IN GOOD HANDS

Physicists' unique role in error prevention and QA

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While radiation therapy is an effective cancer treatment, its maximum efficacy hinges on the abilities of the medical professionals who use it. The interplay between different hardware components of external-beam radiation therapy (EBRT) linacs is rather complex and hard to visualize during the computerized treatment planning. In addition, the

**FIGURE 1.** Graphical simulators for Varian 23iX (left) and Varian 600N (right).

**FIGURE 2.** Measuring tool (as the user moves the red/blue dots in the virtual space, the distance between them is displayed on the screen).

**FIGURE 3.** No collision (left) and collision (right) scenarios.

**FIGURE 4.** A quality assurance phantom device: physical (left) and modeled (right). The red orthogonal axes mark the locations of the surface fiducials (BBs). Images courtesy Dr. Hamza-Lup.
lack of collision detection (CD) on available treatment planning software burdens the planner with the challenge of creating a collision-free plan.

**Solution at work**

Our research team has proposed a 3-D graphical simulator for linacs that will save time and resources in generating the optimal treatment plan while simultaneously serving as a learning tool. Embedding patient-specific data such as computed tomography (CT) scans in the interactive simulator advances the radiation therapy planning process by detecting collision cases early. The Web-based interface helps visualize the behavior of the linac components and detect collisions during planning. The simulator components follow the actual hardware motion and angle conventions, and are controllable individually using a mouse or a keyboard, which enables the user to enter specific values. The simulator allows easy identification of the beam-table intersections by modeling the radiation beam as a prism of light projected at the isocenter and collimated to match the beam geometry.

Several investigators\(^1\) proposed a variety of analytical and graphics-based CD tools for solving the collision problem in EBRT. However, the graphical solutions were highly inaccurate as they were based on manual measurements of linac components. Furthermore, analytical tools are difficult to implement since they involve complicated trigonometric relations that require precise linac dimensions. Also, because these tools employ only generic patient models, potential patient-specific collisions cannot be predicted.\(^5\)

- 3.1 Methods. Using this approach, the simulator implementation takes advantage of X3D,\(^6\) a real-time 3-D computer graphics standard, and several 3-D modeling software tools at the development stage. Figure 1 is a snapshot of the virtual room (denoted 3-D radiation therapy treatment, or 3DRRT), which models the real environment.
- 3.2 GUI. Here, the simulator provides an intuitive floating graphical user interface for controlling the angles and locations of the machine's part (Figure 1). This GUI appears in the form of multiple semitransparent windows containing various volumetric controls. Segregating the controls into semantically logical groups (the scrolls for rotations, slides for translations and buttons for switching between different simulation modes) improves the human-computer interaction. The user can easily rearrange the GUI components to avoid occlusions of important objects.

The measuring mode (Figure 2) enables the user to estimate the exact distance between any two points in the virtual space. These measurements

**FIGURE 5.** The grid table surface (top: virtual, bottom: real).

**FIGURE 6.** Visual collision validation of a 5 mm surface-to-surface separation: the real linac (left) using a 5 mm spacer and the simulator (right).
are useful for simulation assessment and in collision scenarios, when spatial misinterpre-
tation is possible.

The CD mode (Figure 3) activates an au-
tomatic collision warning system to guard for the user's potential misinterpretation of
the visual collision scenario. The CD system is
based on bounding primitives and uses an
algorithm optimized to work in a Web-based
environment. The CD accounts for collisions
between the gantry and the table, alerting the
therapist to any small clearance case. The
measuring tool can be used to obtain accurate
measurements following a collision warning.

An additional menu allows the user to vi-
sualize 3-D patient data on the table. Digital
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Radiation Therapy (DICOM RT) CT data
scans’ and phantom devices (Figure 4) are
used by therapists for testing purposes. The
user can enable the beam projected by the
collimator and control the size of the beam
spot with graphical sliders.

- 3.3 Polyhedral models. To collect point
clouds from several viewpoints, we use laser
scanners. We merge the cloud points, filter
the noise and wrap the valid points into a
polyhedral model. Due to scanner inaccuracies
(approximately 3 mm), we smooth the 3-D
objects and improve the rendering process,
we apply a decimation algorithm and remove
redundant polygons in flat areas. The poly-
hedral model is exported into an X3D object
and employed as part of the virtual scene. We
optimize the scene such that adequate frame
rates (25 frames per second or higher) are obtained
on machines with low rendering power.

To further improve rendering speed and
reduce file size, we use textures to simulate the
geometry of complex areas. Some cases might
call for special processing. For instance, the
table contains a special glass-like component.
Because this material doesn't attenuate the
beam in reality, we tune the transparency of
the detail's surface to resemble the glass and
combine it with a translucent cellular texture
laid underneath (Figure 5).

Results

To improve the features and functionality
of the simulator, we have deployed a pro-
totype on a secure Web site (http://hyperion.
armstrong.edu:8080/3DRTT) equipped with

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