
SMTK Documentation

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Kitware, Inc.

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AEVA USER'S GUIDE

aeva (**a**nnotation and **e**xchange of **v**irtual **a**natomy) is a software suite designed to work with virtual anatomy in various forms. With aeva, one can navigate anatomical information that may be in the form of images (DICOM, NIfTI), surface meshes (stl, ply, vtk) and as volume meshes (vtk, med, exodus). aeva aims to provide import/export of anatomy in various formats and annotation by selecting regions and defining attributes. Templating of annotation can be achieved with simple schemas, e.g. one designed for the knee joint.

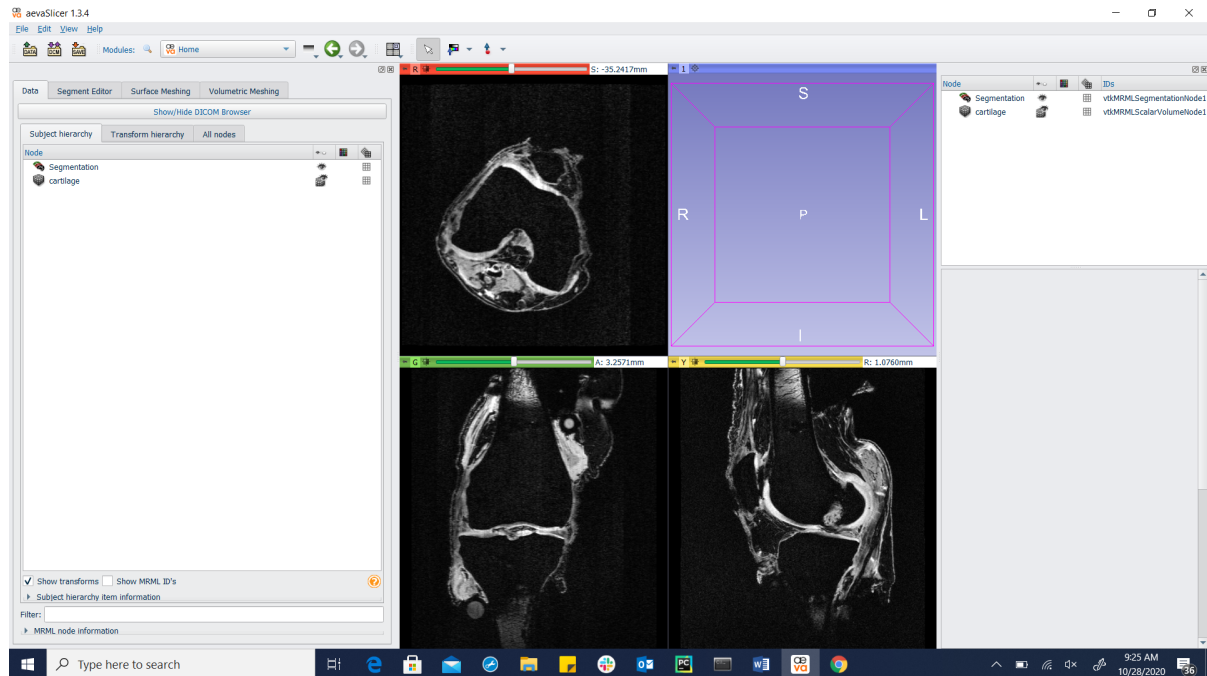
aeva software suite currently consists of

- **aevaSlicer.** aevaSlicer will be familiar to users of Slicer. The interface is customized and new features have been added to accommodate a workflow amenable to generation of surface and volume meshes of anatomy from medical images.
- **aevaCMB.** aevaCMB will be familiar to users of ParaView and Computational Model Builder. The interface is customized and new features have been added to support operations for import and export of anatomical representations and for annotation (template based and freeform, including a powerful set of region selection).

1.1 aevaSlicer User's Guide

1.1.1 aevaSlicer Home module

The aevaSlicer Home module is designed to provide quick access to segmentation, surface meshing, and volumetric meshing tools in one place. Using the tools provided in the Home module, users can go from image to volumetric mesh with intermediate outputs of segmentations and surface volumes. From the Modules drop down menu, select the Home module. The Home module provides quick access to the Data, Segment Editor, Surface Meshing, and Volumetric Meshing modules on the left side of the screen. The subject hierarchy is also displayed on the right side of the screen, for quick access to visibility and display options while working in any of the Home modules.



1.1.2 Segment Editor

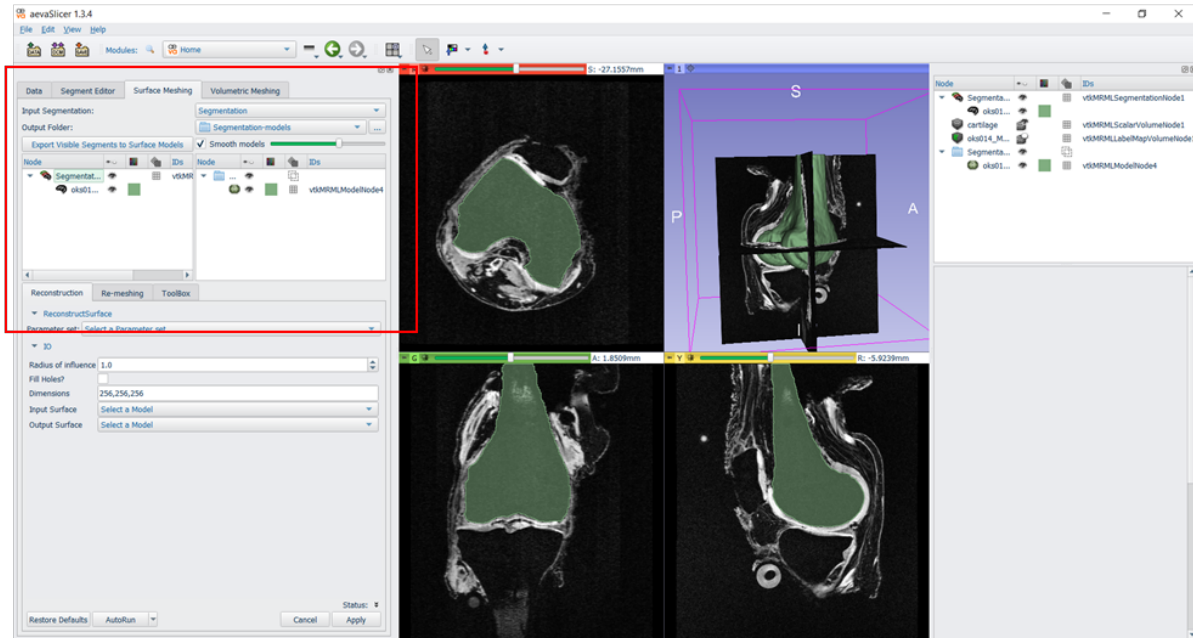
Refer to 3D slicer documentation for details about the [Segment Editor](#) features.

1.1.3 Surface Meshing

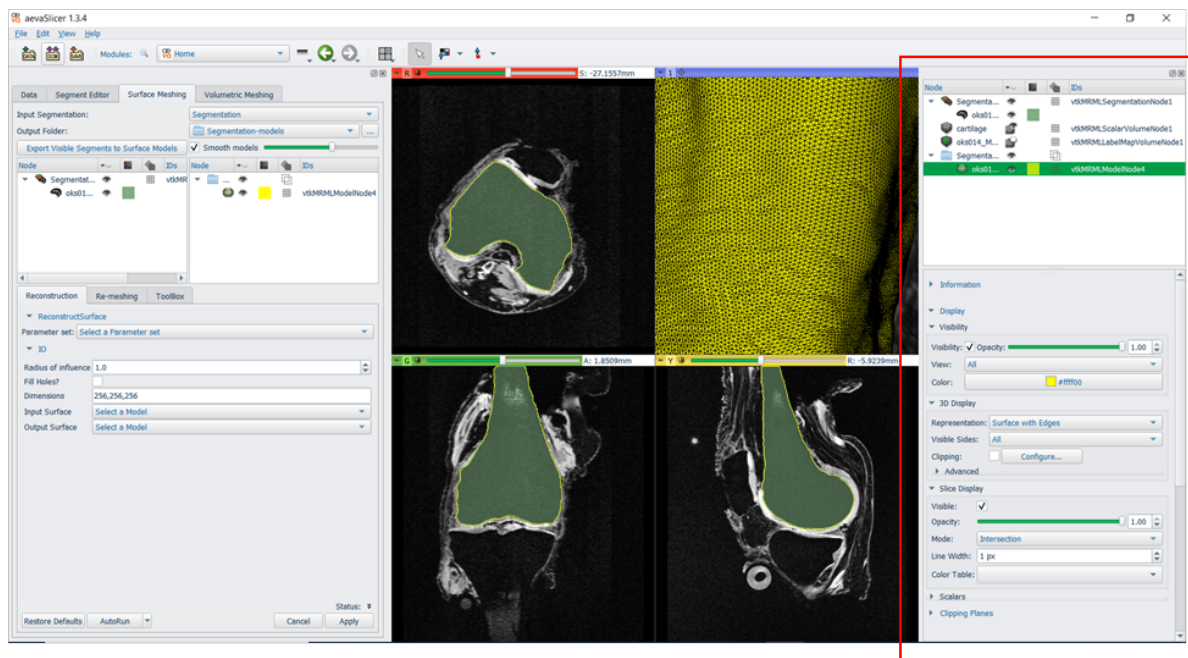
The Surface Meshing module provides tools for generating triangulated surface meshes from segmentations, as well as smoothing, re-meshing, and reconstruction tools to be used on existing triangulated surface meshes.

1.1.3.1 Generating a surface mesh from segmentation

Load the labelmap(s) of interest into the Segment Editor. Select the Input Segmentation, and the output folder for the surface meshes. Use the “smooth models” checkbox and slider for automatic smoothing of the segmentations when generating the triangulated surface mesh. Select “Export Visible Segments to Surface Models” to generate the surface meshes. Toggle visibility of the segments to control which segments a surface mesh is generated for.

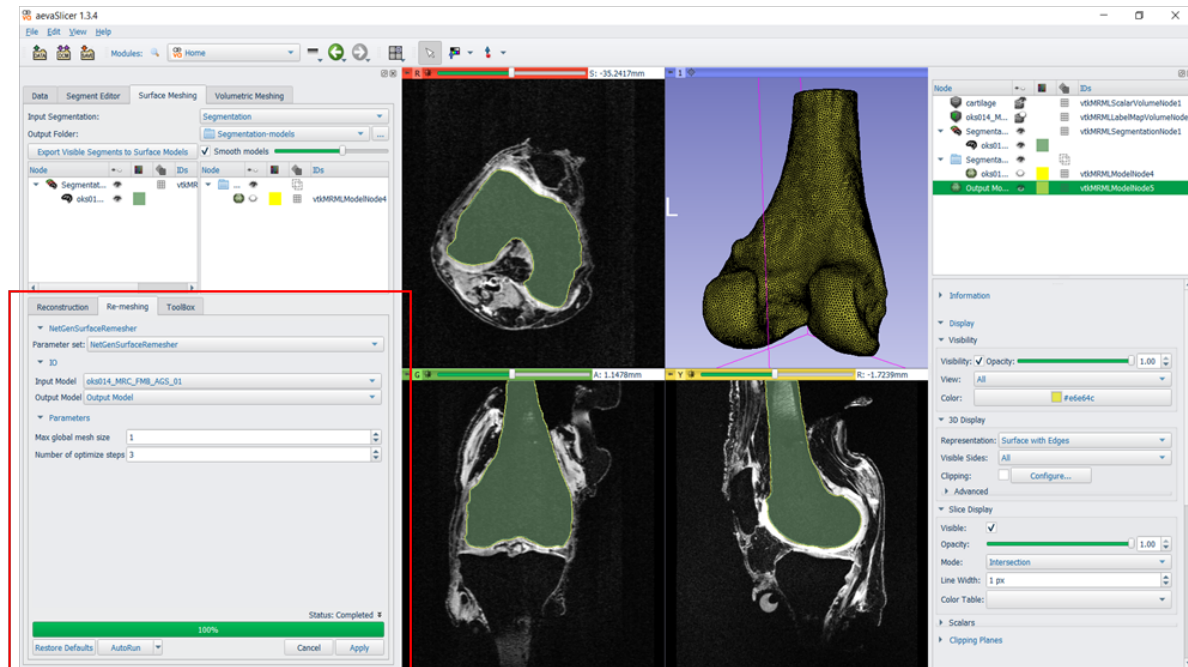


The generated mesh will appear in the data panel, which can be accessed on the right hand side of the screen, in the subject hierarchy. Selecting the mesh from the list will open display options below. Users may change the color, 3D display (ex: Surface with edges), toggle visibility in the slices, etc.



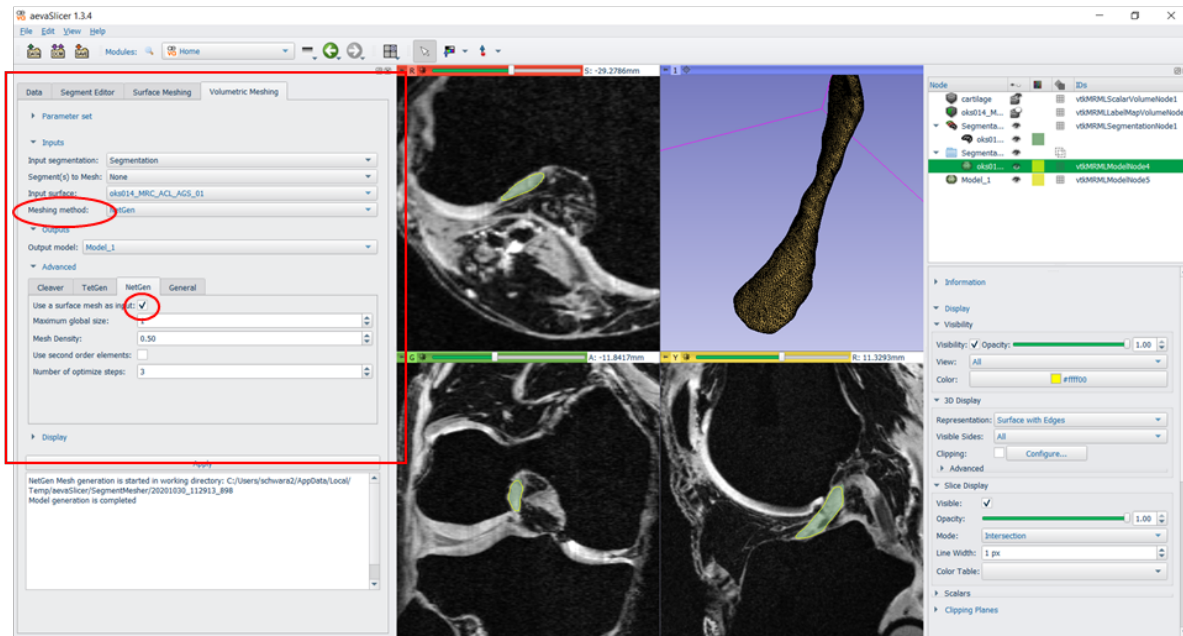
1.1.3.2 Surface Mesh tools

On the lower left side the user can find tools for processing the surface mesh. The Reconstruction tab allows for reconstruction of the triangulated mesh. The Re-Meshing tab provides a tool for changing the density of the surface mesh, using a NetGen algorithm. The toolbox tab includes smoothing, decimation, and other processing tools. Select the tool of interest, select an input model, and output node. Adjust the settings and select apply. The processed mesh will appear in the subject hierarchy, under the selected output node.

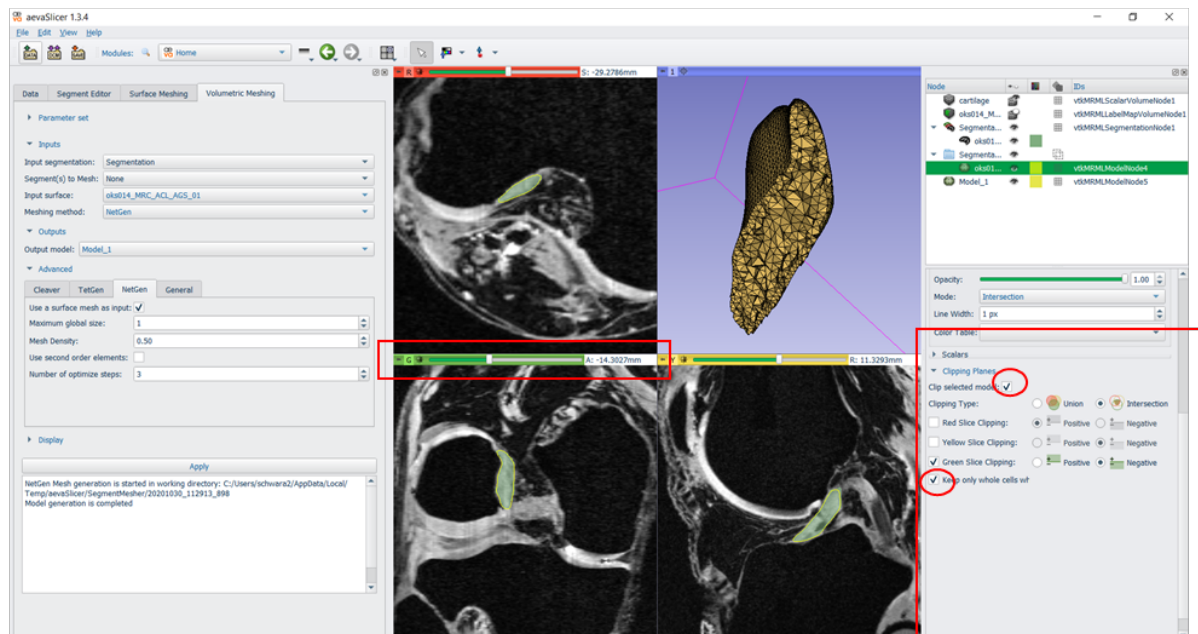


1.1.4 Volumetric Meshing

The Volumetric Meshing module provides a tool for creating an internal mesh from a segmentation or a surface mesh. Several meshing algorithms are available. For creating an internal mesh from an existing surface mesh, begin by selecting the Meshing method (TetGen or NetGen) from the drop down menu. Under Advanced, select the tab for the meshing method, and select the “use surface mesh as input” check box. This will release the Input Surface drop down menu above. Choose the Input surface, and the node for the output model. Adjust the settings, and select Apply



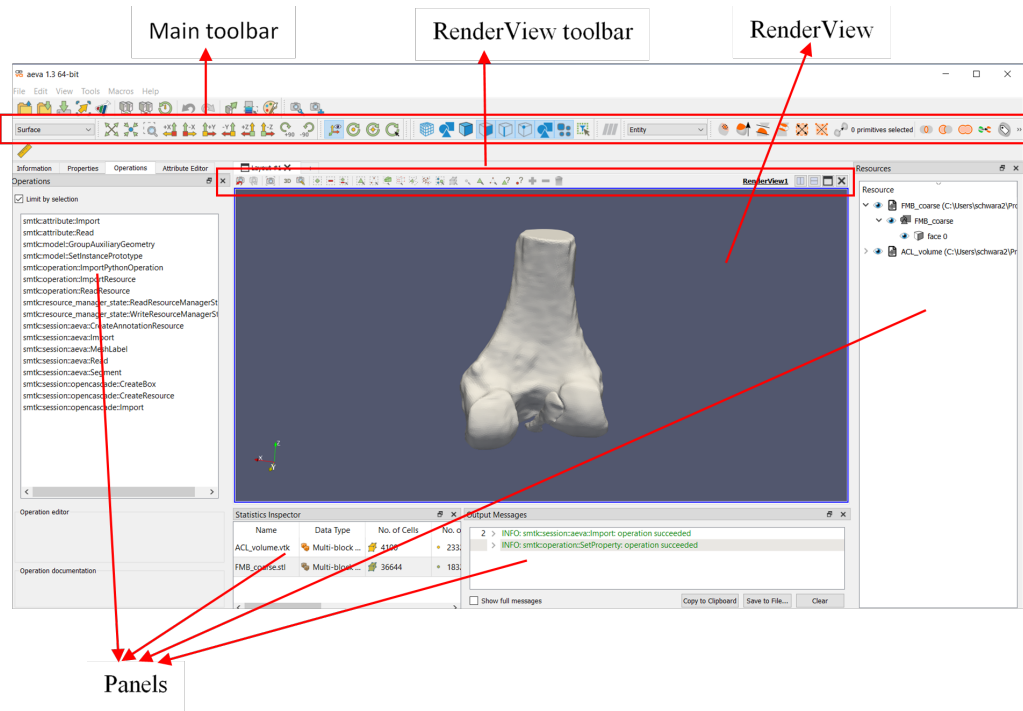
To display the internal mesh, select the mesh from the subject hierarchy on the right hand side of the screen. Under Clipping Planes, select the “clip selected model” check box. Choose the slice along which to clip, and select the “keep only whole cells whole” check box. Moving the slider on top of the selected clipping slice will move the clipping plane along the mesh as well.



1.2 aevaCMB User's Guide

1.2.1 Navigating aevaCMB Interface

The aevaCMB window inherits the interface of ParaView. It contains a RenderView, panels, the main toolbar, and the RenderView toolbar. In addition, a handful of panels and toolbars are customized to facilitate annotations on anatomy.



1.2.1.1 RenderView

- The RenderView is the visualization area.
- Multiple Renderviews may be open simultaneously. Create a new view by:
 1. clicking the + to open a new Layout tab, or
 2. Selecting “Split Horizontal” or “Split Vertical”

1.2.1.2 Panels

- Panel visibility may be turned on and off under ‘View’.
- Panels may be dragged and dropped to arrange them in the window by user preference.
- See aeVaCMB Panels below for more detail.

1.2.1.3 Main Toolbar

- Main toolbar is located at the top of the window.
- The tool bar contains viewing options (left), selection options (middle), and aeVaCMB operation shortcuts (right).

1.2.1.4 RenderView Toolbar

- RenderView toolbar is located at the top of the RenderView.
- The toolbar contains camera options (left), cell selection tools (middle), and RenderView options (right).

1.2.2 aeVaCMB Concepts

1.2.2.1 Resources

Resources are containers to store annotations or geometries.

1.2.2.2 Attributes

Attributes are features (properties, ontologies, etc.) that can be associated with geometry resources and stored as annotations.

1.2.2.3 Operations

Operations are actions performed on a resource (primarily geometry) and include selection of regions, mesh operations, export, freeform annotation, etc.

1.2.3 aeVaCMB Panels

1.2.3.1 Attribute Editor

Attribute Editor provides a gateway to template annotations that can be assigned to geometry resources, e.g. tissue type, organ, etc.

1.2.3.2 Information

Displays details about datasets in the Resource Panel such as number of cells, points, and other file statistics.

1.2.3.3 Operations

Operations provide a list of all available actions for the selected resource or its regions (defined sets). One can view all operations by unchecking “limit by selection”. When an operation is selected (either from the operation panel or using one of the toolbar shortcuts), relevant Operation editor will appear under the Operations panel where the user can provide inputs. See [aevaCMB Operations](#) for a list.

1.2.3.4 Output Messages

When operations are performed, output messages appear in this panel to inform the user of success or failure.

1.2.3.5 Properties

This panel is inherited from Paraview. It can help change visualization settings for a given resource.

1.2.4 aevaCMB Operations

A variety of operations are categorized with access points:

- Region selection and editing
 - At RenderView toolbar
 - * Select Cells On
 - * Select Points On
 - * Select Cells with Polygon
 - * Select Points with Polygon
 - At Main toolbar
 - * Grow to edges
 - * Select by surface normal
 - * Select by proximity
 - * Select by adjacency
 - * Select all surface primitives
 - * Select the nodes of all selected primitives
 - * Duplicate cells
 - * Intersect side sets
 - * Subtract side sets
 - * Unite side sets
 - * Unreferenced primitives
- Annotation

- At Operations panel
 - * Associate
 - * Dissociate
 - * Edit freeform attributes
- Mesh/geometry modification
 - At Main toolbar
 - * Reconstruct surface
 - * Smooth surface
 - * Quadratic promotion
 - * Proportional Edit
 - * Imprint Geometry
 - At Operations panel
 - * NetgenSurfaceRemesher
 - * VolumeMesher
- Volume Inspector *At Operations panel
- File loading, import/export
 - At File drop-down menu
 - * Open...
 - * Import Into Resource...
 - * Save Resource
 - * Save Resource As..
 - * Load All Resources...
 - * Save All Resources As...
 - At Operation panel
 - * Import
 - * Export

AEVA TUTORIALS

A growing list of tutorials to demonstrate the use of **aevaSlicer** and **aevaCMB** can be found here:

2.1 Femur-ACL-Tibia Tutorial

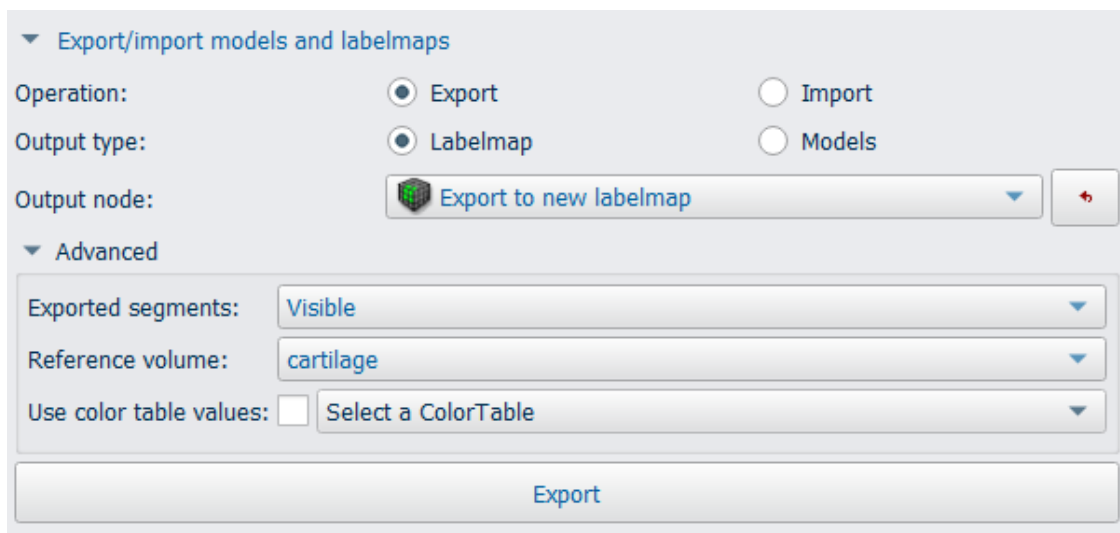
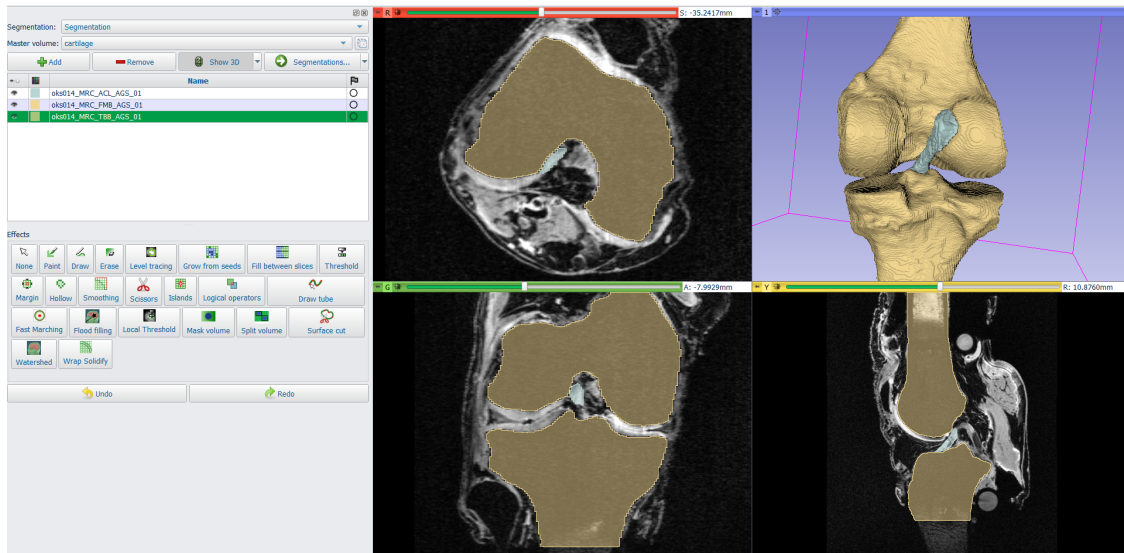
This tutorial illustrates how to use aevaSlicer to create segmentations by listing the steps required to segment a femur, ACL, and tibia starting with an MRI image. The MRI image used in this tutorial is available from the [OpenKnee repository](#). Specifically, we use the oks014 dataset's cartilage image (98 MiB) named 1.3.12.2.1107.5.2.19.45406.2018071814545560005408452.0.0.0.nii.

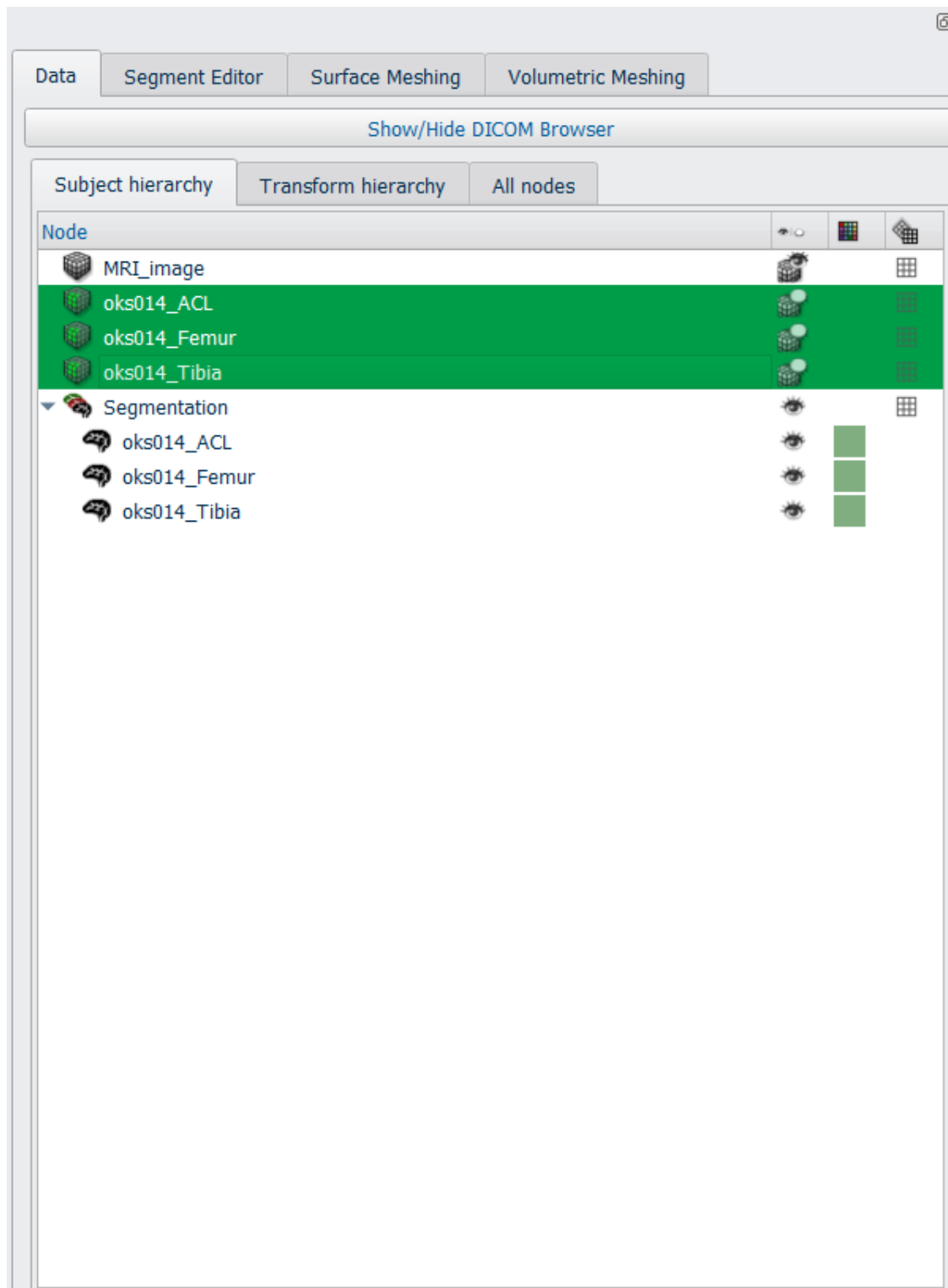
2.1.1 Load an MRI image into aevaSlicer

- Open aevaSlicer
- File→Add Data. Select the MRI image (.nii). Select OK

2.1.2 In aevaSlicer, segment the femur, tibia, and ACL

- Select the home module from the drop down menu. This home screen provides quick access to the data, segment editor, Surface Meshing, and Volumetric Meshing modules.
- Navigate to the Segment Editor Tab. Select the desired MRI as the Master Volume.
- Use the +Add button to create a new segmentation, and use the segmentation tools to delineate the anatomy.
- To save the segmentations, click on →Segmentations..., and then scroll down and expand the export/import models and labelmaps section. Select the Export operation. Select the output node, or export to new labelmap, and click Export below.
- **TIP:** If you are working with multiple segmentations, default settings will save them all in the same labelmap. To save each segmentation individually, expand the Advanced options, and select Visible from the Exported segments drop down menu. Then, toggle the visibility of all other segments from the list above.
- Once the export operation is complete, the exported labelmap/s will appear as nodes in the data module.
- Use File->Save to save the segmentations. Select the check box next to the files you would like to save, and change file format (.nii) and directory.
- You may continue to edit these segmentations at a later time by loading them into Aeva Slicer (Add Data), and importing to the segment editor. When using Add Data, check the “show options” check box on the upper right hand side, and make sure that the “Labelmap” checkbox is selected, so that the segmentations will be imported correctly.

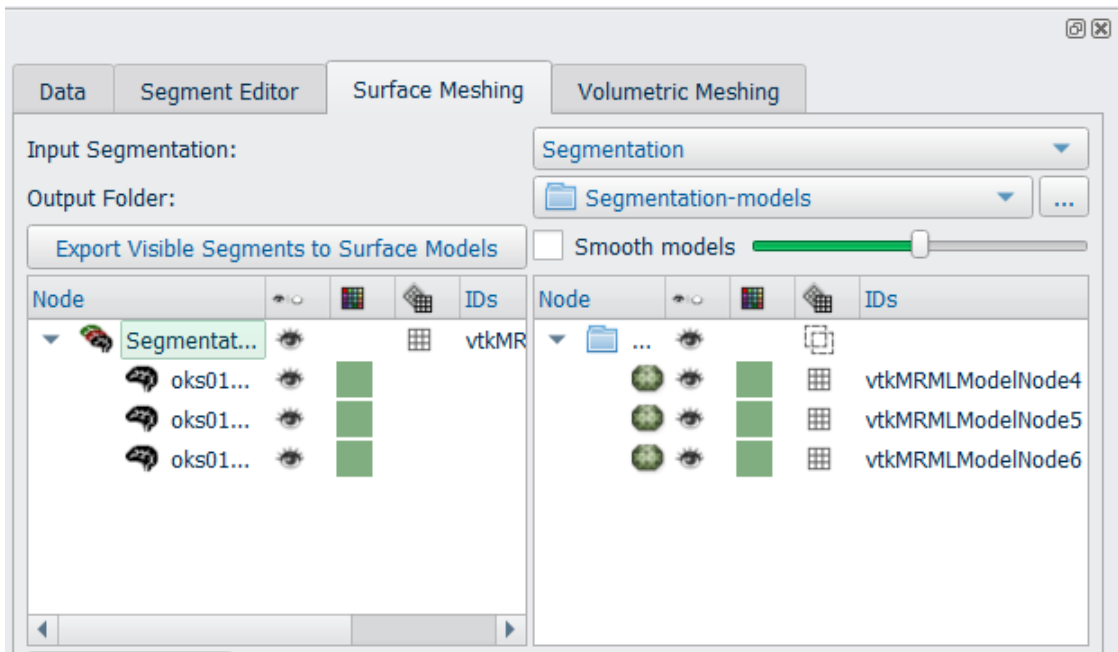




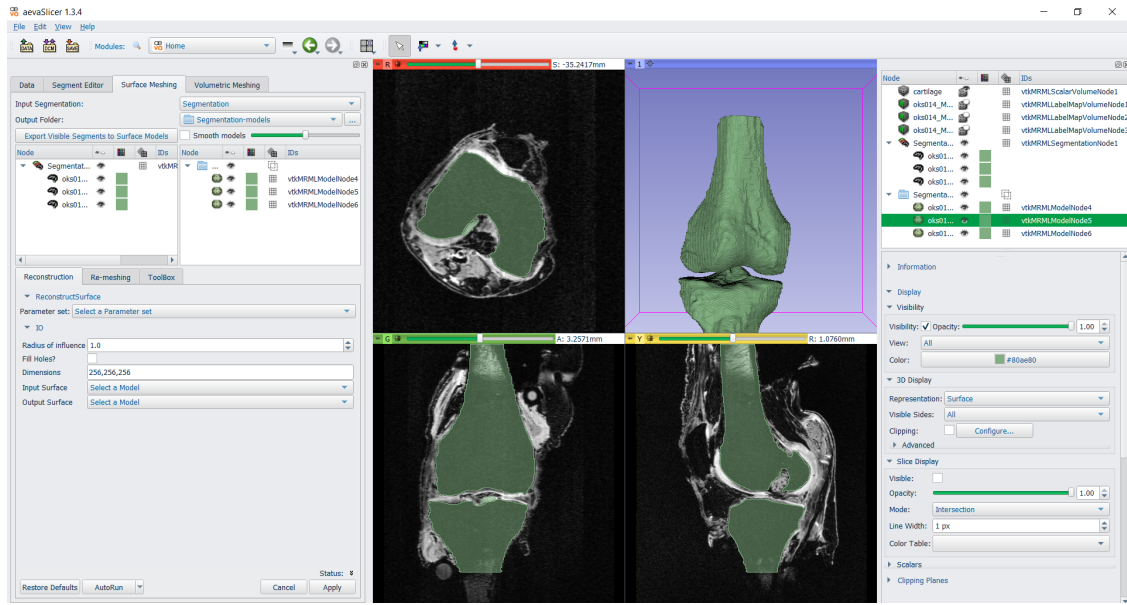
- Note that any changes made in the segment editor are not automatically applied to the data nodes. The changed labelmaps must be exported to the data nodes in order to be able to save the changes.

2.1.3 In aevaSlicer, generate the femur, tibia, and ACL surfaces

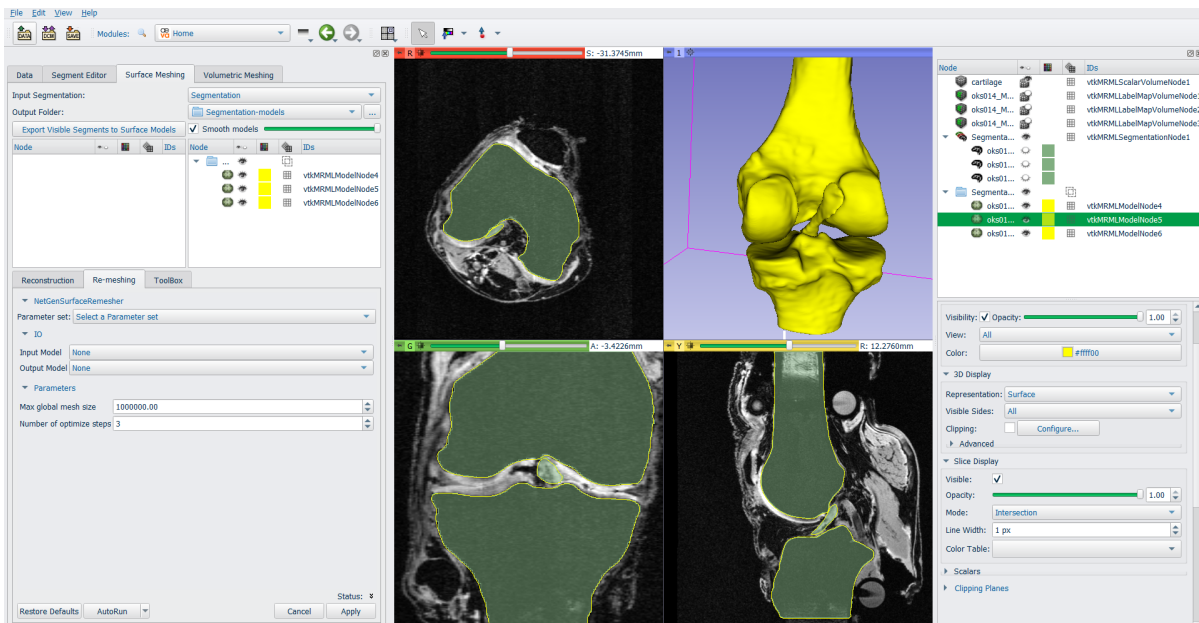
- Import the completed segmentations into the Segment Editor, if they are not already there.
- From the home module, navigate to the Surface Meshing tab. Under the input segmentation, select “Segmentation” (or the name of the current working segmentation in the segment editor)
- To generate triangulated surfaces from the segmentations, select “Export Visible Segments to Surface Models”. Default settings will generate triangulated surfaces without smoothing. Use the “smooth models” checkbox and slider for automatic surface smoothing.



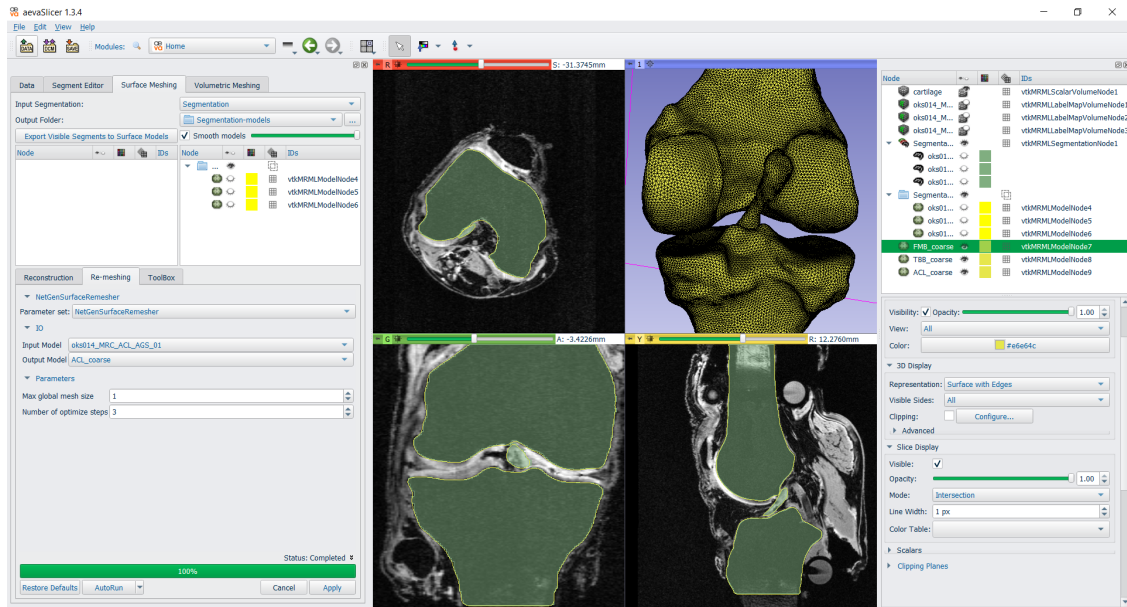
- The left panel will display the labelmaps in the Segment Editor. The right panel will display the generated triangulated surfaces.
- On the right side of the screen, the Data module will be displayed. This provides easy access to toggle visibility, and change properties of the visible meshes. When a mesh is selected on the data list, properties options will appear below.
- On the lower half of the left hand side, there are three tabs with mesh operations. Reconstruction, Re-meshing, and Toolbox. These tools can be applied to an existing surface mesh. Once the segmentations have been exported to Surface Meshes, these operations may be used for further smoothing, decimation, re-meshing, etc. Operations may be performed in any order.
- For this tutorial, the models will be exported with automated smoothing, followed by re-meshing to reduce the density of the surface meshes.
- First, export segments to surface models, with maximum automated smoothing, using checkbox and slider as described above.
- Select each of the meshes on the data list, and change the color to one that is different than the segmentations. Under slice display, check the “visible” box. This will display the outline of the surface mesh on the slice. This



can allow for the user to assess if any volume was lost from the segmentation during smoothing. If this is the case, adjustments can be made to the level of smoothing.



- Navigate to the Re-meshing tab on the lower left side of the screen. Under parameter set, select Create new parameter set. Select the input model, and an output node for the resulting surface mesh (create new model as..). Set the max global mesh size to 1. Select Apply. Repeat this process for each of the tissues, and adjust mesh size as needed. Use the data panel to select each mesh and change the 3D display to Surface with Edges to view the mesh outline.
- To Save the Surface meshes (File→Save). Surface meshes that were created using “Export visible segments to surface models” will appear in the list with the same name as the segmentations, but with a Poly Data (.vtk) extension. Change the name, file format (.stl), and destination directory if desired.



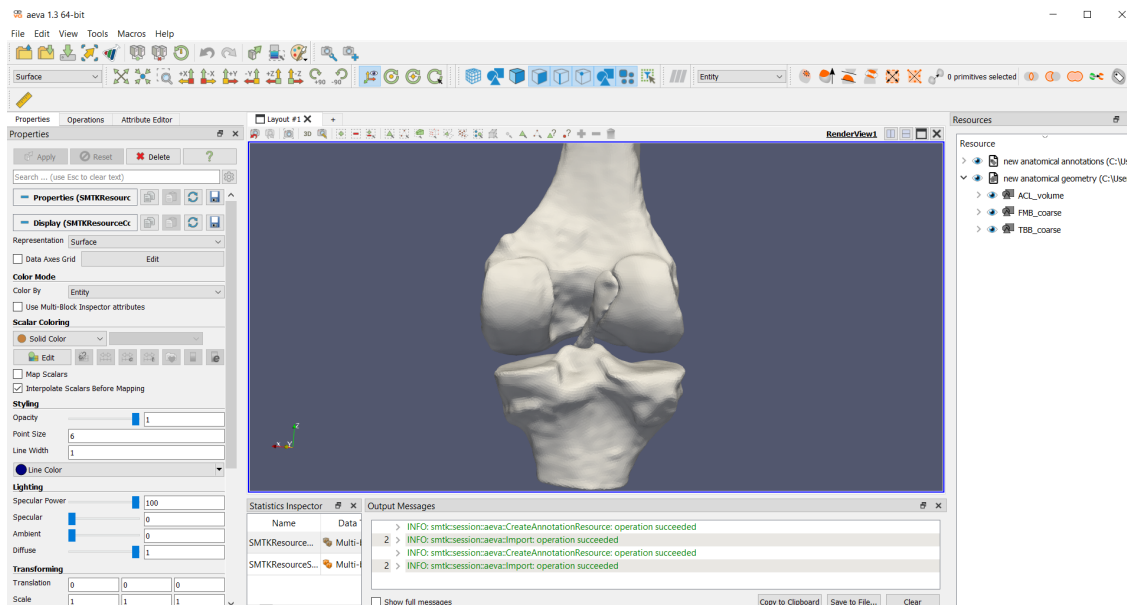
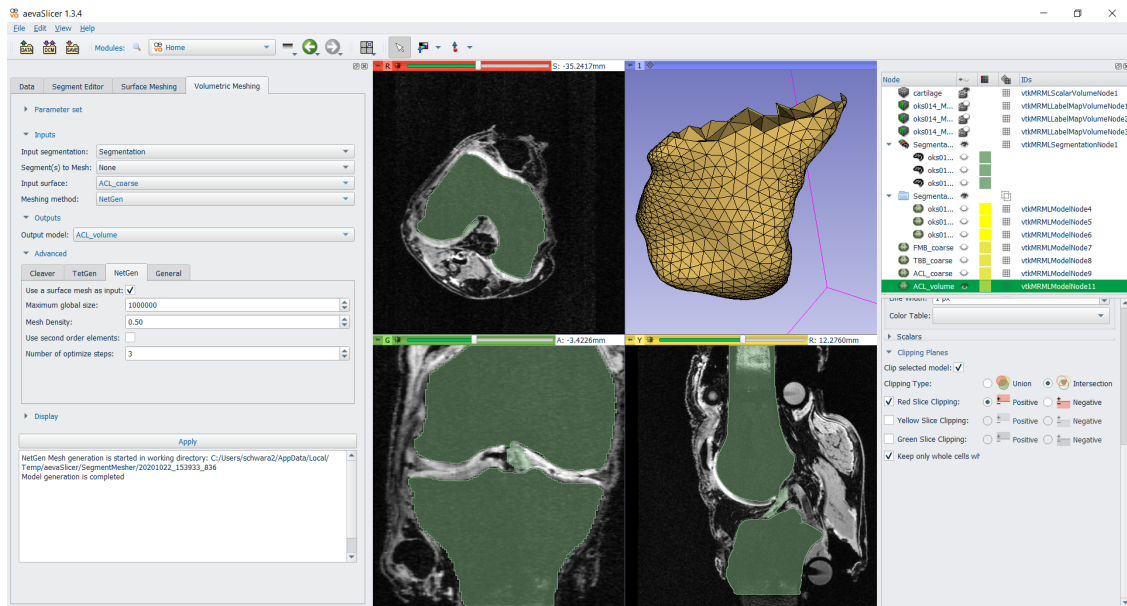
2.1.4 In aevaSlicer, generate the volume mesh for ACL

- For this case study, only the ACL model will have a volumetric mesh, as the bones will be modeled as rigid bodies and can remain as surface meshes.
- From the home module, select the Volumetric Meshing tab.
- Select the input. To use a previously generated surface mesh, first select the Meshing method as NetGen. Then, under Advanced, Select the NetGen tab, and click the “Use surface mesh as input” check box. Now you may select the input surface from the drop down menu above.
- Select the ACL surface mesh from the drop down menu. For the output node, “create new model as. . .”. Select Apply.
- Using the data panel on the right hand side of the screen, display settings can be adjusted to visually inspect the mesh. Select the mesh from the data list. Under 3D display, set the representation to “surface with edges”. Under clipping planes, check the box for “clip selected model” choose the slice along which you wish to clip, and check the box for “keep only whole cells when clipping”. You may then scroll through the slices to move the clipping plane through the mesh.
- Save the mesh as a Poly Data file (.vtk) using File→Save

2.1.5 In aevaCMB, load the meshes

- File->New Resource->Aeva annotation resource
- From the resource tree, select the “new anatomical geometry“ resource, then File->Import into resource.
- Select the bone stl files, and the ACL vtk file. Select OK

Note: These files may also be opened individually, using File->Open. However, it is recommended to import all the meshes into one geometry resource in order to more easily save your work in aevaCMB.



2.1.6 In aevaCMB, define face and node sets

Several different selection tools are available for creating groups of element or node sets to define insertion areas.

2.1.6.1 Manual Selection

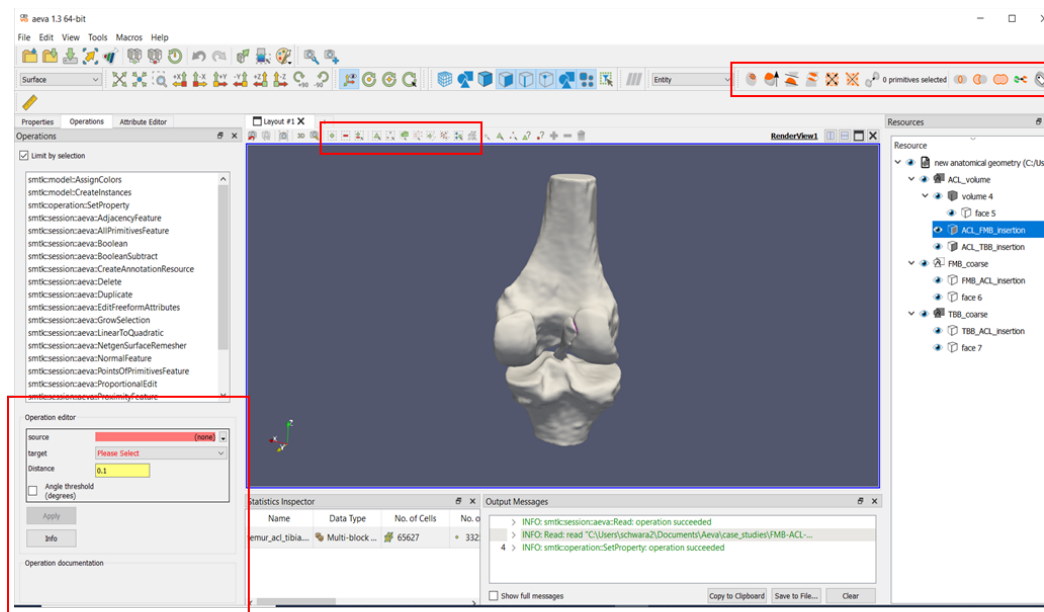
On the panel above the RenderView screen, manual selection tools are available. “Select cells with polygon” is recommended for selecting irregular shapes. Simply click and drag to select the desired region. Once a region has been selected, use the + or – buttons to add or subtract from the existing set. See directions below for saving the sets. Saved selections may also be edited by selecting the set from the resource tree, followed by + and -, and the desired selection tool.

2.1.6.2 Automated Selection

On far right side of the panel at the top of the aevaCMB window, several automated selection tools are available. Choose the desired selection tool. In the operations taskbar, under Operation Editor, select the source and target face (expand the resource tree to see which faces belong to which geometries). The selection will be created on the source mesh, and the target mesh will be used as the tool.

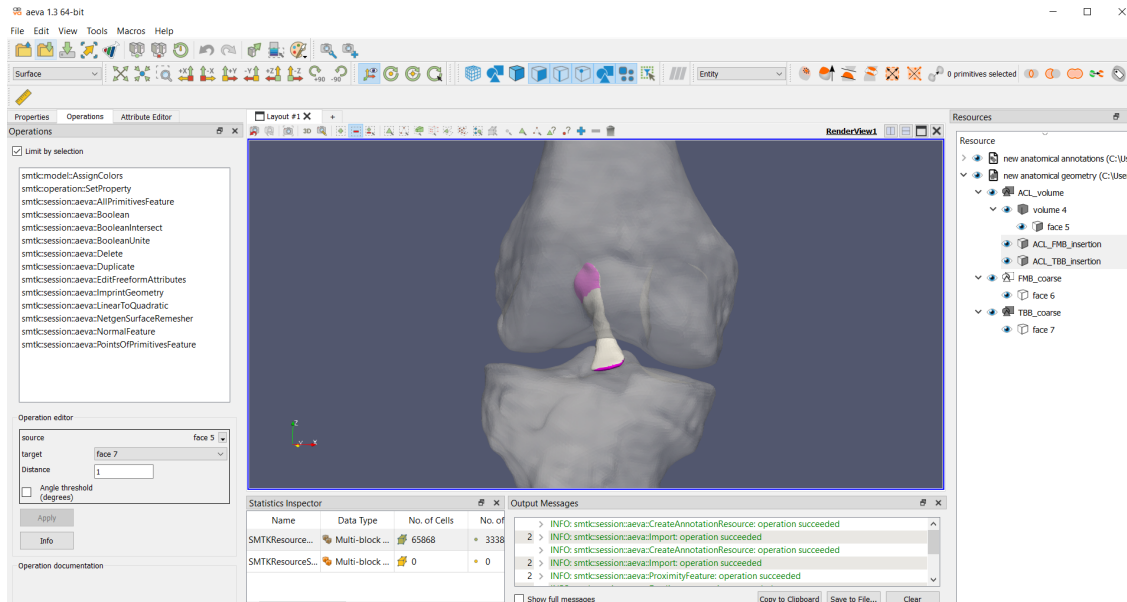
2.1.6.3 Converting element sets to node sets

On far right side of the panel at the top of the aevaCMB window, “Select the nodes of all selected primitives” will create a selection of all nodes of the currently selected elements.



2.1.6.4 Saving Selections

Once a set is defined as desired, select “Duplicate Cells” on the upper right. This will create a new group under the geometry in the resource tree, called “copy of selection”. Double click on the group to rename it as desired.



2.1.7 In aevaCMB, save the resource as smtk

- Select the entire geometry resource (new anatomical geometry), and select File->Save Resource As.
- Save the smtk resource. This smtk file may be easily re-opened in aevaCMB for further editing using File->Open

INDICES AND TABLES

- `genindex`
- `modindex`
- `search`