Paper ID

UNIQUE FORMULATIONS IN TITAN AND PENTRAN FOR MEDICAL PHYSICS APPLICATIONS

Alireza HAGHIGHAT [1*], Katherine ROYSTON [1]
Glenn SJODEN[2], Ce YI[2], Mi HUANG[2]

[1] *Nuclear Engineering Program, Mechanical Engineering Department, Virginia Tech, Virginia Tech Research Center, Arlington, Virginia, USA*
[2] *Nuclear and Radiological Engineering Program, Georgia Tech, Atlanta, Georgia, USA*

Special algorithms for application to medical physical problems have been developed and implemented into the TITAN and PENTRAN 3-D parallel transport codes. TITAN is a 3-D parallel transport code with hybrid algorithms including 1) Sn and Characteristics, and 2) Sn with a fictitious quadrature set and ray-tracing. PENTRAN is a 3-D parallel transport code with adaptive differencing Sn formulation, full domain decomposition, and different angular quadrature types with ordinate splitting.

TITAN has been used for simulation of Computed Tomography (CT) device and Single Photon Emission Computed Tomography (SPECT) devices. In this paper, we will discuss new algorithms developed for SPECT. Specifically, we will elaborate on the use of a hybrid formulation which is comprised of the use of the Sn algorithm in the phantom region, a new fictitious quadrature set for directions starting from the phantom surface and passing through each collimator, and a simplified ray-tracing algorithm for transporting particles along the fictitious directions to the gamma camera. The TITAN projection images are compared with the Monte Carlo MCNP5 predictions. For a collimator of high aspect ratio, it is demonstrated that TITAN yields accurate results (within a few percent) in significantly shorter computation time. However, for low aspect ratios, the accuracy of the current algorithm diminishes, resulting in differences of more than 10%. Work is underway, on developing a new methodology which is applicable to any aspect ratio.

With recent interest in single fraction Stereotactic Body Radiation Therapy, quantification of out-of-field dose assessments is increasingly important. A novel, fast convergence dose computation approach using the parallel PENTRAN code called EDK-Sn, or “Electron Dose Kernel-Discrete Ordinates” has been developed for dose calculations in heterogeneous, voxelized phantoms or other geometries. Pre-computed electron dose kernels generated in advance using full physics Monte Carlo are rapidly projected and integrated over a spatial grid using Sn derived voxelized net currents and fluxes to yield accurate radiotherapy dose calculations. The method has proven effective for fast and accurate computations of in-field and out-of-field whole body dose calculations when benchmarked to Monte Carlo simulations for basic test sources. Utilizing a clinical water phantom yielded a speedup of ~8 over traditional highly parallel Monte Carlo calculation times, with <7% difference in dose among different organs (or smaller given stochastic uncertainties). Work is underway to examine the EDK-Sn method for real radiotherapy sources and the new Varian clinical linear accelerator with clinical phantoms.

KEYWORDS: Radiation Transport, Deterministic, Monte Carlo, SPECT imaging, Radiation Therapy, TITAN, PENTRAN