Implementing a Phase Space File Framework in MC-GPU

R. T. Massera[1 2], R. M. Thomson[2], A. Tomal[1]
1 University of Campinas, Campinas, Brazil
2 Carleton University, Ottawa, Canada

Contact information: rtmassera@gmail.com

JULY 12–16 2020 VIRTUAL
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION & AIM

MC-GPU [1] is a Monte Carlo (MC) code designed to work with graphical processing units. The code provide high performance for simulating complex voxelized geometry. However, it only simulates photons, limiting its usage in microscopic scales. This work implements a phase space file generation algorithm in the code to circumvent this limitation. By using this method, we propose to use MC-GPU in combination with other Monte Carlo codes for dosimetric studies on multi-scale simulations in advanced X-ray breast imaging and possibly other applications.

METHOD

The MC-GPU (v. 1.5b) was adapted to generate phase space files for photons entering a volume of interest. Figure 1 shows the implemented framework. For each photon step, a ray-tracing algorithm adapted from PENELOPE MC code [2] checks if the photon enters a volume of interest. The particle information (coordinates, direction and energy) is stored in memory and later dumped in a binary file. Afterwards, a script is called to convert the binary file to the IAEA standard format [3].

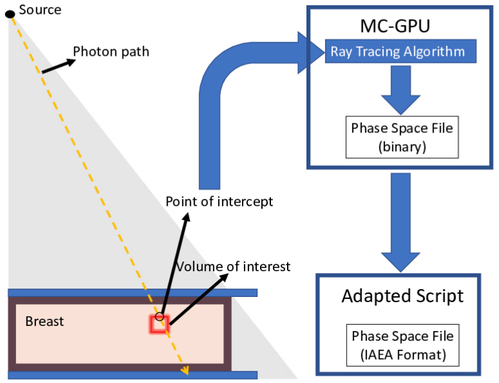

Figure 1: *Illustration of the developed framework to generate phase space files in MC-GPU.*

To validate the implementations, first a mammography simulation was performed in MC-GPU, PENELOPE (2014) + penEasy (2015) [4] and egs_brachy (EGSnrc) [5], the dose in the breast voxels were compared. Afterwards, the recorded photon spectrum in a voxel was compared across the codes.
Five phase space files were generated in MC-GPU for each of 4 breast imaging modalities. The files were loaded in PENELOPE and egs_brachy, then the reconstructed voxel dose was compared with the original in MC-GPU.

RESULTS

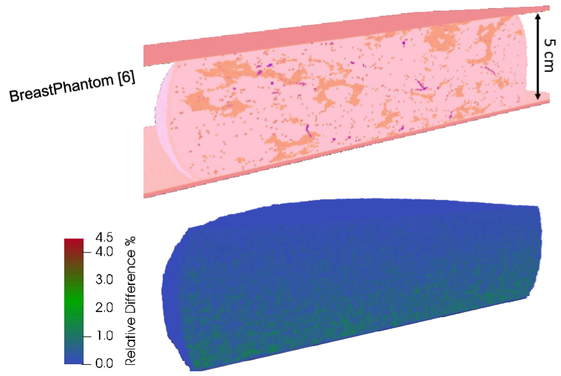

Figure 2: *Top: Illustration of the anthropomorphic computer generated breast phantom employed in this work. Bottom: module of the relative difference of the voxel doses between MC-GPU and egs_brachy. Modality: Mammography (W/Rh 28 kV spectrum).*

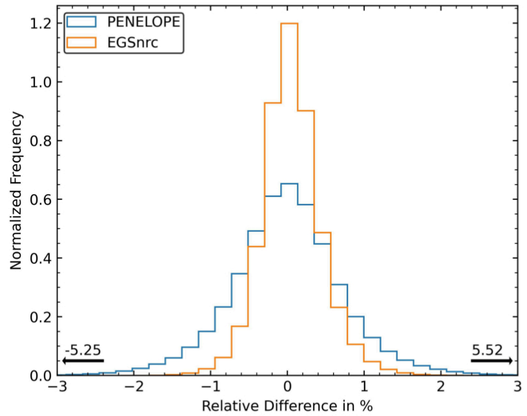

Figure 3: *Distribution of the relative differences of the glandular voxel doses between MC-GPU and PENELOPE|egs_brachy(EGSnrc) . Modality: Mammography (W/Rh 28 kV spectrum).*

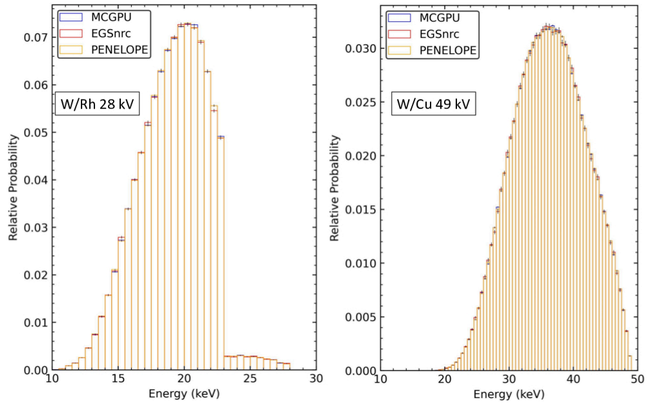

Figure 4: *Photon spectra recorded in a glandular voxel for different Monte Carlo codes. (a) mammography spectrum; (b) Contrast enhanced digital mammography spectrum. The voxel is localized approximately in the middle of the breast (2.5 cm depth).*

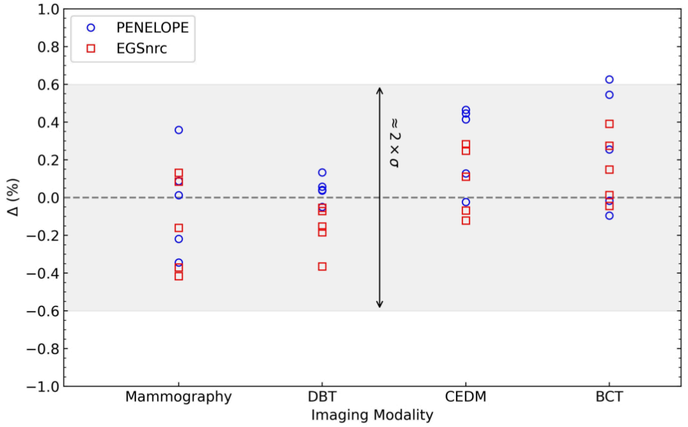

Figure 5: *Relative difference (Δ) between the recorded MC-GPU glandular dose and the reconstructed dose in other Monte Carlo codes loading phase space files. Each point correspond to a different voxel. The shaded area indicates approximately two standard deviations. Modalities (spectrum): Mammography (W/Rh 28 kV); Digital Breast Tomosynthesis (W/Al 32 kV); Contrast Enhanced Digital Mammography (W/Cu 49 kV); breast-CT (W/Al 49 kV).*

Key points

- Voxel doses for MC-GPU agree with those for egs_brachy and PENELOPE within statistical uncertainties (Fig 3).
- Excellent agreement observed in photon spectra evaluated with MC-GPU, egs_brachy, and PENELOPE (Fig. 4).
- Reconstructed voxel glandular doses from phase space file are within 2 standard deviations across all imaging modalities (Fig. 5).

CONCLUSIONS

- MC-GPU provided similar voxel doses compared to other MC codes.
- Phase space file framework successfully implemented in MC-GPU.
- The generated files could be loaded in any MC code that follows IAEA standard.
- A significant performance increase in simulation speed can be achieved combining MC-GPU with other MC codes (up to 100 times).
- This approach allows the study of multi scale Monte Carlo simulations, specially in dosimetric studies of breast imaging techniques.
- The implementations will be available in an online repository.

ACKNOWLEDGEMENTS

ELAP scholarship with support of the Government of Canada. AAPM International Training and Research Coordination Scholarship. Natural Sciences and Engineering Research Council (NSERC) of Canada. Ontario Ministry of Research and Innovation. Canada Research Chairs. Conselho Nacional de Desenvolvimento Cientifico e Tecnológico (CNPQ) project 140155/2019-8. Fundação de Amparo à Pesquisa do Estado de São Paulo project 2015/21873-8.

REFERENCES

1. Badal A, Badano A. Accelerating Monte Carlo simulations of photon transport in a voxelized geometry using a massively parallel graphics processing unit. Med Phys. 2009;36(11):4878–80.
2. Salvat F. PENELOPE-2018: A Code System for Monte Carlo Simulations of Electron and Photon Transport. NEA/NSC/DOC. 2019.
3. Capote R, Jeraj R, Ma CM, Rogers DWO, Sanchez-Doblado F, Sempau J, et al. Phase-space database for external beam radiotherapy. Summary report of a consultants' meeting. IAEA. 2006.
4. Sempau J, Badal A, Brualla L. A PENELOPE -based system for the automated Monte Carlo simulation of clinacs and voxelized geometries-application to far-from-axis fields. Med Phys. 2011;38(11):5887–95.
5. Chamberland MJP, Taylor REP, Rogers DWO, Thomson RM. Egs-brachy: A versatile and fast Monte Carlo code for brachytherapy. Phys Med Biol. 2016;61(23):8214–31.
6. Graff CG. A new, open-source, multi-modality digital breast phantom. International Society for Optics and Photonics; 2016. 978309.