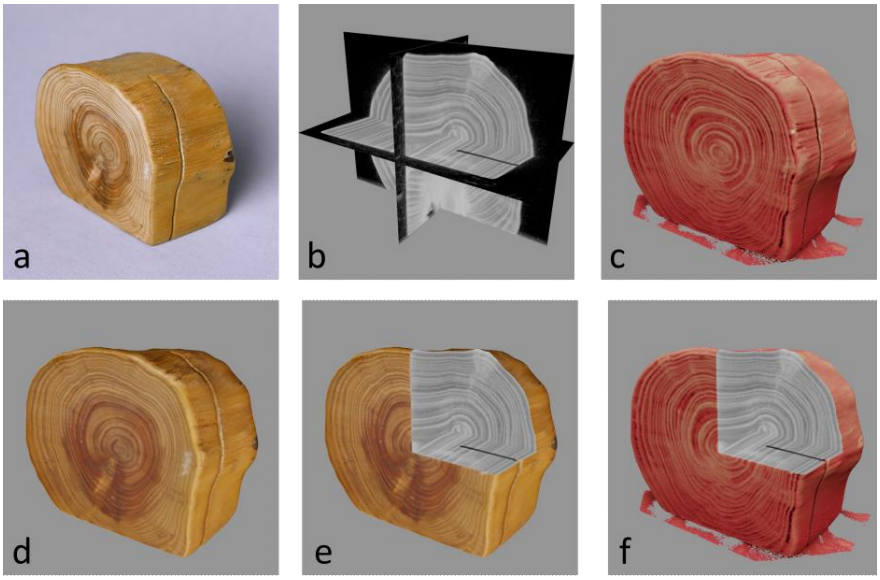
INTACT User guidelines

Version: [31-10-2022]



Visualisation made of the example dataset using the INTACT plugin in Blender: a) Photograph of a small wooden block (h 5cm x w 6cm x d 3cm), b) X-ray CT scan represented as orthogonal slices, c) CT 3D volume render, d) surface scan, e) combined image modalities showing surface scan and slices, f) CT 3D volume render and slices.

These user guidelines are made available as supplementary material to the paper 'Inside Out: Fusing 3D imaging modalities for the internal and external investigation of multi-material museum objects' by Francien G. Bossema, Paul J.C. van Laar, Kimberly Meechan, Daniel O'Flynn, Joanne Dyer, Tristan van Leeuwen, Suzan Meijer, Erma Hermens, and K. Joost Batenburg, Digital Applications in Archaeology and Cultural Heritage (2023).

RIJKS MUSEUM CWI

The British Museum

NETHERLANDS INSTITUTE FOR CONSERVATION + ART + SCIENCE +

Contents

1 Installation

1.1 **Blender**

Installation:

1. Go to https://www.blender.org/download/ and pick the relevant version for your operating system and install.

Why Blender?

- Open source: Blender has a large community with plugins that could perhaps sustain future questions/demands of the INTACT tool.

- Old versions will stay available, so the plugin doesn't have to be updated for compatibility with future updates of Blender.

- Blender is based on Python. It is therefore easy to write and incorporate your own demands, and possible for any user to edit those based on their own needs.

1.2 **Blender Plugin – INTACT**

Installation:

1. Download the plugin here: 10.5281/zenodo.8041844 or clone the github repository.
2. Open Blender
3. Go to "edit -> preferences" (Fig. 1)
4. Go to "add-ons" and click "install" (Fig. 2)
5. Navigate to the INTACT_Windows_main.zip file and select it. Blender will now automatically install the plugin. Make sure to activate it by checking the box next to the plugin name. (Fig. 3)
6. The *INTACT* plugin is now installed within your Blender software. You can find it in the UI Side Panel. Open this panel by clicking the **little arrow** next to the orientation gimbal. (Fig 4.) and then choose the INTACT panel (Fig. 5).
7. When opening the INTACT panel, you'll be prompted to click a button 'Install Modules'. Do this. When it's done close blender and restart.

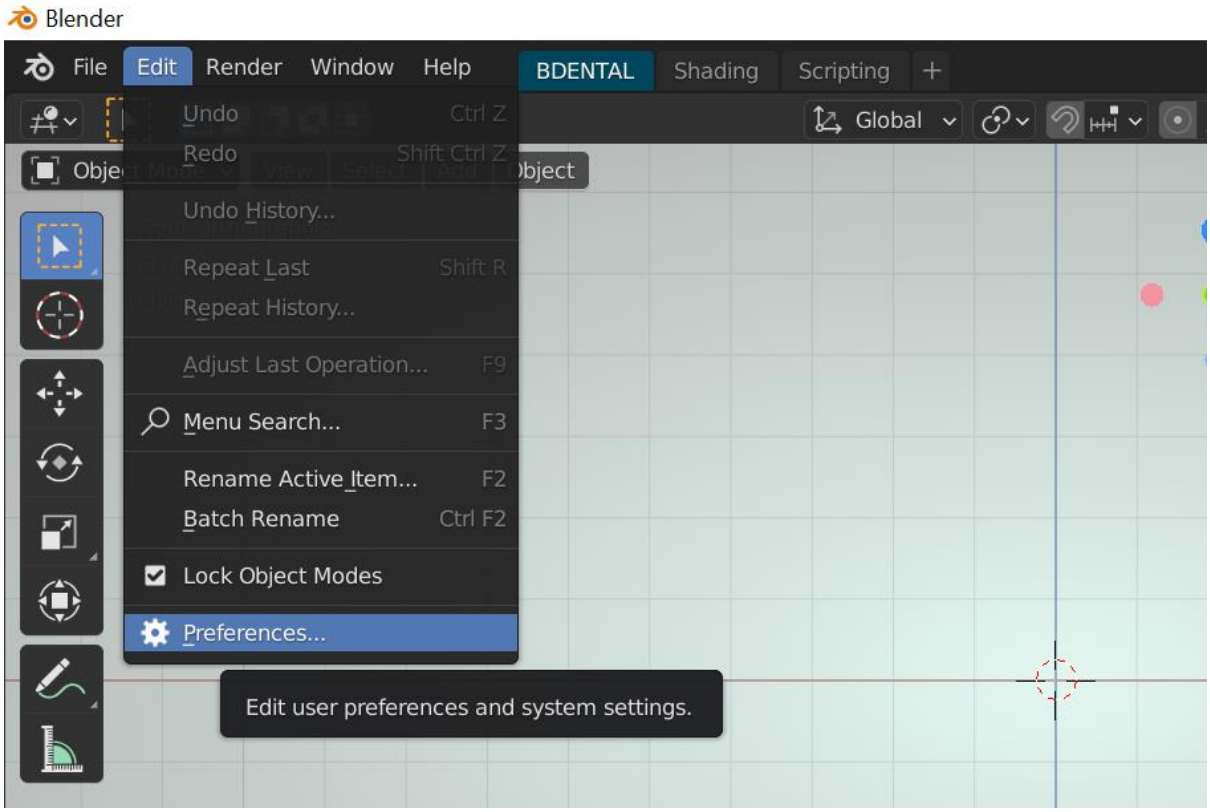

Blender
File
Edit
Render
Window
Help
BDENTAL
Shading
Scripting
Global
Undo
Ctrl Z
Redo
Shift Ctrl Z
Undo History...
Repeat Last
Shift R
Repeat History...
Adjust Last Operation...
F9
Menu Search...
F3
Rename Active Item...
F2
Batch Rename
Ctrl F2
Lock Object Modes
Preferences...
Edit user preferences and system settings.

Fig 1

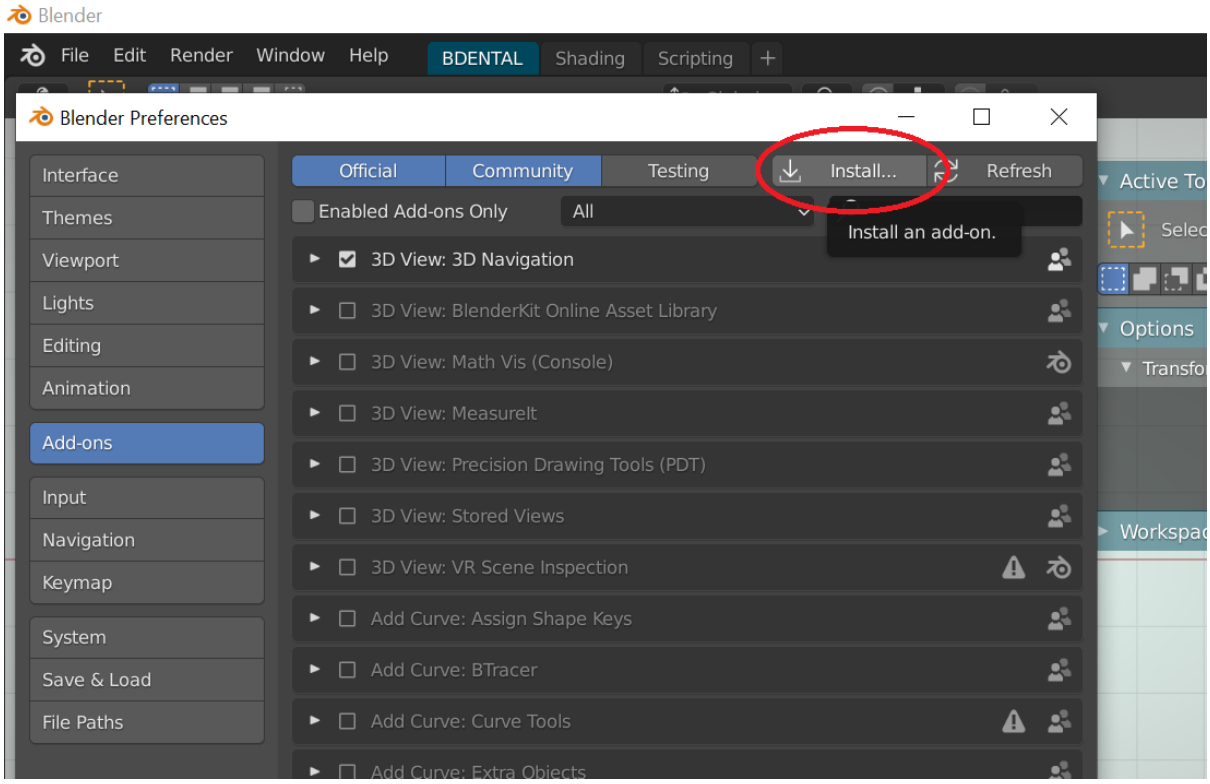

Blender
File
Edit
Render
Window
Help
BDENTAL
Shading
Scripting
Blender Preferences
Interface
Themes
Viewport
Lights
Editing
Animation
Add-ons
Input
Navigation
Keymap
System
Save & Load
File Paths
Official
Community
Testing
Install...
Refresh
Enabled Add-ons Only
All
Install an add-on.
3D View: 3D Navigation
3D View: BlenderKit Online Asset Library
3D View: Math Vis (Console)
3D View: MeasureIt
3D View: Precision Drawing Tools (PDT)
3D View: Stored Views
3D View: VR Scene Inspection
Add Curve: Assign Shape Keys
Add Curve: BTracer
Add Curve: Curve Tools
Add Curve: Extra Objects
Active To
Options
Workspac

Fig 2

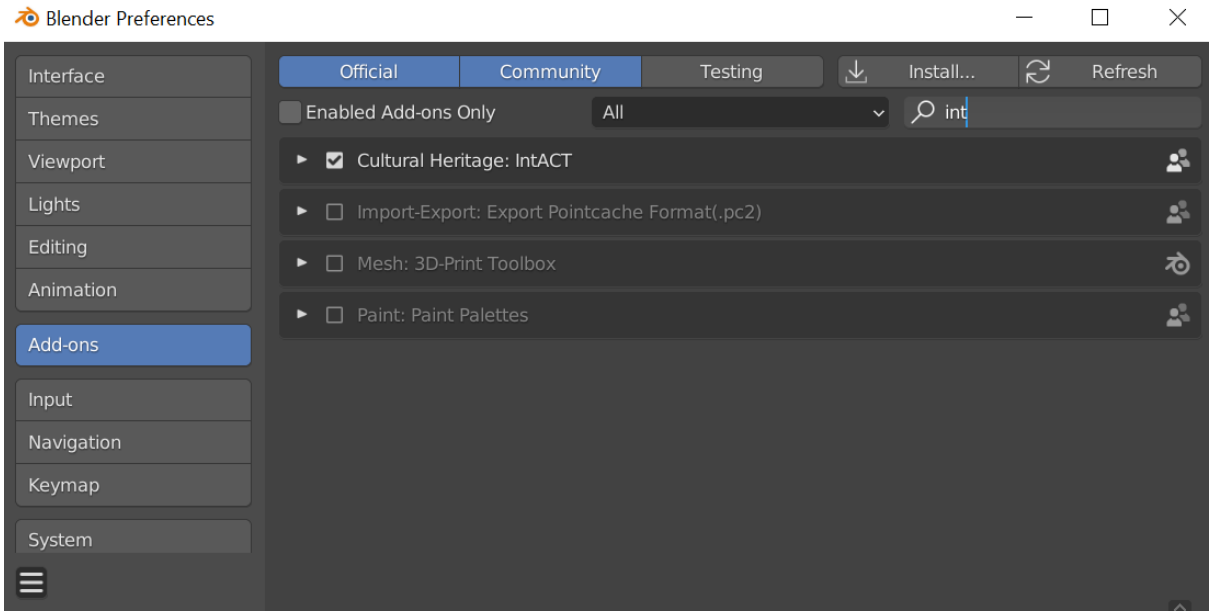

Blender Preferences
Interface
Themes
Viewport
Lights
Editing
Animation
Add-ons
Input
Navigation
Keymap
System
Official
Community
Testing
Install...
Refresh
Enabled Add-ons Only
All
int
Cultural Heritage: IntACT
Import-Export: Export Pointcache Format(.pc2)
Mesh: 3D-Print Toolbox
Paint: Paint Palettes

Fig 3

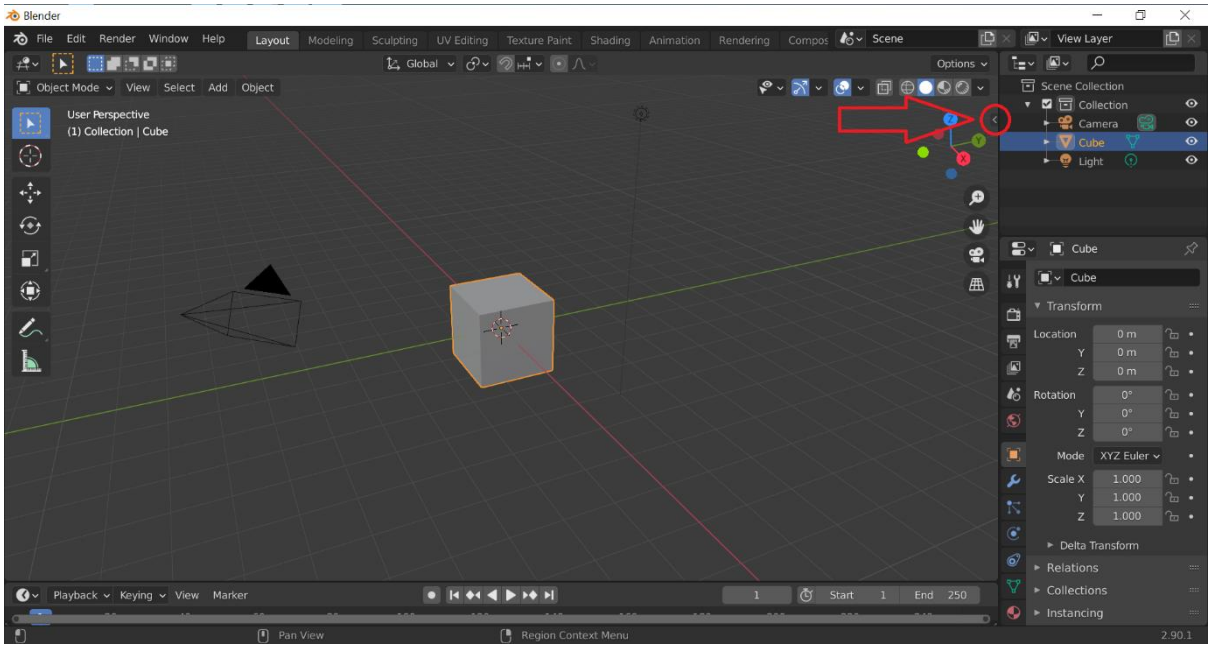

Blender
File Edit Render Window Help
Layout Modeling Sculpting UV Editing Texture Paint Shading Animation Rendering
Object Mode View Select Add Object
User Perspective
(1) Collection | Cube
Scene Collection
Collection
Camera
Cube
Light
Transform
Location
Rotation
Mode
Scale X
Delta Transform
Relations
Collections
Instancing
Playback Keying View Marker
Start
End
Pan View
Region Context Menu

Fig 4

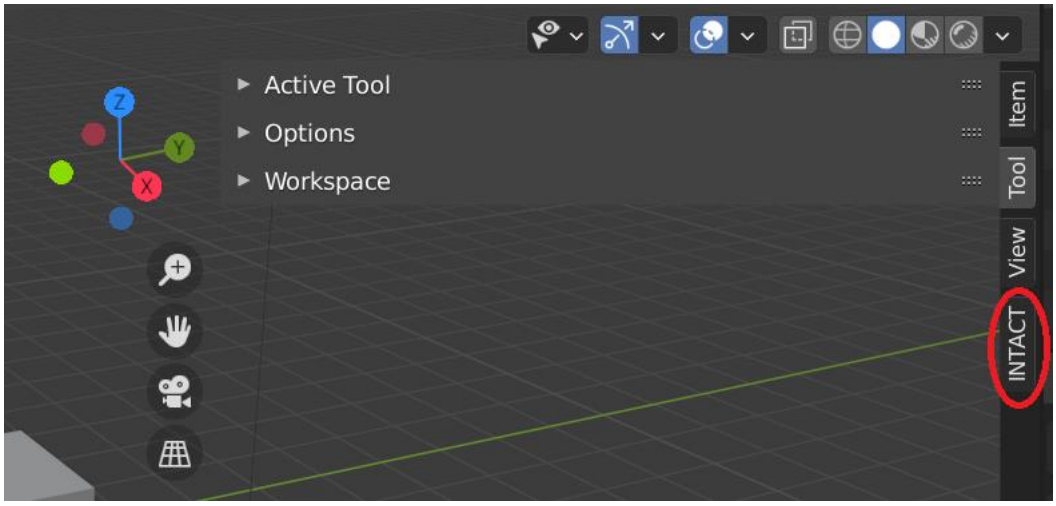


Fig 5

2 The INTACT plugin

The numbering of this section corresponds to the drop-down menu's in the plugin's User Interface (Fig 6.).

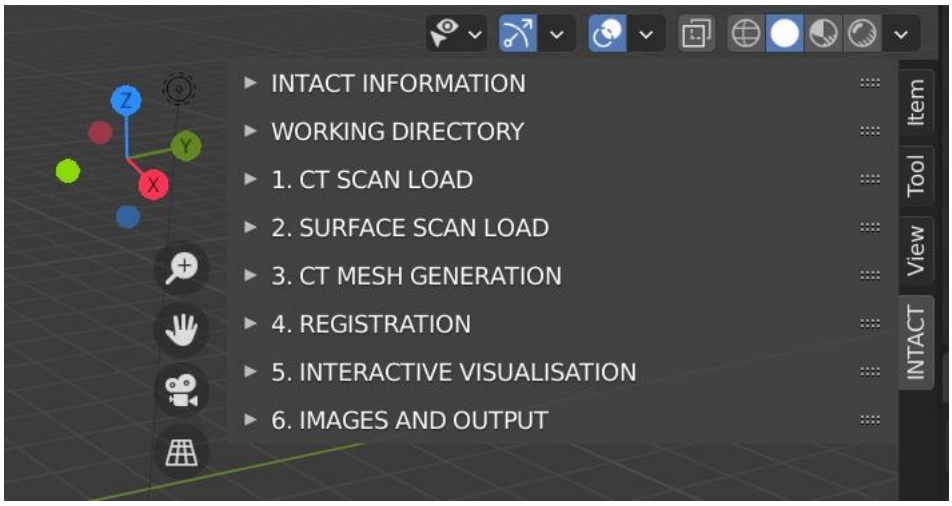


Fig. 6

2.0 **Setting up working directory**

Note: An example dataset is made available to follow along with the guidelines. This includes a 3D-surface scan and a CT scan of a small wooden block. Download the example dataset here: 10.5281/zenodo.8041816

1. Open INTACT, make it bigger by dragging the side. In the 'Working Directory' tab choose a project directory by clicking on the folder next to the empty field. Make this an empty folder, this is where all the files generated by the plugin will be saved.

2.1 **Loading CT scan**

1. Open the ‘CT scan load’ tab.
2. Choose a data type (default is Tiff)
3. Input the directory where your CT scan files are stored.
4. In case of Tiff, input the resolution (test dataset voxel size = 0.13mm).
5. Click “Load CT Scan”, wait (may take a couple minutes)
6. You can move the view by holding the middle button while moving your mouse. Preferably don’t move the CT scan. Don’t worry if you do, its position can be reset in the ‘CT Mesh Generation’ tab.
7. For visualisation purposes you can change the threshold, and color + lighting. (Fig 7)

Note: If you do not have a Surface scan of your object, you can skip to Visualisation (section 2.5).

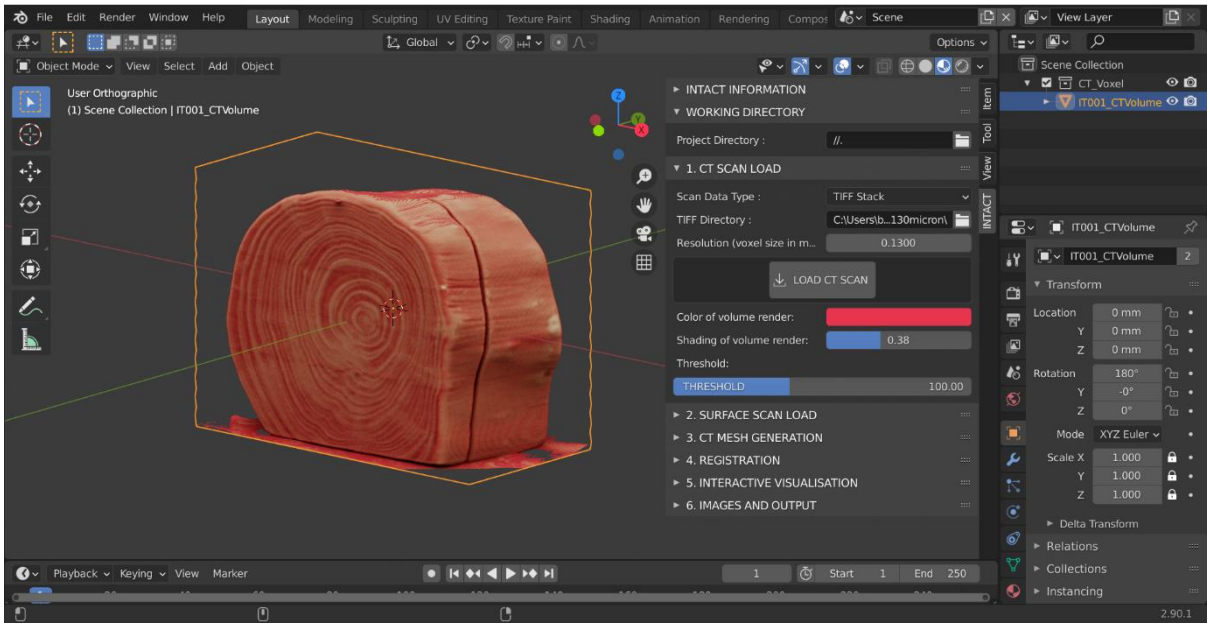


Fig 7

2.2 **Surface scan load**

1. In the ‘Surface scan load’ tab click on the icon of a folder.
2. In the resulting pop-up, navigate to the directory which holds your 3D model, select the .obj model and click accept. Then click the ‘Load surface scan’ button. (Fig 8)

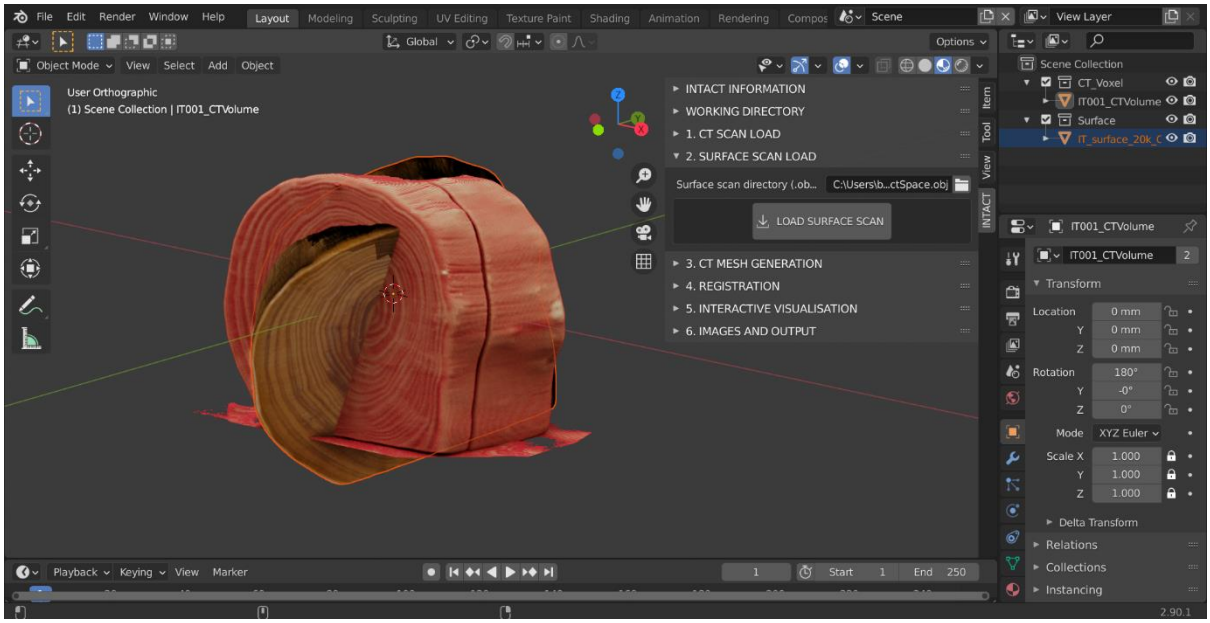


Fig 8

Tip: Sometimes the surface scan is not shown as expected. This can have to do with how the 'normals' are defined. Try going into right hand lower menu, the red ball and change how the normals are calculated. See figure:

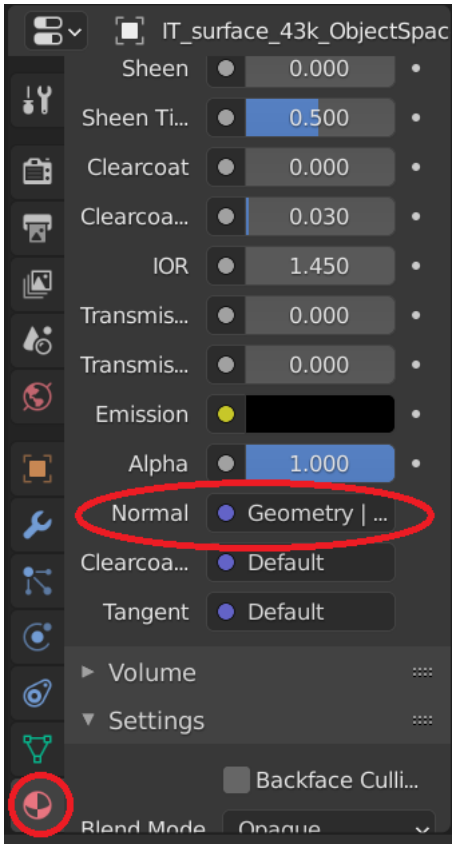


Fig 9

2.3 **CT mesh generation**

1. In the 'CT Mesh Generation' tab, play around with the threshold value to find a value that shows all of the object outline, but not much else. A little noise outside the object is fine.
2. When you're happy with the threshold, click Segmentation. You'll end up with a mesh of the CT scan (fig 10). Wait, this may take a minute. For ease in the next section, it may be nice to turn off the CT volume view by clicking on the eye in the right hand panel, next to the IT001_CTVolume.

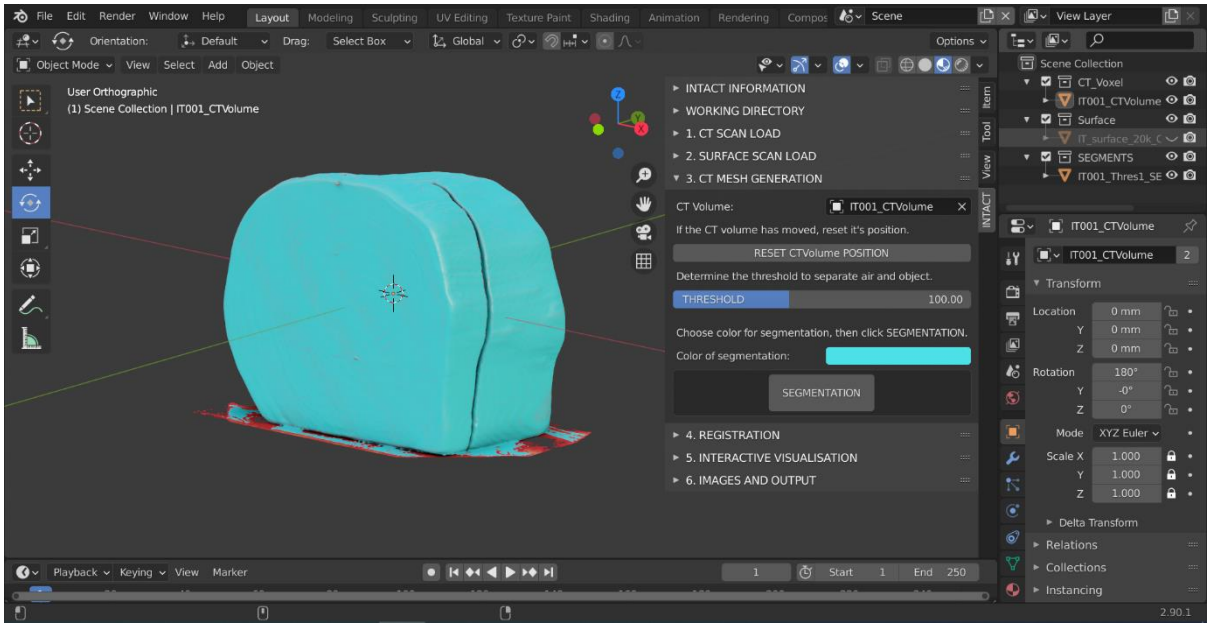


Fig 10

2.4 **Registration**

1. Select CT scan and if needed because the CT scan was moved, click 'reset CT volume position' in the 'CT Mesh Generation' tab. Double check that all values are zero (location, rotation) in the lower right panel, the orange square tab will give you these numbers. If not, change them to zero. Scale is 1.
2. Go to the Registration tab.
3. Manually align your 3D surface scan roughly to the produced CT segment, using the controls as described in section 3.3. This can be a rough alignment (Fig 11).

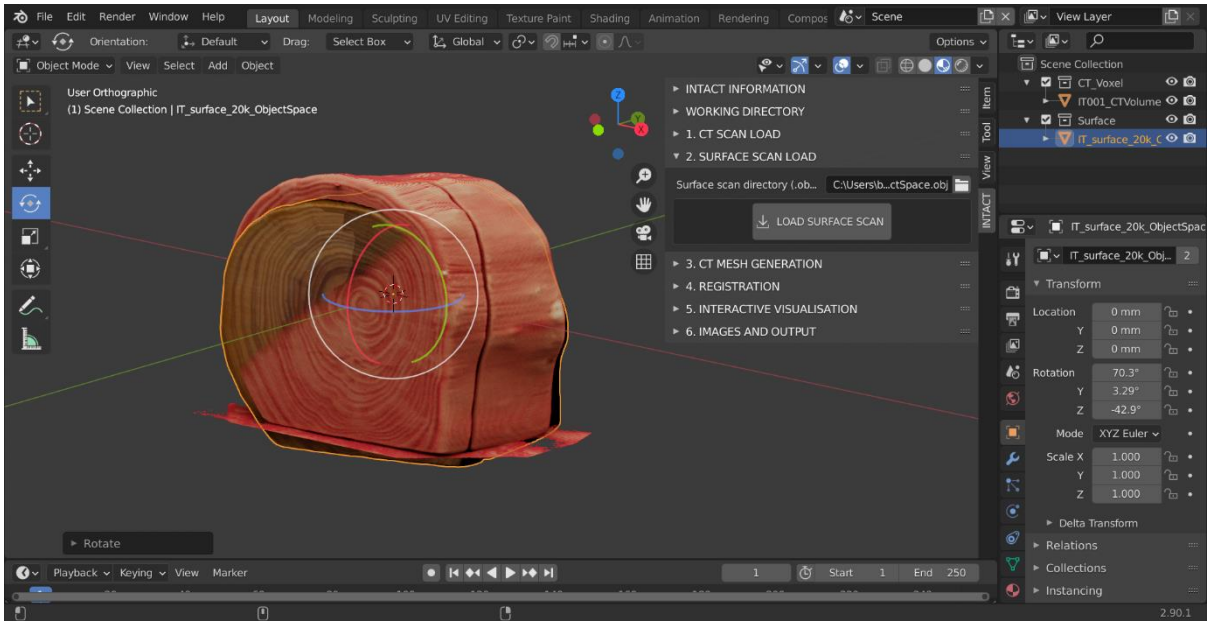


Fig 11

tip: use the pre-defined Front/Back – Left/Right – Top/Bottom views, the coloured axis in the top right corner. Switch between those to align your objects manually along each axis.

4. Check that the surface scan and CT segmentation have been identified correctly in the dropdown box and if not select the right objects by clicking the corresponding white eyedropper icon, then clicking the scan/segmentation in the 3D viewer or in the right hand side panel (segmentation is IT001_Thres1_SEGMENTATION). Check "Allow scaling" if you want the surface scan to be scaled if needed.
5. Press 'Perform Registration'. Wait, this may take a while. You will see a live update of the surface scan mesh move towards the CT mesh. (Fig 12)
6. Is the result satisfactory? If it isn't aligned properly yet, run it again (click the 'Perform Registration' button).
    a. It won't align properly? Perhaps your rough manual alignment can be improved. You can also increase the "Outlier %" to 10 or even higher and the iterations can be increased. Experiment a little bit.
    b. Look at some landmarks in your object .
    c. You should see bits of the CT mesh colour coming through the surface scan.
7. Select your surface scan to see the values for the transformation in the lower right hand panel, orange square tab.

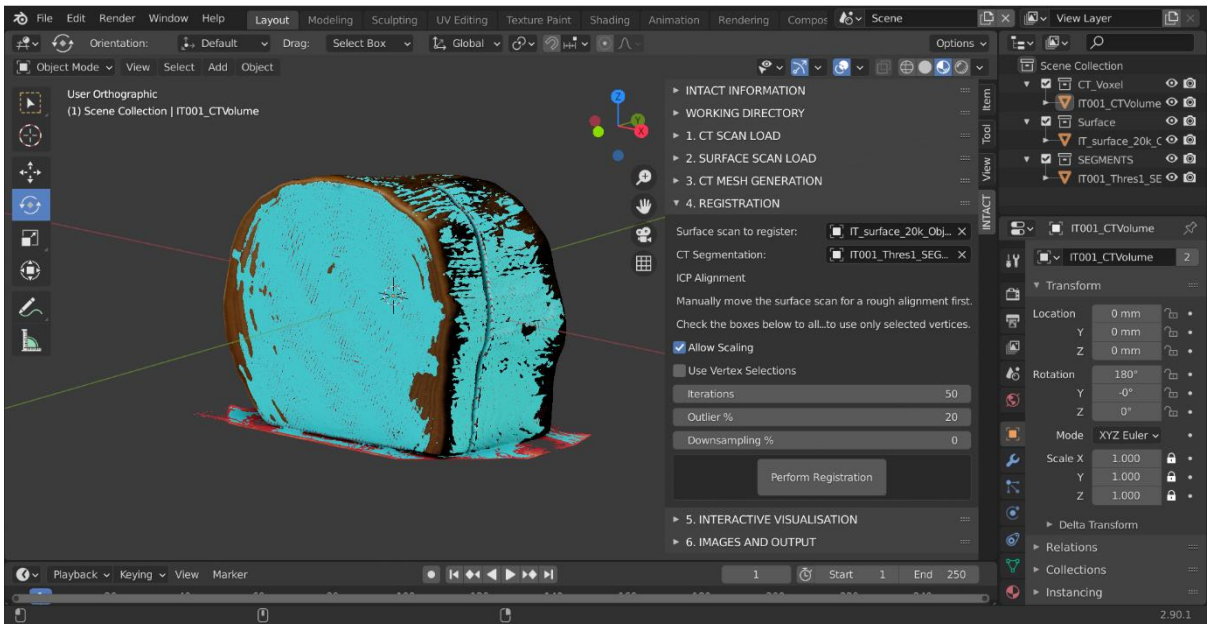


Fig 12

2.5 **Interactive Visualisation**

1. It is usually convenient to hide the visibility of the Segmentation by clicking the eye symbol next to the Segmentation in the right hand upper menu.
2. If given, check the selected CT scan volume, segmentation and surface scan at the top of the 'Interactive Visualisation' tab. If not, please select them from the dropdown menu, or with the white eyedropper icon as previously described.
3. Then click 'Slice volume', to create the CT slices (Fig 13, 14).
4. If required, adjust the contrast of the slices with the min and max sliders (Fig 15).
5. Click 'Create cropping cube'. This will create a cube, that when moved into the object will make everything within it transparent. (Fig 16)
6. Check 'Track slices', to attach the slices to the sides of the cube and make them update when the cube is moved into the object.
7. Check 'Crop slices outside object' to show only the part of the CT Volume that is inside the object (and not the air around it) (Fig 16).
8. Optional: The 'Multi-view' button opens up a user interface that shows the X, Y, Z views plus the 3D view.
9. Optional: Surface scan roughness and slice thickness can be adjusted.

Now that everything is setup, it is possible to interactively manipulate the data, analyse and investigate. Use the visibilities in the upper right-hand menu and standard Blender controls to move (see section 3).

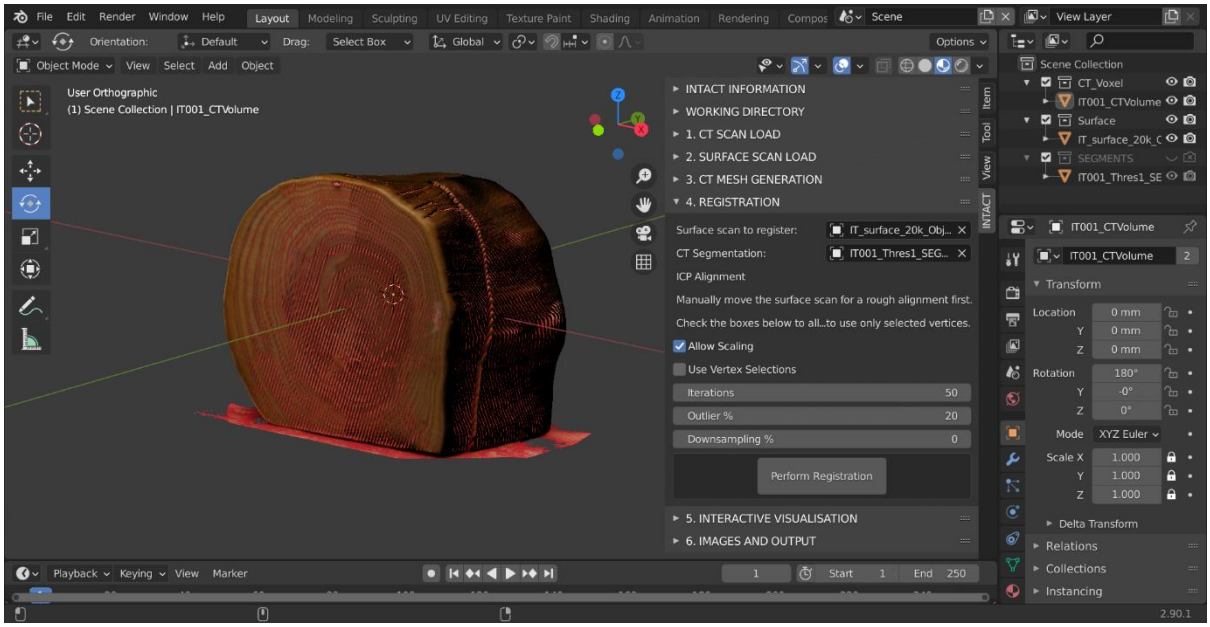

User Orthographic
(1) Scene Collection | IT001_CTVolume
INTACT INFORMATION
WORKING DIRECTORY
1. CT SCAN LOAD
2. SURFACE SCAN LOAD
3. CT MESH GENERATION
4. REGISTRATION
Surface scan to register:
IT_surface_20k_Obj...
CT Segmentation:
IT001_Thres1_SEG...
ICP Alignment
Manually move the surface scan for a rough alignment first.
Check the boxes below to all...to use only selected vertices.
Allow Scaling
Use Vertex Selections
Iterations 50
Outlier % 20
Downsampling % 0
Perform Registration
5. INTERACTIVE VISUALISATION
6. IMAGES AND OUTPUT
Scene Collection
CT_Voxel
IT001_CTVolume
Surface
IT_surface_20k_C
SEGMENTS
IT001_Thres1_SE
Transform
Location 0 mm
Rotation 180°
Mode XYZ Euler
Scale X 1.000
Delta Transform
Relations
Collections
Instancing
2.90.1

Fig 13

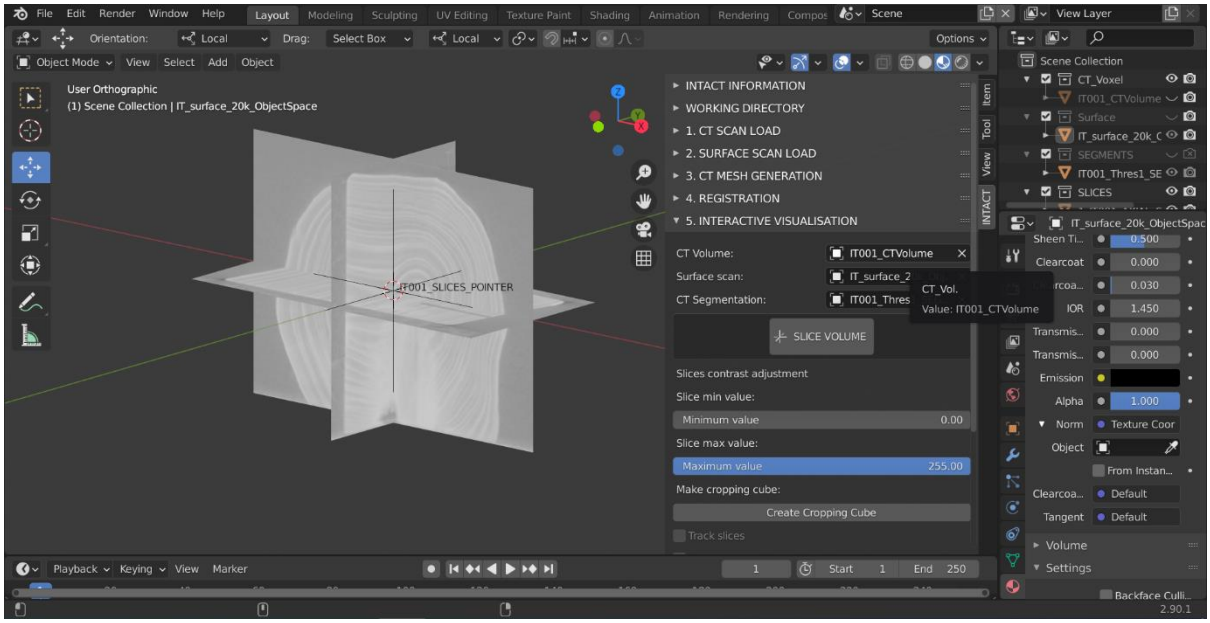

User Orthographic
(1) Scene Collection | IT_surface_20k_ObjectSpace
IT001_SLICES_POINTER
INTACT INFORMATION
WORKING DIRECTORY
1. CT SCAN LOAD
2. SURFACE SCAN LOAD
3. CT MESH GENERATION
4. REGISTRATION
5. INTERACTIVE VISUALISATION
CT Volume:
IT001_CTVolume
Surface scan:
CT Segmentation:
CT_Vol.
Value: IT001_CTVolume
SLICE VOLUME
Slices contrast adjustment
Slice min value:
Minimum value 0.00
Slice max value:
Maximum value 255.00
Make cropping cube:
Create Cropping Cube
Track slices
Scene Collection
CT_Voxel
IT001_CTVolume
Surface
SEGMENTS
IT001_Thres1_SE
SLICES
Sheen Ti... 0.500
Clearcoat 0.000
IOR 1.450
Transmis... 0.000
Emission
Alpha 1.000
Texture Coor
Object
From Instan...
Default
Tangent
Volume
Settings
2.90.1

Fig 14

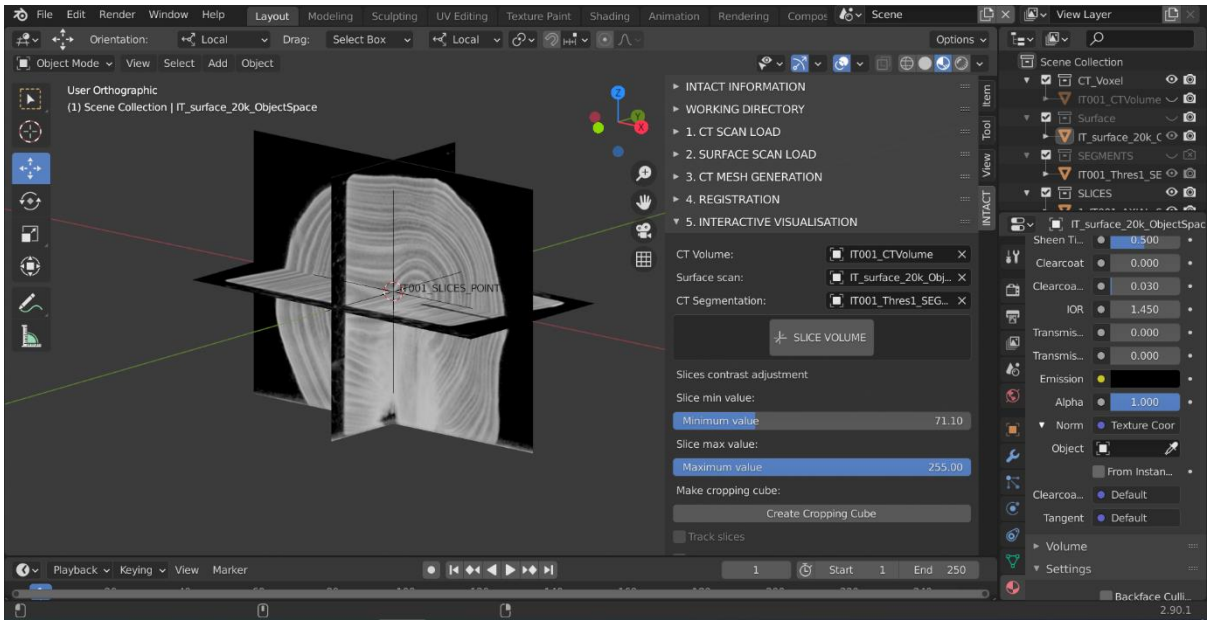

User Orthographic
(1) Scene Collection | IT_surface_20k_ObjectSpace
INTACT INFORMATION
WORKING DIRECTORY
1. CT SCAN LOAD
2. SURFACE SCAN LOAD
3. CT MESH GENERATION
4. REGISTRATION
5. INTERACTIVE VISUALISATION
CT Volume:
IT001_CTVolume
Surface scan:
IT_surface_20k_Obj...
CT Segmentation:
IT001_Thres1_SEG...
SLICE VOLUME
Slices contrast adjustment
Slice min value:
Minimum value
71.10
Slice max value:
Maximum value
255.00
Make cropping cube:
Create Cropping Cube
Track slices

Fig 15

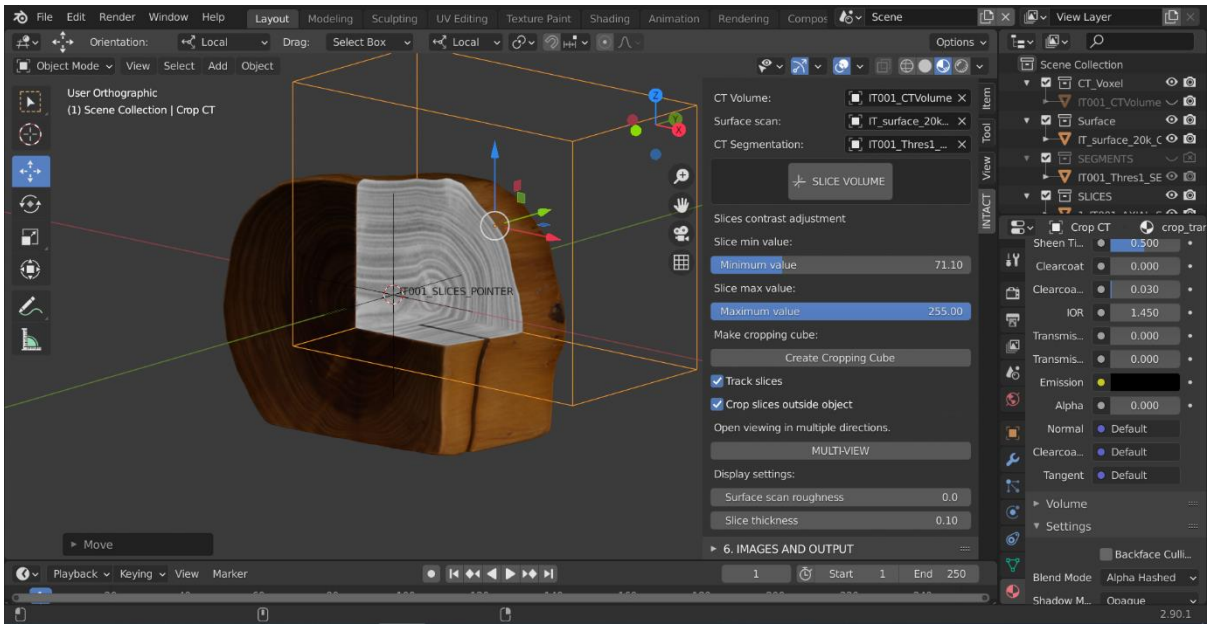

User Orthographic
(1) Scene Collection | Crop CT
CT Volume:
IT001_CTVolume
Surface scan:
CT Segmentation:
SLICE VOLUME
Slices contrast adjustment
Slice min value:
Minimum value
71.10
Slice max value:
Maximum value
255.00
Make cropping cube:
Create Cropping Cube
Track slices
Crop slices outside object
Open viewing in multiple directions.
MULTI-VIEW
Display settings:
Surface scan roughness
0.0
Slice thickness
0.10
6. IMAGES AND OUTPUT

Fig 16

2.6 **Images and output**

Screenshot:

1. To obtain a screenshot of the current view, including all lines and grids, click ‘Take screenshot’.

Rendering images:

1. Click ‘Set camera position’. This opens up the camera view in a grey rectangle. (Fig 17)
2. Change the view of the camera, by moving around using the normal blender controls.
3. Change the size of the camera by changing the resolution parameters.
4. When satisfied click ‘confirm camera position’.
5. Optionally adjust lighting and background colour for the image.
6. Click ‘Render image’. When satisfied, click Image -> Save as...

Rendering videos

1. The same camera position is used as for the image. If needed, adjust using step 1-4 of Rendering images above.
2. Choose an axis around which to rotate the object.
3. Name the movie - make sure to change this for every movie or the previous one will be overwritten.
4. Click ‘Render turntable movie’. Each frame will be rendered separately and then saved in the working directory in a new folder called ‘Movies’.

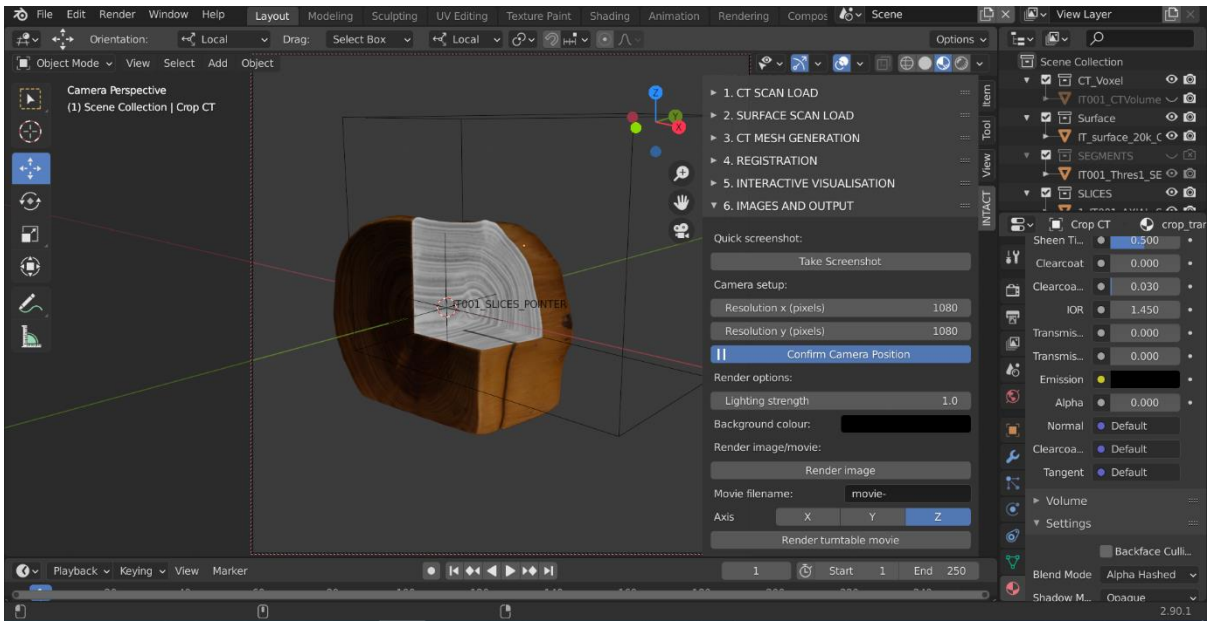


Fig 17

3 Basic Blender controls

3.1 **Viewport shading options**

The virtual space in which we place our 3D models and objects is called the *viewport.* There are 4 different shading options within Blender that we can choose from, each with a different appearance (Fig. 18):

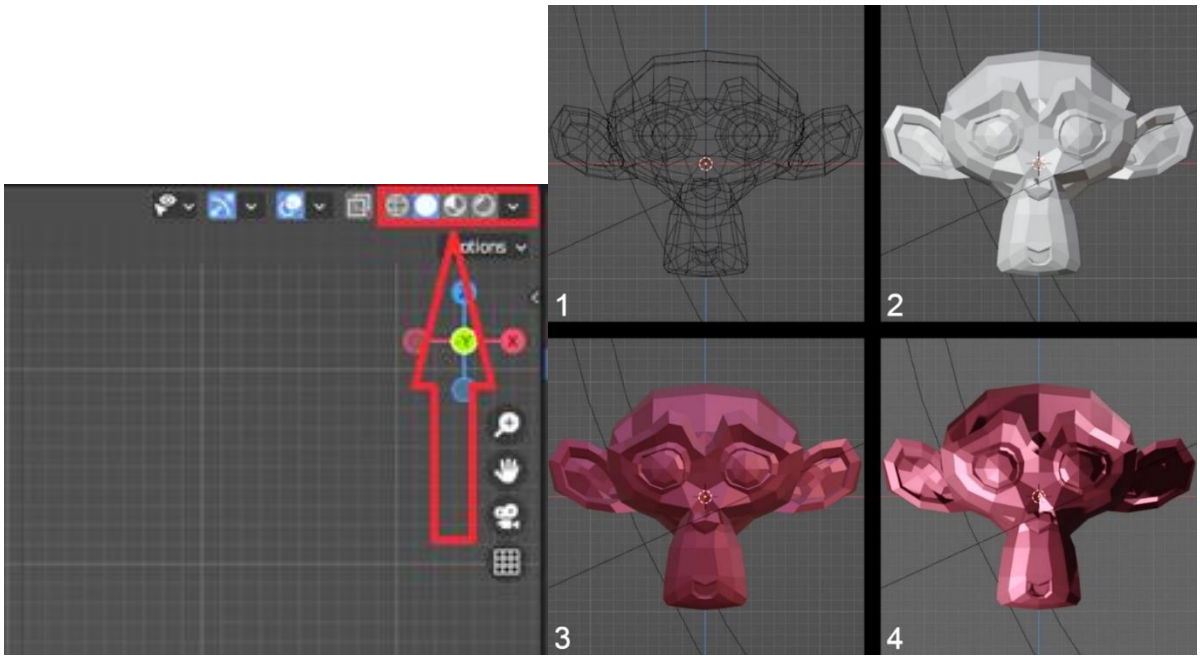


Fig 18

1. Wire edges
   This mode is probably least interesting for our case, and displays the 3D-model as a wireframe.
2. Solid mode
   This is the standard mode upon opening blender, and displays the 3D-model as a solid object *without* its material properties. This mode is best when editing properties, aligning models, or setting up an animation as it's least computationally heavy.
3. Material preview mode
   In this mode the material properties are added to the object, as they would appear with relatively flat lighting (not the lights you can add yourself, but what is called 'world lighting').
4. Render preview
   In this mode the user's 'scene lights' are added. This makes it the most computationally heavy mode as the software has to calculate and render light, reflection, and shadow.

3.2 **Moving the view**

1. Translation
   Move the view by holding shift and the middle mouse button, and moving your mouse.
2. Rotation
   Rotate the view by holding the middle mouse button, and moving your mouse.
3. Zoom
   Zoom in and out by scrolling (either using your trackpad or the middle mouse button).
4. Front-Back-Top-Bottom-Left-Right view
   Blender also has 6 built in views that are quickly accessible via the gimbal in the top right corner (Fig. 19). You can click on each of the 6 dots (representing X, Y, Z in both positive and negative direction), which will bring you immediately to a view along that axis.

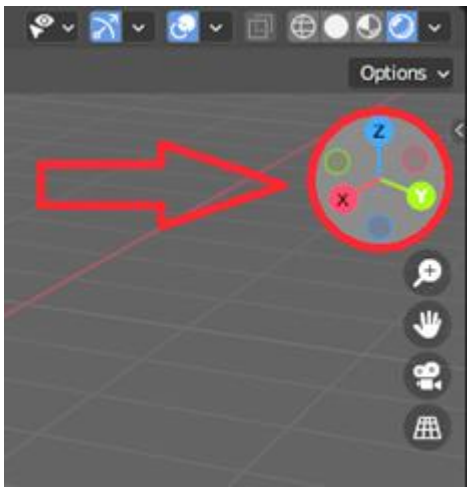


Fig 19

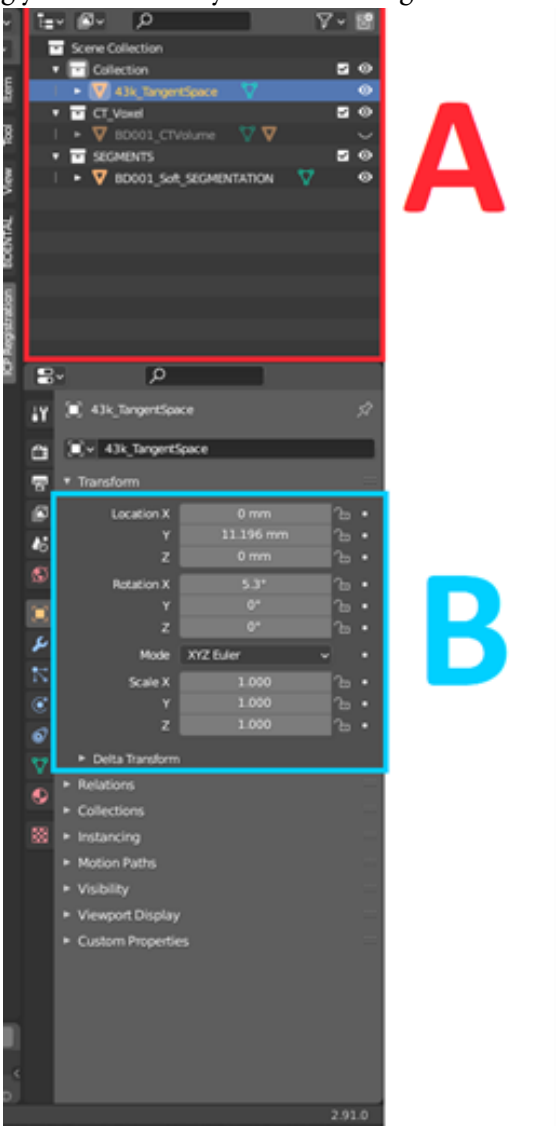


Fig 20

3.3 **Object selection/translation/rotation/scaling**

1. Select an object
   Selecting an object can be done with your left mouse button. You'll see what object is selected in the top right of your screen, in what's called the "Scene collection" (Fig 20.A).

2. Translation | Rotation | Scaling
   There are two ways to move/rotate/scale your object:

   a) Via the properties panel (Fig. 20.B) You can change the values in your object's properties panel. This is best for if you want some very subtle changes (e.g. 0.01°).
   b) In the viewport Click your object, and on the left-hand side you can click "move" and "rotate" (Fig. 21). In the centre of your object, handles will appear that allow you to perform these actions along a certain axis, or along all of them at once.

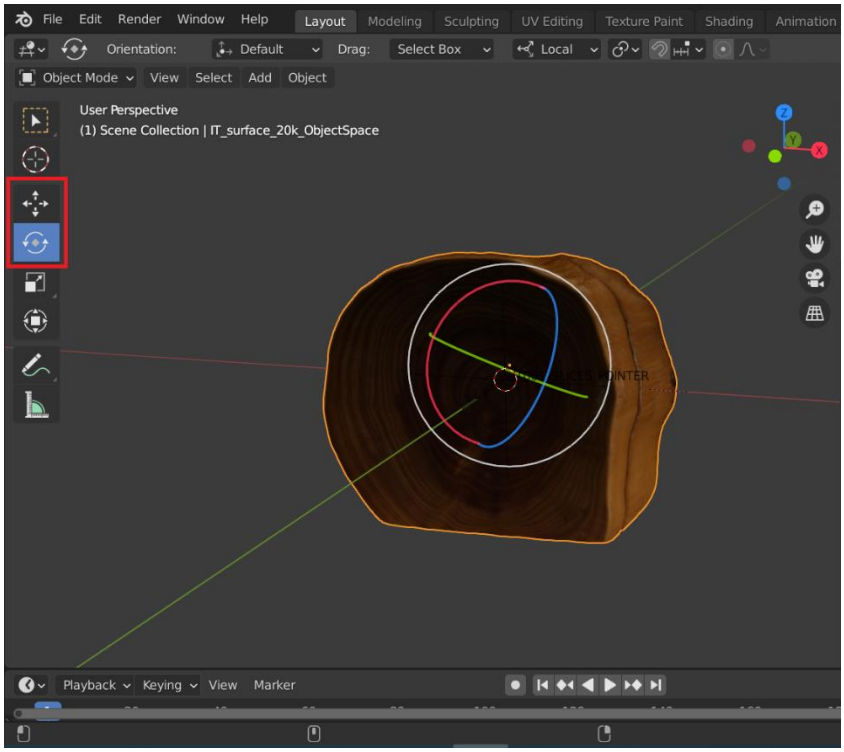


Fig 21

3.4 **Turn on/off visibility and rendering of objects**

You might want to enable/disable the visibility of certain objects in your viewport at a given point of time. You can do this by clicking the *eye* symbol beside the name of your object in the "Scene collection". Clicking the camera will turn on/off the visibility of that object in the rendered image (See Fig 22).

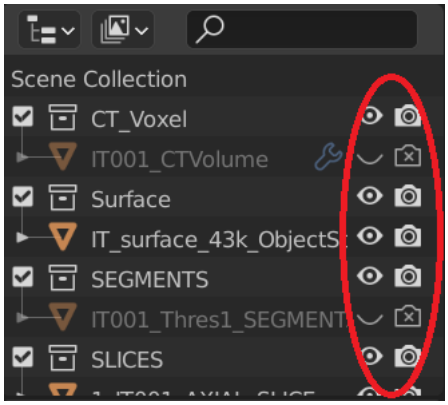


Fig 22

4 Using vertex selections for registration

4.1 **Enabling vertex selections**

In cases where your X-ray CT or surface scan is incomplete, you may want to focus your registration on a sub-region for the best accuracy. This can be done by enabling the 'Use Vertex Selections' option in the Registration tab of the plugin (Fig. 23).

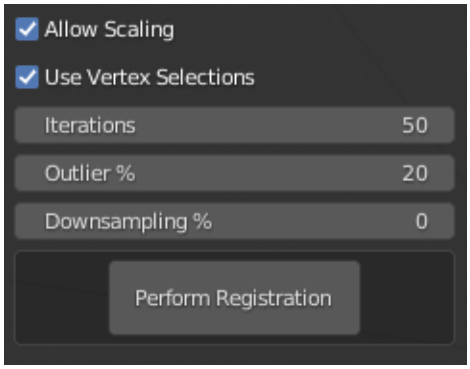


Fig 23

You will need to manually select which vertices to include from both your surface scan and CT segmentation mesh. Only choose areas that appear in both for the best accuracy.

4.2 **How to select vertices**

1. To select vertices, you have to enter Blender's 'Edit mode'. First select the mesh you want to use, then change the dropdown menu in the top left of the viewport to edit mode (Fig. 24). Alternatively, you can select the mesh, and press the tab key on your keyboard. To go back to the normal blender mode, change the menu to 'Object Mode', or press tab again.

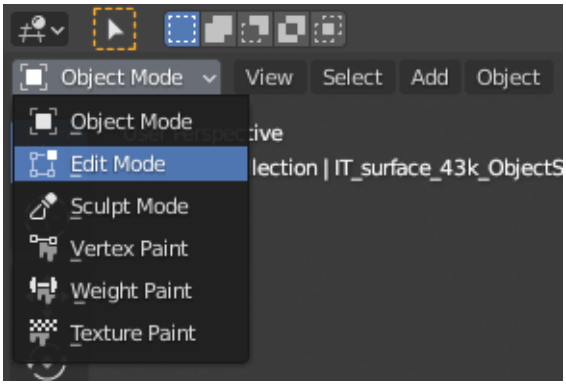


Fig 24

2. Once in edit mode, you can select vertices by clicking and dragging across the parts of the mesh you want to include (Fig. 25). Selected vertices will appear in bright orange. To add to your selection, hold down the shift key while you do this.

3. To select through your mesh (i.e. not just vertices on the face closest to you), you can enable Blender's X-ray mode. Click the symbol with two overlapping squares in the top right of the viewport (Fig. 26) or press alt + Z on your keyboard.

Fig. 25

4.3 **Tips for selecting vertices**

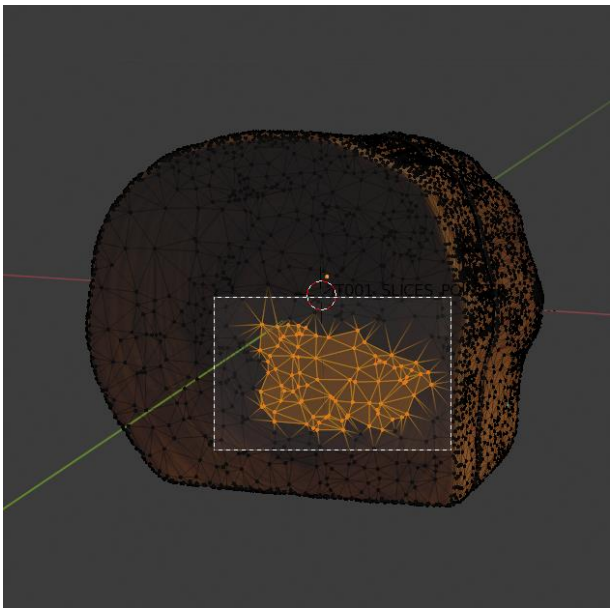


Fig. 25

In some meshes, you may have multiple regions that aren't directly connected to each other. To select all vertices in one piece, you can click one vertex, then press ctrl + L to select everything connected to it.

It can also be useful to hide parts of the mesh you don't want to select. This can be done by selecting the vertices (in the usual way), and pressing H to hide them. Any hidden vertices can be shown again by pressing alt + H.

A line of vertices can be selected by clicking a vertex at one end, then ctrl + click a vertex at the other end. Blender will select all vertices on the shortest path between the two.

Combining these methods can make selecting sub-regions much faster. For example, you could select a line of vertices that separate your region of interest from the rest of the mesh. Hiding this will disconnect your region of interest, and allow it to be selected in one go with ctrl + L.

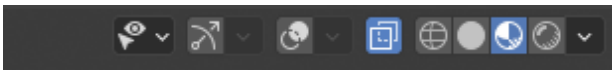


Fig. 26