Astroid Optimization

WIth IMRT plans the variety of possible dose distributions is quite large. Typically if a physician does not like an IMRT plan they will request a plan to be re-run. This requires the planner to input new constraints and objectives and a new plan to be run from the beginning of the optimization process. This is a time consuming process. Astroid eliminates this cycle using a Multi Criteria Optimization (MCO) approach that allows planners and physicians to visualize the tradeoff of target volume coverage vs reduced dose to the OAR's in real time. MCO treatment planning is based on a set of Pareto optimized plans, where a plan is considered Pareto optimal if it satisfies all the constraints and none of the objectives can be improved without worsening at least one of the other objectives. So instead of creating just one plan, Astroid creates a set of optimal plans that satisfies the treatment plan constraints and puts an interactive exploration of dosimetric objectives at the planners and physicians fingertips via a unique, highly intuitive, Pareto surface navigation slider bar system.

Constraints play an important role in the optimization process, as they bound the solution space and ensure your navigation process is focused only on plans that meet your non-negotiable, highest priority dosimetric needs. It should be noted that if the *constraints* are too tight, there may be no feasible plans. However, if the *constraints* are too loose, too many solutions will exist and the navigation will be too broad to provide adequate resolution over the truly clinically useful plans. Therefore care should be taken to ensure appropriate constraints are set, which is facilitated using the Astroid *feasibility* check feature. So while constraints supply hard limits, *objectives* are the negotiable goals, they do not have a hard level that must be obtained, but “pushing” them harder does result in benefit to the patient. The number and type of *objectives* chosen should be such that all the relevant trade offs can be demonstrated and explored.

Feasibility and Constraints

After the *constraints* have been entered, the user may start the *Feasibility* calculation by clicking *calculate* in the *Feasibility* block. The *Feasibility* calculation is based solely on the *constraints* and it should be used to ensure there is a feasible plan possible. The *Feasibility* calculation may be an iterative processes in order to get appropriate constraints established for a particular plan. In other words, the user may need to enter a *constraint*, check the feasibility, then progressively drop the *constraint* and check the *feasibility* until the plan is no longer feasible. It is recommended practice to start by obtaining a feasible plan utilizing only target *constraints* then add OAR *constraints* as desired. Remember, using a narrow range of *constraints* can improve the optimizer performance and improve the resolution of the Pareto surface navigation.

The user also needs to be aware of the impact of *constraints* being set on *Fraction Group* level versus the *Plan* level. For example, it is possible to have a *constraint* set in the *Plan* level so that the whole dose to an OAR is given on one day and none on the other day. This could happen when there are two *Fraction Groups* and the OAR dose is not split between the two by using Fraction Group level constraints.

Running the Optimizer

The *Objectives*, as stated before are the negotiable goals where they may be no hard limit, but there is benefit to improving them. Astroid allows *Objectives* on both Targets and OAR's. *Objectives* can be placed on structures to either increase or decrease dose. The *Objectives* are the sole driving force guiding the MCO and it is important to recall from the discussion above that Astroid will only navigate to plans that are “optimal” in at least one objective (meaning again that this objective cannot be improved without another objective getting worse. Unlike *Constraints*, *Objectives* should be added all at once and there is no need to place them in any particular order (order is irrelevant). Additional information about *Objectives* can be found here. Since the MCO is finding a large set of optimal solutions the optimization can be a lengthy process. The following factors have the largest impact on the optimization run time:

- The number of points in the calculation grid (linear impact)
- The total number of spots from all beams (linear impact)
- The number of objectives (quadratic impact)

The number of calculation points and number spots will have a direct 1:1 (linear) impact on the calculation times; in other words, doubling one of these items will (roughly) double the MCO calculation time. The number of objectives scales quadratically, meaning that doubling the number of objectives creates a four-fold increase ($2^2 = 4$) in the number of MCO calculations that are required. For objectives, this does not always increase the overall wait time on the calculation however, thanks to the parallelization that be achieved using the Astroid cloud services backend. So for small numbers of objectives 1-3, you may not notice much (if any) increase in wait time by increasing up to 3-5 objectives (but this does depend on the availability and load on the Astroid cloud calculation servers).

Once all the desired *Objectives* are entered the MCO calculation is started just by clicking the *calculate* option in the *Navigation* block. It should be noted that the *Feasibility* will be re-checked if any of the *Constraints* have changed since the feasibility was last run. The MCO calculations will run in the cloud and the user can simply leave the Astroid application running and move on to other things while the calculations process. Please note that at this time the Astroid App should be left open in this state to ensure the calculations run to completion, however, users may open additional instances of Astroid and work on other plans while these calculations proceed (no performance issues should be encountered when using multiple instances since the “heavy” calculations are off-loaded to the cloud calculation servers).

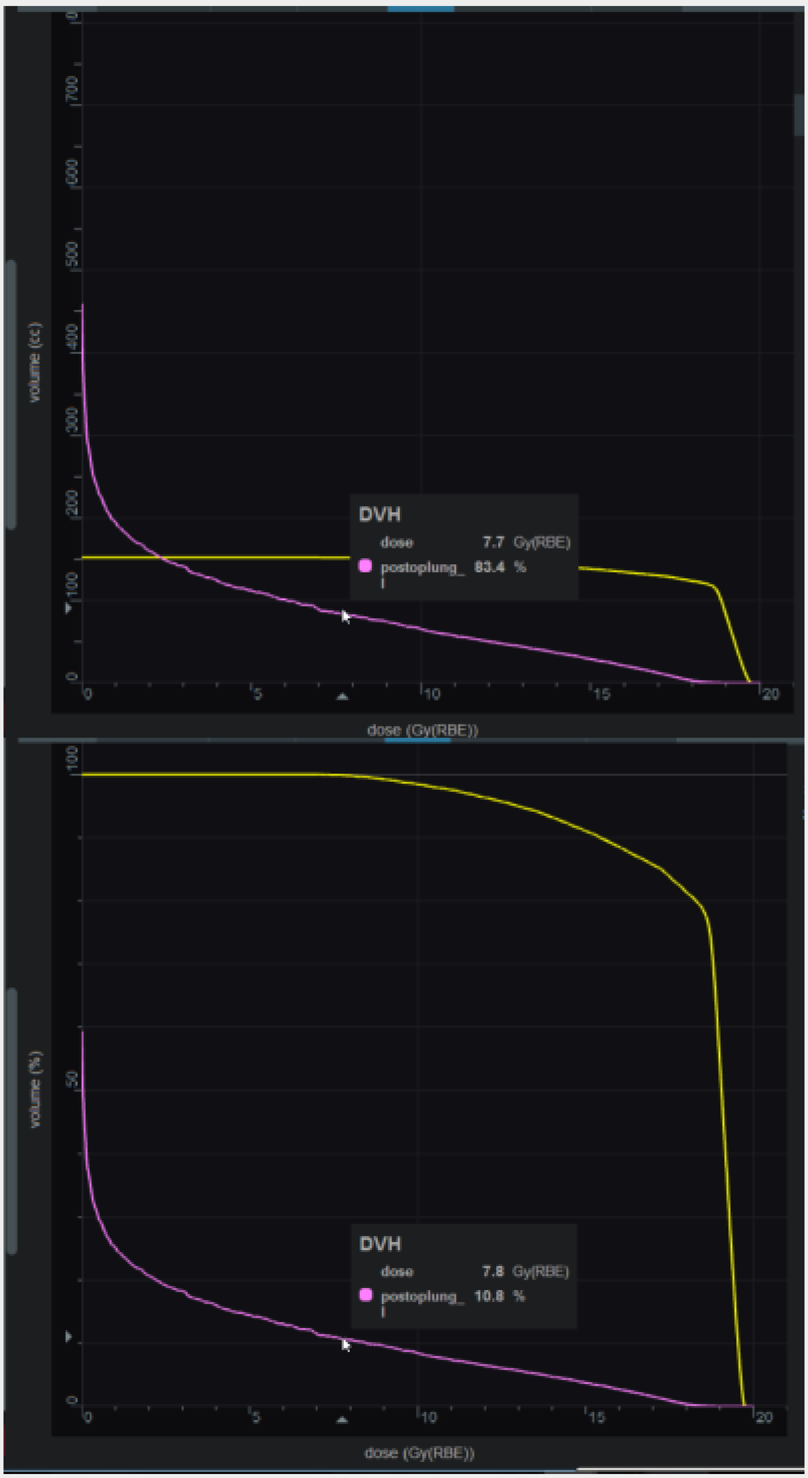
Fix Me! Discuss how to check progress (put in later when progress widget done)

Dose Normalization and Display

The user has many options for how the dose is displayed. The options for controlling the display of the dose are on the right hand side of the display under *Dose Options*. The *Dose Options* provide controls over the DVH type (relative or absolute volume), the colors and scaling of the display dose, and the type of dose display shown (colorwash, isolines, or isobands).

Dose Volume Histogram (DVH)

The planner has the option of viewing the dose for the DVH in relative volume (dose per percentage of the volume) or in absolute volume (dose per cc of the structure) using the *Absolute DVH* option. The user may also hover over any area of the DVH curve to obtain the dose and percentage of a given structure or click on a line to obtain start tracking the cursor value for one or more lines.



🔧 Fix Me! (Change one to a

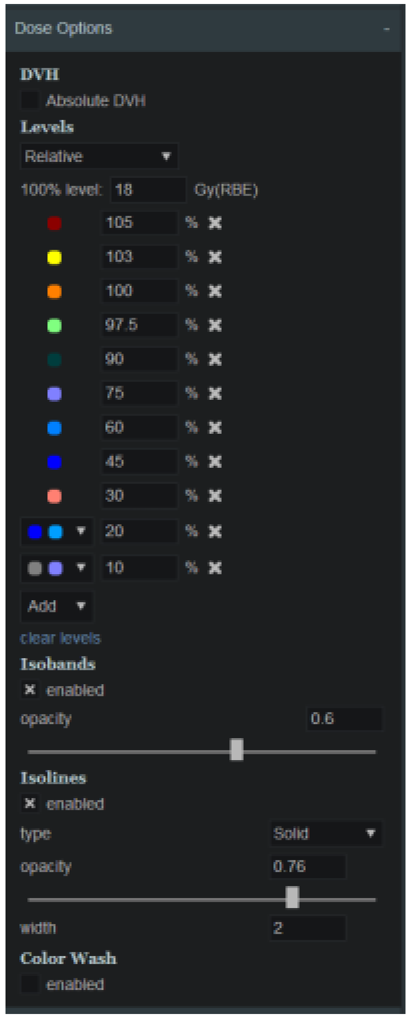
DVH with clicked line view)

Dose Display Normalization

As in the DVH the user has multiple options for displaying the dose. The dose can be displayed in either relative (percentage) or absolute. This can be chosen by using the drop down menu under *Levels*. If the user chooses to view dose in relative mode they must then enter the 100% line dose- usually the prescription dose. The percentage isodose lines that the user wants to see must then be entered. If the user chooses to view absolute dose they need to choose absolute from the drop down and then enter the dose lines that they want to see.

The user also can choose to view the isodose as either isobands, isolines, colorwash or combinations of these. The user may use the sliders to set the opacity for each of these as well. They may also choose the line width and whether it is solid, dashed or dotted for isolines.

Fix Me! Add image and explanation of isobands **Fix Me!** Add image and explanation of isolines **Fix Me!** Add image and explanation of colorwash



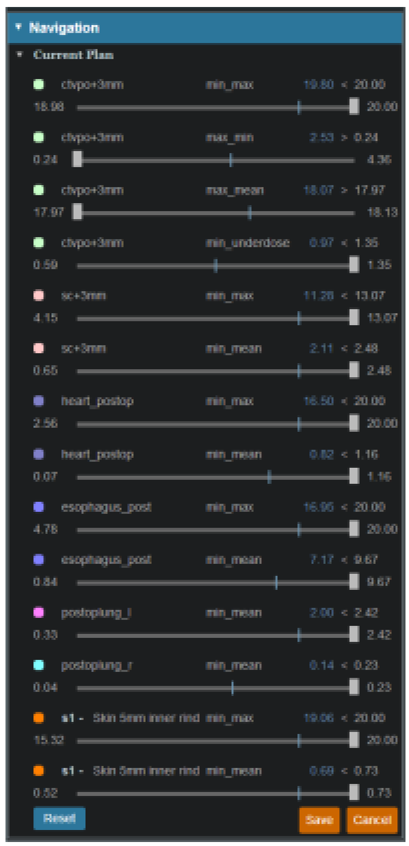
Navigating the Solutions

Once the plan has been calculated the *Navigation* block will become active. This block contains entries for all the active objectives and under each objective is a slider bar. This slider bar allows the user to adjust the importance of an objective and to see, in real time, how the change will affect the dose to the patient.

The Navigation Sliders should provide an intuitive process for finding the optimal plan, but by gaining a complete understanding of the Navigation Sliders users will be better equipped to quickly reach their plan goals. On each slider there are two vertical bars. The thick white bar is the user controlled slider handle and it represents the worst value of an objective that the user wants to allow (note sliders for minimize objectives will slide to the left and sliders for maximize objectives will slide to the right). Simply stated, the objective will not go past this limit. The thin blue bar denotes the actual current value of the objective. Astroid calculates this value by balancing the solution over the available ranges of each objective. It should now be clear that moving a slider does **not** directly set an objective, but rather it places limits on the allowable range of an objective.

The blue and white numbers to the upper right of each slider correlate to the dose the blue and white and white vertical bars are at. The numbers at the end of each slider bar denote the range that the user has to work in. This is the bar the user should grab to slide. Thick white bars that are on opposite ends of the slider means that the objectives are competing very little with each other. An example of this is in the diagram below. The CTVPO+3mm min max is competing very little with the CTVPO+3mm max mean. This means the user can make large adjustments to each of these without effecting the other. If both white slider bars are on the same side and an adjustment is made it will have a great impact on the other structures. The thick grey horizontal bar it the range or window that the user has to adjust the vertical bars. The user will notice as they drag the white bar to the left the window the user has to work in reduces. All of this allows the user to know the limits they have to work in. All of these adjustments are able to be done without running a new plan as would needed to be done in traditional treatment planning systems. This allows the user to look at many different solutions in a short amount of time.

If the user does not like the adjustments they have made to the structure objective slider they may hit the *Reset* button in the bottom left corner to reset all the objectives to their original state. It the user does like the adjustment that was made they may choose the *Save* button in the bottom right hand corner. This will save the objectives at their current position. The *Cancel* button will close the *Navigation* block in its current state.



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