ON PATH UNCERTAINTY AND RANGE LIMIT IN PROTON COMPUTED TOMOGRAPHY

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Abstract

This dissertation addresses the path uncertainty and the range limit issues in proton computed tomography (proton CT or pCT). These two issues rise from proton physics, and are two of the major concerns in the development and application of the single proton-based pCT.

Chapter 1 introduces the motivation and history of pCT study. The renewed interest in pCT stems from the fact that proton radiation therapy requires an accurate stopping power image of the patient for the purpose of treatment planning and delivery verification. Current methods for estimation of such a stopping power image form CT numbers carries an uncertainty of 3% which necessitates the use of margins to account for this uncertainty in the range determination. Proton CT on the other hand allows one to determine a more accurate stopping power image, and hence is the natural candidate

for this purpose, because it uses the same charged particle in imaging as is used for therapy, and allows one to directly reconstruct the proton stopping power image.

Chapter 2 introduces the setup of GEANT4 Monte Carlo simulation used for this, the derivation of the imaging equation, as well as the algebraic reconstruction technique.

Chapter 3 is part of the answer to the path uncertainty question. A method of generating proton path probability map is proposed. The most-probable path estimate and probability envelope can be extracted from the probability map.

Chapter 4 compares three path estimates: most-probable path, cubic spline path (CSP), and straight-line path (SLP), and found CSP and SLP are good path estimates as well, while CSP is well comparable with MPP, which is the theoretically best path estimate. Achievable spatial resolution for pCT at different proton energy and object size is also studied in this chapter.

Chapter 5 explains the origin of the range limit problem, and proposed an solution. The solution is to numerically convert x-ray projection into proton projection, which can be used to compensate for the proton projections missed due to range limit. This method works reasonably well with megavoltage x-ray CT, and could be a promising solution for the range limit problem.

At last, Chapter 6 summarizes the whole dissertation, and discusses some future directions of pCT and accurate proton stopping power reconstruction.