UCRL-PRES-226100

Morphological Algorithms for Non-Destructive Evaluation

Siddharth Manay, Sailes Sengupta, Aseneth Lopez, and Doug Poland

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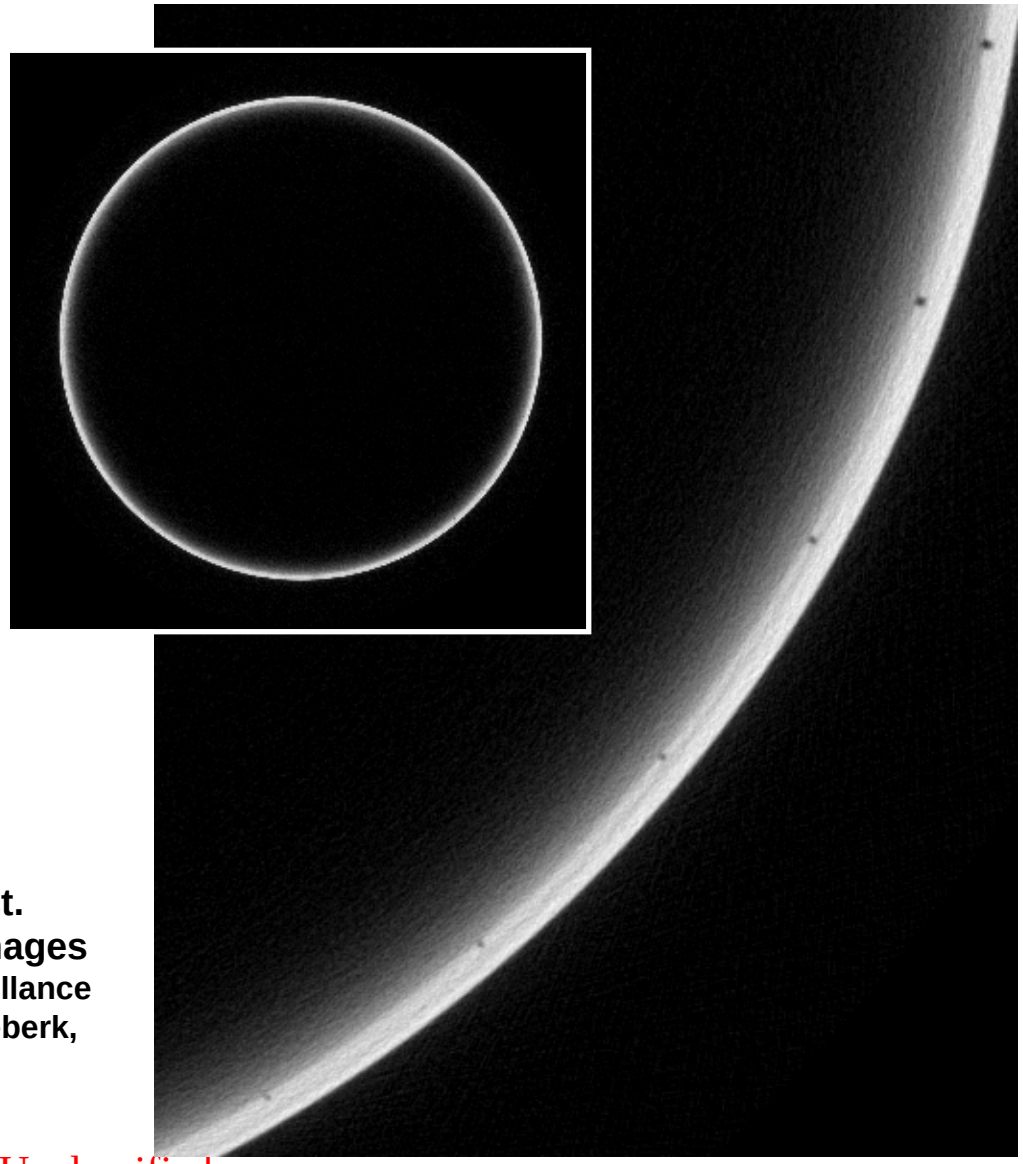
Void Defects in CT Images

- Need to identify small “voids” that can develop in machine parts over time.
- Computed Tomography Images are used
- Current methods include painstaking, time consuming manual inspection of large amounts of data (1000’s of voxels on a side).



One slice of CT test object.
Data: 1900x1900 pixels, 55 images
Data courtesy of: Enhanced Surveillance Program (Roger Perry, Dan Schneberk, Gary Stone)

Image Morphology

- **Binary Morphology is a set of image processing tools used to analyze *shapes* in binary images.**
- **The *structure element* defines the neighborhood, and hence selectivity (size, shape, orientation), for morphology operations.**
- **Fundamental operations are *dilation* and *erosion*.**

Original Image

Dilation "inflates" shapes

Erosion "shrinks" shapes

- **These operators are combined to form more operations.**

Opening
(=Erosion + Dilation)
Deletes small objects

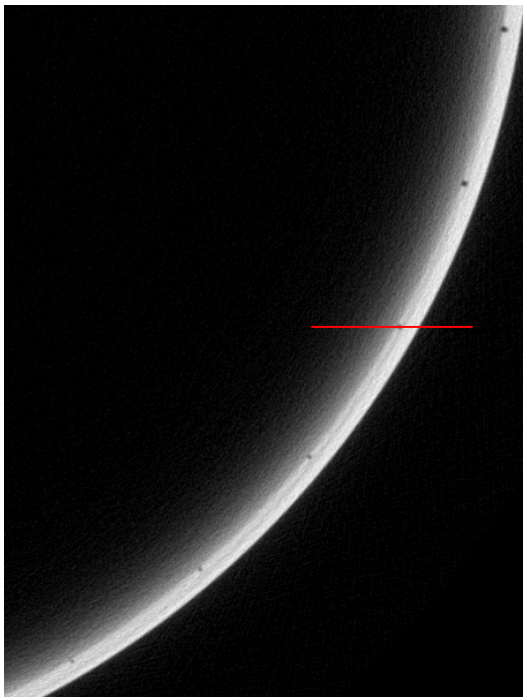
Closing
(=Dilation + Erosion)
Deletes holes

Top-Hat Transform
(=Closing – Image)
Finds small dark objects

- **Morphology can also be applied to 3D datasets.**
- **Grayscale Morphology extends these operations to grayscale images.**

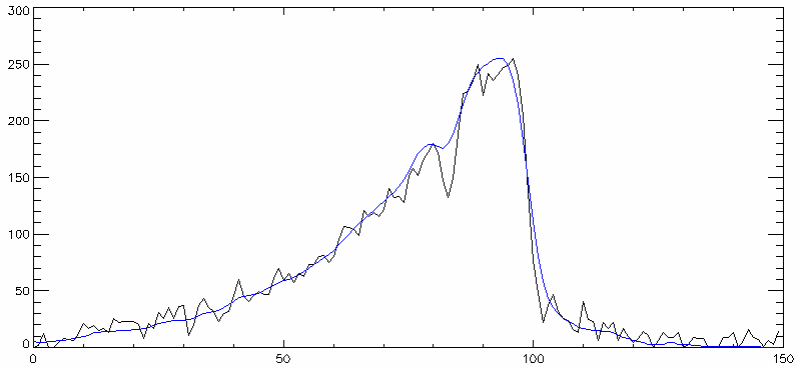
Image Morphology

- Grayscale morphology uses max and min operators for dilation and erosion.
- One-D lineout example:

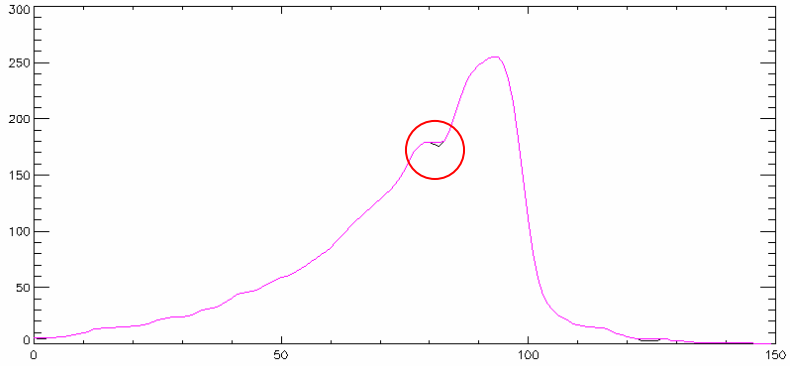


1D Cross Section

Signal and De-noising:



Closing:



Difference and Threshold:

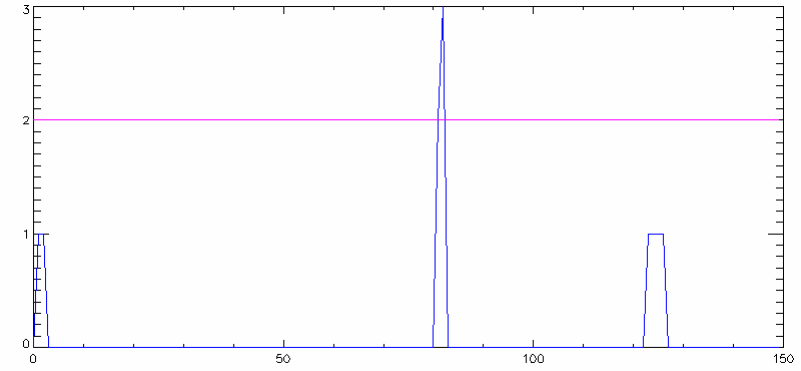
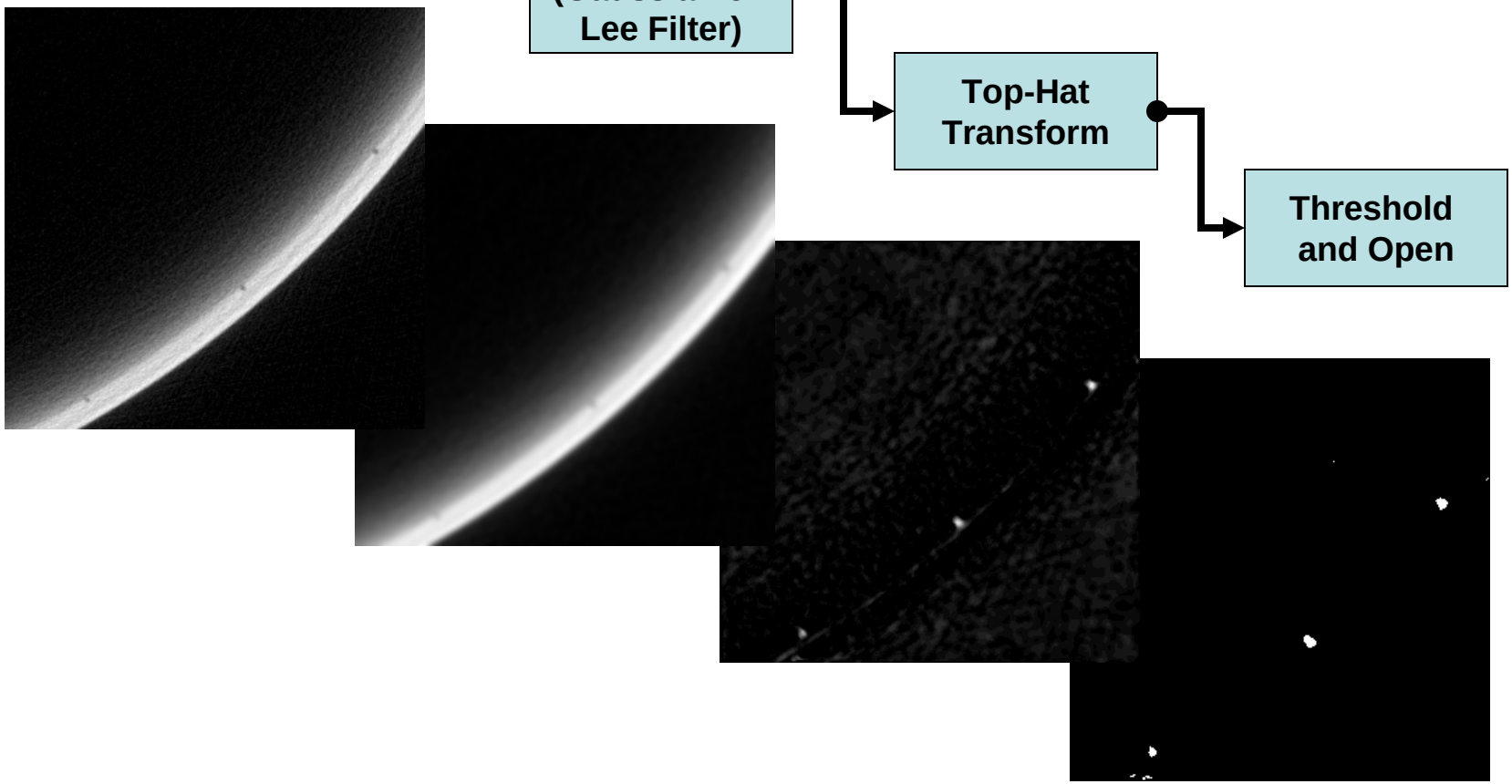


Image Morphology for Void Detection

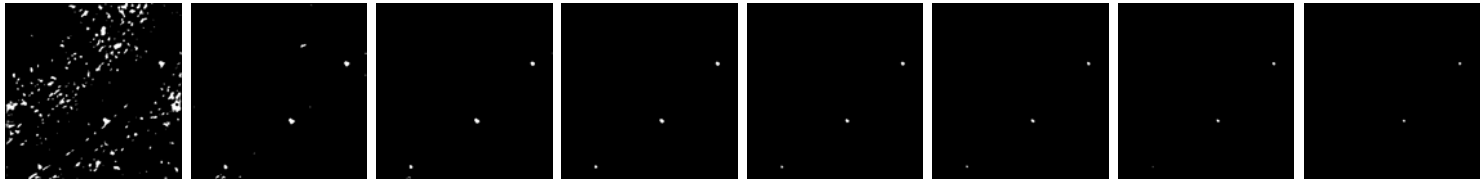
- Image processing pipeline highlights voids.

Original Image → De-noise (Gaussian or Lee Filter) → Top-Hat Transform → Threshold and Open



Threshold Selection

- It is possible to automate the threshold selection.
  - Object stability as a function of varying threshold:



Increasing Threshold: →

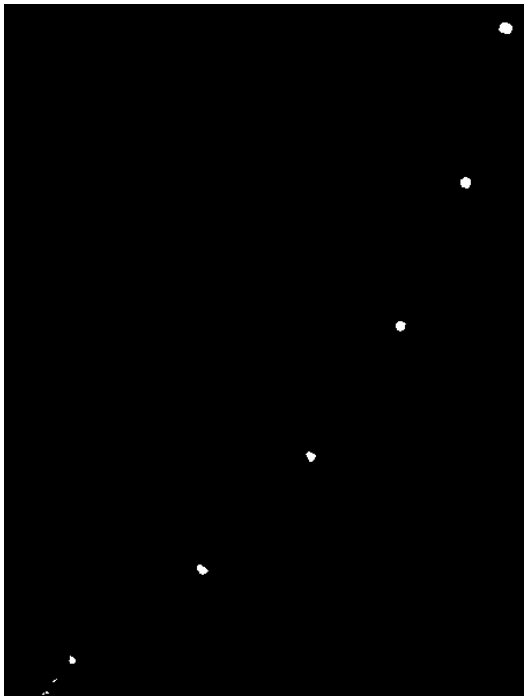
Stable Region: ↔

  - Statistical analysis?
  - Use a 'low' threshold and rely on region analysis.

Image Morphology for Void Detection

- **Automatic analysis of resulting binary image yields void locations, meta-data.**

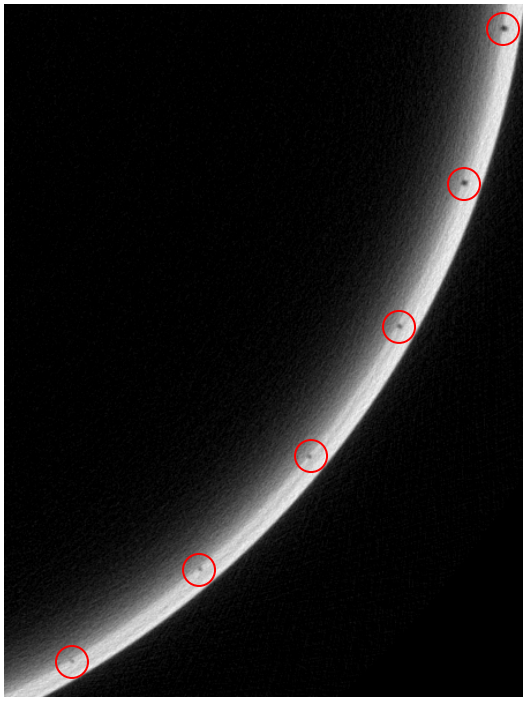
- **Can we compute additional features?**



Connected Component Analysis

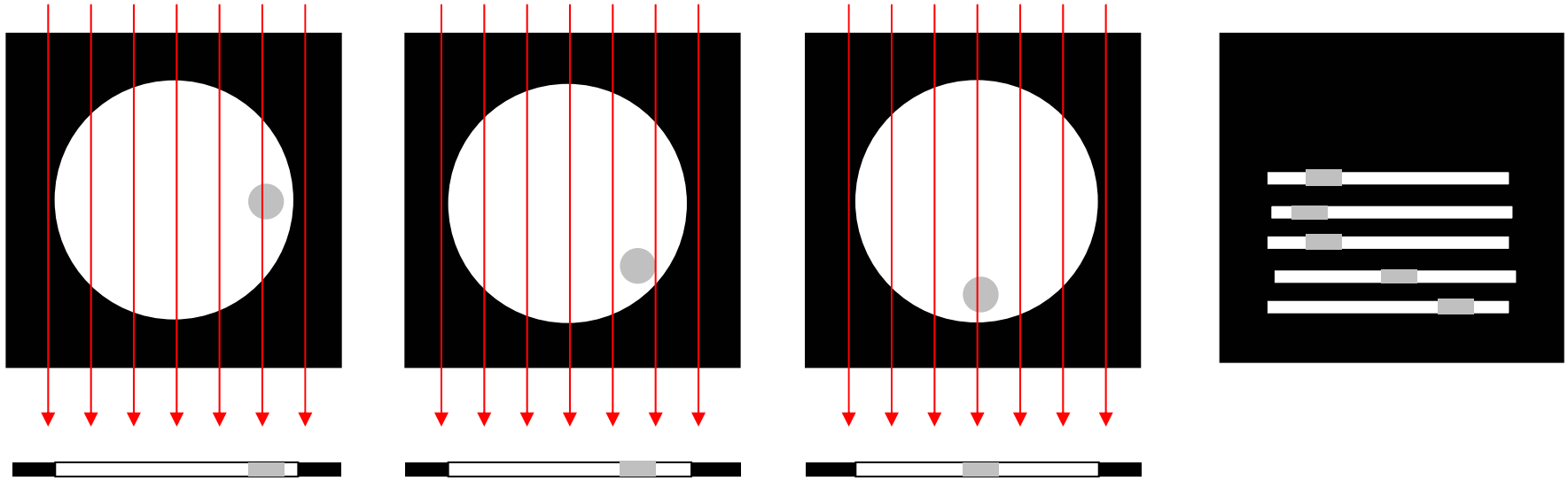
Compute Features:
- **Centroid**
- **Area/Volume**
- **Contrast**
- **???**

Validate/ Discard False Positives



Sinograms

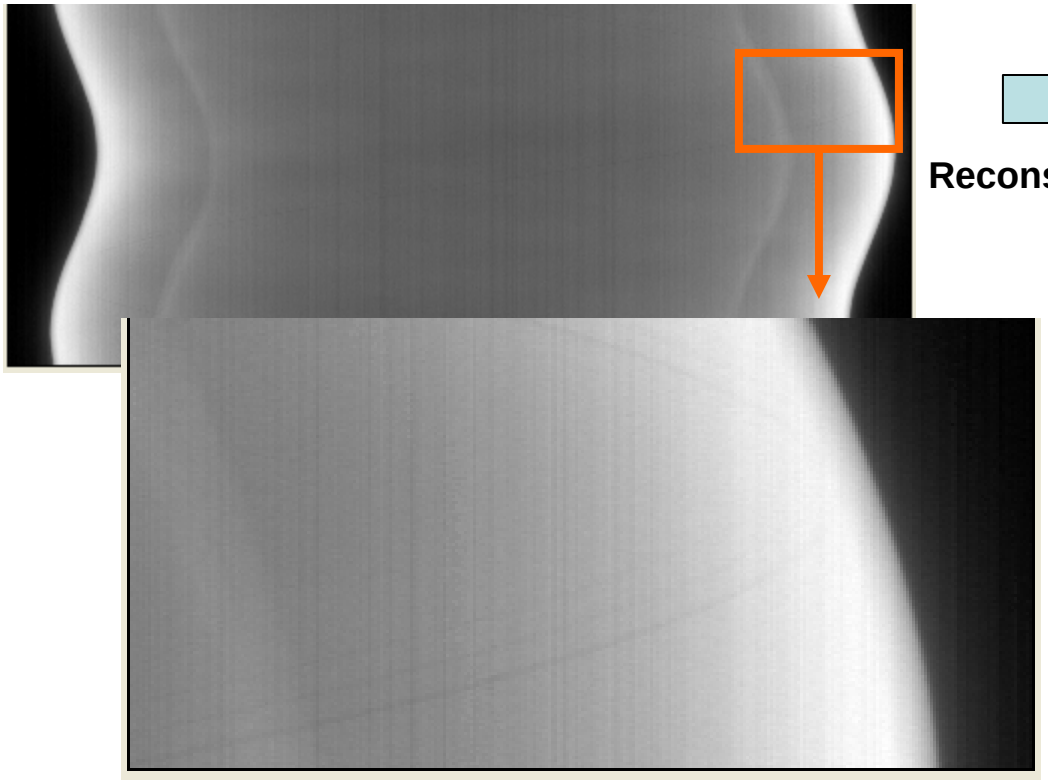
- **Sinograms are a representation of the CT radiogram data *before* reconstruction.**



- **Due to the imaging geometry of CTs, voids leave a distinct sinusoidal trace in the sinogram.**
- **The phase and amplitude of the sinusoid are determined by the azimuthal and radial positions, respectively, of the void within the object.**

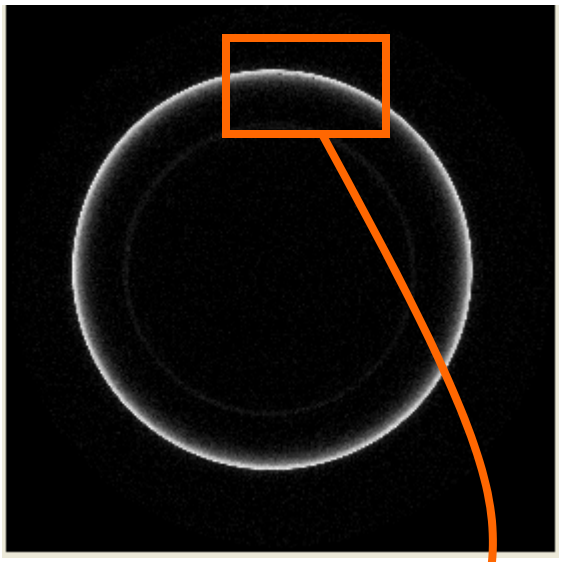
Sinograms

- **Potential for void validation based on contiguous portions of the sinusoid - an advantage when object is more evident at some angles than others.**

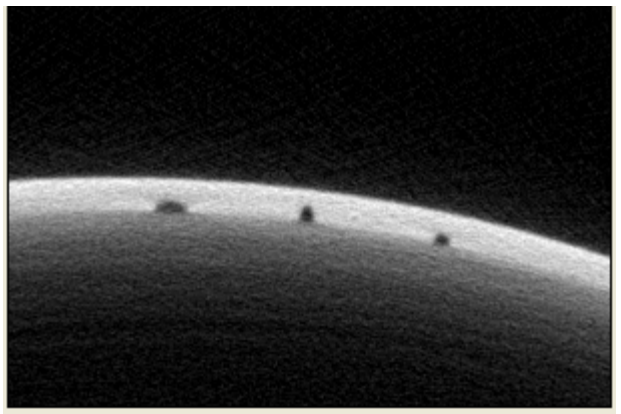


Enlarged view of 3 traces.

Reconstruction



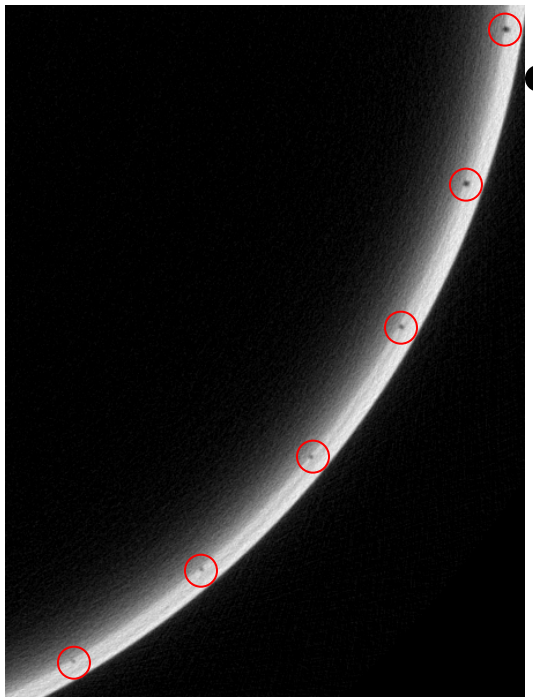
2D slice of W-ring dataset



Enlarged view of voids.

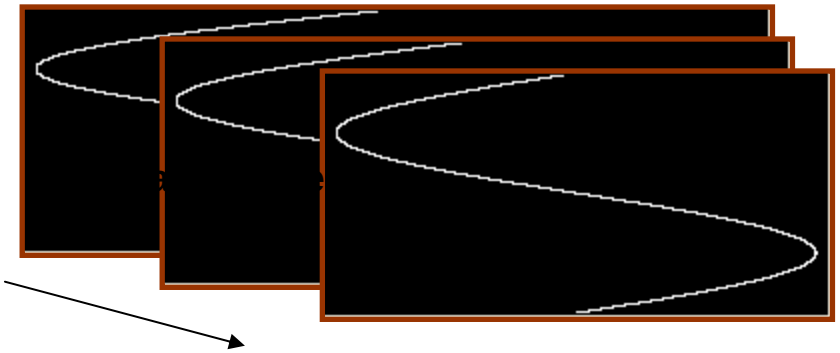
Void validation using Sinogram Analysis*

- To validate: Gradient Direction measures can be used to compute the strength of sinogram traces using a sinusoid model.



Convert void Coordinates to Amp, phase.

Generate GDM Sinusoid Models

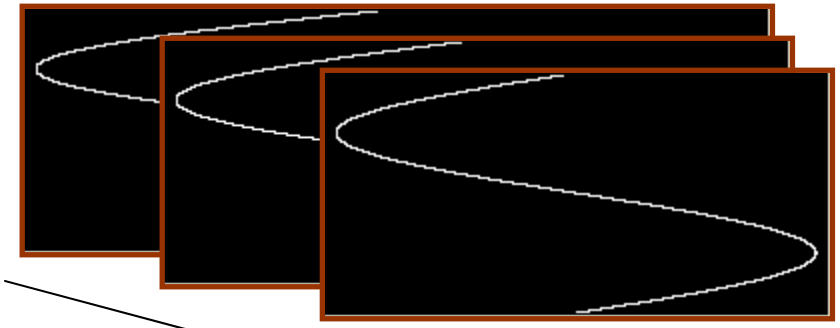


Sinusoid models

* Motivation drawn from human analysts SOP.

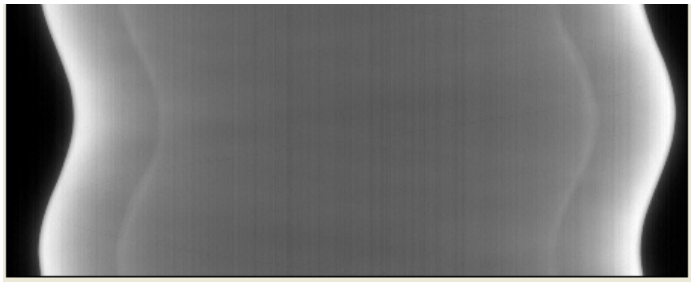
Void validation using Gradient Direction

- GDM computes the sum of the angular differences of the gradients of the model and image.



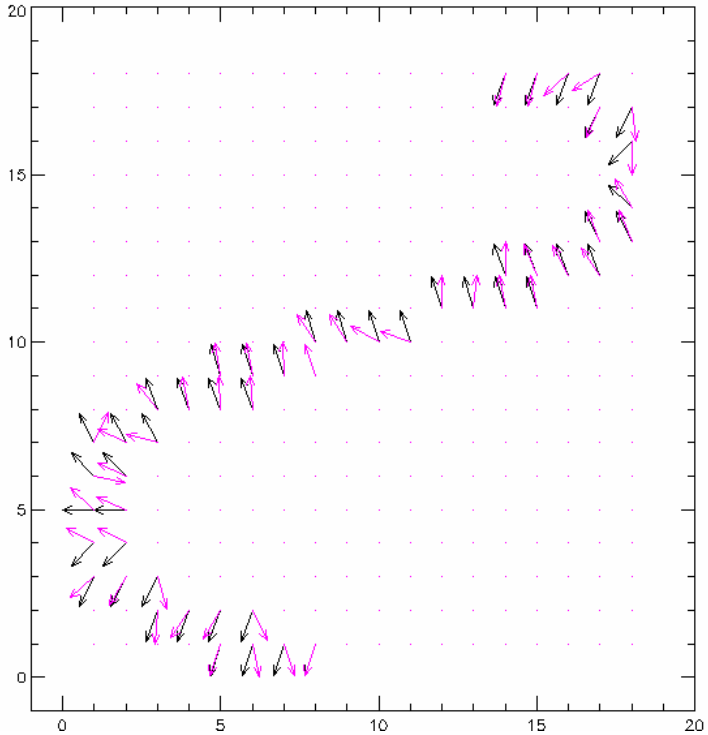
amplitude

Sinusoid models for detected voids



Sinogram

Gradient Direction

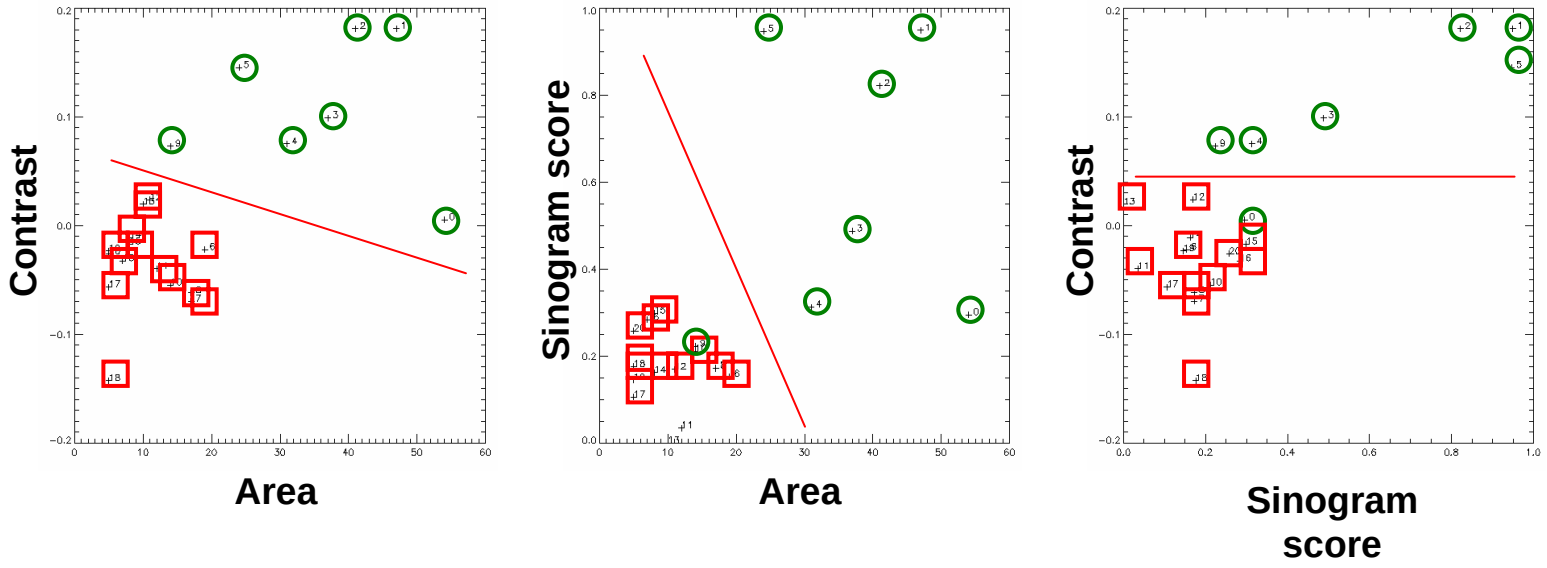


Gradient Direction of model and data (simulated)

Sinusoid strength score

Which Features are Useful?

- To discard false detections, use features such as void contrast, void area, and sinogram GDM score.
- In limited experiments, area and contrast are the strongest features (so far…)

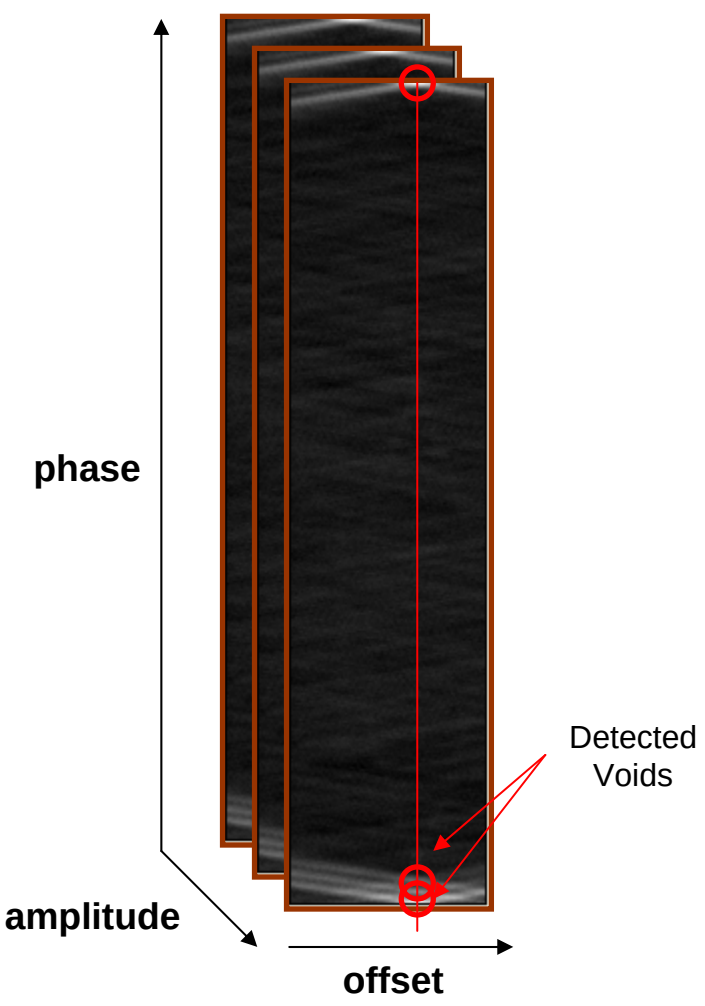


Slice 229 of W-ring dataset: detected 20 voids using 2D morphology.

Discussion / Next Steps

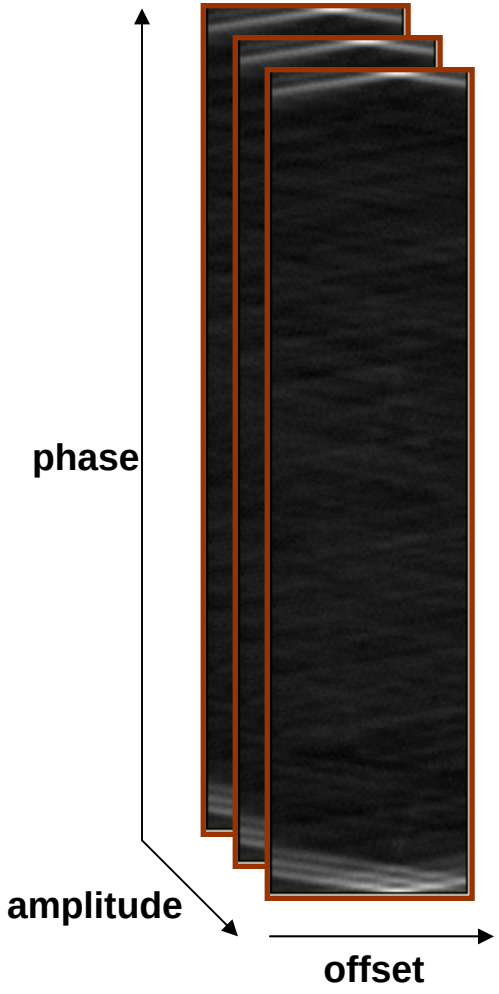
- **Morphology shows strong potential for void extraction.**
  - **Voids can be deleted with grayscale morphology.**
  - **Voids can be validated (and false positives rejected) with computed features.**
- **Sinogram features show potential.**
  - **Image features (void volume, contrast, geometry constraints) result in slightly better false alarm rejection than sinogram features.**
  - **Why? Possibly because image reconstruction is a better algorithm for integrating sinogram information.**
  - **Better sinusoid models (grayscale? More accurate geometry?) may increase performance.**
- **Next steps(ongoing):**
  - **Threshold automation.**
  - **Quantitative evaluation of morphological detection performance against programmatic data (human analysts provide ground truth).**

Extra junk



GDM Match surfaces at different amplitudes, morphologically detected voids marked.

Grad. Dir. Matching



GDM Match surfaces at different amplitudes.