Manual Segmentation of Radial MRA Images

Note:

This tutorial assumes that you already have some basic notions about the Blender 3D interface, and know how to convert DICOM files to standard image file formats. Consult the last section of this tutorial for further references. Also feel free to explore the *blend file that comes with the tutorial.

Materials:

- 3D Modeling software (ex. Blender 3D);

- Medical image converter software (ex. Dicomworks (Windows), OsiriX (Mac), Gimp (PC, Mac));

- MRA radial images (DICOM files) ordered by acquisition angle.

Acronyms:

CT – Computer Tomography
MRI – Magnetic Resonance Imaging
MRA – Magnetic Resonance Artrography
LMB – left mouse button;
MMB – middle mouse button ;
RMB – right mouse button;
NURBS - Non Uniform Rational Basis Spline (or B-Spline).

Methods:

- Convert all DICOM images to a suitable image format (ex. *.dcm → *.png);

- Run the **Blender 3D** application;

- Clean up the **3D View** by selecting all the objects and deleting everything (**Keyboard A > Keyboard X > Enter**);

Rotoscoping Technique

The manual segmentation technique applied in this case is called Rotoscoping, where the desired geometry is obtained by tracing several curves upon an image or photography. By rotoscoping you create rotoscopes, a set of 2D

curves that represent image content. Rotoscoping is a classic animation technique used by animators to trace live-action film movement, frame by frame. This technique allows you to extract the exact proportions of objects from orthogonal projection images, such as CT and MRI medical images. Here, rotoscoping will serve as a geometric modeling tool of biomechanical structures and not as an animation tool. The technique is quite laborious but it allows an accurate modeling based on MRA images.

For the sake of modeling simplicity, rotoscoping will be performed on the same 3D construction plane. After all images are segmented, these radial rotoscopes will be assembled by rotating each and every one of them according to their acquisition angle. Therefore, it is highly recommended to 'mentally' pre-organize your workbench so that you place the several image segmentation results (or rotoscopes) on well known locations. The following figure illustrates an appropriate 'mental' display for the 16 segmentation results upon a wide workbench area. Here the rotoscopes are arranjed in a 4x4 rectangular array. To position a 3D object with numeric precision, select the object (**RMB**), in **Object Mode** press **Keyboard N** to call the **Transform Properties** dialog box. Introduce numerical values for the desired X, Y and Z locations.

Construction Plane/ Workbench.

Current working rotoscope placed right at the workbench center (0.0,0.0,0.0)

Segmented results.
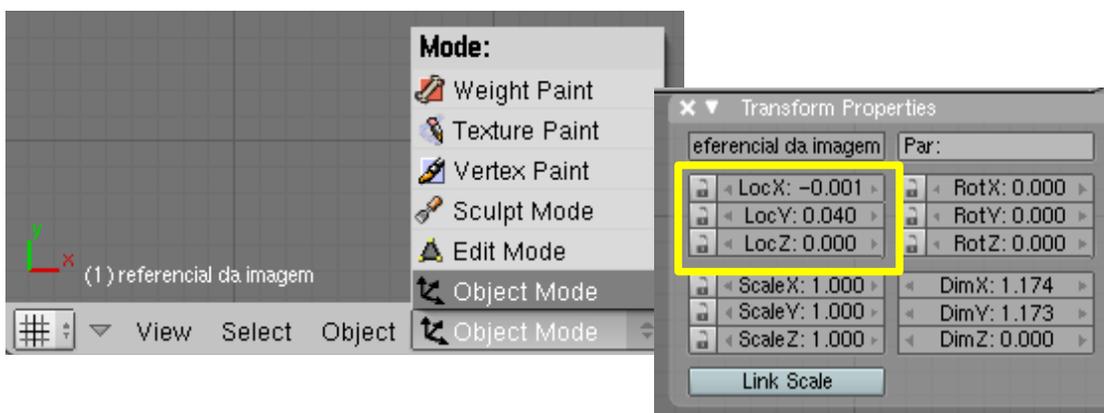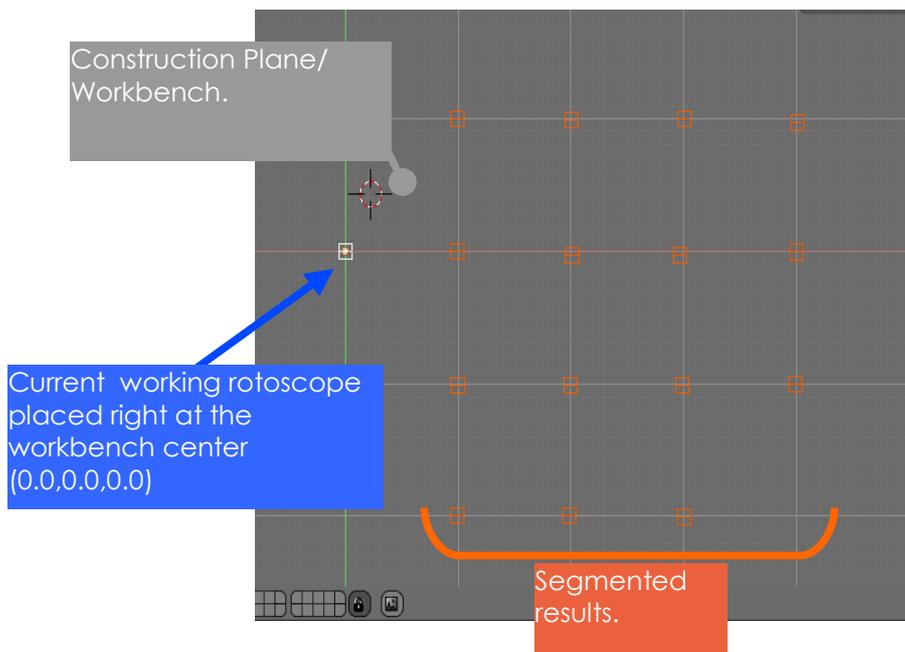
Segment each image in the following manner:

- Hoover the mouse cursor on over the **3D View** window;

- Choose the **Top View** as your construction plane (**View > Top** or **NumPad 7**);

- Load the MRA image as the background image (**View > Background Image ...**). The Background Image dialog box will appear. Click on the **Use Background Imag** button and then load the image file by clicking on the tiny folder icon. The **File Browser** window will emerge allowing you to select the image you want to segment.
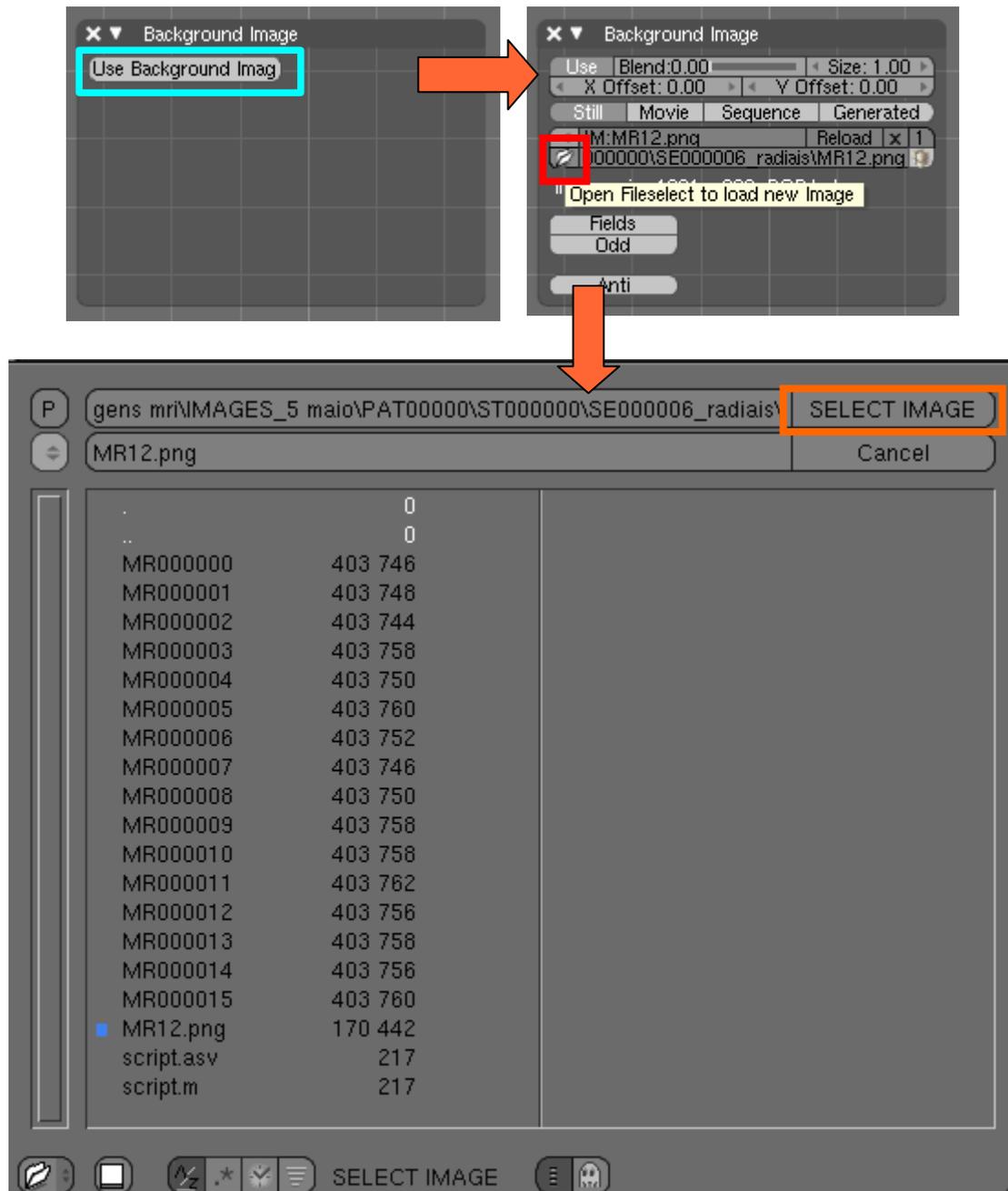
An important modeling practice consists on creating a reference frame object. This allows you to accurately align the contours within a rotoscope with other rotoscope radial planes. Here, the reference object will be a rectangular frame that squares the image borders. A vertical or horizontal line segment (this depends on how the MRI acquisition was undertaken) shall also be included to identify the acquisition axis. This axis runs through the typical line artifact of MRA images. For a more pragmatical modeling, dividing the frame on equally half portions determines the axis position. See the following figures for a more clarifying perception about the reference frame object.

- Open the **View Properties** dialog box (**View > View Properties …**) and center the 3D Cursor at the origin by introducing the numbers in each coordinate box (click precisely on the X, Y or Z letter and digit '0'). This way you can numerically position the 3D cursor on the underlying grid. Alternately, you can call the **Snap** pop up menu and snap the 3D Cursor to the nearest grid point in the vicinity of the 3D Cursor (**Shift + Keyboard S > Cursor → Grid**).
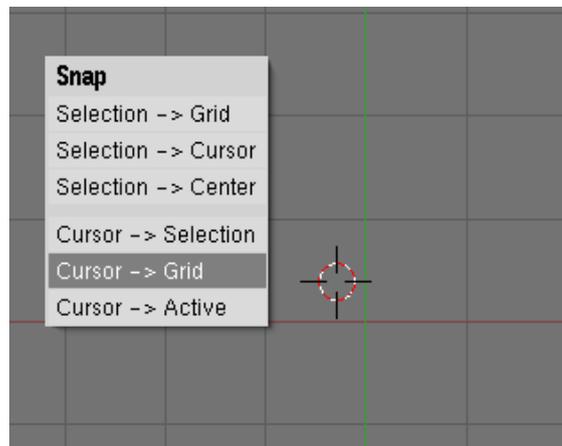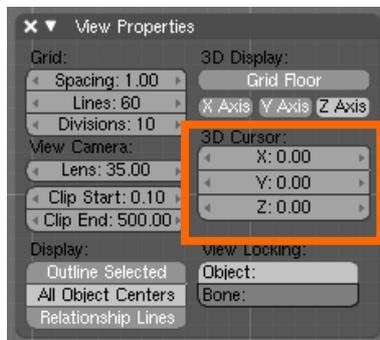
- Press the spacebar to invoke the general pop up menu and add a plane (**Keyboard Spacebar > Add > Mesh > Plane**). Scale the plane in the X and Y directions so that you frame the image borders.
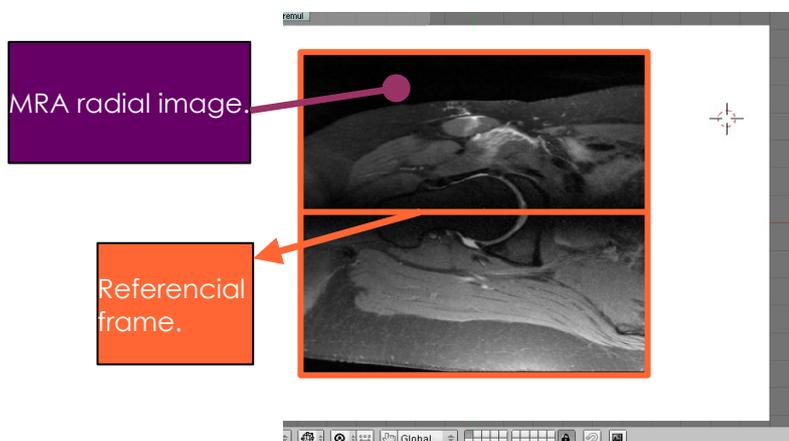
- With the plane object selected, go to **Edit Mode** (**don't forget to press Keyboard F9**). Select all the vertices (**Keyboard A**) and **Subdivide** the mesh (**Keyboard W > Subdivide**). Connect the middle vertices by selecting them (**SHIFT + LMB** or **Keyboard B**) and pressing **Keyboard F**. At this point, you have just created the reference frame object. Name it as *ref_frame_<angle>* in the **Transform Properties** dialog box (**Keyboard N**), where *<angle>* is the radial angle value.

- Do not forget to save your work (**Keyboard CTRL + S** or **Keyboard CTRL + W**) as you go through the modeling process. The file will be saved as a *<file_name>.blend*.
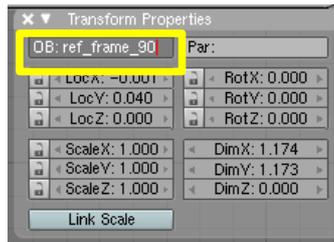
To trace down the tissue contours use NURBS curves. In a nut shell, NURBS are a mathematical representation of a wide range of curves, from strait lines to highly complex organic shapes. NURBS have been used to represent freeform curves and surfaces with great precision as is required for automotive, naval and other product design industries.
In geometric modeling of biomechanical structures, each anatomical tissue has its own set of contours and surrounding tissues may share common curves.

- Call up a NURBS curve (**Keyboard Spacebar > Add > Curve > NURBS Curve**).
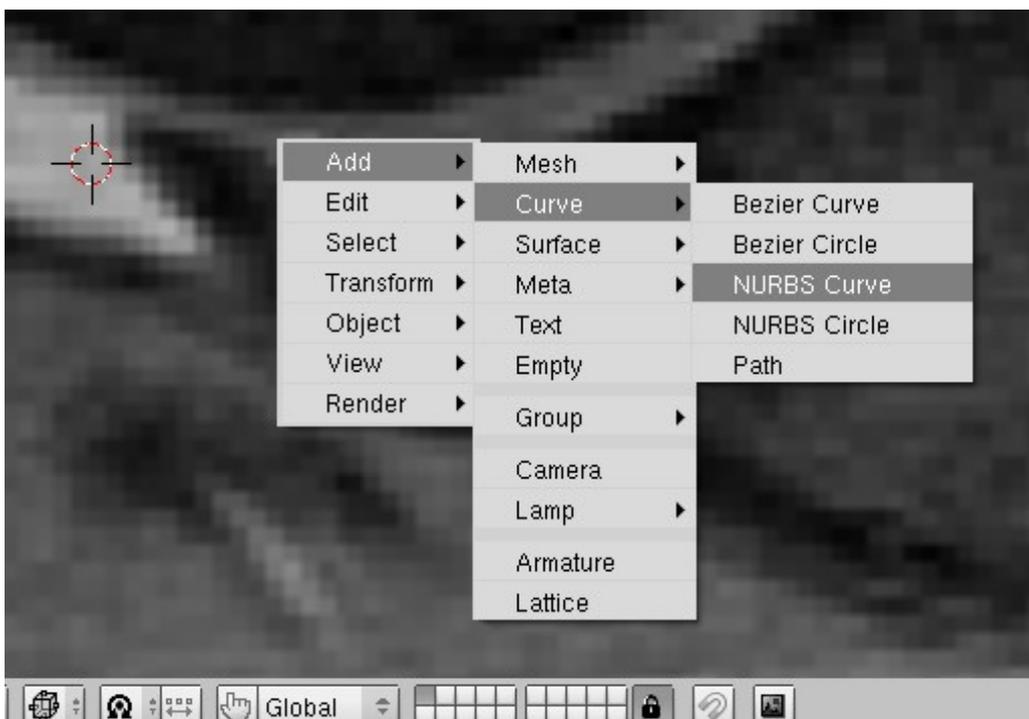
- Turn into **Edit Mode** and press **Keyboard F9**. Select all the NURBS control points (**Keyboard A**). In the **Buttons Window** seek the **Curve Tool** dialog box and press the **Endpoint U** button.
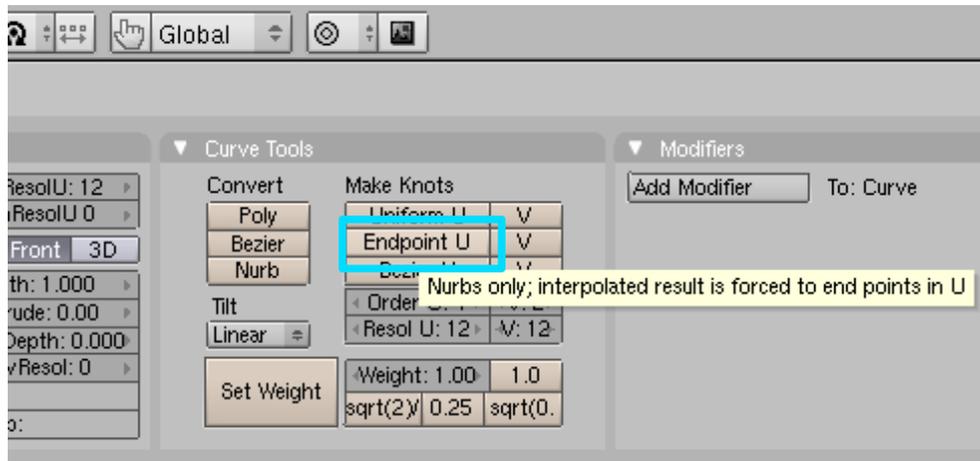
- Enter **Object Mode** (don't forget to press **Keyboard F9**). Use **Keyboard G**, **Keyboard R** and **Keyboard S** to grab, rotate and scale the curve object so that you can place and orient it in the construction plane. Spatially position the curve near a tissue interface.

- Enter **Edit Mode** (don't forget to press **Keyboard F9**). Here you will experience the flexibility of NURBS curves. Use **Keyboard B** or **RMB** to select a control point. Hold down the **Keyboard SHIFT** as you select if you want to pick multiple control points. Press **Keyboard G** to grab each control point to adjust the curve to the tissue interface. After adjusting the curve (when you create a NURBS curve it starts with 4 control points), start modeling from one of the curve endings. Extrude (**Keyboard E**) the elected ending and move your mouse around a bit. This will create a new curve portion that you will align with the neighboring tissue interface. Continue extruding until you cover the desired tissue interface. For closed contours, approximate the NURBS control point endings and press **Keyboard C** to form a close loop. To delete a selected control point use **Keyboard Delete**. To add more control points between two contiguous control points subdivide it with **Keyboard W → Subdivide**.
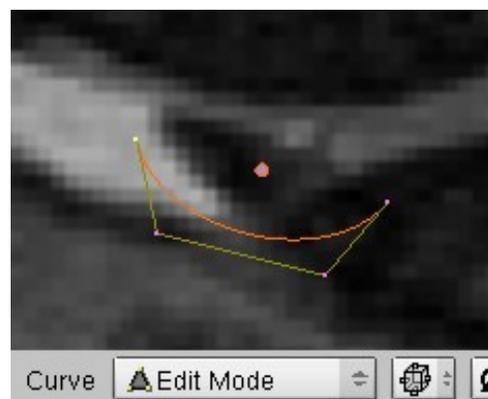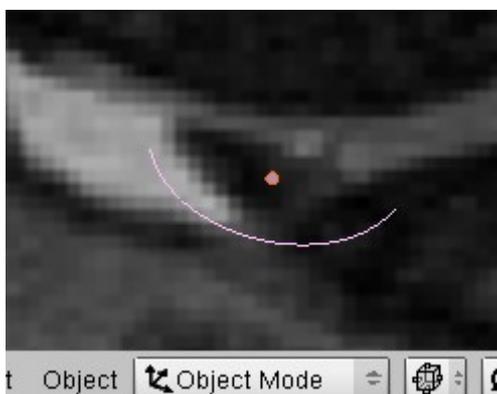
- Name the 3D object according to tissue type and/or anatomical position (anterior, posterior, superior, inferior, medial, lateral, left, right). Call the **Transform Properties** dialog box (**Keyboard N**) and print in the objects name.

- Keep your 3D objects in the XY plane. You can see if the objects are contained within the conventioned construction plane by turning on the **Transform Properties** dialog box in **Object Mode**. Z must be settled to zero, i.e., **Loc Z: 0,000**.
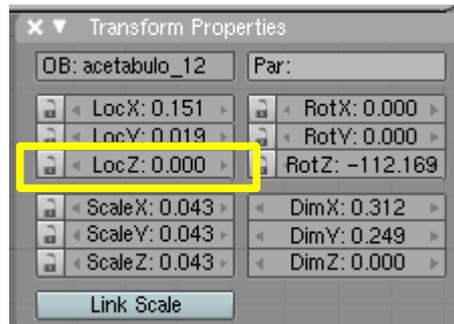
- Once more, do not forget to save your work (**Keyboard CTRL + S > Enter** or **Keyboard CTRL + S > LMB**) as you go through the modeling process.

References:

Blender 3D
http://www.blender.org/

Blender 3D: Noob to Pro/Blender Windowing System
http://en.wikibooks.org/wiki/Blender_3D:_Noob_to_Pro/Blender_Windowing_System

Blender Quickstart Guide
http://www.blendernation.com/2006/01/17/blender-quickstart-guide/

TUFTS University Onpn Courseware - Complete List of Video Tutorials
http://ocw.tufts.edu/Content/28/supplementarymaterial/366743

DicomWorks - free DICOM viewer and converter
http://dicom.online.fr/

OsiriX – DICOM Viewer for Mac users
http://www.osirix-viewer.com/

Gimp - GNU Image Manipulation Program
http://www.gimp.org/