ShotCaller: An Automated Target Placement Algorithm to Streamline Spatially Fractionated Radiation Therapy Treatment Planning

Arjun Karnwal[1,2], Arthur J. Olch[2,3], Hualin Zhang[2,3], and Kenneth Wong M.D.[2,3]

[1]*University of Southern California, Alfred E. Mann Department of Biomedical Engineering*

[2]*Radiation Oncology Program, Children's Hospital of Los Angeles,*

[3]*Department of Radiation Oncology, Keck School of Medicine, University of Southern California*

Children's Hospital LOS ANGELES

USC Norris Comprehensive Cancer Center
Keck Medicine of USC

Introduction

- Spatially Fractionated Radiation Therapy (SFRT) has gained popularity in the last decade due to its low toxicity and increased response rate compared to traditional uniform dosage treatments
- SFRT involves the placement of high dose cores (vertices/spherical targets) within bulky tumors, where high doses of radiation will be applied
- Clinicians often have key considerations when planning for SFRT:
  - Target Center to Center Distance
  - Distance to nearby organs (OARs)
  - Distance to tumor boundary
  - Radius of targets
- There is also a (speculated) benefit to maximizing the number of targets within the arbitrary tumor volume for most effective treatment
- The placement of vertex targets is usually a time-consuming and error-prone process. In fact, approximately **80% of the total treatment planning time** is spent arranging the vertices in a favorable manner: maintaining a reasonable sphere-to-sphere distance, placing the maximum number of spheres, ensuring that spheres do not obstruct others from reaching radiation beams, and maintaining a peak-to-valley dose ratio as high as reasonably possible (>2)
- The purpose of this study is to develop an automated algorithm that can assist in SFRT treatment planning, by optimizing the arrangement of targets for a given tumor volume

Methods

- MATLAB, C# and the Eclipse Scripting Application Programming Interface (ESAPI) were used to develop the automated script
- The script features a graphical user interface (GUI), which has user selectable parameters for key geometric constraints and treatment goals (Figure 1)
- Using a King of the Hill Monte Carlo Style approach (Figure 2 flowchart), the algorithm iteratively searches for the best (defined by bias) arrangement of targets that fit the clinics goals.
- Current Bias Options:
  - Max number of spheres
  - Farthest distance to OAR
  - Most/least planes used for targets
  - Closest to center of PTV

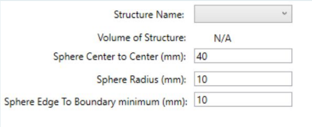

Figure 1. User Selectable parameters in GUI

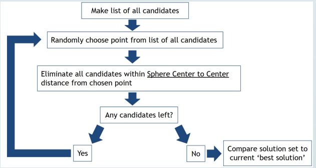

Figure 2. King of The Hill Monte Carlo Style Algorithm Logic

Figures

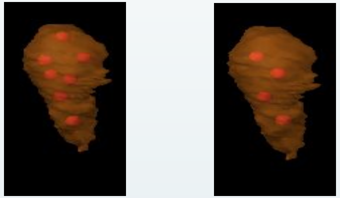

Figure 3. Results of algorithm bias on vertices
Left: Max number of spheres
Right: Bias towards center of PTV

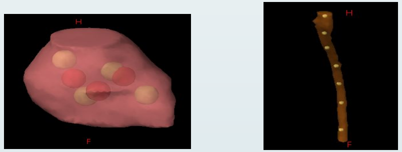

Figure 4. ShotCaller (yellow spheres) compared to SFRTHelper (red spheres) on atypical volumes.

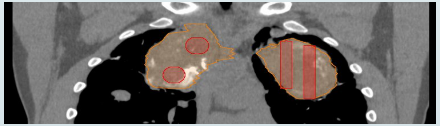

Figure 5. ShotCaller producing both 2D and 3D targets for both GRID and LATTICE therapy

Results

- For a typical SFRT case (25 vertices), MDs/dosimetrists will usually take ~2 hours to optimize the vertice placement
- For the same volume, ShotCaller takes ~4 minutes
- ShotCaller produced 0 geometric placement violations for all volumes
- The script has already saved significant amounts of time for both patients and clinicians

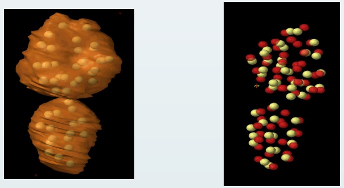

Figure 6. Vertices generated by ShotCaller (yellow) and human operators (red) for an SFRT use case

Conclusions and Next Steps

- Algorithms used in ShotCaller have successfully helped clinicians to treat bulky tumors with LATTICE therapy
- As a result of clinical practice, more features were proposed by clinicians as our next development phases of ShotCaller:

- *A. Replace "King-of-the-Hill" Monte Carlo with AI*
- *B. Display dosage ratios (D5/D95)*
- *C. Edge cases → OAR inside tumor*
- *D. User interface upgrades / multithreading*
- *E. 2D (GRID) Therapy*
- *F. Collaborators welcome!*