



Exploring peritumoral white matter fibers for neurosurgical planning of brain tumor resection

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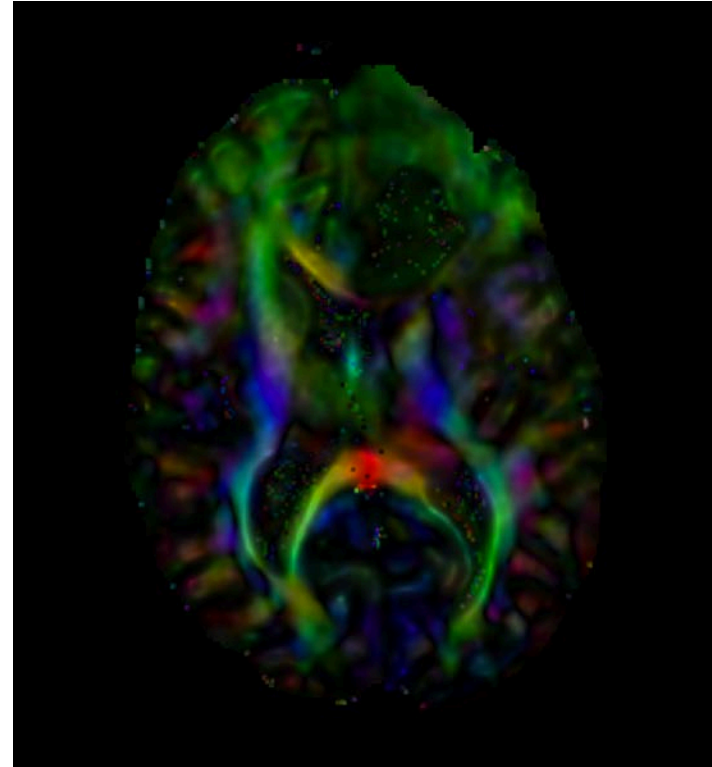
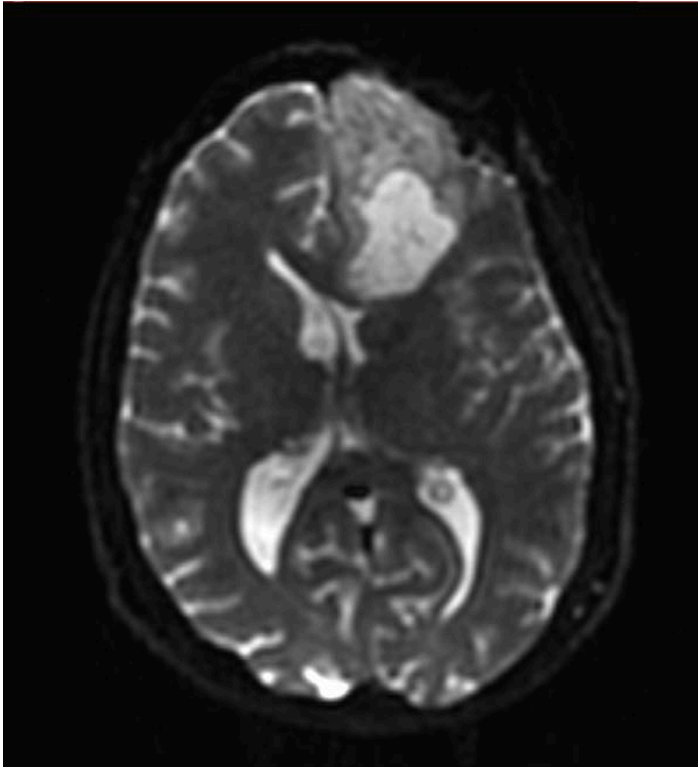
Robert Greenes Director of Biomedical Informatics

Professor of Radiology

Brigham and Women's Hospital

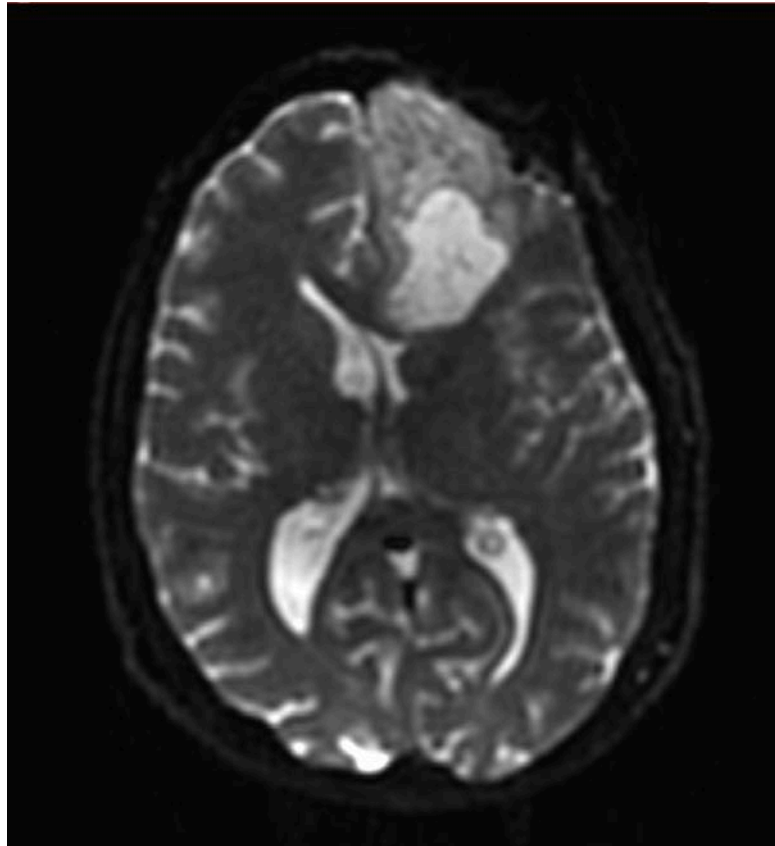
Harvard Medical School

Clinical Case



35 y.o. patient presenting with a Glioblastoma Multiforme

Glioblastoma Multiforme



- Glioblastoma Multiforme (GBM) is a fast-growing high-grade primary gliomas
- Current treatment options combine surgery with radiotherapy and chemotherapy
- GBM spreads to critical areas associated with motor function, language or vision

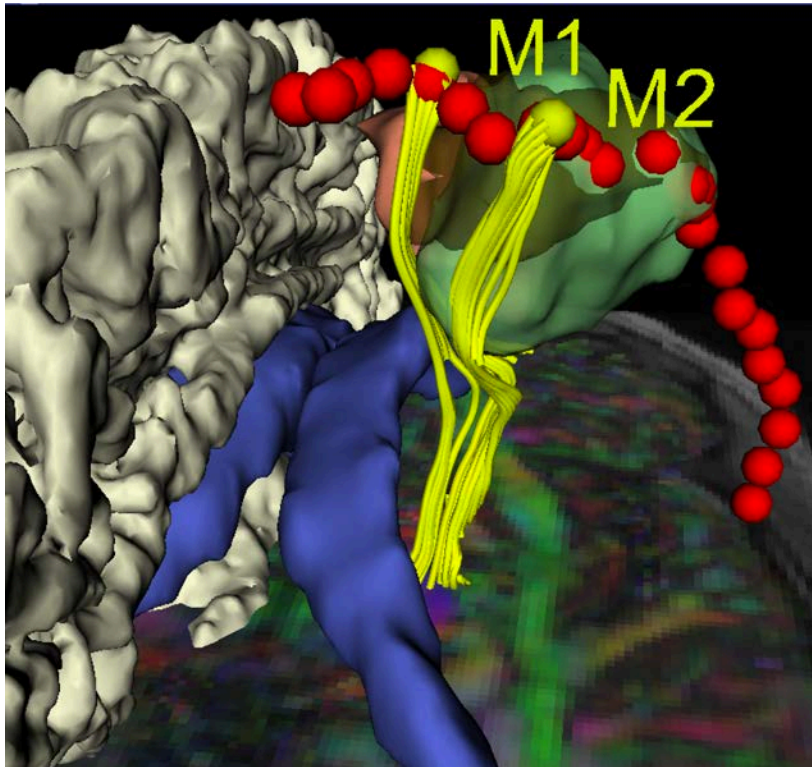
GBM Surgery

- Brain tumor surgery aims to maximize the extent of tumor resection while preserving critical white matter fibers
- Achieving complete resection in GBM surgery is a challenge due to tumor infiltration



Image courtesy of Dr. Alexandra Golby, Brigham and Women's Hospital

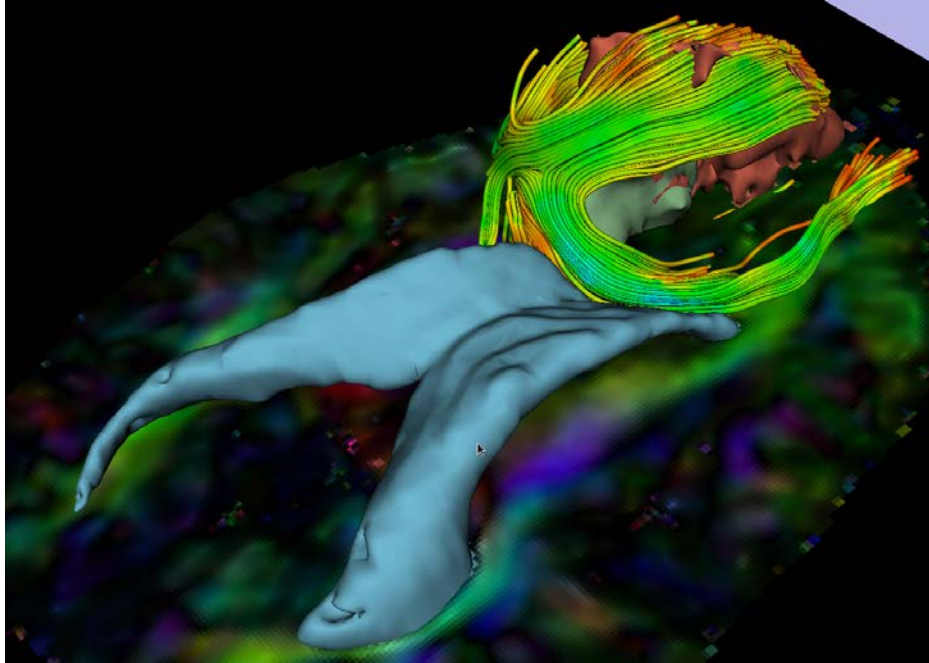
Diffusion MRI for brain surgery



- Diffusion MRI enables non-invasive exploration of white matter anatomy
- Tractography techniques can bring clinically relevant information during surgical planning of brain tumor resection

Pujol S. *Imaging White Matter Anatomy for Surgical Planning of Brain Tumors*. Image-Guided Neurosurgery, First Edition. A. Golby Ed. Academic Press 2015

Overall Objective

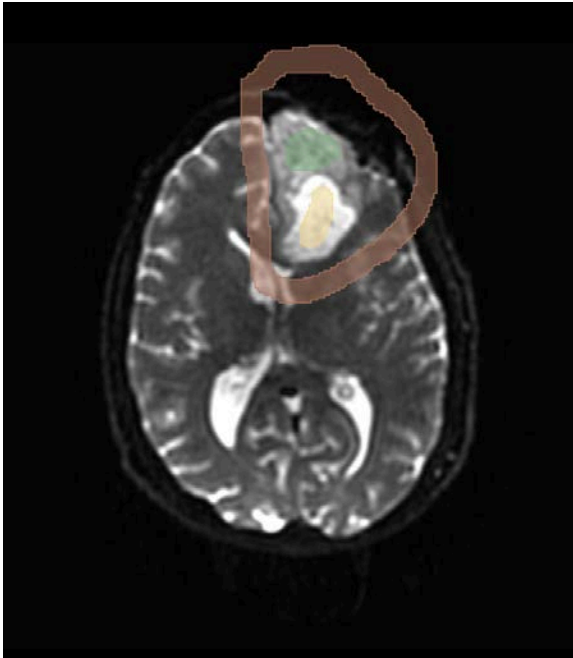


This tutorial provides an end-to-end solution for segmenting the contours of a tumor and generating white matter fiber tracts in the vicinity of the lesion

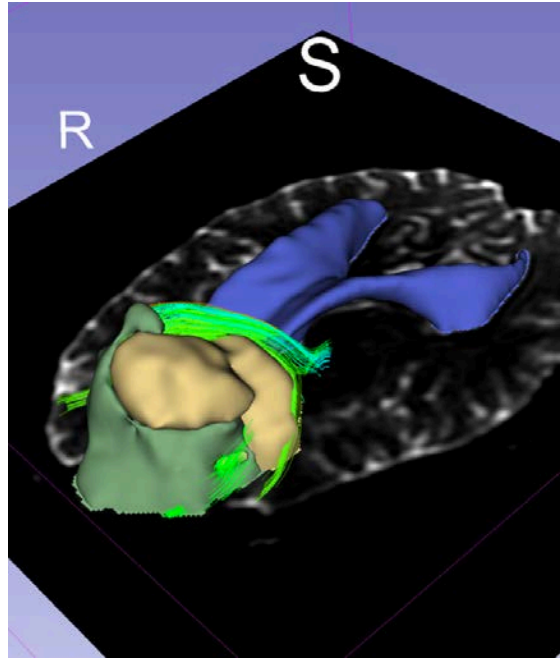
Disclaimer

- 3D Slicer is a free open source software for medical image computing research distributed under a BDS style license.
- The software is not FDA approved or CE-Marked, and is for research use only.

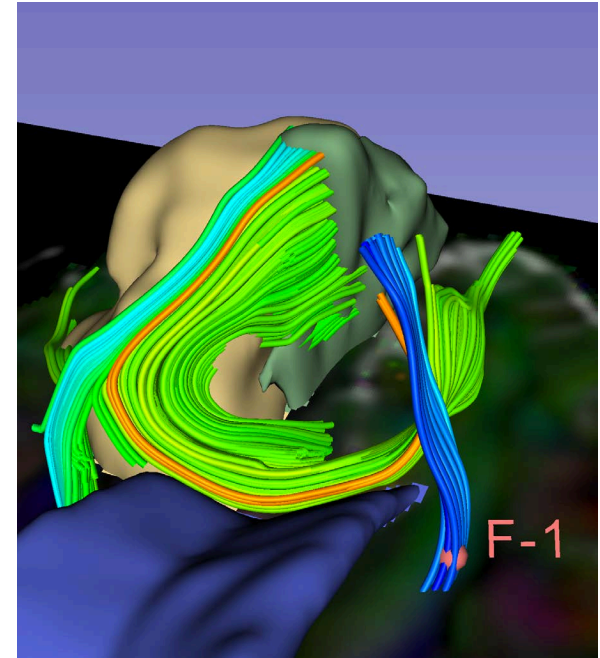
Workflow Overview



Step 1: Tumor Segmentation



Step 2: Fiber Tracts Generation

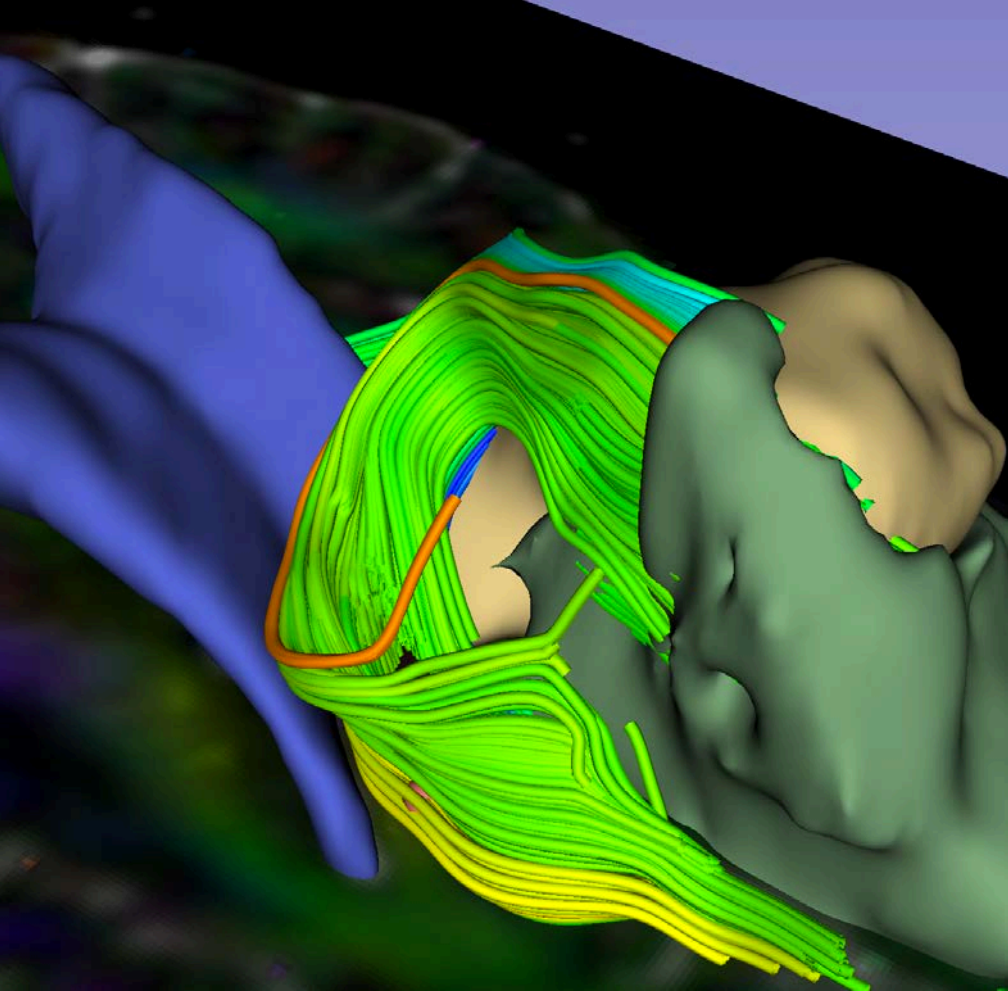


Step 3: Interactive Exploration

Image Processing Workflow

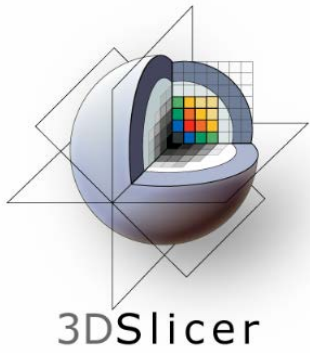
The image processing workflow described in this tutorial uses three algorithms:

- **Grow Cut** algorithm for tumor segmentation
- **Marching Cube** algorithm for surface modeling
- **Single tensor streamline tractography** algorithm for fiber tract generation

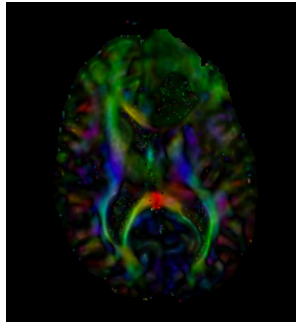
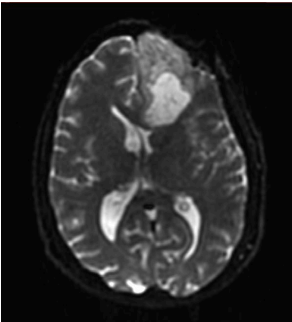


Overall Goal

This tutorial provides an end-to-end solution for segmenting the contours of a tumor and generating white matter fiber tracts in the vicinity of the lesion



Part 1: Tutorial Materials Installation



Tutorial materials

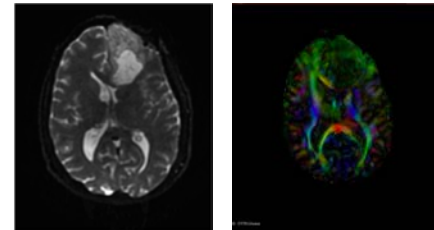
- 3D Slicer release version 4.10



- SlicerDMRI Extension



- White Matter Exploration dataset



3D Slicer installation

- To install and start the 3D Slicer software on your computer, follow the instructions of the **Quick Start Guide tutorial** available at <https://www.slicer.org/wiki/Documentation/4.10/Training>



SlicerDMRI Installation

Left click on the module **Data** to display the list of modules available in 3D Slicer

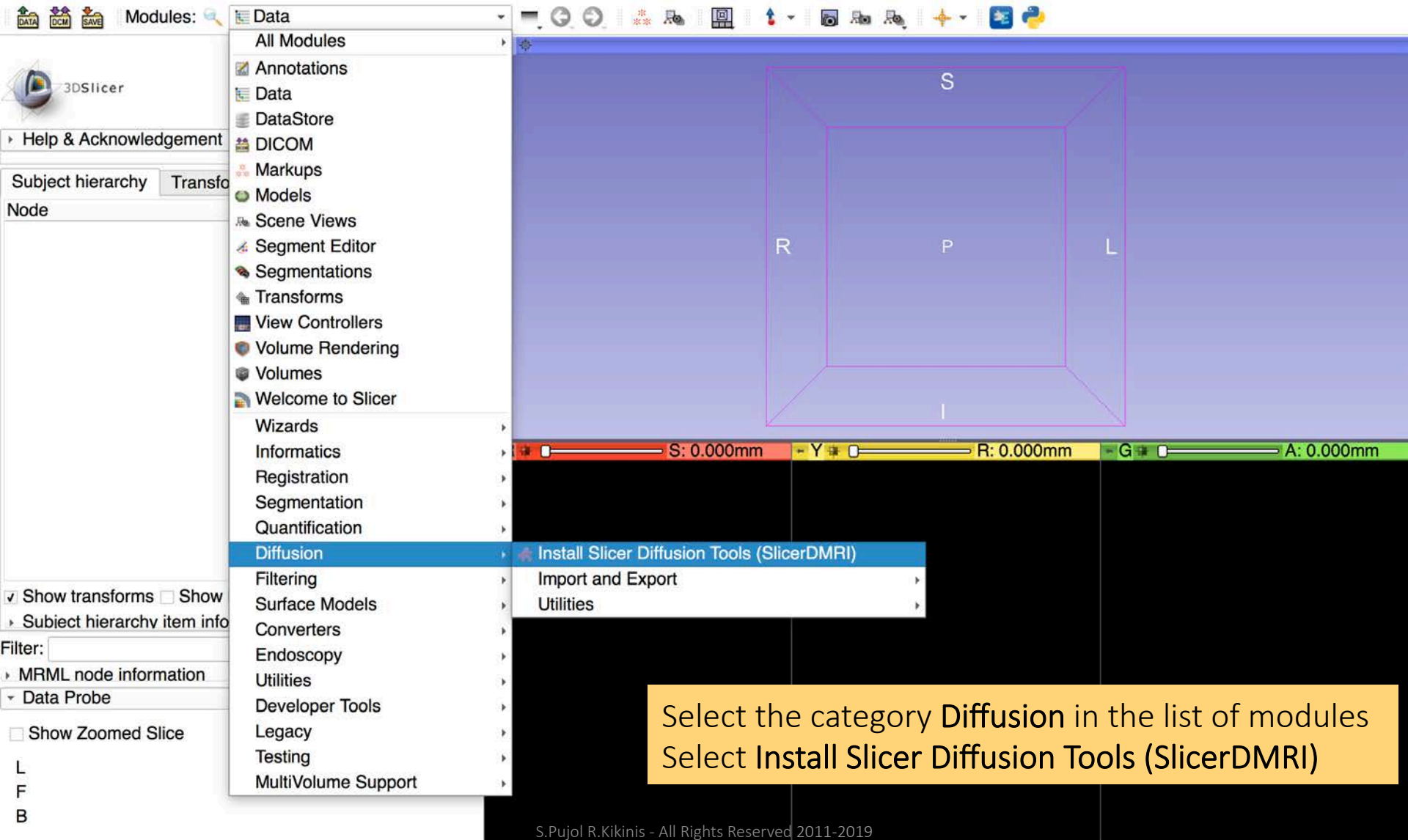
R P L
I

R S: 0.000mm Y R: 0.000mm G A: 0.000mm

Green (L 32.0, A 0.0, S 15.7) Coronal Sp: 1.0
L None
F None
B None



SlicerDMRI Installation



SlicerDMRI Installation

The screenshot shows the 3DSlicer software interface. At the top, the 'Modules' dropdown menu is set to 'Install Slicer Diffusion Tools (SlicerDMRI)'. The main window displays the 'Help & Acknowledgement' section for SlicerDMRI. It lists the following tools provided by the extension:

- Diffusion Tensor Estimation
- Tractography Display
- Tractography Seeding
- Fiber Tract Measurement

Below the list, it provides information on where to find more details and where to ask questions:

For more information, please visit:
<http://dmri.slicer.org>

Questions are welcome on the Slicer forum:
<https://discourse.slicer.org>

At the bottom of the help window, there is a button labeled 'Install SlicerDMRI'. A yellow callout box points to this button with the text 'Click on Install SlicerDMRI'. The interface also shows a 'Data Probe' section with a 'Show Zoomed Slice' checkbox and orientation labels 'L', 'F', and 'B'. The top status bar indicates the current slice position as 'S: 0.000mm'.



SlicerDMRI Installation

3DSlicer

Modules: Install Slicer Diffusion Tools (SlicerDMRI)

Help & Acknowledgement

The SlicerDMRI extension provides diffusion-related tools including:

- Diffusion Tensor Estimation
- Tractography Display
- Tractography Seeding
- Fiber Tract Measurement

For more information, please visit:

<http://dmri.slicer.org>

Questions are welcome on the Slicer forum:

<https://discourse.slicer.org>

Install SlicerDMRI

SlicerDMRI depends on the following extensions:

- UKFTractography

Would you like to install them now?

No Yes

This tutorial does not use UKFTractography
Click on No

Data Probe

Show Zoomed Slice

L
F
B



SlicerDMRI Installation

3DSlicer

Modules: Install Slicer Diffusion Tools (SlicerDMRI)

Help & Acknowledgement

The SlicerDMRI extension provides diffusion-related tools including:

- Diffusion Tensor Estimation
- Tractography Display
- Tractography Seeding
- Fiber Tract Measurement

For more information, please visit:

<http://dmri.slicer.org>

Questions are welcome on the Slicer forum:

<https://discourse.slicer.org>

Install SlicerDMRI

Restart to complete SlicerDMRI installation?

Don't show this message again and always OK

Cancel OK

Click on OK and restart Slicer

Data Probe

Show Zoomed Slice

L
F
B



SlicerDMRI Installation

The screenshot shows the SlicerDMRI software interface. The 'Modules' menu is open, displaying a list of categories. The 'Diffusion' category is highlighted in blue. A yellow callout box points to the 'Diffusion' category with the following text: 'Select the category Diffusion in the list of modules Right-Click on Diffusion to access the different functionalities of the SlicerDMRI module'. The 'Diffusion' sub-menu is also visible, listing options: 'Import and Export', 'Process', 'Quantify', 'Tractography', and 'Utilities'. The background shows the SlicerDMRI 'Welcome' screen with buttons for 'Load DICOM Data', 'Install Slicer Extensions', and 'Customize Slicer'. The top toolbar includes icons for 'DATA', 'DCM', and 'SAVE'. The status bar at the bottom right shows 'S: 0.000mm'.

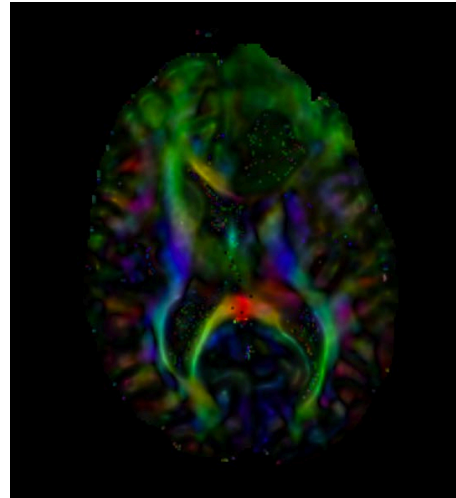
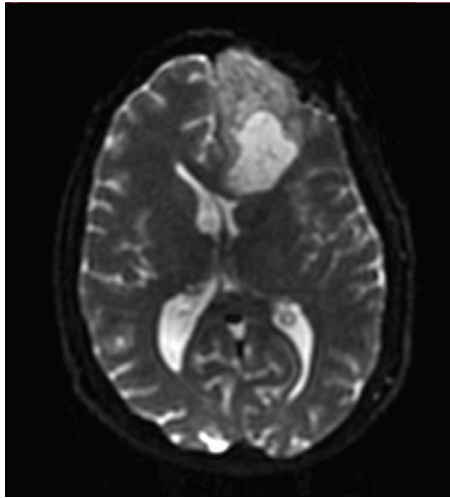
- DATA
- DCM
- SAVE
- Modules:
- Welcome to Slicer
- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Markups
- Models
- Scene Views
- Segment Editor
- Segmentations
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer
- Wizards
- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion**
- Filtering
- Surface Models
- Converters
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- MultiVolume Support
- Import and Export
- Process
- Quantify
- Tractography
- Utilities

Select the category Diffusion in the list of modules
Right-Click on Diffusion to access the different
functionalities of the SlicerDMRI module

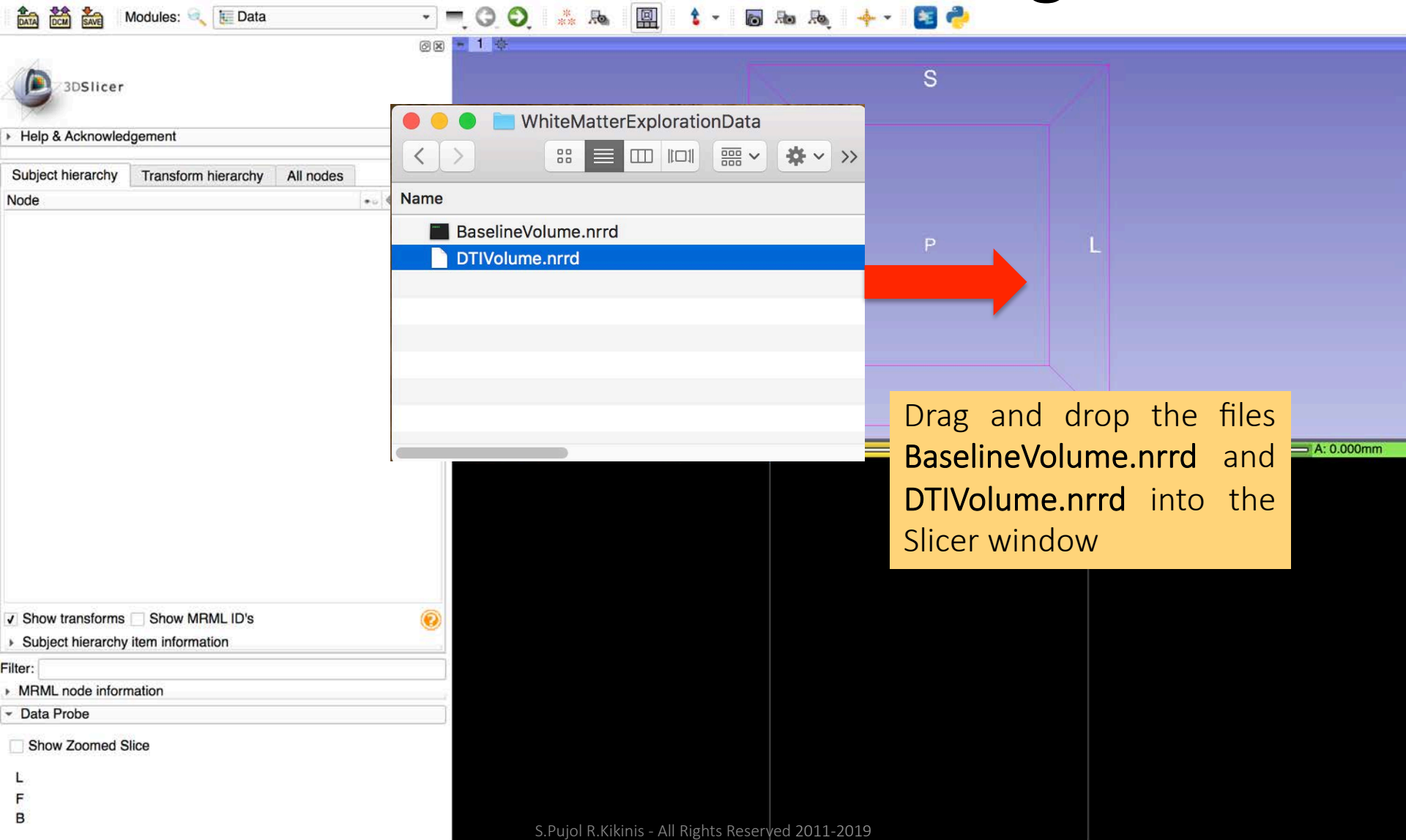


Tutorial Data

- The tutorial data include a baseline volume and a diffusion tensor imaging (DTI) volume



Tutorial Data Loading



Tutorial Data Loading

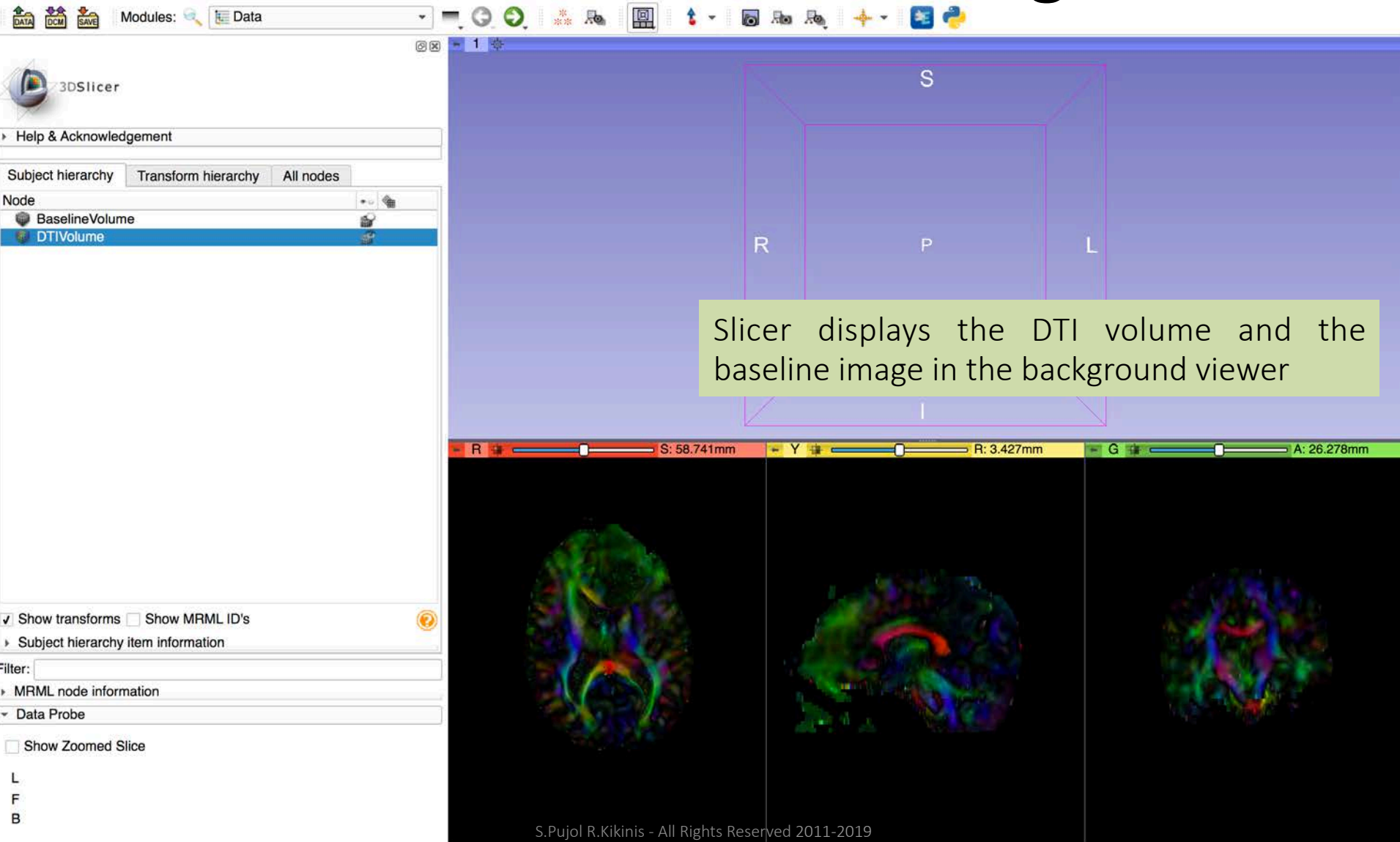
The screenshot shows the 3D Slicer interface. A dialog box titled "Add data into the scene" is open, displaying a table of files to be added. The table has columns for "File" and "Description". Two files are listed, both checked for selection. The "File" column contains the paths: "/Users/kauai/Downloads/WhiteMatterExplorationData/BaselineVolume.nrrd" and "/Users/kauai/Downloads/WhiteMatterExplorationData/DTIVolume.nrrd". The "Description" column shows "Volume" for both. The dialog also includes "Reset", "Cancel", and "OK" buttons, and a "Show Options" checkbox.

File	Description
/Users/kauai/Downloads/WhiteMatterExplorationData/BaselineVolume.nrrd	Volume
/Users/kauai/Downloads/WhiteMatterExplorationData/DTIVolume.nrrd	Volume

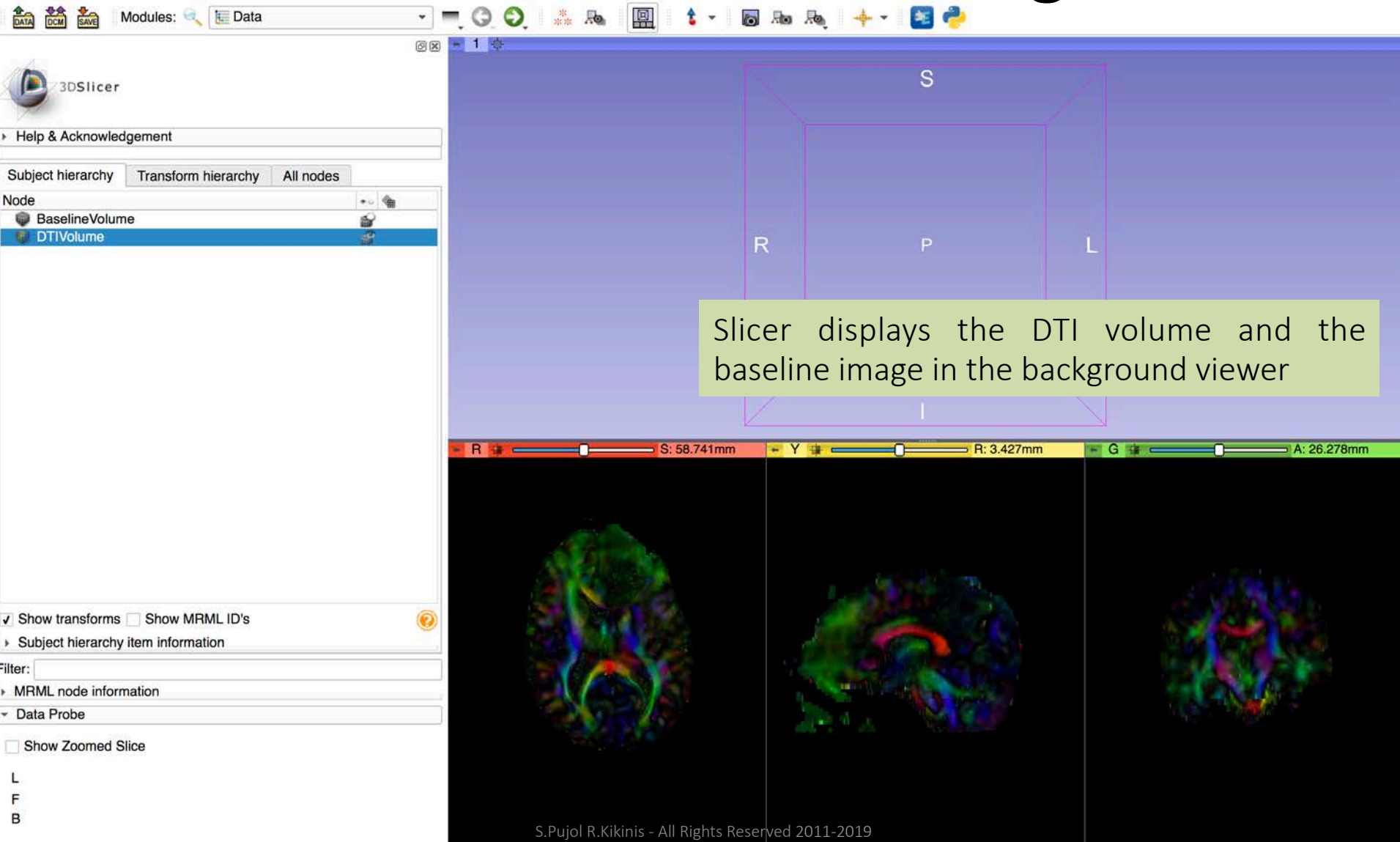
The background shows a 3D view of a brain scan with a purple wireframe box. The axes are labeled S (Superior), I (Inferior), P (Posterior), and L (Lateral). A red arrow points from the "OK" button in the dialog box towards the 3D view. At the bottom of the 3D view, there are sliders for R: 0.000mm, G, and A: 0.000mm.

Click on OK to load the files in Slicer

Tutorial Data Loading



Tutorial Data Loading



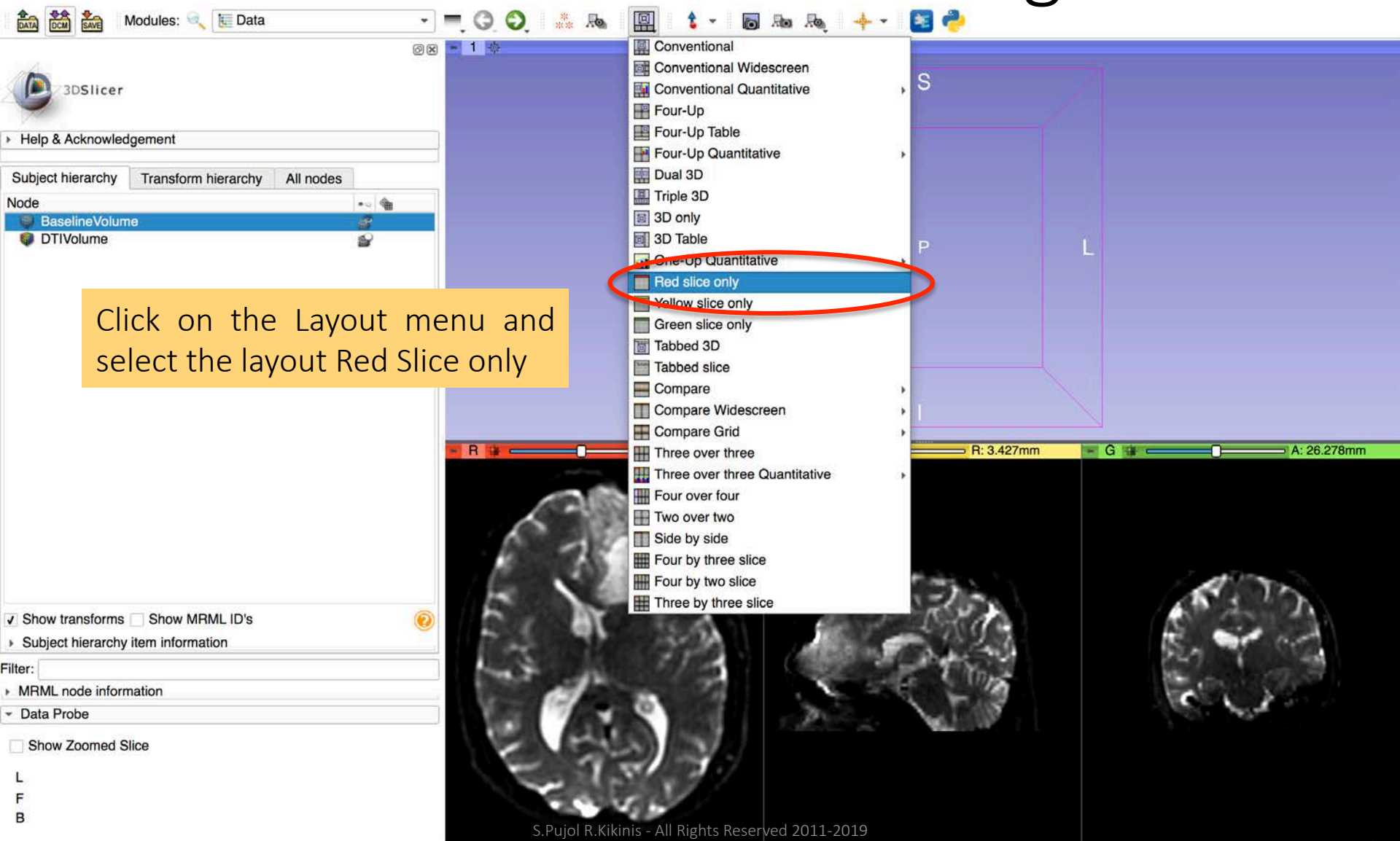
Tutorial Data Loading

The screenshot displays the 3DSlicer software interface. At the top, the 'Modules' dropdown is set to 'Data'. The left sidebar shows the 'Node' list with 'BaselineVolume' selected and highlighted in blue. A red arrow points to the eye icon next to 'BaselineVolume'. The main 3D view shows a brain scan with a purple wireframe box indicating the current slice position, labeled with 'S' (Superior), 'R' (Right), 'P' (Posterior), and 'L' (Left). Below the 3D view, there are three sliders for slice position: 'R' (58.741mm), 'Y' (3.427mm), and 'G' (26.278mm). At the bottom, three orthogonal views (axial, sagittal, and coronal) of the brain scan are displayed. The bottom status bar shows 'Red (L 12.4, A 53.3, S 58.7) Axial Sp: 2.6', 'L None', 'F None', and 'B BaselineVolume (143, 100, 25) 524'.

Click on the eye icon next to **BaselineVolume** in the Data module to display the baseline image in the background viewer

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Tutorial Data Loading



Tutorial Data Loading

3DSlicer

Modules: Data

Help & Acknowledgement

Subject hierarchy Transform hierarchy

Node

- BaselineVolume
- DTIVolume

Show transforms Show MRML ID's

Subject hierarchy item information

Filter:

MRML node information

Data Probe

Red (L 72.6, A 45.8, S 58.7) Axial Sp: 2.6

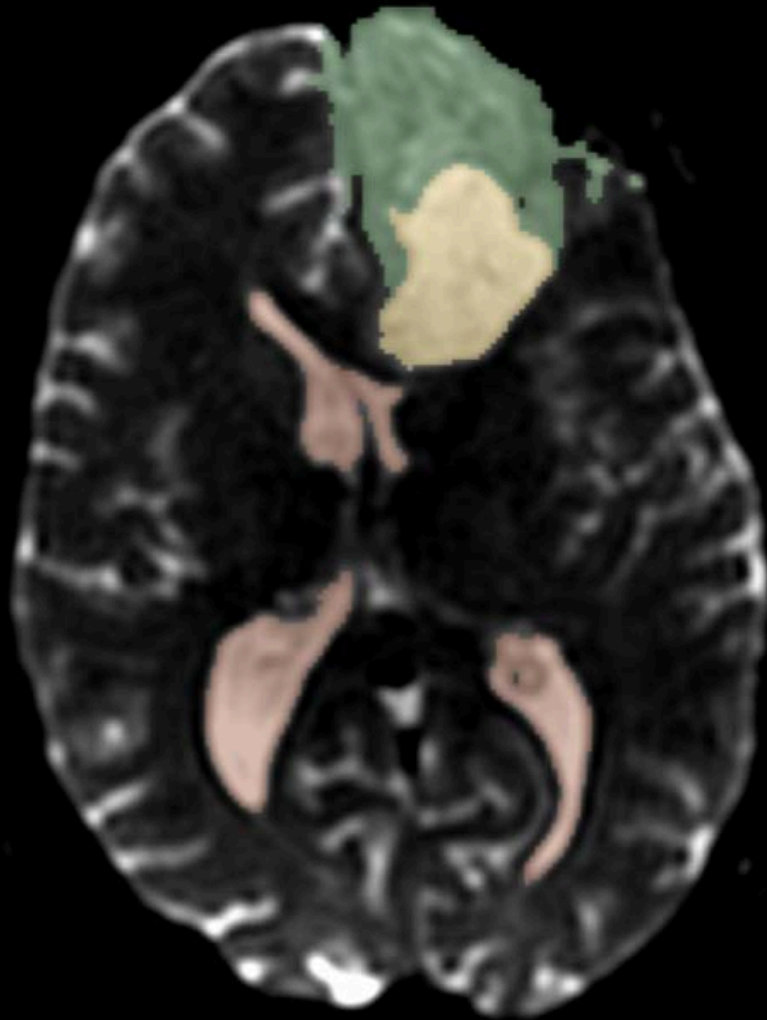
L None

F None

B BaselineVolume (203, 108, 25) 55

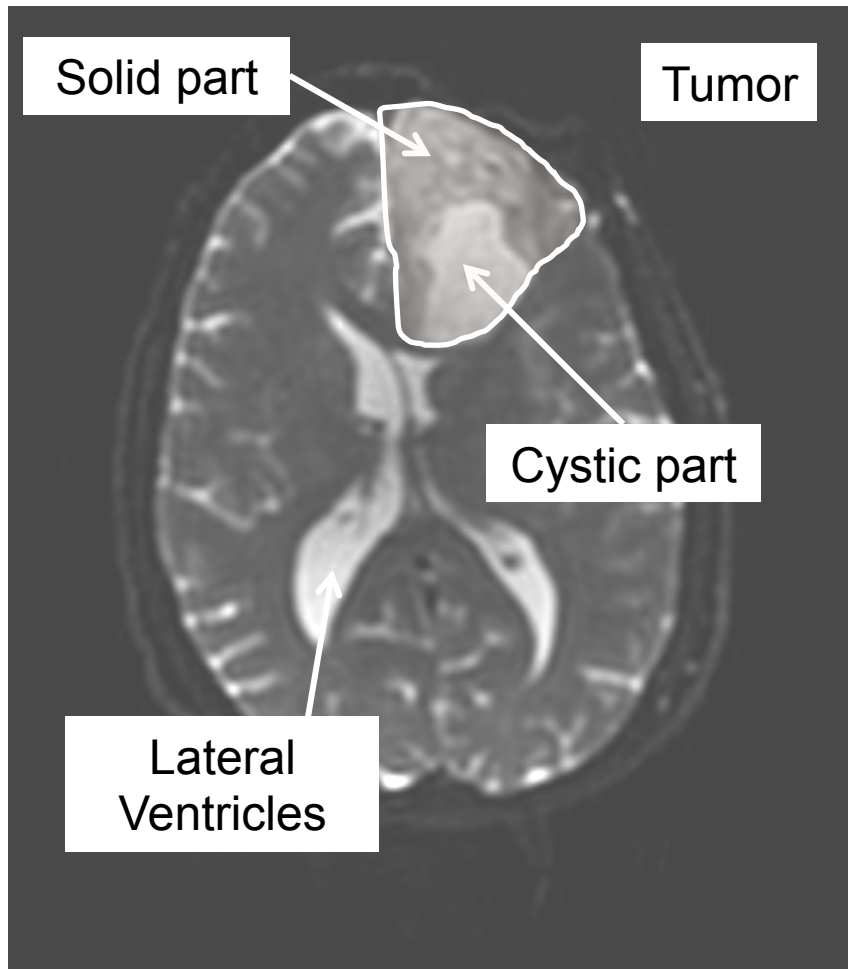
Slicer displays a zoomed view of the baseline volume.

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Part 1: Segmentation of tumor and ventricles

Tumor segmentation



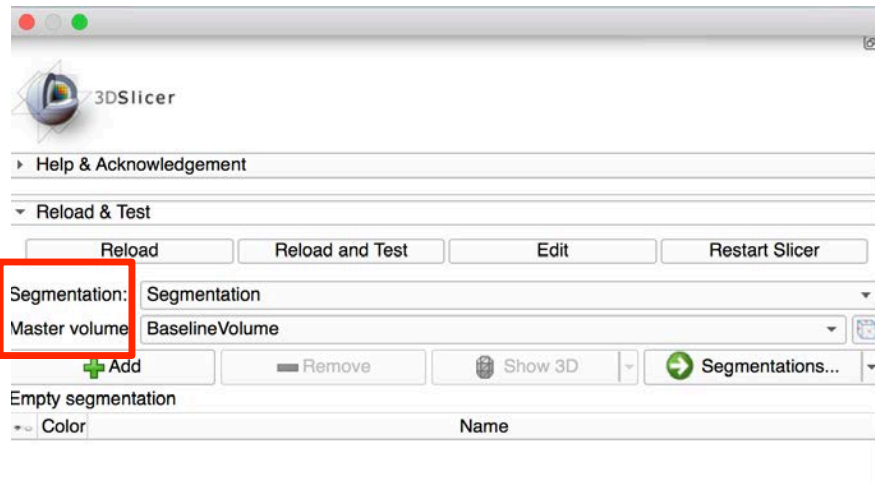
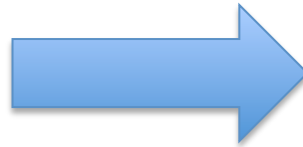
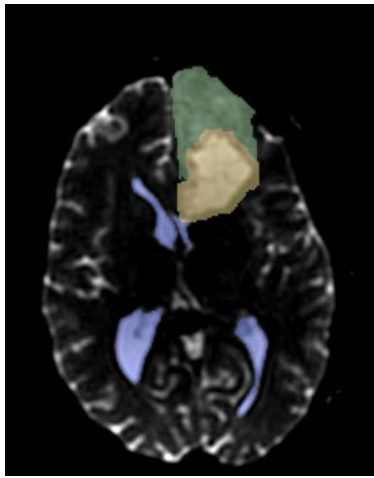
This section shows how to segment the solid and cystic components of the tumor using the **Grow from Seeds** tool of the Segment Editor module.

The section includes the segmentation of the lateral ventricles for anatomical reference.

Segment Editor Module

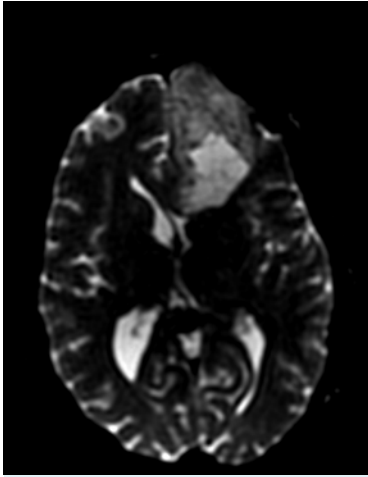
- Segmentation is the process of identifying a structure of interest in imaging data
- The Segment Editor module of 3D Slicer provides powerful tools for manual and semi-automated segmentation

Basic Principle

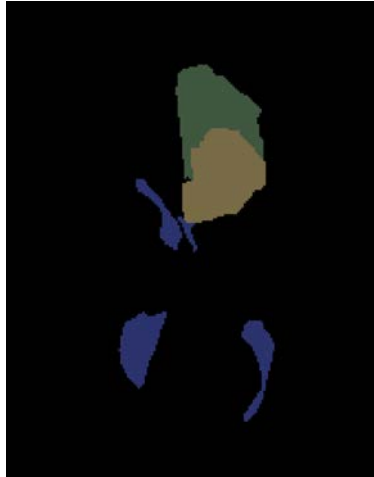


The Segment Editor module takes a reference image (**Master Volume**) as input and produces a segmented image (**Segmentation**) in output

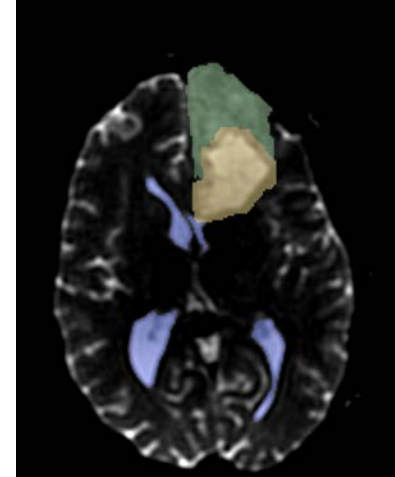
Basic Principle



Master Volume



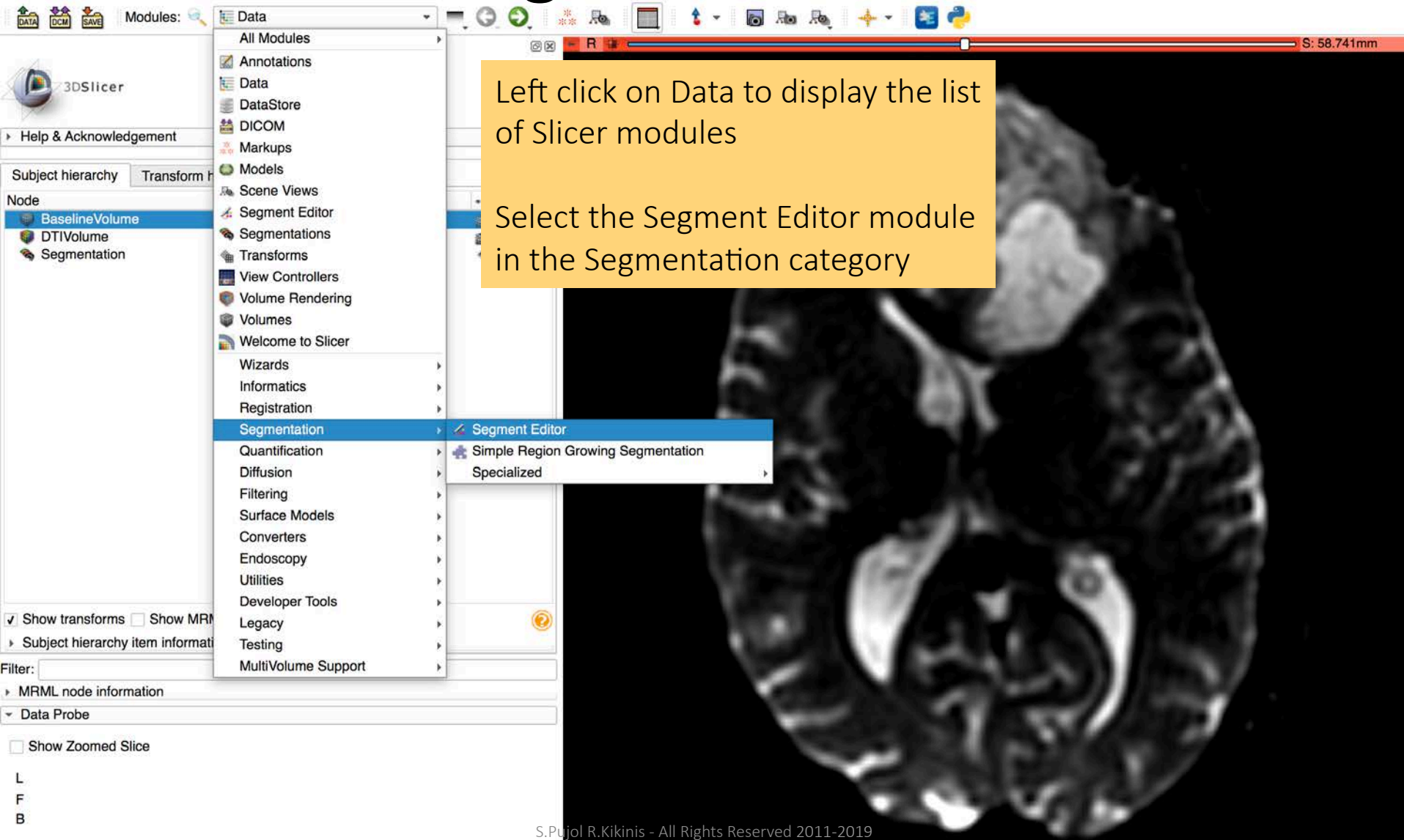
Segmentation



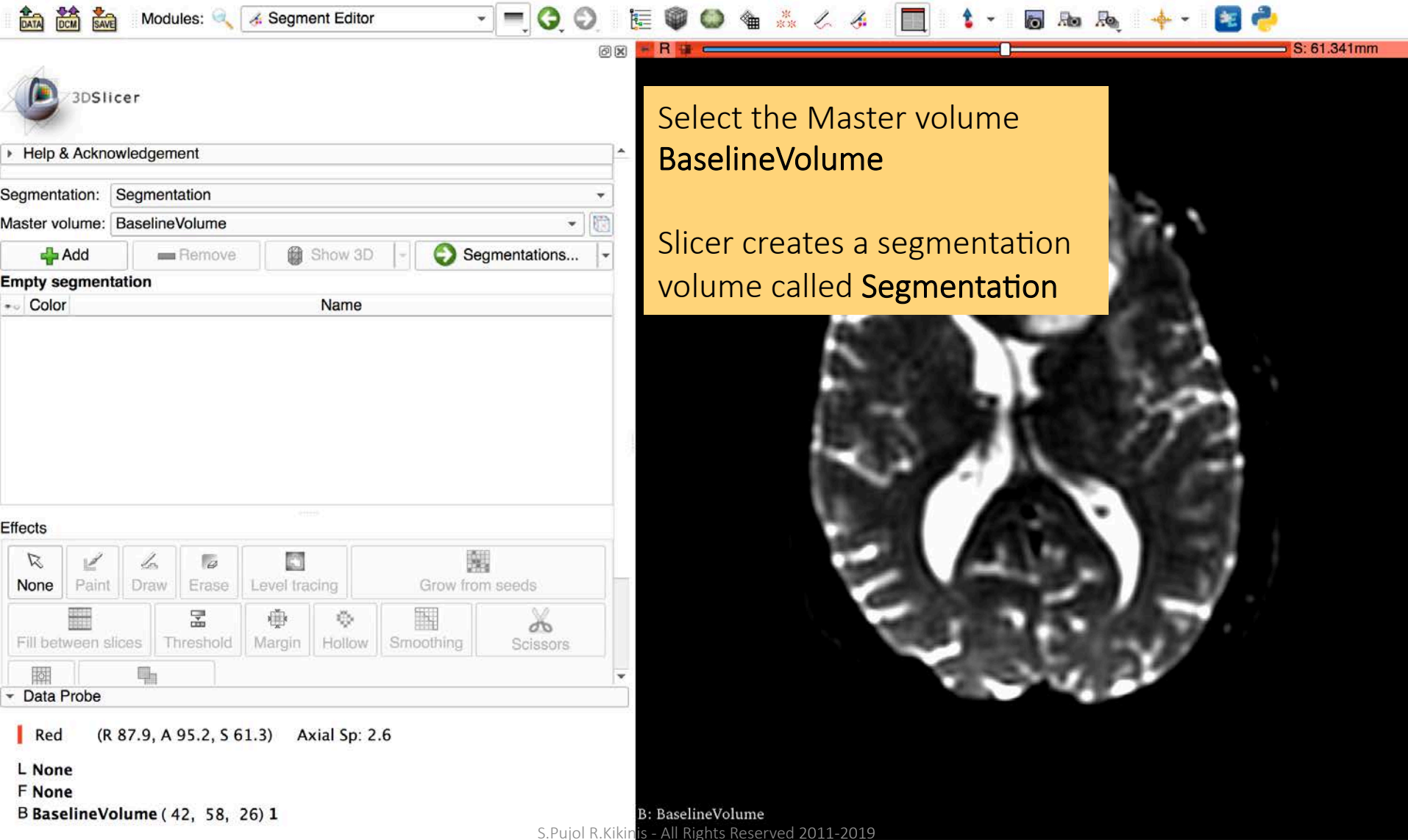
Master Volume +
Segmentation

The Segmentation volume is a binary labelmap with the same origin and resolution as the Master Volume

Segment Editor



Tumor Segmentation



The screenshot displays the 3D Slicer software interface. The top toolbar includes icons for DATA, DCM, SAVE, and a Modules dropdown menu set to Segment Editor. The main window shows an axial MRI slice of a brain. On the left, the Segment Editor panel is visible, with the Master volume set to BaselineVolume and a Segmentation volume created. The Effects panel at the bottom contains various segmentation tools like Paint, Draw, Erase, Level tracing, Grow from seeds, Fill between slices, Threshold, Margin, Hollow, Smoothing, and Scissors. The Data Probe at the bottom left shows the current slice coordinates: Red (R 87.9, A 95.2, S 61.3) Axial Sp: 2.6, L None, F None, and B BaselineVolume (42, 58, 26) 1.

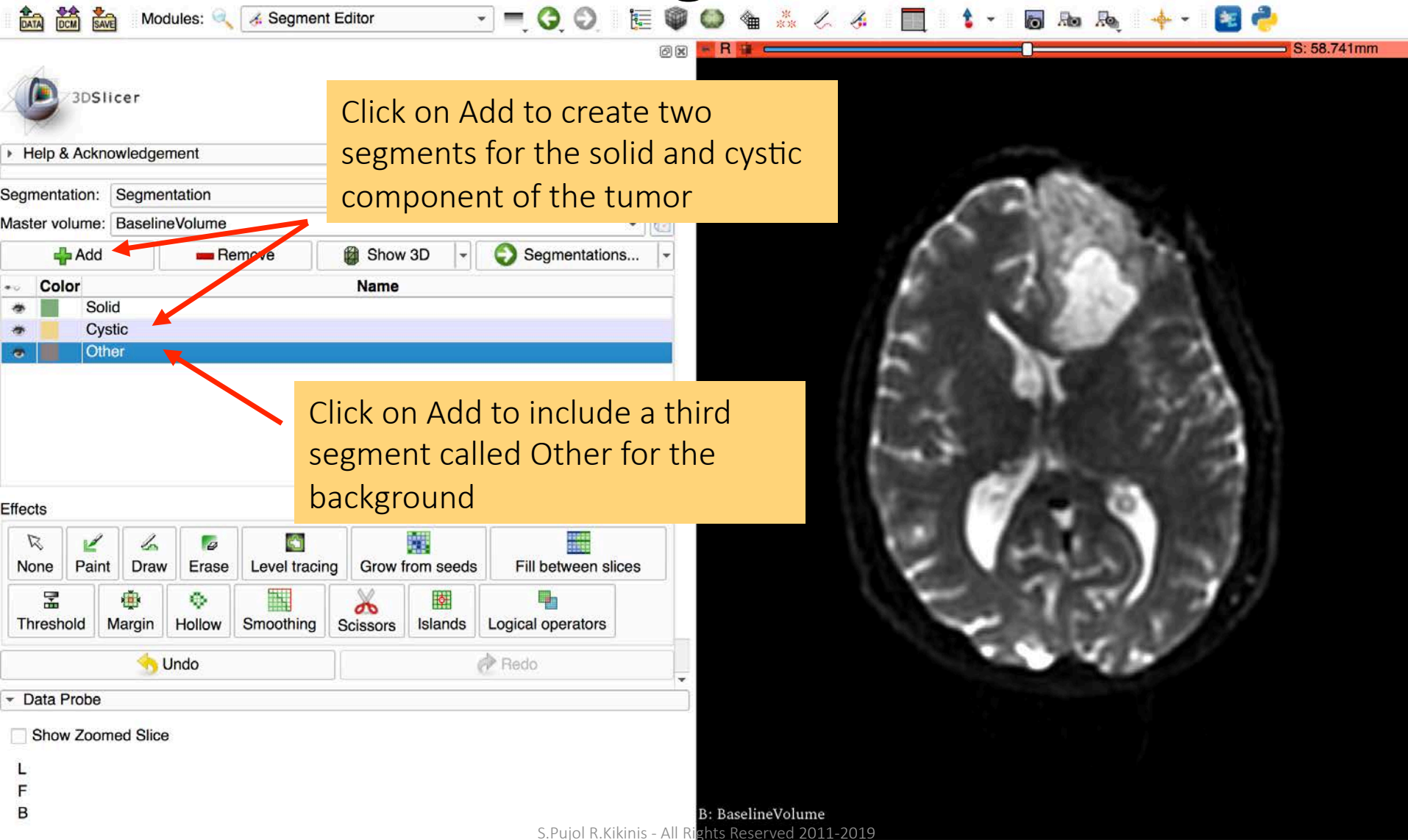
Select the Master volume
BaselineVolume

Slicer creates a segmentation
volume called Segmentation

B: BaselineVolume



Tumor Segmentation



The screenshot displays the 3D Slicer software interface. The top toolbar includes icons for DATA, DCM, SAVE, and a Modules dropdown menu set to Segment Editor. A status bar at the top right shows 'S: 58.741mm'. The main window shows an axial MRI slice of a brain with a tumor. The left sidebar contains the Segmentation panel with 'Segmentation' selected and 'BaselineVolume' as the Master volume. Below this is a table for defining segments:

Color	Name
<input type="checkbox"/> Green	Solid
<input type="checkbox"/> Yellow	Cystic
<input type="checkbox"/> Blue	Other

Below the table is the Effects panel with various segmentation tools: None, Paint, Draw, Erase, Level tracing, Grow from seeds, Fill between slices, Threshold, Margin, Hollow, Smoothing, Scissors, Islands, Logical operators, Undo, and Redo. A 'Data Probe' section at the bottom left has a checkbox for 'Show Zoomed Slice' and labels L, F, B.

Two yellow callout boxes with red arrows provide instructions:

- Top callout: Click on Add to create two segments for the solid and cystic component of the tumor. (Arrows point to the 'Add' button and the 'Solid' and 'Cystic' rows in the table.)
- Bottom callout: Click on Add to include a third segment called Other for the background. (Arrows point to the 'Add' button and the 'Other' row in the table.)



Tumor Segmentation

The image shows the 3D Slicer software interface with a brain MRI slice. A yellow callout box points to the 'Solid' segment in the 'Color' panel, with the text 'Select the segment Solid'. Another yellow callout box points to the 'Paint' tool in the 'Effects' panel, with the text 'Select the Paint tool and draw a mark in the solid component of the tumor in three contiguous slices'. A red arrow points from the 'Paint' tool to a green mark on the tumor in the MRI slice. The 'Color' panel shows a table with columns 'Color' and 'Name':

Color	Name
Green	Solid
Yellow	Cystic
Brown	Other

The 'Effects' panel shows the 'Paint' tool selected, with a diameter of 3% and options for 'Sphere brush', 'Color smudge', and 'Pixel mode'. The 'Data Probe' panel is visible at the bottom left.

B: BaselineVolume



Tumor Segmentation

The image shows the 3D Slicer software interface with a brain MRI slice. The 'Segment Editor' module is active. The 'Segmentation' panel shows a list of segments: 'Solid' (green), 'Cystic' (yellow), and 'Other' (brown). The 'Cystic' segment is selected. The 'Effects' panel shows the 'Paint' tool selected. A red arrow points to the 'Paint' tool, and another red arrow points to the 'Cystic' segment. A yellow callout box contains the text: 'Select the segment Cystic'. Another yellow callout box contains the text: 'Select the Paint tool and draw a mark in the cystic component of the tumor in three contiguous slices'. The MRI slice shows a tumor with a yellow 'Cystic' component and a green 'Solid' component. The 'Paint' tool is used to mark the cystic component in three contiguous slices.

Modules: Segment Editor

Segmentation: Segmentation

Master volume: BaselineVolume

+ Add - Remove

Color	Name
<input type="checkbox"/>	Solid
<input checked="" type="checkbox"/>	Cystic
<input type="checkbox"/>	Other

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between slices

Threshold Margin Smoothing Scissors Islands Logical operators

Paint

Paint with a round brush... [Show details](#)

Diameter: 3% [1] [3] [5] [10] [20] [40] [%]

Sphere brush Color smudge Pixel mode

Undo Redo

Data Probe

B: BaselineVolume

S: 58.741mm



Tumor Segmentation

3DSlicer

Modules: Segment Editor

Segmentation: Segmentation

Master volume: BaselineVolume

Color Name

Color	Name
Solid	Solid
Cystic	Cystic
Other	Other

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between slices

Threshold Margin Smoothing Scissors Islands Logical operators

Erase

Erase from current segment with a round brush... [Show details.](#)

Diameter: 3% 1 3 5 10 20 40 %

Sphere brush Color smudge Pixel mode

Undo Redo

Data Probe

Select the segment Other

Select the Paint tool and draw a line around the solid and cystic component of the tumor

B: BaselineVolume

S: 58.741mm



Tumor Segmentation

The image shows the 3D Slicer software interface. The top toolbar includes icons for DATA, DCM, SAVE, and various editing tools. The main window displays an axial brain MRI slice with a brown outline indicating the tumor region. Inside this region, there are three distinct segments: a green segment (Solid), a yellow segment (Cystic), and a blue segment (Other).

Segmentation Tools Panel:

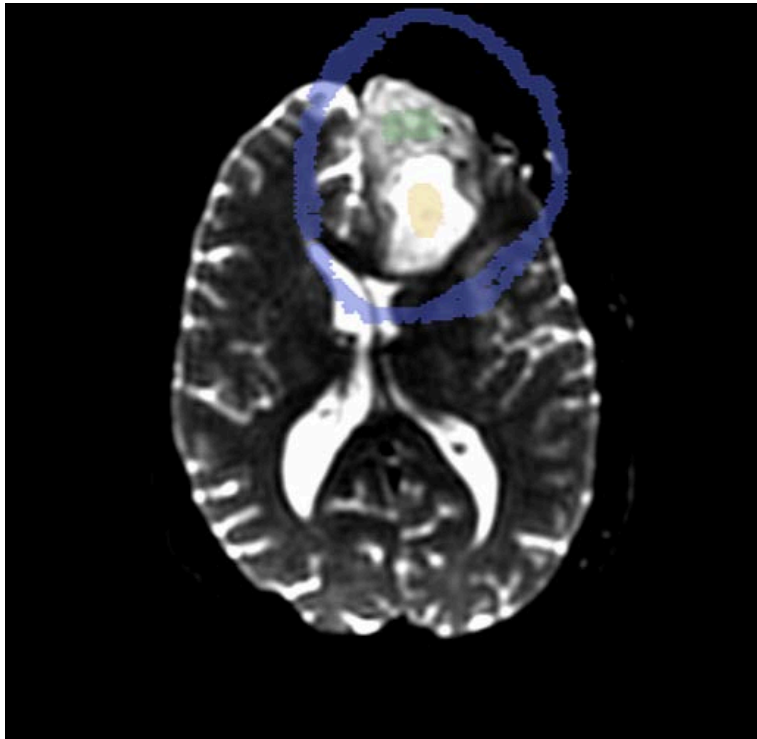
- Color:** Solid (Green), Cystic (Yellow), Other (Blue)
- Effects:** None, Paint, Draw, Erase, Level tracing, **Grow from seeds** (circled in red), Fill between slices, Threshold, Margin, Smoothing, Scissors, Islands, Logical operators
- Grow from seeds:** Growing segments to create complete segmentation... [Show details.](#) Preview: Auto-update Initialize (indicated by a red arrow), Display: inputs results, Cancel, Apply
- Masking:** Editable area: Everywhere
- Data Probe:**

Instructional Text: Select the **Grow From Seeds** tool and click on **Initialize**

System Information: S: 58.741mm, B: BaselineVolume



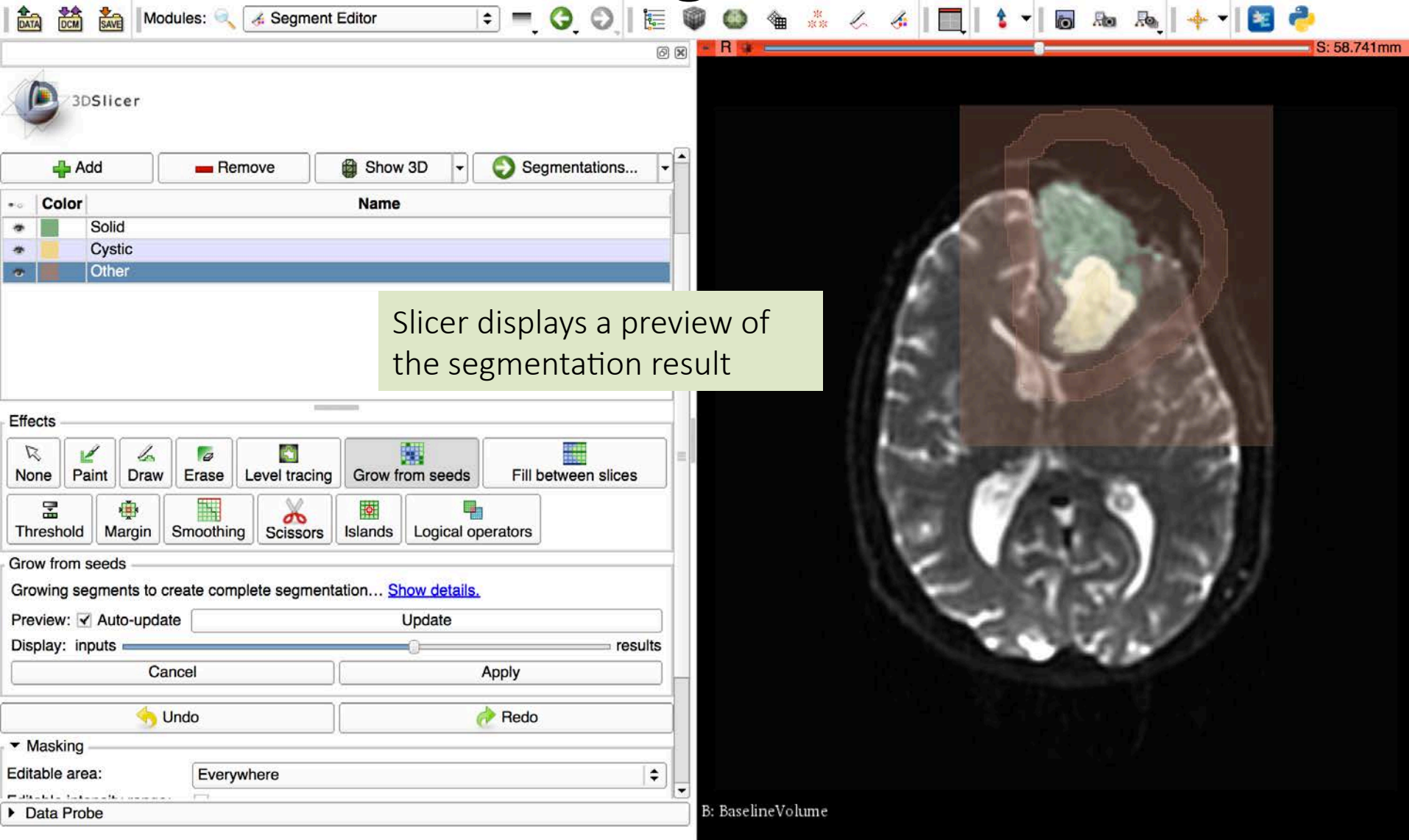
Grow from Seeds Algorithm



- The **Grow from Seeds** tool implements the **Grow Cut** algorithm, a competitive region growing algorithm using a Cellular Automata approach.
- The algorithm performs automated multi-label image segmentation using a set of user input scribbles.

Reference: Vezhnevets V, Konouchine V. "Grow-Cut" - Interactive Multi-Label N-D Image Segmentation". Proc. Graphicon. 2005 .pp. 150-156.




Tumor Segmentation



3DSlicer

Modules: Segment Editor

S: 58.741mm

Color	Name
	Solid
	Cystic
	Other

Effects

None Paint Draw Erase Level tracing **Grow from seeds** Fill between slices

Threshold Margin Smoothing Scissors Islands Logical operators

Grow from seeds

Growing segments to create complete segmentation... [Show details.](#)

Preview: Auto-update Update

Display: inputs results

Cancel Apply

Undo Redo

Masking

Editable area: Everywhere

Data Probe

B: BaselineVolume

Slicer displays a preview of the segmentation result



Tumor Segmentation

3DSlicer

Modules: Segment Editor

S: 58.741mm

Color	Name
	Solid
	Cystic
	Other

Effects

None Paint Draw Erase Level tracing Grow from seeds

Threshold Margin Smoothing Scissors Islands Logical o

Grow from seeds

Growing segments to create complete segmentation... [Show details.](#)

Preview: Auto-update Update

Display: inputs results

Cancel Apply

Undo Redo

Masking

Editable area: Everywhere

Data Probe

B: BaselineVolume

Click on Apply to create the segmentation



Tumor Segmentation

The image shows the 3D Slicer software interface. The top toolbar includes icons for DATA, DCM, SAVE, and various editing tools. The 'Modules' dropdown is set to 'Segment Editor'. The main window displays an axial MRI slice of a brain with a tumor segmented into three regions: a green region (Solid), a yellow region (Cystic), and a brown region (Other). The 'Segment Editor' panel on the left shows the 'Segmentations...' tab with a list of segments: Solid (green), Cystic (yellow), and Other (brown). The 'Effects' panel includes tools like None, Paint, Draw, Erase, Level tracing, Grow from seeds, Fill between slices, Threshold, Margin, Smoothing, Scissors, Islands, and Logical operators. The 'Grow from seeds' section is active, showing a 'Preview' checkbox for 'Auto-update', an 'Initialize' button, and a 'Display: inputs' slider. The 'Masking' section shows 'Editable area' set to 'Everywhere'. The 'Data Probe' section is visible at the bottom left. A status bar at the top right indicates 'S: 58.741mm'. A text box at the bottom right of the image contains the text 'Slicer displays the segmentation result'.

3DSlicer

Modules: Segment Editor

S: 58.741mm

Color	Name
	Solid
	Cystic
	Other

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between slices

Threshold Margin Smoothing Scissors Islands Logical operators

Grow from seeds

Growing segments to create complete segmentation... [Show details.](#)

Preview: Auto-update Initialize

Display: inputs results

Cancel Apply

Undo Redo

Masking

Editable area: Everywhere

Data Probe

B: BaselineVolume

Slicer displays the segmentation result

Tumor Segmentation

The screenshot displays the 3DSlicer software interface. The top toolbar includes icons for DATA, DCM, SAVE, and various editing tools. The 'Segment Editor' module is active. On the left, a 'Color' panel lists 'Solid' (green), 'Cystic' (yellow), and 'Other' (blue), with a red arrow pointing to 'Other' and a yellow callout box stating 'Select the segment Other'. Below this is the 'Effects' panel, where the 'Threshold' tool is selected with a red arrow and a yellow callout box stating 'Select the Threshold tool and set the Threshold Range to 1700'. The 'Threshold' panel shows a 'Threshold Range' of 1700.00, with a red arrow pointing to the input field. The 'Apply' button is circled in red. The 'Masking' panel shows 'Editable area' set to 'Everywhere' and 'Overwrite other segments' set to 'Outside all segments', with a yellow callout box stating 'Set the Editable area to Outside all Segments and click on Apply'. The main 3D view shows an axial brain slice with a segmented tumor region in light blue.

Modules: Segment Editor

3DSlicer

Color Name

- Solid
- Cystic
- Other

Select the segment Other

Effects

- None
- Paint
- Draw
- Erase
- Level tracing
- Grow from seeds
- Fill between slices
- Threshold
- Margin
- Hollow
- Smoothing
- Scissors
- Islands
- Logical operators

Threshold

Fill segment based on master volume intensity range... Show

Threshold Range:

1700.00

Automatic threshold: auto->maximum Otsu

Use for masking

Apply

Undo Redo

Masking

Editable area: Everywhere

Editable intensity range: Everywhere

Overwrite other segments: Outside all segments

Set the Editable area to Outside all Segments and click on Apply

S: 58.741mm

Ventricles Segmentation

3DSlicer

Modules: Segment Editor

Help & Acknowledgement

Reload & Test

Reload Reload and Test Edit Restart Slicer

Segmentation: Segmentation

Master volume: BaselineVolume

+ Add - Remove Show 3D Segmentations...

Color	Name
Solid	
Cystic	
Other	

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between

Threshold Margin Hollow Smoothing Scissors **Islands** Logical operators

Islands

Edit islands (connected components) in a segment.

Keep largest island **Keep selected island**

Remove small islands Remove selected island

Split islands to segments Add selected island

Minimum size: 1000 voxels

Apply

Data Probe

S: 58.741mm

Select the Islands tool

Select the option Keep selected island

Left-click on the posterior part of the lateral ventricles to isolate the island

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Ventricles Segmentation

The image shows the 3DSlicer software interface. The main window displays an axial brain MRI slice with segmented ventricles. The segment list on the left shows 'Ventricles' selected. A yellow callout box contains the instruction: "Double click on the segment Other and rename it Ventricles".

Modules: Segment Editor

3DSlicer

Help & Acknowledgement

Reload & Test

Reload Reload and Test Edit Restart Slicer

Segmentation: Segmentation

Master volume: BaselineVolume

+ Add - Remove Show 3D Segmentations...

Color	Name
Solid	
Cystic	
Ventricles	

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between slices

Threshold Margin Hollow Smoothing Scissors Islands Logical operators

Islands

Edit islands (connected components) in a segment.

Keep largest island Keep selected island

Remove small islands Remove selected island

Split islands to segments Add selected island

Minimum size: 1000 voxels

Apply

Data Probe

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Ventricles Segmentation

Click on the color icon next to the Ventricles segment : a pop-up window appears

3DSlicer

Modules: Segment Editor

Segmentation: Segmen
Master volume: Baselin

Color

Color	Name
Solid	
Cystic	
Ventricles	

Segmentation category and type - 3D Slicer General Anatomy list

Category... Ventricle

Tissue	
Anatomical Structure	Brain ventricle
	Fourth ventricle
	Lateral ventricle
	Left Ventricle
	Right Ventricle

Name: Ventricles

Color: [Color Picker]

Effects

None Paint Draw Erase Level tracing Grow from seeds

Threshold Margin Hollow Smoothing Scissors Islands Logic

Islands

Edit islands (connected components) in a segment.

Keep largest island Keep selected island

Remove small islands Remove selected island

Split islands to segments Add selected island

Minimum size: 1000 voxels

Apply

Data Probe

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Tumor and Ventricles Segmentation

The image shows the 3D Slicer software interface. The top toolbar includes icons for DATA, DCM, SAVE, and a Modules dropdown menu set to Segment Editor. The main window displays a 3D view of a brain scan with a red overlay. A yellow text box overlaid on the 3D view contains the following instructions: "Select the Category Anatomical Structure, enter the structure Ventricle, select Brain Ventricle and click on Select to change the Ventricles segment color to blue".

In the lower-left panel, the Segmentation section shows the Master volume as BaselineVolume. Below it, a table lists segmentation categories:

Color	Name
	Solid
	Cystic
	Ventricles

The Effects panel below the Segmentation section contains various tools: None, Paint, Draw, Erase, Level tracing, Grow from seeds, Fill between, Threshold, Margin, Hollow, Smoothing, Scissors, Islands, and Logical operators.

The Islands panel at the bottom left provides options for editing connected components in a segment:

- Keep largest island
- Keep selected island
- Remove small islands
- Remove selected island
- Split islands to segments
- Add selected island

A "Minimum size: 1000 voxels" input field and an "Apply" button are also present.

The Segmentation category and type dialog box is open, showing the "General Anatomy list". The "Category" dropdown is set to "Ventricle". The "Anatomical Structure" category is selected in the left pane. The "Brain ventricle" option is highlighted in the right pane with a red arrow. The "Name" field is set to "Ventricles", and the "Color" dropdown is set to blue. The "Select" button is circled in red.



Tumor and Ventricles Segmentation

The image shows the 3DSlicer software interface. On the left, the 'Color' panel has 'Cystic' selected, and a yellow callout box with an arrow points to the 'Show 3D' button, containing the text 'Click on Show 3D'. Below this is the 'Effects' panel with various segmentation tools like 'Paint', 'Draw', 'Erase', 'Level tracing', 'Grow from seeds', 'Fill between slices', 'Threshold', 'Margin', 'Hollow', 'Smoothing', 'Scissors', 'Islands', and 'Logical operators'. The 'Margin' section is expanded, showing 'Operation' set to 'Grow' and 'Margin size' set to '3.0mm'. On the right, a 'Layout' menu is open, listing various views. A yellow callout box with an arrow points to 'Conventional Widescreen', containing the text 'Select the Conventional Widescreen view from the layout menu'. The background shows a brain MRI slice with segmented regions in green, blue, and yellow.

Click on Show 3D

Select the Conventional Widescreen view from the layout menu



Tumor and Ventricles Segmentation

The screenshot displays the 3D Slicer software interface. The main 3D viewer shows a brain slice with a green tumor and yellow lateral ventricles. The left sidebar contains the 'Segmentation' module, with a 'Segmentations...' button highlighted. The bottom toolbar includes various effects like 'Paint', 'Draw', 'Erase', 'Level tracing', 'Grow from seeds', 'Fill between slices', 'Threshold', 'Margin', 'Hollow', 'Smoothing', 'Scissors', 'Islands', and 'Logical operators'. The right sidebar shows three orthogonal views (axial, sagittal, and coronal) of the brain slice, with a coordinate system (R, Y, G, A) and a scale bar (S: 56.141mm).

Modules: Segment Editor

3DSlicer

Help & Acknowledgement

Reload & Test

Reload Reload and Test Edit Restart Slicer

Segmentation: Segmentation

Master volume: BaselineVolume

+ Add - Remove Show 3D Segmentations...

Color	Name
Solid	
Cystic	
Ventricles	

Effects

None Paint Draw Erase Level tracing Grow from seeds

Fill between slices Threshold Margin Hollow Smoothing Scissors

Islands Logical operators

Undo Redo

Data Probe

The 3D viewer shows 3D surface models of the tumor and lateral ventricles

Click on Segmentations to access the Segmentation module

R

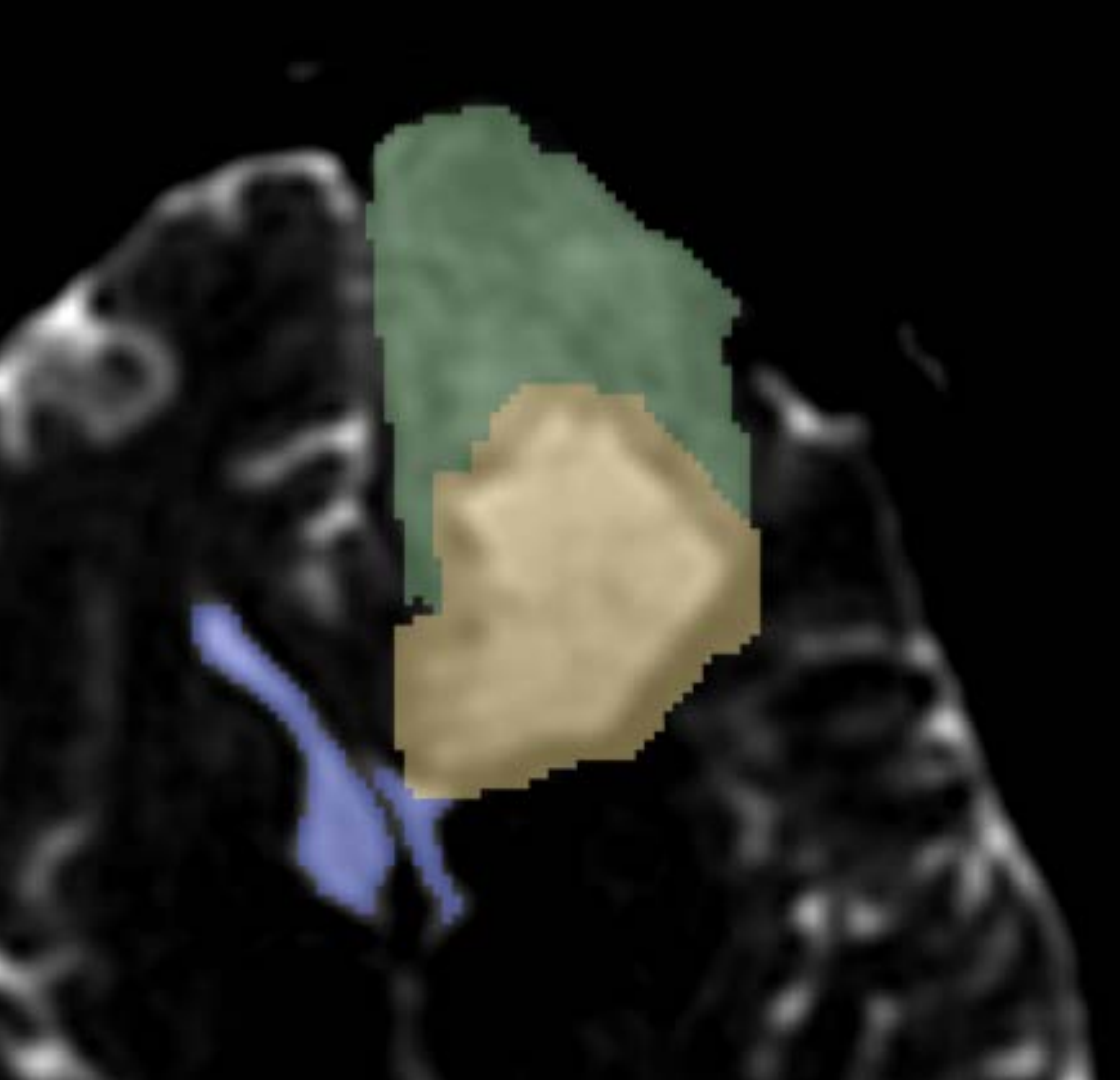
A

S: 56.141mm

Y R: -11.598mm

G A: 31.278mm

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Part 2: Peritumoral volume generation

Tumor and Ventricles Segmentation

Active segmentation: Segmentation
Source geometry: BaselineVolume

Color Opacity Name

Color	Opacity	Name
Solid	1.00	Solid
Cystic	1.00	Cystic
Ventricles	1.00	Ventricles

Overall visibility:

Slice fill: Visibility: 0.50 Opacity: 1.00

Slice outline: Visibility: 1.00 Opacity: 1.00

3D: Visibility: 1.00 Opacity: 1.00

Export/import models and labelmaps

Operation: Export Import

Output type: Labelmap Models

Output node: Export to new model hierarchy (selected), Export to new model hierarchy, Rename current ModelHierarchy, Delete current ModelHierarchy

Set the output node to Export to new model hierarchy

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Tumor and Ventricles Segmentation

3DSlicer

Active segmentation: Segmentation
Source geometry: BaselineVolume

+ Add segment - Remove selected Edit selected

Color	Opacity	Name
Green	1.00	Solid
Yellow	1.00	Cystic
Blue	1.00	Ventricles

Display

Overall visibility:

Visibility	Opacity
Slice fill: <input checked="" type="checkbox"/>	0.50
Slice outline: <input type="checkbox"/>	1.00
3D: <input checked="" type="checkbox"/>	1.00

Advanced

Representations

- Binary labelmap
- Closed surface Update Make master
- Fractional labelmap Create

Copy/move segments

Export/import models and labelmaps

Operation: Export Import

Output type: Labelmap Models

Output node: Segmentation-models

Advanced

Export

Click on Export

R P

S: 56.141mm

Y R: -11.598mm

G A: 31.278mm

A

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Tumor and Ventricles Segmentation

Modules: Models

Select the module Models

Click on the eye icon to turn off the visibility of the models Solid and Ventricles

3DSlicer

Include Fibers

Scroll to...

Scene

- Segmentation-models
- Solid 1.00
- Cystic 1.00
- Ventricles 1.00

Information

Display

Visibility

Visible:

View: All

Color: #f1d691

3D Display

Opacity: 1.00

Representation: Surface

Visible Sides: Front-facing

Clipping: Configure...

Advanced

Slice Display

Visible:

Opacity: 1.00

Mode: Intersection

Line Width: 1 px

Color Table:

Data Probe

R S: 56.141mm

Y R: -11.598mm

G A: 31.278mm

A

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Peritumoral volume generation

The screenshot displays the 3D Slicer software interface. The 'Segment Editor' module is selected in the top toolbar. The 'Segmentation' panel on the left shows the 'Cystic' segment selected. The 'Effects' panel shows the 'Margin' tool selected, with the 'Grow' operation chosen and a margin size of 3.0mm. The 'Margin' panel also shows the 'Grow' operation selected. The main 3D view shows a brain slice with a yellow segment and a blue segment. The right panel shows three axial slices of the brain with the yellow segment highlighted. The bottom right corner shows the coordinates: R: -11.598mm, A: 31.278mm, S: 56.141mm.

Modules: Segment Editor

Segmentation: Segmentation
Master volume: BaselineVolume

Color Name
Solid
Cystic
Ventricles

Effects
None Paint Draw Erase Level tracing Grow from seeds
Fill between slices Threshold Margin Hollow Smoothing Scissors
Islands Logical operators

Margin
Grow or shrink selected segment by specified margin size.
Operation: Shrink Grow
Margin size: 3.0mm 3x3x1 pixels
Apply
Undo Redo

Masking
Editable area: Everywhere
Data Probe

Select the module Segment Editor

Select the segment Cystic

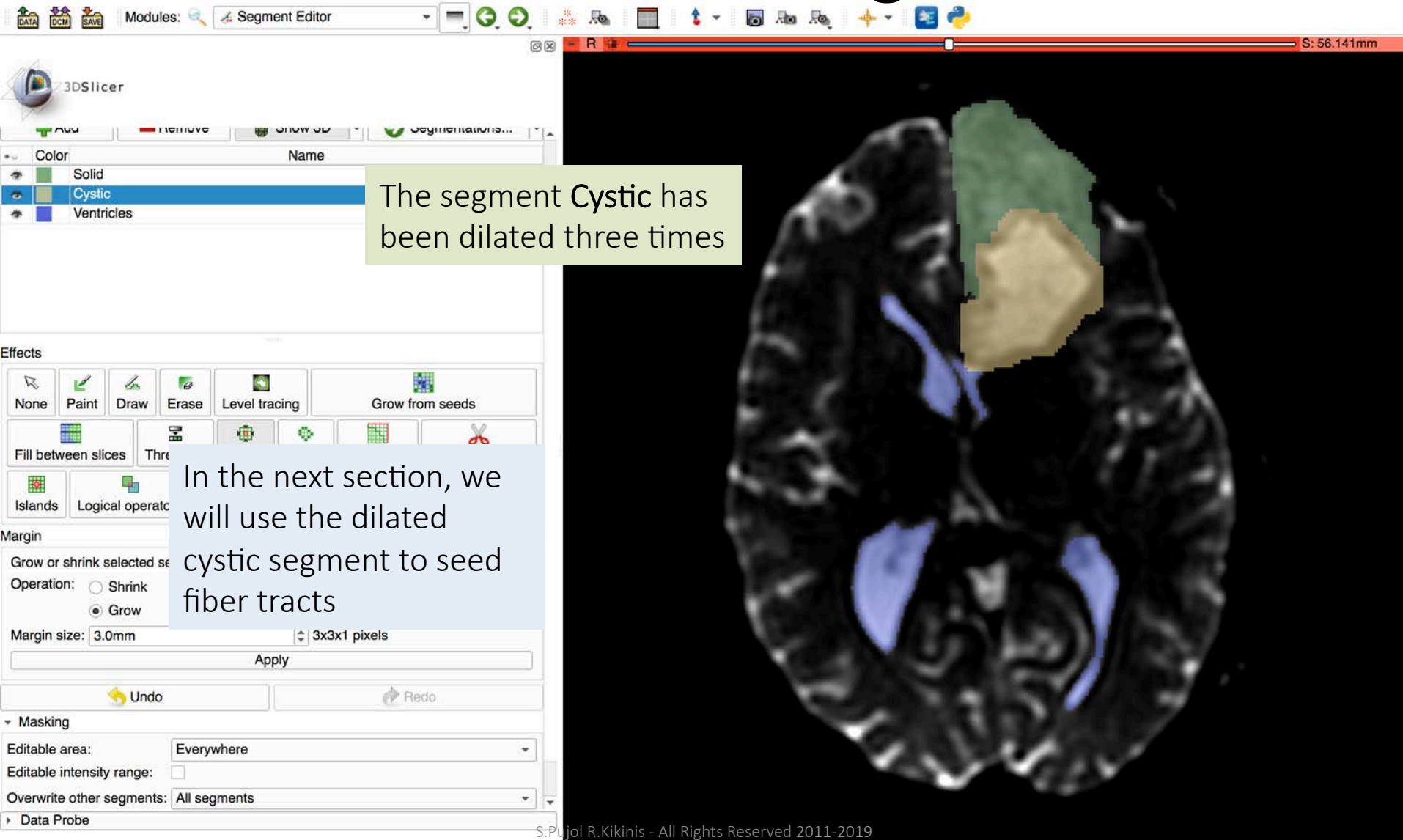
Select the tool Margin and the operation Grow
Click on Apply 3 times to dilate the segment Cystic

R S: 56.141mm
Y R: -11.598mm
G A: 31.278mm

A

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Peritumoral volume generation



The segment Cystic has been dilated three times

In the next section, we will use the dilated cystic segment to seed fiber tracts

Margin size: 3.0mm 3x3x1 pixels

Operation: Shrink Grow

Apply

Undo Redo

Masking

Editable area: Everywhere

Editable intensity range:

Overwrite other segments: All segments

Data Probe

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Peritumoral volume generation

3DSlicer

Modules: Segment Editor

Help & Acknowledgement

Reload & Test

Reload Reload and Test Edit Restart Slicer

Segmentation: Segmentation

Master volume: BaselineVolume

+ Add - Remove Show 3D Segmentations...

Color	Name
<input type="checkbox"/>	Solid
<input checked="" type="checkbox"/>	Cystic-Dilated
<input type="checkbox"/>	Ventricles

Effects

None Paint Draw Erase Level tracing Grow from seeds

Fill between slices Threshold Margin Hollow Smoothing Scissors

Data Probe: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml

Red (L 42.1, A 93.4, S 56.1) Axial Sp: 2.6

L None

F None

B BaselineVolume (172, 60, 24) 1083

R S: 56.141mm

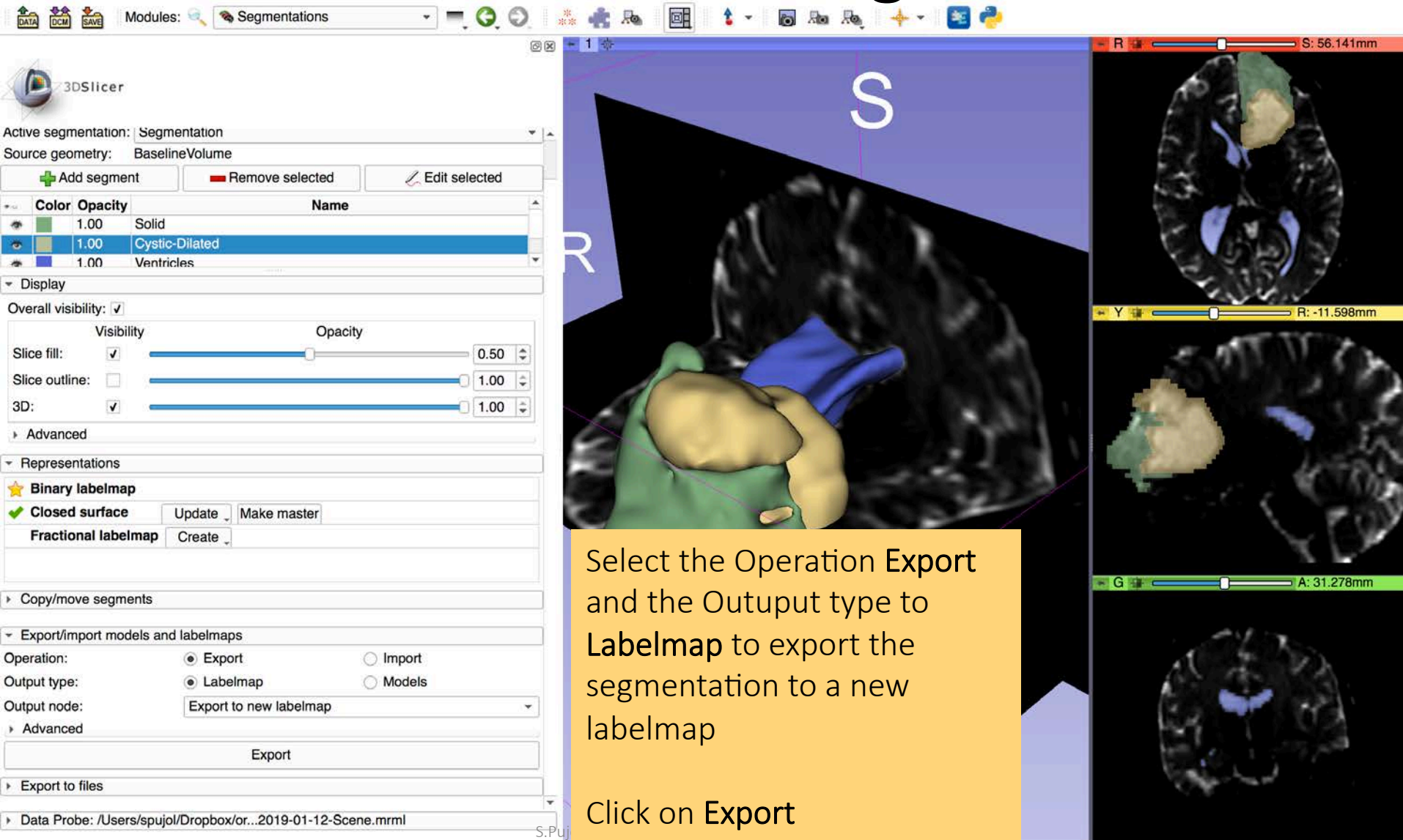
Y R: -11.598mm

G A: 31.278mm

Rename the segment Cystic 'Cystic-Dilated' and click on Segmentations to access the Segmentations module

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Peritumoral volume generation



The screenshot displays the 3D Slicer software interface. The main 3D view shows a brain scan with a segmented tumor (yellow) and ventricles (blue). The left sidebar contains the 'Segmentation' panel, which is currently active. The 'Active segmentation' is 'Segmentation', and the 'Source geometry' is 'BaselineVolume'. The 'Color' table shows the following settings:

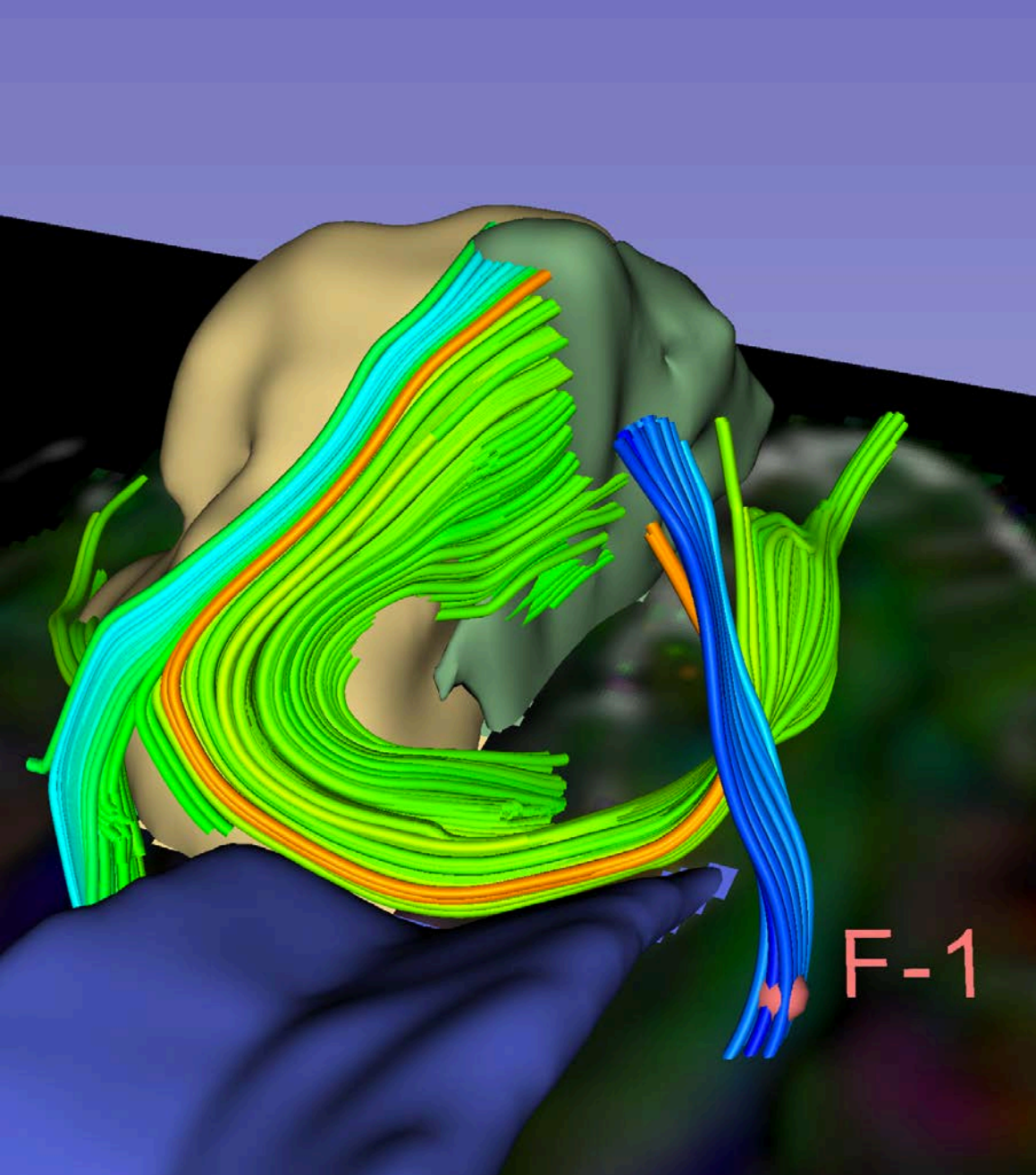
Color	Opacity	Name
Green	1.00	Solid
Yellow	1.00	Cystic-Dilated
Blue	1.00	Ventricles

The 'Display' section shows 'Overall visibility' checked. The 'Slice fill' checkbox is checked with an opacity of 0.50. The 'Slice outline' checkbox is unchecked with an opacity of 1.00. The '3D' checkbox is checked with an opacity of 1.00. The 'Representations' section shows 'Binary labelmap' selected, 'Closed surface' checked, and 'Fractional labelmap' unchecked. The 'Operation' section shows 'Export' selected, 'Output type' set to 'Labelmap', and 'Output node' set to 'Export to new labelmap'. The 'Export' button is visible at the bottom of the 'Export/import models and labelmaps' section.

On the right, three orthogonal views (axial, sagittal, and coronal) show the segmented tumor and ventricles overlaid on the brain scan. The axial view shows the tumor and ventricles in a cross-section. The sagittal view shows the tumor and ventricles in a side view. The coronal view shows the tumor and ventricles in a front view. The coordinates for each view are: Axial (R: -11.598mm), Sagittal (S: 56.141mm), and Coronal (G: 31.278mm).

Select the Operation Export and the Output type to Labelmap to export the segmentation to a new labelmap

Click on Export



Part 3: Fiber Tracking in peritumoral area

Tractography Seeding

The image shows the 3DSlicer software interface. On the left, the 'Modules' menu is open, showing a tree view of modules. The 'Diffusion' module is selected, and its sub-menu is open, showing 'Tractography' and 'Tractography Seeding' highlighted. A yellow callout box on the right contains the text: 'Select the module Tractography Seeding from the Diffusion Tractography section'. The main window displays a brain scan with a 3D model of a brain region. The top right corner shows the coordinate system: R: 56.141mm, Y: -11.598mm, S: 56.141mm. The bottom left corner shows the 'Data Probe' path: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml.

3DSlicer

Modules:

- Data
- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Markups
- Models
- Scene Views
- Segment Editor
- Segmentations
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer
- Wizards
- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion
- Filtering
- Surface Models
- Converters
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- Testing
- MultiVolume Support

Diffusion

- Import and Export
- Process
- Quantify
- Tractography
- Utilities
- Region-based

Tractography

- Tractography Display
- Tractography Seeding
- Region-based

Tractography Seeding

Select the module Tractography Seeding from the Diffusion Tractography section

R: 56.141mm

Y: -11.598mm

S: 56.141mm

✓ Show transforms Show MRML ID's

Subject hierarchy item information

Filter:

MRML node information

Data Probe: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml

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Tractography Seeding

Select the Input DTI volume DTIVolume
Set the Output Fiber Bundle to Create New Fiber Bundle As
and name it Peritumoral_Fibers
Set the Input Label Map to Segmentation-label

Set the Fractional Anisotropy Threshold to 0.15

Click on Update to generate the tracts

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Tractography Seeding

3DSlicer

Modules: Tractography Seeding

Slicer generates the peritumoral fibers

Help & Acknowledgement

Parameters Node

IO

Input DTI Volume DTIVolume

Output Fiber Bundle Peritumoral_Fibers

Seeding

Input Fiducials, Model or Label Map Segmentation-label

Seeding Label Value 1

Seed Spacing (mm) 2.00

Use Index Space

Random Grid

Update

Tractography Parameters

Threshold Type Fractional Anisotropy

Seeding Threshold 0.15

Stopping Threshold 0.25

Integration Step Length (mm) 0.500mm

Advanced Options

R S

R: -11.598mm

Y

G A: 14.278mm

The fibers are color-coded according to Fractional Anisotropy (FA) values (red = low FA, blue = high FA)

Data Probe: /Users/spujol/Dropbox/or...2019-

Interactive Tractography

Click on the Arrow to position a fiducial near the tumor

In the IO section, set the Output Fiber Bundle to Create New Fiber Bundle As and name it New_FiberBundle
In the Seeding section, set the Fiducials to F

Check the box next to Update to turn on the interactive mode

3DSlicer

Modules: Tractography Seeding

Input DTI Volume DTIVolume

Output Fiber Bundle newFiberBundle_Segmentation-label

Seeding

Input Fiducials, Model or Label Map F

Fiducial Region Size (mm) 2.50

Fiducial Seeding Step Size 1.00

Max Number of Seeds 100

Seed Selected Fiducials Only

Update (check for interactive)

Tractography Parameters

Threshold Type Fractional Anisotropy

Seeding Th...

Stopping Th...

Integration Step Leng...

Advanced Options

Data Probe: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml

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Interactive Tractography

Set the DTI volume in Foreground and fade between Background and Foreground

3DSlicer

Modules: Tractography Seeding

Input DTI Volume: DTIVolume

Output Fiber Bundle: newFiberBundle

Seeding

Input Fiducials, Model or Label Map: F

Fiducial Region Size (mm): 2.50

Fiducial Seeding Step Size: 1.00

Max Number of Seeds: 100

Seed Selected Fiducials Only:

Update (check for interactive)

Tractography Parameters

Threshold Type: Fractional Anisotropy

Seeding Threshold: 0.15

Stopping Threshold: 0.25

Integration Step Length (mm): 0.500mm

Advanced Options

Data Probe: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml

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Interactive Tractography

3DSlicer

Modules: Tractography Seeding

Help & Acknowledgement

Parameters Node

IO

Input DTI Volume DTIVolume

Output Fiber Bundle newFiberBundle

Seeding

Input Fiducials, Model or Label Map F

Fiducial Region Size (mm) 2.50

Fiducial Seeding Step Size 1.00

Max Number of Seeds 100

Seed Selected Fiducials Only

Update (check for interactive)

Tractography Parameters

Threshold Type Fractional Anisotropy

Seeding Threshold 0.15

Stopping Threshold 0.25

Integration Step Length (mm) 0.500mm

Advanced Options

Data Probe: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml

Move the fiducial F1 in the 3D scene to display the tracts in the ipsilateral and contralateral side

R S: 71.741mm

Axial

Segmentation All

Segmentation-label

DTIVolume

BaselineVolume

Y R: -11.598mm

G A: 14.278mm

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Interactive Tractography

Modules: Tractography Display

3DSlicer

Help & Acknowledgement

Simple Display

Solid Tube Color

Name	Lines	Tub	Tubes	Slice	Glyphs	Tubes
Peritumoral_Fibers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
newFiberBundle	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Percentage of Fibers Shown 100%

Fiber Bundle Selection

Advanced Display

S: 61.341mm

R: -11.598mm

A: 14.278mm

F-1

Data Probe: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml

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Select the module Tractography Display

Turn the Peritumoral_Fibers and newFiberBundle visibility mode to Tubes

Move the fiducial in the 3D scene to explore the white matter architecture on the contralateral side

Summary

- **3D Slicer** enables interactive exploration of white matter fibers in the vicinity of a tumor:
 - The **Segment Editor** module provides tools for building 3D models of the tumoral region
 - The **SlicerDMRI solution** enables 3D interactive reconstruction of white matter fibers in the peripheral region

Acknowledgments

- Neuroimage Analysis Center (NIH P41 EB015902)