MCNP SPEED ADVANCES FOR BORON NEUTRON CAPTURE THERAPY

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MCNP Speed Advances for Boron Neutron Capture Therapy

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ABSTRACT

The Boron Neutron Capture Therapy (BNCT) treatment planning process of the Beth Israel Deaconess -M.I.T team relies on MCNP to determine dose rates in the subject's head for various beam orientations. In this time consuming computational process, four or five potential beams are investigated. Of these, one or two final beams are selected and thoroughly evaluated. Recent advances greatly decreased the time needed to do these MCNP calculations. Two modifications to the new MCNP4B source code, lattice tally and tracking enhancements, reduced the wall-clock run times of a typical one million source neutrons run to one hour twenty five minutes on a 200 MHz Pentium Pro computer running Linux and using the GNU FORTRAN compiler. Previously these jobs used a special version of MCNP4A created by Everett Redmond, which completed in two hours two minutes. In addition to this 30% speedup, the MCNP4B version was adapted for use with Parallel Virtual Machine (PVM) on personal computers running the Linux operating system. MCNP, using PVM, can be run on multiple computers simultaneously, offering a factor of speedup roughly the same as the number of computers used. With two 200 MHz Pentium Pro machines, the run time was reduced to forty-five minutes, a 1.9 factor of improvement over the single Linux computer. While the time of a single run was greatly reduced, the advantages associated with PVM derive from using computational power not already used. Four possible beams, currently requiring four separate runs, could be run faster when each is individually run on a single machine under Windows NT, rather than using Linux and PVM to run one after another with each multiprocessed across four computers. It would be advantageous, however, to use PVM to distribute the final two beam orientations over four computers.

1. INTRODUCTION

Boron Neutron Capture Therapy (BNCT) is an experimental bimodal cancer treatment utilizing neutron irradiation and a tumor seeking $^{10}$B loaded pharmaceutical. The BNCT treatment planning process of the Beth Israel Deaconess Medical Center (BIDMC) - M.I.T team relies on Monte Carlo N-Particle (MCNP$^1$) transport code to determine dose rates throughout a model of the subject's head, or other body part. The model is constructed using patient specific CT data with the aid of treatment planning software, MacNCTPlan. This program allows the medical physicist to combine the thermal and fast neutron, structural and induced gamma, and $^{10}$B dose rates calculated by MCNP with appropriate relative biological effectiveness (RBE). It also allows the comparison of RBE dose rates to normal tissue, sensitive structures and tumor from scooping run results of four or five potential beam orientations. Of these, one or two final beams are selected and thoroughly evaluated. Both the scooping and final runs are time intensive computational tasks, limiting the practicality of the BNCT treatment planning process. Increased computational efficiency and running tasks in parallel has greatly decreased the time needed to do these MCNP calculations.

2. BACKGROUND

2.1 MCNP

There are several reasons MCNP is used for the dose rate calculation. It has the ability to accurately represent the subject's head, the irradiation beam's spatial, angular and energy distributions, the flux depression caused by neutron absorption, and the detailed transport and thermalization of epithermal neutrons. MCNP also operates on a variety of computer platforms, including Windows NT, Windows 95 and Linux, all of which operate on PCs. MCNP is a benchmarked reliable code, created and maintained by Los Alamos National Labs.

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$^1$ MCNP is a trademark of the Regents of the University of California, Los Alamos National Laboratory.
4. RESULTS

This new lattice optimized executable was compared against the standard MCNP4B release using non lattice geometry, and against the previous executable "MCNPNEHD", an optimized lattice version of MCNP4A created by Everett Redmond II. The time decreases were quantified and the dose rates were verified against the previously accepted code.

4.1 Single Task Reduction

The combination of the tracking and tallying enhancements and PVM significantly reduced wall clock runtimes. The single beam scooping evaluation of both the neutron and gamma components, previously totaling one hundred fifty minutes on one 200 MHz Pentium Pro running MCNPNEHD, was reduced to fifty nine minutes using two 200 MHz Pentium Pros. The runtimes for "MCNPNEHD". MCNP4B with the lattice and non lattice geometry, and the PVM enabled MCNP4B lattice model with two 200 MHz Pentium Pros are shown in Fig. 1. Both lattice models use the tracking and tallying optimizations.

![Figure 1. Total wall clock runtimes for a single beam evaluation. The error associated with each point is a few minutes. The numbers in parentheses in the key are how many CPUs were added to the virtual machine.](image)

Scooping runs are typically one or three million source particles, and final evaluations are ten million source particles. This reduces the statistical error from 5% to 1.5% in the regions of interest, in and around the maximum dose and tumor locations.

4.2 Single Task Verification

Before this new version was used during the BNCT treatment planning process, its calculated dose rates were verified with the previous version. This is especially necessary since the lattice enhanced version will not run the MCNP test suite. When ten million source particles were run, the two versions agreed within two percent for cells with RBE dose rates greater than 1 RBE*cGy/min, and within four percent for lower dose rate cells.