Automatic Brain Segmentation for 3D Printing - Phase 2

Group B1
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Our Team

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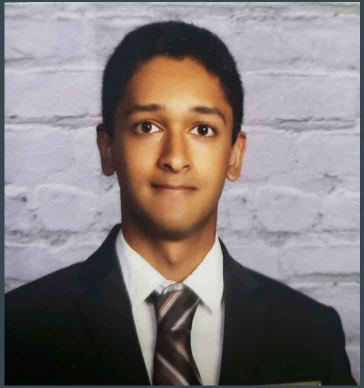

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Project Recap

- Create a personalized brain model from an MRI scan
- Make the process from MRI scan to brain model nearly fully automatic
- Print 3D model to help doctor/surgeons have a general visual aid when explaining the patient's brain ailments or upcoming surgeries
- Create 3D models to serve as gifts/souvenirs for patients receiving brain-related treatment
- Phase 1:
  - Scope defined
  - State-of-the-art review
  - Needs and specifications
  - Concept development and selection

Phase 1 Feedback Responses

Phase 1 Panel Feedback	Solutions/Responses
The group should show how to evaluate the segmentation software tools (DICOM and Nifti) in concept selection matrix form with the list of selection criteria	The group decided to evaluate the segmentation software tools by looking at three different features, automization, usability and segmentation time. The software with the best ratings among these will be chosen
Once you can generate the 3d model of the brain, it would be useful if you can break down into a set of brain segments and print them together. That may reduce the supports	Once the softwares and other components of our pipeline which will be explained shortly are finalized this is something that the group will look into more.
With regards to fabrication, in addition to the Photo-polymer jetting (Polyjet) printer that I mentioned during your presentation you should also look into other soft FDM materials like TPU and TPE filaments. You make also want to consider using the 3D printer to create a mold for the brain model. You can then use the mold to cast the brain model out of a material that has similar material properties as the brain.	The use of a softer material is something the group is definitely looking into doing as this would provide a very accurate representation of the brain. The idea would be for the softer material to be used for the outer grey matter area and a more firm one to be used for the inside.

3D Printing the Brain

Nicolas Re, Bailey Gano, Nathan Carpenter, Achira Fernandopulle, Leo Musacchia

This graphic will outline the process that must be used in order to go from an MRI image to a 3D printed model of the brain. The purpose of this project is to create a personalized model of a patients brain that can the be used by doctors as a reference when conveying diagnoses and other technical information. This product could be incredibly beneficial to patients because having an accurate visual representation of the brain will make it a lot easier to understand complicated ideas and terminology to those that are not medically trained. This will cause patients to be more well-informed when they leave to doctor's office and reduce the risk of obtaining misinformation.

1 Gather Input

MRI scans of the brain come in either a Nifti file or a DICOM series. The type of file it comes in effects the image resolution, patient information, dimensional data, and the required processing for upcoming steps.

2 Segmentation

This step will utilize a program that cuts the MRI images into slices that can be individually refined to ensure an accurate model of the brain. This step will also remove any extraneous data captured by the MRI machine such as air, skin, eyes, etc.

3a One Material

If the brain model were to be 3D printed using one material, each slice would be homogenous throughout while going through the segmentation software. The primary area of interest is the outer boundary of the brain, making sure that all of the folds and indentations are accurate.

3b Two Materials

If the brain were to be 3D printed using two materials, each slice would be comprised of two areas: an inner section where most of the mass is located and a thin outer layer. These two areas denote white and grey matter, respectively, and the grey matter will be printed using a translucent material so the white matter can also be seen underneath. In this case, the areas of interest are the outer boundary of the brain and the white matter-grey matter interface.

4 Reconstruction

The segmentations can now be recompiled into a 3D surface model. The model will either have one or two surfaces to generate depending on if there are one or two materials being used in the printing process. This reconstruction will also convert the Nifti/DICOM file into an STL file that can be 3D printed.

5 Final Repairs

The reconstructed brain can be refined and cleaned up for the final print. Possible repairs that can be made include smoothing out the surface of the model, cleaning up any holes or deformations that may have formed, and a general quality check./*

6 Print

The model can now be printed!

Pipeline Text

1. **Gather Input**: MRI scans of the brain come in either a Nifti file or a DICOM series. The type of file it comes in effects the image resolution, patient information, dimensional data, and the required processing for upcoming steps.
2. **Segmentation**: MRI scans of the brain come in either a Nifti file or a DICOM series. The type of file it comes in effects the image resolution, patient information, dimensional data, and the required processing for upcoming steps.
3. Materials
   a. **One Material**: MRI scans of the brain come in either a Nifti file or a DICOM series. The type of file it comes in effects the image resolution, patient information, dimensional data, and the required processing for upcoming steps.
   b. **Two Materials**: If the brain were to be 3D printed using two materials, each slice would be comprised of two areas: an inner section where most of the mass is located and a thin outer layer. These two areas denote white and grey matter, respectively, and the grey matter will be printed using a translucent material so the white matter can also be seen underneath. In this case, the areas of interest are the outer boundary of the brain and the white matter-grey matter interface.

Pipeline Text

4. Reconstruction: The segmentations can now be recompiled into a 3D surface model. The model will either have one or two surfaces to generate depending on if there are one or two materials being used in the printing process. This reconstruction will also convert the Nifti/DICOM file into an STL file that can be 3D printed.
5. Final Repairs: The reconstructed brain can be refined and cleaned up for the final print. Possible repairs that can be made include smoothing out the surface of the model, cleaning up any holes or deformations that may have formed, and a general quality check.
6. Print

Segmentation Software Comparison

Table 2 Software comparison

Software	Automatization	Usability	3D visualization	Segmentation time	Registration	Tractography	OS		
							Windows	Linux	Macintosh
3D Slicer	3	3	4	15th	x	x	x	x	x
Anatomist	1	1	1	>25 h			x	x	x
AW Server	3	3	3	>20 h	x	x	x		x
Freesurfer	2	2	1	>20 h	x	x		x	x
FSL	1	1	2	>25 h	x	x		x	x
ImageJ	2	2	1	>25 h	x		x	x	x
ITK-SNAP	3	4	4	10 h			x	x	x
Mango	1	3	2	>20 h	x		x	x	x
MedInria	3	3	3	>20 h	x	x	x	x	x
MIPAV	3	2	2	>20 h	x	x	x	x	x
Myrian Studio	3	3	4	9 h	x		x		
Olea Sphere	3	33	4	>20 h	x	x	x	x	x
OsiriX	3	3	4	>20 h	x				x
Seg3D	2	4	3	20 h			x	x	x

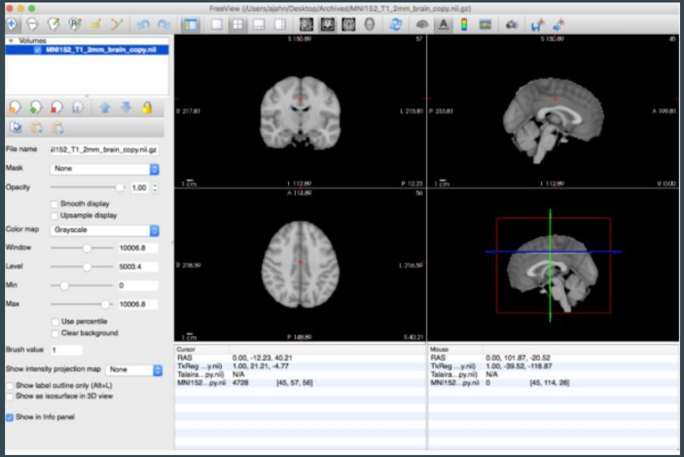
Alessio Virzì, 24 June 2019, Comprehensive Review of 3D Segmentation Software Tools for MRI Usable for Pelvic Surgery Planning, retrieved from https://link.springer.com/content/pdf/10.1007/s10278-019-00239-7.pdf

Segmentation Software Comparison

	Segmentation Software		
Criteria	ITK-Snap	3D Slicer	Free Surfer
Automization	1	2	3
Usability	1	2	3
Segmentation Time	1	1	2

Freesurfer Progress

- Successfully installed Freesurfer onto our computer
- Learning how to upload and construct Nifti Files
- Exploring various tutorials to gain a better understanding of Freesurfer
- Working with other students from our lab who have experience with this software and its applications



Material

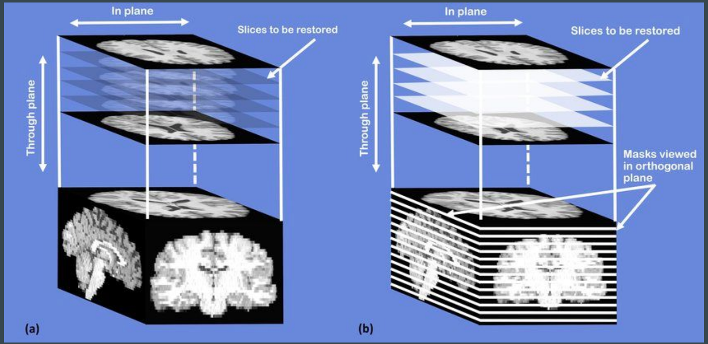
- Opaque Material (for use in a single material model and the core of a two material model)
  - Poly Lactic Acid (PLA) Filament
    - Low cost- about $10-$40 per kg
    - Handles very complex geometries well- can sometimes print overhangs of up to 80 degrees
    - Relatively stiff and strong
    - Biodegradable
- Transparent Material (for the outer layer of a two material model)
  - There are also clear PLA options!

Printing

- Decided on two-material model
- Polyjet printing using Objet 350 Connex 3
  - Build volume of 340mm x 340mm x 200mm
  - Layer resolution of 0.016mm or 0.03mm
  - 5 material families and 140 digital materials
- Polyjet Support Materials
  - SUP705: gel-like photopolymer
  - SUP706: soluble support

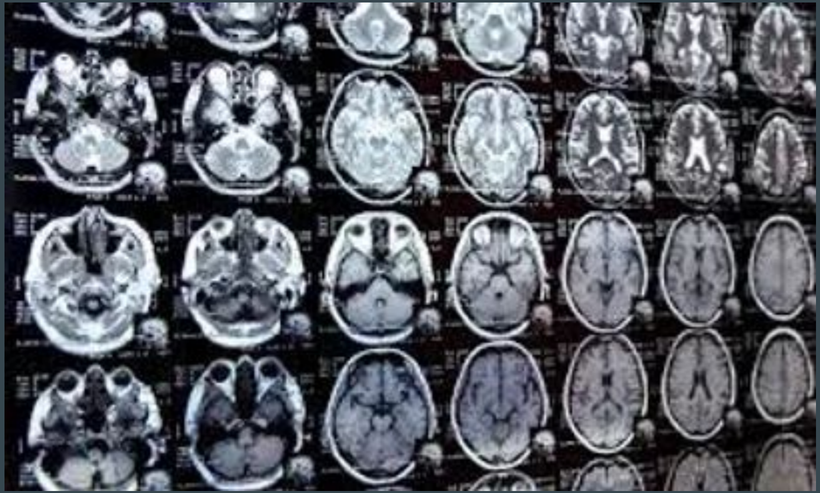
Technical Analysis - Gathering Input

- Medical images → stack of 2D images with in-plane and out-of plane resolution
- Medical MRI scanners typically take 20-60 minutes, have magnetic field strengths of 1.5 or 3T, and can reach resolutions of 1.5 x 1.5 x 4 mm^3
- Typical scans are isentropic with voxel dimensions of 3 x 3 x 3 mm^3
- Slice thickness: Diagnosis MRI thicknesses >2mm
- Want both in-plane and through-plane resolution to be as isentropic as possible



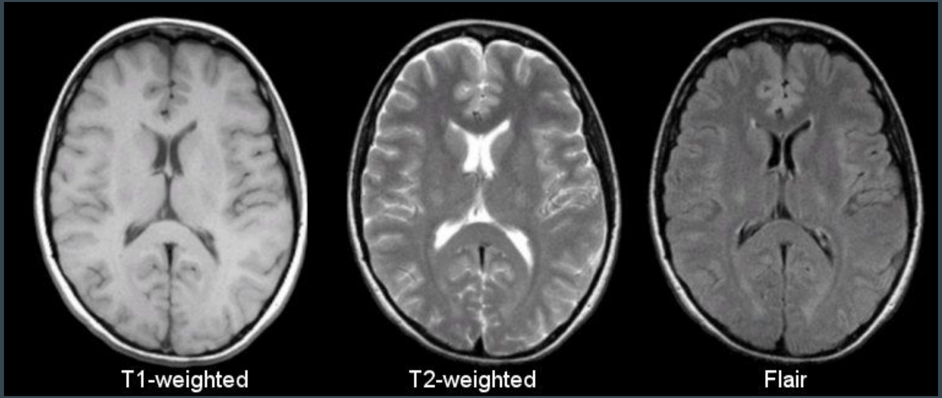
Technical Analysis - Gathering Input

- Databases that have open access to MRI files, such as OASIS and ADNI
  - Both healthy and unhealthy brains
  - Need to apply to programs for access
  - The thousands of scans from varying backgrounds would help fine tune our program



Technical Analysis - Segmentation

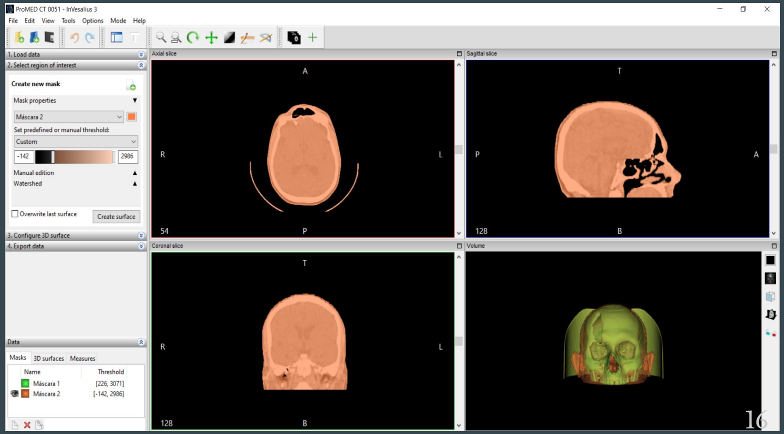
- To create model we need to delineate the gray matter and white matter interface
- In order to achieve that we need high contrast between white and gray matter so that our code will be able to easily detect and distinguish the two
- Three methods would be using T1-weighted scans, T2-weighted scans, and Flair (Fluid Attenuated Inversion Recovery)
    - Each create different contrasts and brightnesses for the different regions



https://case.edu/med/neurology/NR/MRI%20Basics.htm

Technical Analysis - Reconstruction - InVesalius

- Free open source software
- Specifically for converting DICOM, Analyze, or Nifti into a 3D image
- Works for Linux, Windows, and macOS
- Includes 3D surface creation, connectivity tools, and exportation to STL, OBJ, VRML, and Inventor
- Contains settings with varying degrees of intensity projection
- Requirements:
    - Intel Pentium 4 processor or 1.5 GHz equivalent
    - 1 GB of RAM
    - 80 GB hard drive
    - 64 MB graphics card
    - 1024 × 768 pixel video resolution
- Automatically fills holes based on size in voxels



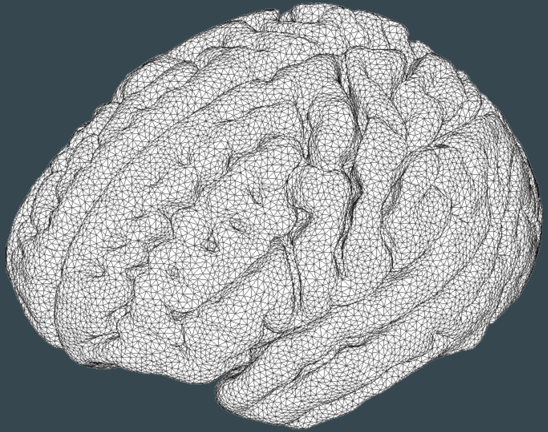
Technical Analysis - Repair - Meshmixer vs. Brain2Mesh

Meshmixer

- Free
- Compatible with multiple materials
- Uses STL as primary input and allows for manipulation
- Automatic features

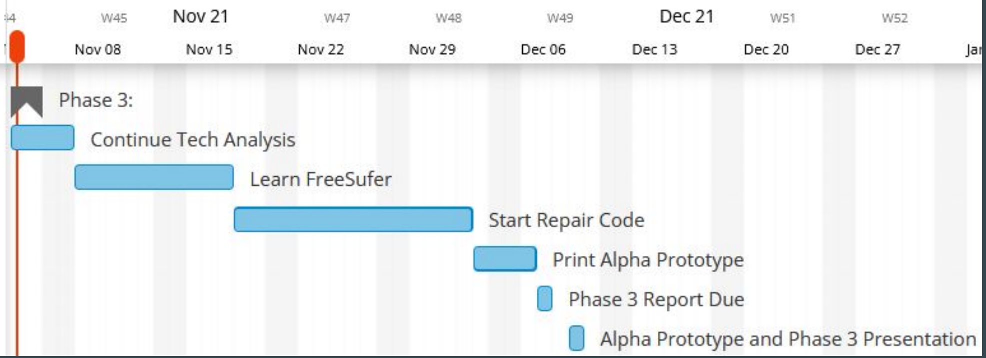
Brain2Mesh

- Free
- MATLAB based
- Dedicated to multilayered brain models
- Contains internal database of brain models



Project Plan - Gantt Chart

	Search tasks...	ASSIGNEE	EH	START	DUE	%
	Phase 3:		-	04/Nov	09/Dec	0%
1	Continue Tech Analysis	Unassigned	-	04/Nov	07/Nov	0%
2	Learn FreeSufer	Unassigned	-	08/Nov	17/Nov	0%
3	Start Repair Code	Unassigned	-	18/Nov	02/Dec	0%
4	Print Alpha Prototype	Unassigned	-	03/Dec	06/Dec	0%
5	Phase 3 Report Due	Unassigned	-	07/Dec	07/Dec	0%
6	Alpha Prototype and Phase ...	Unassigned	-	09/Dec	09/Dec	0%



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http://fmri.ucsd.edu/Howto/3T/structure.html

https://case.edu/med/neurology/NR/MRI%20Basics.htm

http://biomechanics.stanford.edu/paper/WNS16.pdf

http://mcx.space/brain2mesh/

https://www.meshmixer.com/

Thank You!