 2 140 keV	16.6	5.0 %	2.6 %

In111	eff	Analog %	ARF %
channel 1 scatter	39.1	24.7 %	5.0 %
channel 2 174 keV	21.6	05.4 %	2.0 %
channel 3 scatter	47.3	34.6 %	5.8 %
channel 4 scatter	56.8	37.2 %	5.2 %
channel 5 245 keV	26.5	06.3 %	1.9 %

Lu177	eff	Analog %	ARF %
channel 1 scatter	29.9	19.5 %	5.8 %
channel 2 113 keV	24.7	06.3 %	2.3 %
channel 3 scatter	34.1	22.49%	5.9 %
channel 4 scatter	36.3	22.0 %	5.4 %
channel 5 208 keV	27.8	05.8 %	1.8 %
channel 6 scatter	87.6	27.4 %	2.8 %

I131	eff	Analog %	ARF %
channel 1 scatter	90.5	24.1 %	2.2 %
channel 2 364 keV	51.5	09.6 %	1.5 %
channel 3 scatter	172.9	28.8 %	1.4 %
channel 4 scatter	167.3	30.9 %	1.5 %
channel 5 scatter	313.8	57.6 %	1.5 %
channel 6 637 keV	206.7	38.4 %	1.5 %
channel 7 722 keV	184.5	47.3 %	2.1 %

TABLE 4 – Efficiency speedup ratio per channel. For ex, Lu177 in channel 3 (scatter 3) is 34 times faster with garf.

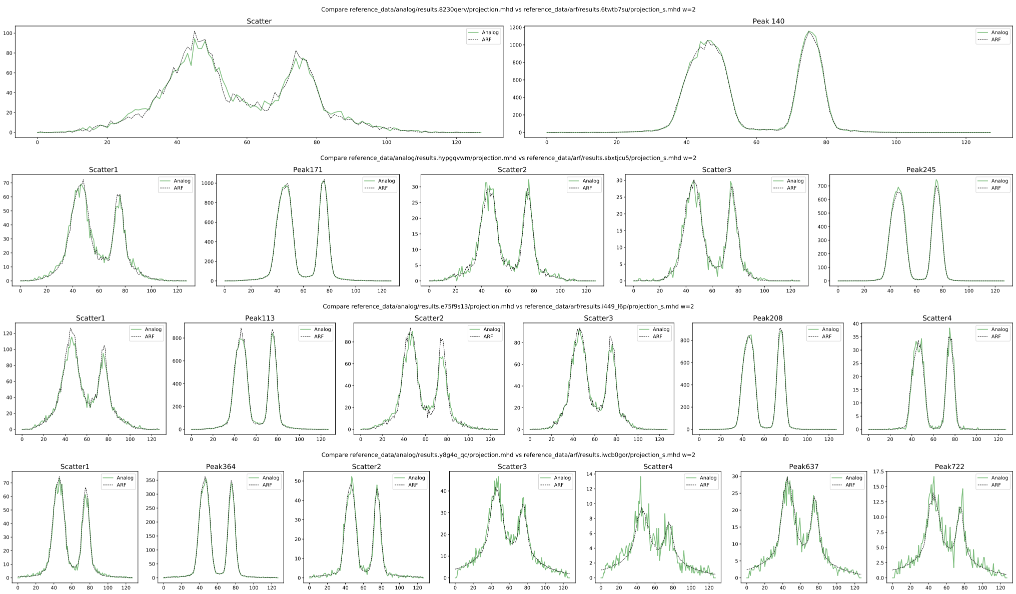

Figure 1 – Profiles comparison, for all windows.