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Phase Plane Rotation as Variance Reduction Method in Monte Carlo Simulations of Axial-Symmetric Radiation Sources

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Monte Carlo algorithms often require large computing resources, primarily in the form of processing time. Knowledge of the underlying principles governing the simulated problem under specific circumstances allows the use of certain variance reduction methods. This work introduces a novel approach to variance reduction based on the partial axial symmetry of the clinical accelerator.

The development of the title method was performed using an accelerator simulation that was divided into two phases: The first phase involves simulating the fluence through the symmetrical part of the accelerator, while the second one involves fluence through the non-symmetrical part. Simulation outputs of the first phase in the form of phase space files were manipulated using in-house software for rotation of the intermediate phase plane. This way, multiple simulations of particle fluence from the source to the last rotationally symmetric component were effectively replaced by multiple random rotations of the phase plane. Analysis of phase plane rotation effects and usability of this approach as a variance reduction method is further investigated in the EGSnrc code.

Usage of phase plane rotation increased the number of particles by the number of rotations factor, resulting in less variance of the estimated dose. However, rotation introduces artifacts that can be treated as a systematic error and these artifacts are discussed throughout this work. Qualitative analysis of the dose profiles undoubtedly shows the superiority of phase space rotations in comparison to particle recycling variance reduction. Also, notable improvement is achieved in terms of the efficiency of the simulation.

The presented results demonstrate improvement in the overall accuracy of the simulation. Given the geometry independent software solution, it is to be expected that the presented method can be applied with equal success to a variety of axial symmetrical radiation sources, and further extended to other packages for Monte Carlo simulations of radiation transport.

References

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