Collison detection for external beam radiation therapy applications in SlicerRT

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Introduction

- Collision detection is important in external beam radiation therapy to help eliminate the need for dry-runs, confirming usability of beam angles, and prevent patient-machine collisions.
- Commercial treatment planning systems (TPS) used to determine proper radiation doses and visualizing the plan are expensive and proprietary.
- SlicerRT [1] is an open-source radiation therapy research toolkit based on the 3D Slicer medical image analysis and visualization software platform.
- Propose the development of a collision detection module in SlicerRT.

Methods

RT treatment machine geometric model

- Used an openly accessible model of Varian TrueBeam™ STx linear accelerator
- Model split into its multiple components and loaded into SlicerRT (Fig 1).
- Created additional treatment device models such as applicator holders and electron applicators based on visits to Kingston General Hospital.

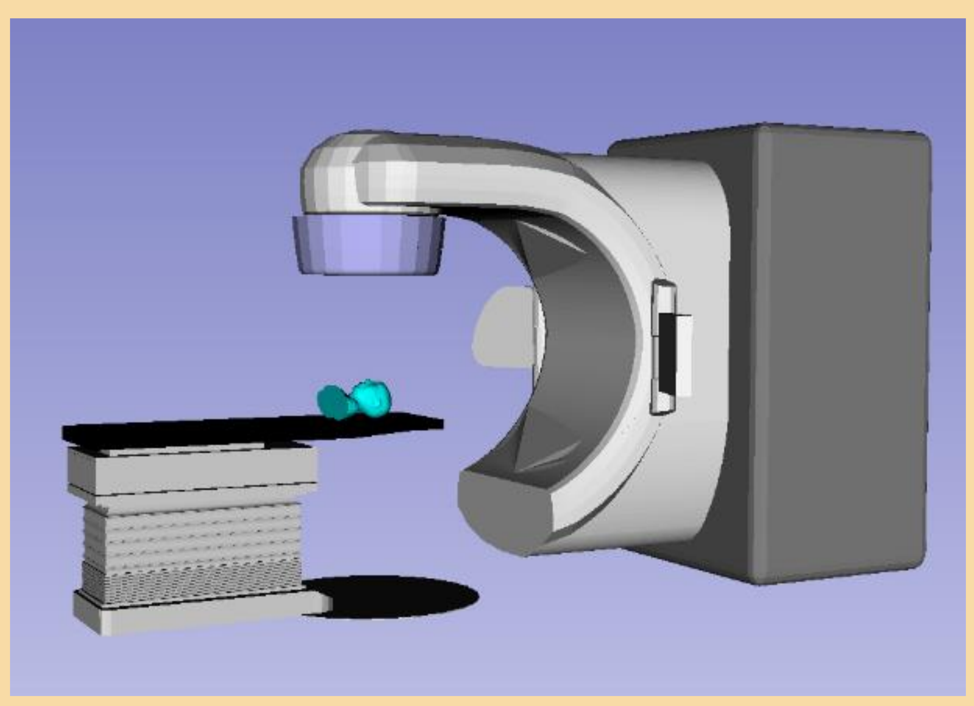

Figure 1. Treatment machine components loaded into SlicerRT.

Room’s eye view and beam visualization

- IEC standard specifies the set of movements and motion ranges for RT treatment machines.
- The coordinate system hierarchy specified by the standard is implemented using a chain of rigid transformations (Fig 2).
- These transformations are dynamically concatenated to determine pose for the individual machine components

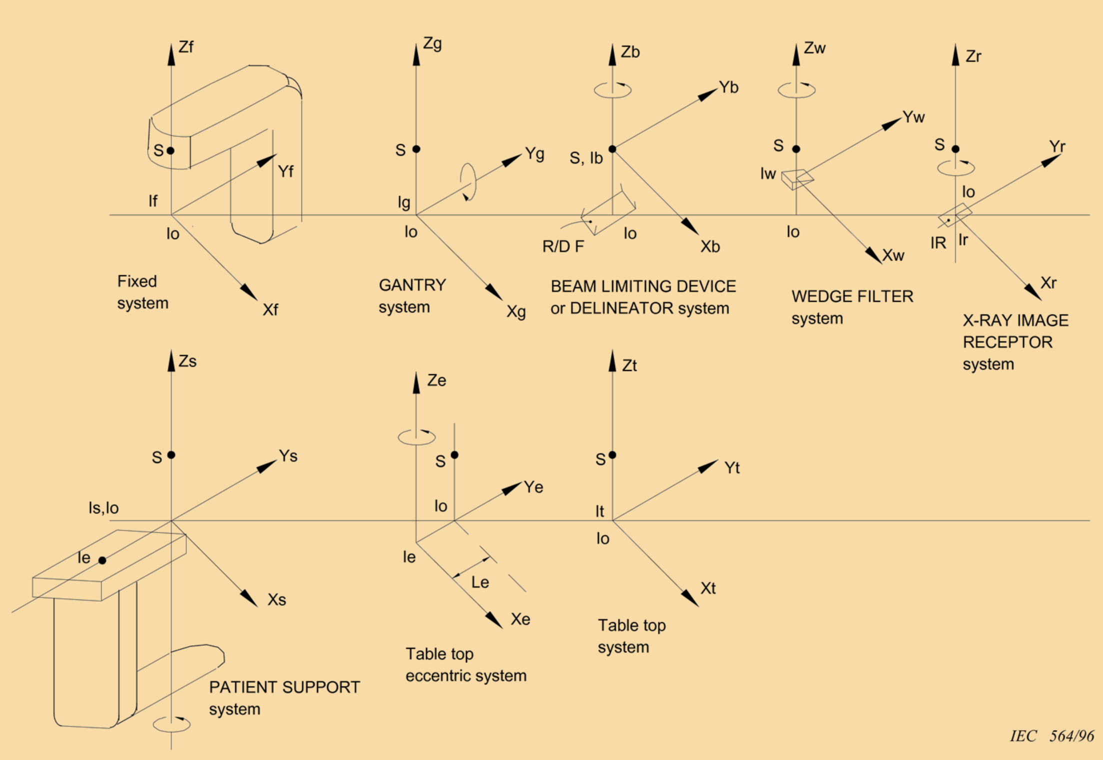

Figure 2. The coordinate systems and movements of each piece in the linear accelerator (linac) defined in the IEC standard.

Collision detection

- Used vtkbioeng[2], an open-source software library, to implement automated collision detection.
- Collision detection calculated real-time between multiple machine components to encompass all possible collisions that could cause damage (see example in Fig 3).

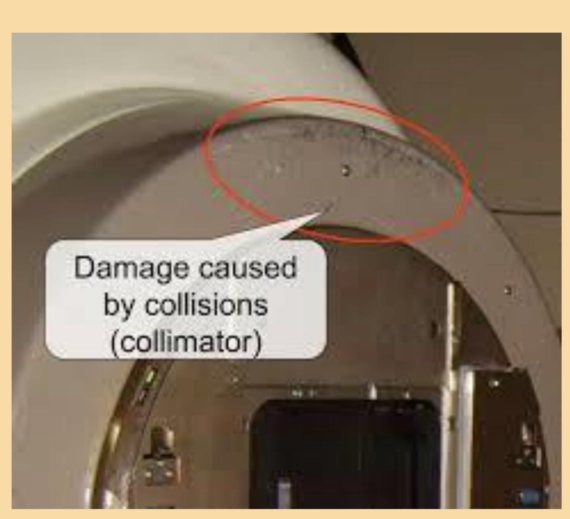

Figure 3. Collimator damage caused by collisions with other parts of linac.

Results

Visualization

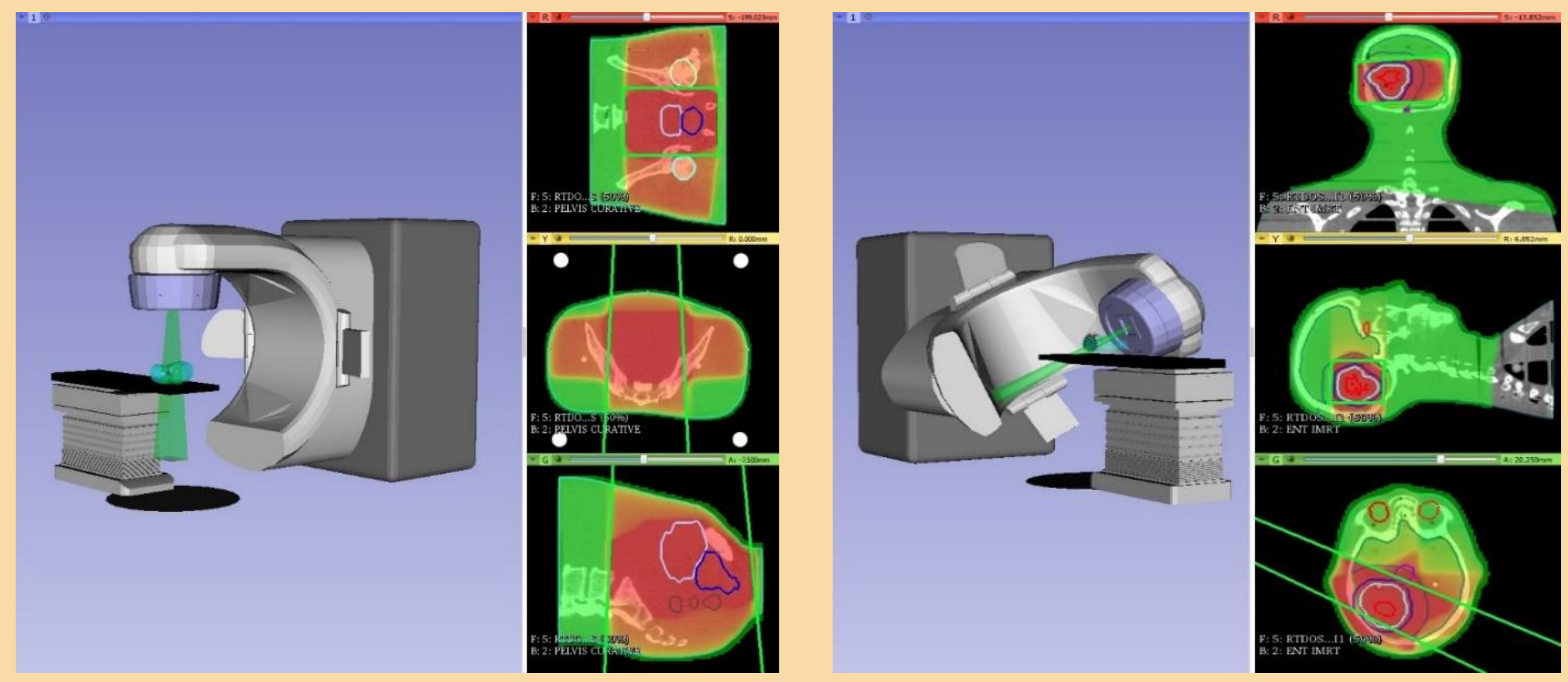

Figure 4. Successful modeling of treatment machine, radiation beam, and room based on geometric parameters (gantry and collimator angle) for both prostate (left) and head and neck (right) RT treatment plans.

- Treatment machine movements were verified using two RT treatment plans, one for a prostate tumor and another for a head and neck tumour (Fig 4).
- Treatment machine is automatically transformed based on the beam angles specified in the RT plan.

Collision detection

- Accurate collision detection was tested for by changing the geometric parameters of the different machine components.
- The detected collisions were verified using notification labels in the UI (see example in Fig 5).
- Ability to detect simultaneous collisions was tested by causing multiple components of the machine to collide (see example in Fig 5).

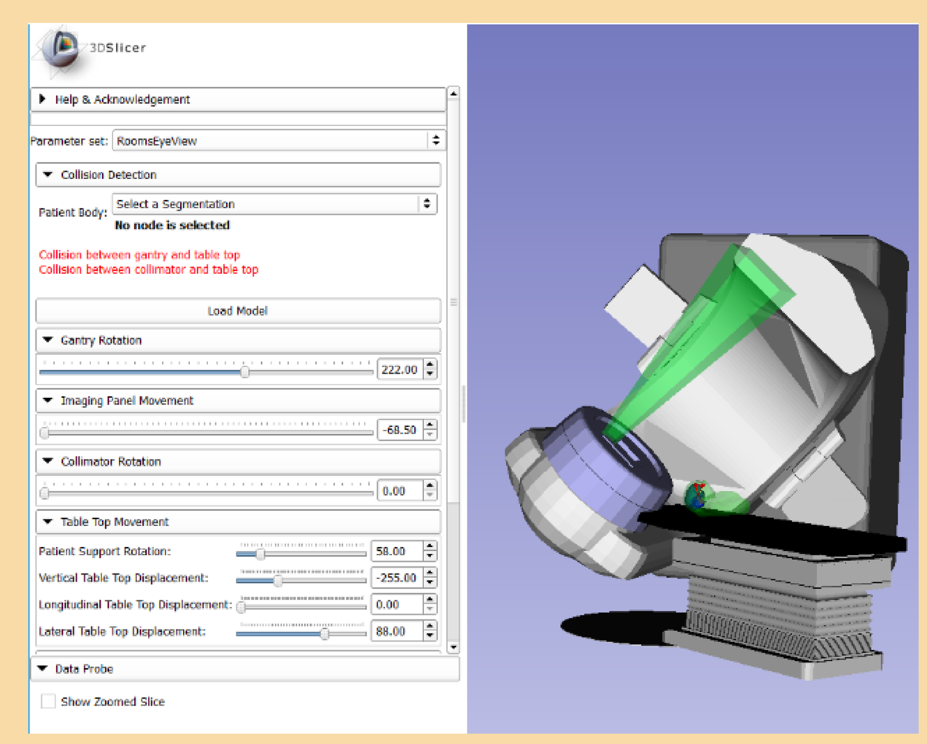

Figure 5. Successful simultaneous collision detection between table top and collimator and the gantry and the table top indicated by the red text notification.

Conclusion

- Room’s eye vie visualization module with automated collision detection was developed as component of an open-source TPS in SlicerRT.
- TPS is currently being used at:
  - Massachusetts General Hospital, Boston, MA, USA
  - ELI-ALPS Laser Research Center, Szeged, Hungary

References

[1] C. Pinter, A. Lasso, A. Wang, D. Jaffray, and G. Fichtinger, “SlicerRT: Radiation therapy research toolkit for 3D Slicer,” Medical Physics, vol. 39, no. 10, p. 6332, 2012.

[2] vtkbioeng. http://www.bioengineeringresearch.com/software/vtkbioeng. (as of December 2016).