Anatomical Models from Imaging Data

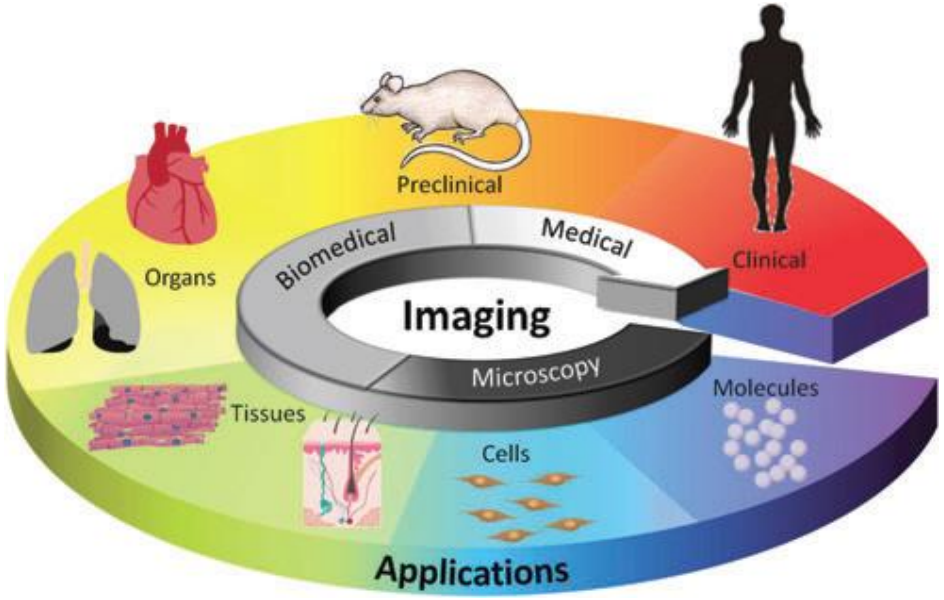
Prof. Steven S. Saliterman

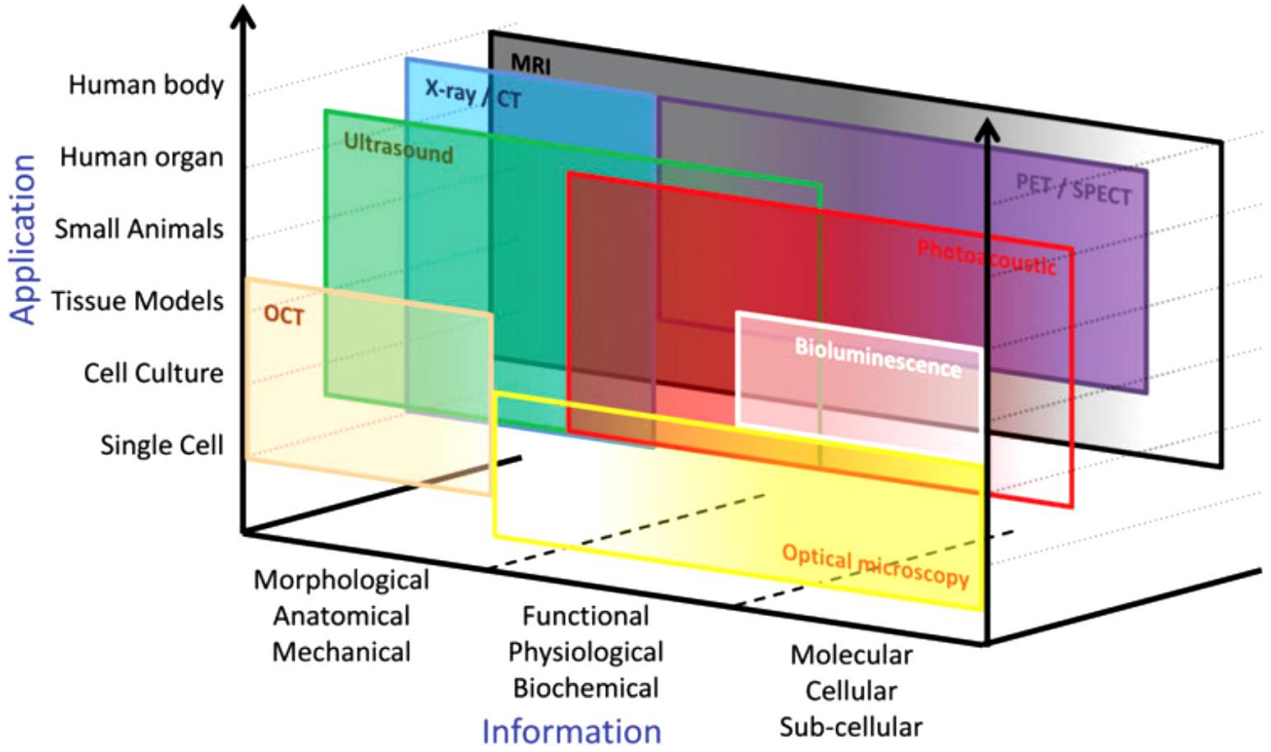
Department of Biomedical Engineering, University of Minnesota

http://saliterman.umn.edu/

BMEN 2151 Medical Device Prototyping

Imaging





Nam, S. Y., et. al. "Imaging Strategies for Tissue Engineering Applications." *Tissue Engineering Part B-Reviews* 21, no. 1 (Feb 2015): 88-102.

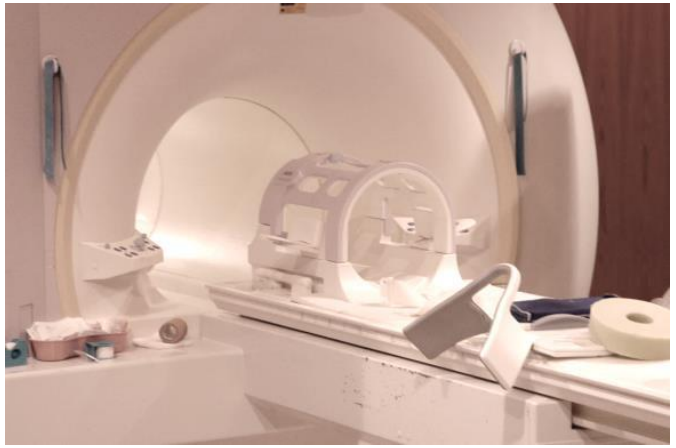
Some Common Imaging Methods…

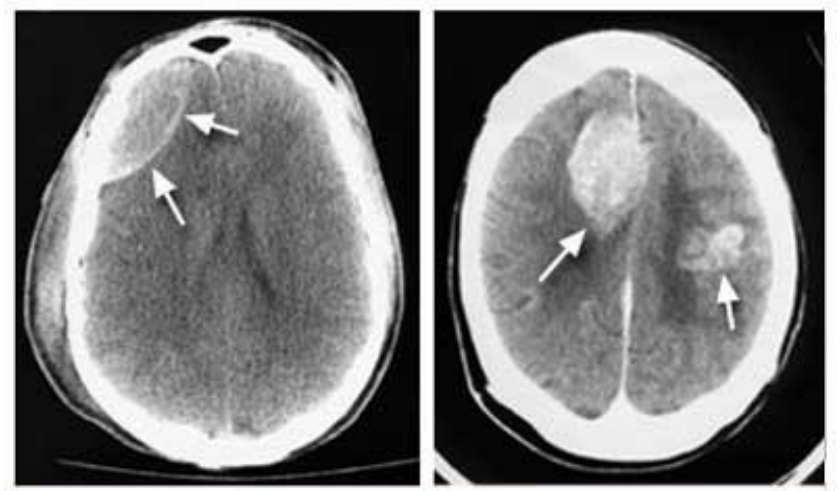
- Magnetic Resonance Imaging (MRI) or NMR
  - Human max. is 3T (Tesla) – resolution of 250μm x 250μm 0.5mm.
  - High spatial resolution μMRI, 7–10T, 5–200μm.
  - Magnetic nanoparticles.
- Computed tomography (CT)– *Computer Axial Tomography*
  - Typical resolution of 0.24 – 0.3mm.
  - μCT, resolution of 1–200μm.
- Ultrasound (less useful in bioprinting)
  - Resolution of 1mm x 1.mm x 0.2mm.
- PET – Positron emission tomography
- SPECT – Single photon emission computed tomography
- Optical Coherence Tomography (OCT)
- Traditional optical techniques.

Components of Medical Imaging…

- Image *formation* & *reconstruction* – using machines to create 2D and 3D images.
- Image *processing* and *analysis* – algorithms to enhance image properties (like noise removal); extracting quantitative information or a set of features from the image for object identification and classification.
- Input into *Machine Leaning* and *Deep Learning* systems for more advanced analysis.

Magnetic Resonance Imaging (MRI) & Computed tomography (CT)...





Positron Emission Tomography (PET)…

CT scan/PET Scan/ Combined

Mayo Foundation for Medical Education and Research

Design Techniques…

- Underlying methods in CAD systems:
  - Constructive solid geometry (solid primitives and boolean operators)
  - Boundary representation (vertices, edges and faces)
  - Spacial enumeration (cubic elements)
- Image-based design
- Implicit surfaces
- Space-filling curves
- Irregular porous structures

Giannitelli, S. M., et. al.. "Current Trends in the Design of Scaffolds for Computer-Aided Tissue Engineering." [In English]. *Acta Biomaterialia* 10, no. 2 (Feb 2014): 580-94.

Segmentation

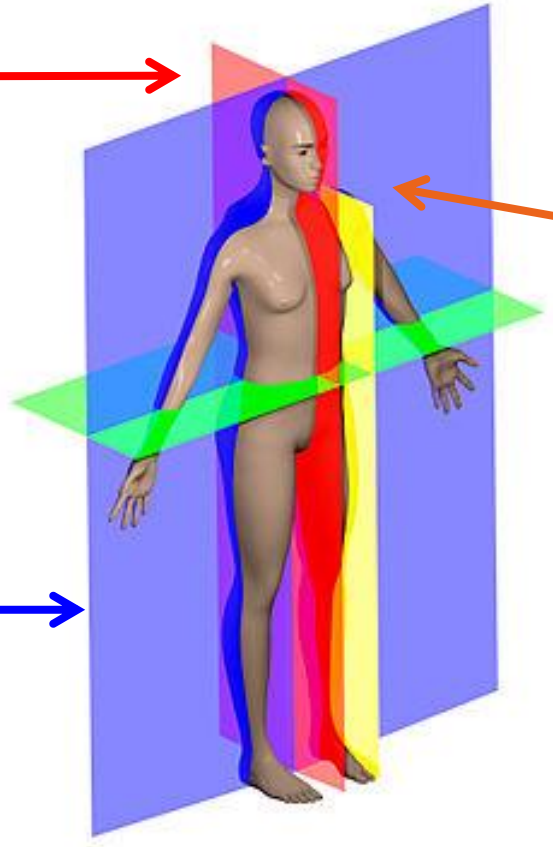
- Purpose
  - To delineate and isolate anatomical features within an imaging database- e.g. bone, cartilage, soft tissue, edema; muscle, lung, brain & other organs, and tumors.
- Categories
  - Manual, Semi-automatic and fully automatic.
- Techniques
  - Thresholding
  - Clustering based approach
  - Edge-based

Segmentation with Available Software…

- Extract images from DICOM files (ITK-Snap, Onis) and possible deidentifying them for HIPPA regulations (DICOMCleaner).
- Segmentation Software (ITK-Snap, Seg3D2, Materialise Mimics, Materialise 3-matic).
  - Pre-segmentation Phase – identify parts of image as foreground and background.
  - Active Contour Phase – manual and semiautomatic methods.
- Editing and fixing mesh files (.STL) – Autodesk Meshmixer.
- Slicer software – Simplify3D and Repetier.
  - G-coding for the specific bioprinter – e.g. Slic3R (printer customized interface to control what happens in a sequence of control steps.)

Know the Main Anatomical Planes…

Sagittal or Median



Parasagittal
(Yellow)

Transverse or Axial

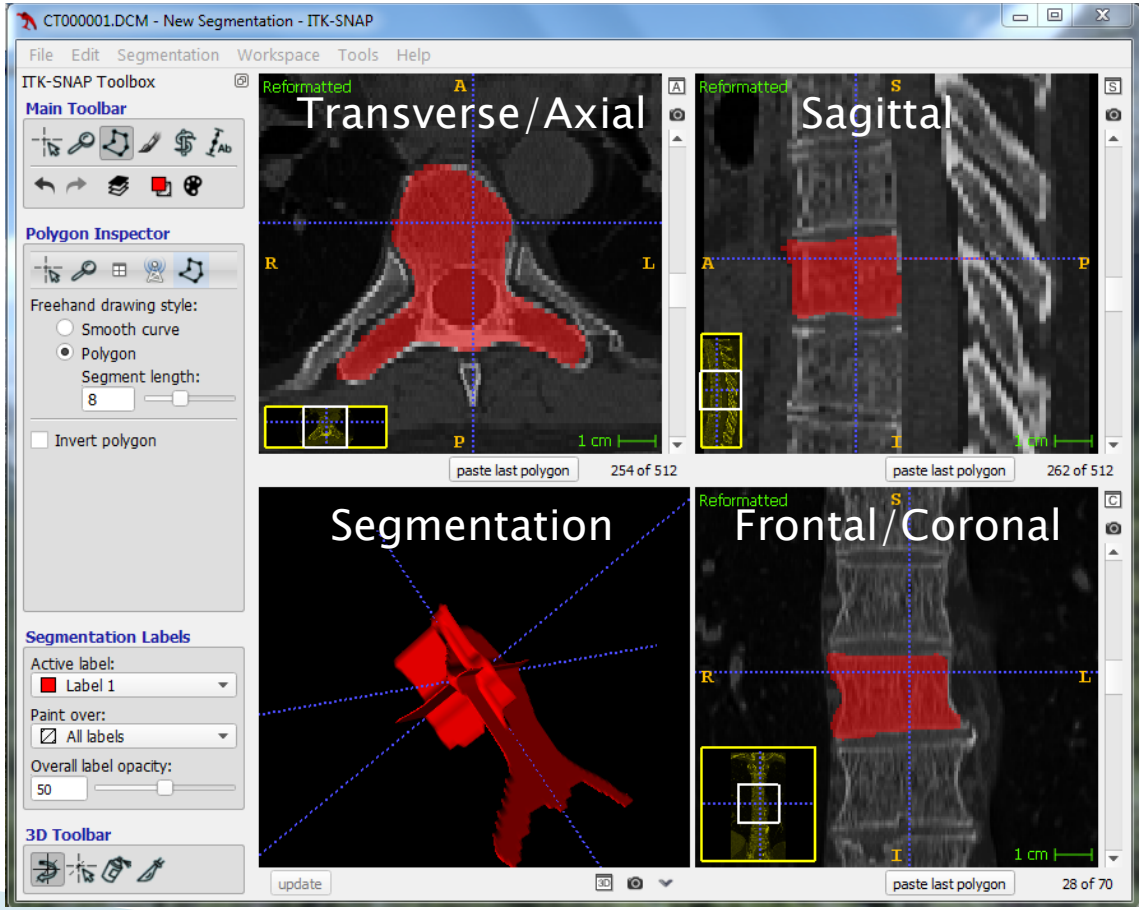
Frontal or Coronal

ITK Snap Demo Next…

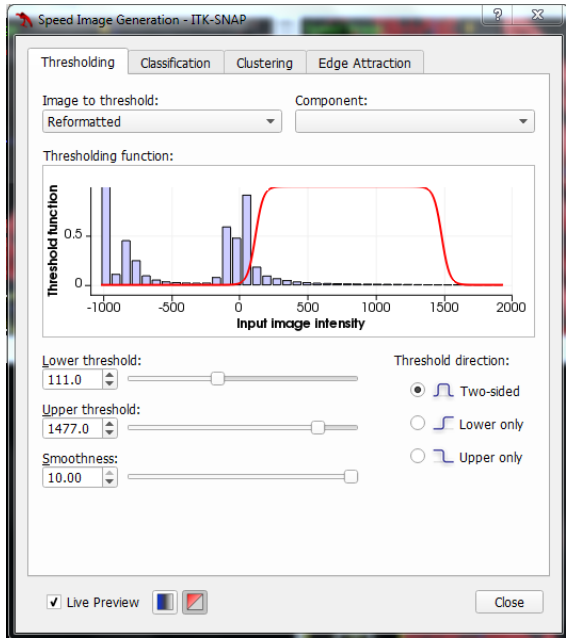
Image, Wikipedia

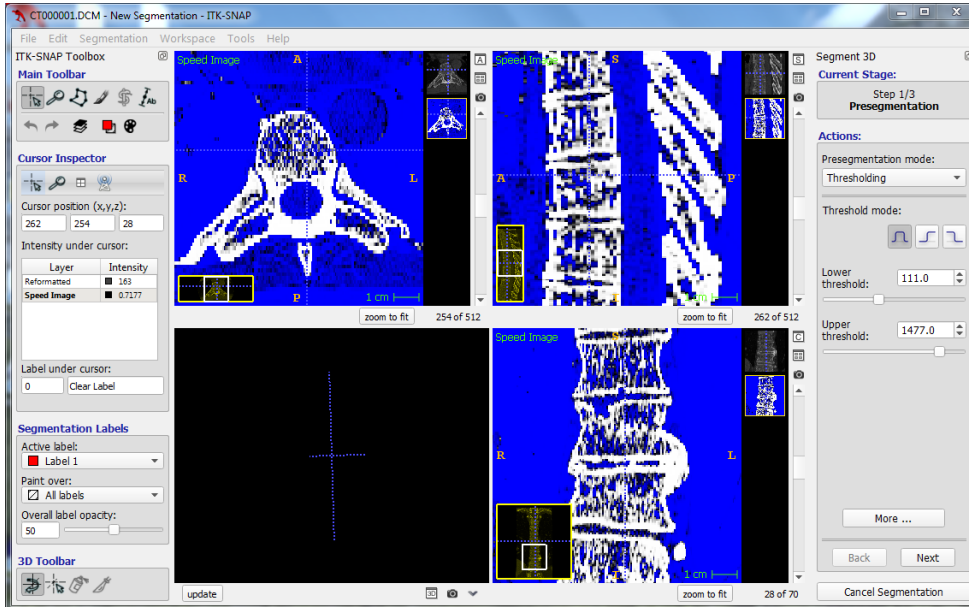
Segmentation with ITK-Snap (freeware).

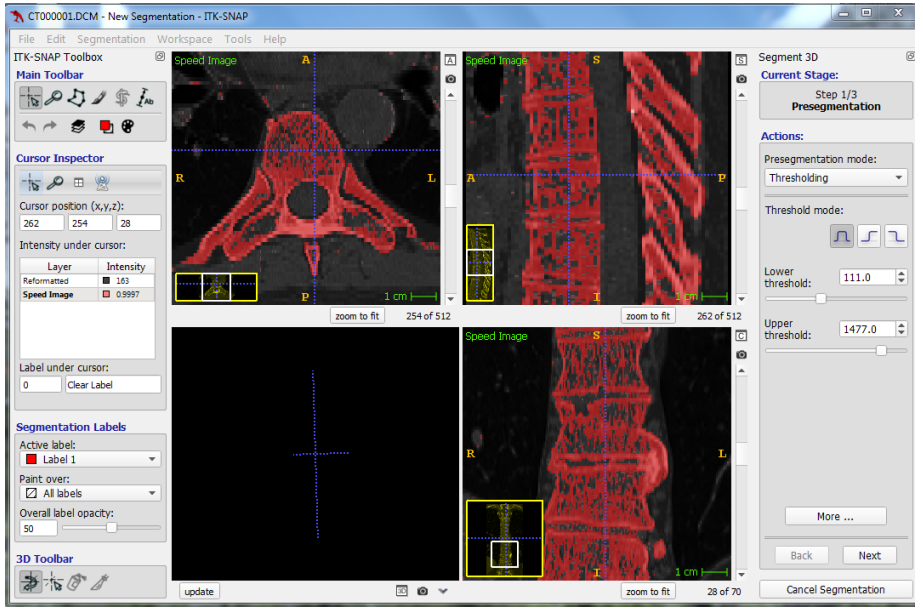
Manual Segmentation…



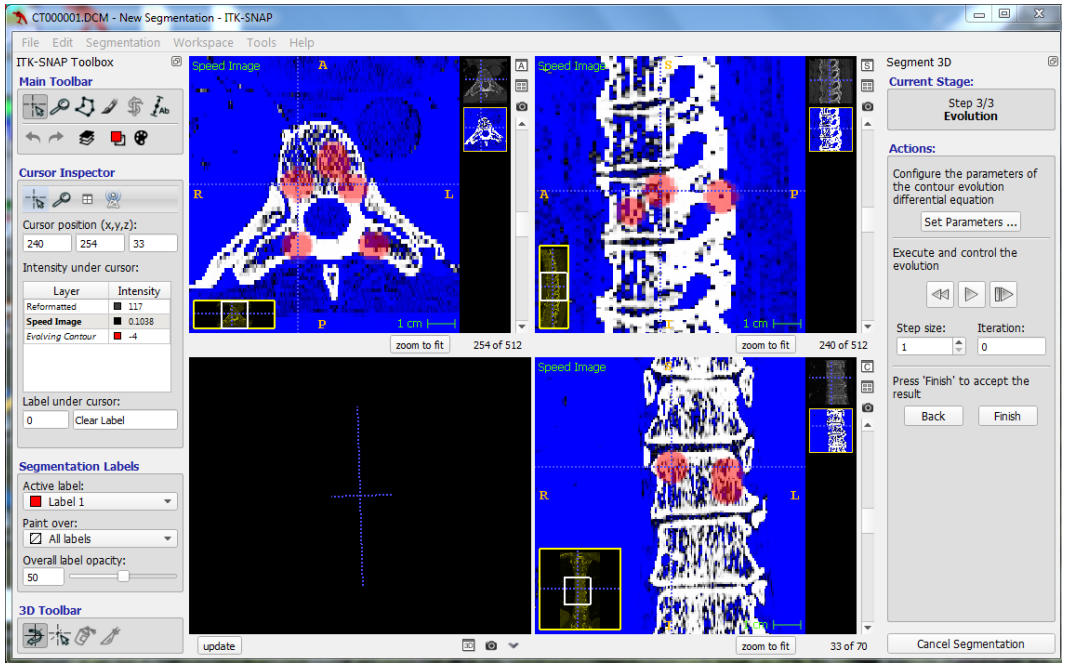
Semiautomatic – Contrast Adjustment…

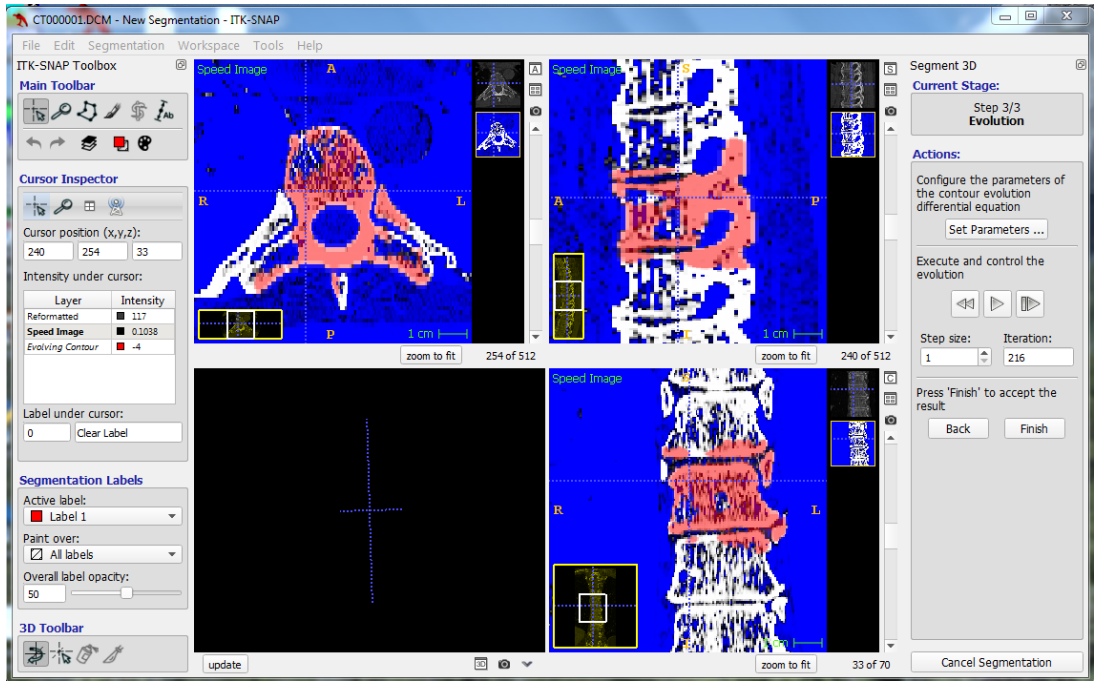




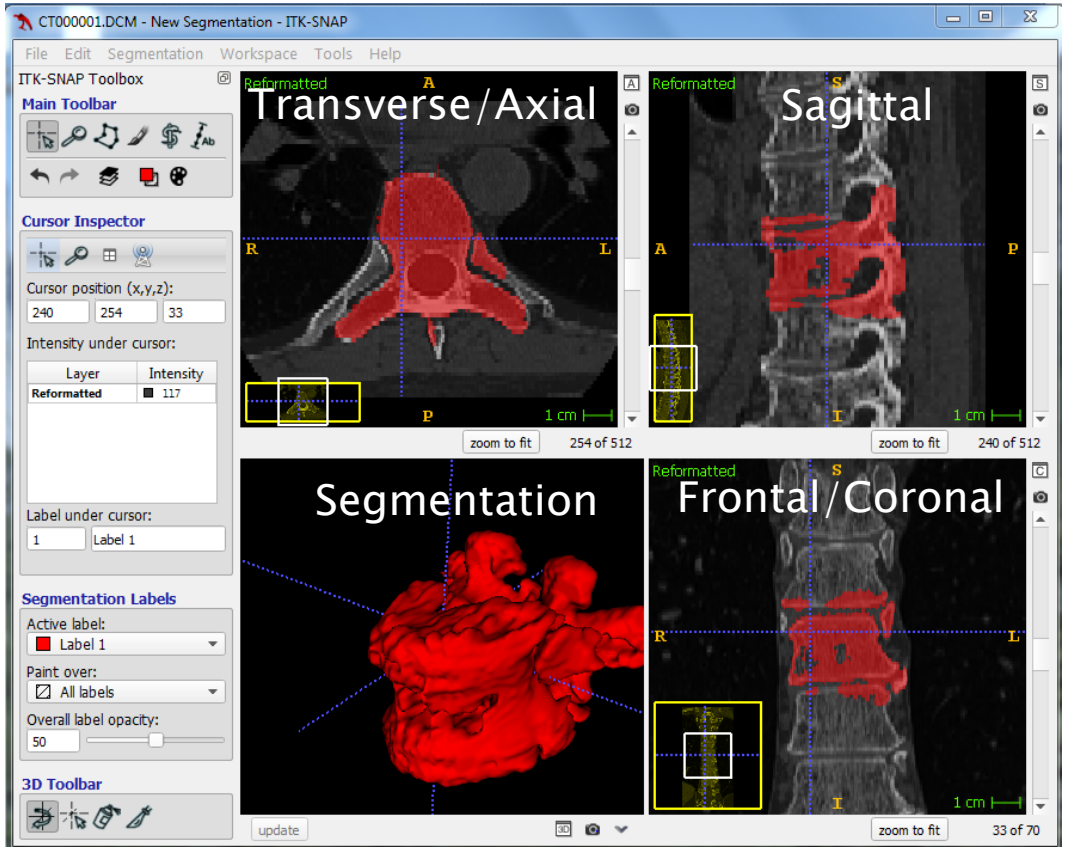


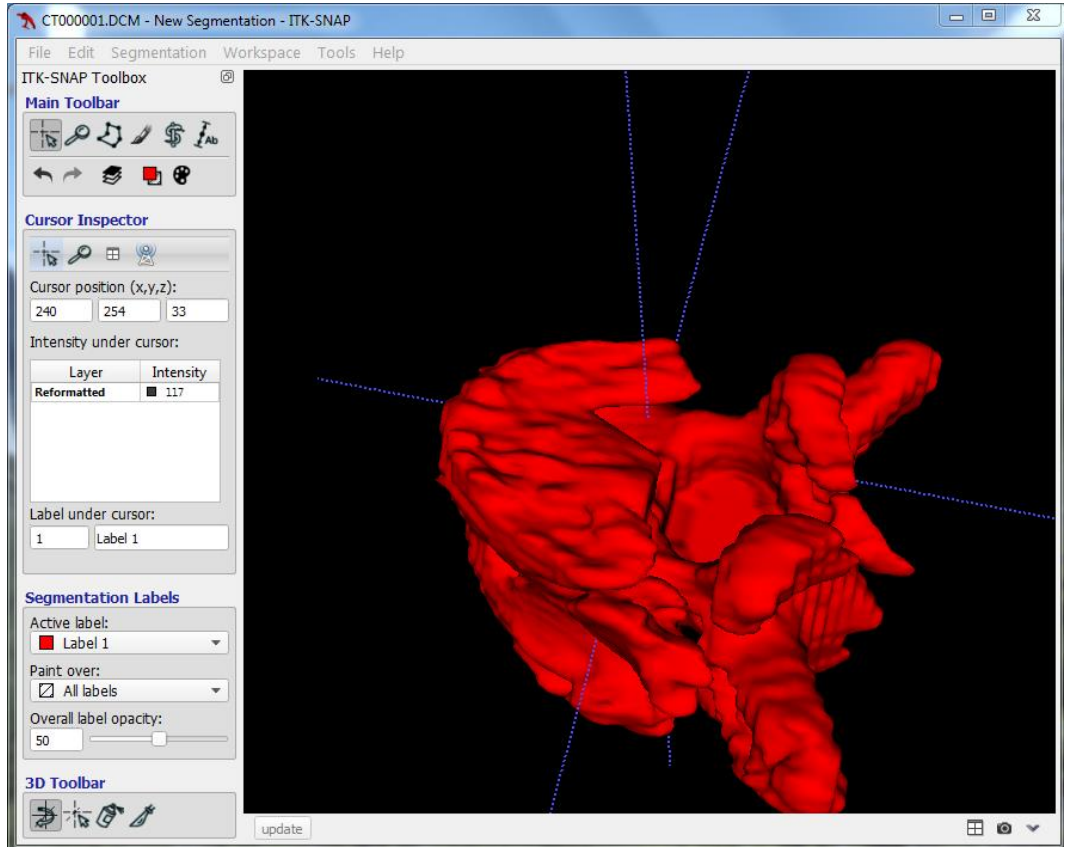
“Balloon” Placement & Inflation…



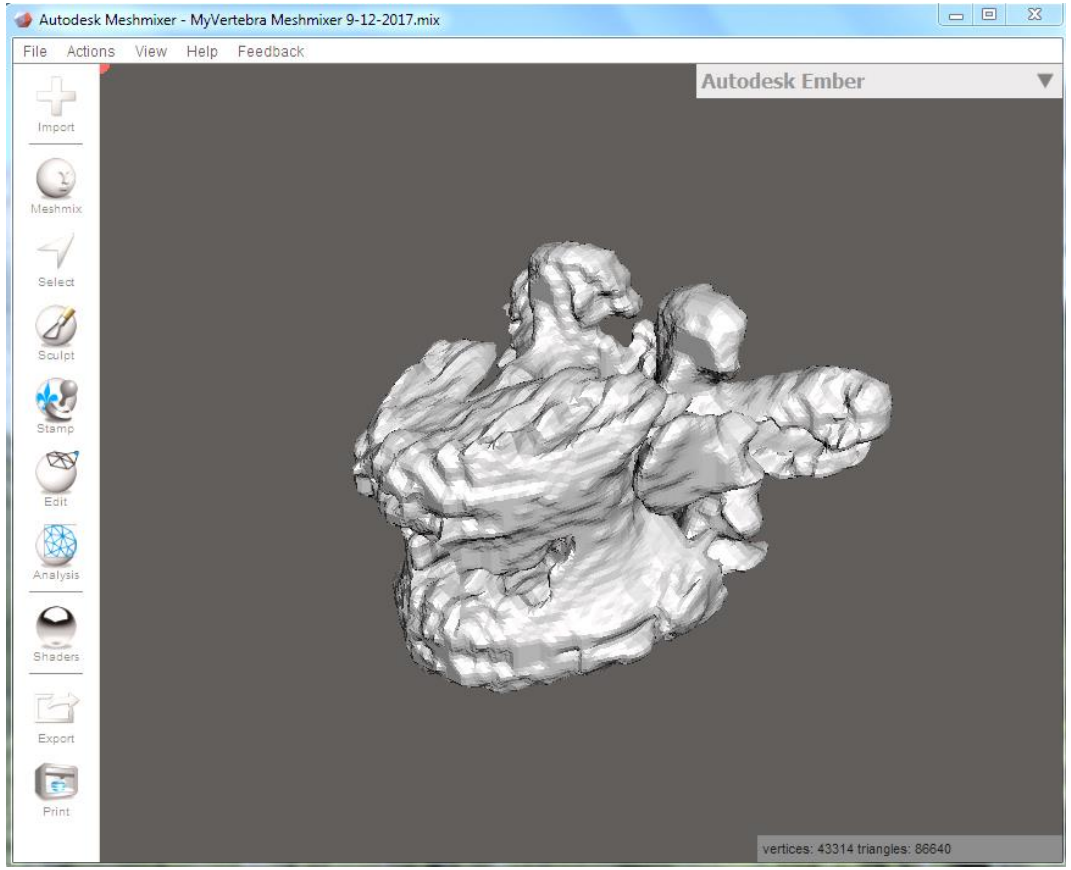


3D Rendering…

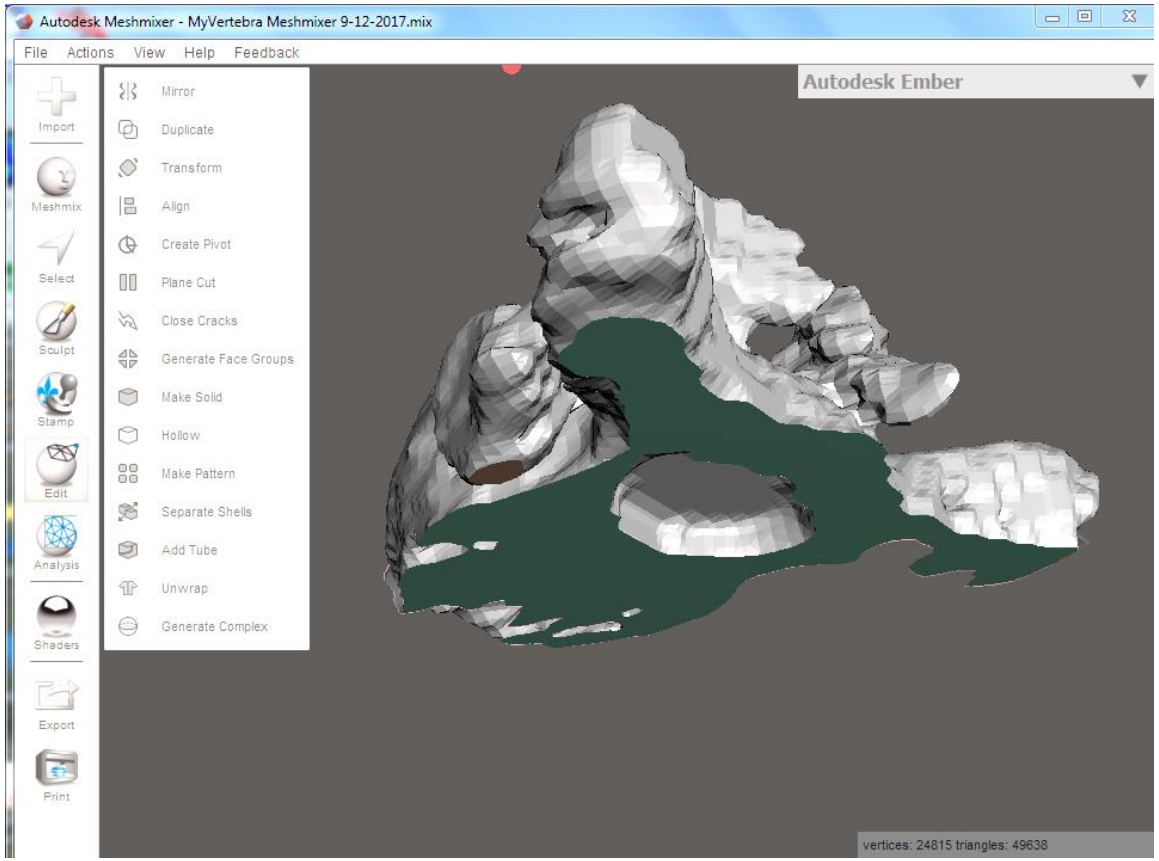




Editing with Meshmixer (freeware)…

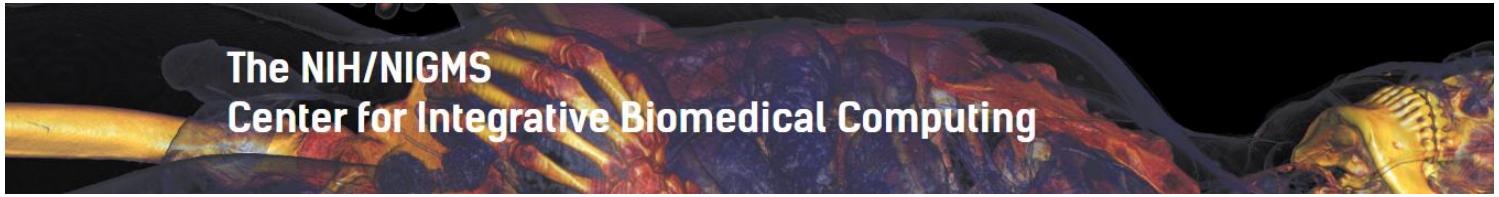


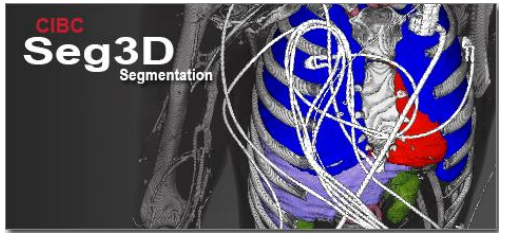
Import the STL Mesh file generated by ITK-Snap.



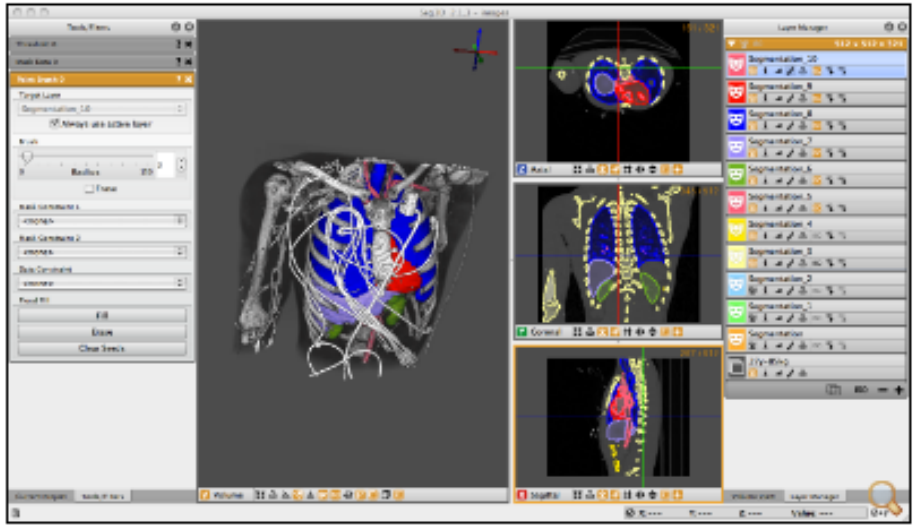
Edit feature – here slicing in a plane, bottom view.

Segmentation of the Cerebellum





Seg3D is a free volume segmentation and processing tool developed by the NIH Center for Integrative Biomedical Computing at the University of Utah Scientific Computing and Imaging (SCI) Institute. Seg3D combines a flexible manual segmentation interface with powerful higher-dimensional image processing and segmentation algorithms from the Insight Toolkit. Users can explore and label image volumes using volume rendering and orthogonal slice view windows.

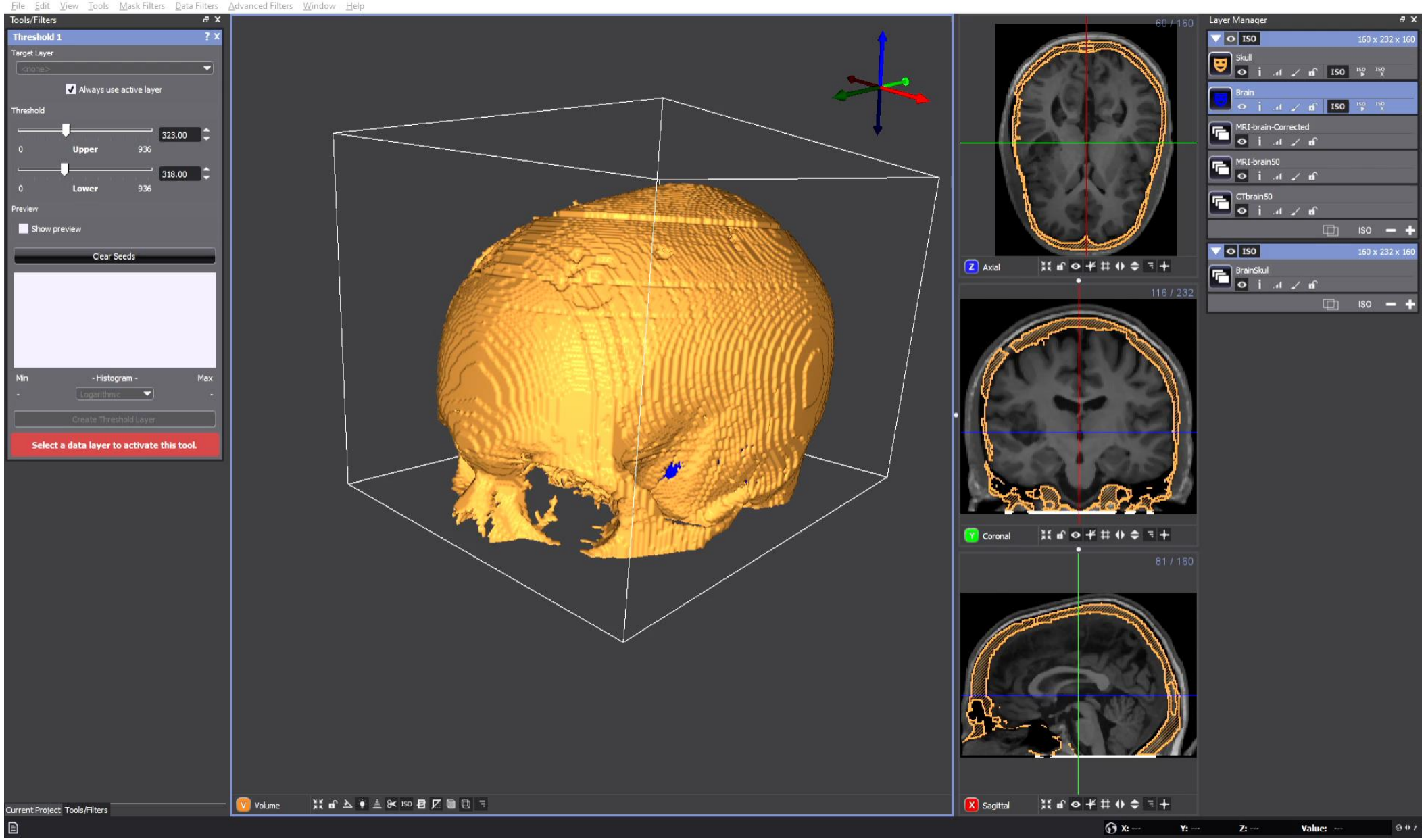


Seg3D at a glance:

- Fully 3D interface with multiple volumes managed as layers
- Automatic segmentation integrated with manual contouring
- Volume rendering with 2D transfer function manipulation in real-time
- Image processing and segmentation from the Insight Toolkit (ITK)
- Real time display of ITK filtering output allows for computational steering
- 64-bit enabled for handling large volumes on large memory machines
- Supports many common biomedical image formats
- Open source with BSD-style license
- Cross platform: Windows, OSX, and Linux

Seg3D

https://www.sci.utah.edu/cibc-software/seg3d.html

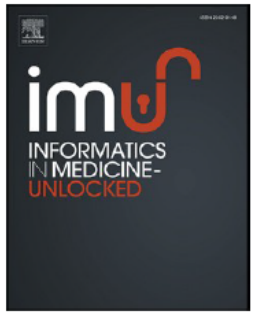

File Edit View Tools Mask Filters Data Filters Advanced Filters Window Help
Tools/Filters
Threshold 1
Target Layer
<none>
Always use active layer
Threshold
323.00
0 Upper 936
318.00
0 Lower 936
Preview
Show preview
Clear Seeds
Min - Histogram - Max
Logarithmic
Create Threshold Layer
Select a data layer to activate this tool.
Current Project Tools/Filters
Volume
60 / 160
Axial
116 / 232
Coronal
81 / 160
Sagittal
Layer Manager
ISO 160 x 232 x 160
Skull
Brain
MRI-brain-Corrected
MRI-brain50
CTbrain50
ISO
ISO 160 x 232 x 160
BrainSkull
ISO
X: --- Y: --- Z: --- Value: ---

Informatics in Medicine Unlocked 18 (2020) 100297

Contents lists available at ScienceDirect

Informatics in Medicine Unlocked

journal homepage: http://www.elsevier.com/locate/imu



Deep learning approaches to biomedical image segmentation

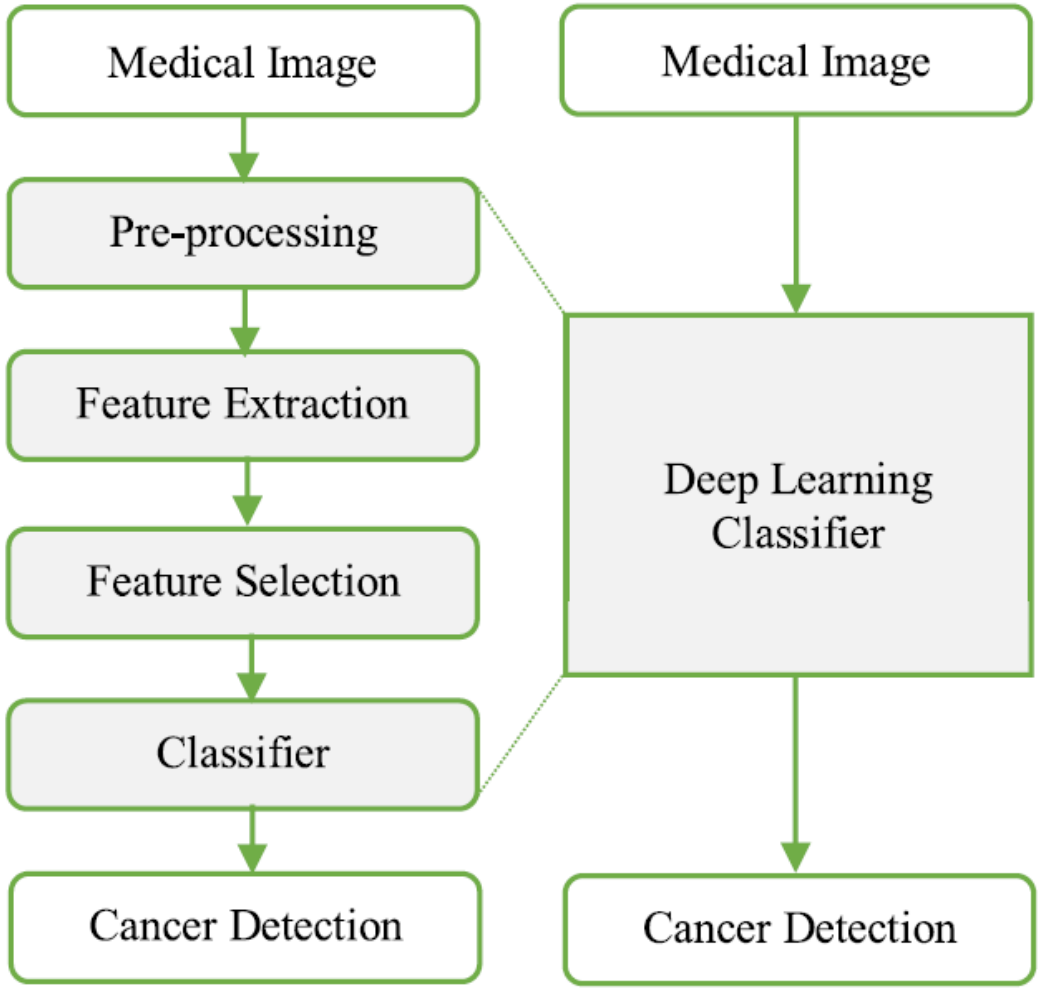
Intisar Rizwan I Haque [a,b,*,1], Jeremiah Neubert [c,2]

[a] University of North Dakota (UND), College of Engineering and Mines, Grand Forks, ND, USA
[b] National University of Sciences and Technology (NUST), Islamabad, Pakistan
[c] University of North Dakota, College of Engineering and Mines, Grand Forks, ND, USA

Machine & Deep Learning

- Identification and quantification of patterns in medical images.
- Implications for clinical diagnosis with automated and enhanced throughput, and applications of segmentation – including 3D model building and bioprinting.
- Simple machine learning includes automated analysis, beginning with *feature extraction* based on visually distinct regions – color, gray scale, texture, contrast and size. These regions have semantic meaning for the given problem. This becomes input into an *ML classifier*, which can determine optimal boundaries.
- With a *deep learning-based classifier (DLC),* raw image data is processed without pre-processing, segmentation and feature extraction.

Traditional



Future

Fig. 1. Change in classifier approach using typical machine learning algorithm and deep learning. Figure adapted from Ref. [14].

Haque, IR, J. Neubert, Deep learning approaches to biomedical image segmentation. Informatics in Medicine, 18 (2020).

frontiers in Bioengineering and Biotechnology

MINI REVIEW
published: 10 January 2020
doi: 10.3389/fbioe.2019.00443

Check for updates

Engineering Tissue Fabrication With Machine Intelligence: Generating a Blueprint for Regeneration

Joohyun Kim[1], Jane A. McKee[2], Jake J. Fontenot[2] and Jangwook P. Jung[2]**

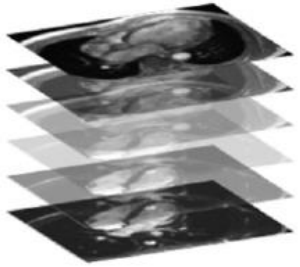
[1] Center for Computation and Technology, Louisiana State University, Baton Rouge, LA, United States, [2] Department of Biological Engineering, Louisiana State University, Baton Rouge, LA, United States

Prof. Steven S. Saliterman

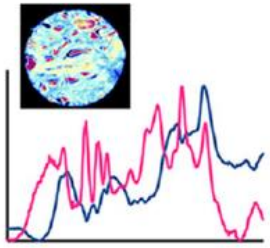
1) Generation of a blueprint for regeneration

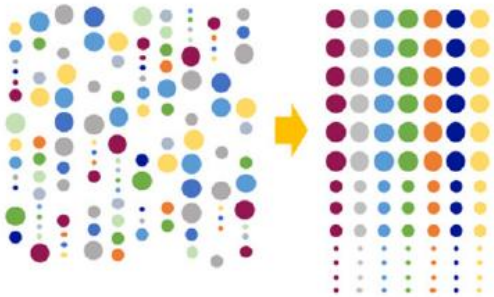
Information retrieval → Feature extraction → Generation of a blueprint

Imaging data



Spectral data





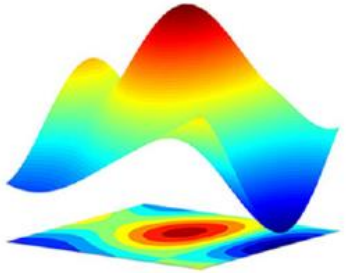
2) Machine intelligence-guided 3DBP

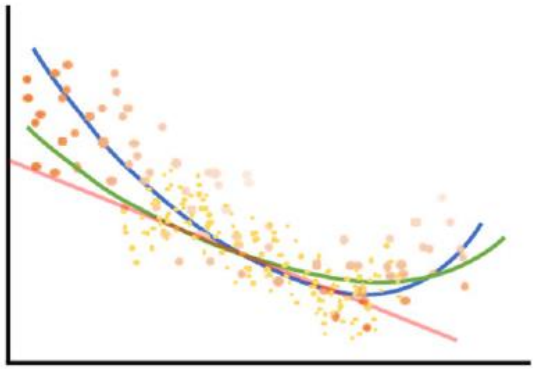
Parameter optimization → Predictive modeling → 3DBP guided by MI

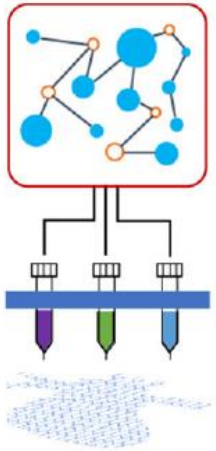
$$\mathbf{F}, \mathbf{T}$$

$$\pi, \rho, \eta, \varepsilon, \Lambda, \Sigma, \Theta$$

$$f^l = g(W^l f^{l-1} + b^l)$$







Combining 1) and 2) for producing an end-to-end (E2E) platform with unprecedented and accelerated advancement of tissue fabrication

Kim J, McKee JA, Fontenot JJ, Jung JP. Engineering Tissue Fabrication With Machine Intelligence: Generating a Blueprint for Regeneration. *Frontiers in Bioengineering and Biotechnology.* 2020;7.

Summary

- Review of Workflow
- Imaging
- Design
- Segmentation
- Application of Machine Learning and Deep Learning