Comprehensive 3D Visual Simulation for Radiation Therapy Planning

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Abstract. External beam radiation therapy is concerned with the precise and accurate delivery of radiation for cancer treatment. Highly-collimated beams are generated in a linear accelerator, consisting of several hardware components that move around the patient in a complex geometry to allow radiation target the tumor from every possible angle. The complex arrangements of the hardware components may give rise to collisions among the components or between the components and the patient. We present a premiere Web-based 3D visual simulator that enables early detection of collision scenarios based on the accurate 3D representation of a specific linear accelerator model and volumetric patient-specific CAT scan data.

Keywords. Radiation Therapy, 3D Simulation, Web 3D.

Introduction

External beam radiation therapy is the precise use of high-energy radiation to treat cancer. About 50-60% of cancer patients are treated with radiation at some time during their disease [1]. A radiation oncologist may use the radiation generated by a machine for non-invasive treatment procedures. Radiation is generated by a linear accelerator (LINAC), consisting of three components: the gantry (rotates around the horizontal axis), the table (translates on the axes and rotates in the horizontal plane) and the collimator (rotates and shapes the radiation beam) as illustrated in Figure1.

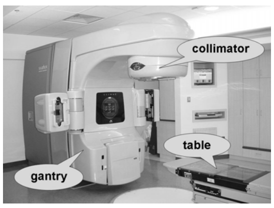

Figure 1. Varian 23iX Trilogy™ Linear Accelerator

1. Problem and Related Work

The complex relative orientations of the LINAC components may cause collisions with the components themselves or between the components and the patient. In addition,

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LINAC head attachments and various patient immobilization devices may contribute as additional sources of collisions. Therefore, a radiation treatment planner may generate a seemingly optimal plan, only to result in a collision when a “dry run” (i.e. an execution of the plan without radiation for collision checking) is executed. This is a serious problem as it may cause significant delays to the patient treatment since the plan has to be revised and re-approved to account for these unforeseen collisions. Additional time and resources must be invested to adjust or to create an alternative treatment plan.

Analytical methods for collision detection have been proposed in the past as a means to improve the planning process [2, 3]. Even though mathematically accurate, these methods are based on the hardware rotational and translational numerical values disregarding LINAC and patient-specific geometry. The existing 3D simulations of the LINAC system have major limitations; they involve only generic patient body representations [4, 5] and do not use accurate three-dimensional graphical models of the LINAC components [4].

Our contribution combines the integration of a highly accurate representation of a specific LINAC model (i.e. Varian 23iX Trilogy™) and the integration of patient-specific CAT (Computed Axial Tomography) scan data in a Web-based simulation system that enables collaboration with remote experts during treatment planning or teaching sessions. A brief description of the system follows.

2. Web-based 3D Radiation Therapy Simulator

Employing the X3D standard [6] and considering the lessons learned from a previous implementation of the simulator [7], we have developed a Web-based 3D simulator, employing the laser scan model of a Varian 23iX Trilogy™ and a 3D surface reconstruction from patient-specific CAT scans as illustrated in Figure 2.

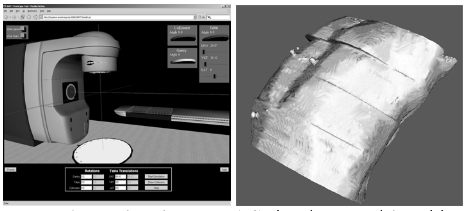

Figure 2. X3D LINAC simulator and 3D skin model reconstruction from CAT scans

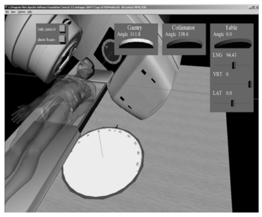

Figure 3. Simulator with patient specific data

We optimized the marching cubes algorithm [8] to obtain a patient-specific 3D skin surface model. Several steps were necessary to process the laser scans of the LINAC into an optimized polygonal model. The decimation algorithm of the polygonal model was particularly important as it improved the rendering speed of the Web-based application.

The simulator (Figure 3) provides an intuitive floating graphical user interface (GUI) to control the angles and locations of the LINAC’s parts. The user may rearrange the GUI components to avoid occlusion of important objects. Volumetric slides and scrolls keep operations simple and naturally fit in the 3D scene. The user can also show/hide the patient and the radiation beam by turning designated switches on/off. The system has a distributed functionality and can easily be shared among researchers and medical personnel at remote locations.

3. Assessment

We have deployed the system on a secure web site and allowed the medical personnel from M. D. Anderson Cancer Center, Orlando, to remotely access the simulation. As an objective test of collision scenarios, we asked radiation therapy technicians to simulate a plan that contains collisions among the system components. The preliminary assessment using visual inspection from different angles (illustrated in Figure 4) provides an early validation for the accuracy of the simulator (i.e. centimeter accuracy).

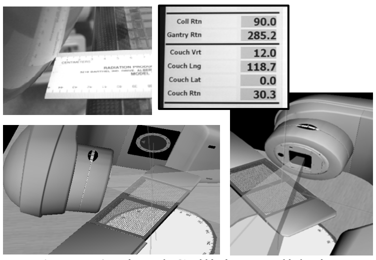

Figure.4 Visual Collision Validation

4. Conclusion and Future Work

We have presented a 3D simulation system that improves the planning process for radiation therapy. The system can be used to detect/predict possible collisions between LINAC components for a given patient and eliminate the need for backup plans, saving planning time. It also enables planners to explore variant and unconventional gantry-couch-collimator combinations of for treatment that may give rise to better quality plans.

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