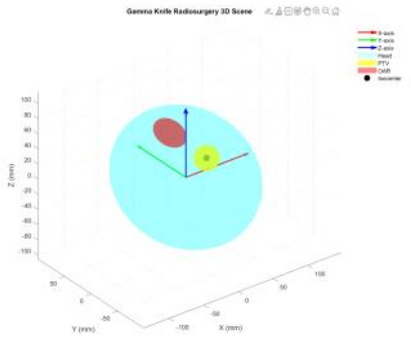
A4

Thursday, November 28, 2024 1:29 PM

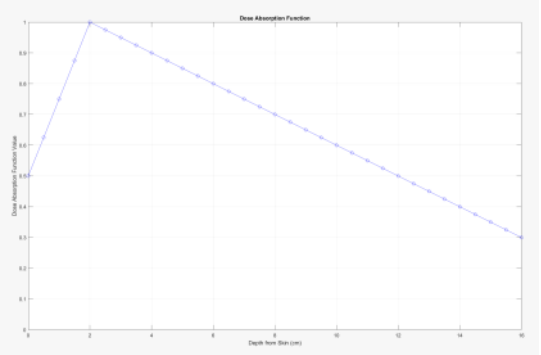
Gamma knife radiosurgery

My study group was Rena, Jade, Dharsan, Noah.

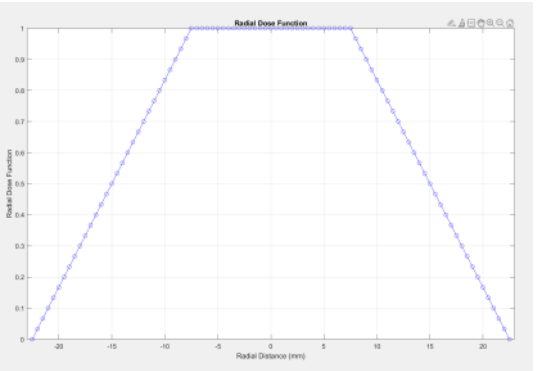
1. Draw 3D Scene



2. Compute Dose Absorption Function Table

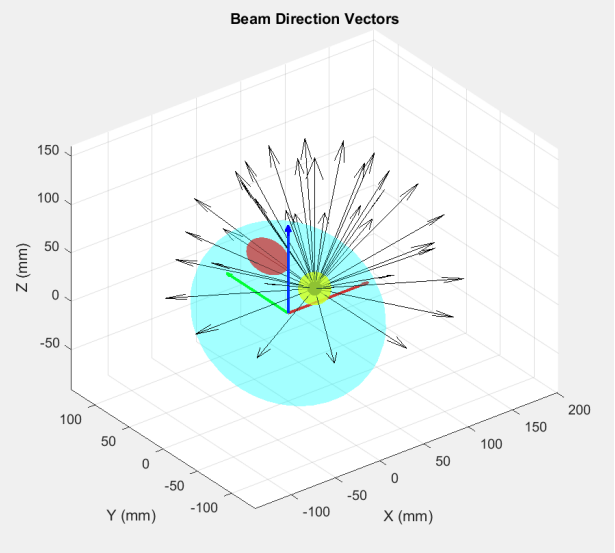


3. Compute Radial Dose Function Table



Note: I had to increment this very tightly because later questions ask to retrieve points at each fraction of the radial distances.

4. Compute Beam Direction Vectors
Diameter of the beam is beam_diameter = 30mm



Note:
Beam vectors are pointing to the PTV to radiate the tumor.

5. Compute Skin Entry Points

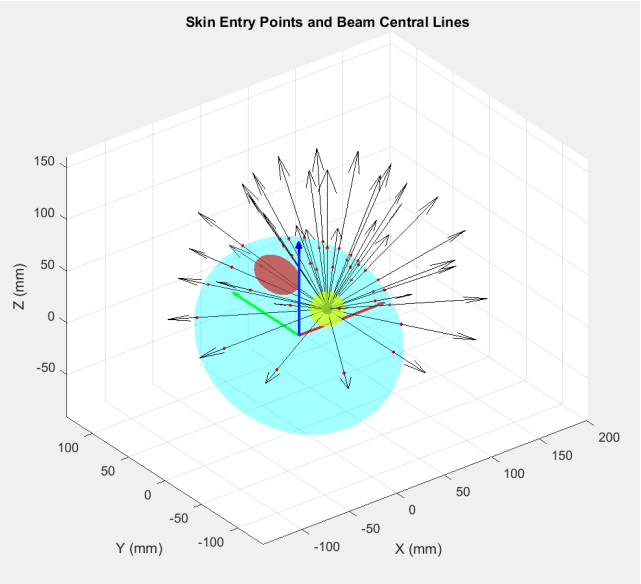


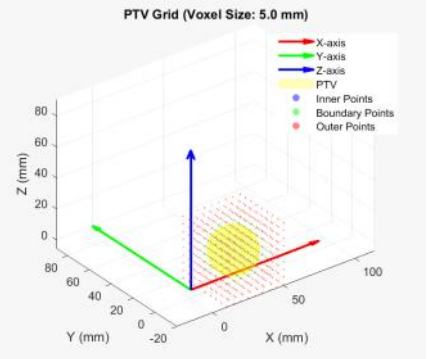
Figure 5: red dots show the skin entry points which is the intersection of the beam with the ellipsoid.

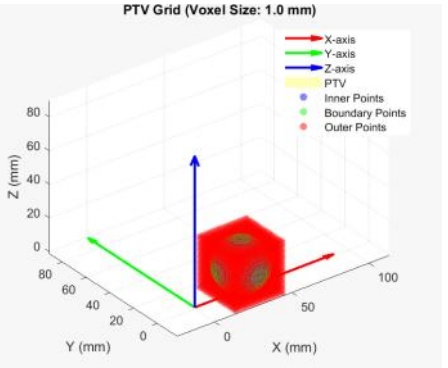
I had a conversation with chatGPT to write this function, this is what I told it to do:
Beam Central Line Equation:
Parametric form: P(t) = O + t * D
O is the origin [0, 0, 0]
D is the normalized beam direction vector t is a scalar parameter
Ellipsoid Intersection: Use scaled ellipsoid equation: $(x/a)^2 + (y/b)^2 + (z/c)^2 = 1$
Solve quadratic equation to find intersection point
Take the smallest positive solution (first intersection)
Depth Computation: Calculate vector from skin entry point to isocenter
Compute norm (magnitude) of this vector
Key features of the implementation: Computes skin entry points for a random subset of beams
Visualizes the beams, entry points, and head ellipsoid
Provides detailed output of entry point coordinates and depths
Handles cases where no real intersection exists
To use the function q4 call:
[skin_entry_points, isocenter_depths]=compute_skin_entry_points();
https://chatgpt.com/c/6750f5fd-1d48-8008-9cfc-16565c38bf39

Note: skin_entry_points, isocenter_depths are printed in the console.

6. Compute Grid for PTV

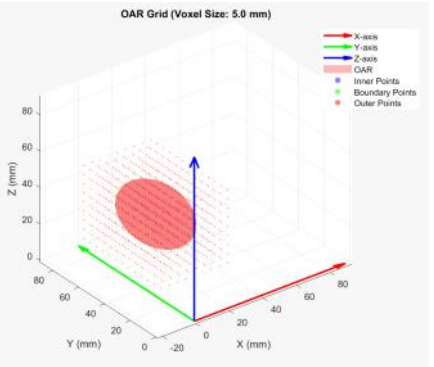
Make the grid size (i.e. voxel size) variable, because you may like to use a coarser grid size (such as 5.0 mm) to speed up development and testing of other functions, and then refine later to a finer grid (such as 1.0 mm) for dosimetric analysis

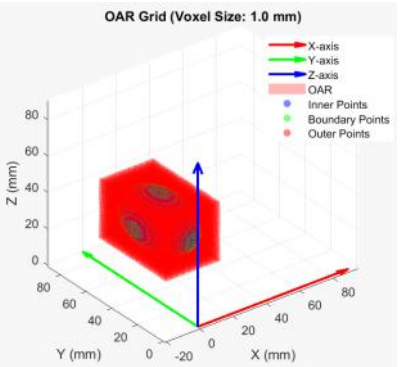




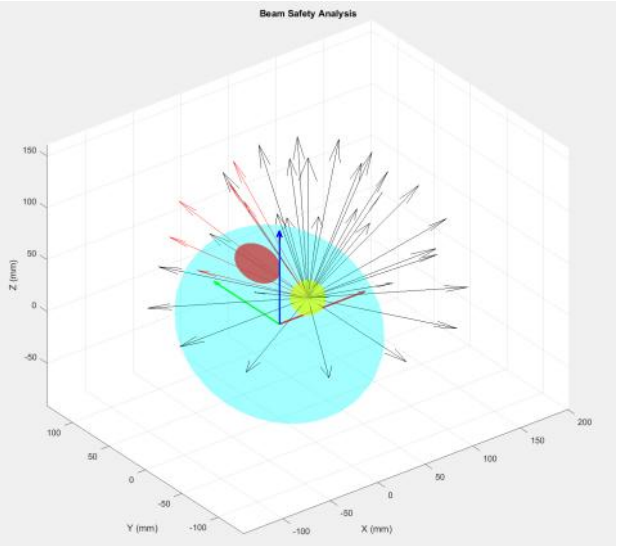
7. Compute Grid for OAR

Make the grid size (i.e. voxel size) variable, because you may like to use a coarser grid size (such as 5.0 mm) to speed up development and testing of other functions, and then refine later to a finer grid (such as 1.0 mm) for dosimetric analysis.



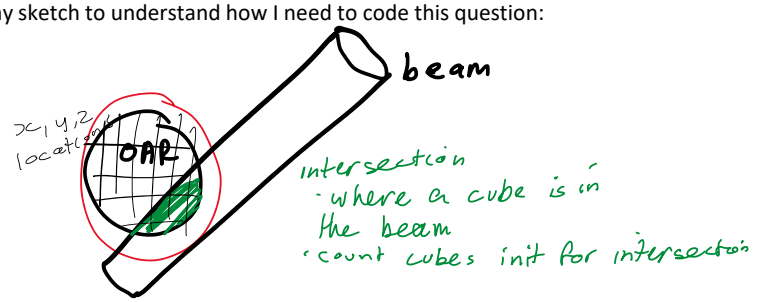


8. Compute Beam Safety



Red beams are unsafe because they would radiate the organ at risk which needs to maintain no damage to its tissue.
Beam Safety Analysis:
Total Beams: 37
Unsafe Beams: 6
Unsafe Beam Indices: 6 7 8 18 19 20

This is my sketch to understand how I need to code this question:



9. Compute Radial Distance from Beam

I tested my code by putting the helmet in the center so the isocenter is [0,0,0]. To test this code I first ran the simple axes with simple points. When I test points on the axes, I get a radial distance of 0. For example, the point [1,0,0] tested with a beam on the x axis would result in a radial distance of 0 which makes sense because the point is on the axis and the distance of that is 0.
If I test a point for example, [1,1,0] with a beam on the y axis the radial distance is 1 because it is 1mm away from the y axis along the x axis. This makes sense.

Now if we test a more complex point like [30,20,10] with a beam on the z axis, we get a distance of 36.05. Lets check if this math is good

$PA = A - P = [30,20,10] - [0,0,0] = [30,20,10]$

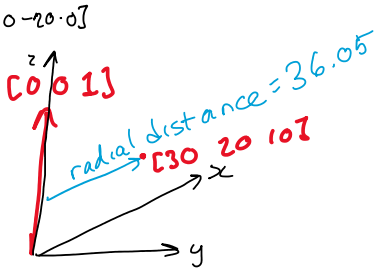
$PA \times v = [30,20,10] \times [0,0,1] = [20 \cdot 1 - 10 \cdot 0 \quad 10 \cdot 0 - 30 \cdot 1 \quad 30 \cdot 0 - 20 \cdot 0]$

$= [20 \quad -30 \quad 0]$

$$\text{Distance} = \frac{\|[20 \quad -30 \quad 0]\|}{\|[0 \quad 0 \quad 1]\|}$$

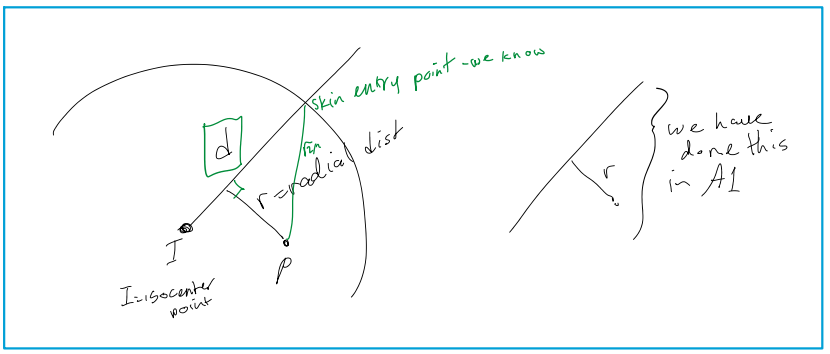
$$= \frac{\sqrt{1300}}{1}$$

$= 36.05$



After this initial test, I switched the helmets center back to the isocenter = ptv center = [30, 0, 15]. Now when I run my code I know the output will be correct!

This is a sketch of my understanding which I based my code off of:



10. Compute Depth from Skin Along Beam

I used the equation in the notes.
Check my output for the tests.

11. Compute Point Dose by One Beam

I found the radial distance from q9 and the depth from skin from question 10. then I found these values in the dose absorption and radial dose files and then plugged them into the final equation:
dose = D0 * DAF * RDF
I have to change my q2 and q3 to plot values in increments of 0.1 so that my q11 function can find the exact values.

My output for my tests are:
Test 1: X-axis beam
Point Dose by One Beam: 0.755000

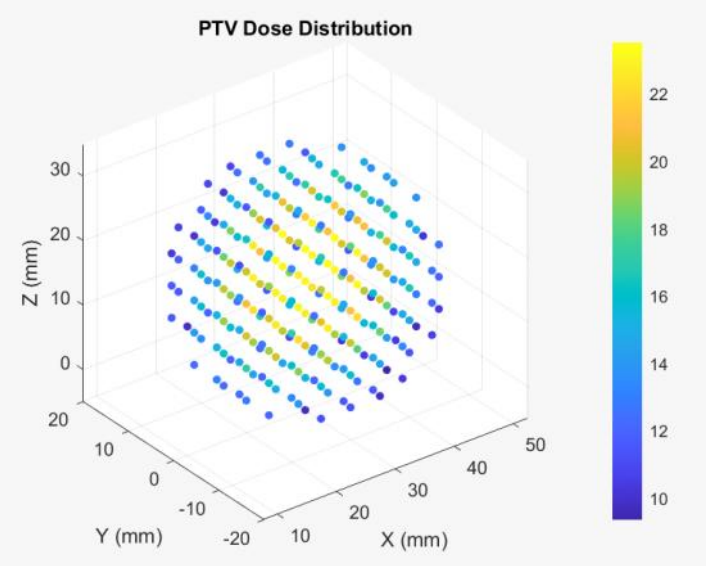
Test 2: Y-axis beam
Point Dose by One Beam: 0.208500

Test 3: Z-axis beam
Point Dose by One Beam: 0.078000

12. Compute Point Dose by All Beams

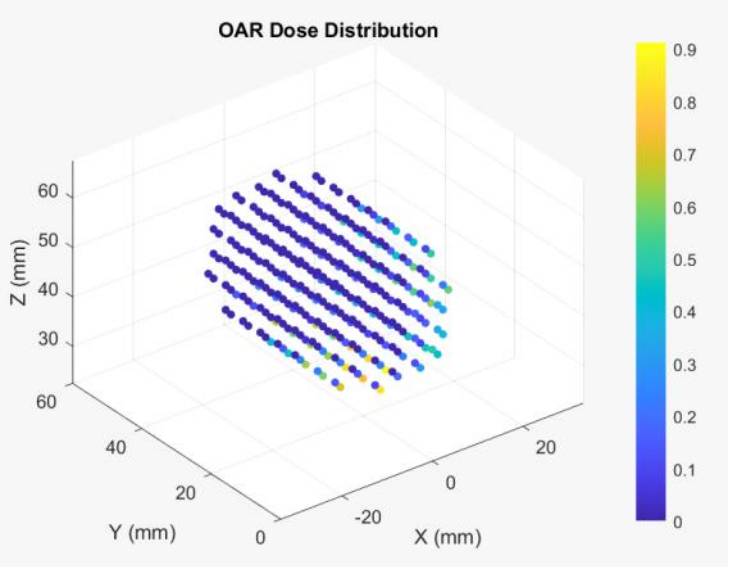
Total dose at the center of the PTV (isocenter): 23.0600

13. Compute Volume Dose in PTV



Extreme Doses:
Minimum Dose: 9.33
Maximum Dose: 23.50

14. Compute Volume Dose in OAR

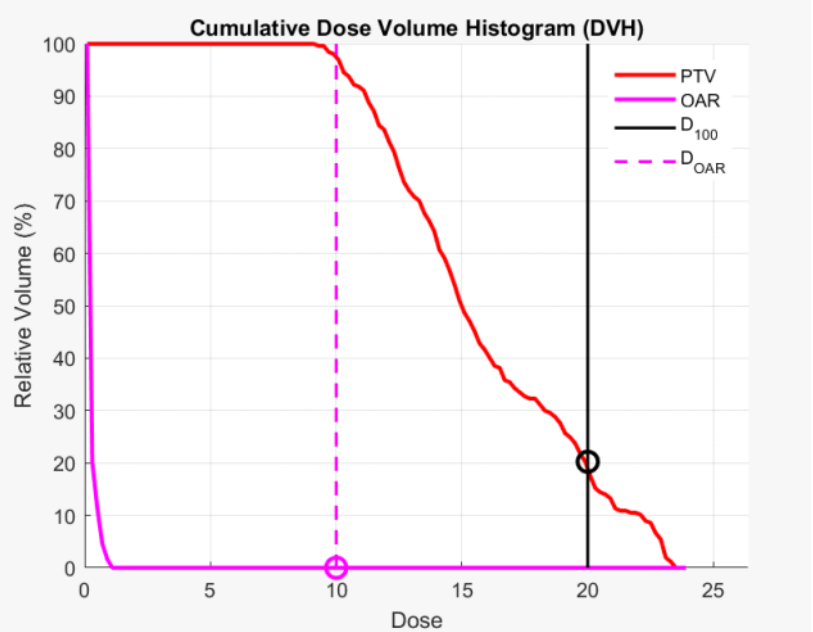


Extreme Doses:
Minimum Dose: 0.00
Maximum Dose: 0.91

15. Compute Optimal Irradiation Time

The beams that are blocked are the 6 unsafe beams in question 8: Unsafe Beam Indices: 6 7 8 18 19 20.
With these blocked the treatment objective is achieved:
Optimal irradiation time: 2.14 minutes
Minimum PTV dose: 20.00 DU
Maximum PTV dose: 50.38 DU
Maximum OAR dose: 1.95 DU
Therefore, we didn't have to block any more beams and recalculate.

16. Compute Dose Volume Histogram

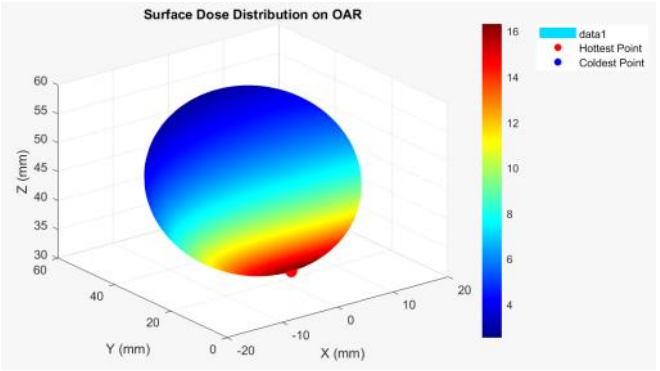


I use the PTV and OAAR doses and the max and min doses to make the histogram.
Note:
Instead of running question 13 and 14 each time (because that takes forever), I find the ptv and oar doses from the csv files and hard code the min and max doses, adding them as variables. Therefore I have commented out the function call to question 13 and 14, as you can see.

I make the histograms by calling the histcounts function, and plotting the D100, Doar and the doses.

17. Compute Surface Dose for OAR

Hottest Dose: 16.31 at [-0.553610, 15.334365, 32.864745]
Coldest Dose: 2.52 at [0.795237, 51.066546, 53.037402]

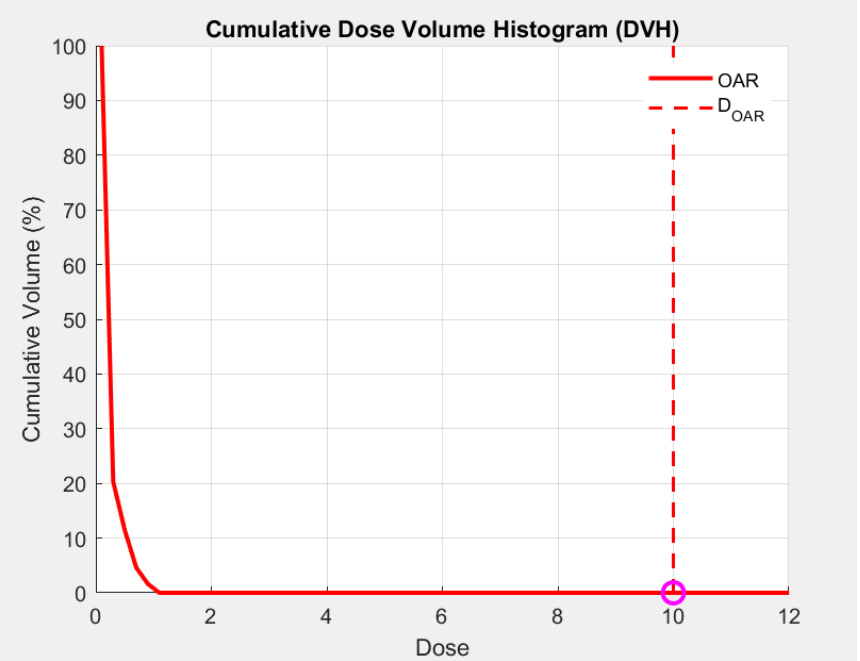


Analysis
Hottest Dose information is crucial for evaluating potential overdosing to the OAR. It's very important to ensure that the maximum dose adheres to established dose constraints to minimize the risk of adverse effects on the organ.

Coldest Dose is significant for analysis as it indicates the point with the lowest dose on the OAR. Assessing this minimum dose helps identify areas where the radiation dose to the organ may be insufficient, ensuring that the organ receives an appropriate dose for therapeutic efficacy.

The clinical Implications are that the information obtained from this analysis guides clinicians in assessing the OAR's response to radiation therapy. It aids in refining treatment plans to balance therapeutic efficacy with the protection of critical structures.

18. Compute Dose Surface Histogram for OAR



The Dose Surface Histogram quantifies the cumulative dose distribution across the organ at risk (OAR) surface, providing insight into dose uniformity and adherence to treatment goals.
The plot has the percentage of the OAR surface exposed to varying dose levels, with the cumulative volume starting at 100%. By marking the maximum allowable dose (D_OAR) on the histogram, it is possible to evaluate whether the treatment spares the OAR effectively. In our analysis, the cumulative volume receiving doses above D_OAR was minimal, indicating successful dose sparing. This aligns with treatment goals to minimize OAR exposure while delivering an effective therapeutic dose.