Slicer SALT

Shape AnaLysis Toolbox

Shape analysis via skeletal models

User Tutorial

Zhiyuan Liu, Stephen M. Pizer, Beatriz Paniagua, Jared Vicory, Junpyo Hong

August 2018

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Kitware

Skeletal representations

Shape Analysis allows studying morphology in populations of anatomic structures. A **skeletal representation (s-rep) is** used to model the structure of a non-branching object, providing a rich geometric representation with correspondence across cases.

The S-rep Extension (short for **Skeletal Representation Extension**) in SlicerSALT provides utilities to visualize, establish and refine s-reps of 3-dimensional objects.

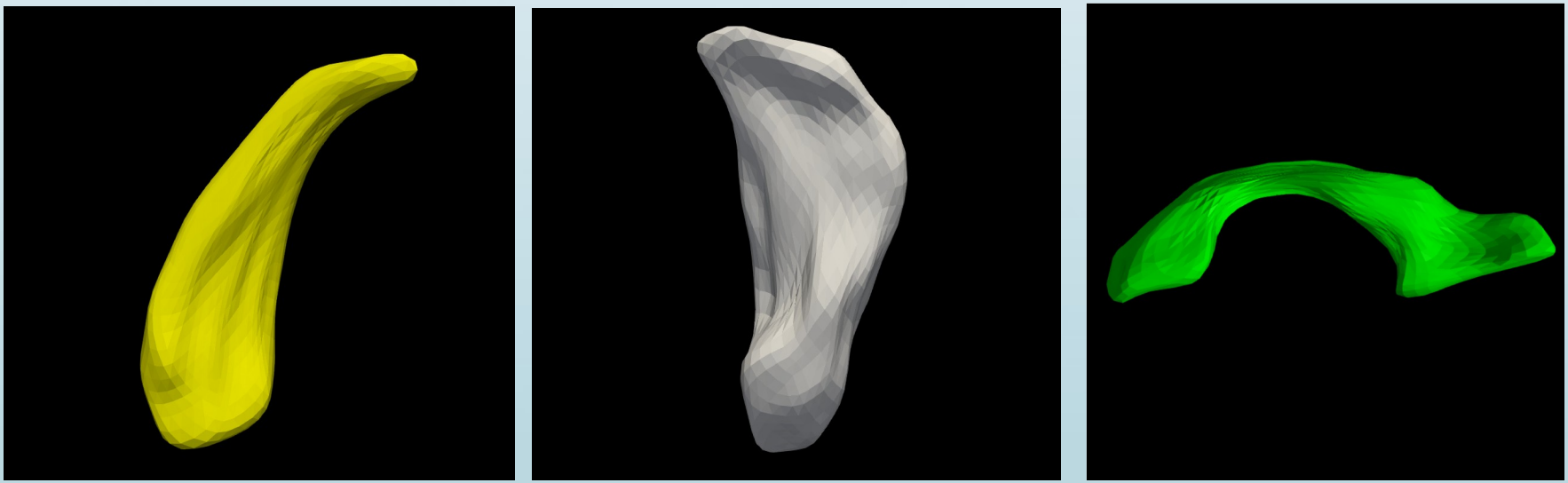


Figure: Some examples have been researched via s-rep
Left: caudate nucleus Middle: hippocampus Right: cerebral ventricle

The Slabular S-rep

A 3D object whose length is notably larger than its width which is notably larger than its thickness is suitable for modeling by a slabular s-rep

A slabular s-rep (from now on just referred to as an s-rep) consists first of a folded, two-sided quasi-medial sheet inside the object. This sheet is called the “skeletal sheet”. It is sampled into a network of skeletal positions

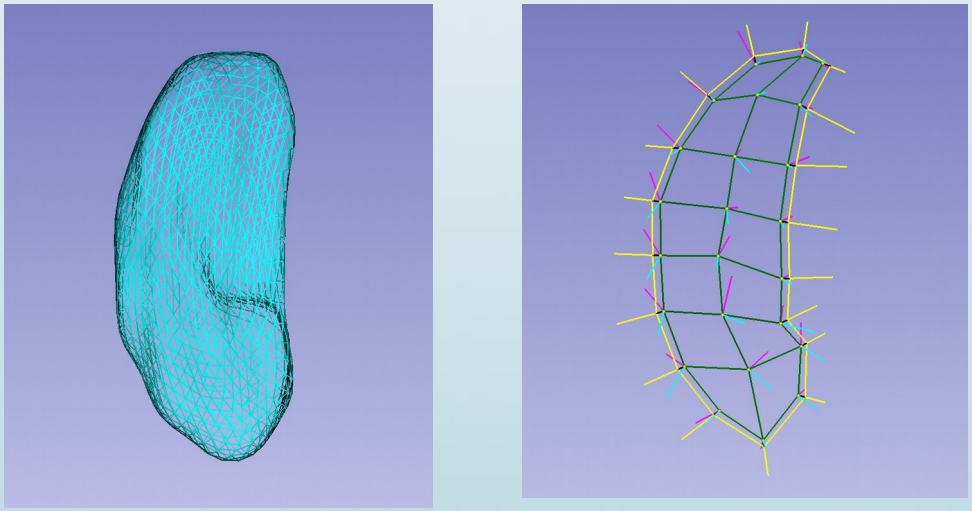


Figure: A skeletal model for a hippocampus. Left: the surface mesh of hippocampus. Right: the skeletal sheet of the s-rep of this hippocampus

Special skeletal samples are at positions where the sheet folds back onto itself

Slicer SALT
Shape Analysis Toolbox

The Slabular S-rep (2)

From each sample point on the skeleton, a vector to and approximately orthogonal to the boundary is provided as part of the s-rep. These vectors are called “spokes”.

The spokes emanating from the fold curve of the sheet meet the object surface at crest points.

The spokes can be interpolated into a finer mesh, and the spoke endpoints can be interpolated into a implied boundary for the object.

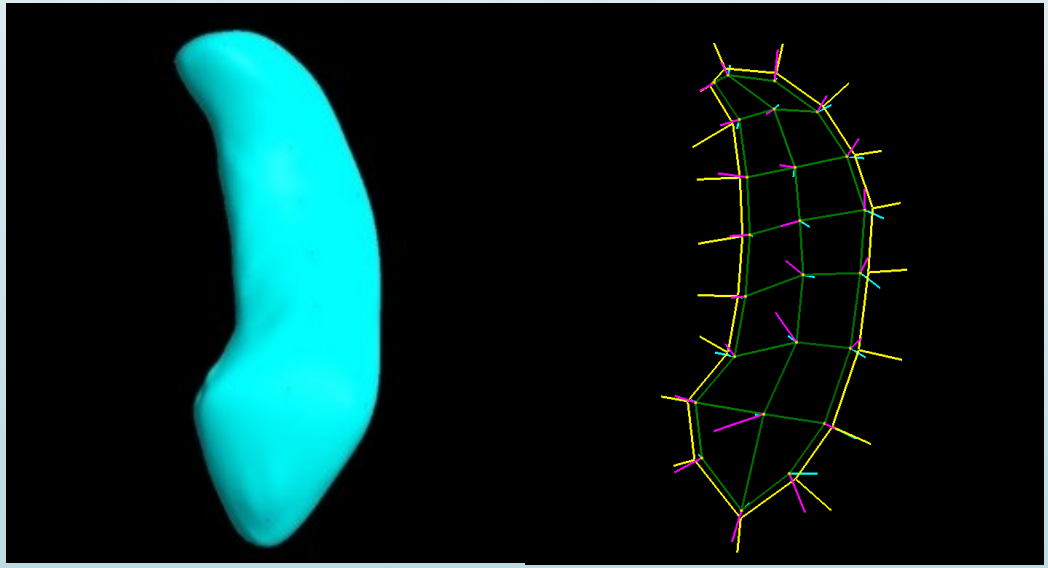


Figure: A skeletal model for a hippocampus.
Left: implied boundary of hippocampus.
Right: the s-rep of hippocampus

Slicer SALT
Shape Analysis Toolbox

Modules in S-rep Extension

Module 1: Establish an s-rep by mean curvature flow of an object boundary

Module 2: Refine an s-rep to fit an object boundary

Module 3: Visualize an s-rep

Slicer SALT
Shape Analysis Toolbox

Description of S-rep Extension

This extension consists of the following detailed steps:

Input: Surface Mesh
Step 1 (a) : Flow surface mesh into quasi-ellipsoidal surface
Outputs: quasi-ellipsoidal surface & the best fitting ellipsoid

Input: Surface Mesh
Step 1 (b) : Reverse the flow to derive s-rep of the original object
Output: the s-rep of input object

Inputs: Surface Mesh + initial s-rep
Step 2 : Refine the input s-rep to be better fit
Output: Optimized s-rep

Input: an s-rep
Step 3 : Visualize the details of the s-rep
This tutorial focuses on this part of the extension.

Slicer SALT
Shape Analysis Toolbox

Inputs of the S-rep Extension

The input describes an object as either a label image, a tile mesh of the object surface, or a signed distance image of distances to the object boundary, where negative distances are interior to the object, positive distances are exterior to the object, and the object boundary is the zero level set.

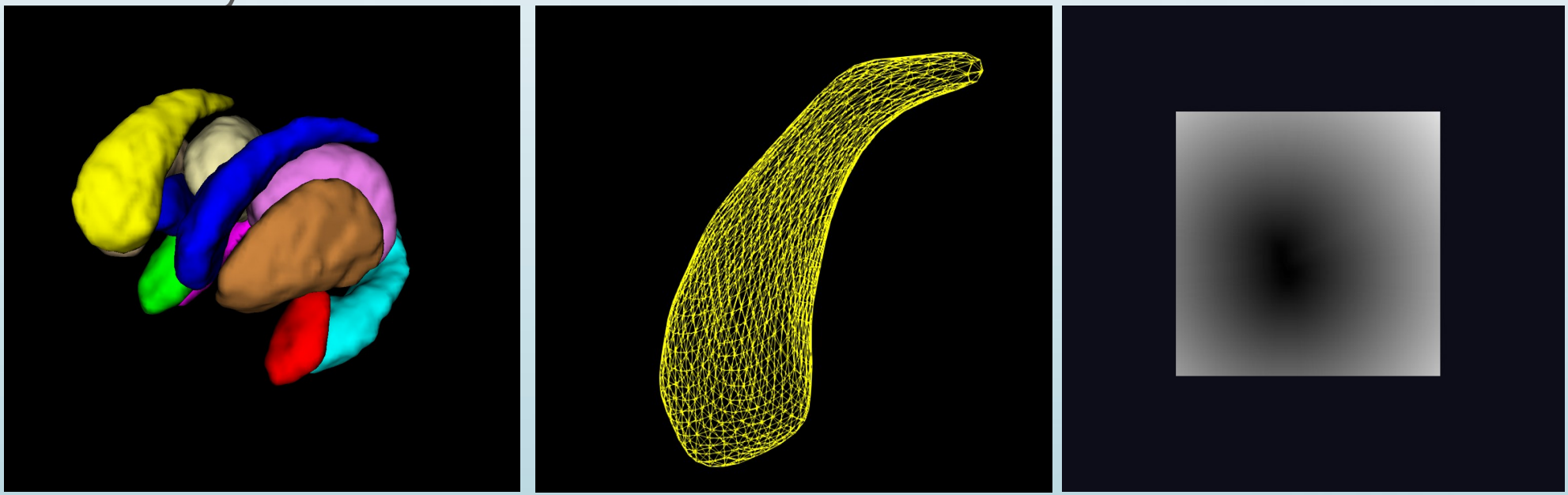


Figure: Different input image types:
Left: 3D model of a label image for multiple objects.
Middle: Surface mesh of a caudate nucleus
Right: one slice of signed distance image

Slicer SALT
Shape Analysis Toolbox

Output of the S-rep Extension

The output is an s-rep object model that captures both boundary shape and object width.

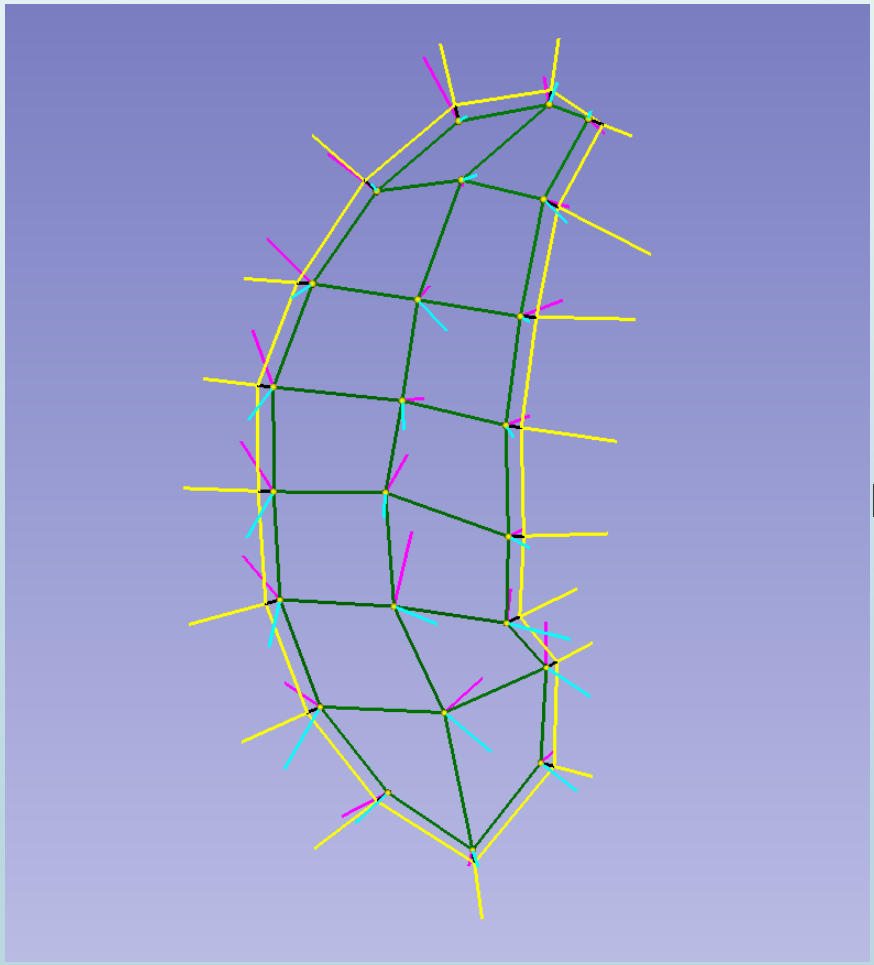


Figure: an example of output

Slicer SALT
Shape Analysis Toolbox

Installation of the S-rep Extension

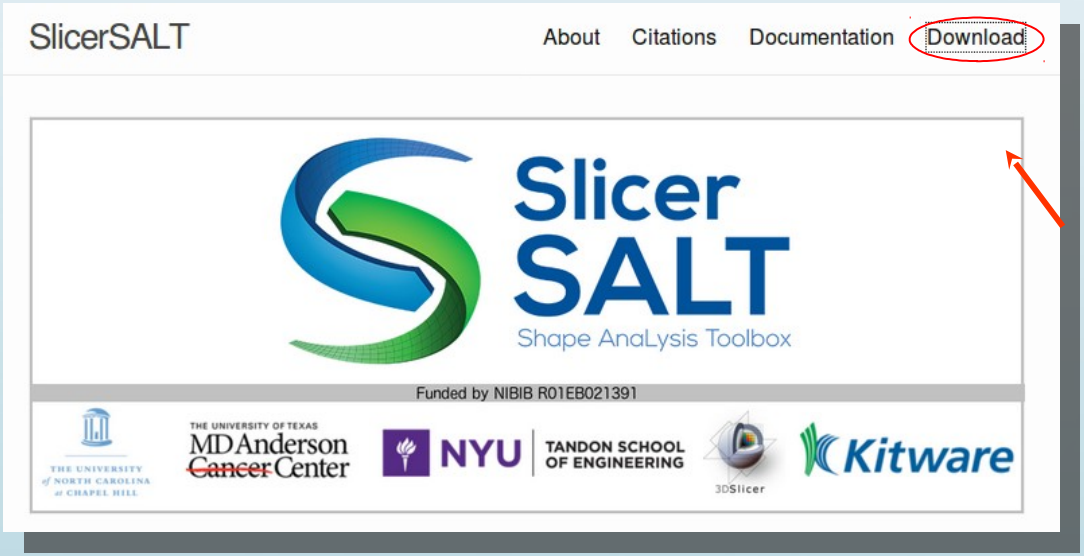
The S-rep Extension can be used with two open-source software platforms:

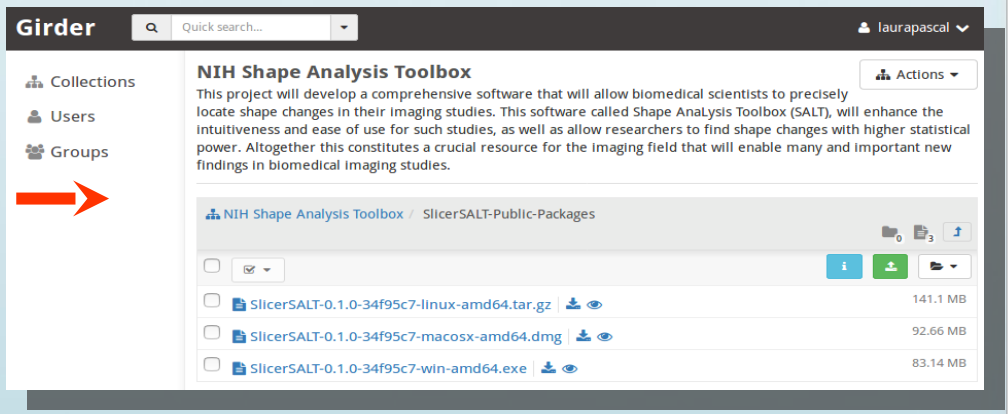
- **SlicerSALT**: which is the dissemination vehicle of powerful shape analysis methodology. This software is a light-weight, customized version of 3D Slicer. It contains the S-rep extension as modules

- **3D Slicer**: which is an open-source and free software platform for medical image informatics, image processing, and three-dimensional visualization. "SkeletalRepresentation" can be downloaded as an extension

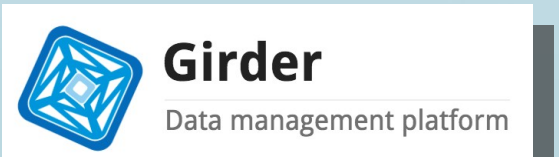
S-rep Extension Installation through SlicerSALT

Download the SlicerSALT packages for your respective operating system from the SlicerSALT website and install it. *SkeletalRepresentation* will be ready to use when





Powered by Girder



Slicer SALT
Shape AnaLysis Toolbox

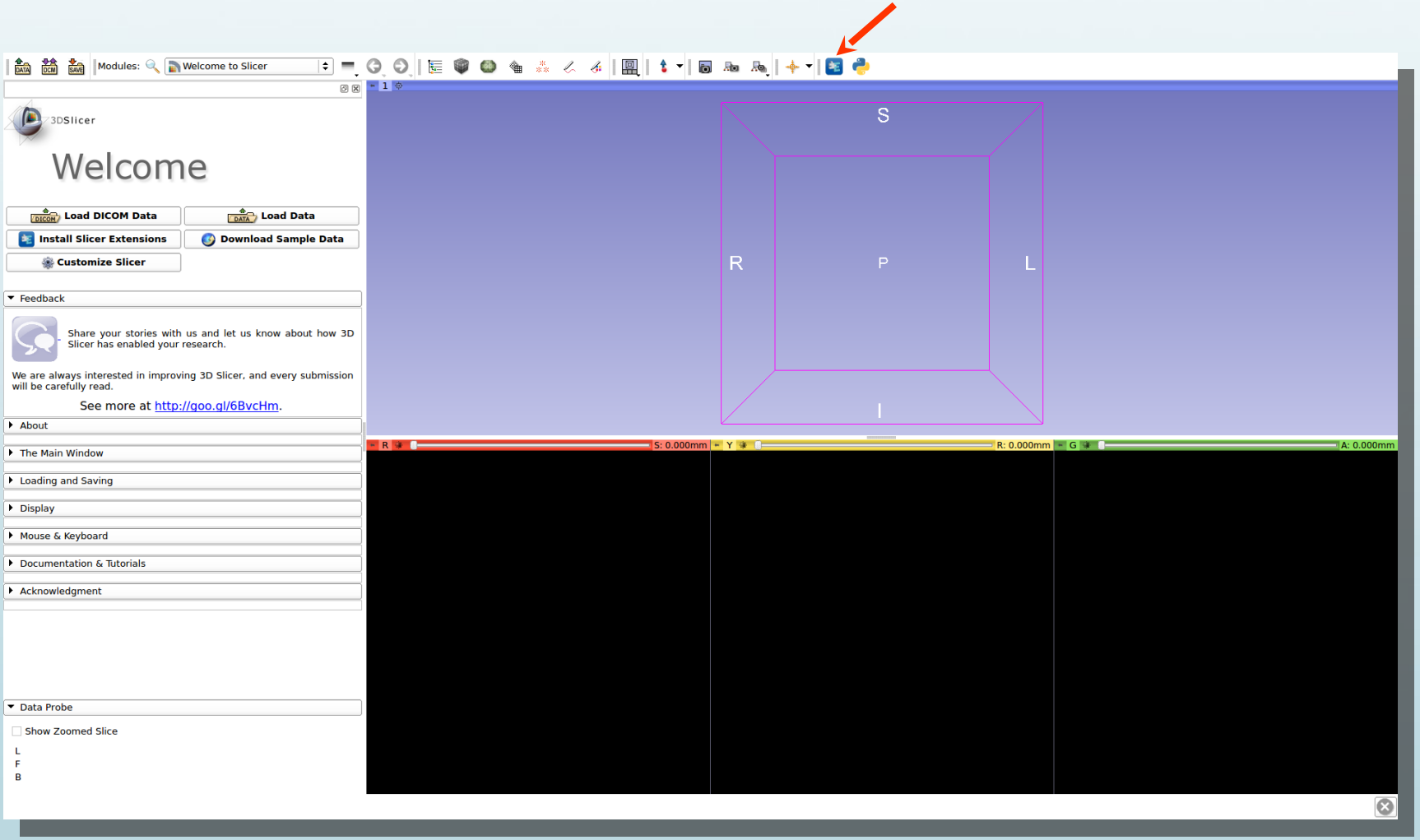
S-rep Extension Installation on 3D Slicer

1. Download 3D Slicer packages for your respective operating system on the 3D Slicer website and install it

Slicer SALT

S-rep Extension Installation on 3D Slicer

2. In 3D Slicer, open the Extension Manager



S-rep Extension Installation on 3D Slicer

3. In the *Install Extension* tab, select ***Shape Analysis*** under *Categories*
4. Under **SkeletalRepresentation**, select the *Install* button and restart Slicer when prompted

Slicer SALT
Shape AnaLysis Toolbox

Feature 1: Visualization of s-rep

This tutorial is about features that

- Visualize an s-rep as a whole
- Toggle different parts of an s-rep

Start 3DSlicer

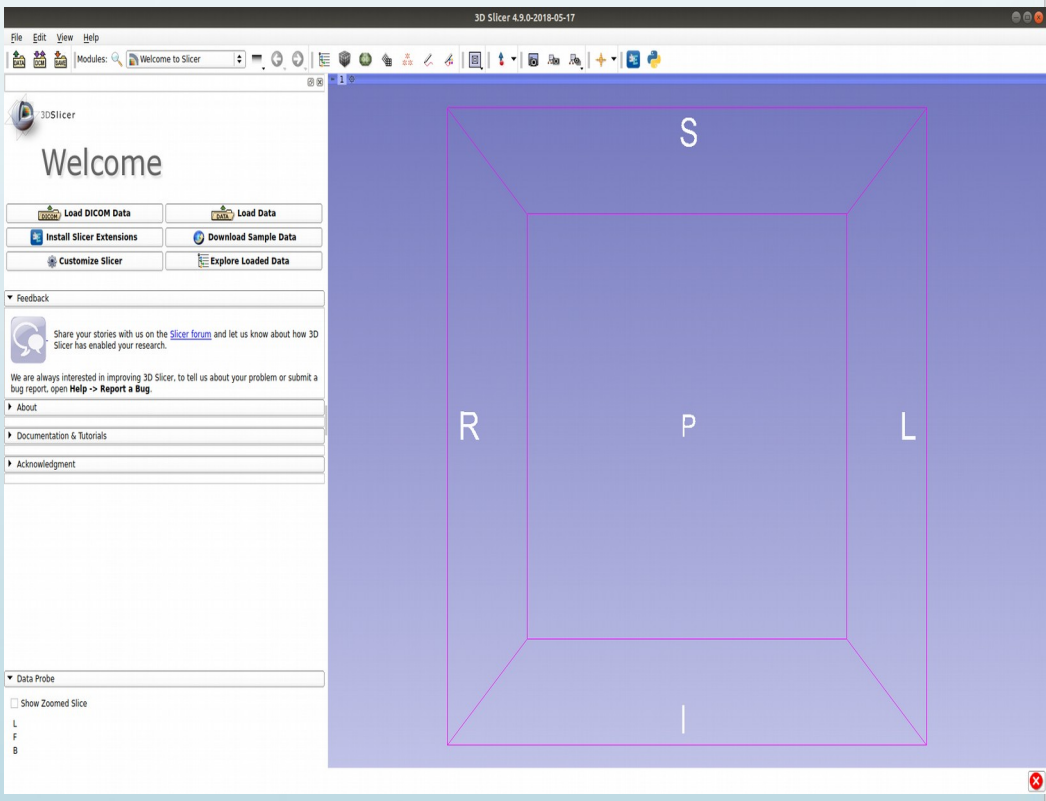


Figure: Welcome module of Slicer

Slicer SALT
Shape AnaLysis Toolbox

How to visualize an s-rep

Steps:

1. Set the module path in Slicer:
   Edit->Application Settings ->Modules

Add the position of module scripts. Then restart Slicer.

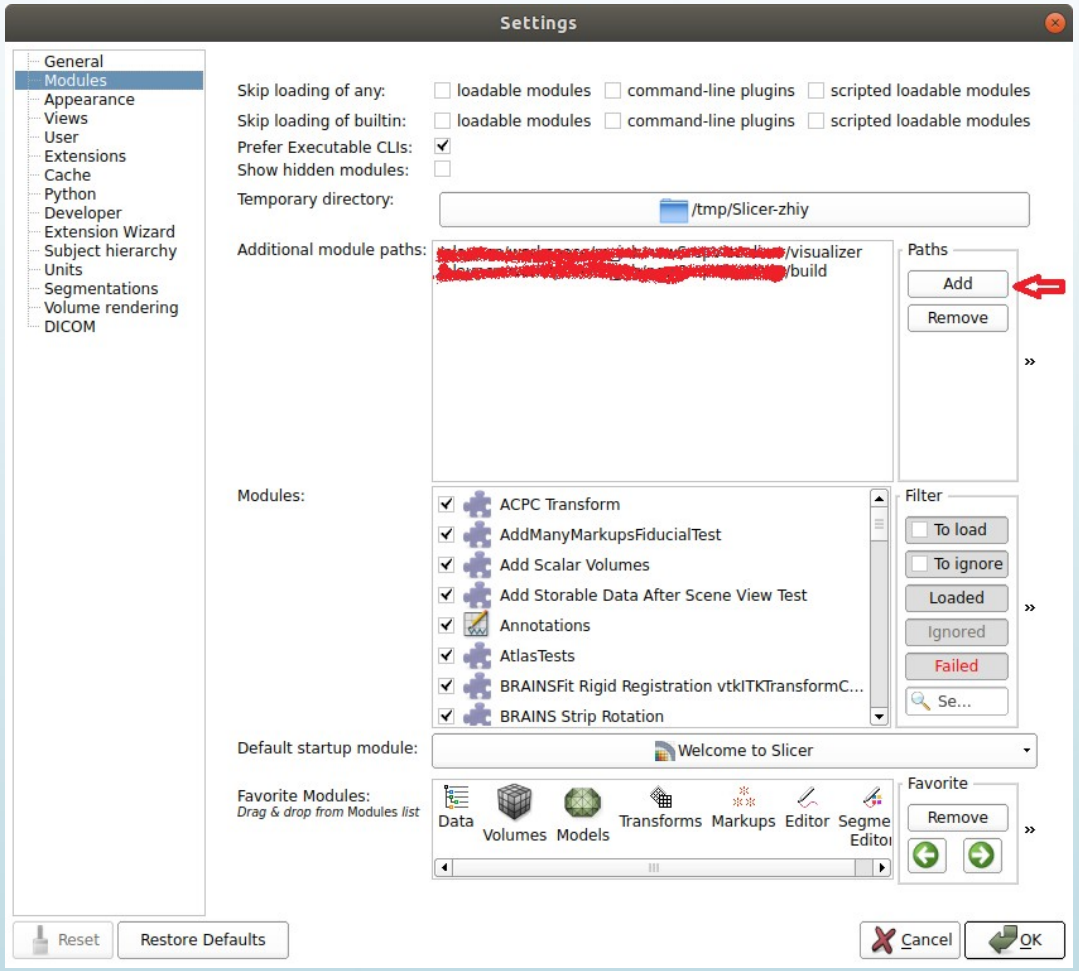


Figure: Set module path

How to visualize an s-rep

Steps :

2. Load the *Skeletal Representation Visualizer* module in Slicer

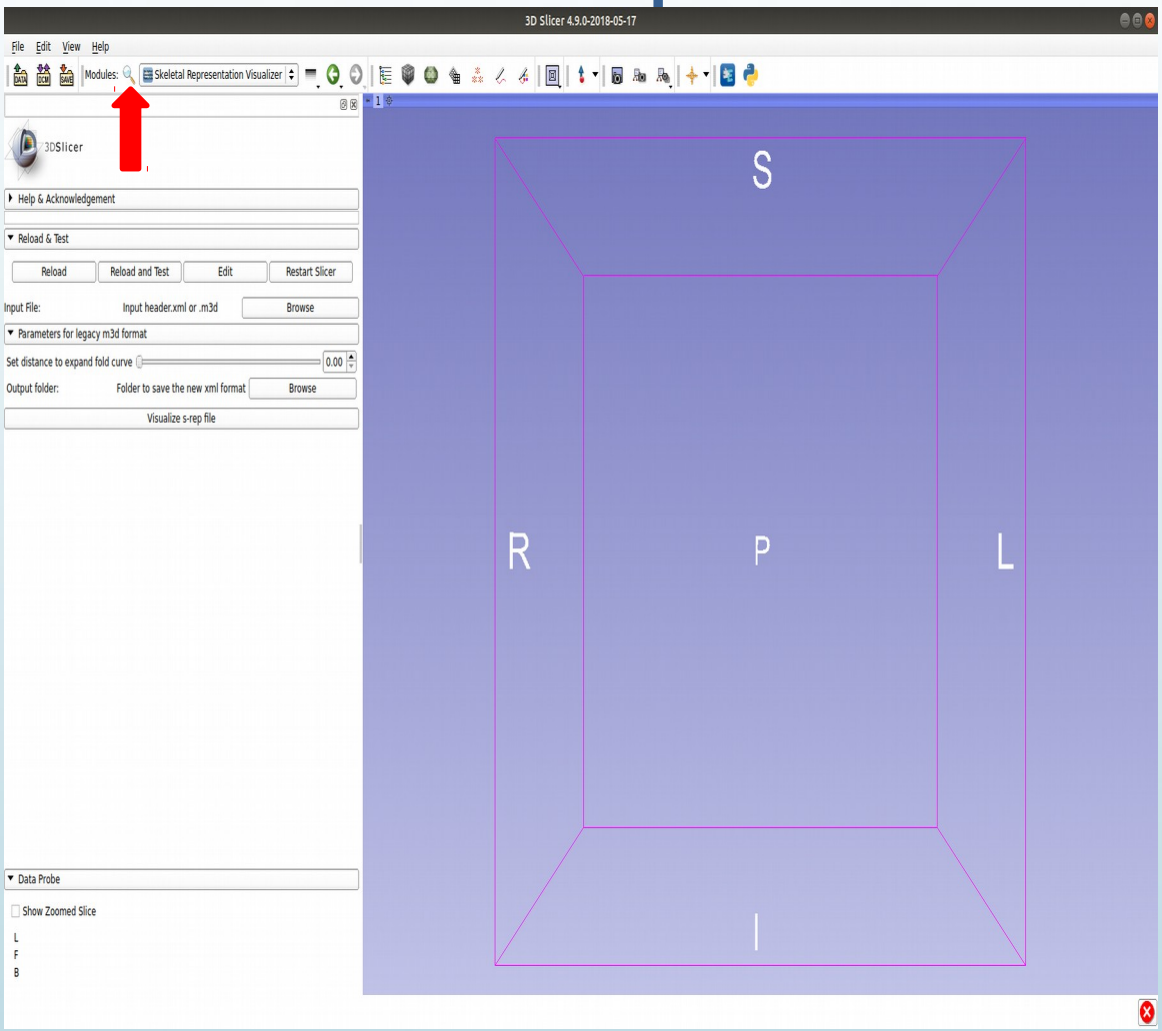


Figure: Use the magnifier to search and load *visualizer* module

Slicer SALT
Shape Analysis Toolbox

How to visualize an s-rep

Steps :

3. Select an s-rep file.

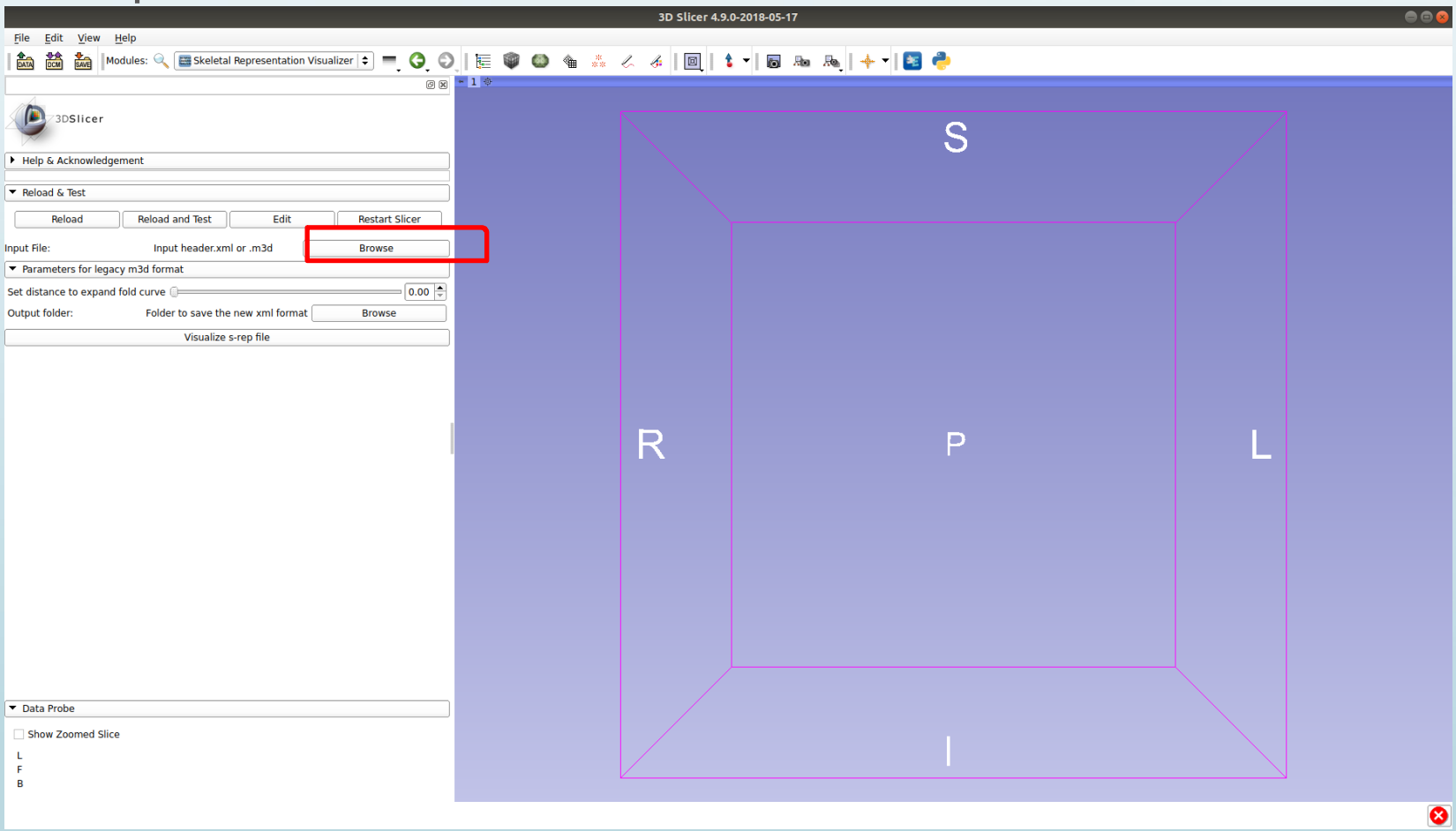


Figure: Click this button to select s-rep file

How to visualize an s-rep

Steps :

4. Select a header file for an s-rep. In Slicer-SALT, the s-rep would be rendered in 3D window.

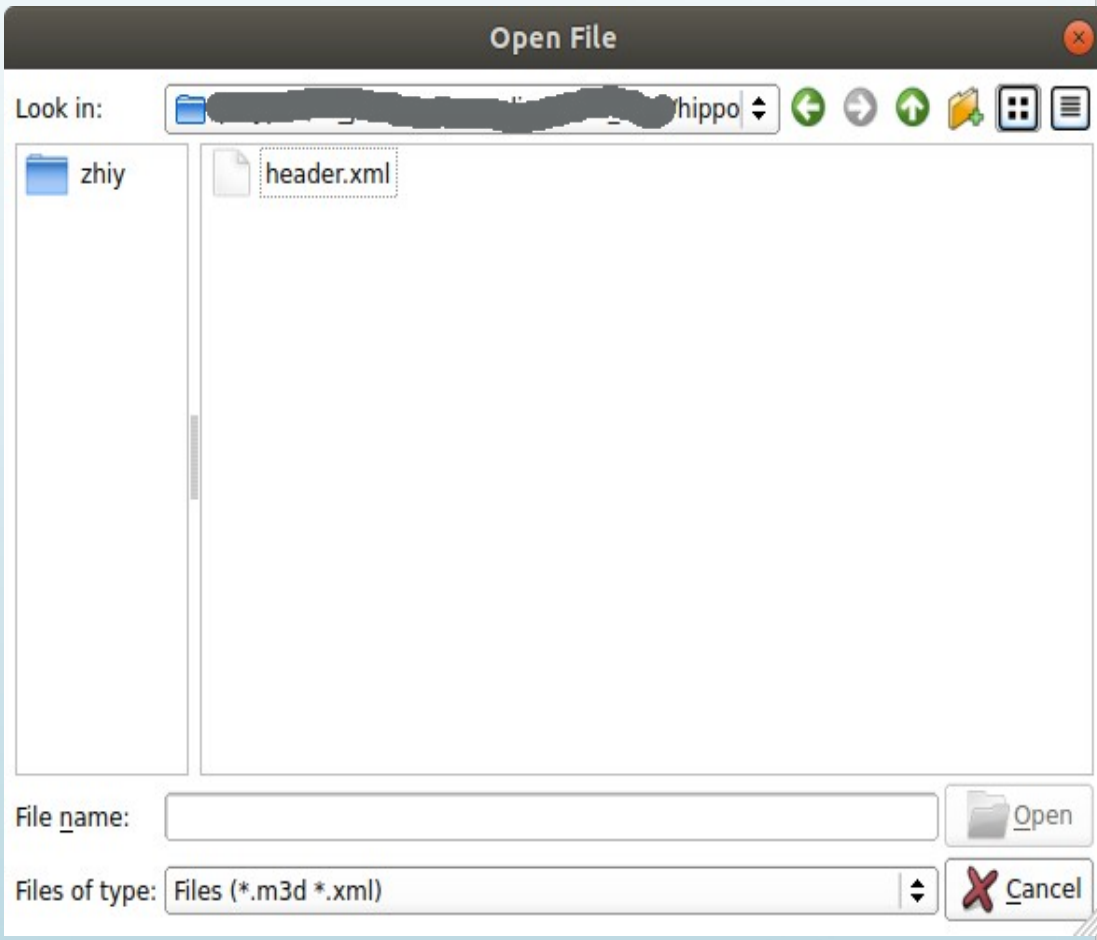


Figure: Select a new s-rep

The header file is an xml file that stores general information of the s-rep, such as the dimension of the s-rep and the location of other related files. It looks like following:

```
<?xml version="1.0" ?>
<s-rep>
  <nRows>3</nRows>
  <nCols>8</nCols>
  <meshType>Quad</meshType>
  <color>
    <red>0</red>
    <green>0.5</green>
    <blue>0</blue>
  </color>
  <isMean>False</isMean>
  <meanStatPath/>
  <upSpoke>/home/up.vtp</upSpoke>
  <downSpoke>/home/down.vtp</downSpoke>
  <crestSpoke>/home/crest.vtp</crestSpoke>
</s-rep>
```

Slicer SALT
Shape Analysis Toolbox

How to visualize an s-rep

Steps :

5. Click *Visualize s-rep file*. Center and zoom in to view s-rep in 3D window.

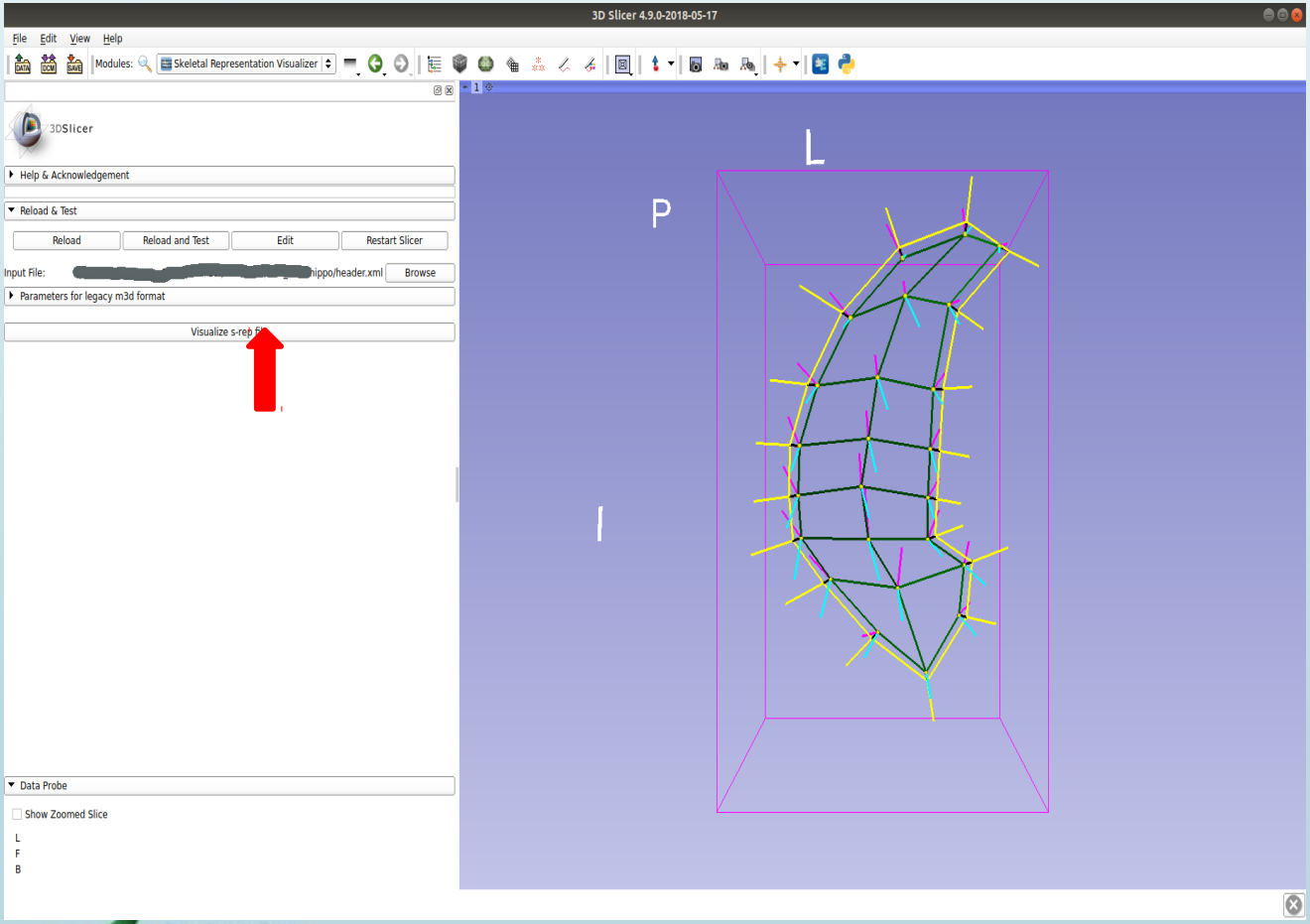


Figure: View the s-rep

How to visualize an s-rep

Steps :

6. Select the s-rep part(s) to display in the *Data* tree.

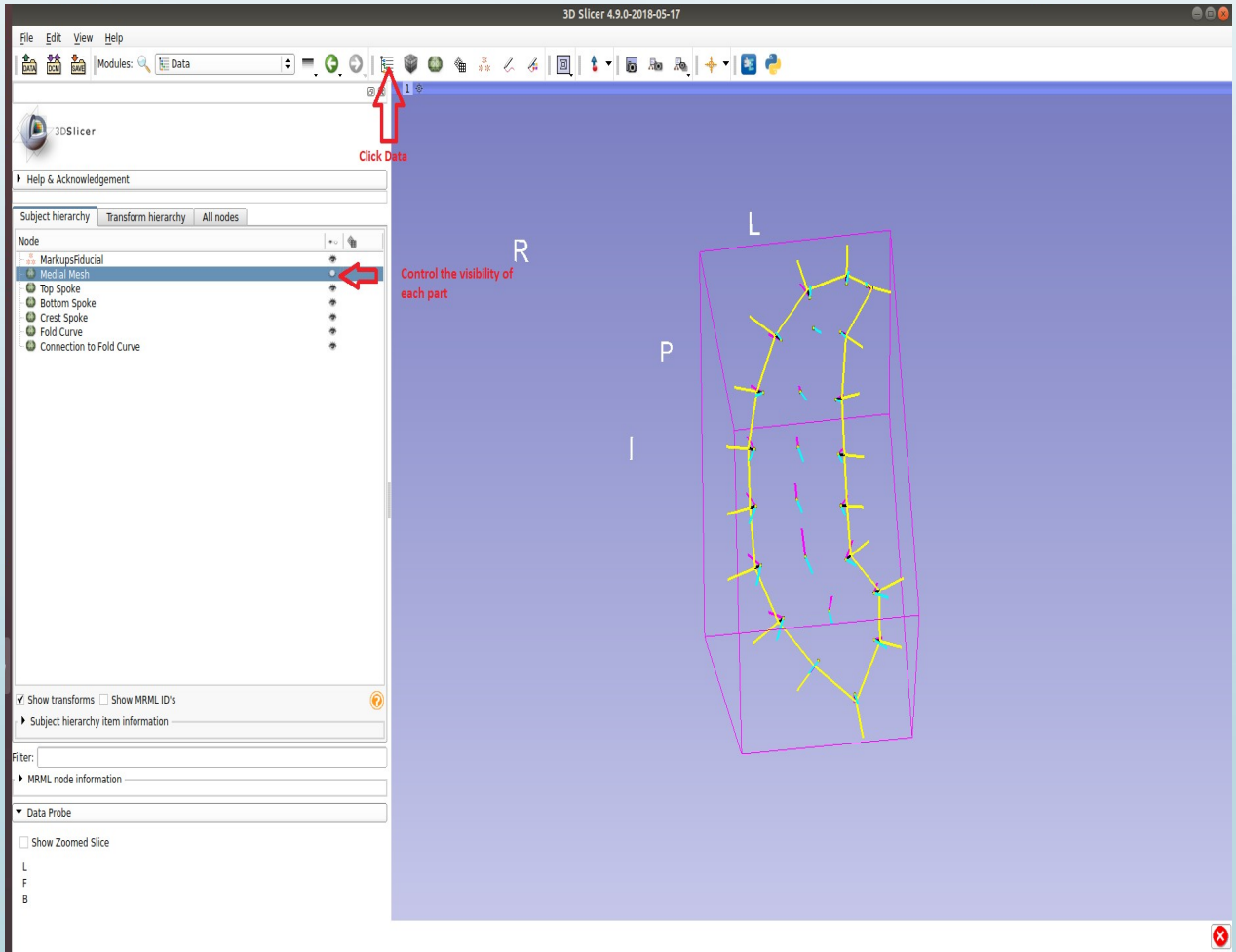


Figure: Illustration of how to toggle visibility of skeletal mesh in data tree

How to visualize an s-rep

Steps :

6. Select the s-rep part(s) to display in the *Data* tree.

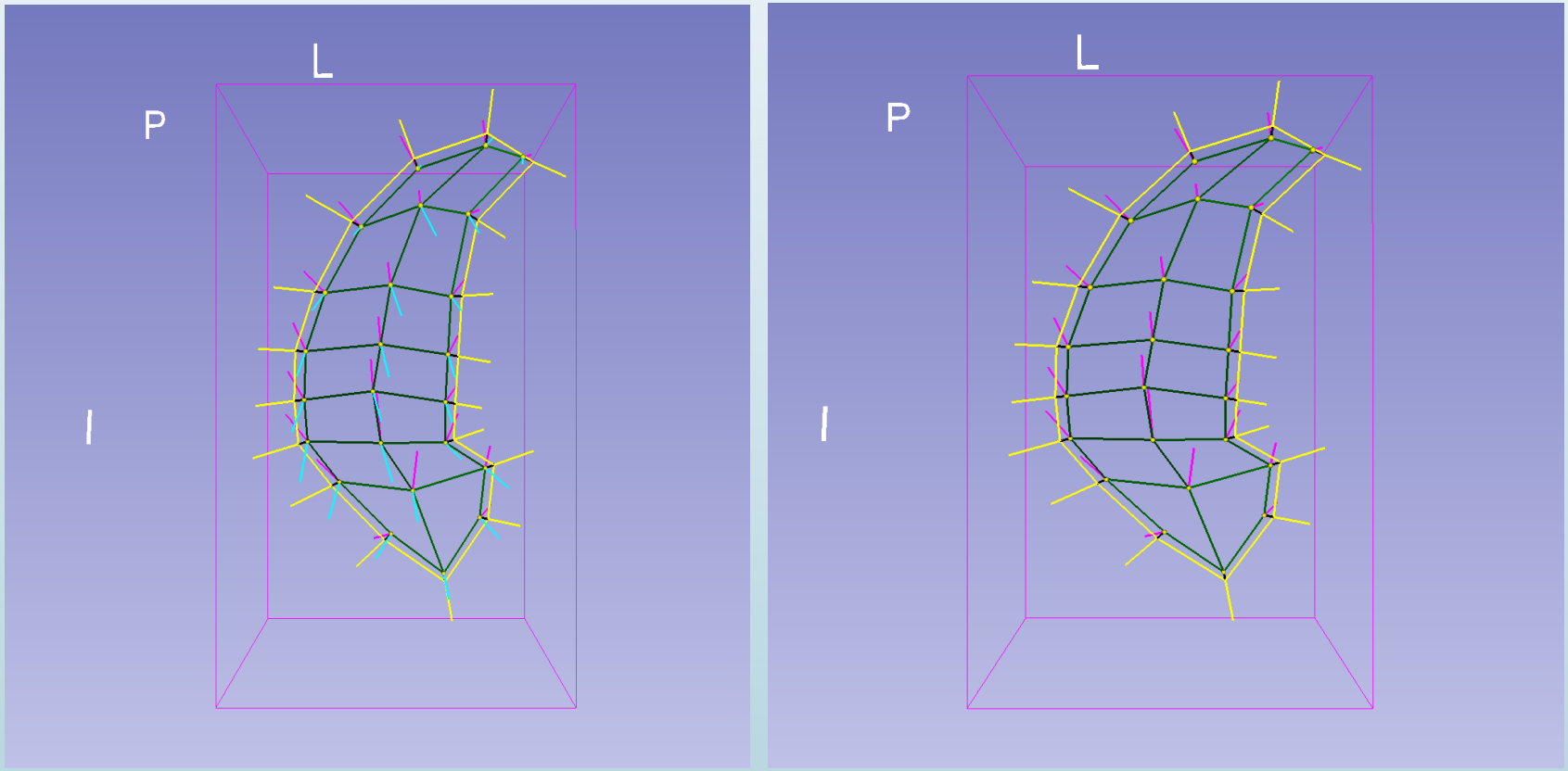


Figure: Toggle visibility of bottom spokes. Left: original s-rep. Right: hide bottom spokes

How to visualize an s-rep

Steps :

6. Select the s-rep part(s) to display in the *Data* tree.

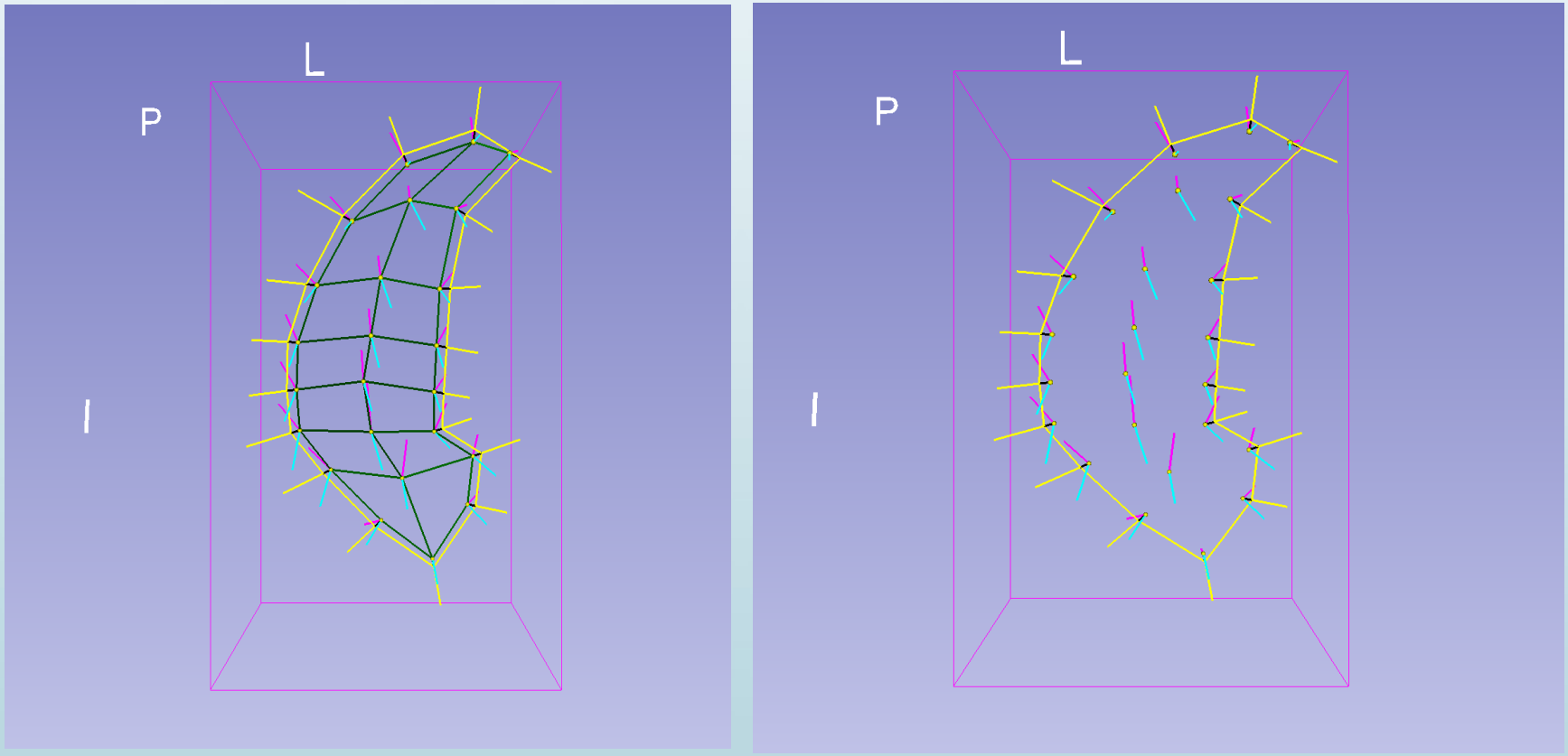


Figure: Toggle visibility of skeletal mesh. Left: original s-rep. Right: hide skeletal mesh

How to visualize an s-rep

Steps :

6. Select the s-rep part(s) to display in the *Data* tree.

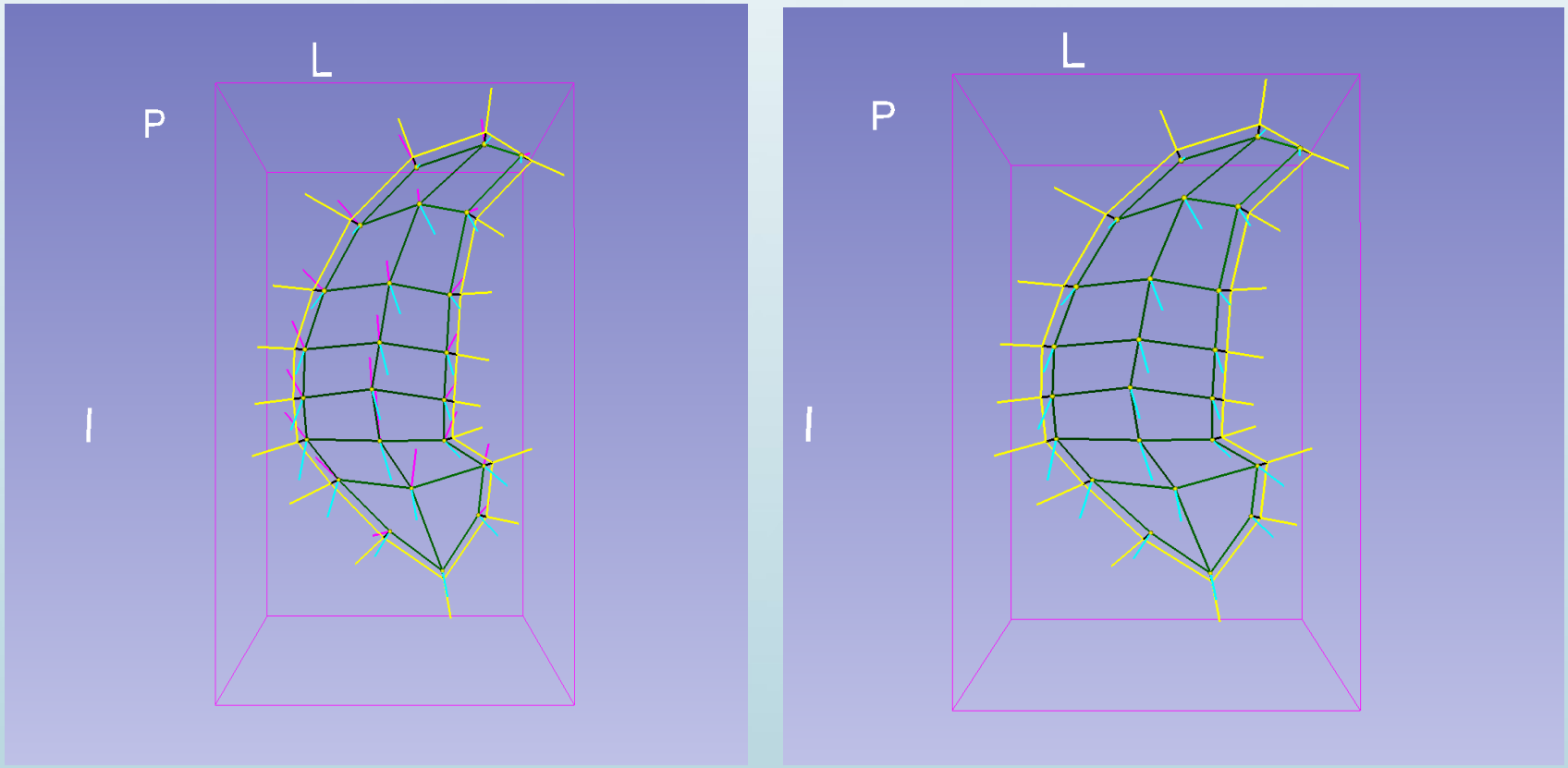


Figure: Toggle visibility of top spokes. Left: original s-rep. Right: hide top spokes

How to visualize an s-rep

Steps :

6. Select the s-rep part(s) to display in the *Data* tree.

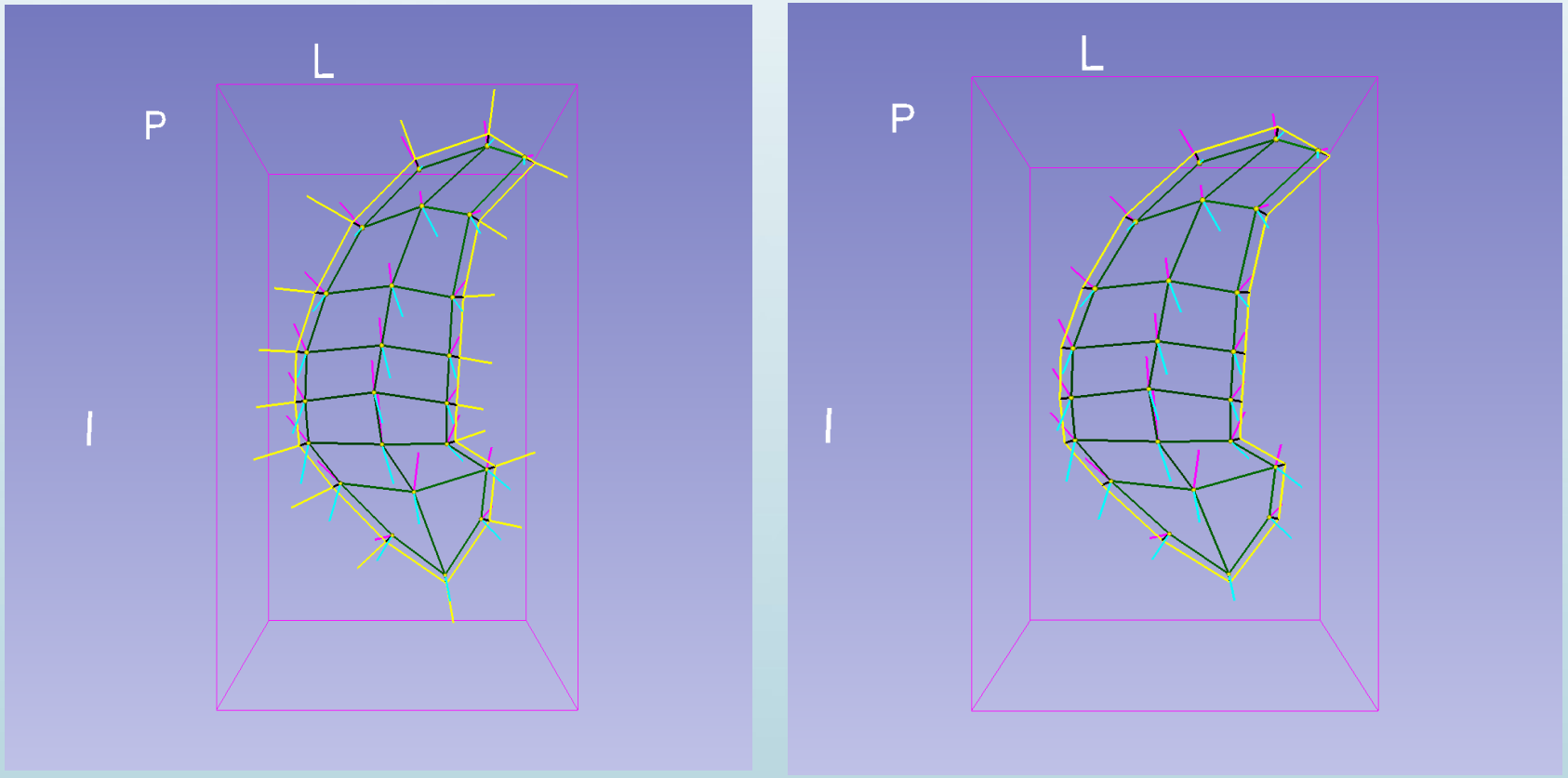


Figure: Toggle visibility of fold spokes. Left: original s-rep. Right: hide fold spokes

How to visualize an s-rep

Steps :

6. Select the s-rep part(s) to display in the *Data* tree.

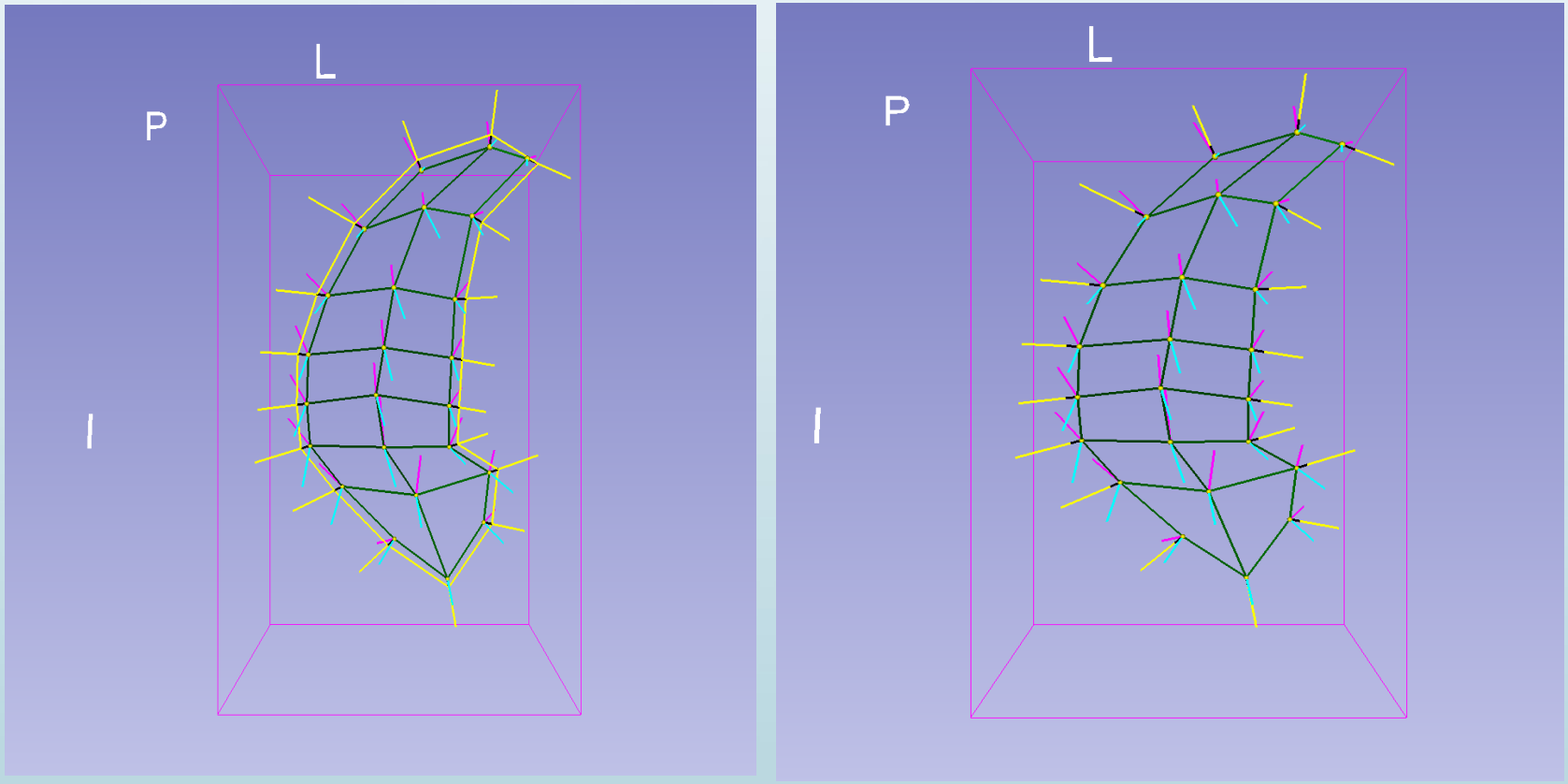


Figure: Toggle visibility of fold curve. Left: original s-rep. Right: hide fold curve

Feature 2: S-rep filter

This function allows users to

- Transform a legacy s-rep to new s-rep, save it and visualize it as aforementioned

Start 3DSlicer

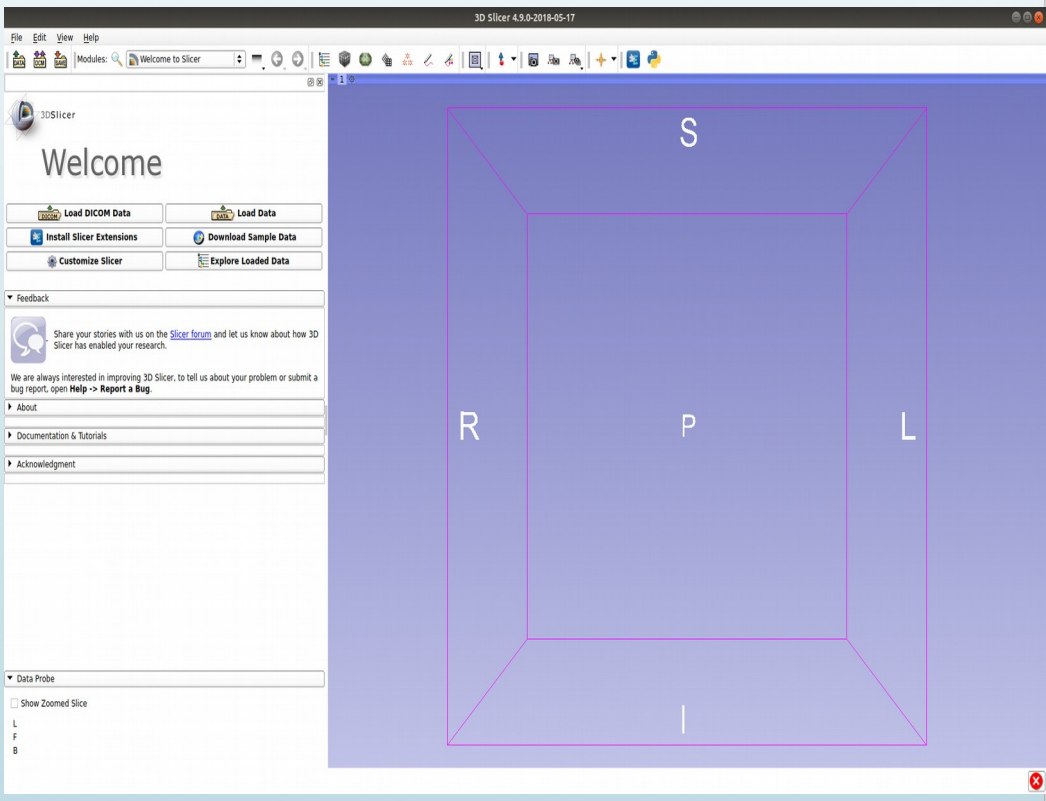


Figure: Welcome module of Slicer

Slicer SALT
Shape AnaLysis Toolbox

S-reps in the Legacy Representation

- If the visualizer is presented with an s-rep in the legacy representation (*.m3d), auto filter and display

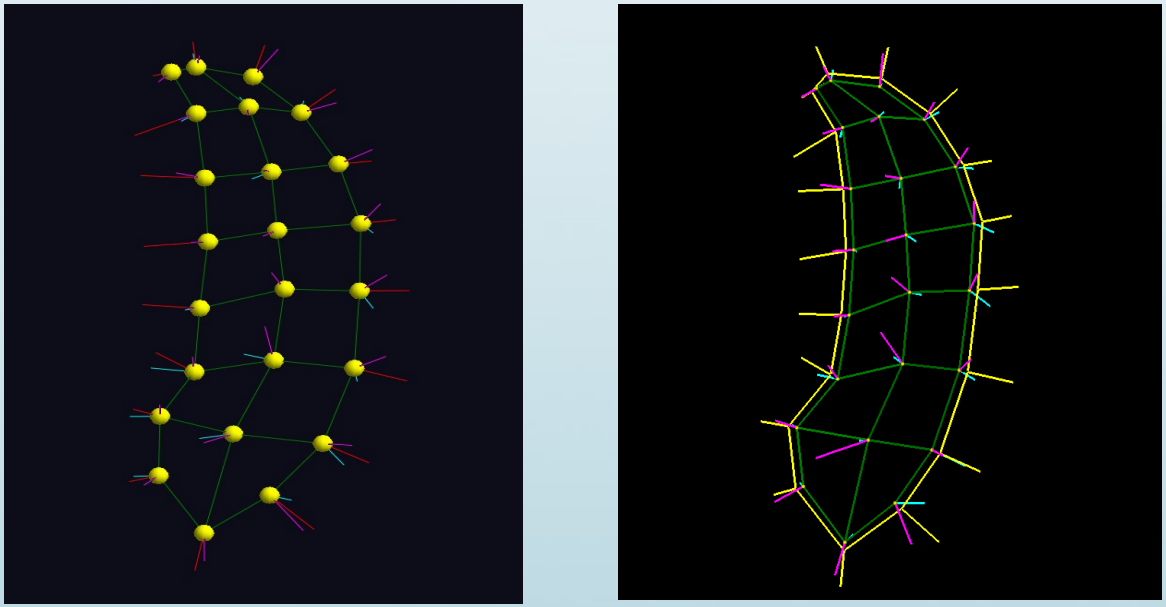


Figure: transformation from legacy s-rep to new s-rep
Left: legacy s-rep of hippocampus
Right: new s-rep of hippocampus

How to visualize a legacy s-rep

Steps :

Select an s-rep file. If you select a legacy s-rep file (*.m3d), the module would transform it to new s-rep and save it to the output folder. **A non-zero distance (see the yellow arrow) is recommended to expand the outer skeletal points in the legacy s-rep into the fold curve .**

If the transformation succeeds, the s-rep will be rendered in the 3D window and related files would be saved in the output folder.
For hippo.m3d in test data, we recommend distance as 0.02.

For more details of legacy s-reps, please refer section 2.1 of this document: https://www.nitrc.org/docman/view.php/718/2065/Pablo_user_manual.pdf.

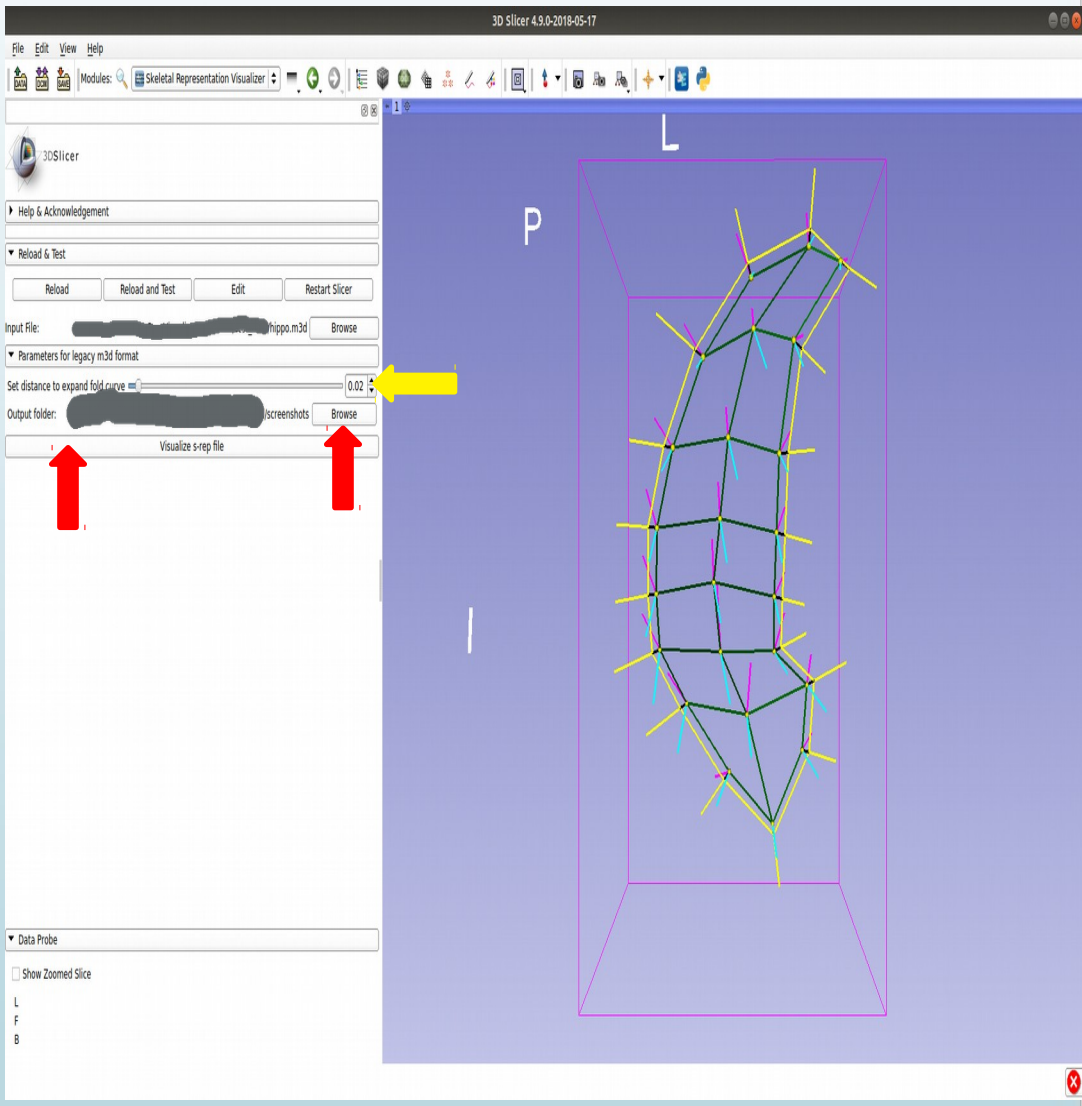


Figure: Transform, save and visualize a legacy s-rep

Acknowledgements - Resources - Questions

- The S-rep module developers gratefully acknowledge funding for this project provided by NIH NIBIB R01EB021391 (Shape Analysis Toolbox for Medical Image Computing Projects), as well as the Slicer community.

- Github repository:
  - SkeletalRepresentation
  - SlicerSALT
  - 3D Slicer

- Forums:
  - SlicerSALT
  - 3D Slicer

- Papers & manuals:
  - Object Shape Representation via Skeletal Models (s-reps) and Statistical Analysis
  - Skeletal shape correspondence through entropy
  - S-rep fitting and stats manual

- For other remarks or questions, please email:
  - zhiy@cs.unc.edu