Variance Reduction Techniques for the Monte Carlo Calculations of Electron Dose Distributions

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Accurate calculation of the distribution of the dose deposited in the patient's body is a critical portion of the information used in the completion of radiation therapy. The current state of the art in electron dosimetry calculations (the pencil-beam algorithms) have been demonstrated to result in errors in the dose that can be as large as 40% near heterogeneities (Mah - 1989 and Cygler et al., 1987). It is possible that errors of this magnitude can have a serious effect on the outcome of the treatment.

The Monte Carlo method provides a more accurate way of determining the dose distribution in the patient. However, an accurate calculation of dose using this technique would require tens of hours of computing time on the affordable computers available at this time.

The main goals of this work is to apply several different variance reduction techniques to the Monte Carlo method of dose calculation. The techniques applied are splitting and roulette, correlated correction factors, and an efficient look-up table model of the electron multiple scattering distribution. The splitting and roulette method is presented with a simple procedure for generating target weights that result in improved relative efficiency for most of the voxels in simple three dimensional phantoms.

The secondary goal of this work is to develop tools for the analysis of improvements in the efficiency of the Monte Carlo dose calculation. A method is presented that can be used to determine when an estimated efficiency value is statistically significant. Several different weighted averages are developed that may be useful as relative performance indicators for automated efficiency optimization. In addition, several graphing methods are presented that allow qualitative and visual analysis of the efficiency throughout the phantom.