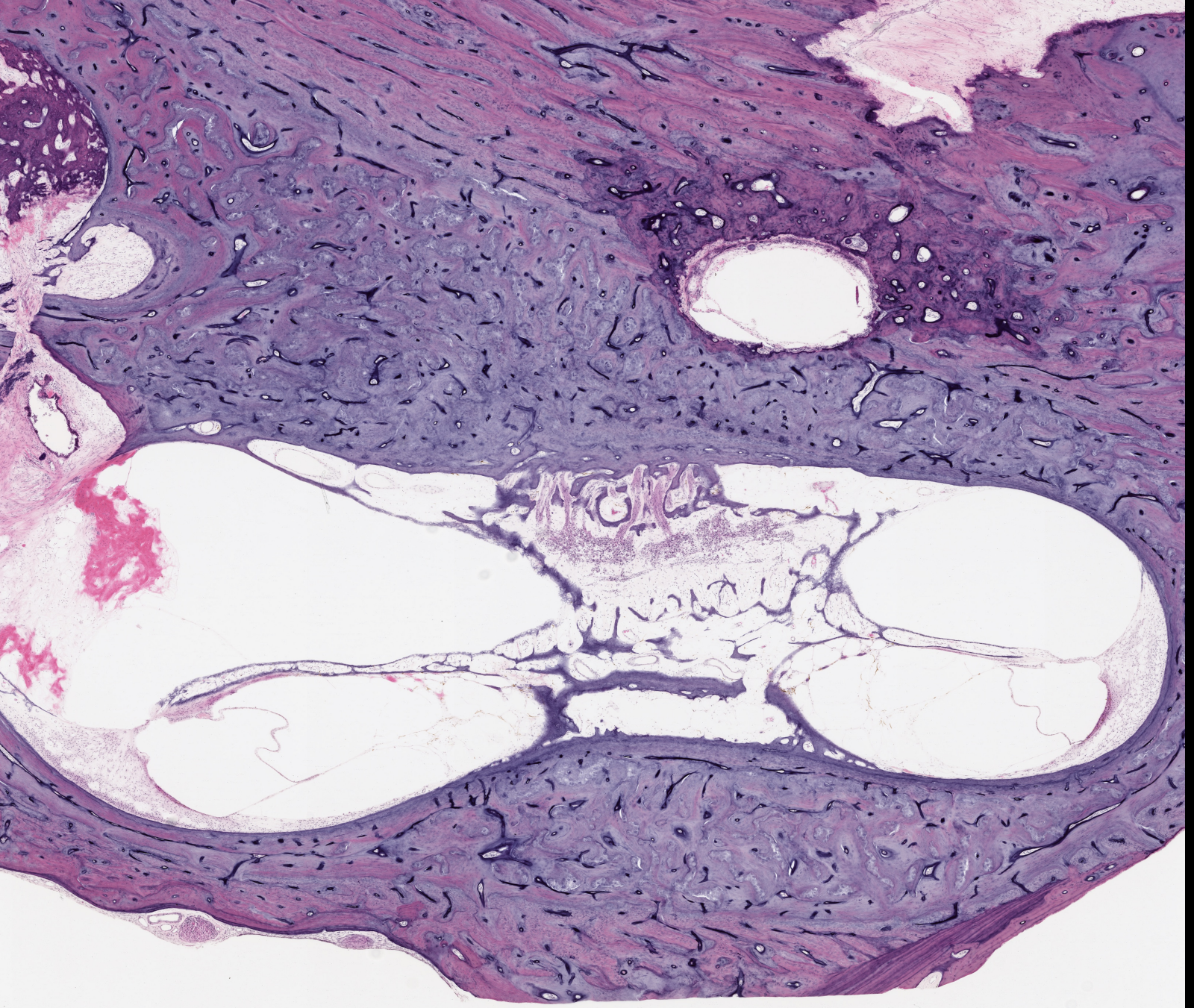
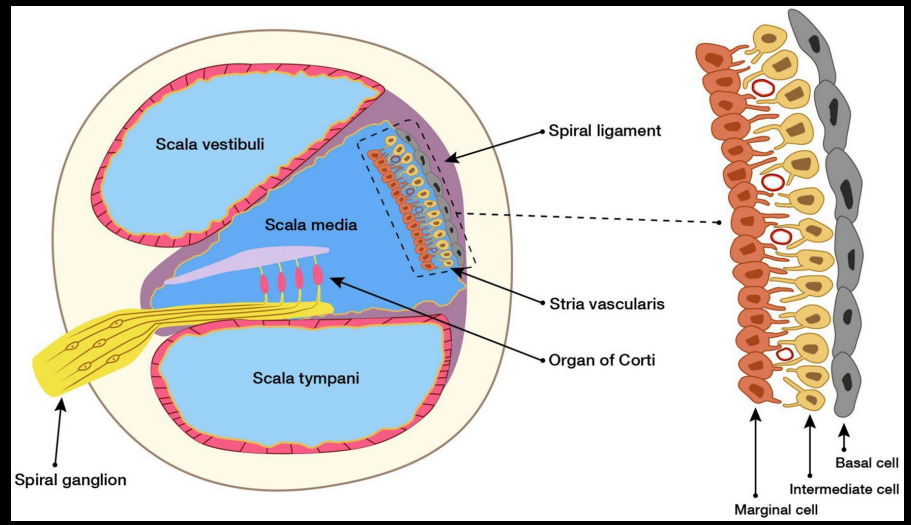


Automatic Segmentation and 3D Reconstruction of the Inner Ear from Histology slides

Aseem Jain

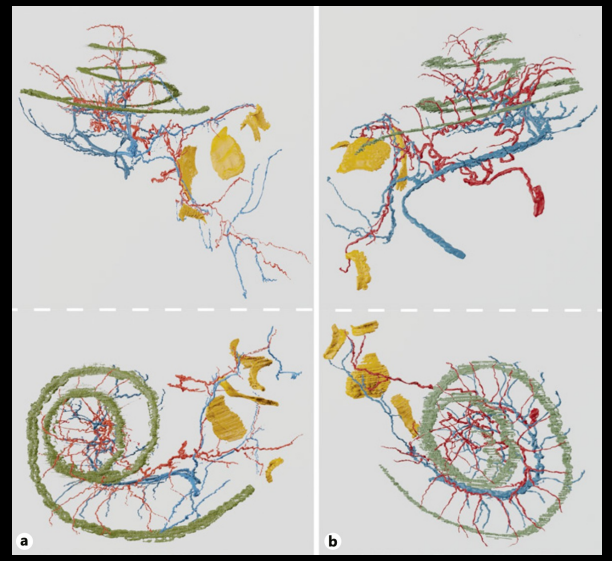
The Project

- We plan to develop an automated method to extract clinically relevant features from histopathology slides and use the segmentations to construct a 3D model of the ear. Such features include relevant vasculature, scala media/vestibuli, and stria vascularis. To do this, we will use deep learning methods to perform semantic segmentation. To reconstruct the inner ear, we will first align adjacent slides and the stack/interpolate between slices to generate a 3D model



Clinical Motivation

- Histopathology is the key to understanding the pathophysiology of various diseases in the inner ear. Such diseases include menieres, vestibular neuritis, etc. Researchers currently manually segment out relevant structures for 2D analysis; few have reconstructed these 2D slices into 3D reconstruction.



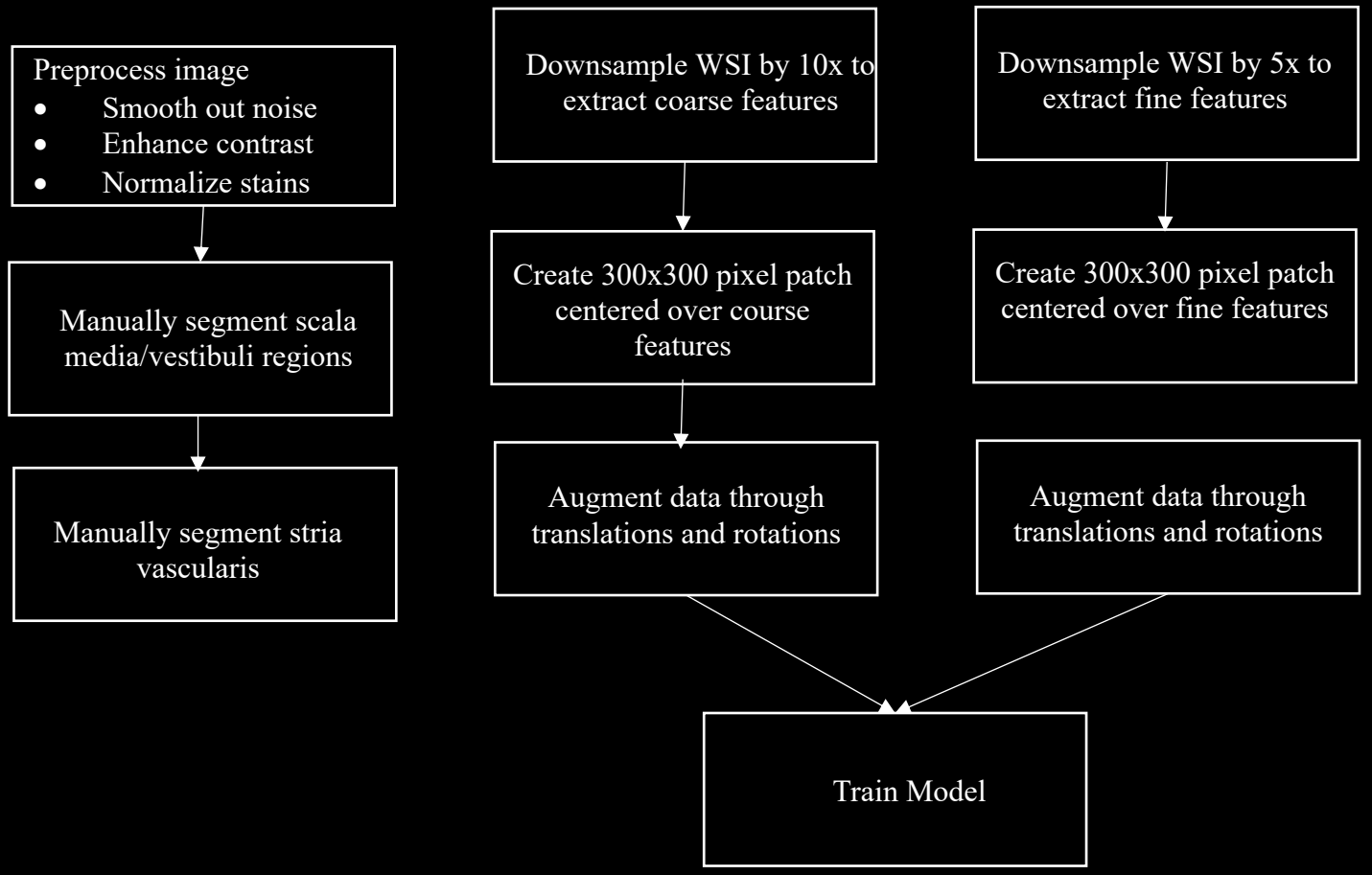
Prior work

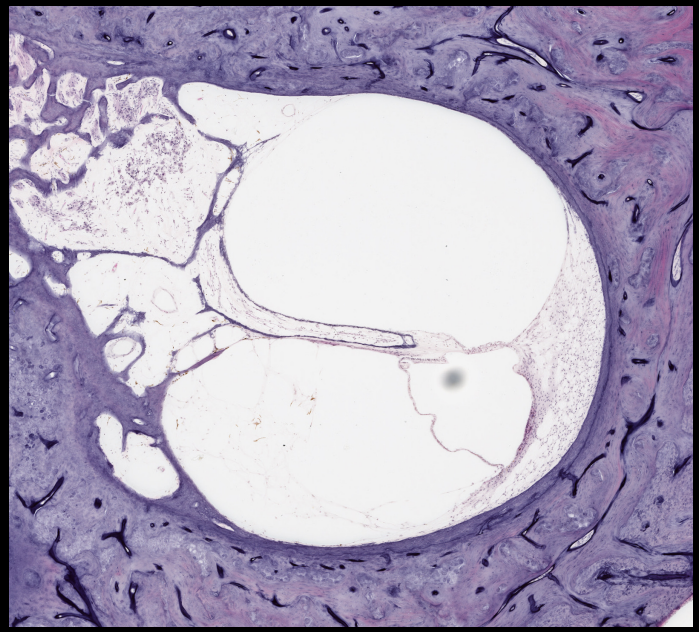
- Semantic Segmentation of Whole Slide Imaging(WSI)
  - Khened et al: A generalized deep learning framework for whole-slide image segmentation and analysis
    - U-Net with various backbones to encode features
  - Guo et al: A Fast and Refined Cancer Regions Segmentation Framework in Whole-slide Breast Pathological Images
    - V3_DCNN: patch based approach to rapidly segment
- WSI image registration
  - Jansen et al: Three-dimensional histopathological reconstruction of bladder tumours
    - Used Elastix Tool Box to align images

Goals

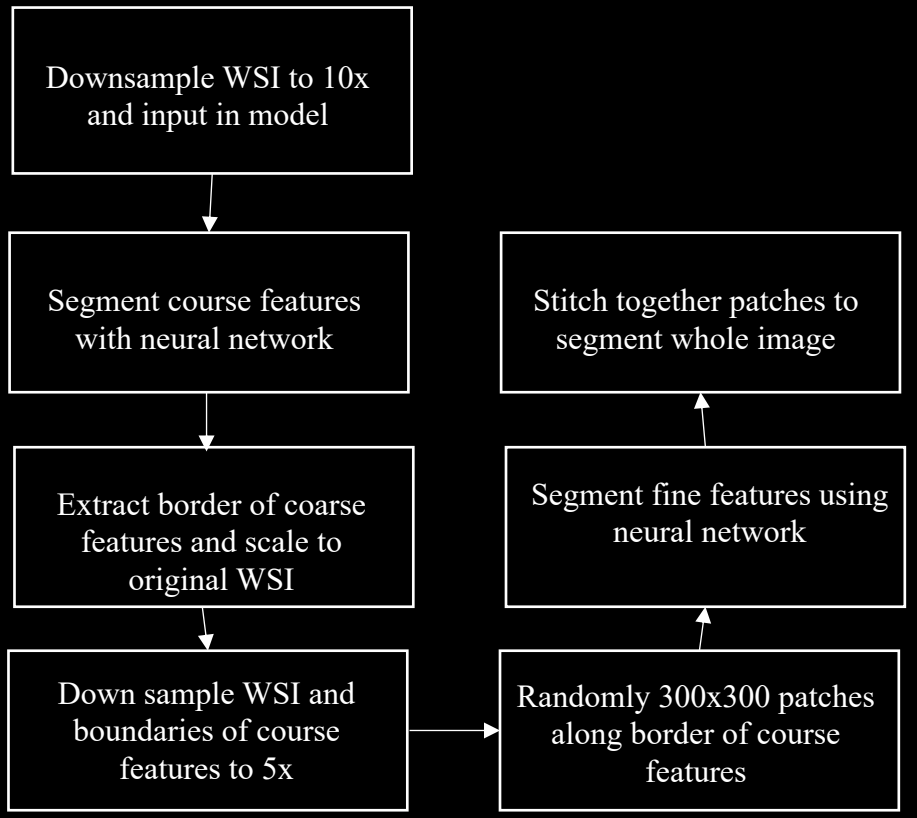
- Minimum: Create a tool to perform semantic segmentation of Temporal Bone WSI of macaque ears
- Expected: A tool that can segment and reconstruct a 3D volume of the inner ear
- Maximum: Apply this technique to human temporal bone anatomy
  - Extract clinically relevant features of such as volume, density of cells, curvature, etc
  - Assess difference between normal and sickle cell patients

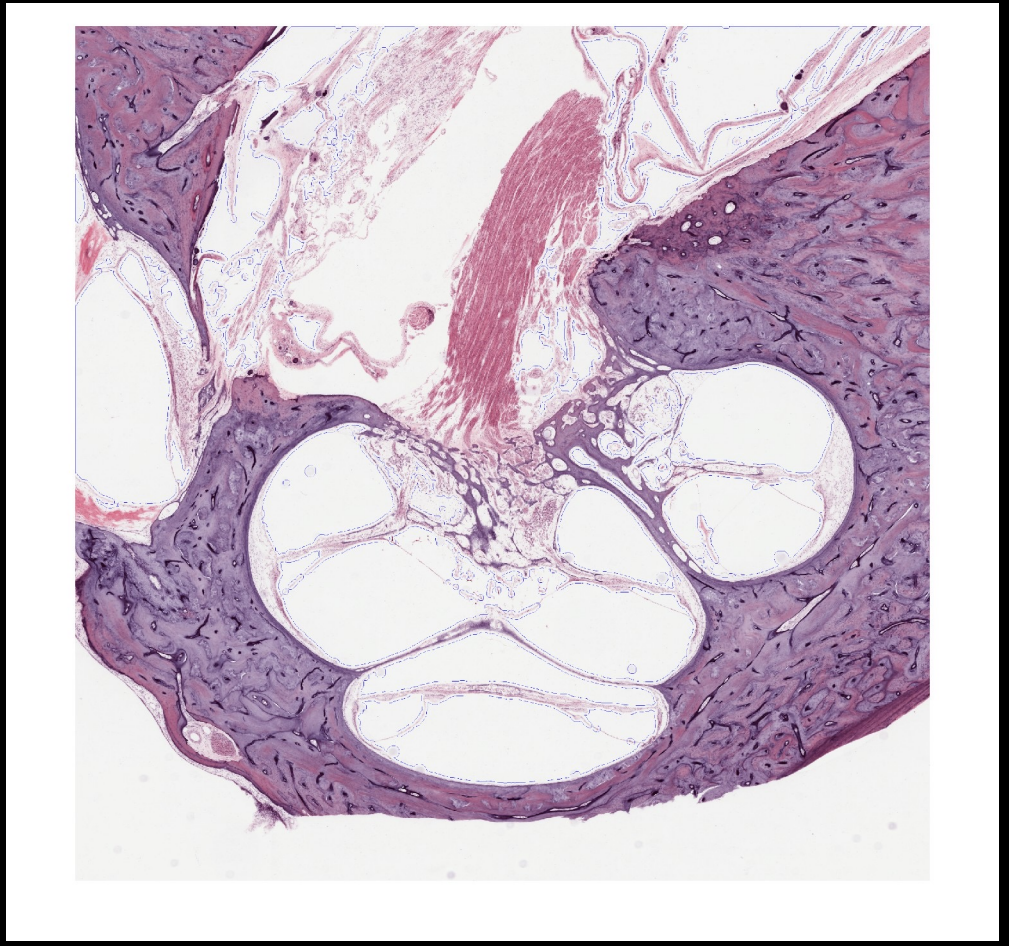
Phase 1 Train: Semantic Segmentation





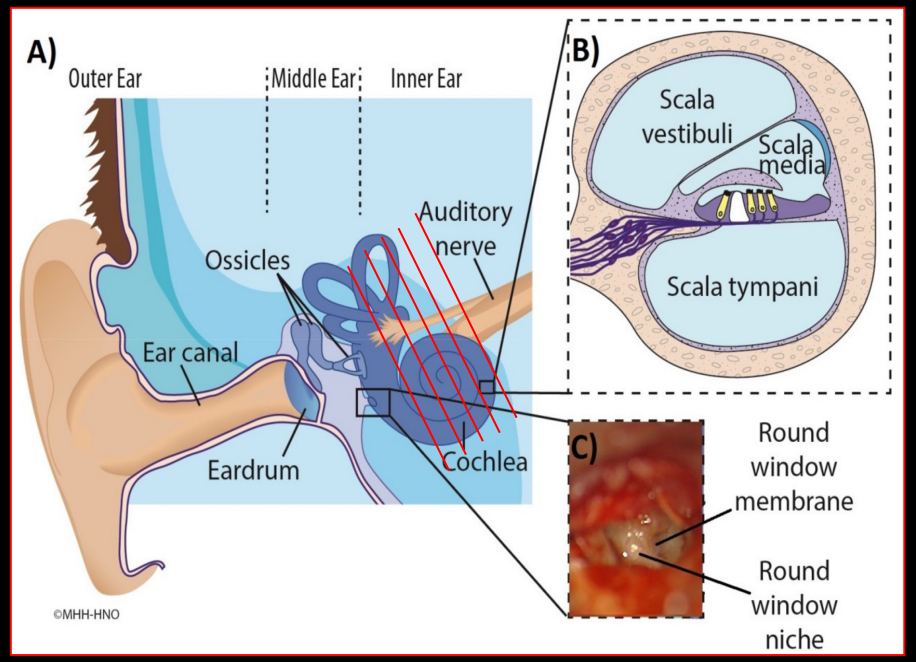
Phase 1 Test: Search and Stitch





Phase 2: Align/Register image

- 92 slices in each inner ear(approximately 10micron thickness)
- Align slides to each other
  - Start with middle slices and work out
  - Simple Elastix-->python implementation of elastix toolbox
- Input aligned 2D segmented slices into Slicer
  - Use interpolation feature in slicer to generate 3D volume



Additional Requirements

Requirement	Need	Status	Follow up	Contingency Plan	Planned	Hard
Scan 4 macaque ears	Need to create database for training and testing	Started	n/a	Use existing temporal bone scans	2/16	2/22
Manually segment 50 slides	Need to create training dataset	Started	With clinical mentors	n/a	2/22	2/28
Install Pytorch set up U-net	Setup environment	Completed	n/a	Switch to different architecture	n/a	n/a
3D Slicer	Generate 3D model	Installed	n/a	Use other open source 3D rendering software?	n/a	N/a
SimpleElastix	Align/Register Images	Needs to be setup in environment	n/a	Align images via ITK	2/16	2/22

Testing plan

- 3 ears with 91 slides each
- Semantic segmentation
  - 5 fold cross validation of model; accuracy
  - IoU/Jaccard Similary Coefficient
- 3D reconstruction: validate against a manual alignment and reconstruction.

Milestones

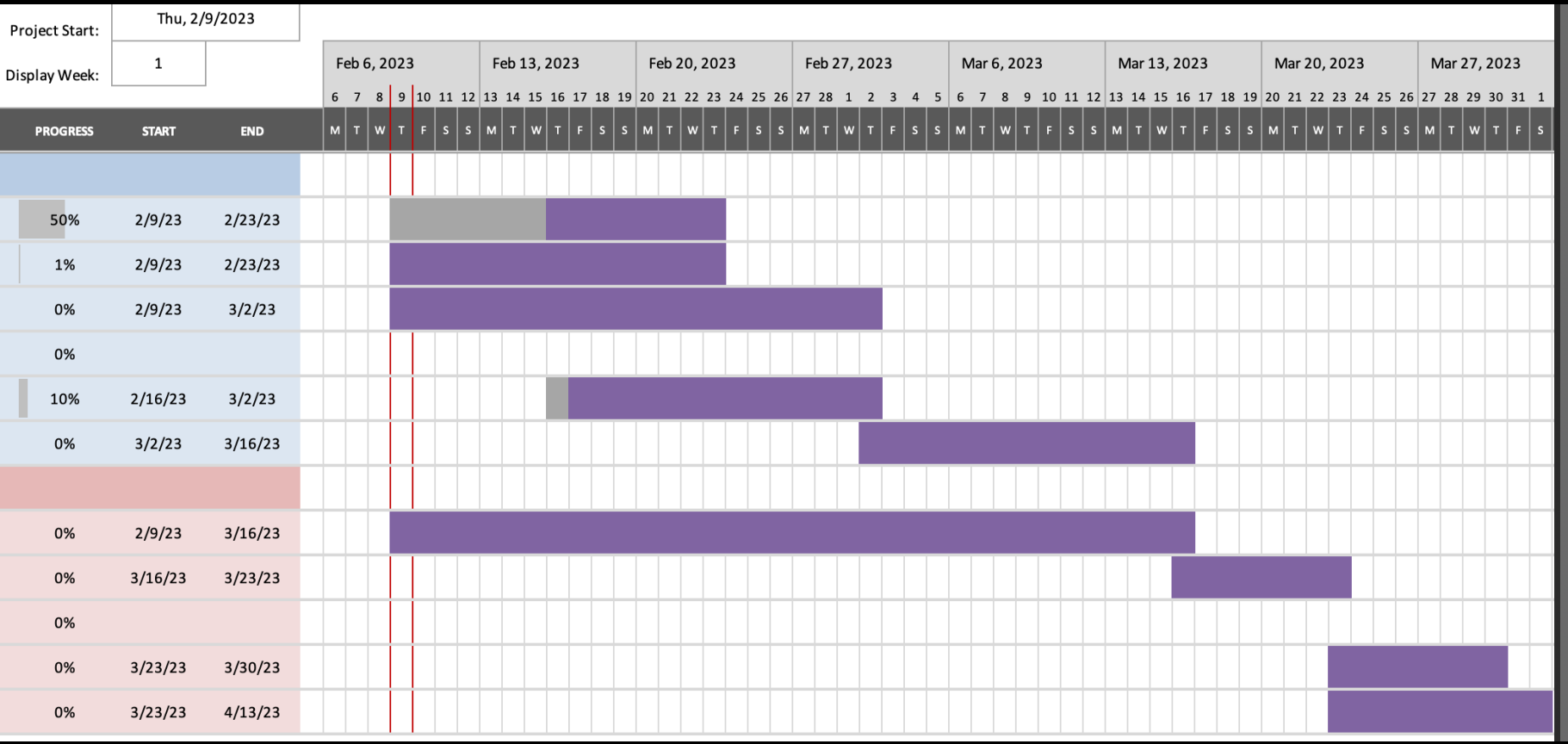
	Activities	Deliverable /Validation
Minimum	Scan and Label Appropriate structure	50+ labeled slides; 91 scanned slides
	Create training model	Split dataset into train, validate, test→ measure accuracy across fold
	Create Search Feature	Validate appropriate search boundaries Compare against already segmented slides
	Test model on remaining ears	Validate against manually segmented slides
Expected	Align segmented images	Validate against manual alignment
	Reconstruct in 3D	Validate against reconstruction with manual alignment
Maximum	Extract clinically relevant features from reconstruction	Extract cell density, volume, curvature, etc
	Apply tool to various pathologies	Test reconstruction of sickle cell patients

Project Timeline

Project Start: Thu, 2/9/2023

Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Phase 1 Semantic Segmentation				
Project Proposal	Aseem	50%	2/9/23	2/23/23
Scan Macaque ears	Dianela/Aseem	1%	2/9/23	2/23/23
label Macaque ears	Dianela/Aseem	0%	2/9/23	3/2/23
Checkpoint presentation	Aseem	0%		
Train nerual network	Aseem	10%	2/16/23	3/2/23
Test/Validate neural network	Aseem	0%	3/2/23	3/16/23
Phase 2 3D Reconstruction				
Setup/Validate environment of image alignment	Aseem	0%	2/9/23	3/16/23
Reconstruct images in Slicer to generate 3D model	Aseem	0%	3/16/23	3/23/23
Generate final report/paper	Aseem	0%		
Test reconstruction on human temporal bone	Dianela/Aseem	0%	3/23/23	3/30/23
Apply algorithm to sickle cell patients	Dianela	0%	3/23/23	4/13/23



Management Plan

- Meetings: Biweekly meetings with med students until scans are completely segmented
  - Relay progress to sponsors via email/text
- Documentation
  - Github for code repository
  - Google Drive/doc for manuscript writeup

Roles and Responsibilities

- Aseem Jain: *Masters Student, MS4 University of Cincinnati*
  - Project Lead: Design/Validate algorithm to accomplish Phase I/II
- Dianela Perdomo: *MS2 Johns Hopkins*
  - Will assist with scanning/labeling slides
- Clinical Sponsors
  - Francis(Pete) Creighton, MD
  - Bryan Ward, MD
  - Amanda Lauer, PhD

References

- Jansen, I., Lucas, M., Savci-Heijink, C.D. et al. Three-dimensional histopathological reconstruction of bladder tumours. Diagn Pathol 14, 25 (2019). https://doi.org/10.1186/s13000-019-0803-7
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