The macro response Monte Carlo method for electron transport

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This thesis proves the feasibility of basing depth dose calculations for electron radiotherapy on first-principles single scatter physics, in an amount of time that is comparable to or better than current electron Monte Carlo methods.

The Macro Response Monte Carlo (MRMC) method achieves run times that have potential to be much faster than conventional electron transport methods such as condensed history. This is possible because MRMC is a Local-to-Global method, meaning the problem is broken down into two separate transport calculations. The first stage is a local, single scatter calculation, which generates probability distribution functions (PDFs) to describe the electron's energy, position and trajectory after leaving the local geometry, a small sphere or "kugel". A number of local kugel calculations were run for calcium and carbon, creating a library of kugel data sets over a range of incident energies (0.25 MeV-8 MeV) and sizes (0.025 cm to 0.1 cm in radius).

The second transport stage is a global calculation, where steps that conform to the size of the kugels in the library are taken through the global geometry, which in this case is a CT (computed tomography) scan of a patient or phantom. For each step, the appropriate PDFs from the MRMC library are sampled to determine the electron's new energy, position and trajectory. The electron is immediately advanced to the end of the step and then chooses another kugel to sample, which continues until transport is completed.

The MRMC global stepping code was benchmarked as a series of subroutines inside of the Peregrine Monte Carlo code against EGS4 and MCNP for depth dose in simple phantoms having density inhomogeneities. The energy deposition algorithms for spreading dose across 5-10 zones per kugel were tested. Most resulting depth dose calculations were within 2-3% of well-benchmarked codes, with one excursion to 4%.

This thesis shows that the concept of using single scatter-based physics in clinical radiation treatment planning calculations would not only be possible, but would likely be more efficient than current methods, provided large kugels were generated.