Fast treatment head simulations for photon beams using Directional Radiative Splitting

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ABSTRACT

Introduction: Monte Carlo (MC) simulations of the treatment head of linear accelerators are a valuable tool for the development of source models needed for dose computations in RTP. The vast majority of published treatment head simulations have been performed using the BEAM/BEAMnrc code[1]. Apart from the difficulty to obtain reliable geometry specification from the linear accelerator manufacturers, the main problem when trying to commission a linear accelerator using MC simulations is the very long calculation time. Because the phase space distribution of electrons incident on the photon target are unknown, a large number of simulations with varying incident electron energy and spot size are necessary until good agreement with measured data is found. This paper introduces Directional Radiative Splitting (DRS) for the VMC++ code[2]. DRS is a new variance reduction technique that improves the efficiency of treatment head simulations by more than 2 orders of magnitude compared to BEAMnrc with Selective Bremsstrahlung Splitting (SBS), which was previously the fastest option in BEAMnrc.

Directional Radiative Splitting (DRS): Treatment head simulations (THS) for photon beams are slow because i) without use of any variance reduction techniques (VRT) most of the time is spent tracking electrons and ii) only a small fraction of the bremsstrahlung and scattered photons set in motion (~ 2-3%) escape from the treatment head. DRS addresses i) and ii) by using a complex combination of interaction splitting for processes resulting in the creation of photons, Russian Roulette for interacting photons and the cylindrical symmetry of the upper portion of the treatment head. In addition, it introduces “electron importances” (EI) that are associated with individual regions and components of the treatment head. In regions with higher EI photon interactions result in the creation of more electrons and vice versa. Electrons moving from a region of lower EI to a region with higher EI are split, electrons moving from higher EI to lower EI are subjected to Russian Roulette. The relative EI of regions increases when moving from the top to the bottom of the treatment head.

Results: When DRS is used with the VMC++ code, around 5 (at 18 MV) or 12 (at 6 MV) photons per minute are produced on a 1.53 GHz Athlon CPU in a typical THS that includes the photon target, primary collimator, flattening filter, monitor chamber and photon jaws. This is about a factor of 500 faster than BEAMnrc with SBS. As VMC++ uses a splitting technique for the transport in the patient, thus effectively transporting each photon many times, the time spent for the THS is a small fraction of the CPU time needed for the simulation in the patient (about 10%). One can therefore conclude that a complete THS for each patient dose calculation is possible without a significant increase of CPU time compared to a simulation with an empirical source model.

Future work: Future work will involve the implementation of VMC++ geometry modules for MLC, wedges and compensators. In VMC++ with DRS, most of the CPU time is spent with geometry related checks and therefore the development of extremely fast geometry module implementations is imperative for efficient simulations. The development of an automated beam commissioning process is also envisioned.

REFERENCES

1. D. Rogers *et al*, BEAMnrc Users Manual, NRC Report PIRS 509(a) revF (2001).

2. I. Kawrakow, VMC++, electron and photon Monte Carlo calculations optimized for Radiation Treatment Planning, in *Advanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications*, edited by A. Kling, F. Barao, M. Nakagawa, L. Tavora, and P. Vaz, pages 229 – 236, Springer, Berlin, 2001.