Automating Stereotactic Radiosurgery: Clinical Validation of In-House Collimator and Couch Optimization

Shane McCarthy, PhD, Matthew Wagar, MS, Daniel Alexander, PhD, and Colleen Fox, PhD
Department of Radiation Oncology and Applied Sciences, Dartmouth Cancer Center, Lebanon, NH

INTRODUCTION

- Manual collimator angle selection for multi-target radiosurgery is time-consuming and meticulous
- Introduces inherent inter-planner variability
- Existing solutions are often proprietary with limited customization for an individual clinic's preferences
- Developed in-house solution to optimize both collimator and couch angles
  - Transparent algorithm
  - Extensive customization options
  - Python-based, TPS-agnostic

METHOD

- Python-based tool minimizes normal brain exposure in the beam's eye view (BEV)
  - Parallelized to evaluate nearby couch angles for optimal collimator/couch combinations
- Highly customizable
  - Any single layer MLC
  - User-set couch angle explorations
- Implemented in Eclipse TPS with Eclipse Scripting API for clinical usage
- Retrospective validation on 20 multi-target SRS cases (20 Gy in one fraction)
- Comparing four plans for each case
  - Clinical
  - Clinical geometry re-optimized (CRO)
  - Collimator optimized (ACO)
  - Collimator and couch optimized (ACCO)
- Re-optimized plans used clinically used optimization objectives
- Collimator and couch optimizations started from standard SRS templated arcs at 0°, 45°, 315°, and 90°
- Evaluated target coverage, indices, normal brain dose, and monitor units
- Sought to demonstrate non-inferiority to clinical references
  - Repeated-measures ANOVA
  - Post hoc paired t-test
  - Holm-Bonferroni corrections

Table 1: Target demographics from 20 SRS plans

Parameter	Value
Number of Targets	153
Targets per Plan	7.7 ± 3.5 (3.0 – 16.0)
PTV Volume (cc)	0.33 ± 0.43 (0.06 – 2.96)
Distance to Isocenter	5.33 ± 1.32 (1.20 – 7.93)

ACKNOWLEDGEMENTS

Thank you to the faculty, staff, and students at the Dartmouth Cancer Center

This work was conducted under an IRB approved protocol from Dartmouth Health

CONTACT

Shane McCarthy, PhD
shane.c.mccarthy@hitchcock.org

Want to test it? Reach out!

ALGORITHM

Overview

- Python executable ran via command line
- TPS-agnostic with simple text-based input/output
- Exploits symmetry to expedite calculations
- Executes in under 2 minutes

Process

- Projects target structures to BEV per control point
- Discretizes projections to MLC leaf-sized blocks
- Calculates cost as the area of exposed normal tissue between targets
- Couch optimization achieved through parallel evaluation of nearby couch angles

Customization

- Couch scan defaults to ±10° in 5° increments
  - Fully customizable range and step size
- Used for Varian HDMLC
  - Compatible to any single-layer MLC

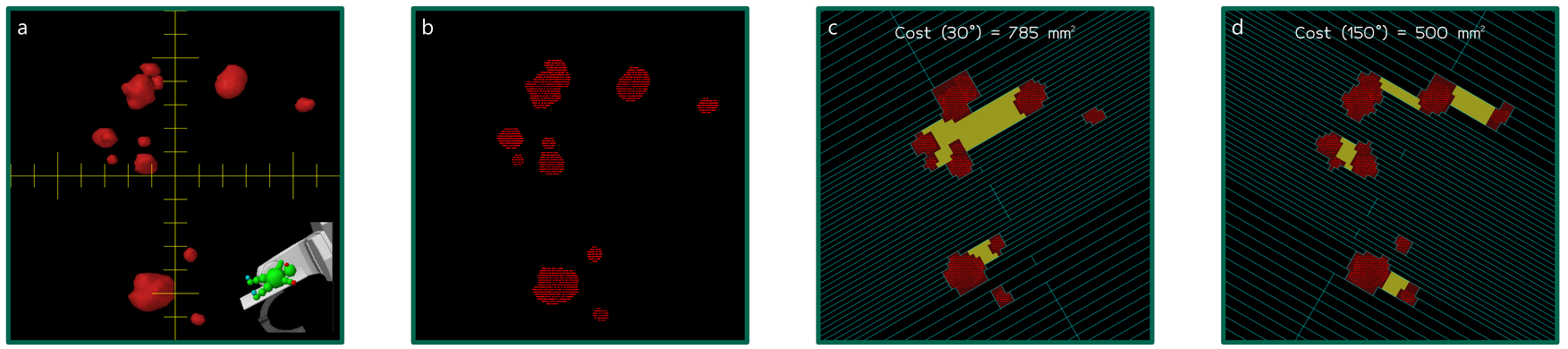

Figure 1: Graphic renderings of the collimator optimization process. (a) Eclipse TPS' BEV for a 13-target SRS case at a couch angle of 0° and gantry at 240°. (b) The same case and positioning, shown as the raw structure contour data. (c, d) The raw contour data (red), discretized (red shadow) to the MLC leaves (blue) with the MLCs fit to the targets and the corresponding cost (yellow) shown. The cost value is calculated for a collimator angle of 30° (c) and 150° (d). This process is repeated for all viable collimator angles, at each gantry angle, along each arc, returning the optimal collimator angle that scores the lowest cost across all gantry angles for that arc.

RESULTS

- Outputs from optimization algorithm shown in Figure 2 compared against clinical geometry
  - Clinical and CRO plans used the same, clinical beam geometry
  - ACO had only collimator angles optimized
  - ACCO had collimator and couch angles optimized
- Figure 3 shows evaluation metrics that indicated statistical significance from RM-ANOVA
  - GTV $D_{99.9\%}$, D_{mean}, $D_{0.03cc}$, PTV Homogeneity Index (HI), and total monitor units (MUs)
  - Pairwise comparisons indicated on plots
- Figure 4 shows evaluation metrics that did not indicate statistical significance
  - PTV $D_{99.9\%}$, Paddick's Conformity Index (PCI), and normal brain V_{12Gy}

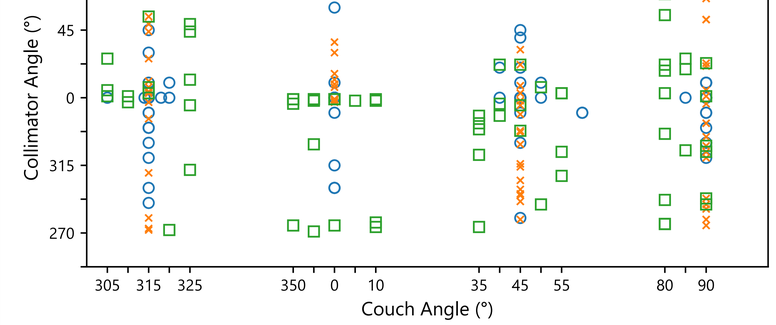

Figure 2: Couch and collimator angle distributions for all three distinct beam geometries for the 20 test cases. The Clinical and CRO plans used the original, clinically-delivered beam geometry. ACO had only the collimator optimized from templated couch positions. ACCO had both couch and collimator angles optimized.

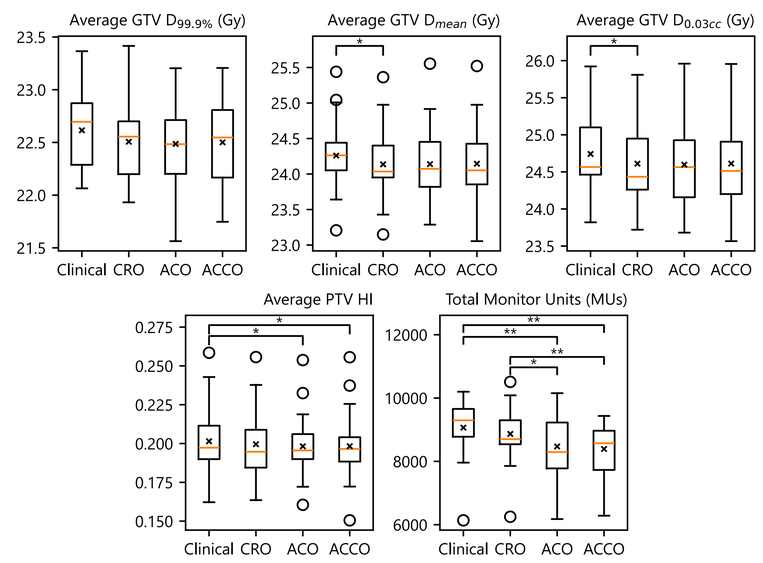

Figure 3: Box and whisker plots visualizing the distributions of various evaluation parameters for all 20 test cases across all four plans. Plots depict parameters that reached statistical significance from repeated-measures ANOVA tests. Central line denotes median, center X-mark denotes mean. Significant pairwise differences determined by post hoc paired t-tests are marked where * = $p \leq 0.05$ and ** = $p < 0.01$.

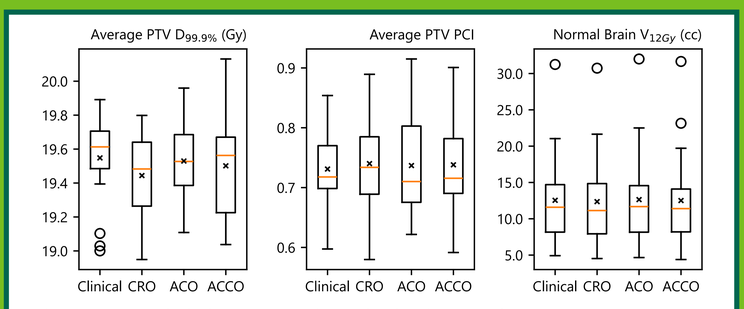

Figure 4: Box and whisker plots visualizing the distributions of various evaluation parameters for all 20 test cases across all four plans. Plots depict parameters that did not demonstrate statistical significance from repeated-measures ANOVA tests. Central line denotes median, center X-mark denotes mean.

CONCLUSIONS

- Fast, TPS-agnostic, and customizable tool for collimator and couch angle selection in multi-target SRS planning
- Clinical validation demonstrated non-inferior target coverage and normal brain dose compared against clinical references
  - Significant reduction in monitor units, possibly enabling improved delivery efficiency
- Couch and collimator angle optimization demonstrates no superiority over collimator angle optimization alone
- Practical tool for standardizing and automating collimator angle selection
  - Facilitating faster SRS planning and reducing planner's cognitive load

MEDICAL PHYSICS COMMUNITY INSPIRATION INNOVATION IMPACT
2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING