Thesis Title: Macro-Step Monte Carlo Methods and their Applications in Proton Radiotherapy and Optical Photon Transport

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Monte Carlo modeling of radiation transport is considered the gold standard for radiotherapy dose calculations. However, highly accurate Monte Carlo calculations are very time consuming and the use of Monte Carlo dose calculation methods is often not practical in clinical settings. With this in mind, a variation on the Monte Carlo method called macro Monte Carlo (MMC) was developed in the 1990's for electron beam radiotherapy dose calculations. To accelerate the simulation process, the electron MMC method used larger steps-sizes in regions of the simulation geometry where the size of the region was large relative to the size of a typical Monte Carlo step. These large steps were pre-computed using conventional Monte Carlo simulations and stored in a database featuring many step-sizes and materials. The database was loaded into memory by a custom electron MMC code and used to transport electrons quickly through a heterogeneous absorbing geometry.

The purpose of this thesis work was to apply the same techniques to proton radiotherapy dose calculation and light propagation Monte Carlo simulations. First, the MMC method was implemented for proton radiotherapy dose calculations. A database composed of pre-calculated steps was created using MCNPX for many materials and beam energies. The database was used by a custom proton MMC code called PMMC to transport protons through a heterogeneous absorbing geometry. The PMMC code was tested against MCNPX for a number of different proton beam energies and geometries and proved to be accurate and much more efficient.

The MMC method was also implemented for light propagation Monte Carlo simulations. The widely accepted Monte Carlo for multilayered media (MCML) was modified to incorporate the MMC method. The original MCML uses basic scattering and absorption physics to transport optical photons through multilayered geometries. The MMC version of MCML was tested against the original MCML code using a number of different geometries and proved to be just as accurate and more efficient. This work has the potential to accelerate light modeling for both photodynamic therapy and near-infrared spectroscopic imaging.