Structure Relationships

Introduction

The Structure Relationships package is used to generate an interactive and customizable diagram on the geometrical relationships between radiation therapy structures. It is primarily intended as a quality assurance tool to assist with the treatment plan checking process.

The Structure Relationships package provides a quick, easy-to-read diagram of the geometrical relationships between structures. For example, PTV *contains* CTV; If the CTV was modified to add a suspicious node, but the PTV expansion was not re-generated, the relationship would change to PTV *overlaps* CTV. If there are multiple target volumes, the diagram will allow the physicist to quickly verify that each of the target CTV and PTV expansions are correctly labeled to match each other and their corresponding GTVs.

The Structure Relationships package also provides appropriate metrics for the relationships. For example, with PTV *contains* CTV, the metrics would be the margins between the PTV and CTV in the 6 orthogonal directions, as well as the maximum, minimum and mean margins. Similarly, with PTV *overlaps* Parotid RT the metrics would be the volume percentage of the overlap between the PTV and Parotid RT structures.

There are many redundant (logical) relationships between structures, such as: "PTV *contains* CTV, and CTV *contains* GTV, therefore PTV *contains* GTV". To reduce the clutter in the diagram, these redundant relationships are hidden by default, so that the important relationships are highlighted.

The Structure Relationships diagram and accompanying report simplify the process of verifying the appropriateness of the structures used in the planning process.

Simple workflow example

The following is a typical workflow example.

1. The Plan and Structures are exported as DICOM RT files.
2. The DICOM structure file is selected and loaded.
3. The program automatically extracts the information for each of the structures found in the file.
4. Certain structures are automatically dropped from further processing based on their name or structure type.
5. Geometrical data for all remaining structures is analyzed to identify the relationships between each structure and all other structures.
6. Appropriate metrics are calculated based on the relationships identified.
7. A diagram is generated, with each structure as a labeled geometric shape, based on its structure type, and with its color matching the structure's color in the plan. Lines of different styles are used to indicate the type of relationship between two structures.

8. Hovering the mouse over a structure in the diagram gives a popup with details about the structure, such as its volume, and any assigned Hounsfield Units.
9. Hovering the mouse over a relationship line in the diagram gives a popup with the calculated metrics for that relationship.
10. Right clicking on a structure brings up a menu with options to hide the structure, restore a hidden relationship line, or insert a note into the structure's label.
11. Right clicking on a relationship line brings up a menu with options to hide the line, select which metrics to display, or add a note beside the line.
12. At completion, a PDF document is generated that includes the final version of the diagram along with a table of all structures and relationships visible in the diagram.

Example simple breast contours.

Diagram illustrates:

Targets

- CTV *Contained In* PTV
- eval_PTV *Part Of* PTV

OARs

- Lung_L *Part Of* Lung_B
- Lung_R *Part Of* Lung_B

OARs with targets

- Body *Overlaps* PTV
- Body *Contains* eval_PTV

Relationship values in table

- Mean (selected) margin between CTV and PTV
- Volume (in %) of PTV within eval_PTV
- Volume (in %) of Lung_B not contained in Lung_L + Lung_R
- Minimum (selected) Margin between eval_PTV and Body

Design Details

Available Structure information

Identification

- Structure Id
- Structure Category:
  - Target
  - Organ
  - External
  - Planning
  - Dose
  - Other
- Structure Type (from DICOM Standard)
- Structure Code (Eclipse)
- Code Meaning (Eclipse)
- Structure Code Scheme (Eclipse)
- Color

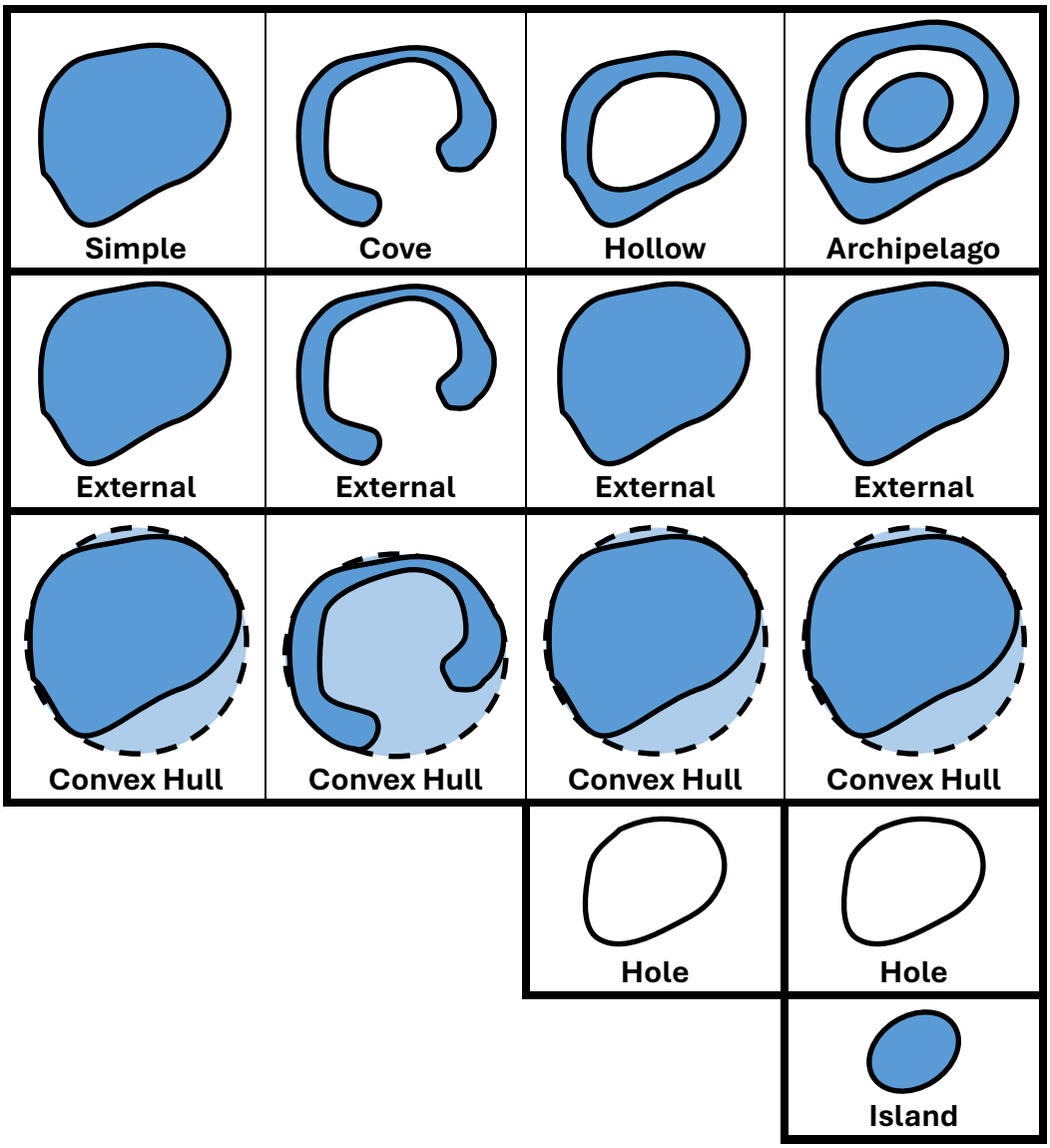
Structure Geometry

- Volume
- Surface Area
- Thickness (for wall structures)
- Length (with SUP and INF extent)
- Sphericity (Metric of how close to a spherical shape.
- Geometrical Center coordinates
- Contour Resolution (Eclipse)

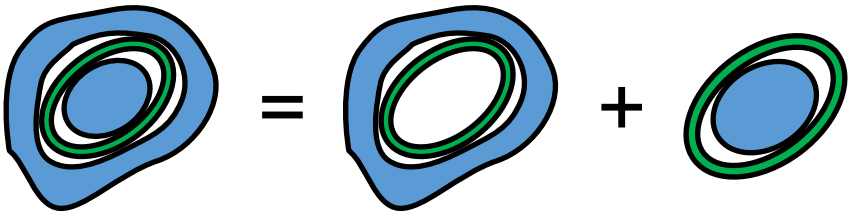
Types of Shapes

The following shape approximate a 2D region. A region consists of one or more contour. When the region contains multiple contours, the contours must not overlap. In the example below (Multi), one contour is embedded within the hole of another contour, but the two contours do not overlap because the hole is not part of the contour.

Each contour has two components: An *external* and a list of *holes*. In addition, the *convex hull* of a contour allows for the identification of relationships between crescent shapes contours and contours partially surrounded by the crescent.



Islands can be treated as separate contours for determining relationships



2D Relationship Matrix (DE-9IM)

DE-9IM is used to describe the spatial relations between two geometries in two-dimensions. The DE-9IM model is based on a 3×3 intersection matrix with the form below, where ***dim*** is the dimension of the intersection of the interior (***I***), boundary (***B***), and exterior (***E***) of geometries a and b:

	Interior	Boundary	Exterior
Interior	 $\dim[I(a) \cap I(b)] = 2$	 $\dim[I(a) \cap B(b)] = 1$	 $\dim[I(a) \cap E(b)] = 2$
Boundary	 $\dim[B(a) \cap I(b)] = 1$	 $\dim[B(a) \cap B(b)] = 0$	 $\dim[B(a) \cap E(b)] = 1$
Exterior	 $\dim[E(a) \cap I(b)] = 2$	 $\dim[E(a) \cap B(b)] = 1$	 $\dim[E(a) \cap E(b)] = 2$

Some examples of defined relationships are:

Name	DE-9IM	Meaning and definition
Disjoint	$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$	*a* and *b* have no points in common.
Overlaps	$\begin{bmatrix} 2 & 1 & 2 \\ 1 & * & 1 \\ 2 & 1 & * \end{bmatrix}$	*a* overlaps *b*: they have some but not all points in common.
Within	$\begin{bmatrix} 2 & * & F \\ * & \mathrm{F} & F \\ * & * & * \end{bmatrix}$	*a* lies in the interior of *b*.

Note:

- All mask string codes end with *. This is because EE is trivially true, and thus provides no useful information.
- The relationships between external contours of (a and b with their holes filled) or convex hulls are only specified where necessary to distinguish relationships.
- The geometrical relations between 3D structures must be inferred by combining the relationships for the contours on each slice.

Relationship Types and Definitions

region a
region b
intersection of a & b

Disjoint Relations

Surrounds/ Embeds — Transitive

a and *b* have no interior points in common, and with holes filled *b* lies in the interior of *a*.

Region	Exterior	
	Surrounds	Embeds
$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$	$\begin{bmatrix} 2 & * & * \\ * & F & * \\ F & F & * \end{bmatrix}$	$\begin{bmatrix} 2 & * & F \\ * & F & F \\ * & * & * \end{bmatrix}$

Metrics

Distances between the surrounded and surrounding shape.

$$Margin_{\perp} = \text{bounds}(a) - \text{bounds}(b)$$
$$Margin_{Min} = \text{distance}(a, b)$$
$$Margin_{Max} = \text{distance}_{hausdorff}(a, b)$$

Shelters / Sheltered — Transitive

a and *b* have no points in common, but the *Convex Hull* of *a* contains *b*.

Region	Hull	
	Shelters	Sheltered
$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$	$\begin{bmatrix} 2 & * & * \\ * & F & * \\ F & * & * \end{bmatrix}$	$\begin{bmatrix} 2 & * & F \\ * & F & * \\ * & * & * \end{bmatrix}$

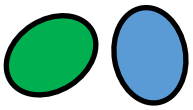
Metrics

Distances between the sheltered island and surrounding shape.

$$Margin_{\perp} = \text{bounds}(a) - \text{bounds}(b)$$
$$Margin_{Min} = \text{distance}(a, b)$$

Fully Disjoint — Symmetric

a and *b* have no points in common.



Region	Hull
$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$	$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$

Metrics

None

Borders

The exterior boundaries of ***a*** and ***b*** have more than one point in common, but their interiors do not intersect.

	Region	Exterior
	$\begin{bmatrix} F & F & * \\ F & 1 & * \\ * & * & * \end{bmatrix}$	$\begin{bmatrix} F & F & * \\ F & 1 & * \\ * & * & * \end{bmatrix}$

Metrics

Ratio of the length of overlaping exterior borders to the average length of the two exterior perimeters:

$$R_l = \frac{2\,\mathrm{l}(a_p \cap b_p)}{\mathrm{l}(a_{px}) + \mathrm{l}(b_{px})}$$

Where:

$\mathrm{l}(a_p \cap b_p)$ is the length of the perimeter that a_p and b_p have in comon.

a_{px} is the exterior perimeter of *a*.

Confines / Exsects

The interior boundary of one shape ***a*** and the exterior boundary of another shape ***b*** have more than one point in common, but their interiors do not intersect.

	Matrix	Exterior	
		Confines	Exsects
	$\begin{bmatrix} F & F & * \\ F & 1 & * \\ * & * & * \end{bmatrix}$	$\begin{bmatrix} 2 & * & 2 \\ * & \mathrm{F} & * \\ F & F & * \end{bmatrix}$	$\begin{bmatrix} 2 & * & F \\ * & \mathrm{F} & F \\ 2 & * & * \end{bmatrix}$

Metrics

Ratio of the length of overlaping interior border to the average length of the relevant perimeter (exterior or hole):

$$R_l = \frac{\mathrm{l}(a_p \cap b_p)}{\mathrm{l}(a_{ph}) + \mathrm{l}(b_{px})}$$

Where:

a_{ph} is the perimeter of the relevant hole in *a*

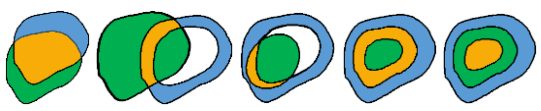
b_{px} is the exterior perimeter of *b*

$\mathrm{l}(a_{ph} \cap b_{px})$ is the length of the perimeter that a_{ph} and b_{px} have in comon.

Overlaps

Symmetric

a overlaps ***b***: both have some but not all points in common.

	Region
	$\begin{bmatrix} 2 & 1 & 2 \\ 1 & * & 1 \\ 2 & 1 & * \end{bmatrix}$

Metrics

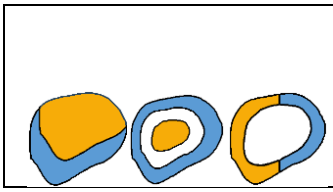
Ratio of the area of overlap to area of both:

$$R_a = \frac{2 \times \mathrm{area}(a \cap b)}{\mathrm{area}(a) + \mathrm{area}(b)}$$

Partitions / Incorporates

Transitive

All points of ***a*** lie in the interior of ***b***, no points of ***a*** lie in the exterior of ***b***, some points in ***b*** are exterior to ***a***, and the boundaries of ***a*** and ***b*** have more than one point in common.



Region Test	
Partitions	Incorporates
$\begin{bmatrix} 2 & * & F \\ * & 1 & \mathrm{F} \\ 2 & * & * \end{bmatrix}$	$\begin{bmatrix} 2 & * & 2 \\ * & 1 & * \\ \mathrm{F} & \mathrm{F} & * \end{bmatrix}$

Metrics

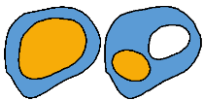
Ratio of the area of overlap to area of the larger shape:

$$\mathrm{R}_a = \frac{\mathrm{area}(a \cap b)}{\mathrm{area}(b)}$$

Within / Contains

Transitive

All points of ***a*** lie in the interior of ***b***, no points of ***a*** lie in the exterior of ***b***, some points in ***b*** are *exterior to* ***a****, and the boundaries of* ***a*** *and* ***b*** *do not intersect.*



Region	
Within	Contains
$\begin{bmatrix} 2 & * & F \\ * & \mathrm{F} & \mathrm{F} \\ 2 & * & * \end{bmatrix}$	$\begin{bmatrix} 2 & * & 2 \\ * & \mathrm{F} & * \\ \mathrm{F} & \mathrm{F} & * \end{bmatrix}$

Metrics

Distances between the exterior of ***a*** and the boundary of ***b***. (For Within, ***a*** & ***b*** reversed for Contains).

$$Margin_{\perp} = \mathrm{bounds}(b) - \mathrm{bounds}(a)$$
$$Margin_{Min} = \mathrm{distance}(a, b)$$
$$Margin_{Max} = \mathrm{distance}_{hausdorff}(a, b)$$

Equals

Symmetric, Transitive

The interiors of ***a*** and ***b*** intersect and no part of the interior of one geometry intersects the exterior of the other.

Region
$\begin{bmatrix} 2 & * & F \\ * & * & F \\ F & F & * \end{bmatrix}$

Metrics

None

Summary

Relationship	Region	Exterior	Hull
Surrounds	$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$ `FF*FF****`	$\begin{bmatrix} 2 & * & * \\ * & F & * \\ F & F & * \end{bmatrix}$ `T***F*FF*`	
Embeds	$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$ `FF*FF****`	$\begin{bmatrix} 2 & * & F \\ * & F & F \\ * & * & * \end{bmatrix}$ `T*F*FF***`	
Shelters	$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$ `FF*FF****`		$\begin{bmatrix} 2 & * & * \\ * & F & * \\ F & * & * \end{bmatrix}$ `T***F*F**`
Sheltered	$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$ `FF*FF****`		$\begin{bmatrix} 2 & * & F \\ * & F & * \\ * & * & * \end{bmatrix}$ `T*F*F****`
Disjoint	$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$ `FF*FF****`		$\begin{bmatrix} F & F & * \\ F & F & * \\ * & * & * \end{bmatrix}$ `FF*FF****`
Borders	$\begin{bmatrix} F & F & * \\ F & 1 & * \\ * & * & * \end{bmatrix}$ `FF*FT****`	$\begin{bmatrix} F & F & * \\ F & 1 & * \\ * & * & * \end{bmatrix}$ `FF*FT****`	
Confines	$\begin{bmatrix} F & F & * \\ F & 1 & * \\ * & * & * \end{bmatrix}$ `FF*FT****`	$\begin{bmatrix} 2 & * & 2 \\ * & F & * \\ F & F & * \end{bmatrix}$ `T*T*F*FF*`	
Exsects	$\begin{bmatrix} F & F & * \\ F & 1 & * \\ * & * & * \end{bmatrix}$ `FF*FT****`	$\begin{bmatrix} 2 & * & F \\ * & F & F \\ 2 & * & * \end{bmatrix}$ `T*F*FFTFF`	
Overlaps	$\begin{bmatrix} 2 & 1 & 2 \\ 1 & * & 1 \\ 2 & 1 & * \end{bmatrix}$ `TTTT*TTT*`		
Partitions	$\begin{bmatrix} 2 & * & F \\ * & 1 & F \\ 2 & * & * \end{bmatrix}$ `T*F*TFT**`		
Incorporates	$\begin{bmatrix} 2 & * & 2 \\ * & 1 & * \\ F & F & * \end{bmatrix}$ `T*T*T*FF*`		
Within	$\begin{bmatrix} 2 & * & F \\ * & F & F \\ 2 & * & * \end{bmatrix}$ `T*F*FFT**`		
Contains	$\begin{bmatrix} 2 & * & 2 \\ * & F & * \\ F & F & * \end{bmatrix}$ `T*T*F*FF*`		
Equals	$\begin{bmatrix} 2 & * & F \\ * & * & F \\ F & F & * \end{bmatrix}$ `T*F**FFF*`		

Relationship	Region Test	Exterior Test	Hull Test	Complement
Disjoint	`FF*FF****`	`FF*FF****`	`FF*FF****`	Disjoint
Shelters	`FF*FF****`	`FF*FF****`	`T***F*F**`	Sheltered
Sheltered	`FF*FF****`	`FF*FF****`	`T*F*F****`	Shelters
Surrounds	`FF*FF****`	`T***F*FF*`		Embeds
Embeds	`FF*FF****`	`T*F*FF***`		Surrounds
Borders	`FF*FT****`	`FF*FT****`		Borders
Confines	`FF*FT****`	`T*T*F*FF*`		Exsects
Exsects	`FF*FT****`	`T*F*FFTFF`		Confines
Partitions	`T*F*TFT**`			Incorporates
Incorporates	`T*T*T*FF*`			Partitions
Within	`T*F*FFT**`			Contains
Contains	`T*T*F*FF*`			Within
Overlaps	`TTTT*TTT*`			Overlaps
Equals	`T*F**FFF*`			Equals

Convert each test string into two binary number:

1. An ignore mask (0 indicates ignored):
    a. Replace '`*`' with '`0`'
    b. Replace '`F`' and '`T`' with '`1`'
    c. Convert string to a binary integer `int(string, 2)`
2. A value (Binary number)
    a. Replace '`*`' with '`0`'
    b. Replace '`F`' with '`0`'
    c. Replace '`T`' with '`1`'
    d. Convert string to a binary integer `int(string, 2)`

Relationship	Masks and Values
Disjoint	*Mask* (110110000, 110110000, 110110000) *Value* (000000000, 000000000, 000000000)
Shelters	*Mask* (110110000, 110110000, 100010100) *Value* (000000000, 000000000, 100000000)
Sheltered	*Mask* (110110000, 110110000, 101010000) *Value* (000000000, 000000000, 100000000)
Surrounds	*Mask* (110110000, 100010110, 0) *Value* (000000000, 100000000, 0)
Embeds	*Mask* (110110000, 101011000, 0) *Value* (000000000, 100000000, 0)
Borders	*Mask* (110110000, 110110000, 0) *Value* (000010000, 000010000, 0)
Confines	*Mask* (110110000, 101010110, 0) *Value* (000010000, 101000000, 0)
Exsects	*Mask* (110110000, 101011111, 0) *Value* (000010000, 100000100, 0)
Partitions	*Mask* (101011100, 0, 0) *Value* (100010100, 0, 0)
Incorporates	*Mask* (101010110, 0, 0) *Value* (101010000, 0, 0)
Within	*Mask* (101011100, 0, 0) *Value* (100000100, 0, 0)
Contains	*Mask* (101010110, 0, 0) *Value* (101000000, 0, 0)
Overlaps	*Mask* (111101110, 0, 0) *Value* (111101110, 0, 0)

Properties

The spatial predicates have the following properties of binary relations:

symmetric

Equals, Overlaps, Disjoint, Borders

A relation is **symmetric** if $aRb \iff bRa$ for all a and b. For example, if ***a*** *Equals* ***b*** then ***b*** *Equals* ***a***.

transitive

Equals, Contains, Within, Shelters, Sheltered, Surrounds, Embeds.

A relation is **transitive** if whenever, aRb and bRc then aRc. For example, if ***a*** *Contains* ***b*** and ***b*** *Contains* ***c*** relation, then ***a*** *Contains* ***c***.

Relationship	Symmetric	Transitive	Complement	Link Name
Disjoint	*Yes*	*No*	*Disjoint*	*NA*
Shelters	No	Yes	Sheltered	Shelter
Sheltered	No	Yes	Shelters	Shelter
Surrounds	No	Yes	Embeds	Island
Embeds	No	Yes	Surrounds	Island
Borders	Yes	No	Borders	Borders
Confines	No	No	Exsects	Cut-out
Exsects	No	No	Confines	Cut-out
Partitions	No	No	Incorporates	Group
Incorporates	No	No	Partitions	Group
Within	No	Yes	Contains	Expansions
Contains	No	Yes	Within	Expansions
Overlaps	Yes	No	Overlaps	Overlaps
Equals	Yes	Yes	Equals	Equals

Relationship	Metrics	
Surrounds Embeds	Distances between the surrounded and surrounding shape. $Margin_{\perp} = \text{bounds}(a) - \text{bounds}(b)$ $Margin_{Min} = \text{distance}(a, b)$ $Margin_{Max} = \text{distance}_{hausdorff}(a, b)$	
Shelters Sheltered	Distances between the sheltered island and surrounding shape. $Margin_{\perp} = \text{bounds}(a) - \text{bounds}(b)$ $Margin_{Min} = \text{distance}(a, b)$	
Disjoint	*N/A*	
Exterior Borders	Ratio of the length of overlap to the length of the exterior perimeter. $R_l = \frac{2\,\text{l}(a_p \cap b_p)}{\text{l}(a_{px}) + \text{l}(b_{px})}$	Where: a_p is the perimeter of *a* a_{px} is the exterior perimeter of *a* a_{ph} is the perimeter of the relevant hole in *a* $\text{l}(a_p)$is the length of the perimeter of *a*
Interior Borders	Ratio of the length of overlap to the length of the relevant hole perimeter. $R_l = \frac{\text{l}(a_p \cap b_p)}{\text{l}(a_{ph}) + \text{l}(b_{px})}$	
Overlaps	Ratio of the area of overlap to area of both: $R_a = \frac{2 \times \text{area}(a \cap b)}{\text{area}(a) + \text{area}(b)}$	
Partitions Incorporates	Ratio of the area of overlap to area of the larger shape: $\text{R}_a = \frac{\text{area}(a \cap b)}{\text{area}(b)}$	
Contains Within	Distances between the exterior of ***a*** and the boundary of ***b***. (For Within, ***a*** & ***b*** reversed for Contains). $Margin_{\perp} = \text{bounds}(b) - \text{bounds}(a)$ $Margin_{Min} = \text{distance}(a, b)$ $Margin_{Max} = \text{distance}_{hausdorff}(a, b)$	
Equals	*N/A*	

Diagram

Default Structure Properties

Property	Value
fixedsize	shape
width	1
height	0.6
fontname	Helvetica-Bold
fontsize	12
labelloc	c
penwidth	3
style	filled
fontcolor	black

Structure Shape and Style

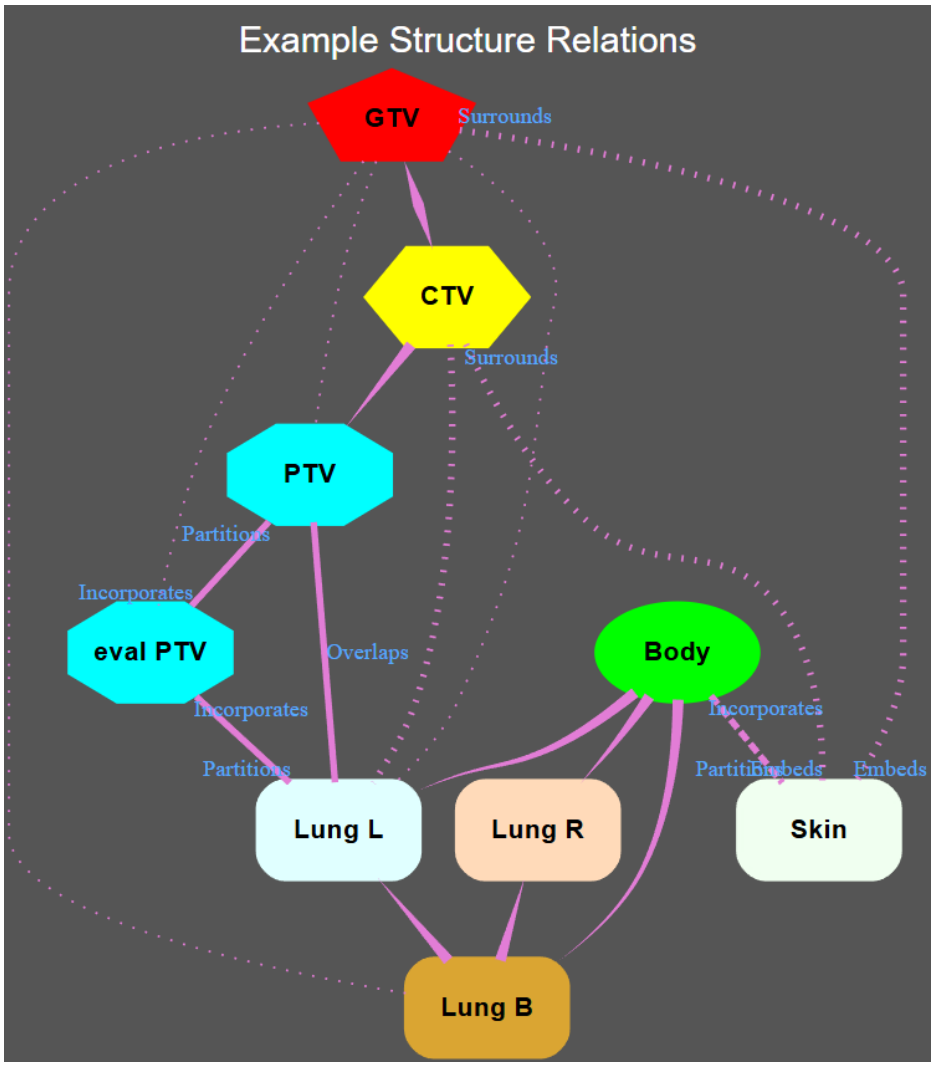
DicomType	shape	style	penwidth	fillcolor	subgraph
GTV	pentagon	"filled"	3		Targets
CTV	hexagon	"filled"	3		Targets
PTV	octagon	"filled"	3		Targets
EXTERNAL	doublecircle	"filled"	2	white	External
ORGAN	rectangle	"rounded, filled"	3		OAR
NONE	trapezium	"rounded, filled"	3		OAR
AVOIDANCE	house	"rounded, filled"	3		Planning
CONTROL	invhouse	"rounded, filled"	3		Planning
TREATED_VOLUME	parallelogram	"rounded, filled"	3		Planning
IRRAD_VOLUME	parallelogram	"rounded, filled"	3		Planning
DOSE_REGION	diamond	"rounded, filled"	3		Dose
CONTRAST_AGENT	square	"rounded, filled"	3		Other
CAVITY	square	"rounded, filled"	3		Other
SUPPORT	triangle	"rounded, bold"	3		External
BOLUS	oval	"bold"	3		External
FIXATION	diamond	"bold"	3		External

Default Relationship Line Properties

Property	Value
arrowhead	none
arrowtail	none
penwidth	3
style	"solid"
labelfloat	"false"
labelfontname	"Times"
fontcolor	"#55AAFF"
fontsize	10
color	#e27dd6ff"

Relationship Line Properties

Relationship	Symmetric	Transitive	Complement	Link Name	style	dir	penwidth	color
Disjoint	Yes	No	Disjoint	NA	"invis"			
Logical	No	No	NA	Logical	"dotted"		1	
Shelters	No	Yes	Sheltered	Shelter	"tapered"	"forward"	3	"blue"
Sheltered	No	Yes	Shelters	Shelter	"tapered"	"back"	3	"blue"
Surrounds	No	Yes	Embeds	Island	"tapered"	"forward"	3	"blue"
Embeds	No	Yes	Surrounds	Island	"tapered"	"back"	3	"blue"
Borders	Yes	No	Borders	Borders	"dashed"	"both"	3	"green"
Confines	No	No	Exsects	Cut-out	"tapered"	"forward"	3	"magenta"
Exsects	No	No	Confines	Cut-out	"tapered"	"back"	3	"magenta"
Partitions	No	No	Incorporates	Group	"tapered"	"back"	6	"white"
Incorporates	No	No	Partitions	Group	"tapered"	"forward"	6	"white"
Within	No	Yes	Contains	Expansions	"tapered"	"back"	6	"cyan"
Contains	No	Yes	Within	Expansions	"tapered"	"forward"	6	"cyan"
Overlaps	Yes	No	Overlaps	Overlaps	"tapered"	"both"	6	"green"
Equals	Yes	Yes	Equals	Equals	"bold"		5	"red"


Example Structure Relations
GTV
Surrounds
CTV
Surrounds
PTV
Partitions
Incorporates
eval PTV
Overlaps
Body
Incorporates
Partitions
Incorporates
Partitions
Embeds
Embeds
Lung L
Lung R
Skin
Lung B

Definitions

Structure file: An RS_DICOM file contining all data used by the program.

- The file must follow the NEMA DICOM StructureSet format (Modality=RS) . (RT Structure Set CIOD – DICOM Standard Browser (innolitics.com))

ROI number: A Region-Of-Interest index number.

- The ROI number provides a reference for a 3D space, kown as a "Structure", which is used for treatment planning.

Slice: An axial plane at a set location and with a specified thickness.

- The location is specified as an offset in the SUP/INF (Z) direction from the DICOM origin.
- Thickness is defined as the sum of half the distance to its two neighbouring slices.
- For end slices (without a neighbour in one direction) Thickness is the distance to the existing neighbour and are assumed to extend a half slice distance beyond the end location.
- Thicknesses are calculated using all slice locations referenced in the structure file.

Contour: A regular closed line defining a polygon.

- The line must define a single area (i.e the line segments do not cross).
- The coordinates of the line points are in 3 dimensions (i.e. have X, Y, and Z coordinates).
- The Z coordinate is expected to be the same for all points in the contour (i.e. limited to an axial plane).
- Each contour has an associated slice (based on its Z coordinate) and an ROI number.

Hole: A contour that defines an area within the external bounds of a larger area, that should be excluded from that larger area.

- A hole contour is always linked to another contour that it is to be subtracted from.

Island: A contour that defines an area within a hole, that should be excluded from hole.

- This concept allows for doughnut shaped holes to exist.
- An island contour is always linked to the same contour that its corresponding hole is linked to.

External Contour: A contour with a given ROI number and slice index, which is not contained within any other contours with the same ROI number and slice index.

- An external contour may be linked with other other contours that are entirely contained within it (Holes and Islands).
- An external contour must not overlap with any other contours with the same ROI number and slice index except its holes and islands.

Convex Hull: A bounding contour generated from an external contour.

- A convex hull can be pictures as an elastic band stretched around the external contour.

Region: A defined area on a given slice.

- A region consists of:
    1. An external contour.
    2. A convex hull contour (generated).
    3. All hole and island contours belonging to the external contour.
- A region is formed by combining a contour with all other ***overlapping*** contours on the same axial plane having the same ROI number.
- The convex hull contour is generated from the region's external contour.

Volume: A collection of regions that define a single 3D surface.

- A volume is formed from all contours with the same ROI number which can be combined to form a single 3D surface.
- A given volume may contain more than one contour per slice.

Structure: A collection of all volumes with the same ROI number in the structure file.

- Structure properties include information regarding the labeling and use of the structure.

StructureSet: A collection of all structures from one RS_DICOM file.

- StructureSet propertines include information about the associated image set

Relationship: A description of the geometric interaction between two stuctures

- A relationship has a type and metrics
- The type describes how the structures interact
- The metrics quantifty the interactions
- Different metrics are used depending on the type

Maximum Gap: The largest allowable distance (in cm) between neighbouring slices where the contours can still be considered as matched.

This is to help idenify structures with distinct volumes that are SUP / INF of each other.
The gap may be derived from the slice spacing and a maximum number of skipped slices.

Minimum Overlap: The smallest percent overlap between two contours where the contours can still be considered as matched.

Precision: The grid size (in cm) to use for the contours.

- Contour coordinates will be snaped to this grid size.
- It is used to avoid floating point errors when calculating relationships.
- Distance metrics will be rounded to the is precision.