AbstractID: 8821 Title: Probability Density Distribution of Proton Range as a Function of Noise in CT Images

Purpose: Proton range computed in geometry defined by the CT images is a random parameter because of the stochastic component in the CT numbers. We evaluate numerically the probability density functions (PDF) of the computed proton range for different PDFs of the noise in CT images.
Method and Materials: We have used the random number generators to simulate white noise in the CT numbers along the proton pathlength in the model geometry. The noise was simulated using both Gaussian and uniform PDFs. Proton range was computed using continuous slowing down approximation which is valid for most of the proton range. To simulate the statistical straggling of the computed proton range, we have simulated 100000 random combinations of noise.
Results: We show that the PDF of the computed proton range approaches Gaussian distribution for both Gaussian and uniform white noise in CT numbers. The parameters of the range PDF have been determined by least squares fitting of an analytical Gaussian distribution to the numerically obtained PDF using a quasi-Newton optimization algorithm. We have investigated the range PDF as a function of the standard deviation of noise and the computational grid size. We show that 1) the standard deviation of the proton range increases linearly with the standard deviation of noise and 2) standard deviation of proton range linearly increases with the grid size. For homogeneous media, 200 MeV proton beam and the 3mm grid, the standard deviation of the proton range changed between 1-5mm when the standard deviation of noise changed between 2.5%-15%.
Conclusions: Standard deviation of computed proton range increases linearly with the standard deviation of noise in CT images. Noise reduction algorithms for the CT images as smoothing or denoising can minimize the standard deviation of the computed proton range.