Concurrent Image and Dose Reconstruction for Image Guided Radiation therapy

Ke Sheng

Under the supervision of Professors Bhudatt Paliwal and Thomas Rockwell Mackie
At the University of Wisconsin-Madison

December 23, 2004

It is very important to know the patient actual position at the time of radiation therapy treatment so the radiological dose can be precisely delivered to the tumor. The importance becomes more prominent for intensity modulated radiation therapy (IMRT), which has significantly tightened treatment margins and employs an escalated tumor dose. Patient positioning errors and internal organ motion are major reasons for geometrical uncertainties that affect the accuracy of treatment. In order to minimize the uncertainty in IMRT, daily imaging should be employed. To be compatible with the highly conformal dose distribution in IMRT, 3-D image guided radiation therapy (IGRT) by computerized tomography (CT) has obvious advantages in terms of image quality compared to 2-D modalities such as portal imaging and ultrasound. Megavoltage CT (MVCT) and cone beam CT on the gantry are two examples of online monitoring using computerized tomography. The imaging dose, limited field of view and the imaging concurrency of MVCT are investigated in this work. By applying partial volume imaging (PVI), imaging dose can be reduced for a region of interest (ROI). The imaging dose and the image quality are quantitatively balanced with inverse imaging dose planning. CT reconstruction from truncated and modulated beams using different algorithms is studied. The algebraic reconstruction technique (ART) based on projection onto convex sets (POCS) is more robust than filtered back projection when available imaging data is sparsely sampled. However, when the projection is continuous as in the actual delivery, a non-iterative, wavelet based multiresolution local tomography (WMLT) is able to more accurately reconstruct images of the ROI with little additional dose.

The improvement in concurrency and interactive imaging is also discussed in this thesis based on the combination of PVI and WMLT. The combination was tested for simulated data from various experimental platforms. Useful target images were acquired with treatment images for little or no additional imaging dose on a Helical Tomotherapy machine. Data truncation problems with a portal imager installed on a Varian 2100C were also studied, and satisfactory images were obtained using different levels of truncation windows.

When online imaging is available, a perturbation dose calculation (PDC) that estimates the actual delivered dose is proposed. Corrected from Fano's theorem, PDC counts the first order term in the density variation to calculate the internal and external anatomy change. As a conclusion, changes in dose distribution that are caused by internal organ motion are negligible, but external anatomical changes have substantial impact on isodose lines and dose volume histograms. The influence of external contour changes on dose distributions can be quickly calculated by PDC at the time of treatment.