

A CAD System for Detection of Flat Lesions in CT Colonography

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Overview

- Review of first half work
 - Why are we doing this?
 - Other recent research
 - Colon resegmentation
 - Generation of surface mesh
 - Morphology-based approach
- Implementation of morphology
- Clustering for candidate detection
- Discussion of results
- Future work

Colon Cancer and Flat Lesions

- Colorectal cancer is the second leading cause of cancer deaths in the US
 - Estimated 50,000 in 2009 [Jemal et al., 2009]
- Flat lesions relatively common in Western populations [Soetikno et al., 2008]
- Ten times more likely to contain carcinoma than Type 0-I [Ibid]
- Much harder to detect, even for trained doctors

Types of Colorectal Neoplasms

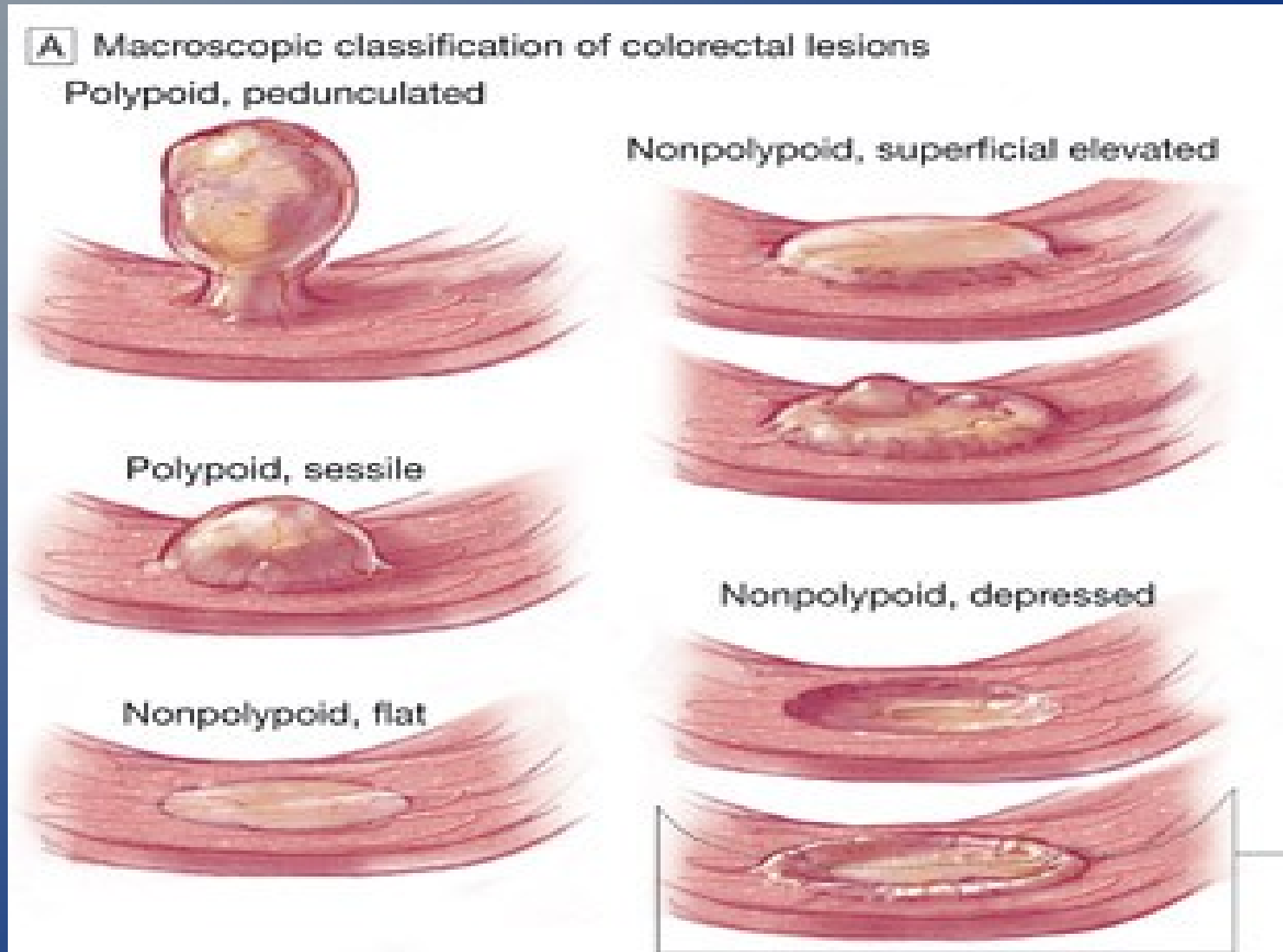


Image courtesy Soetikno et al., 2008

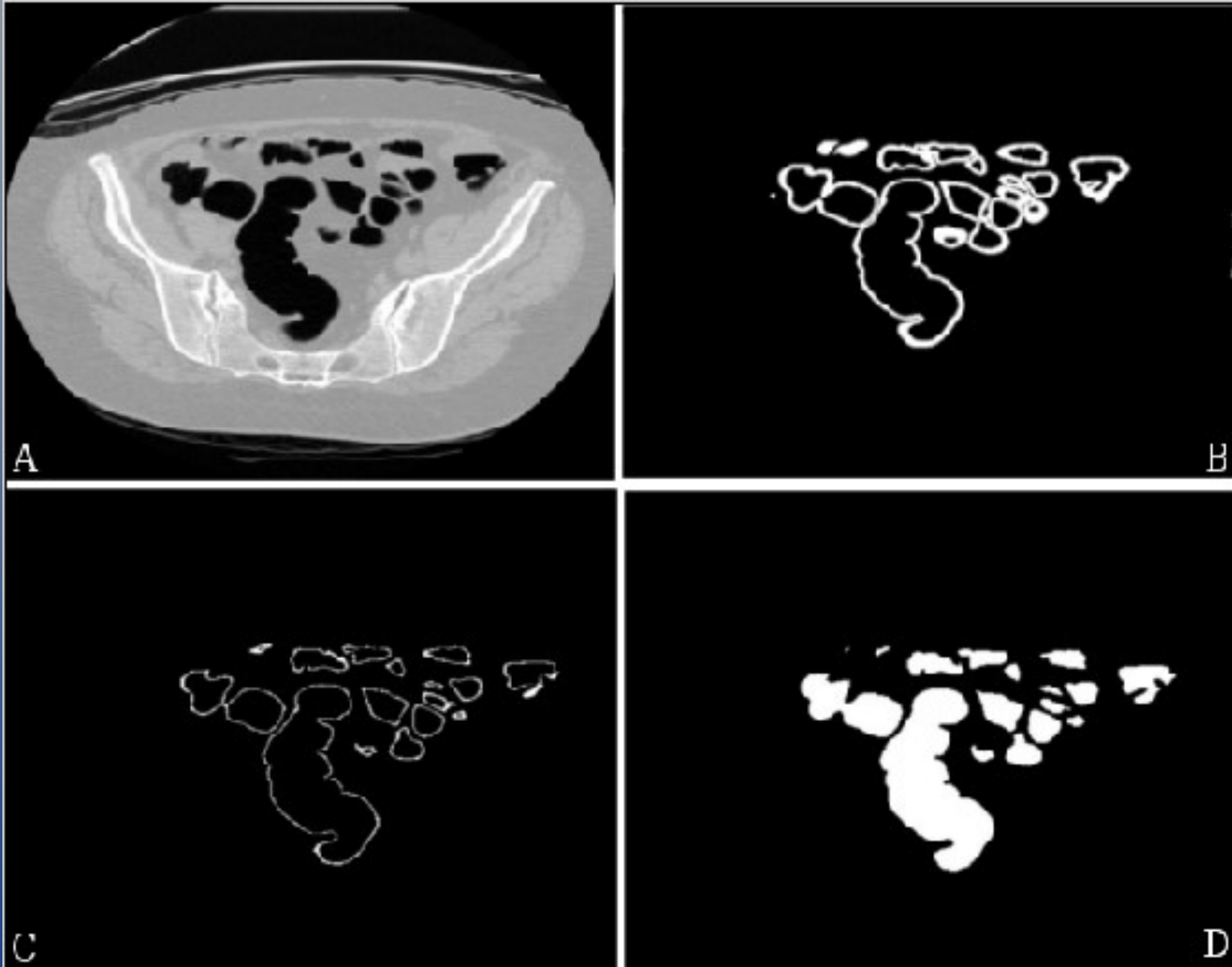
Recent Research

- CAD schemes for Type 0-I very successful
 - Shape index [Yoshida and Näppi, 2001]
 - MTANN for false positive (FP) reduction [Suzuki et al., 2008]
- Type 0-I schemes generally do not adequately detect flat lesions
- Type 0-II schemes are not “clinic-ready,” or are non-existent
 - Park et al., 2009 achieved 57.6% sensitivity
 - Suzuki et al., 2009 achieved 67% sensitivity, 10 FPs/patient using precise shape (PS) index derived from Yoshida/Näppi method

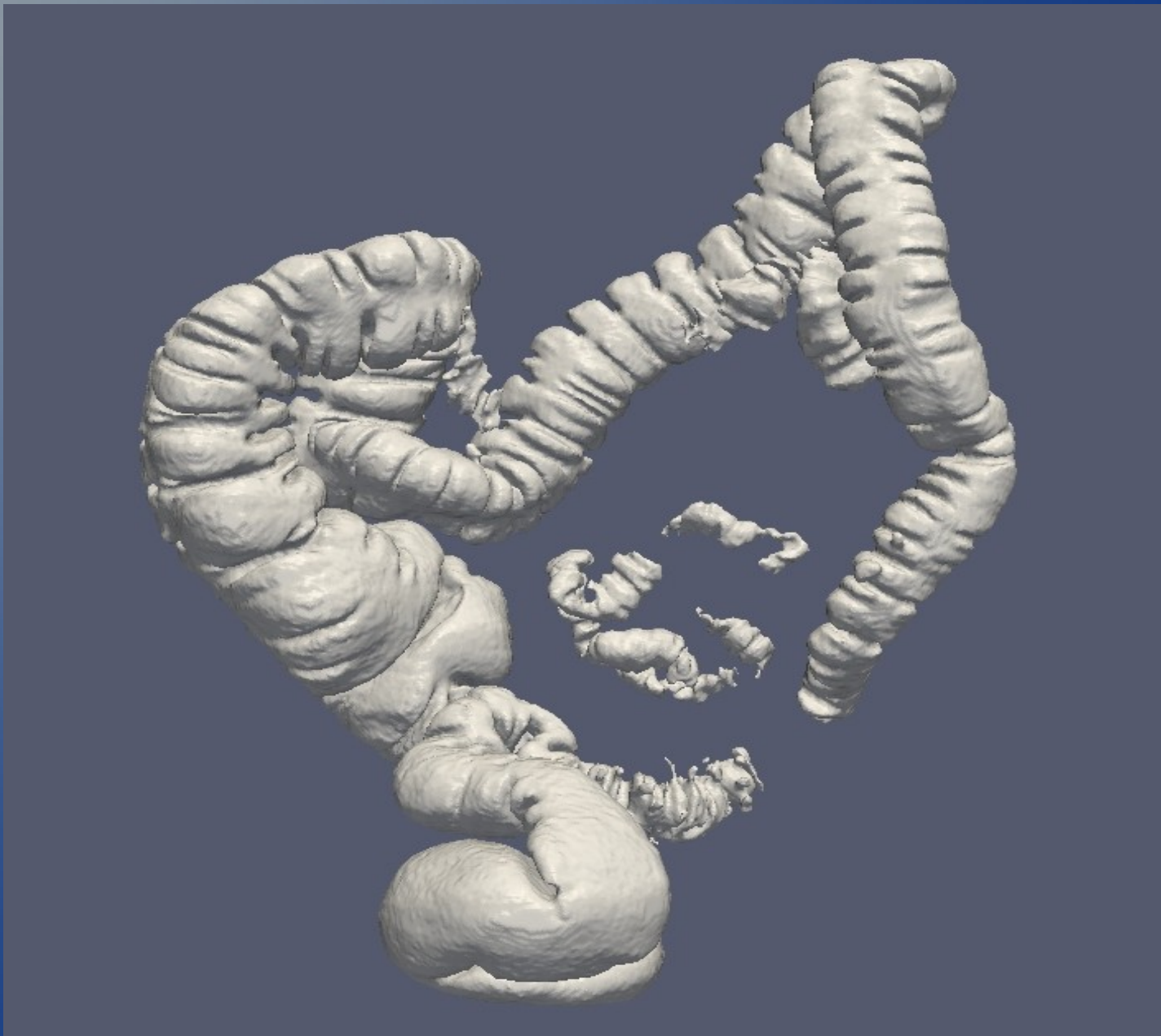
Our Database

- Same as the one used in Suzuki lab's PS Index study
- 50 CTC scans with identified flat lesions from multicenter clinical trial [Rockey et al., 2005]
- 25 patients, scanned in both supine and prone positions
- 28 flat lesions in total, defined as being either $< 3\text{mm}$ in height or with height $< \frac{1}{2}$ length of the long axis
- Average size 9 mm, range 6-18 mm

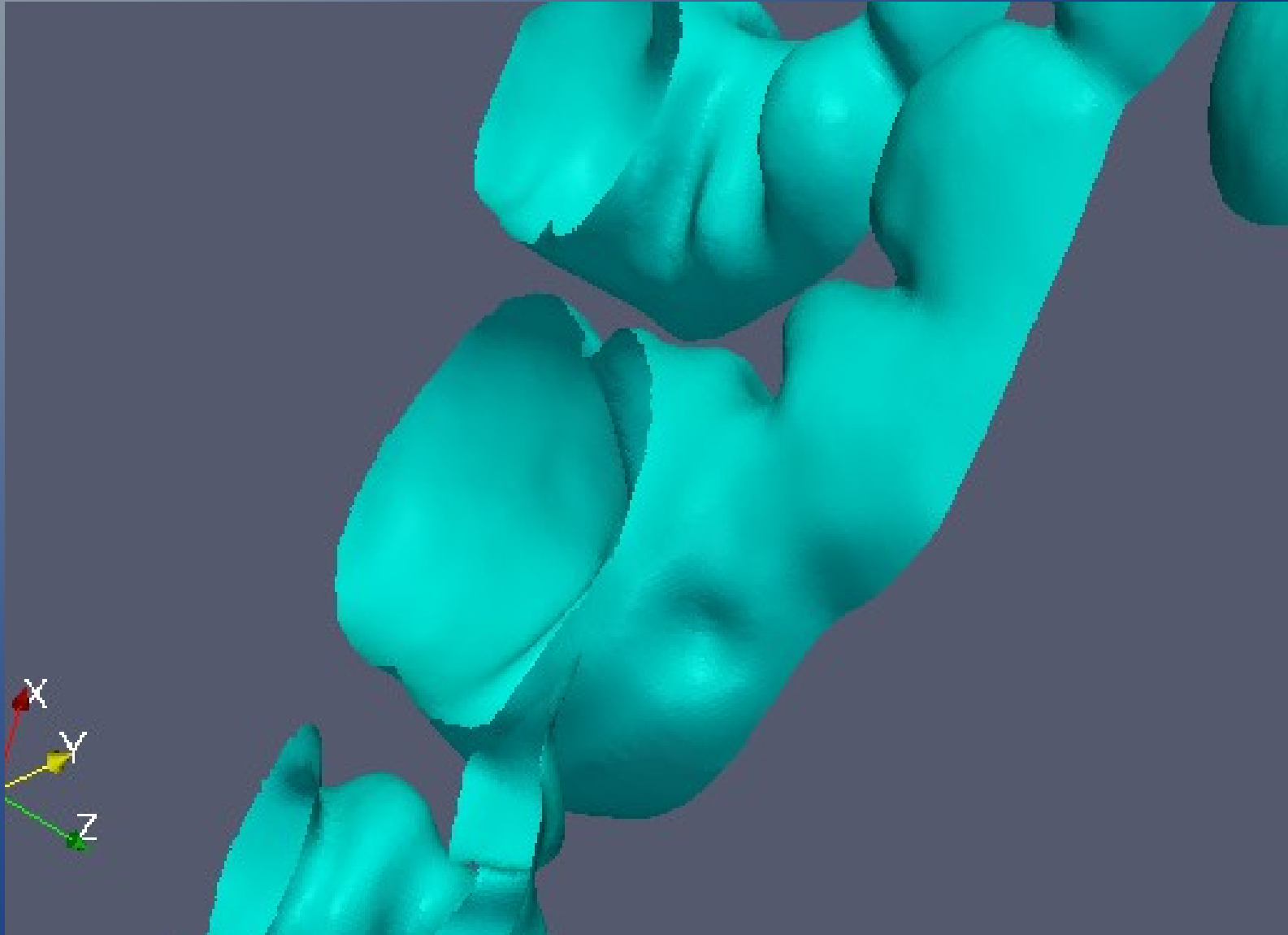
Colon Resegmentation



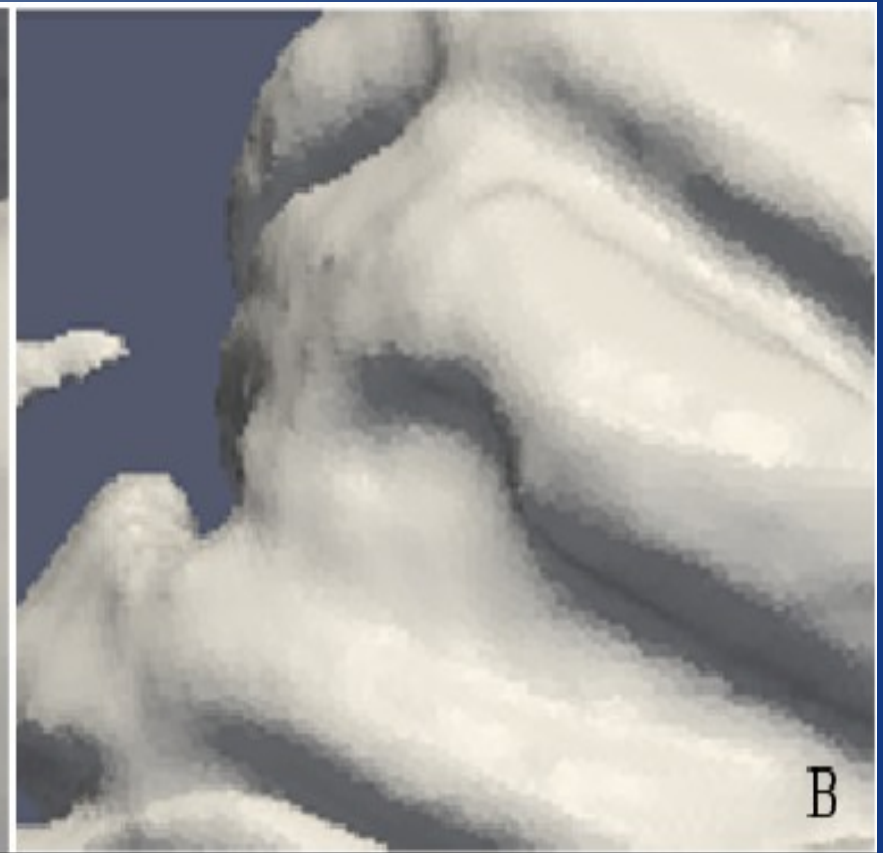
Surface Mesh-Whole



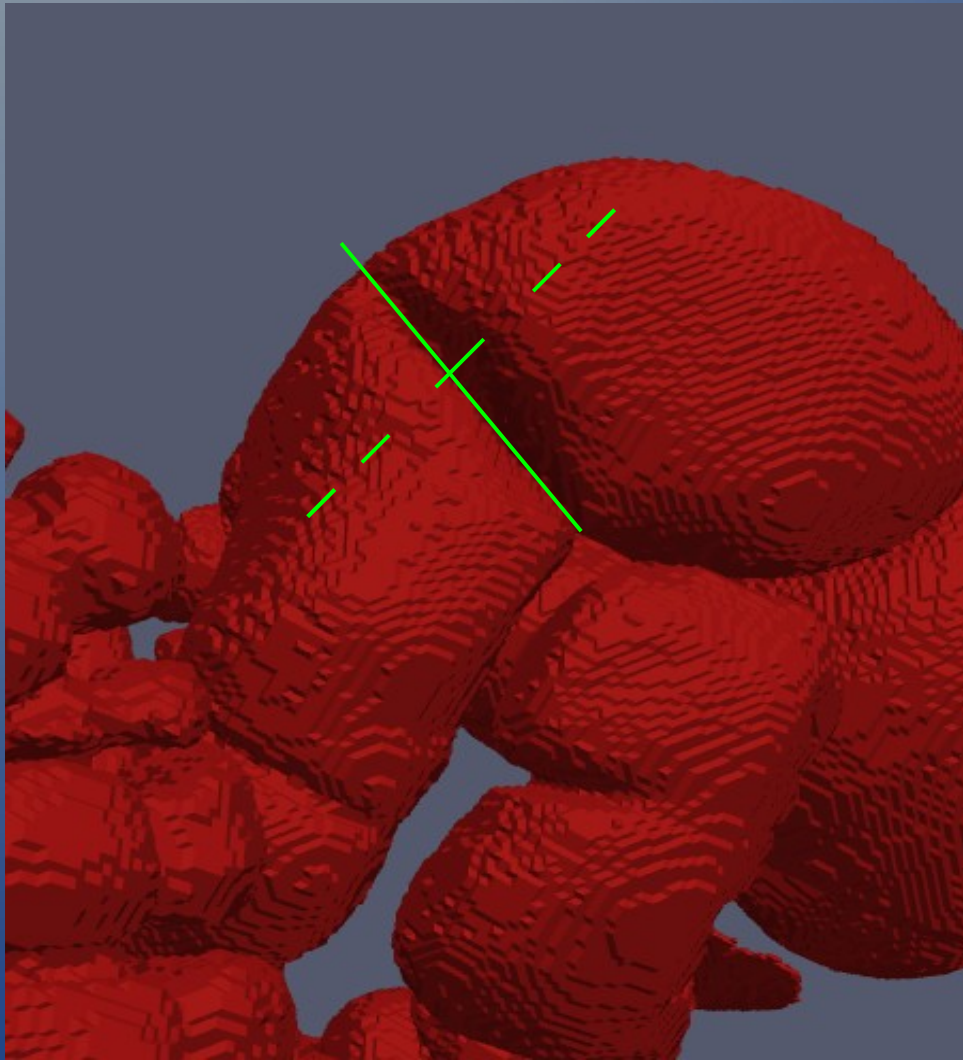
Surface Mesh-Lesion Closeup



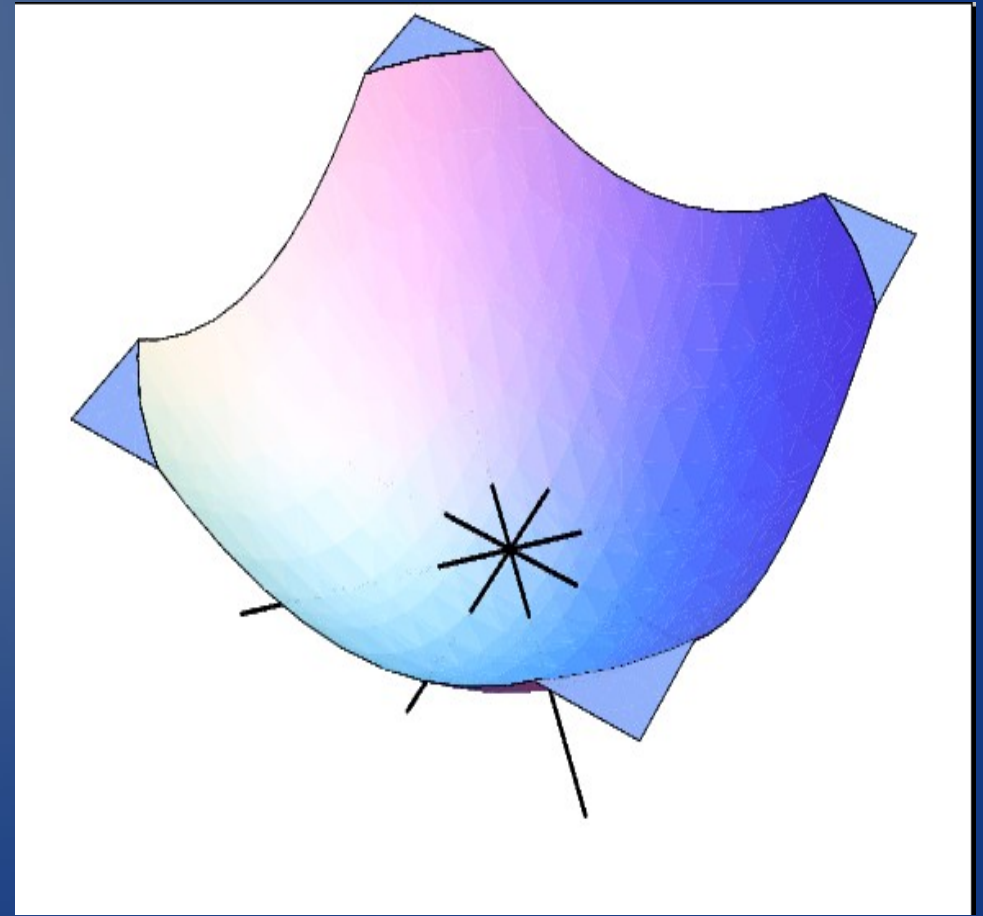
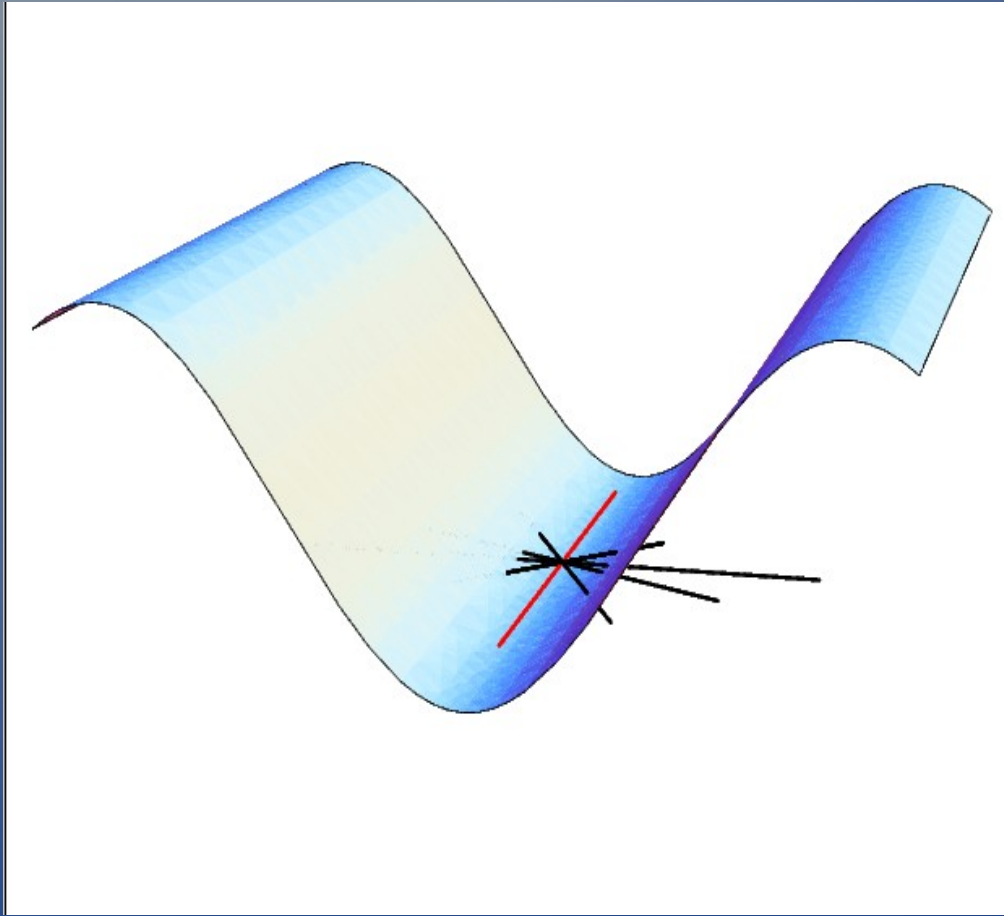
Closeup of Fold and Lesion



Tangent Lines in Fold and Lesion



Another View



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Morphology Basics

- “Spinning tangent line” technique, loosely based on “rolling ball” [Sternberg 1983]
- Calculate normal vectors for each point in mesh
- Generate sufficiently sized line segment on tangent plane at each point and rotate
- If line segment intersects with mesh at all orientations, that point is considered a lesion candidate voxel

Considerations

- How do we deal with the fact that the mesh is discrete, not continuous?
 - Allow for a certain amount of error around the tangent line
- What if a point in a fold lies in the middle of a plane? Won't the tangent line touch the mesh at each point then?
 - Raise the line above the mesh a small amount by following the normal vector
- What is a good length for the line?
 - 10

Mathematics of Morphology

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$$L_{e^-} = \begin{pmatrix} x_{min} \\ p_y \\ \mathcal{P}_{\tilde{p}}(x_{min}, p_y) \end{pmatrix}$$

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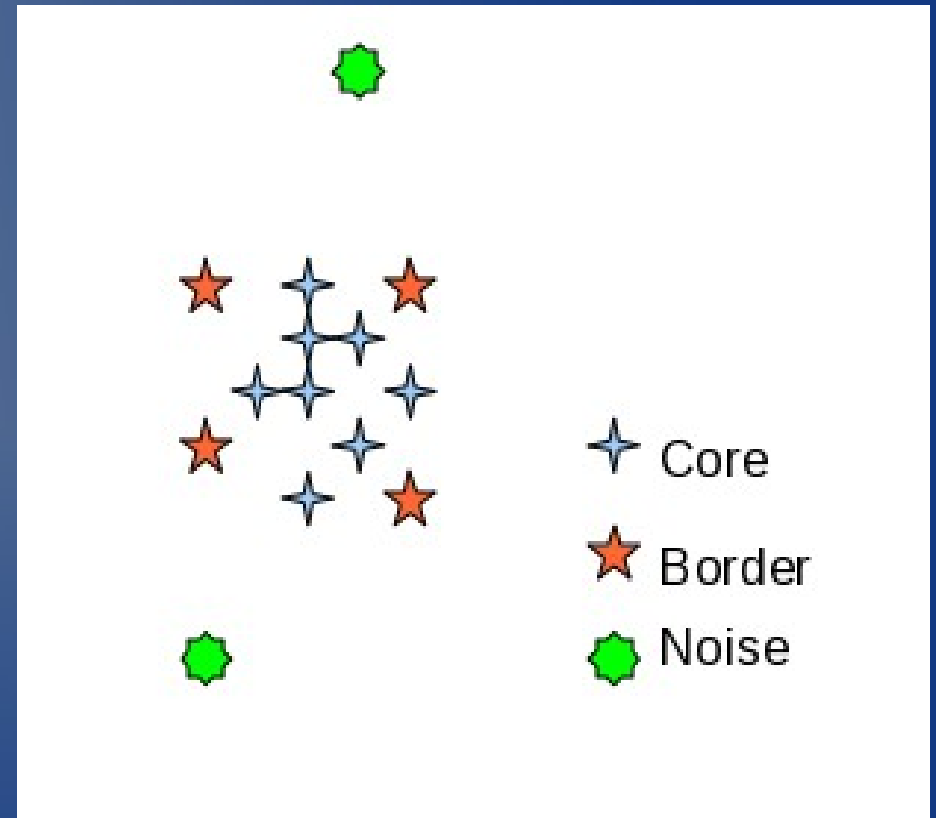
- Rotate around normal vector using a sequence of translation and rotation operations

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What is DBSCAN?

- Density-based clustering algorithm proposed by Ester et al. (1996)
- Points are either core, border or noise depending on how many other points are in their immediate vicinity



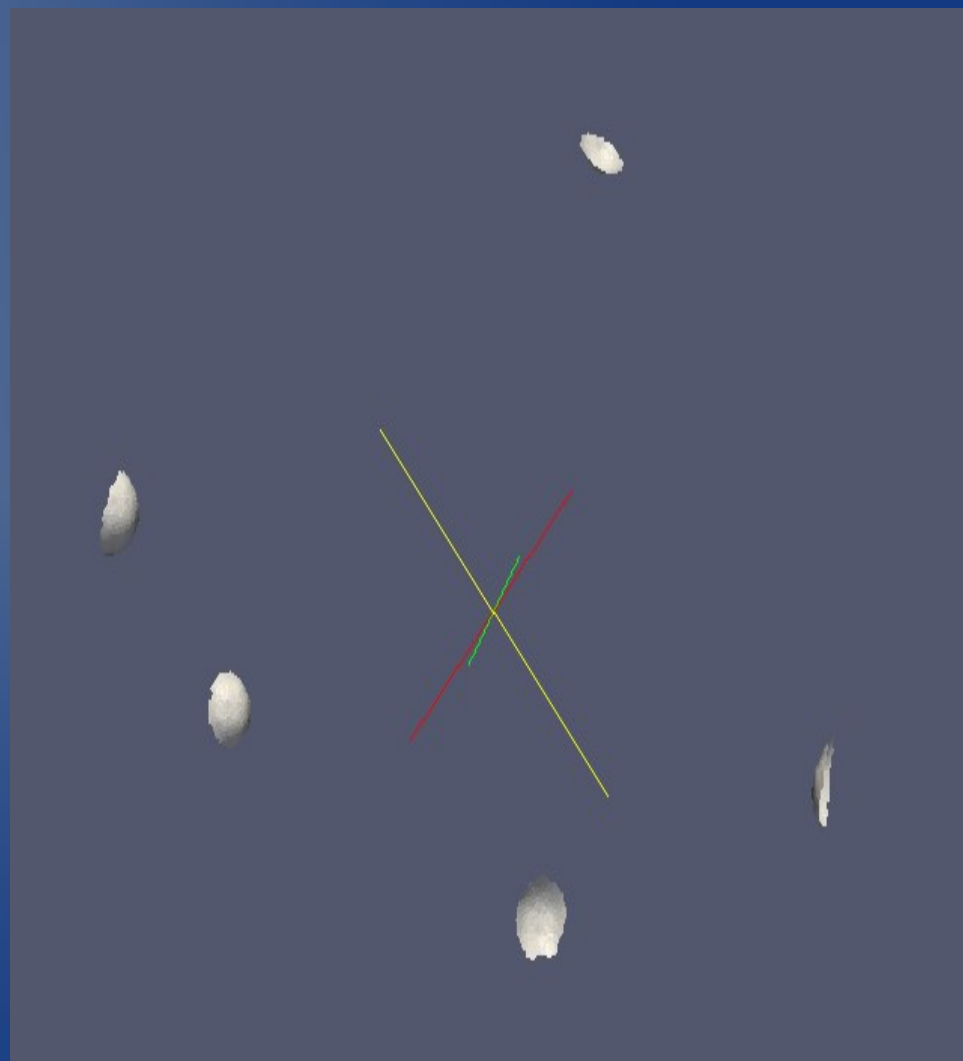
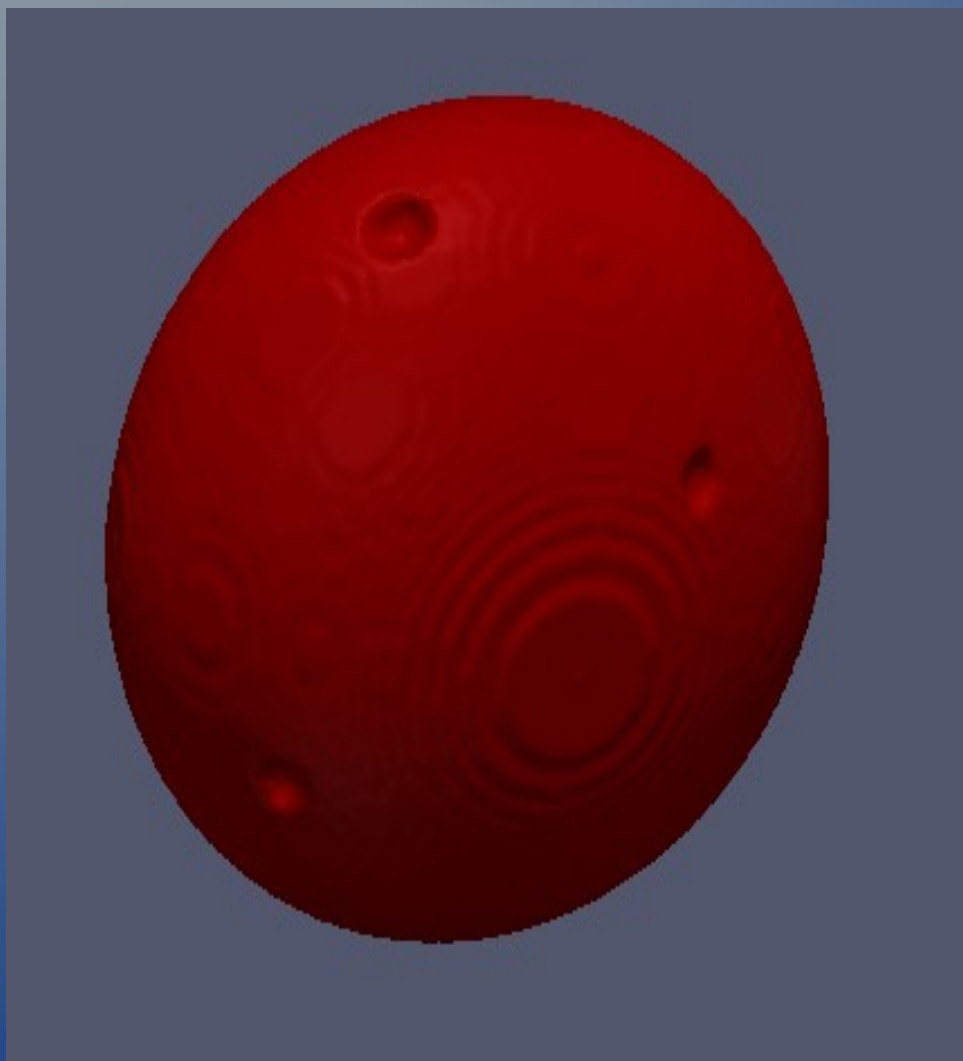
From Independent Voxels to Lesion Candidates

- Use DBSCAN to assign voxels to clusters
 - Main advantage-unnecessary to pick a starting number of centroids
- Problem: Many colon features and some lesions are detected several times with this method
- Solution: Merge clusters whose centroids are within a certain distance
- Size thresholding to cut out noise and overly large components such as lungs

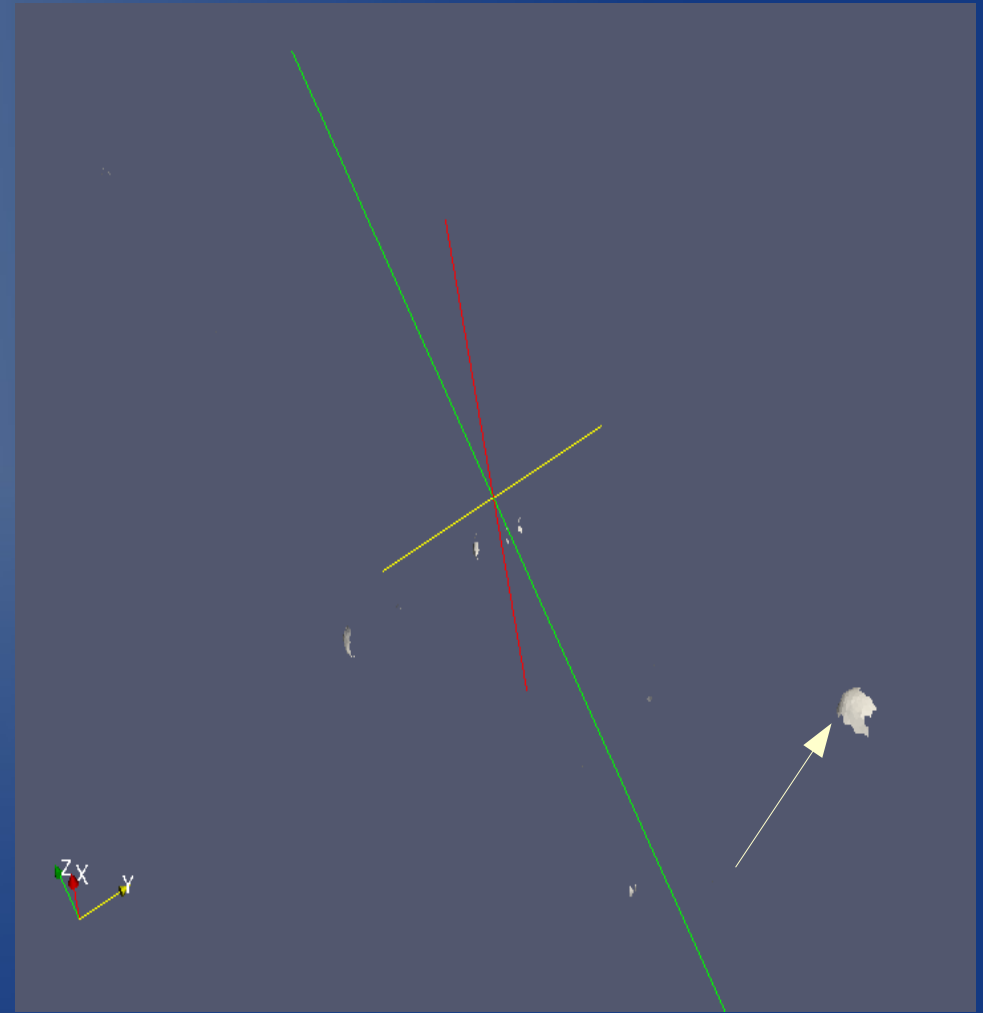
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Phantom Colon - Before and After CAD



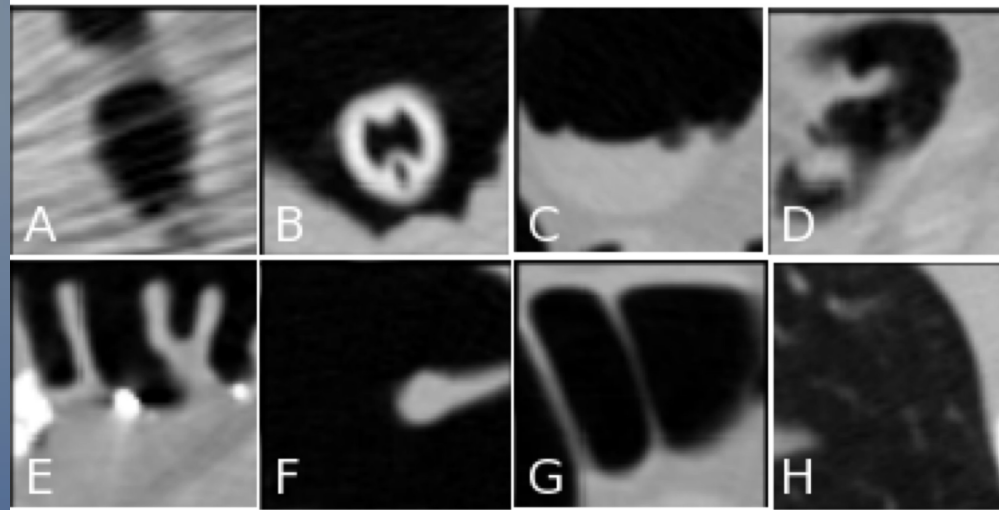
Real Colon – Before and After CAD



Results

	Spinning Tangent Line (Kawaler and Ferraro)		Precise Shape Index (Suzuki)	Shape Index (Yoshida)
	L=20, U=200	L=25, U=200		
Sensitivity (by polyp)	82%	79%	71%	57%
FP (per patient)	31	28	25	19

Examples of False Positives



(A) Poor scan quality

(B) Rectal tube

(C) Stool

(D) Stool on haustral folds

(E) Oddly shaped folds

(F) Oddly shaped fold

(G) Faint folds

(H) Lung

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Future Work

- FP reduction
 - Feature extraction for LDA, SVM
 - Run with multiple parallel MTANN
- Create scoring method for candidate voxels
- Speed it up!

Thanks to...

- Everyone in the Suzuki lab, with special thanks to Dr. Suzuki, Mark Epstein, Ivan Sheu and Jianwu Xu
- The National Science Foundation
- The folks in charge of the MedIX REU, including Daniela Raicu and Jacob Furst
- Emily's mom, for pretending to be excited when her email inbox was clogged with endless pictures of diseased colons

No thanks to...

- Rebecca and Alex, who didn't find any flat lesions at all this summer
- Nice try though

References

- Ester, M. et al. “A Density-Based Algorithm for Discovering Clusters in Large Spatial Databases with Noise.” *Proc. KDD-1996*.
- Jemal A., et al. “Cancer Statistics, 2009.” *CA Cancer J Clin*, 2009: 59(4).
- Park S.H., et al. “Flat Colorectal Neoplasms: Definition, Importance and Visualization on CT Colonography.” *AJR*, April 2007: 188.
- Rockey, D.C. et al. “Analysis of air contrast barium enema, computed tomographic colonography, and colonoscopy: prospective comparison,” *Lancet* 2005: Vol 365.
- Soetikno R.M., et al. “Prevalence of Nonpolypoid (Flat and Depressed) Colorectal Neoplasms in Asymptomatic and Symptomatic Adults.” *JAMA* 2008, 299(9).
- Sternberg, S.R. “Biomedical Image Processing.” *IEEE Computer*, January 1983.
- Suzuki K., et al. “A CAD utilizing 3D massive-training ANNs for detection of flat lesions in CT colonography: Preliminary results.” *Proc. SPIE Medical Imaging (SPIE MI)*, February 2009.
- Suzuki K., et al. “Mixture of Expert 3D Massive-Training ANNs for Reduction of Multiple Types of False Positives in CAD for Detection of Polyps in CT Colonography.” *Med. Phys.*, February 2008: 35(2).
- Yoshida, H. and Janne Nappi. “Three-Dimensional Computer-Aided Diagnosis Scheme for Detection of Colonic Polyps.” *IEEE Trans. Med. Imag.*, December 2001: 20(12).