Checkpoint Presentation: Auto-Segmentation of Spine CT for Data-Intensive Analysis of Surgical Outcome

Group 21
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Team Members and Mentors

Team Members

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Biomedical Engineering 2018

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Mentors

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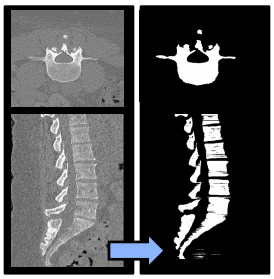
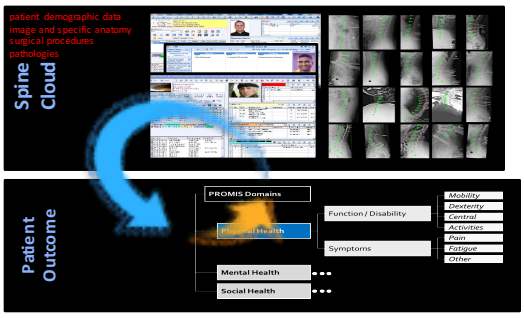
Dept. of Computer Science

Motivation and Goals

- Overall: To Develop and Test the "max-flow/min-cut" segmentation method for spine CT images

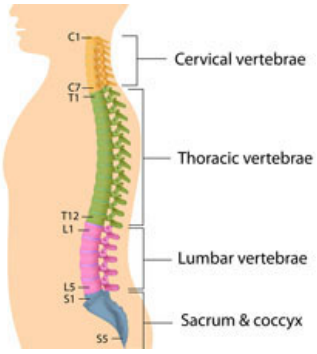


- "Spine Cloud" – a big data approach to improve spine surgery outcomes
- Correlate defined clinical variables and anatomical quantification to patient surgical outcomes
- Inform future spine surgeries to create more favorable and consistent outcomes



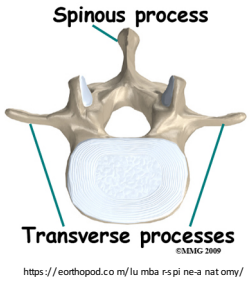
Original Deliverables

- Minimum Deliverable:
  - Assess accuracy of N=20 segmented dataset (L1-L5)
  - Implementation of slice-based Max-flow/Min-cut extended to spine CT
- Expected Deliverable:
  - Analysis of Parameter Sensitivity
  - Evaluation of Segmentation Accuracy
  - Generation of a large (N=200) segmented dataset
- Maximum Deliverable:
  - Methods for patient-specific parameter selection
  - Methods to accommodate spine anomalies



https://lowbackpainprogram.com/your-lumbar-spine/

Updated Deliverables



- Minimum Deliverable:
  - Assess accuracy of N=20 segmented dataset
  - Implementation of 3D Max-flow/Min-cut extended to spine CT
- Expected Deliverable:
  - Analysis of Parameter Sensitivity on N=20
  - Generate and Evaluate Segmentation Accuracy on N=20
  - Segmentation of (N=200) dataset for Lumbar CT (without Spinous Process)
- Maximum Deliverable:
  - Segmentation of (N=200) dataset for Lumbar CT with Spinous Process
  - Segmentation of (N=200) dataset for Full Spine
  - Automatic vertebrate labelling

Original Dependencies

Dependency	Plan to Resolve	Date Expected	Contingency Plan
Access to I-STAR Lab	Gain Access	Completed	-
Workstation / MATLAB	Gain Access / Download	Completed	Remote access using TeamViewer
TCIA Collection (N20 and N200 Datasets)	Obtain from Mentors	Completed	-
Existing Generalized Implementation	Obtain from Mentors	Completed	-
Max Flow / Min Cut Segmentation Method	-	-	Consult Mentors & Explore alternative segmentation methods
Mentor Scheduling	Consult Mentors	Completed (Bi-weekly meetings)	Skype / Accommodate with remote meetings

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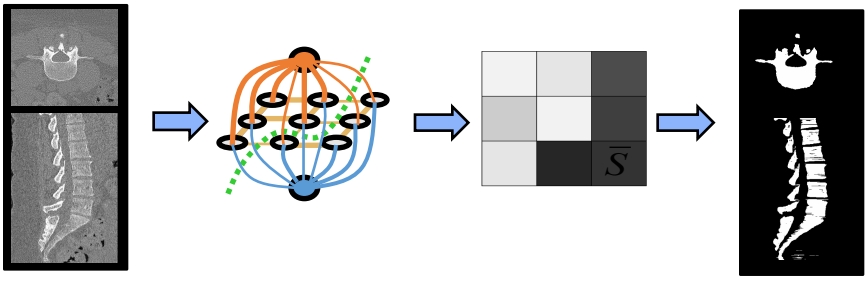
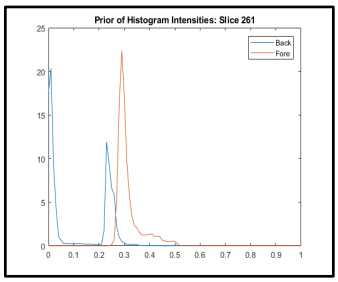
Centroid Positions of N20	Obtain from mentors	Completed	-
Centroid Positions of N200	Obtain from mentors	Completed	-

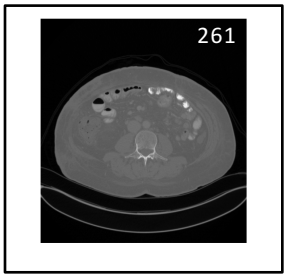
Graph Cut Explanation

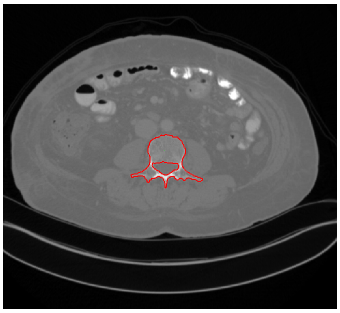


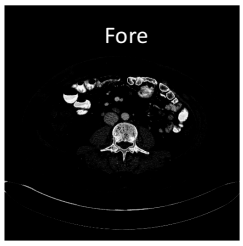
t-links – voxel nodes to terminal nodes
n-links – voxel nodes to voxel nodes
Cut defined by minimization of sum of weights

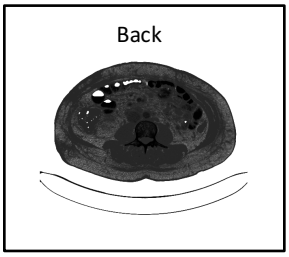
Pre-Processing / Defining Weights By Intensities

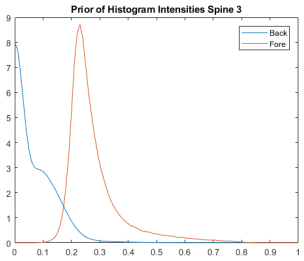




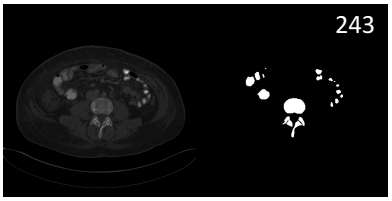


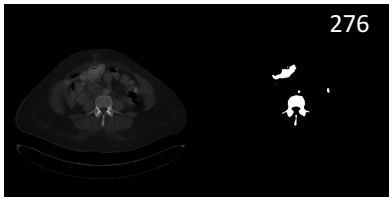


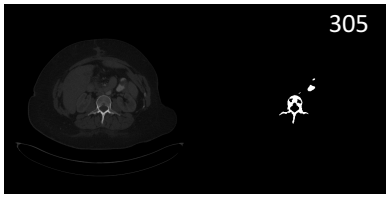


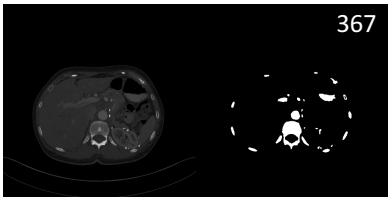


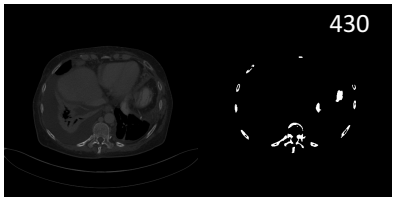
Basic 2D Segmentation Method Output of N20

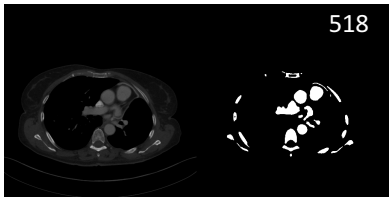








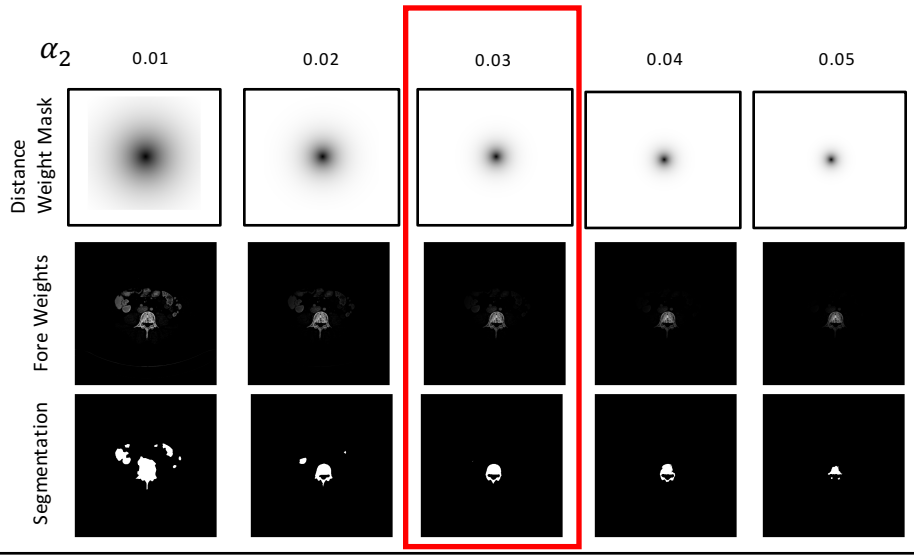




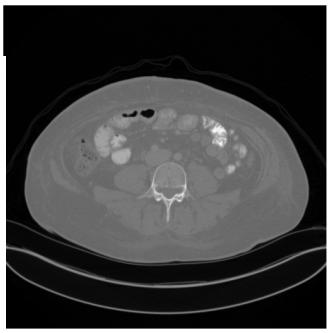
Centroid Distance Transform in 2D

$$\boldsymbol{Distance\ Transform}$$
$$\boldsymbol{\alpha_1 e^{-\alpha_2 \|x-c\|}}$$

c *is centroid position*
α_1 *– scaling parameter*
x *is pixel location*
α_2 *– exponential parameter*

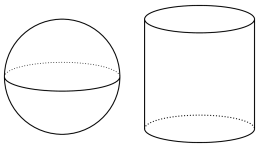


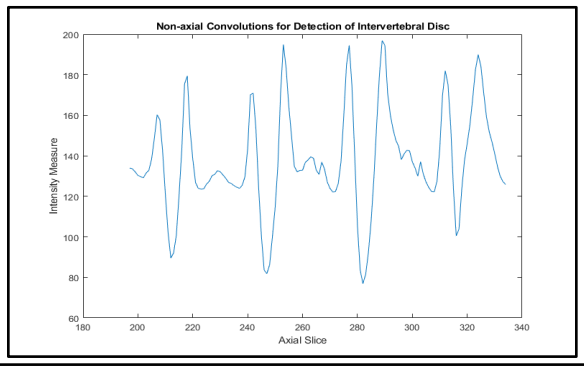
Constant: Axial Slice 229

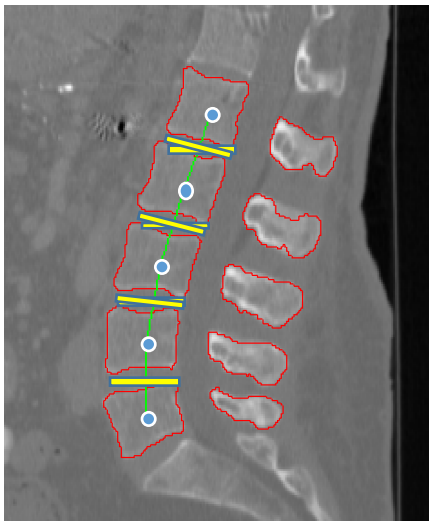


3D Segmentation Method

Modeling the Spine:

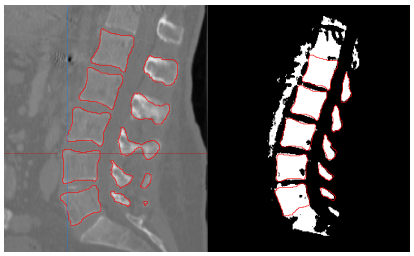






Results

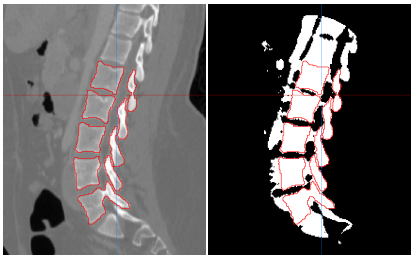
Spine 3



DICE
0.8318

RMSE
5.6321 voxels

Spine 22



DICE
0.6568

RMSE
22.0022 voxels

N20 Dataset

- DICE = 0.70426
- RMSE = 14.5667 voxels

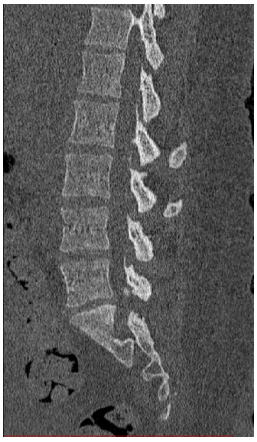
Analysis

- The validation metrics provide limited meaning
  - Only based on Lumbar
- The aorta is being segmented
- Need to tune parameters based on each image
- Impose post processing steps

Applying to N200

- Pros
  - No aorta
  - Have centroids
  - Clean gradient
- Cons
  - Speckle
  - Different parts of spine

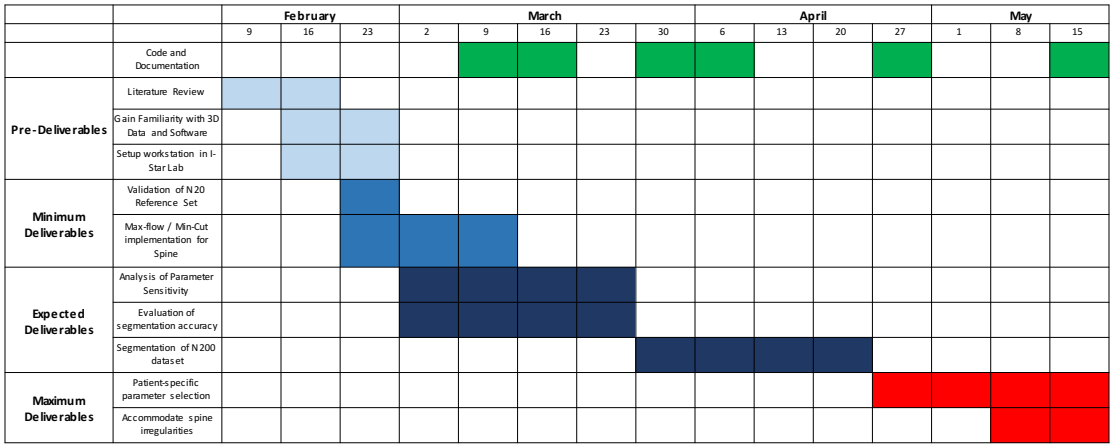
Spine 1



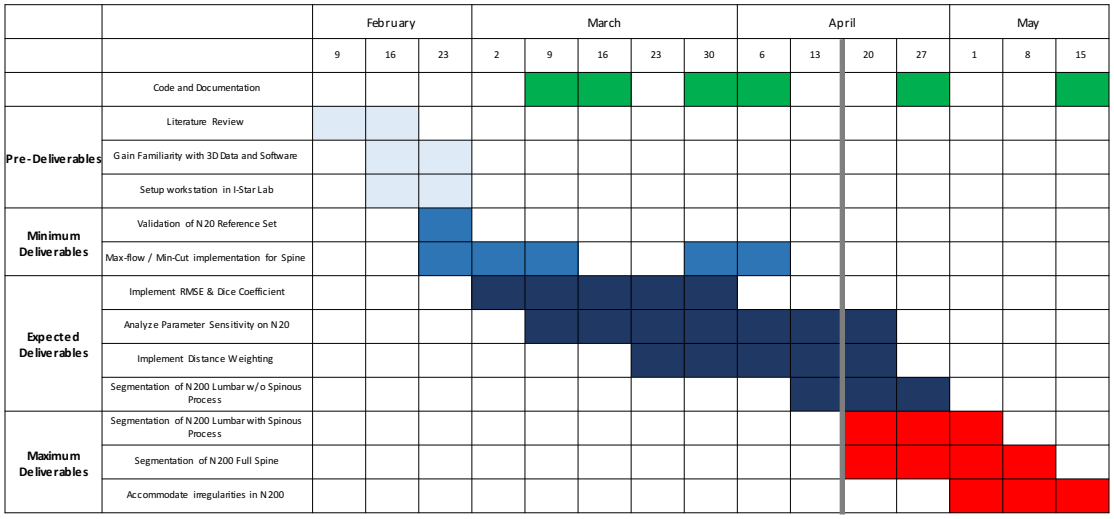
Spine 2

Spine 3

Project Timeline



Updated Project Timeline



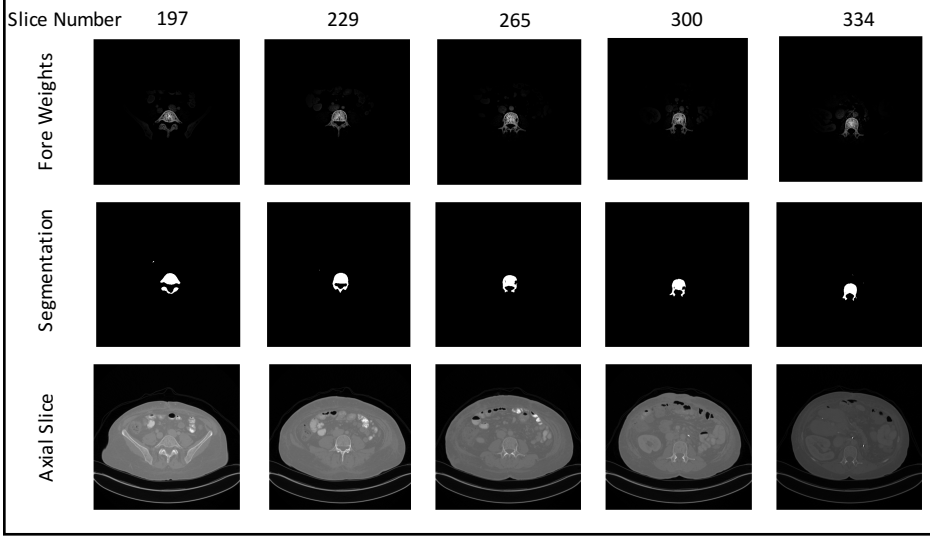
Management Plan

- Biweekly team meetings at I-STAR lab (every other Friday med campus)
- Weekly meetings with Tharindu to go over progress
- Code repository on gitlab for easy / VPN remote access
- Documentation on code, at end we will create user guide

Reading List

- Yuan, Jing, et al. "A Study on Continuous Max-Flow and Min-Cut Approaches." *2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 2010
- Boykov, Y.y., and M.-P. Jolly. "Interactive Graph Cuts for Optimal Boundary & Region Segmentation of Objects in N-D Images." *Proceedings Eighth IEEE International Conference on Computer Vision. ICCV 2001*
- Boykov, Yuri, and Vladimir Kolmogorov. "An Experimental Comparison of Min-Cut/Max-Flow Algorithms for Energy Minimization in Vision." *Lecture Notes in Computer Science Energy Minimization Methods in Computer Vision and Pattern Recognition*, 2001, pp. 359–374.

2D Segmentation Using Distance Weighting



Constant: $\alpha_2 = 0.03$