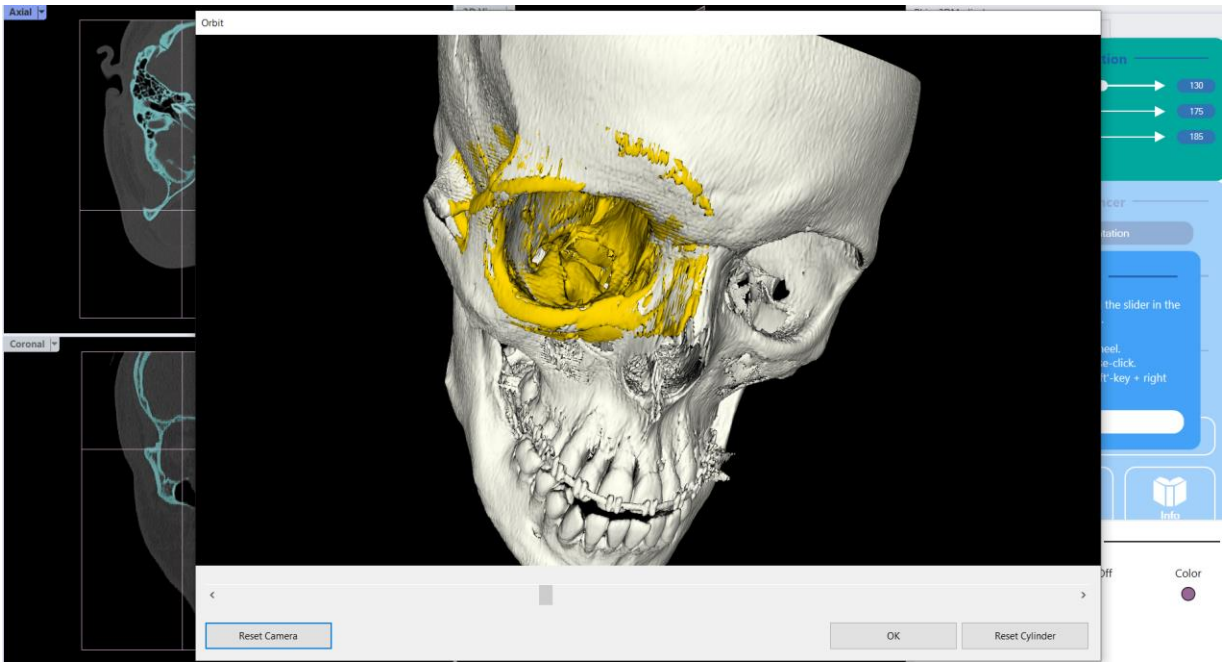
Rhino3DMedical Documentation



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1 Installation

To install Rhino3DMedical for evaluation, two steps must be done: first **install CAD software Rhinoceros3D** (version 7, also called Rhino 7), and second **install Rhino3DMedical plug-in**. Check in this link that you have the minimum system requirements (for Windows): https://www.rhino3d.com/7/system-requirements/ Please do the following:

1. **Download and install Rhino 7** 90-day trial license here: https://www.rhino3d.com/download/rhino-for-windows/evaluation. You'll receive a trial license key by e-mail, which you insert when opening Rhinoceros. You'll have to create a McNeel account. The key is for evaluation purposes.
2. **Download and install Rhino3DMedical** 90-day trial license here: https://rhino3dmedical.com/installation-guide/. When filling the registration form, you will receive a license key by e-mail (different from the one of point 1). Upon opening Rhinoceros and Rhino3DMedical, you'll be prompted to enter this license key.

When acquiring Rhino 7 and Rhino3DMedical, there won't be any change to be made to both licenses of points 1 and 2.

2 Open Rhino3DMedical

To open Rhino3DMedical, **open application Rhino 7 in Windows Start Menu** or from your desktop (Fig. 1).

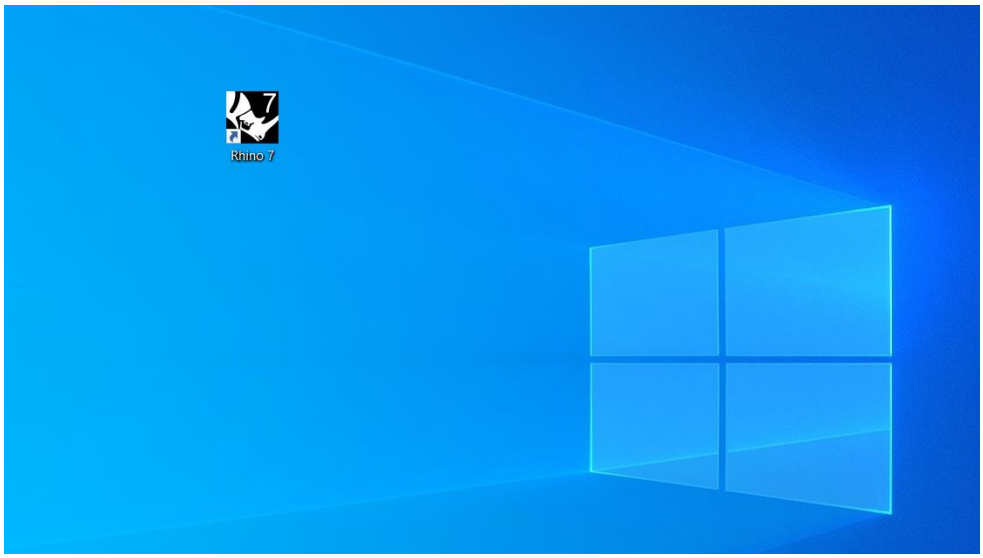

Fig. 1: Desktop view with icon of Rhino 7.

3 Interface and basic controls

Rhino3DMedical is embedded in Rhino 7 (Fig. 2). It appears as a toolbar, a set of tabs, a 3D view with different sub-views and projections (Top, Front, Right and Perspective), a command line and a menu.

The **toolbar** (Fig. 3) calls the different command sections of Rhino3DMedical, which appear in the tab section. The **command line** prompts instructions and information in certain situations, and the **menu** contains the same commands as the toolbar, in addition with to extra functionality.

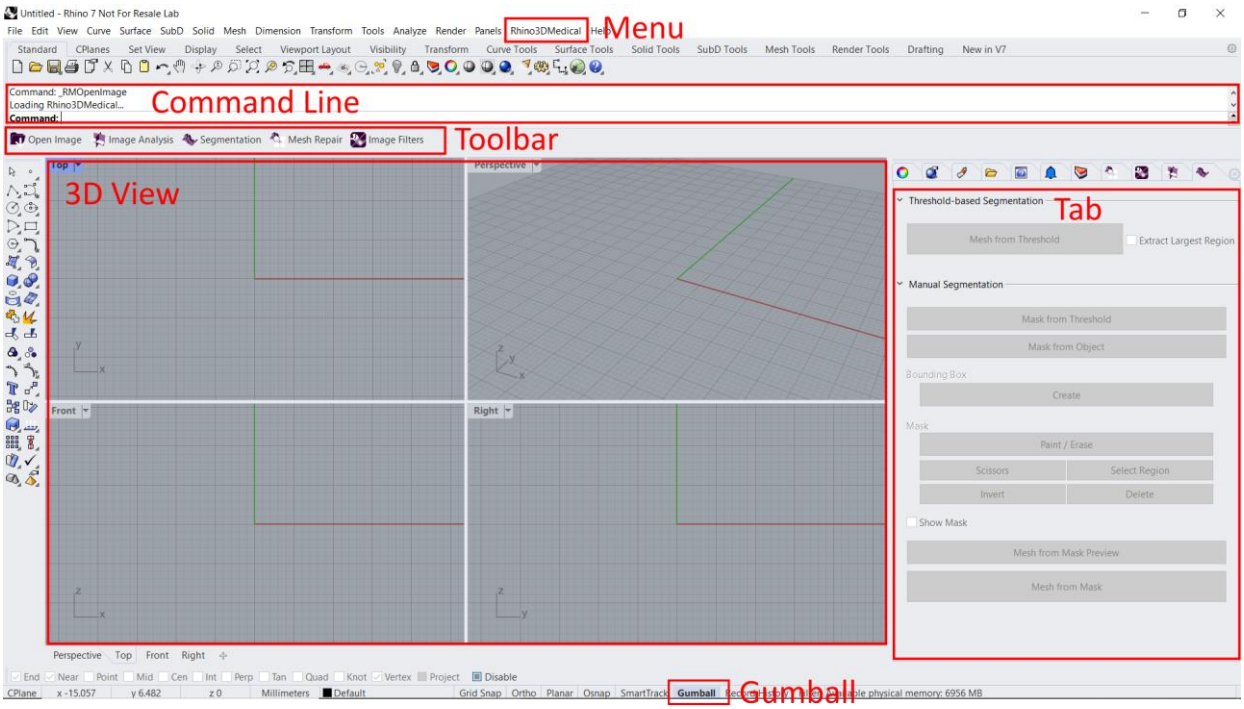

Fig. 2: Interface of Rhino3DMedical embedded in Rhino 7.

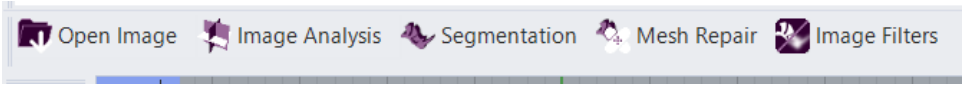

Fig. 3: Rhino3DMedical toolbar.

Make sure that the *Gumball* option at the bottom of Rhino is always checked, and that other options at its left like Grid Snap or Osnap are unchecked.

To navigate the 3D view, hold mouse right-button to move the scene in Top/Front/Right, and to rotate it in Perspective. Use mouse wheel to zoom the scene in any projection. In Perspective view, press Shift key and hold mouse right-button to move the scene. Double-click on the name of a projection to enlarge it and hide the rest. Double-click on the name again to return to 4-grid view.

3.1 If the Rhino3DMedical toolbar does not appear

If the toolbar does not appear, click on to the command line and type command *Toolbar* (type it and press keyboard key *Enter*). The window of Fig. 4 will appear; click on *Rhino3DMedical* (inside *Files*) and check the box at left of *Toolbar group*. Press *OK* and the toolbar should be visible.

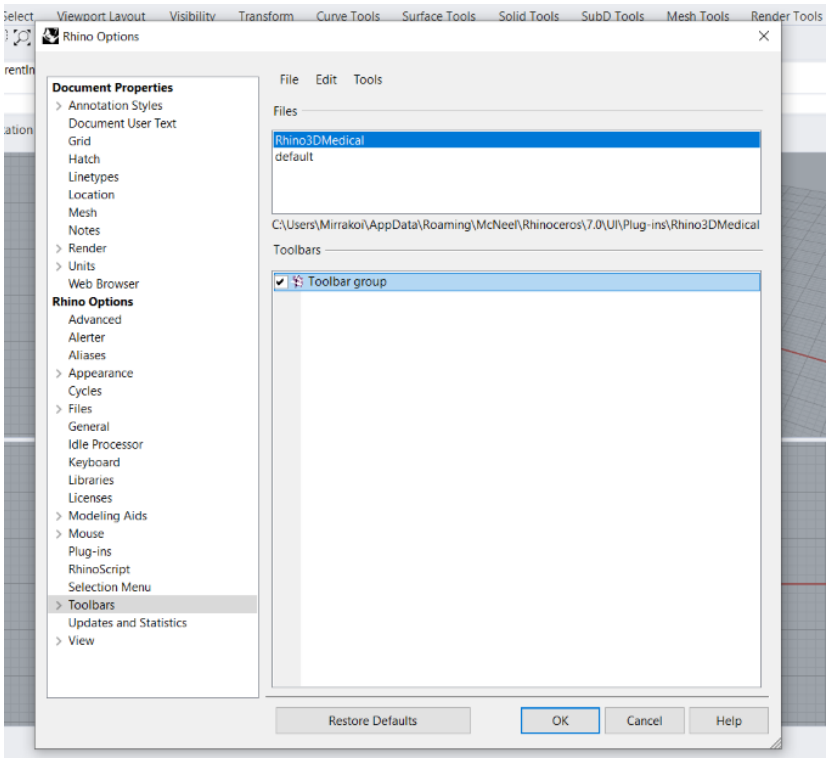

Fig. 4: Toolbar Rhino Options.

4 Open Image

To open an image, press button *Open Image* in Rhino3DMedical toolbar. A window will ask you to select a file (Fig. 5). If your medical image is of DICOM format, go to its directory and double-click or open any file inside the DICOM directory. If your medical image is of another format (MHD, NIFTI, NRRD, TIFF), just double-click or open it.

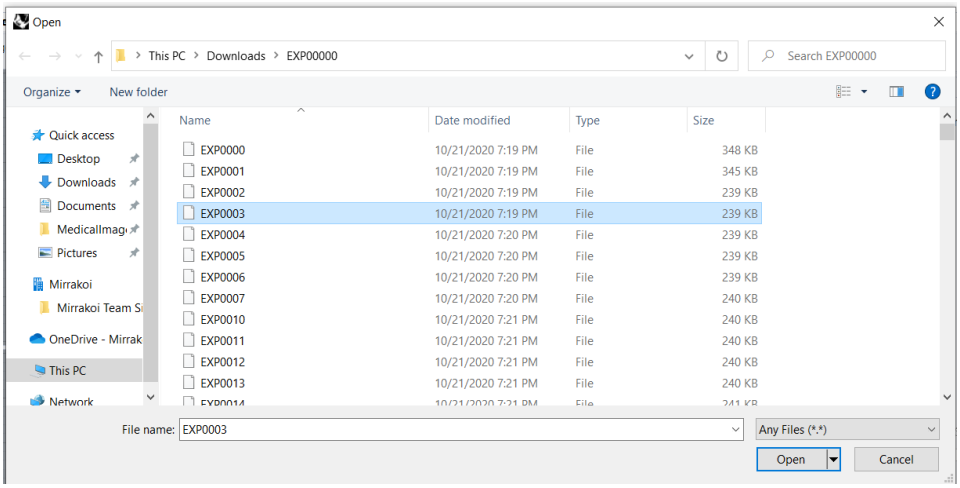

Fig. 5: Open Image prompt window.

For DICOM images, you will be prompted a window (Fig. 6) containing all the information of the patient and image, and the details of the DICOM series (if there is any). Select the DICOM series from the drop-down menu at top left, and then press *Ok* to open the image. Finally, the image will appear in the 3D view (Fig. 7).

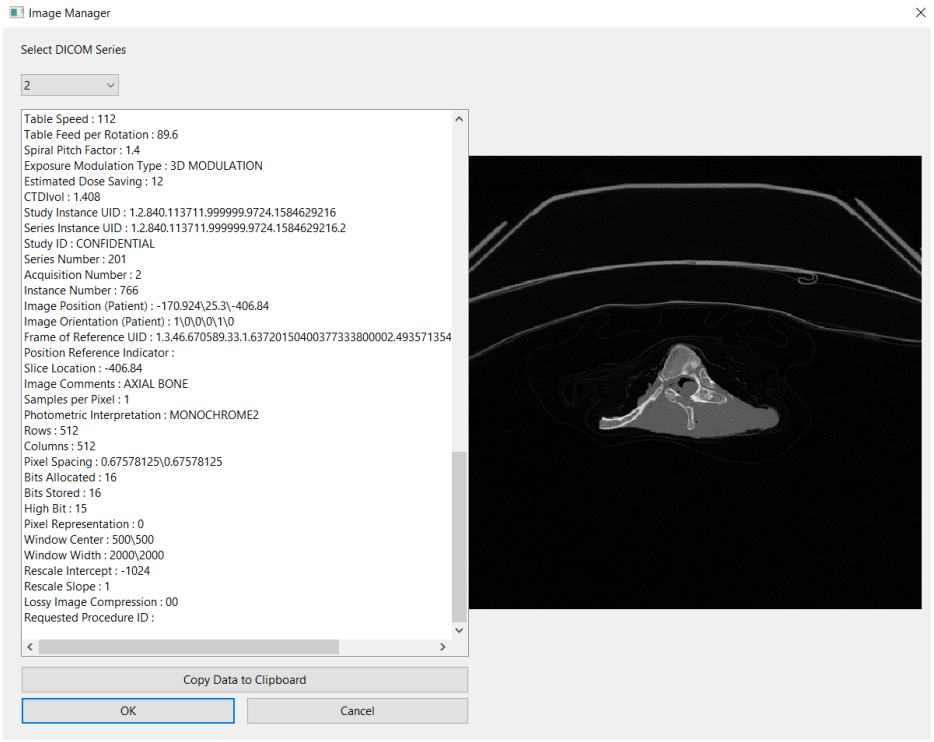

Fig. 6: Open Image DICOM Manager.

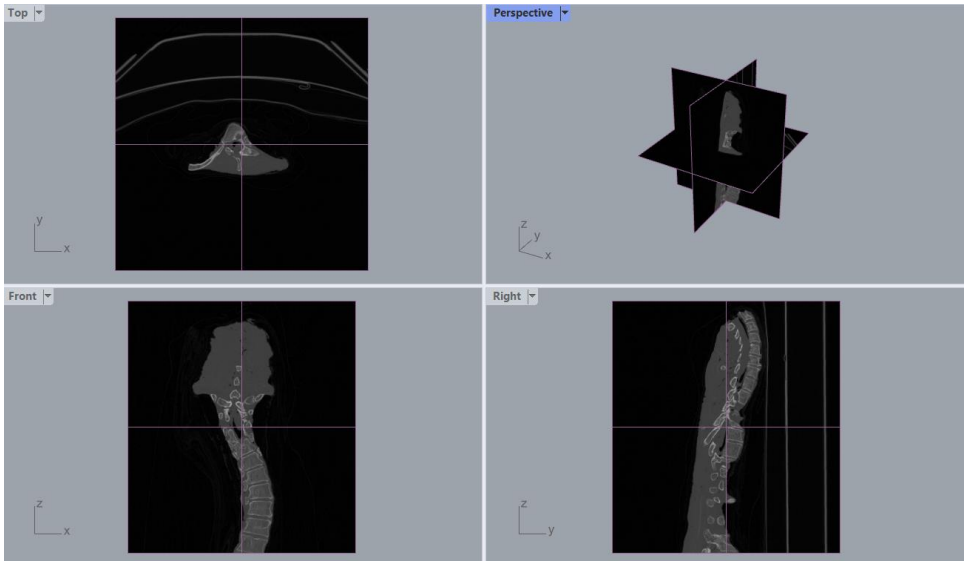

Fig. 7: Medical image in 3D view.

5 Image Analysis

After opening a medical image, press *Image Analysis* button in the toolbar, type it in the command line or find it in the menu. The corresponding tab will open (Fig. 8).

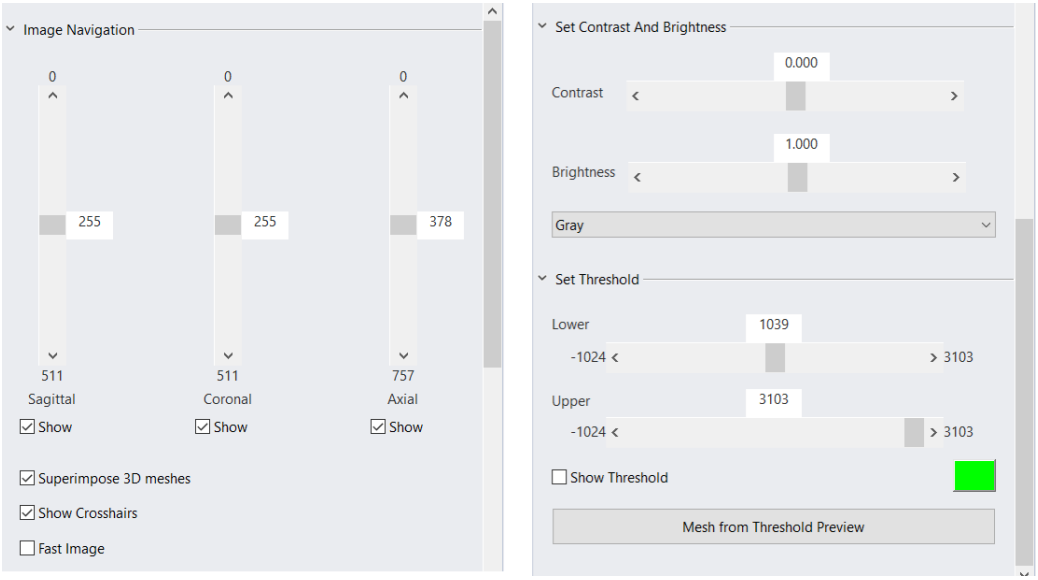

Fig. 8: Image Analysis tab.

5.1 Image Navigation and Show Slices

Use the Image Navigation control bars to navigate the slices of the volumetric medical image in 3D view. *Axial* corresponds to *Top*, *Sagittal* to *Front* and *Coronal* to *Right*. **Double-click with left mouse button on any point inside Top/Front/Right view to move all slices to its intersection**. **Check/uncheck *Show* boxes to show/hide the corresponding image slices in Perspective** (Fig. 9).

Fig. 9: Show Slices boxes and their effect on the Perspective view.

5.2 Superimpose 3D meshes

When checked, *Superimpose 3D meshes* box shows the intersection of the medical image with all 3D meshes and 3D objects presents in the scene, with the same color of these objects. When unchecked, all meshes and 3D objects in the scene are visible with priority over the medical image (Fig. 10).

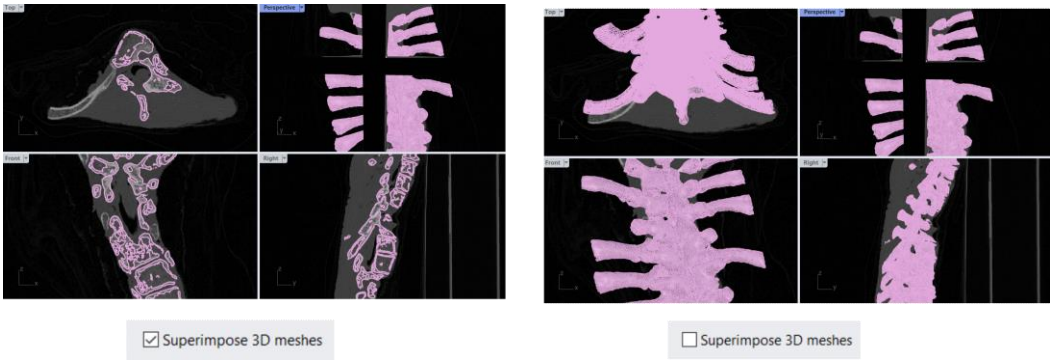

Fig. 10: Superimpose 3D meshes box and its effect on the 3D view.

5.3 Show Crosshairs

Show Crosshairs checkbox shows/hides the wireframe surrounding the medical image (Fig. 11).

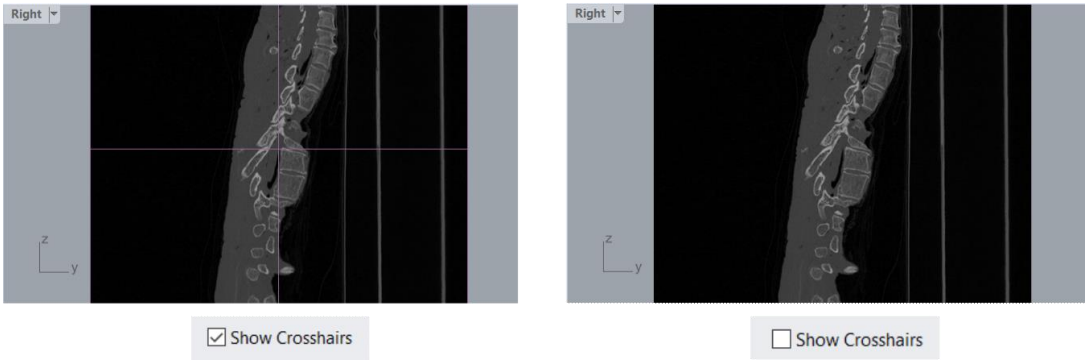

Fig. 11: Show Crosshairs effect on the wireframe surrounding the medical image.

5.4 Fast Image

Fast Image checkbox makes a simplification of the image (Fig. 12), so that navigation controls become faster for interaction. This is particularly needed when the resolution of the image is so high that normal navigation is very slow (for example, for X-Ray images). Although *Fast Image* makes the image look with low-resolution, all following commands in analysis and segmentation (like meshing) are always based on the original image.

Fig. 12: Fast Image control.

5.5 Contrast and brightness

Contrast and brightness controls enhance these properties (Fig. 13). Drop-down *Gray* menu allows to change color and tonality of the medical image to more warm or cold ones.

Fig. 13: Contrast and brightness controls.

5.6 Set threshold

Use *Lower* and *Upper* threshold controls to define a region of interest in your medical image (Fig. 14 left). Check *Show Threshold* to show the region in color (green by default). The color can be changed by clicking on the color box.

If you press button *Mask from Threshold Preview*, a window will appear to show the region of interest in 3D (Fig. 14 right). You can modify the lower threshold live, and already create a mesh with everything that is shown. **To navigate the 3D view, hold mouse right-button to rotate, use mouse wheel to zoom the scene, and press Shift key and hold mouse right-button to move the scene**. Press *Reset Camera* to return the camera to its default position. The color code denotes connected components: every colored

region is an isolated 3D connected component. Uncheck *Check Connectivity* to see everything in the same color. *Create Mesh* already extracts a 3D mesh containing all visible components.

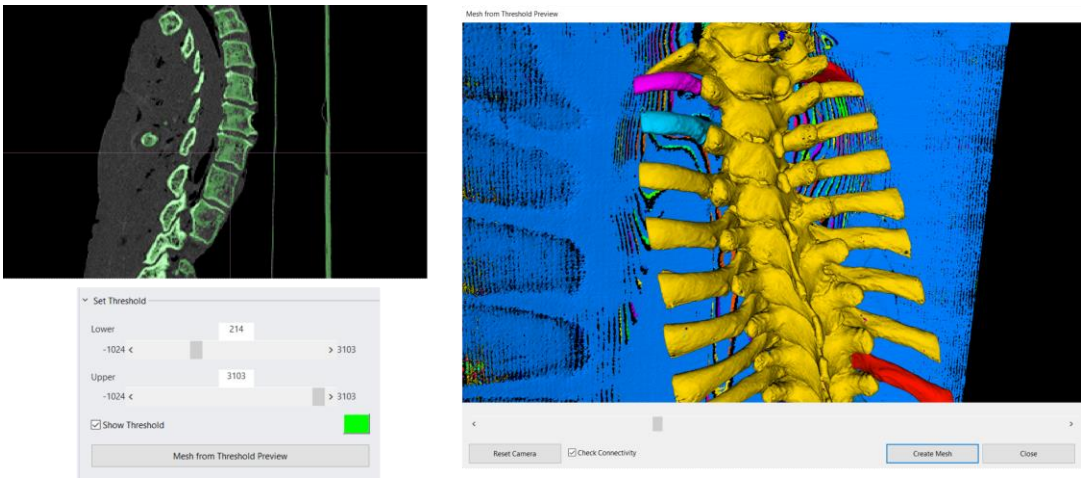

Fig. 14: Set Threshold and Mesh from Threshold Preview.

6 Segmentation

To perform segmentation and meshing tasks, press *Segmentation* button in the toolbar, type it in the command line or find it in the menu. The tab will open (Fig. 15, left). When creating 3D objects, this tab heavily relies on *Layer* tab. Call it by clicking on its icon (Fig. 15, right), or running command *Layer* in the command line. You can switch between *Segmentation* tab and *Layer* tab by clicking on their respective icons.

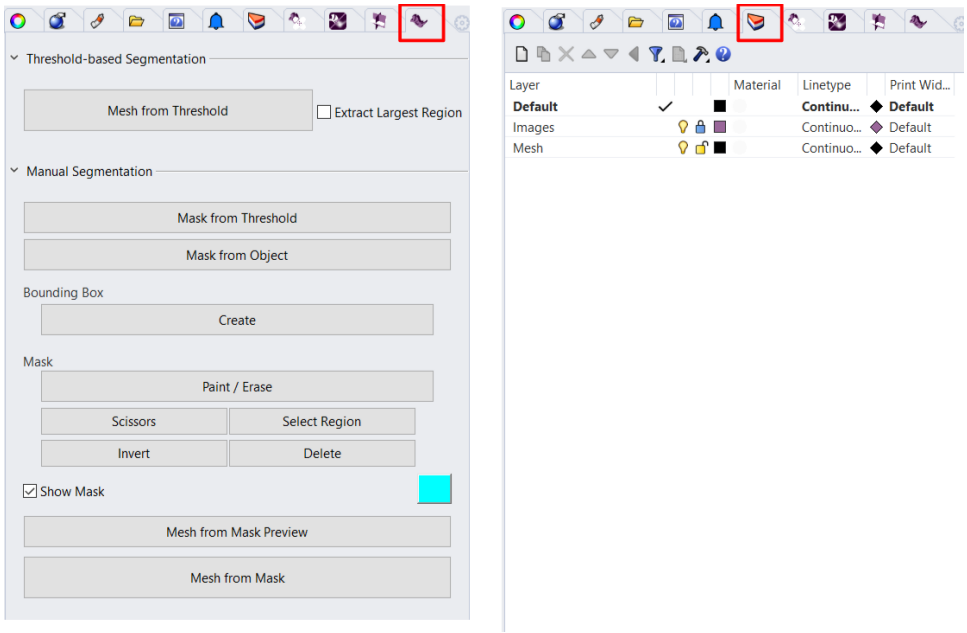

Fig. 15: Segmentation and Layers tab.

6.1 Mesh from Threshold

Mesh from Threshold takes the threshold set in *Image Analysis* and extracts a 3D mesh. Check *Extract Largest Region* to extract the biggest of the connected components of the thresholded region. If unchecked, this mesh coincides with the one of *Mesh from Threshold Preview Create Mesh* (from *Image Analysis*).

6.2 Layer and Shaded/Rendered controls

Once you start creating 3D meshes, check *Layer* tab to see the elements of the scene. They appear listed, and can be hidden (by clicking on the light bulb), and its color changed (by clicking on the color square). **Object *Images* denotes the 3D volumetric medical image, and its color relates to its surrounding wireframe**. Mesh objects naturally intersect with the medical image, and you can choose the color of this intersection in the *Layer* tab. **You can also enforce the visibility of the mesh objects in all projections, by unchecking *Superimpose 3D meshes* in *Image Analysis***. It is recommended also to uncheck *Show* in *Image Analysis* for the three projections (Axial, Sagittal, Coronal), so that they don't appear in Perspective view and the meshes can be properly seen.

In order to change mesh visibility, click on the arrow next to a view, and select *Shaded*. The mesh will appear solid, with the wireframe (Fig. 16, 17). You can change its color in the *Layer* tab. In order to see the mesh in a rendered view, click on the arrow next to a view and select *Rendered* (Fig. 18).

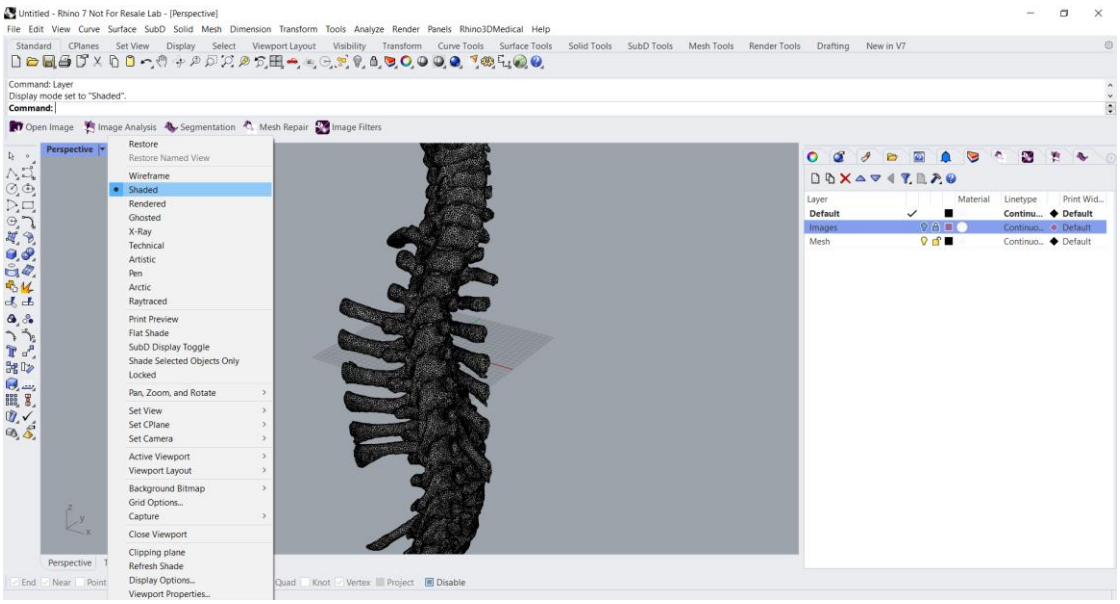

Fig. 16: Shaded Perspective.

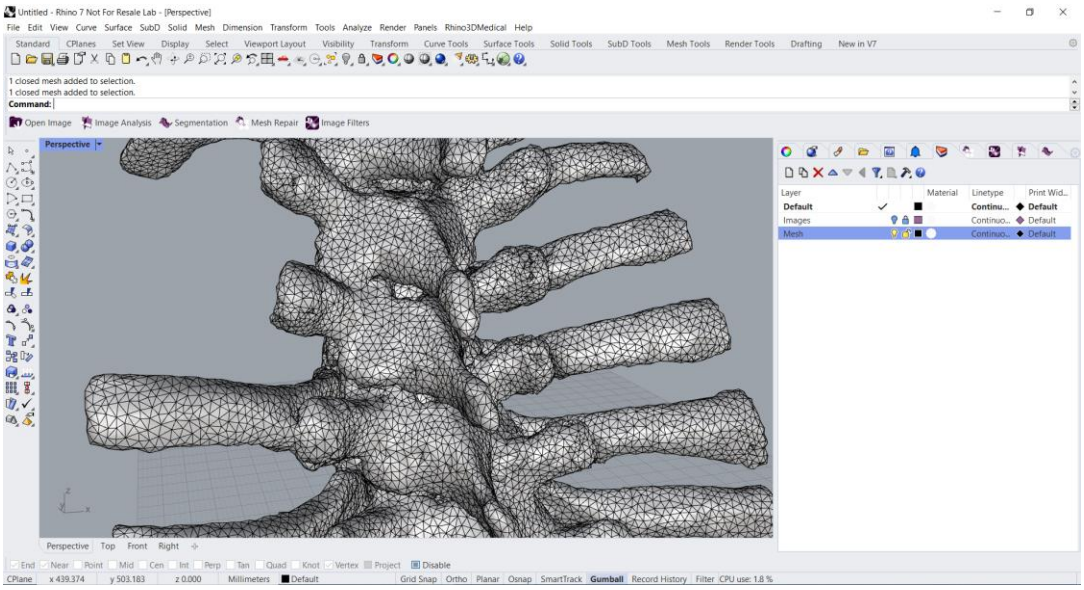

Fig. 17: Shaded Perspective with zoom.

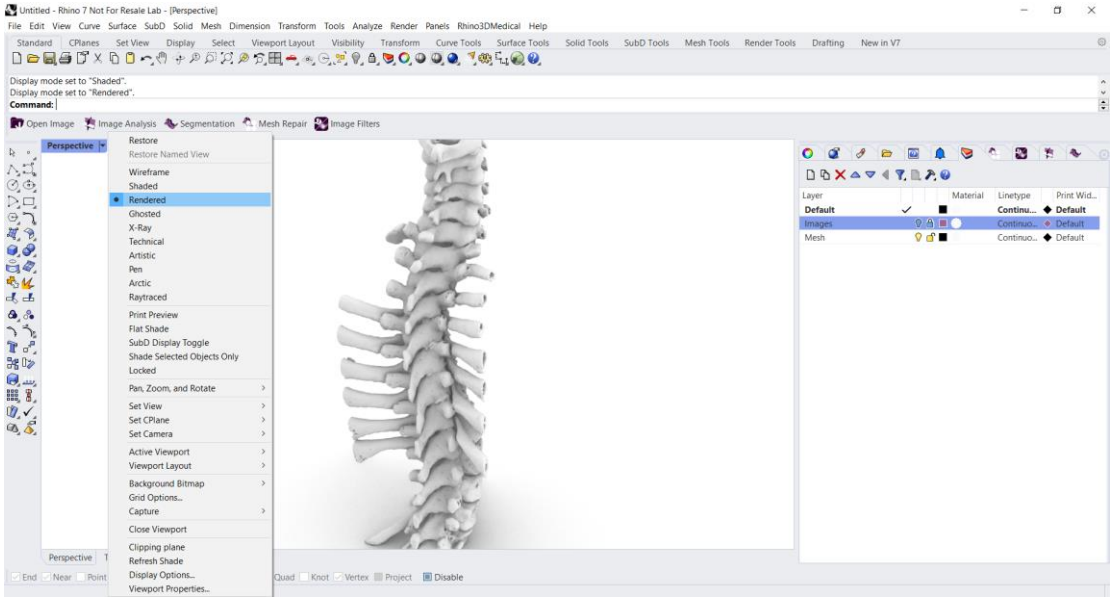

Fig. 18: Rendered Perspective.

6.3 Mask from Threshold

Mask from Threshold button converts the thresholded region defined in Image Analysis into a manual mask (Fig. 19). This mask can be later modified throughout subsection *Manual Segmentation*. You can show and hide the mask with checkbox *Show Mask*, and modify its color by clicking on the color square at bottom right. You can press *Mesh from Mask Preview* to see it in 3D view, and already extract its 3D mesh with *Mesh from Mask* button.

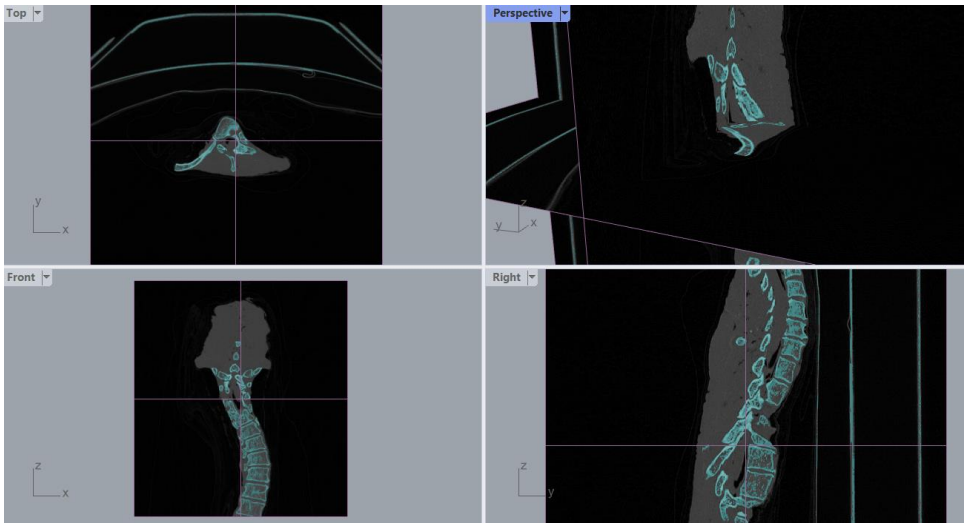

Fig. 19: Mask from Threshold.

6.4 Mask from Object

Mask from Object button gets as input any Rhino solid object, and lets you create a mask within the intersection of the object with the medical image. As in the example of Fig. 20, you can create a sphere object (left side of Rhino interface), place it over the medical image with the help of the gumball direction arrows, and press keyboard key *Enter*. An auxiliary window will let you visualize the interior of the object for a particular lower threshold. You can fine-tune this threshold live, and choose to add all visible region or only the largest one to the manual mask.

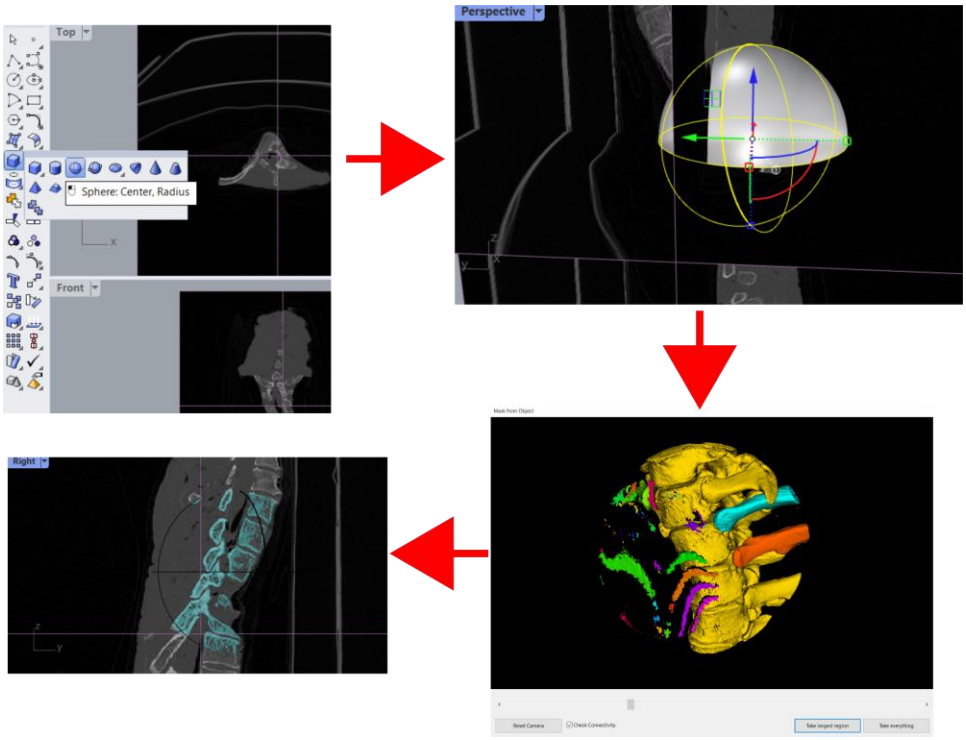

Fig. 20: Mask from Object.

6.5 Bounding Box

Press *Bounding Box* button to create a red box in any view (Fig. 21). Follow the steps in the command line to pick box center, corner and height. If there is a manual mask visible, the bounding box will clip it and show only its interior. If you click on *Mesh from Mask Preview* or *Mesh from Mask*, only the inside of the bounding box will be visible or extracted. The bounding box belongs to a layer called *Bounding Box*, and its color can be changed and visibility modified. To remove its effect, delete the bounding box (*Delete* key).

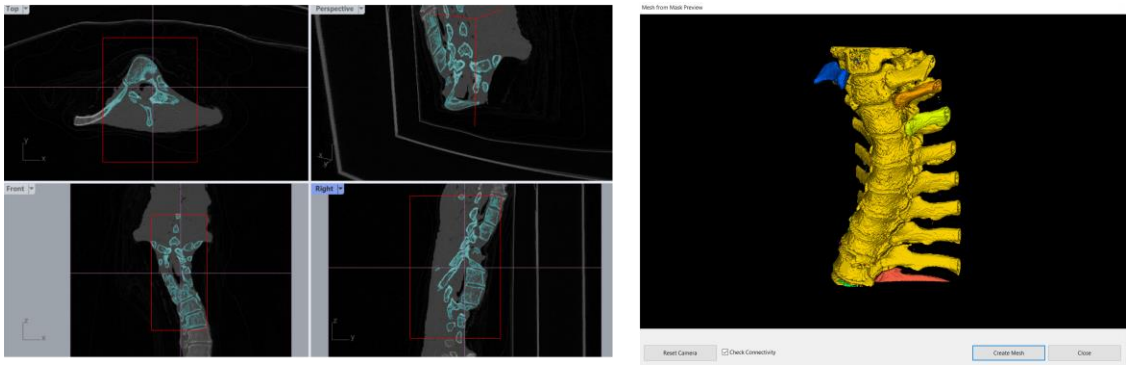

Fig. 21: Bounding Box and Mesh from Mask Preview.

6.6 Paint/Erase

Press *Paint/Erase* to add and remove manual details. A window will appear with several tools (Fig. 22). The main one is *Brush*, with which you can paint on top of any view over the medical image. Press and hold mouse left button to add area, and click over *Apply Selection* to add/remove it to/from mask, (option *Add to Mask/Remove from Mask*). You can delete the full brush area from a slice, or remove it from all slices with buttons *Delete on slice*, *Delete all*. When brushing, follow the instructions of the command line (remove area by holding *Shift* key, change the size of the brush live with *Alt* key). You can also change brush size and shape in the window. Use option *Fill Between Slices* if you have painted in several separated slices and want to interpolate in between.

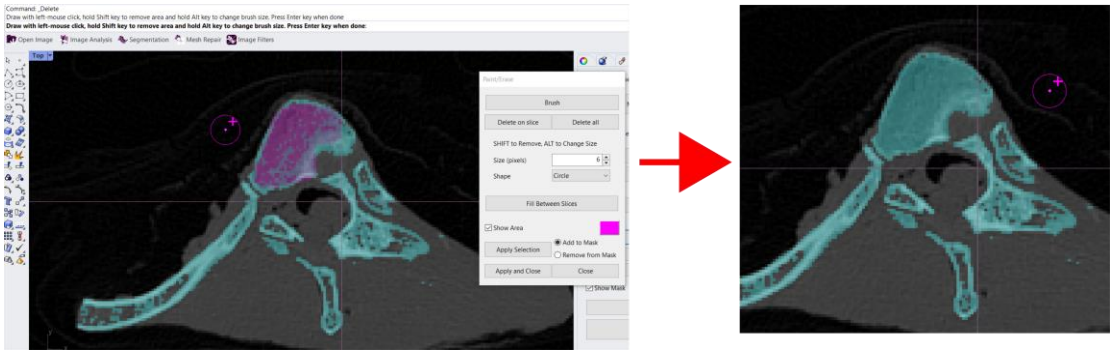

Fig. 22: Paint Erase window and effect of painting on mask.

6.7 Scissors

Scissors button enables a temporary brush that directly removes material from the mask (Fig. 23). Contrary to the *Paint/Erase* brush, the one of *Scissors* affects all the slices in the projected view. It has the goal of disconnecting the two sides of the mask.

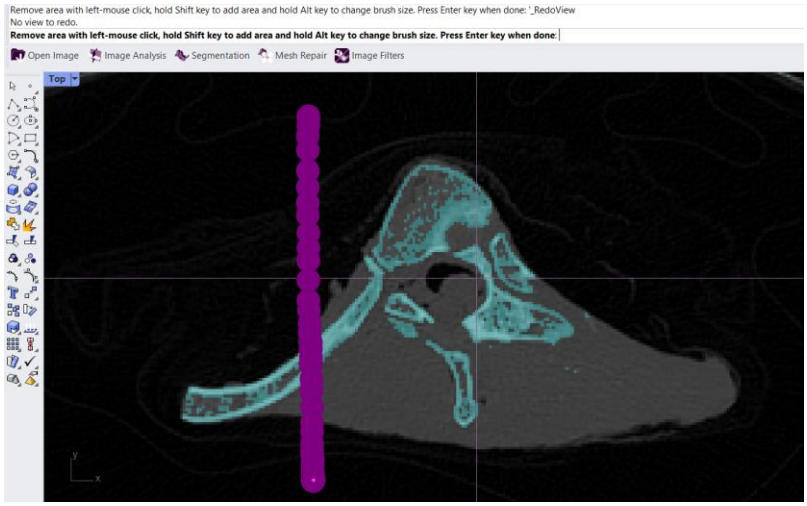

Fig. 23: Scissors effect on mask.

6.8 Invert and Delete

Invert button literally inverts the manual mask (Fig. 24): every part of the image that was not mask, becomes mask, and every part that was mask becomes not mask. This may be needed to extract the negative shape of a 3D reconstruction. *Delete* button removes all existing mask.

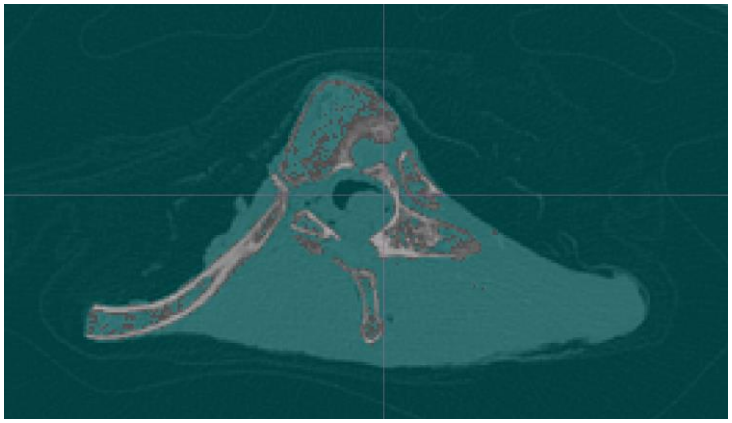

Fig. 24: Invert mask.

6.9 Select Region

Select Region button lets you select a point over the medical image, and extracts the biggest connected component containing it (Fig. 25).

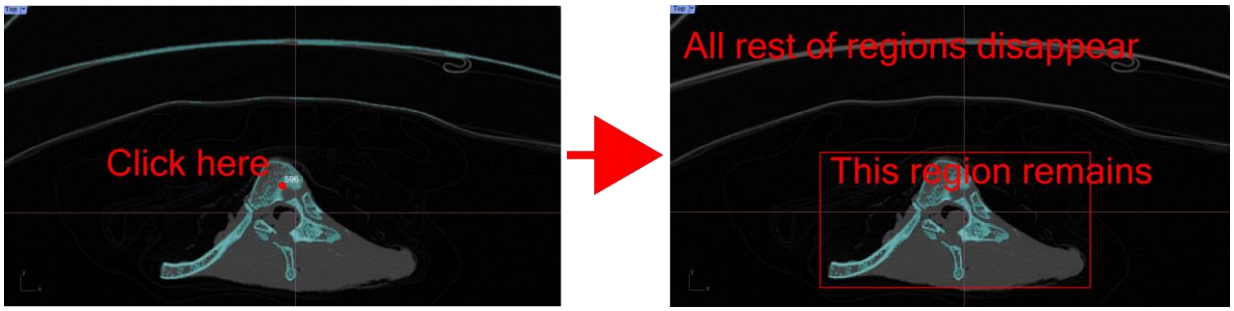

Fig. 25: Select Region.

6.10 Mesh from Mask and Preview

Mesh from Mask button can be pressed at any time since creation of a manual mask. It extracts the corresponding manual mask as a 3D mesh (Fig. 26). *Preview* button quickly visualizes the 3D mask without extracting it to the 3D view. Use this functionality together with that shown in subsection 6.2 to make the most out of it.

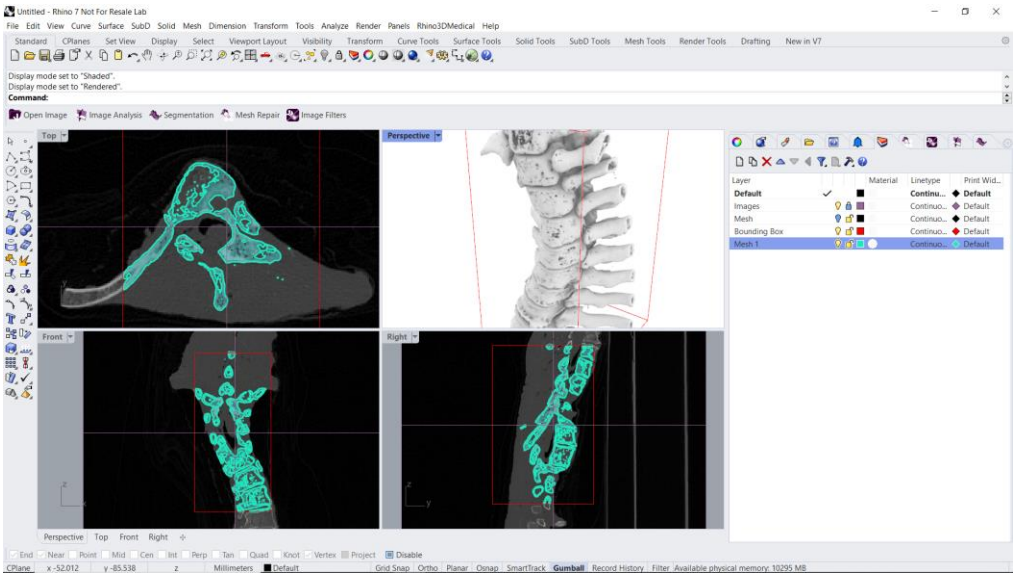

Fig. 26: Mesh from Mask.

7 Mesh Repair

Mesh Repair tab (Fig. 27) contains specific tools to process 3D meshes. To open it, press *Mesh Repair* button in the toolbar, type it in the command line or find it in the menu. All commands in this section take as input any 3D mesh, and give as output a new 3D mesh. In most cases the mesh is placed in a new layer with a distinguishable name. It is recommended to open *Layer* tab (see subsection 6.2), hide the original mesh and show the new one. The gumball can be used (the color arrows showing when the mesh is selected) to move the new mesh to a different position.

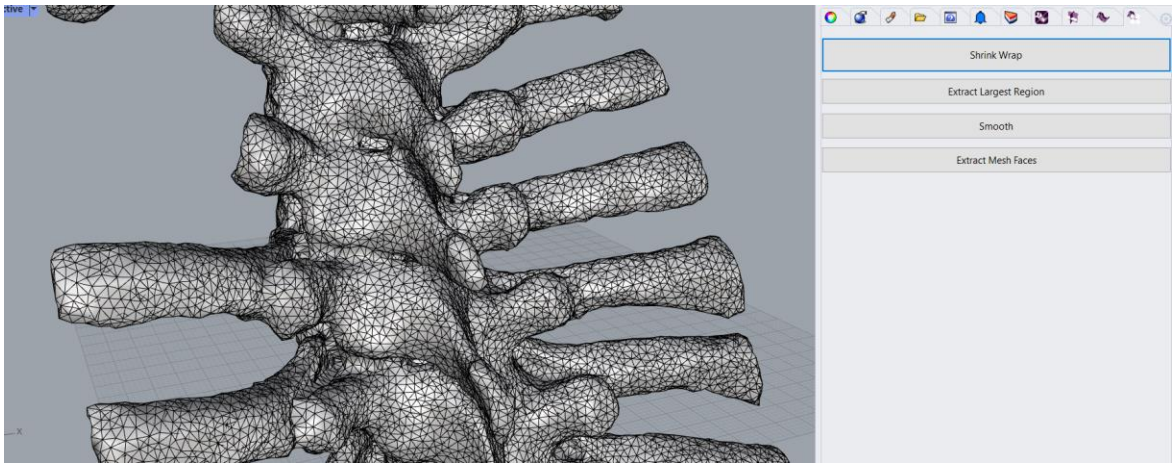

Fig. 27: Mesh Repair tab.

7.1 Shrink Wrap

Shrink Wrap wraps the input mesh with a high-quality solid object (Fig. 28). The resulting mesh fills holes and removes artifacts and intersections. When running it, command line displays parameters *Alpha* and *Offset*. These parameters control, in the case of alpha, how fine the wrapping is done, and in the case of offset the relative precision with respect to the original mesh. If the output mesh is not satisfactory, it is recommended to try different parameters of alpha up from 3'000, until 5'000. Same for offset in case the precision of the output mesh is not enough.

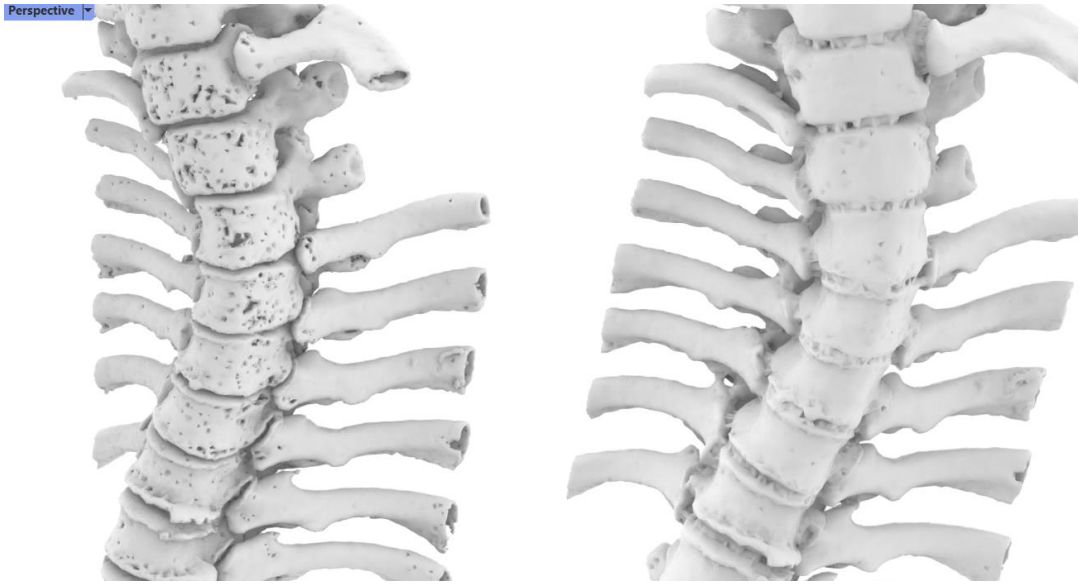

Fig. 28: Original mesh at left, and Shrink Wrap mesh at right.

7.2 Extract Largest Region

This command takes the original mesh and creates a new one containing the largest connected component of the original one. It is a useful command to remove isolated small artifacts from a given mesh.

7.3 Smooth

This command smoothens the input mesh, locally flattening areas with sharp geometry (Fig. 29). The intensity of the command is controlled by two parameters in the command line: Iterations and s*moothing*. Both can be modified to make the effects proportionally more or less pronounced, specially the smoothing factor which can go up to 1.0.

Fig. 29: Smooth mesh.

7.4 Extract Mesh Faces

Extract Mesh Faces runs a brush that can be placed over the input mesh by holding left mouse button (Fig. 30). After pressing keyboard key *Enter*, the painted area will appear as a separate set of mesh faces, that behaves as a new independent mesh. This command creates meshes on the surface of the input mesh, to be used later for offsetting or solid operations.

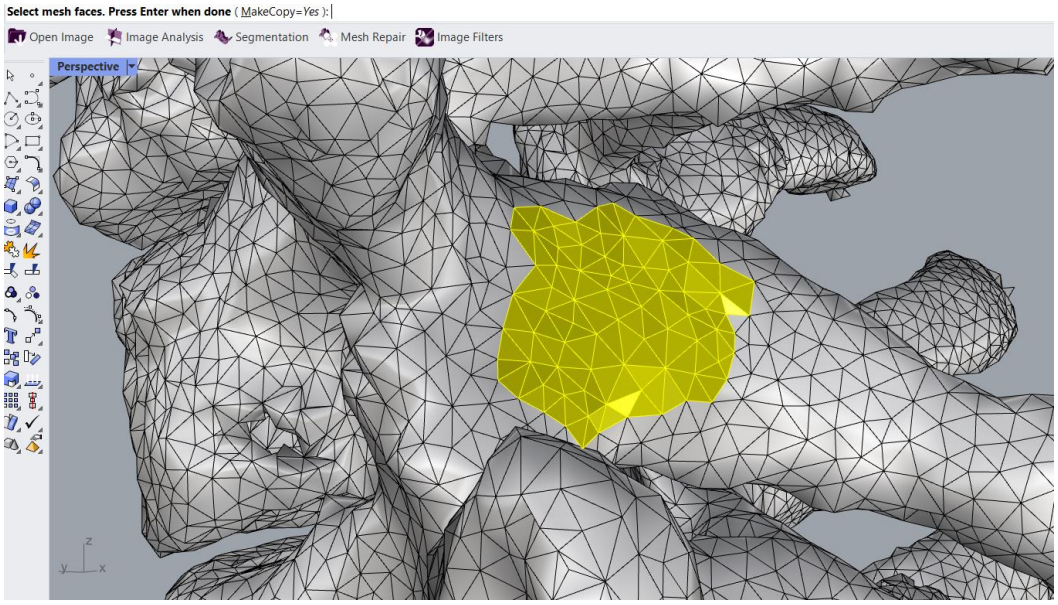

Fig. 30: Extract Mesh Faces.

8 Image Filters

Image Filters tab (Fig. 31) contains specific tools to process medical images. To open it, press *Image Filters* button in the toolbar, type it in the command line or find it in the menu. All commands in this section take as input the medical image, and give as output a new medical image. If *Preview* checkbox is checked, the new image is just a preview and does not replace the original one. If *Apply* button is pressed, the new image completely replaces the original one. Every filter has its own set of input variables, which may be accessed and modified upon selecting the corresponding filter.

Current list of filters include (Fig. 32):

- *Close*: remove small bright areas.
- *Dilate*: increase bright areas.
- *Erode*: increase dark areas.
- *Flip*: flip image axis in X, Y or Y direction.
- *Gradient*: detect edges.
- *Median*: reduce noise by taking the median image intensity over local regions.
- *Open*: remove small dark areas.
- *Ridge Detector*: detect ridges.
- *Smooth*: reduce noise by averaging the image intensities over local regions.
- *Voxel Spacing*: rescale the spacing of the image unit voxel in X, Y or Z direction.

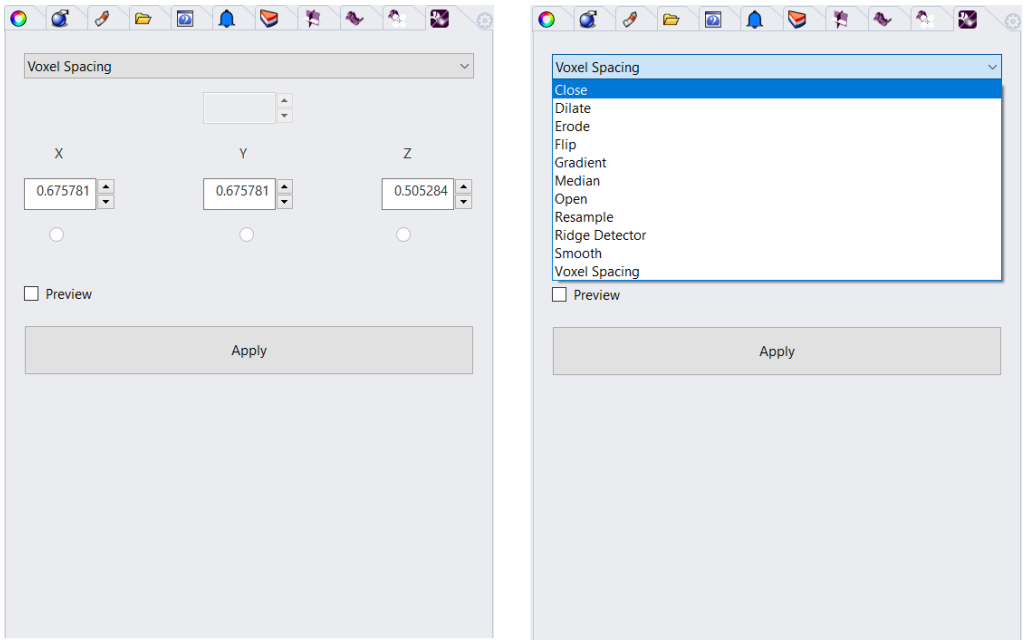

Fig. 31: Image Filters tab and filter options.

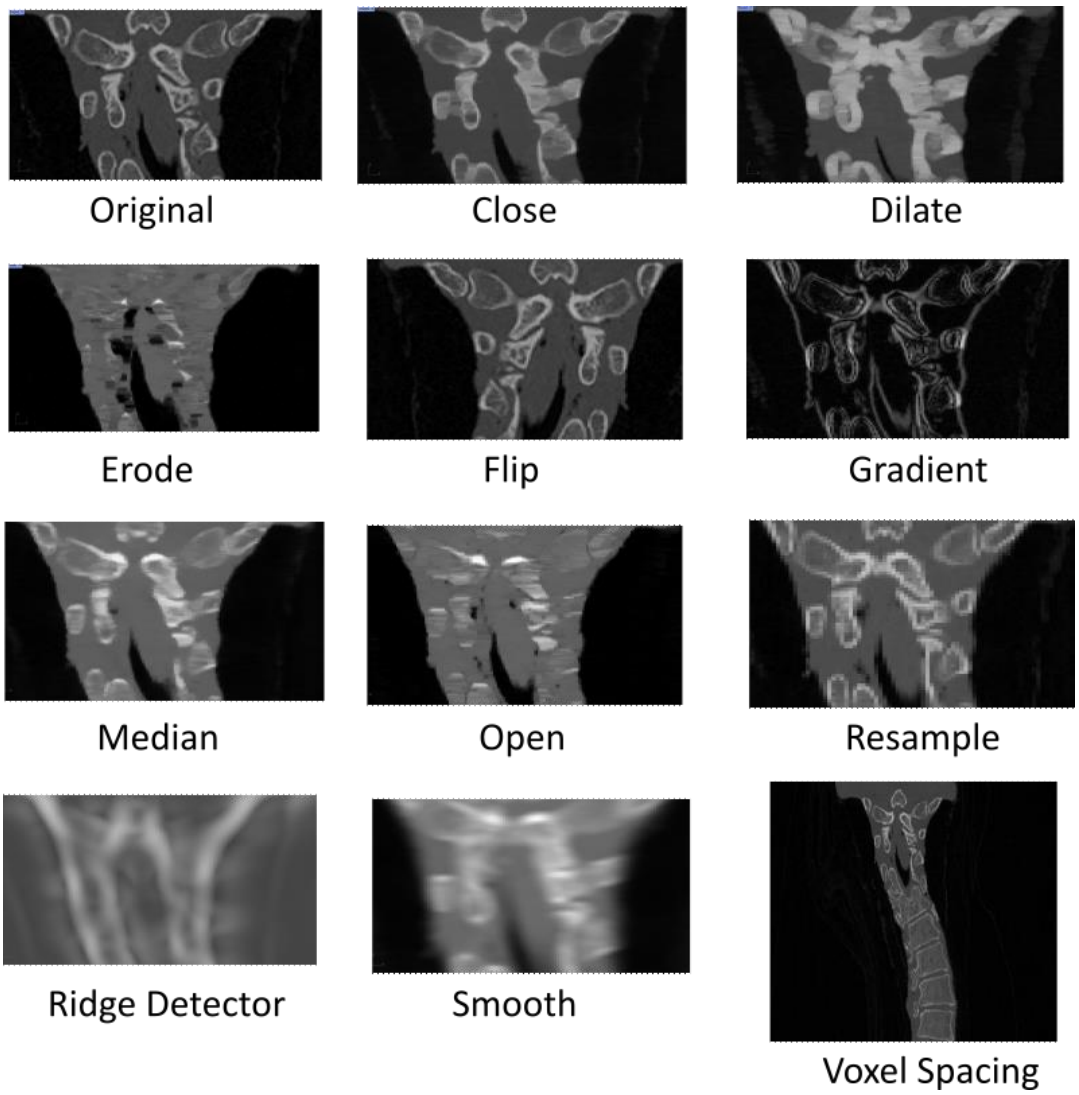

Fig. 32: Image Filters and effects.

9 R3DMedical interface

When installing Rhino3DMedical, a second icon will appear on your desktop, called R3DMedical (Fig. 33). If you open it, you will be shown a simplified version of Rhino 7 (Fig. 34), that we call R3DMedical interface. This is a work-in-progress interface where special modules for clinical use are placed. Currently there are two particular modules: orbit and joint separation.

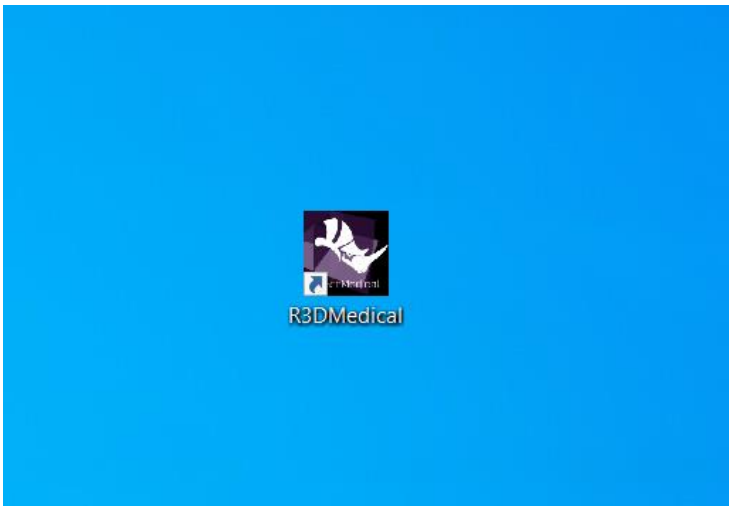

Fig. 33: Desktop view with icon of R3DMedical.

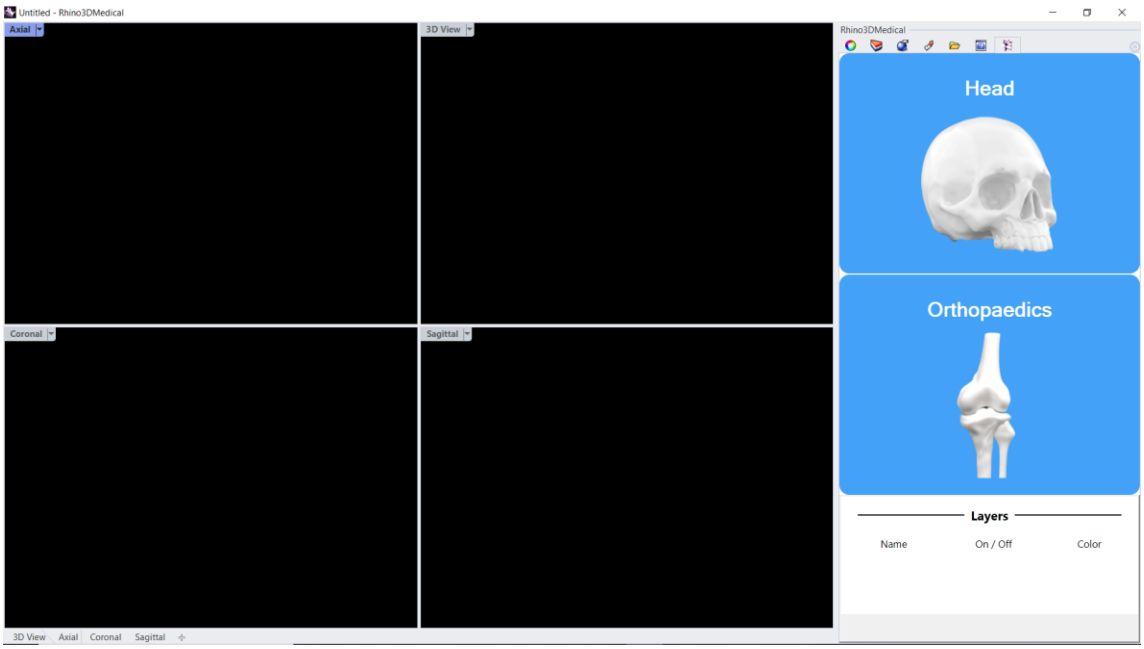

Fig. 34: R3DMedical interface.

9.1 Orbit module

Orbit module is accessed through *Head* option in R3DMedical interface. Follow the instructions on screen to open a medical scan of a head, and segment one or two orbital cavities (Fig. 35). The controls at the right of the program help navigate the image and perform thresholding, segmentation and meshing operations.

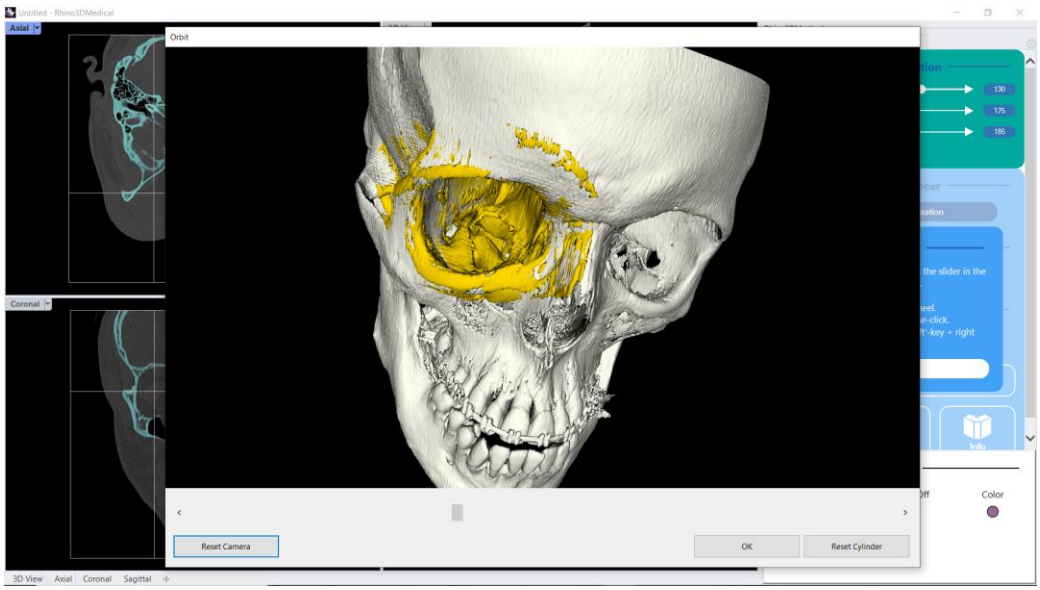

Fig. 35: Orbit module.

9.2 Joint Separation module

Joint Separation module is accessed through Orthopaedics option in R3DMedical interface. Follow the instructions on screen to open a medical scan of hip or pelvis, perform segmentation operations and separate the femoral head from the acetabulum with a 3D half-sphere (Fig. 36).

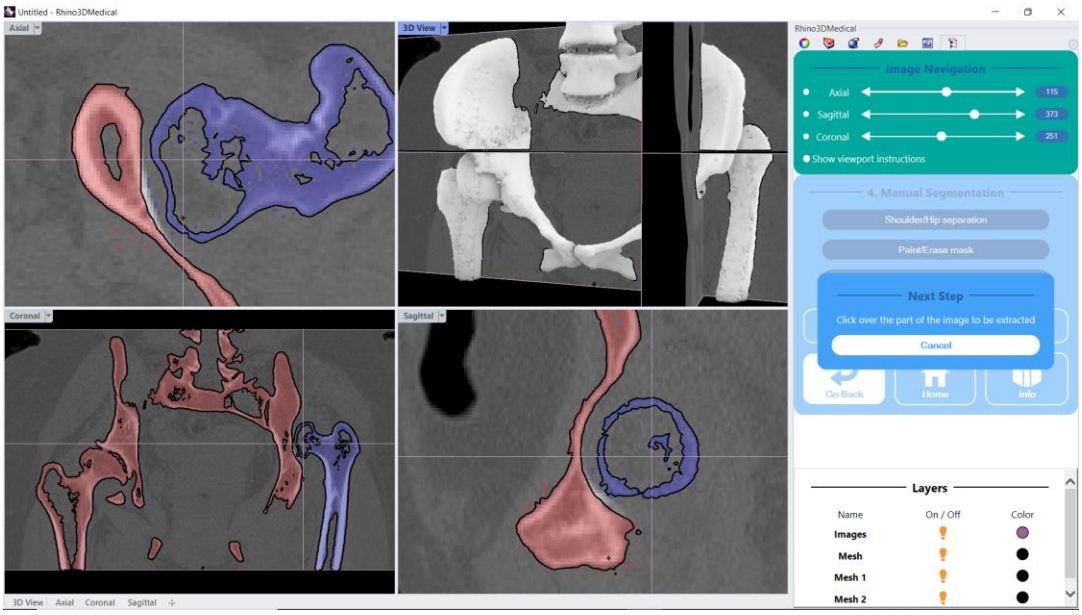

Fig. 36: Joint Separation module.

10 Menu items

The menu of Rhino3DMedical (Fig. 2) gives access to the same main elements of Rhino3DMedical: *Open Image*, *Image Analysis*, *Segmentation*, *Mesh Repair* and *Image Filters* tabs. In addition, it features the two modules of R3DMedical interface *Orbit* and *Joint Separation*. It also has a few exclusive commands, that we divide in three categories: export/import masks, slicing plane and MRI Bias Field Correction.

10.1 Export/Import masks

These menu items export and import medical images and masks into files out of Rhino3DMedical:

- *Export Image* exports current medical image to an image of format MHD, MHA, TIFF, NIFTI or NRRD.
- *Import Manual Mask* prompts to select an image file (any of the image formats is correct though the most convenient one for pure masks is TIFF). A normal image can also be imported as mask (hence setting any non-zero voxel intensity as 1 and all zero voxel intensities as 0). The command will then import this image as mask on top of current medical image. It only works if there is a medical image opened.
- *Export Manual Mask to TIFF* exports current manual mask to a TIFF file.
- *Export Masked Image* exports the superposition of the currently active image with the current mask (Fig. 37). It creates a new image which keeps the image voxel intensities where the mask values are 1, and uniform background intensities elsewhere.

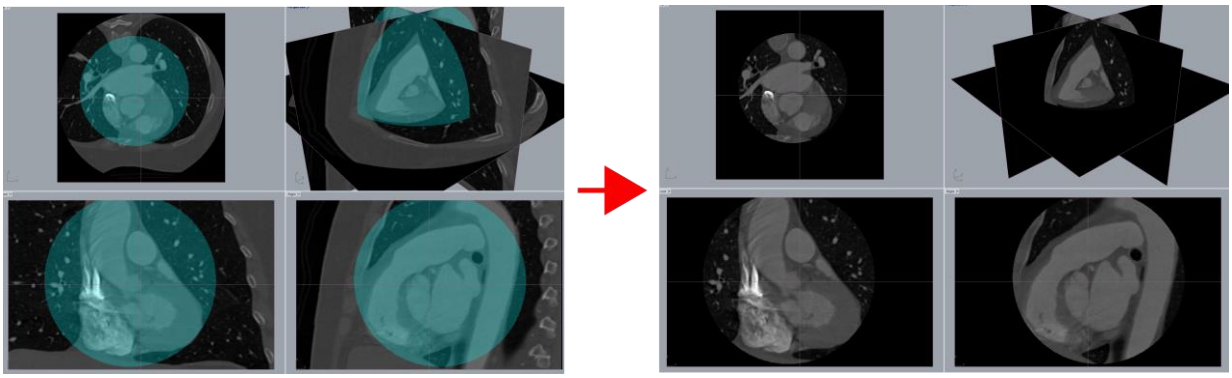

Fig 37: Mask at left and Masked Image at right.

10.2 Slicing Plane

Menu item *Slicing Plane* prompts instructions in the command line to create a rectangle in any view. After creation, this rectangle intersects the medical image, in any orientation of the plane (Fig. 38). Select the plane and use the gumball (colored arrows, circles and squares close to its center) to enlarge and rotate it. The Slicing Plane has its own associated layer in the *Layer* tab.

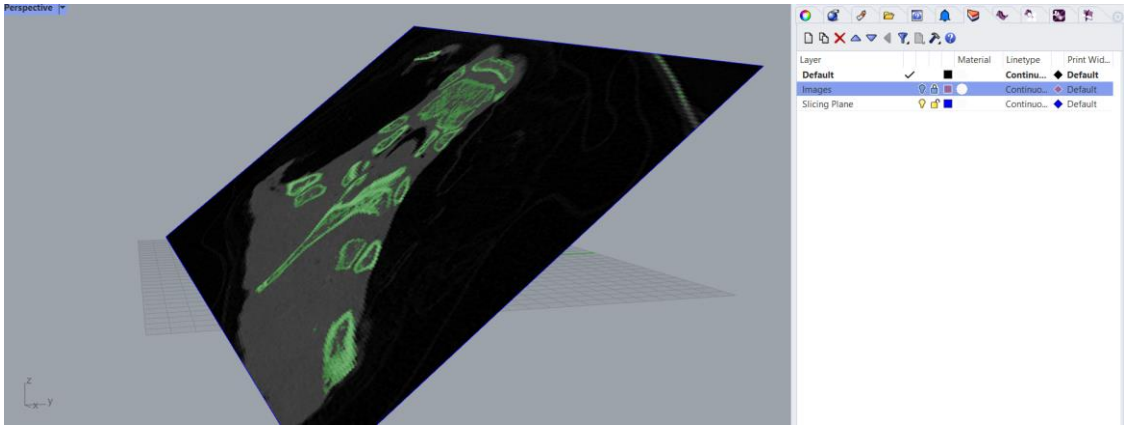

Fig. 38: Slicing Plane.

10.3 MRI Bias Field Correction

When processing MRI images, quite often the intensities are not evenly distributed: we observe that some parts of the image are brighter than the rest while some others are darker, in a gradual and smooth fashion. This is due to the behavior of the transmit/receive coil operating in MRI scanning, which in effect is adding an undesired bias field to the signal.

Menu item *MRI Bias Field* applies an optimization algorithm to estimate this bias field and subtract it from the input signal (Fig. 39). It operates on the current image and gets a number of iterations through the command line as input (write the number and press *Enter*, default value is 100). This number of iterations restricts the optimization length: the bigger the number of iterations, the better the final reconstruction, but the slower to eventually give a result.

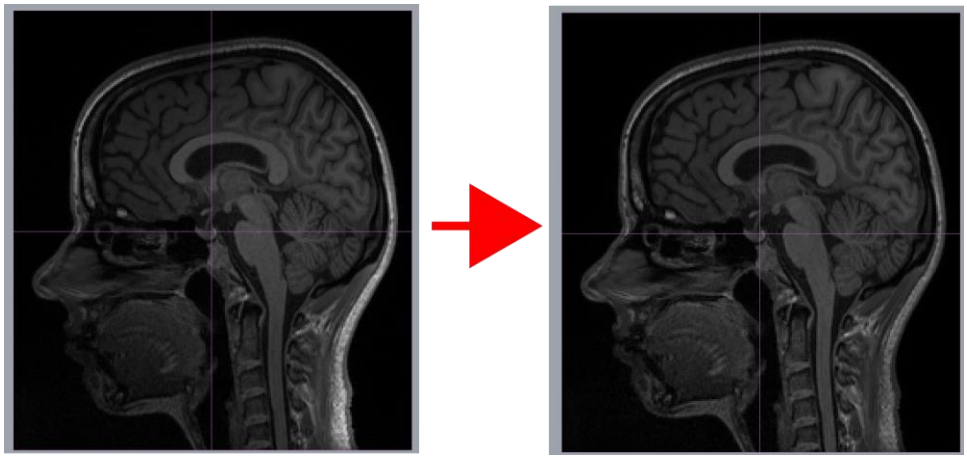

Fig. 39: MRI scan before and after applying bias field correction.

11 Grasshopper toolbox

Grasshopper is a cutting-edge parametric modelling environment included within Rhino 7. It provides a coding platform for you to create your own automated scripts using a rich ecosystem of third-party plug-

ins. These plug-ins are in the form of building blocks, also called components, that you can call (as an Application Programming Interface) in your own customized scripts. Therefore, you can automate your own processes and routines through the use of these components. Rhino3DMedical automatically installs a set of components in Grasshopper, which include most of the functionality seen in this manual. More information on Grasshopper itself in https://www.grasshopper3d.com/.

To open Grasshopper, click on Grasshopper icon in Rhino (Fig. 40) or type in the command line *Grasshopper*. A new window will open, with a new environment providing access to a flat scene, and a menu with all components installed. This menu contains the components of Rhino3DMedical. In the following we provide a list of all Rhino3DMedical components: 

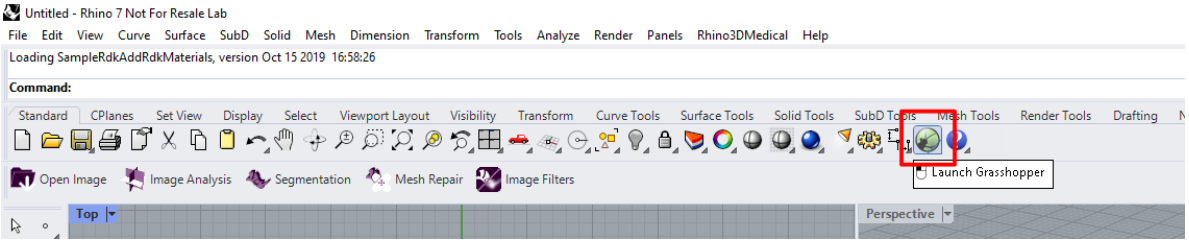

Fig. 40: Grasshopper icon inside Rhino.

11.1 Analysis components

Extract Slice

- Get a single slice
  - The slice is returned as a mesh with vertex colors
- IN Image (I) [**custom object** no default]
- IN Plane (P) [**integer** default=0]
  - 0 = XY, 1 = XZ, 2 = YZ
- IN Number (N) [**number** default=0]
  - slice number to be displayed
  - clamped to the extents if it exceeds them
- OUT Slice (S) [**mesh**]
  - The resulting mesh with vertex colors

Get Bounding Box

- Get the bounding box of an image
- IN Image (I) [**custom object** no default]
- OUT BBox (B) [**box**]

Get Extents

- Get the extents of an image in the X, Y and Z direction
    - The extents are the valid indices in any direction, useful for the **ExtractSlice** component
- IN Image (I) [**custom object** no default]
- OUT XExtents (X) [**interval**]
- OUT YExtents (Y) [**interval**]
- OUT ZExtents (Z) [**interval**]
    - The size in the X, Y, and Z dimension

Get Range

- Get the intensity range of an image
- IN Image (I) [**custom object** no default]
- OUT Range (R) [**interval**]

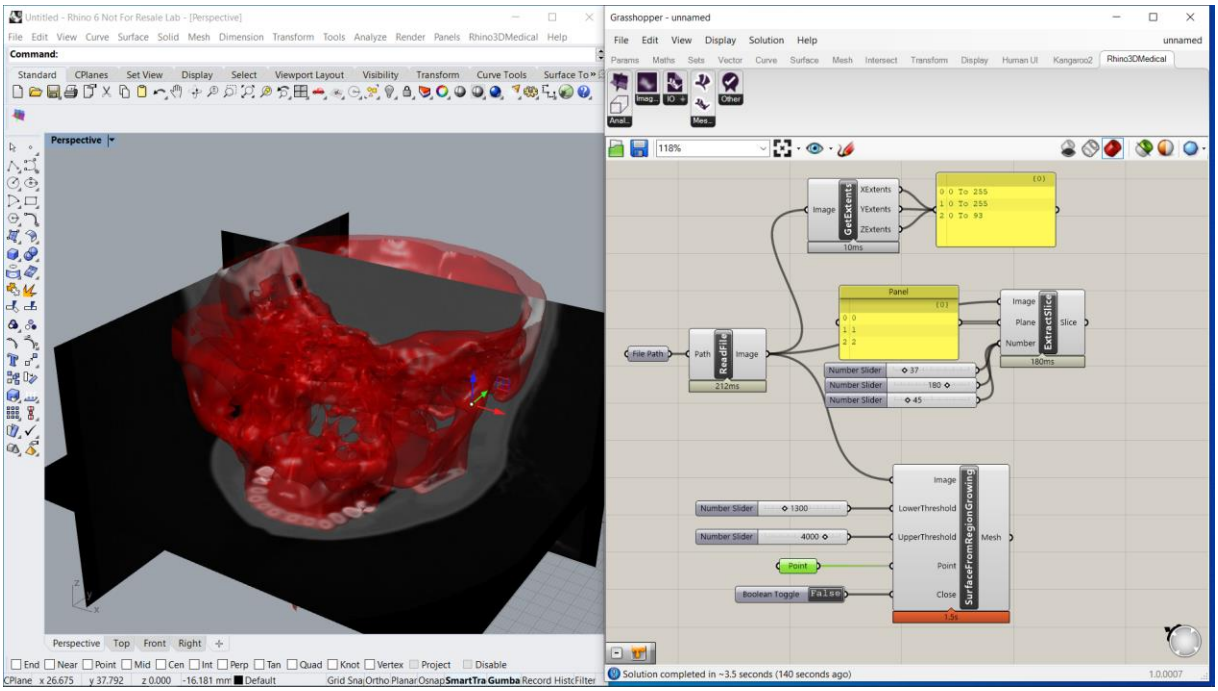

Fig. 41: Rhino3DMedical in Grasshopper for image analysis.

11.2 Image Filters

Close

- Applies closing operation to a 3D volume
    - Removes small holes (dark areas) from the image
    - Equivalent to dilation followed by erosion
- IN Image (I) [**custom object** no default]

- IN Size (S) [**integer** default=5]
    - Size of the dilation and erosion kernel
- OUT Image (I) [**custom object**]

 **Dilate**

- Applies dilation operation to a 3D volume
    - Enhances objects (bright areas)
- IN Image (I) [**custom object** no default]
- IN Size (S) [**integer** default=5]
    - Size of the dilation kernel
- OUT Image (I) [**custom object**]

 **Erode**

- Applies erosion operation to a 3D volume
    - Enhances holes (dark areas)
- IN Image (I) [**custom object** no default]
- IN Size (S) [**integer** default=5]
    - Size of the erosion kernel
- OUT Image (I) [**custom object**]

 **Gradient**

- Computes the magnitude of the gradient of the image
- IN Image (I) [**custom object** no default]
- OUT Image (I) [**custom object**]

 **Median**

- Compute the local median for each pixel
    - Useful for noise removal
- IN Image (I) [**custom object** no default]
- IN Size (S) [**integer** default=5]
    - Size of the median kernel
- OUT Image (I) [**custom object**]

 **Modify Origin Spacing Flipping**

- Modify Origin Spacing Flipping
- IN Image (I) [**custom object** no default]
- IN Origin Point (Orig) [**3D Point** default=Unset]

    - Point that will be the new origin
- IN Spacing X (SpacX) [**number** default=0]
    - Voxel spacing X coordinate
- IN Spacing Y (SpacX) [**number** default=0]
    - Voxel spacing Y coordinate
- IN Spacing Z (SpacX) [**number** default=0]
    - Voxel spacing Z coordinate
- IN Flipping X (FlipX) [**boolean** default=false]
    - Flip image along X axis
- IN Flipping Y (FlipY) [**boolean** default=false]
    - Flip image along Y axis
- IN Flipping Z (FlipZ) [**boolean** default=false]
    - Flip image along Z axis
- OUT Image (I) [**custom object**]

 **Open**

- Applies opening operation to a 3D volume
    - Removes small objects (bright areas) from the image
    - Equivalent to erosion followed by dilation
- IN Image (I) [**custom object** no default]
- IN Size (S) [**integer** default=5]
    - Size of the dilation and erosion kernel
- OUT Image (I) [**custom object**]

 **Smooth**

- Applies gaussian smoothing to a 3D volume
- IN Image (I) [**custom object** no default]
- IN Size (S) [**number** default=3.0]
    - Size of the gaussian blur kernel
- OUT Image (I) [**custom object**]

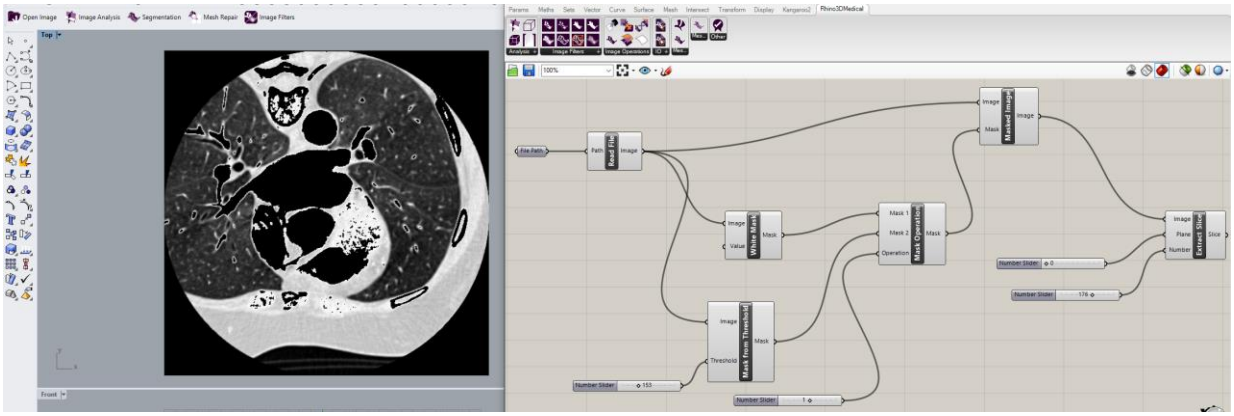

Fig. 42: Rhino3DMedical in Grasshopper for mask operations.

11.3 Image Operations

Invert Mask

- Invert the input mask: 1 goes to 0 and 0 goes to 1
- IN Mask (M) [**custom object** no default]
- OUT Mask (M) [**custom object**]

Masked Image

- Create an image from the superposition of an image and a mask
- IN Image (I) [**custom object** no default]
- IN Mask (M) [**custom object** no default]
- OUT Image (I) [**custom object**]

Masked Image from Threshold

- Create an image from the superposition of an image and a threshold
- IN Image (I) [**custom object** no default]
- IN Threshold (T) [**number list** no default]
    - Thresholds for image extraction
- OUT Image (I) [**custom object**]

Mask from Mesh

- Extract a binary mask from an image and a closed mesh
- IN Image (I) [**custom object** no default]
- IN Mesh (M) [**mesh** no default]
    - Input mesh, closed

- OUT Mask (M) [**custom object**]

Mask from Threshold

- Extract a binary mask from an image and a threshold
- IN Image (I) [**custom object** no default]
- IN Threshold (T) [**number list** no default]
  - Thresholds for mask extraction
- OUT Mask (M) [**custom object**]

Mask Operation

- Perform mask operation of addition, subtraction or intersection
- IN Mask 1 (M1) [**custom object** no default]
- IN Mask 2 (M2) [**custom object** no default]
- IN Operation (O) [**integer** default=0]
  - 0 = Add, 1 = Subtract, 2 = Intersect
- OUT Mask (M) [**custom object**]

White Mask

- Create a white mask with the image extents and dimensions
- IN Image (I) [**custom object** no default]
- IN Value (V) [**boolean** default=true]
  - Value of the output mask
- OUT Mask (M) [**custom object**]

11.4 IO

Read File

- Read a MetaImage, NIFTI, DICOM, NRRD, TIFF file
  - To read a DICOM series, input the path of any file in the series
- IN Path (P) [**text** no default]
  - The path to the file
- OUT Image (I) [**custom object**]
  - The 3D image object

Write Image

- Write Image
- IN Path (P) [**text** no default]

    - Path of a folder (for DICOM) or a file (for non-DICOM) with format .mhd/.mha/.tiff/.nii/.nrrd
- IN Initial DICOM Path (DICOMP) [**text** default=empty]
    - Path of the initial image to take DICOM header info from

11.5 Mesh Extraction

Surface from Region Growing

- Create the surfaces from a given 2 thresholds and a point
- IN Image (I) [**custom object** no default]
- IN LowerThreshold (LT) [**number** default=0]
- IN UpperThreshold (UT) [**number** default=1000]
    - Lower and upper threshold may also be flipped, which one has the smaller value is not important
- IN Point (P) [**3D Point** default=0,0,0]
    - The point from which to grow the region
- IN Close (C) [**boolean** default=false]
    - Whether to return a closed mesh
- IN Smooth (S) [**boolean** default=true]
    - Whether to produce a smooth output
    - If this is set to false, the result may have jagged bumps in it
- OUT Mesh (M) [**mesh**]

Surface from Threshold

- Create a surface from a given list of thresholds
- IN Image (I) [**custom object** no default]
    - The 3D image object
- IN Threshold (T) [**number list** no default]
    - Thresholds for extracting the mesh
    - If there are 2 thresholds a single closed surface can be created
- IN Close (C) [**boolean** default=false]
    - Whether to return a closed mesh or a surface
- IN Smooth (S) [**boolean** default=true]
    - Whether to produce a smooth output
    - If this is set to false, the result may have jagged bumps in it
- OUT Mesh (M) [**mesh**]

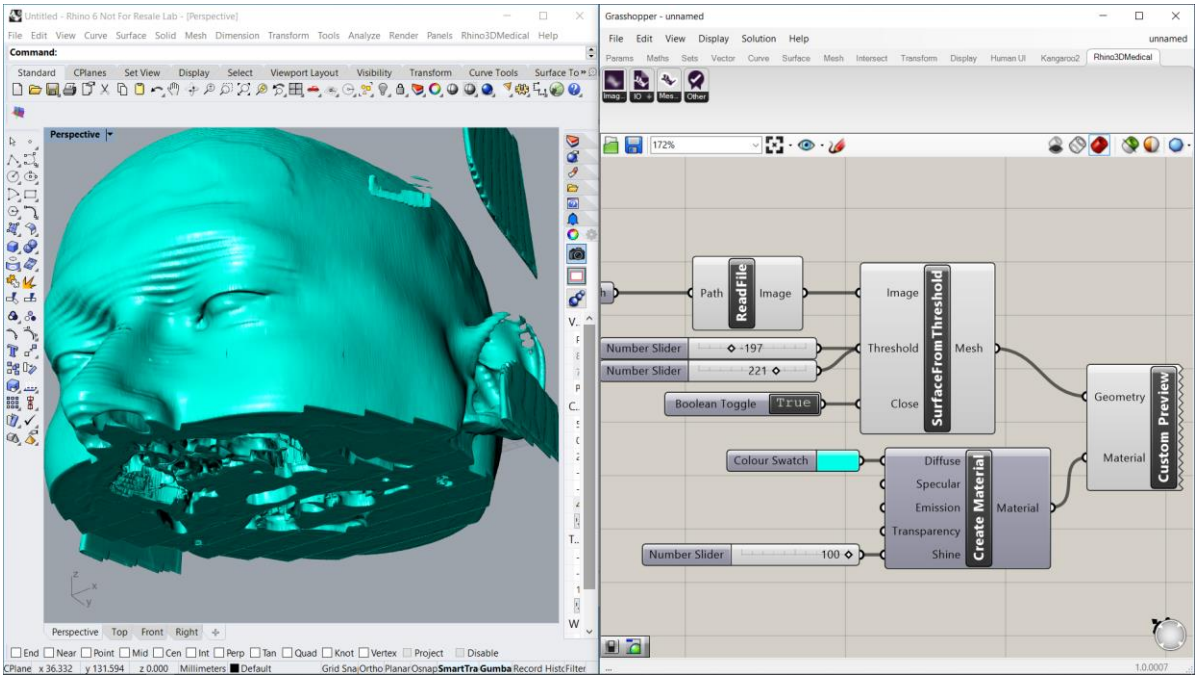

Fig. 43: Rhino3DMedical in Grasshopper for meshing.

11.6 Mesh Filters

MeshFilter Fill Holes

- Creates a closed mesh by filling any openings in a mesh
  - If the input mesh is closed this component doesn't modify it
- IN Mesh (M) [**mesh** no default]
  - Input mesh, open or closed
- OUT Mesh (M) [**mesh**]
  - Closed output mesh

11.7 Other

License

- Validate / disable / modify the installed license
- IN ShowWindow (S) [**boolean** default=false]
  - If true display the wizard for modifying the state of your license or activating another
- OUT IsValid (I) [**boolean**]
  - Whether license is valid