Implementation of arc-based collision detection in Eclipse TPS

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Purpose

To implement a collision detection software into the Eclipse treatment planning software that can be accessed by both remote and on-site personnel.

If a collision detection test can be run on patient plans before the patient is on the treatment table, it can cut down on hours/days of replanning and QA. It could improve both sim-to-treat time and the quality of the treatments.

Objectives & Tools

Objectives:

- Develop a script that can determine the shape of the patient's body along with the support structure(s)
- Develop a system of determining where the head of the gantry is in relation to the patient
- Develop a time-effective way of determining if the gantry head will collide with the patient or support structure(s)
- Report possible collisions back to the user in an understandable and useful fashion
- Evaluate accuracy of reported collisions using physical measurements

Tools:

- Fields created using Varian Eclipse 16.1
- Tests were run on both Varian TrueBeam and Clinac iX machines
- Code written using Microsoft Visual Studio 2019 – Community

Materials & Methods

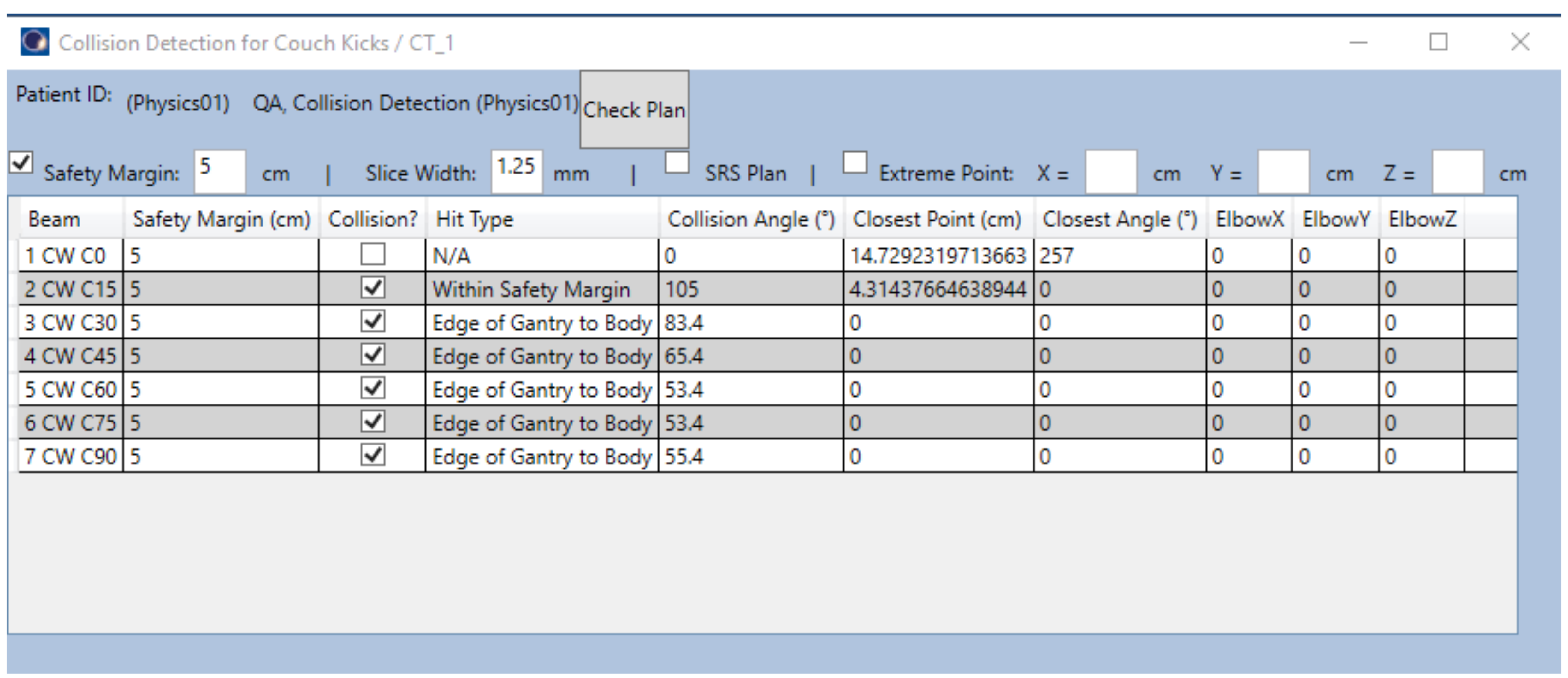
A contour of the patient's skin and of the couch exterior are created/placed by the planner. Those structures are then segmented within the software into four quadrants on each slice to cut down on computation time. Isocenter is found for the specific beam that is being tested. Using start/stop angles of the beam, an arc is created about isocenter with a radius equal to the distance from isocenter to gantry head. The software then searches the segmented structures on each slice for the closest point to the generated arc. The closest distance for the structure is reported back, along with the angle of the gantry head at that point. It was found that additional searches were needed to account for collisions with the edge of the gantry head. The distance from the center of the collimator to the edge of the gantry was found. Using that measurement and the isocenter to gantry head distance, the angle that the gantry head subtends along with the distance from the edge of the gantry to isocenter was determined.

Due to the design of the collimator, a safety margin was introduced into the algorithm. A default value of 5 cm was chosen to give clearance over the interface mount retainer post and guide pins, along with some additional room for inaccuracy.

For Stereotactic Radiosurgery plans, it was realized that the patient support structures that are added to the plan are different than for conventional plans. Therefore, an SRS Plan checkbox was added to account for that difference.

Finally, it was found that additional points would need to be added to account for the extremities in lung/chest arc treatments (i.e., elbows). A manual point can be added by typing in the corresponding coordinates for that point. That point is then added to the list of points to be checked by the script.

Below is an image of the script running in Eclipse showing user inputs and results.



Beam	Safety Margin (cm)	Collision?	Hit Type	Collision Angle (°)	Closest Point (cm)	Closest Angle (°)	ElbowX	ElbowY	ElbowZ
1 CW C0	5	☐	N/A	0	14.7292319713663	257	0	0	0
2 CW C15	5	☑	Within Safety Margin	105	4.31437664638944	0	0	0	0
3 CW C30	5	☑	Edge of Gantry to Body	83.4	0	0	0	0	0
4 CW C45	5	☑	Edge of Gantry to Body	65.4	0	0	0	0	0
5 CW C60	5	☑	Edge of Gantry to Body	53.4	0	0	0	0	0
6 CW C75	5	☑	Edge of Gantry to Body	53.4	0	0	0	0	0
7 CW C90	5	☑	Edge of Gantry to Body	55.4	0	0	0	0	0

Results

Using a CT scan of a 30x30x10 cm stack of Solid Water as a test patient, beams were placed in both static and arc fashions. All tests were run in Eclipse within a Citrix Environment.

Static

The following static fields were applied to the phantom to determine the scripts accuracy in reported distance.

Angle (Degrees)	Predicted Distance (cm)	Measured Distance (cm)	Difference (cm)
0	36.8	37	0.2
15	35.4	33	2.4
30	32	30	2
45	29	27.5	1.5
60	27	22.5	4.5
75	21.7	18	3.7
90	16.6	15	1.6
105	14.8	14	0.8
120	17	15	2
135	21.1	18.5	2.6
150	26.4	22	4.4
165	30.5	28	2.5
180	32	31.5	0.5

The script reported back distance values within 5 cm of the predicted values.

Arc

Arcs were placed on the phantom with couch kicks applied every 15°. This test was to determine the accuracy of the reported angle of collision if one is discovered.

Couch Angle	Predicted Collision Angle	Measured Collision Angle
0	N/A	N/A
15	N/A	N/A
30	83.4	72.2
45	65.4	59
60	53.4	54.9
75	53.4	53.9
90	55.4	53.9

The script was able to correctly predict the angle within 5° for most collisions with the only one greater than 10°.

On average, the computational time was very reasonable at around 18 seconds for two full arcs with no couch kicks. Couch kicks will add around 5 seconds per arc to the run time.

Discussion

The script was found to be in good agreement with the physical measurements during the static gantry test. The accuracy of 5 cm further emphasized the need for a safety margin when using this script .

The script performed very well when couch angles were 45° and above, along with 15° and below. For 45° and above, the script was able to predict the collision angle to within 6.4°. For 15° and below, the script correctly predicted that no collision would occur and that the 15° couch kick would come within the 5 cm safety margin.

The script underperformed in the arc collision test when the couch was between 30° and 45°. This is due to the collision occurring at a different point on the gantry than was expected.

Another limitation-is that this script does not include patient support structures (i.e., the vaclock bag) outside of the couch structure. This is usually not a problem for head and neck plans, or chest plans with extremity points being manually entered, but can be an issue for unusual setups. In that case, a dry run should be performed with the setup device in place in addition to the collision detection script.

Conclusion

Overall, the script performed reasonably well and can still be used clinically to check plans for potential collisions. It is also of note that the script can be executed by both on-site and remote users, making it very accessible. It should be subject to some restrictions, however. First, a minimum of 5 cm should be used as a safety margin. Second, when using arcs, subtract a minimum of 10° from the reported collision angle if one is found. Lastly, the script should not replace a dry run with the patient prior to treatment for angles that are of concern.

Future Development

Developments to improve the accuracy of the collision angle prediction are underway. The point of collision on the gantry head can be determined from the distance between the collision point, isocenter, and the couch angle. This modification has shown to improve accuracy in preliminary testing.

Developments to improve the accuracy of manual extremity point placement are underway. By utilizing the setup photos taken at the CT, the most extreme points of the body can be measured, and their coordinates determined in a much more accurate method.

Contact & Acknowledgements
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