

Determining Aggregate Characteristics of HMA: 3D Processing of X-ray CT Images

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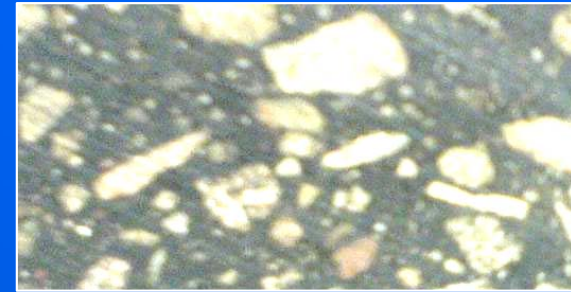
Rick Meininger, P.E.

Edith Arambula, Ph.D.



Effect of aggregate properties

- **Fine** graded HMA mix
 - **Coarse** Aggr: Little or no contact points
 - **Fine** Aggr: Very important
- **Coarse** graded HMA mix
 - **Coarse** Aggr: Some contact points
 - **Fine** Aggr: Important
- **SMA** Mix
 - **Coarse** Aggr: Many contact points
 - **Fine** Aggr: Less important

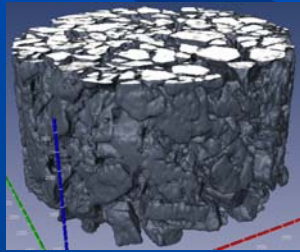


Steps of Image-based Aggregate Extraction



Specimen Prep.
(Lab compacted /
field core)

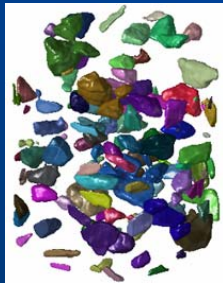
Varying aggregate type,
compaction characteristics



**Measurement of 3D
internal geometry**

X-ray CT imaging

**Rigorous image
processing & analysis**



Separation of aggregates

Individual aggregate props:
3D orientation, angularity,
Specific surface area ...etc.

**Calculation of contact
points**



X-ray Computed Tomography setup

X-Ray Source

Detector

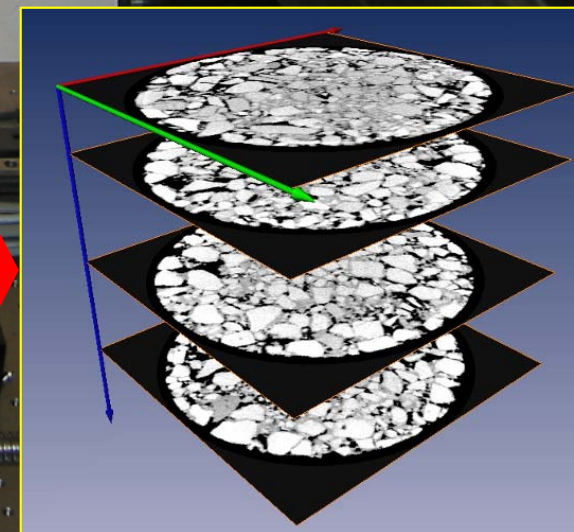
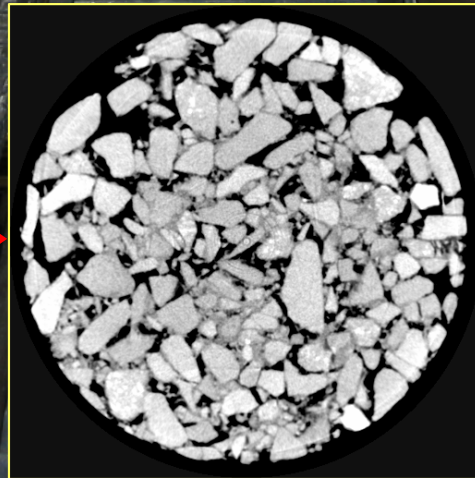
Specimen

CT# (in)

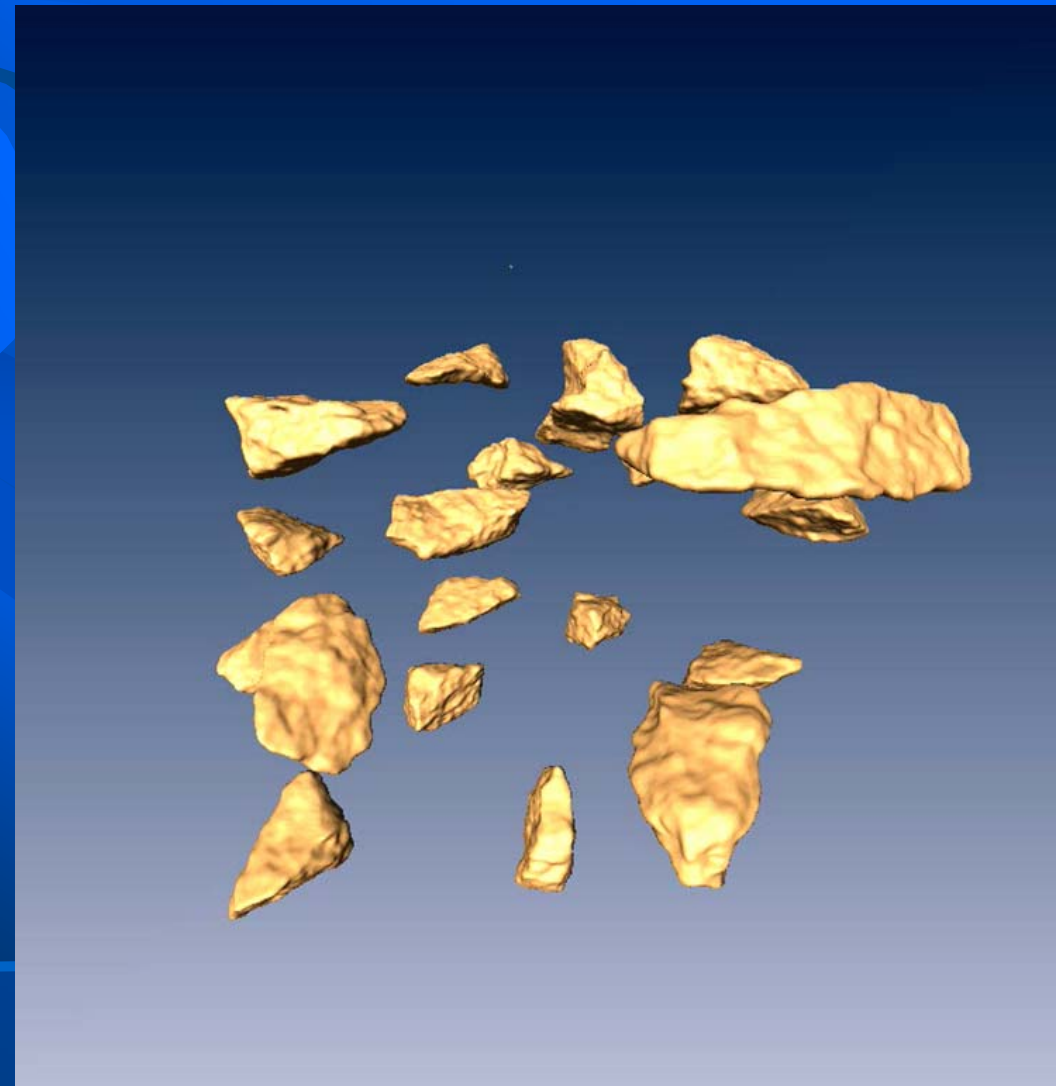
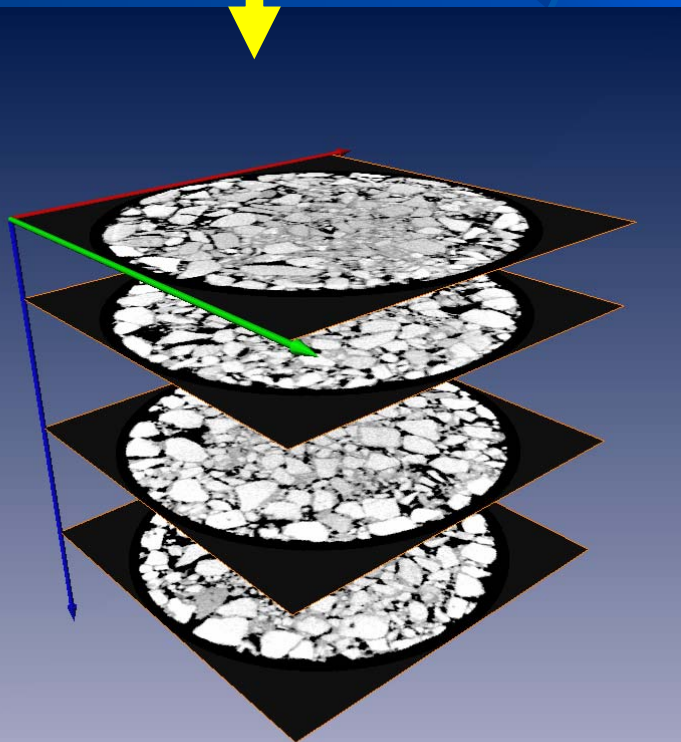
CT# (Out)

Algorithms

Vertical shift

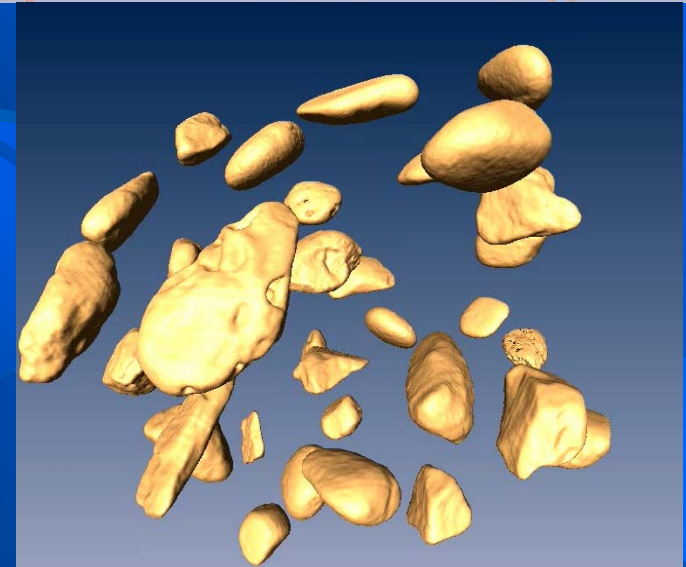
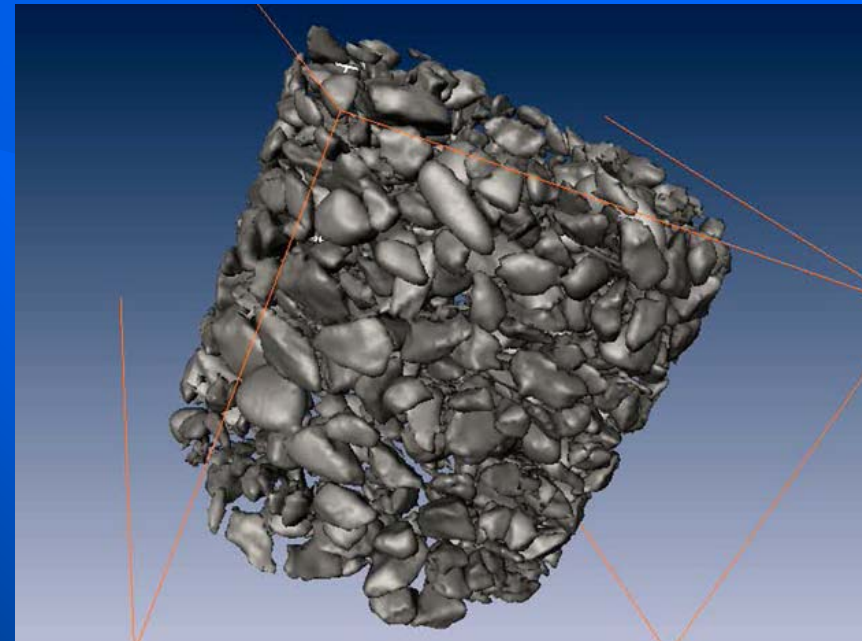


Direct measurement of aggregate characteristics: 3D image analysis



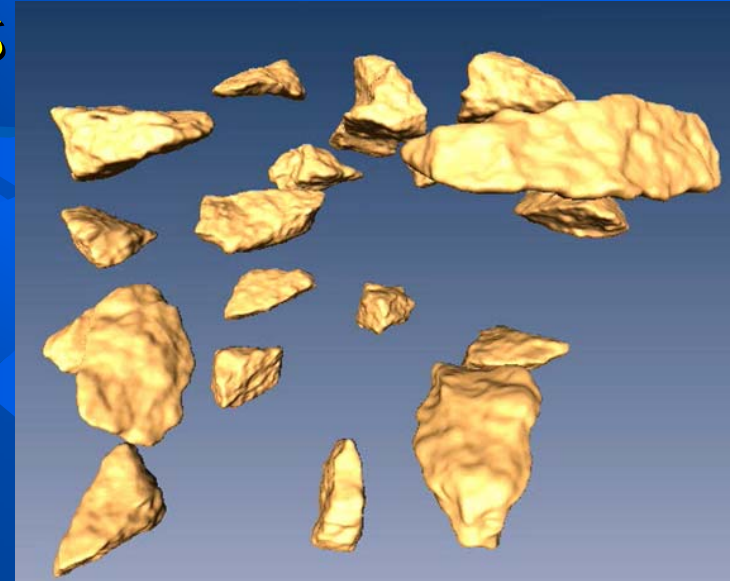
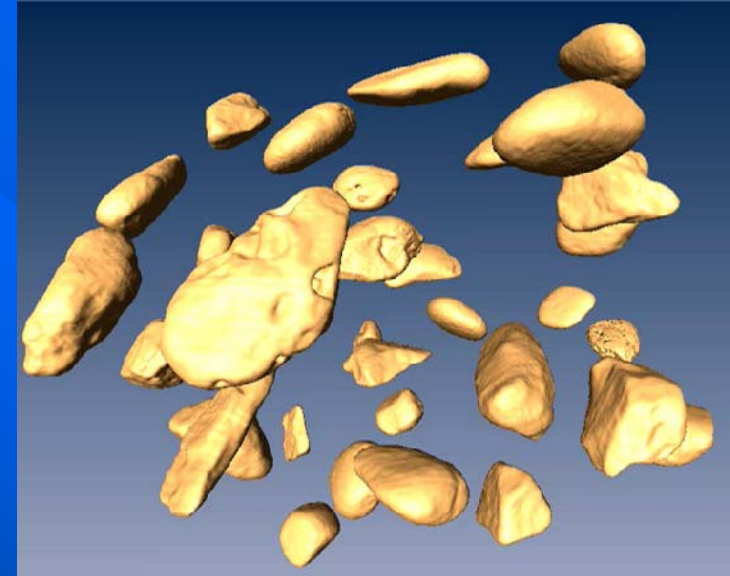
Characteristics of aggregates packed in an asphalt mixture

- 3D Contact points (or influence zone)
- 3D Orientation
- Segregation:
 - Spatial distribution of different sizes
- 3D Angularity, sphericity, specific surface area and texture



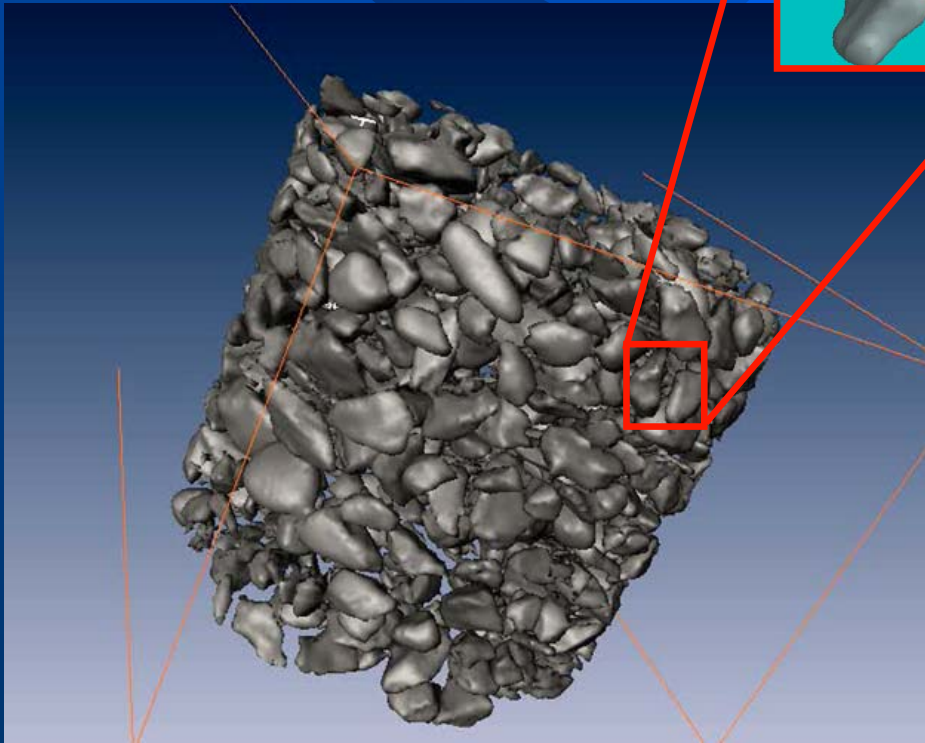
Aggregate contact points

- Given : gradation and compaction level
 - Variation of **contact points** for different aggregates: **rectangular, flat, elongated and round**
- **Locking point**
- Effect of number of **contact points** on HMA **performance**
- **Mix design** considering **contact points** and **packing**

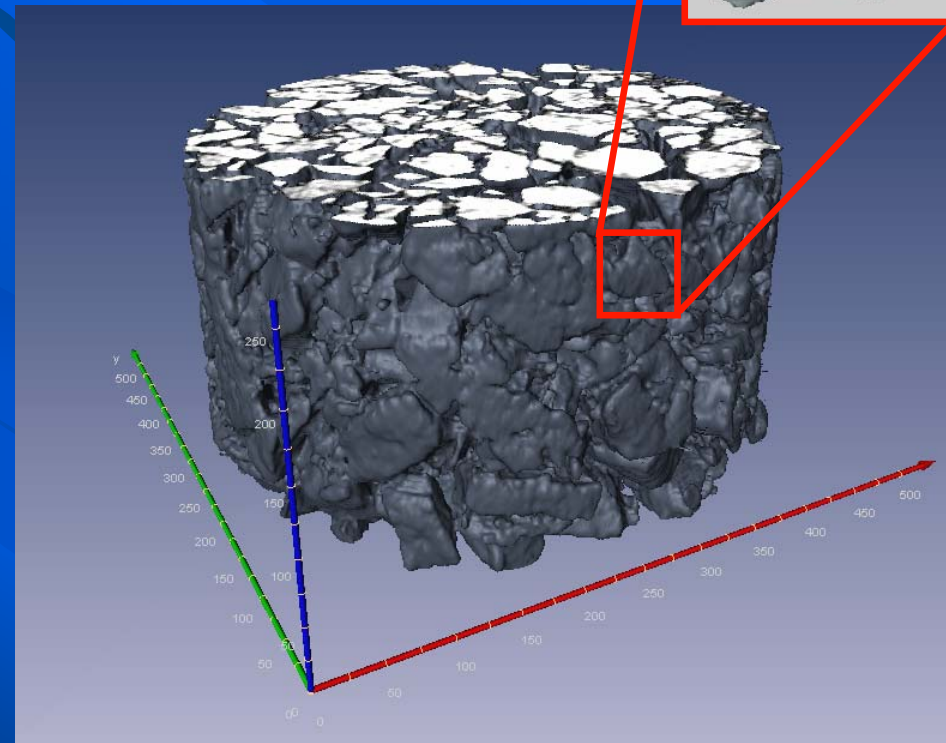
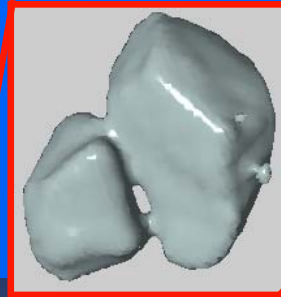


Challenge in experimentation: separation of aggregates

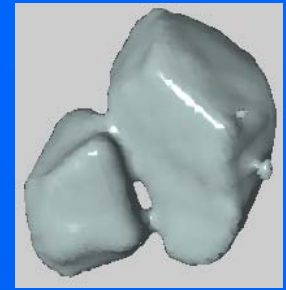
Ideal



Real

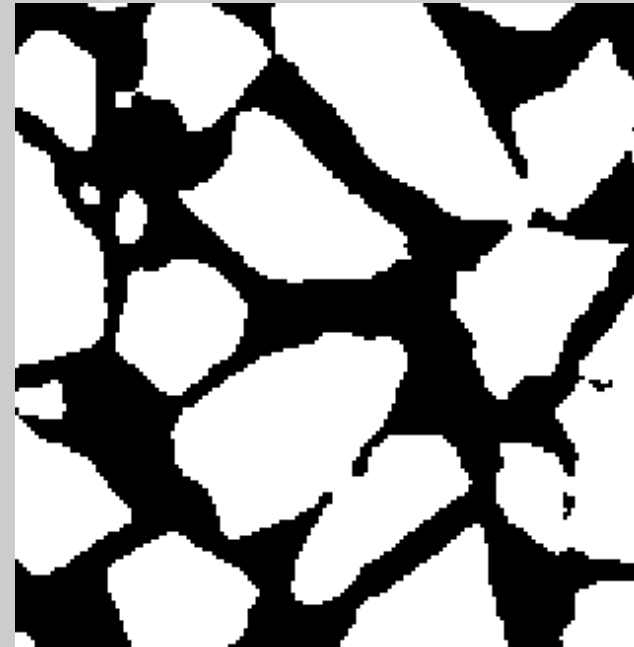
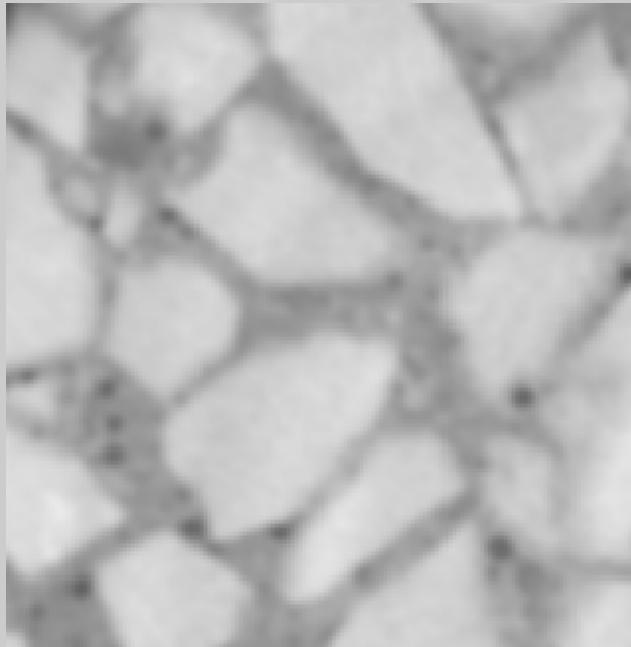


Thresholding and labeling (2D description)

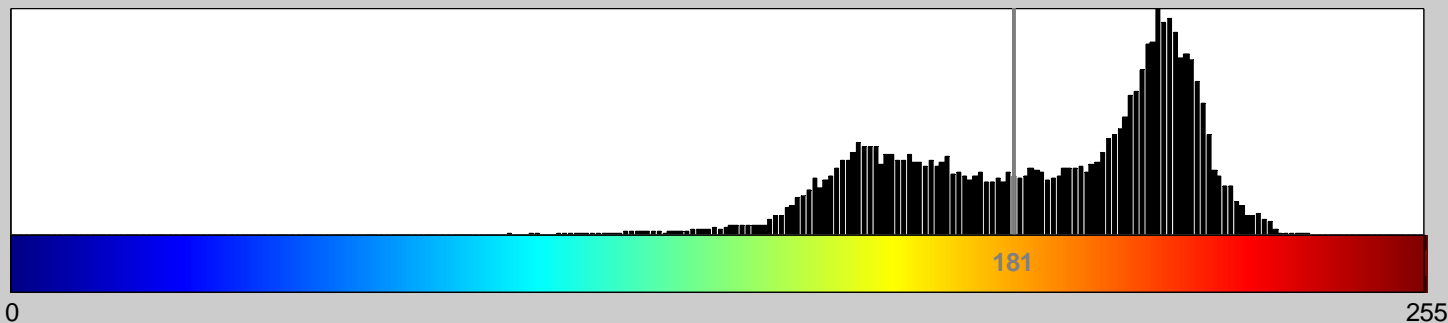


Grayscale image

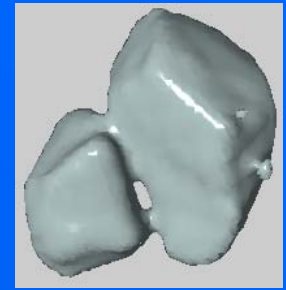
Thresholded binary image



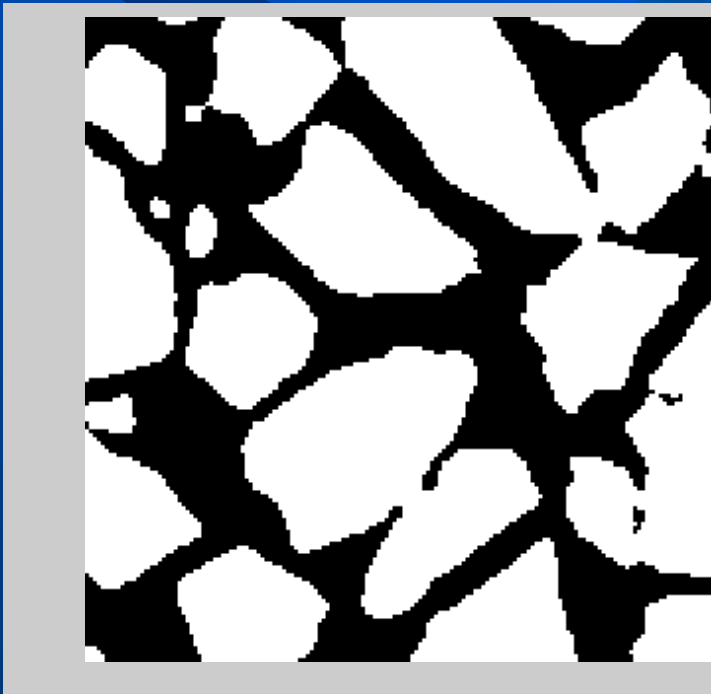
Intensity Distribution



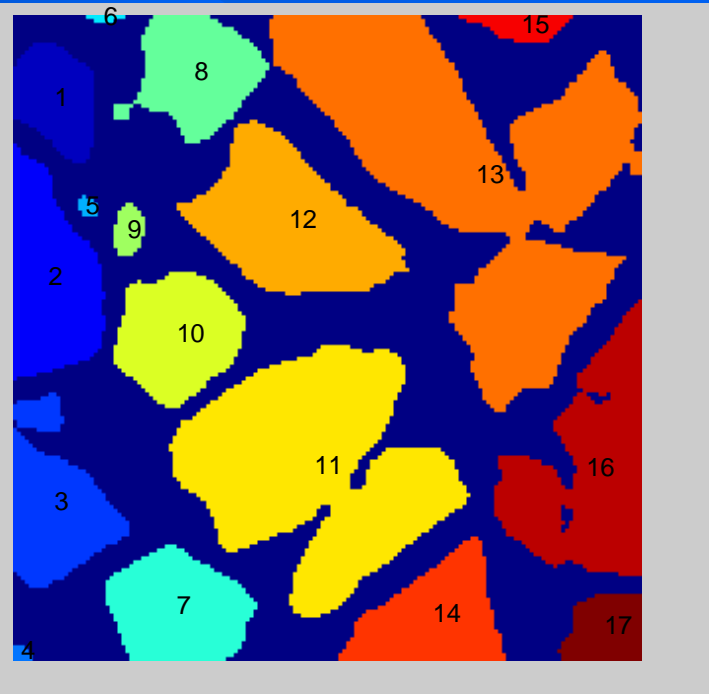
Thresholding and labeling (2D description)



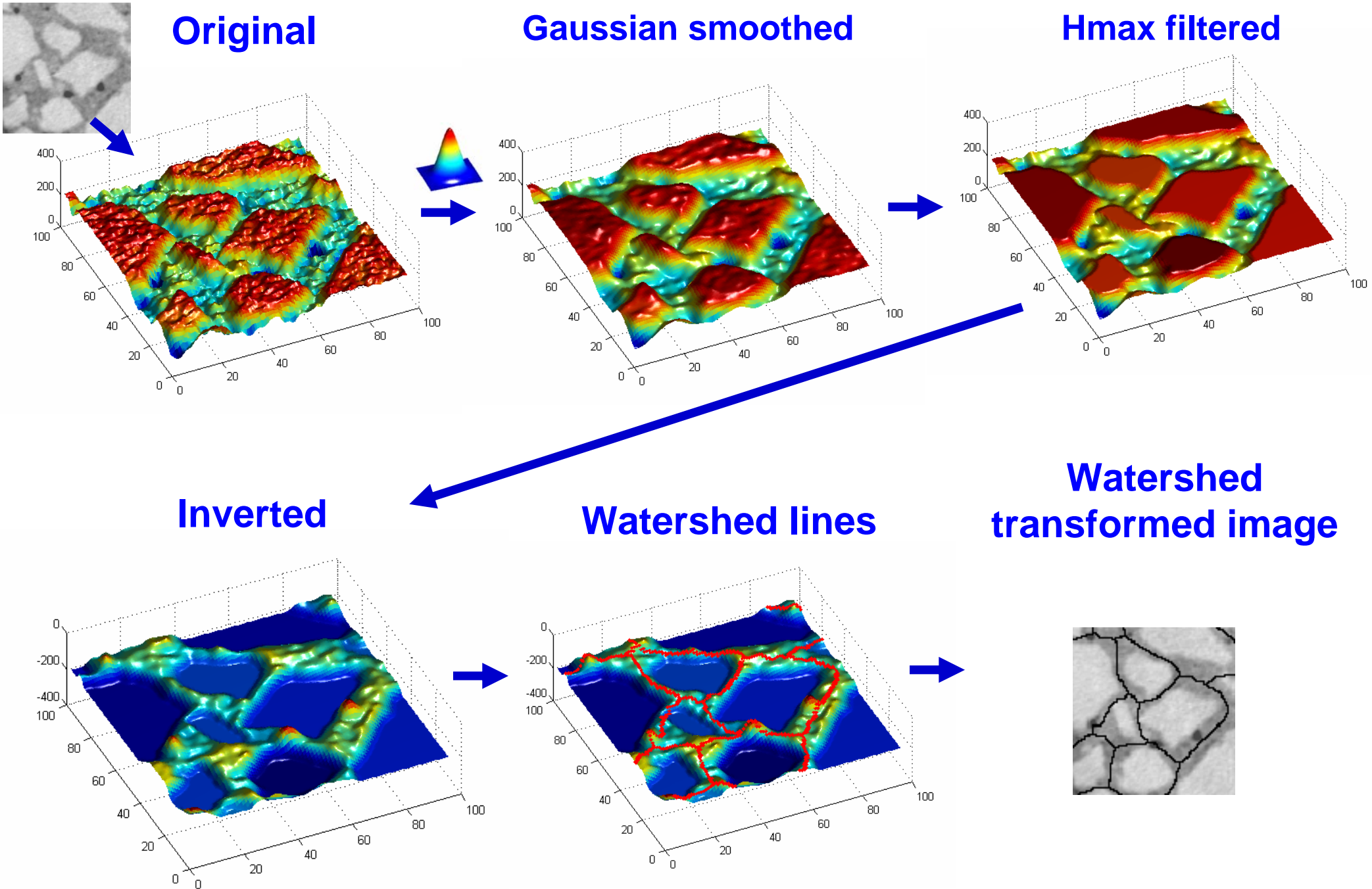
Binary image



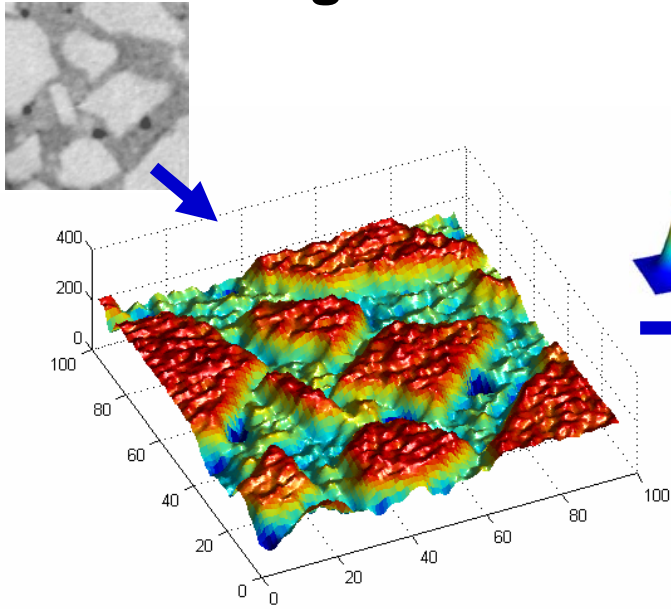
Labeled image



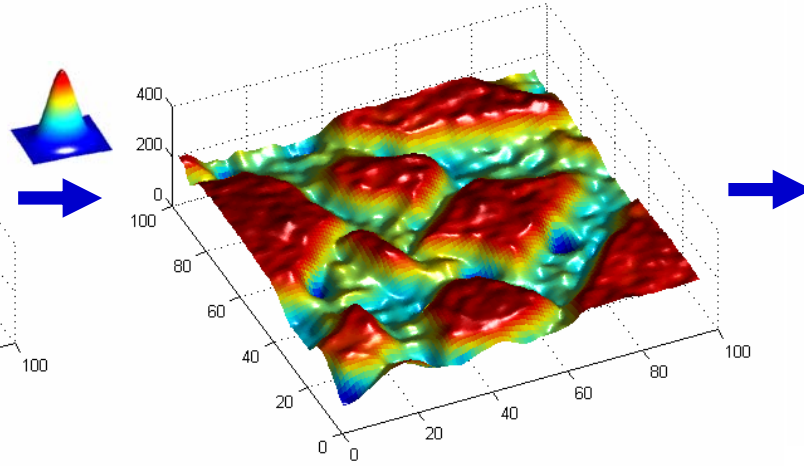
Filtered watershed transformation



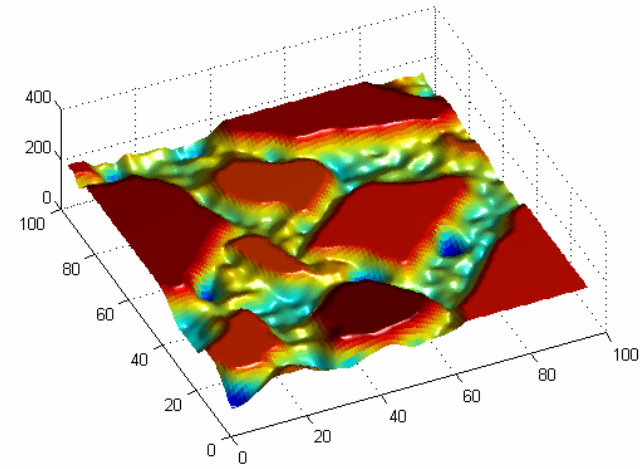
Original



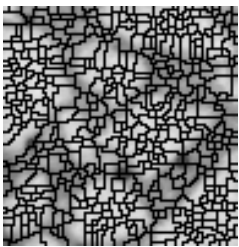
Gaussian smoothed



Hmax filtered



Watershed transformed image



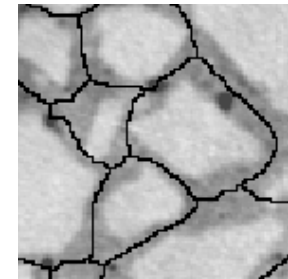
Not good

Watershed transformed image



Not good

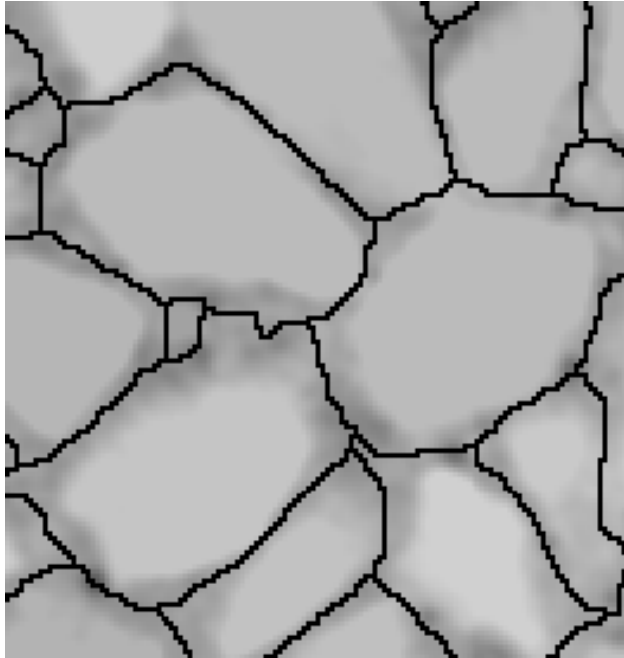
Watershed transformed image



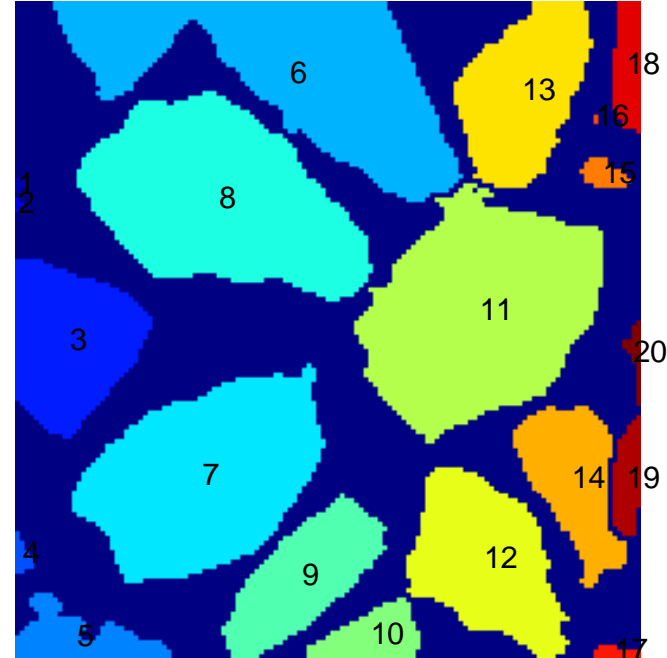
Good

Thresholding and labeling

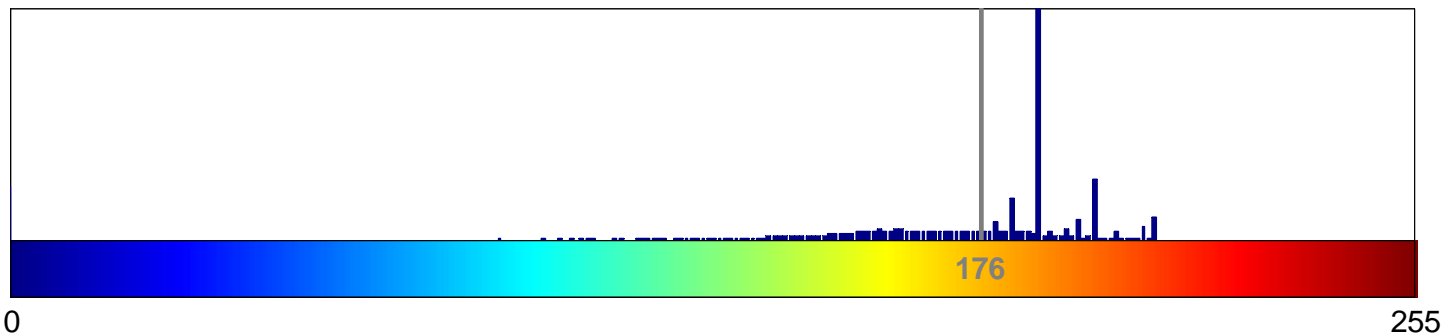
Image after watershed



Labeled image

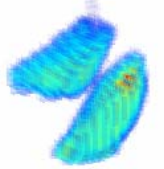



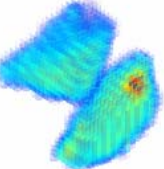
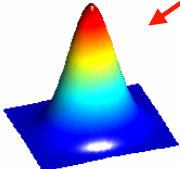
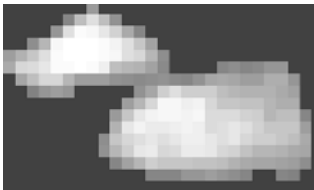
Intensity Distribution

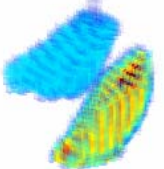
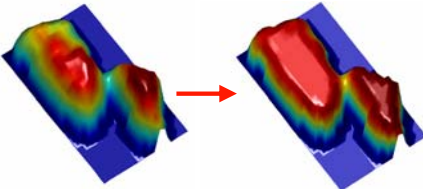



Separation of aggregates: 3D image processing steps



 **Original 3D image** 

 **3D Gaussian smoothing**  

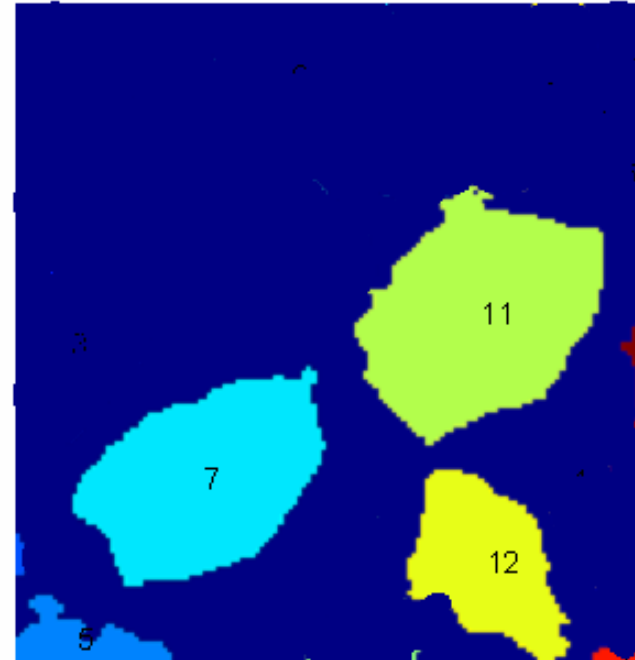
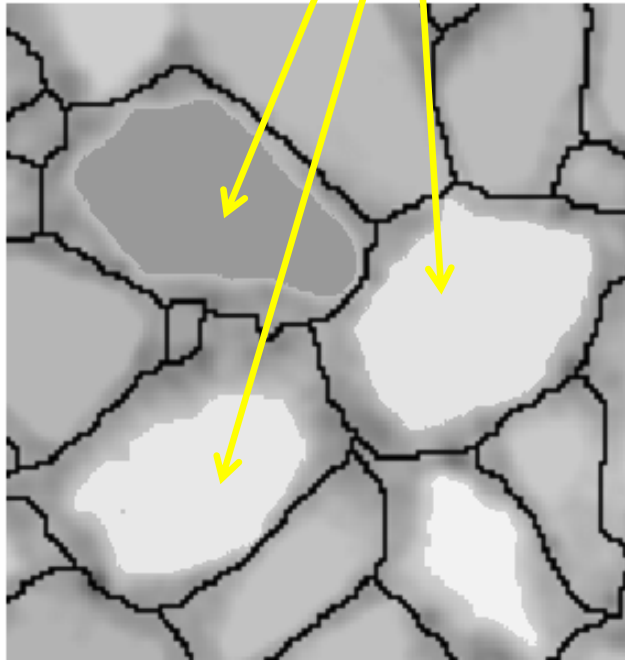
 **3D Hmax filtering**  

 **3D Watershed surfaces (lines)** 

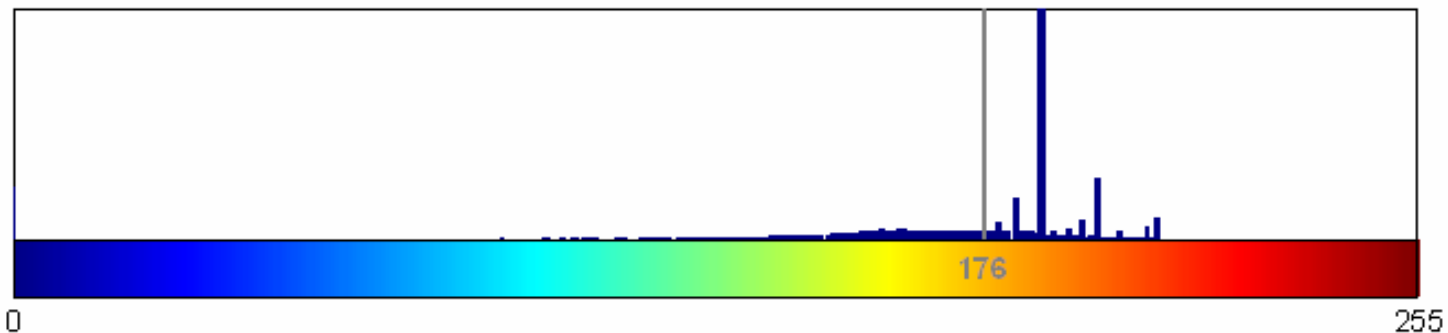
 **Thresholding & labeling** 

Thresholding Issues...

Different intensities

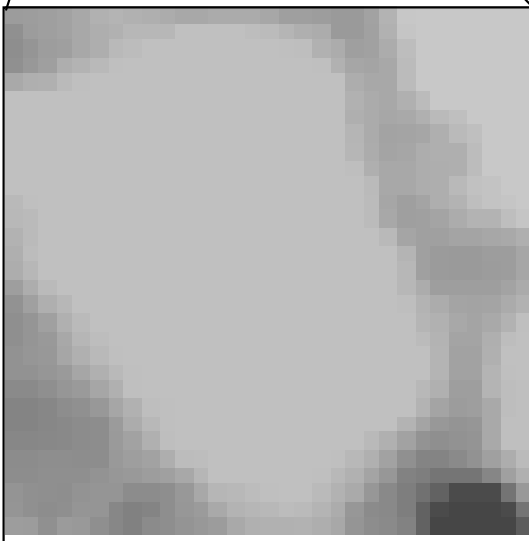
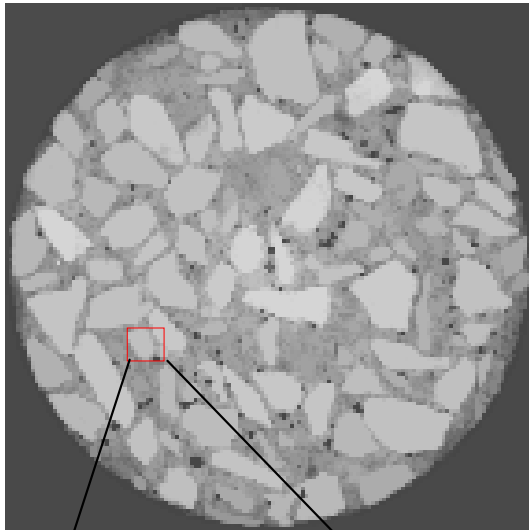


Intensity Distribution

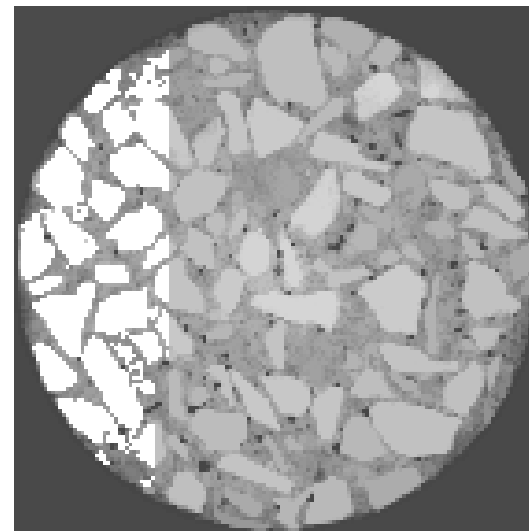
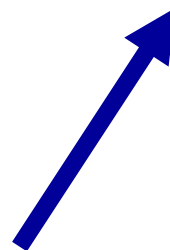
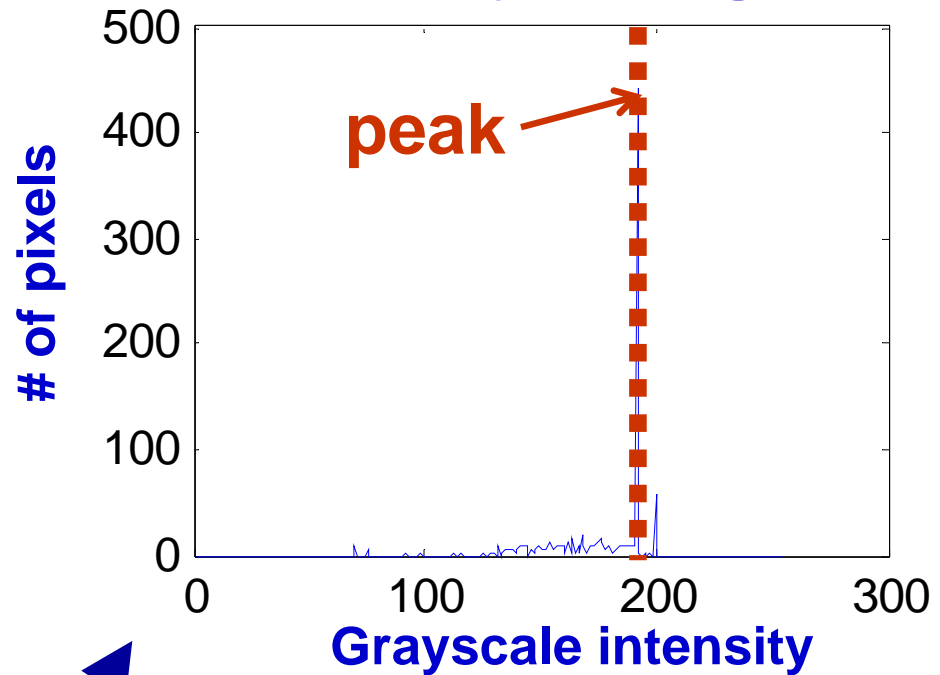


Dynamic thresholding in 2D

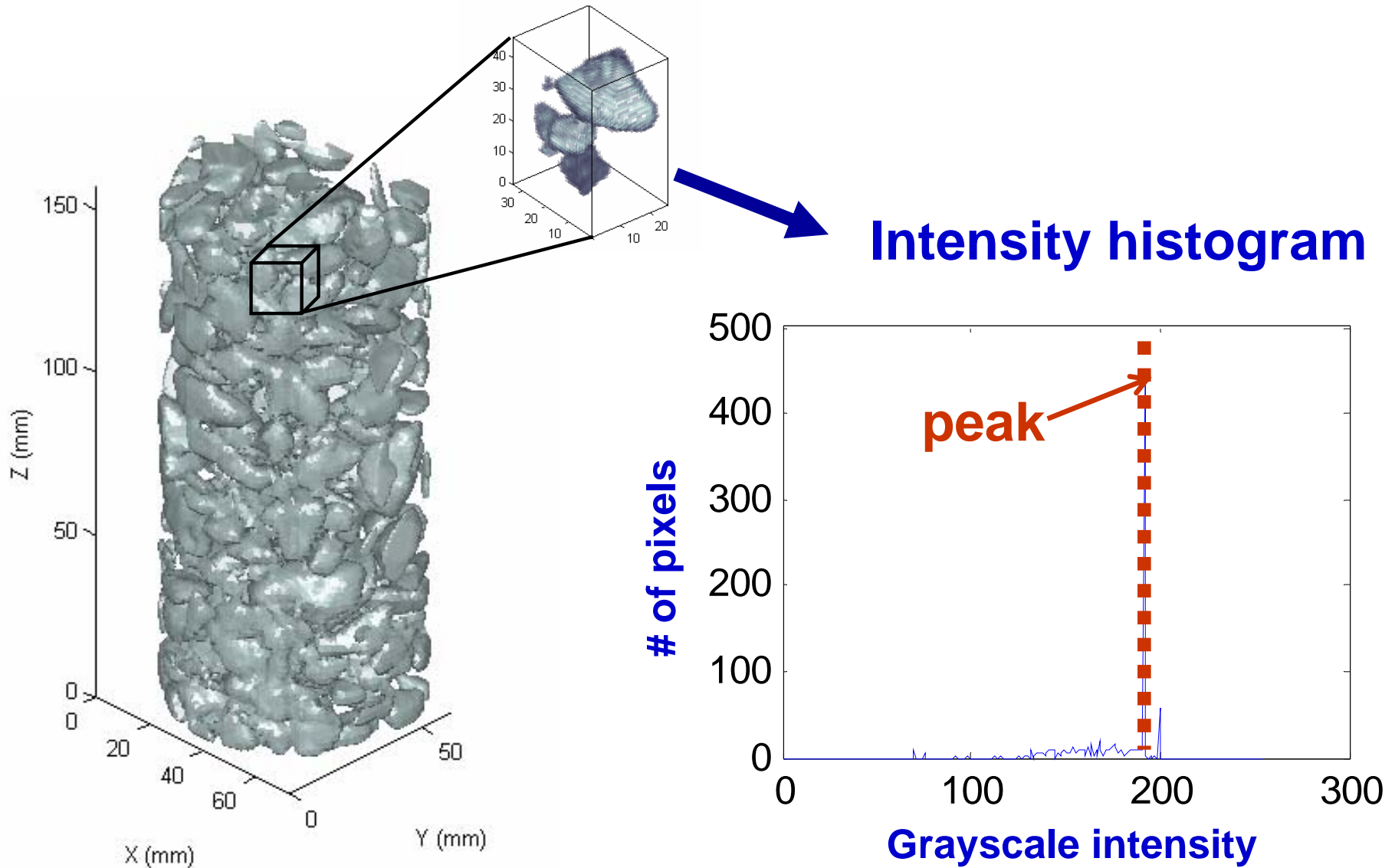
Original image



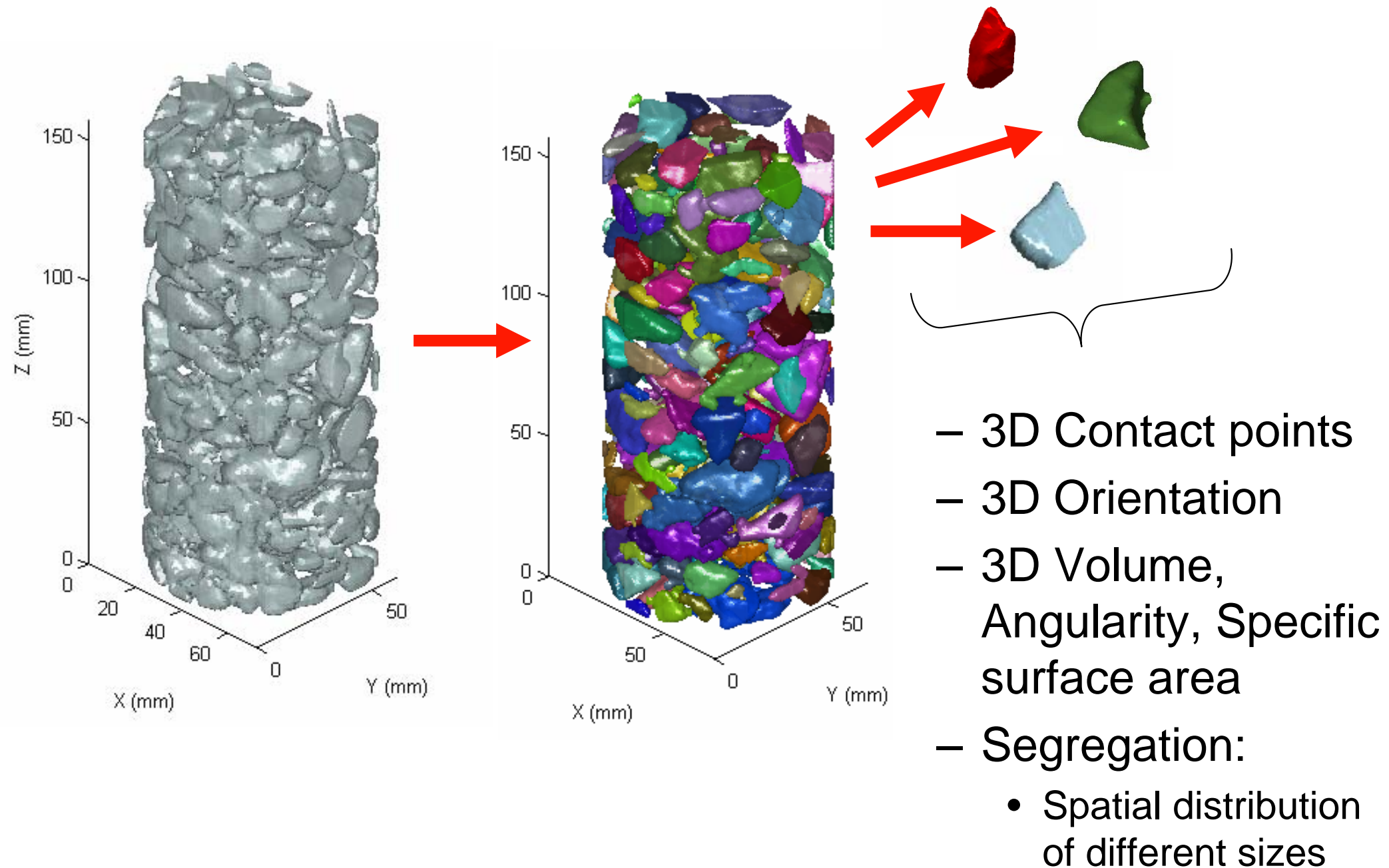
Intensity histogram



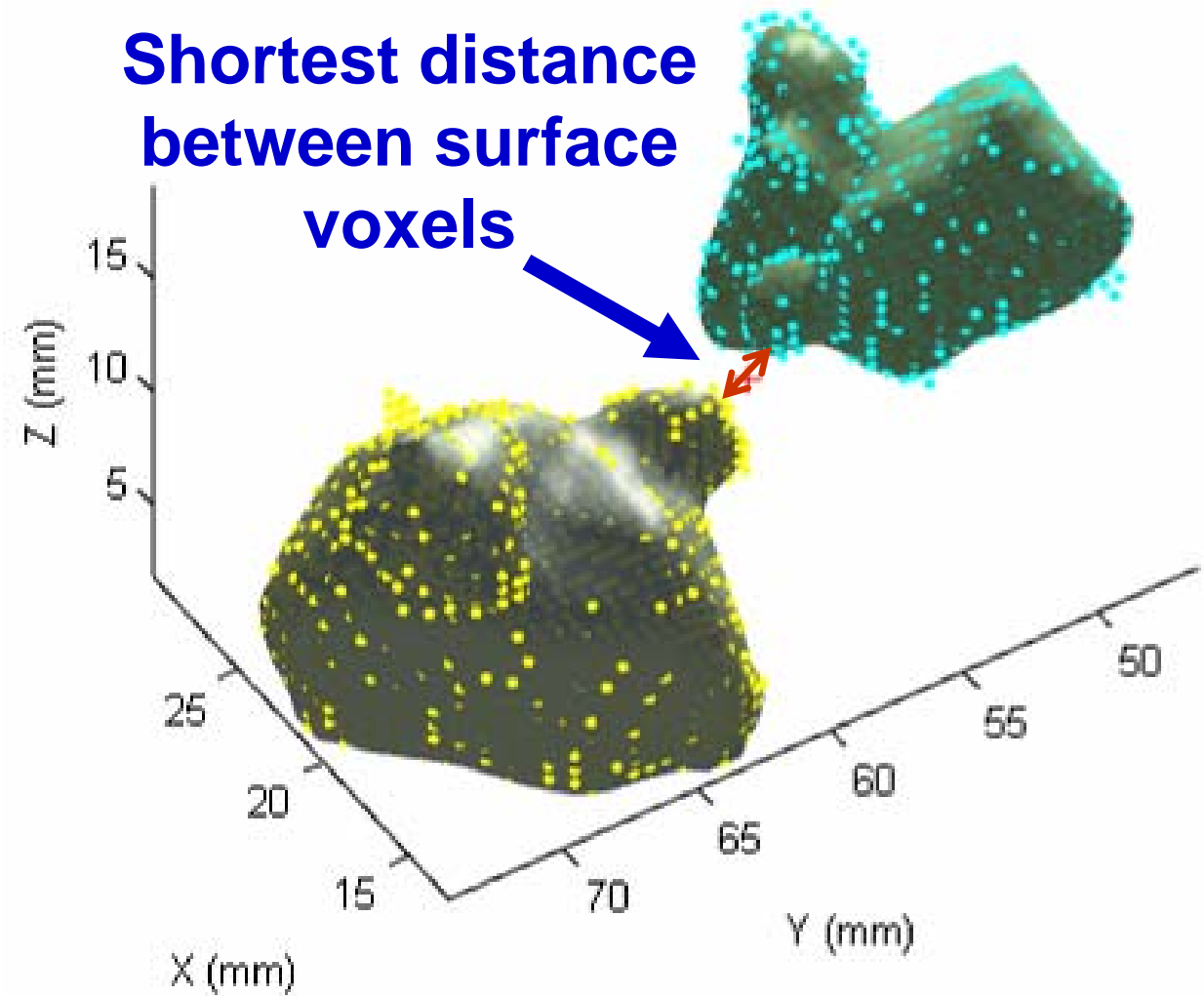
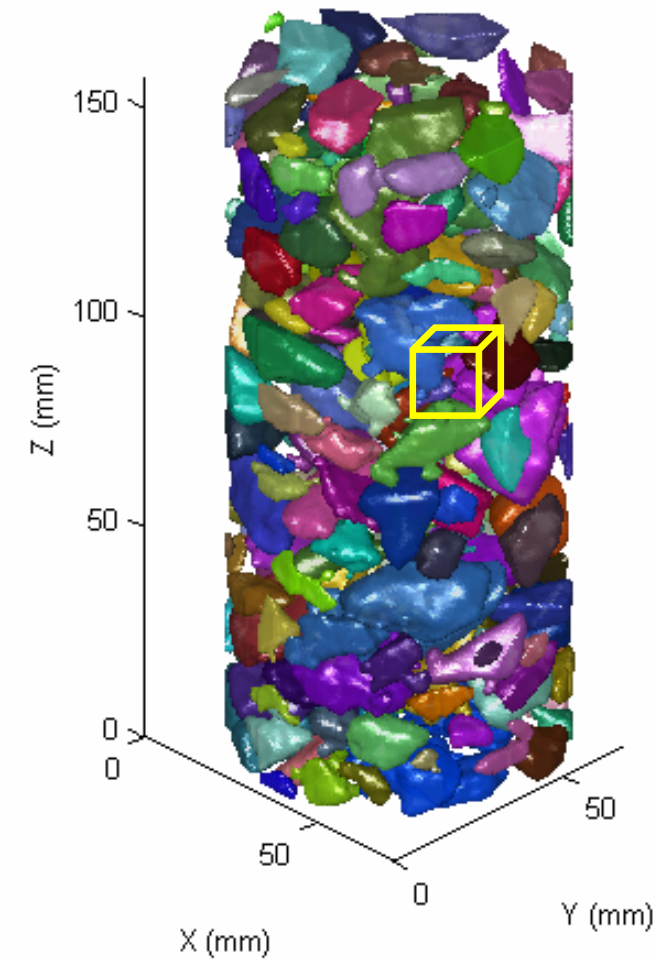
Dynamic thresholding in 3D



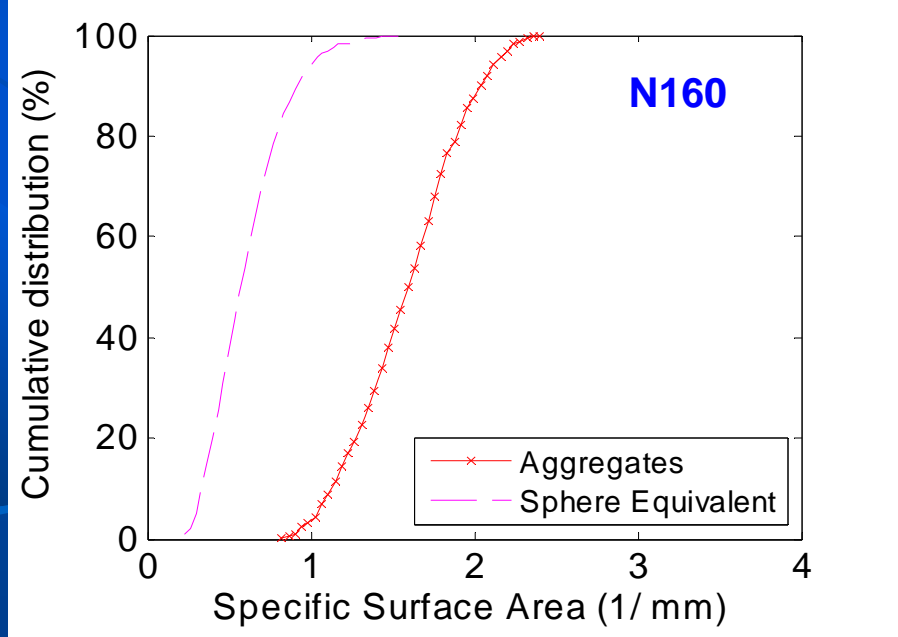
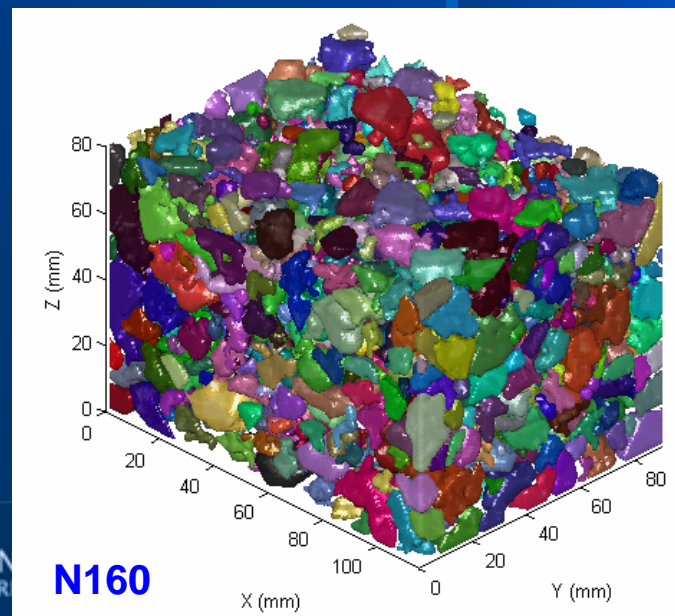
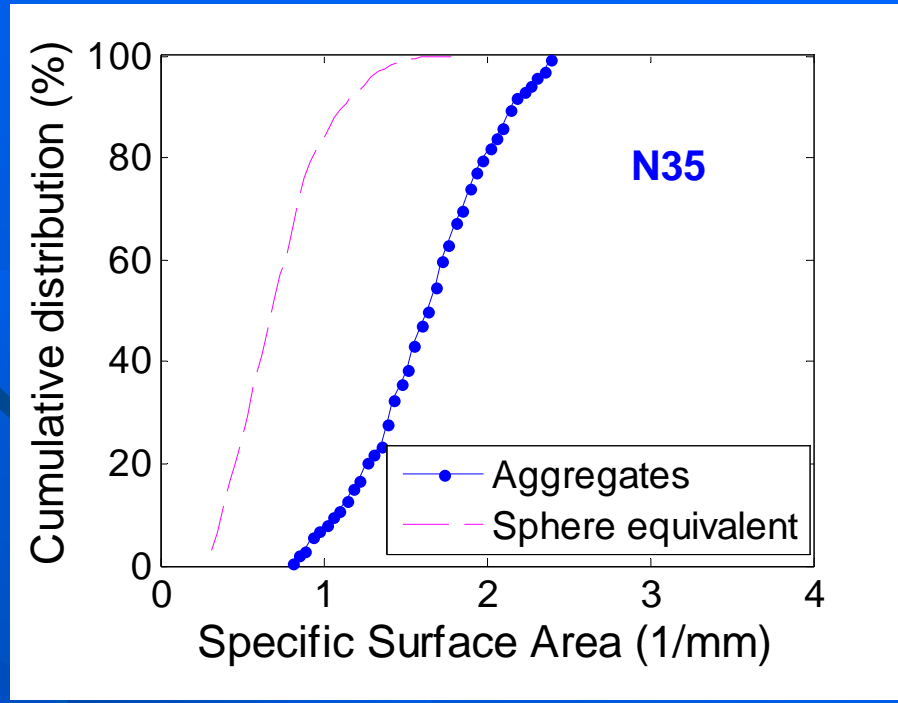
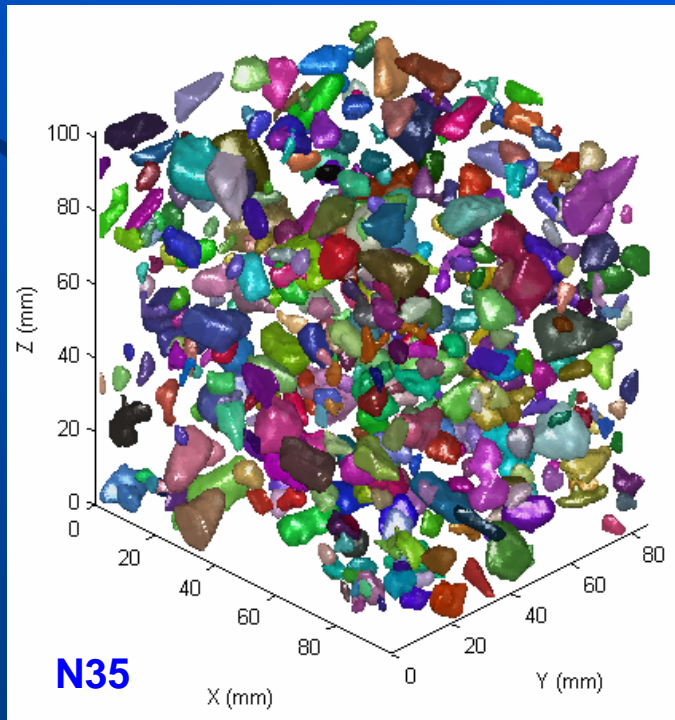
Calculation of aggregate properties



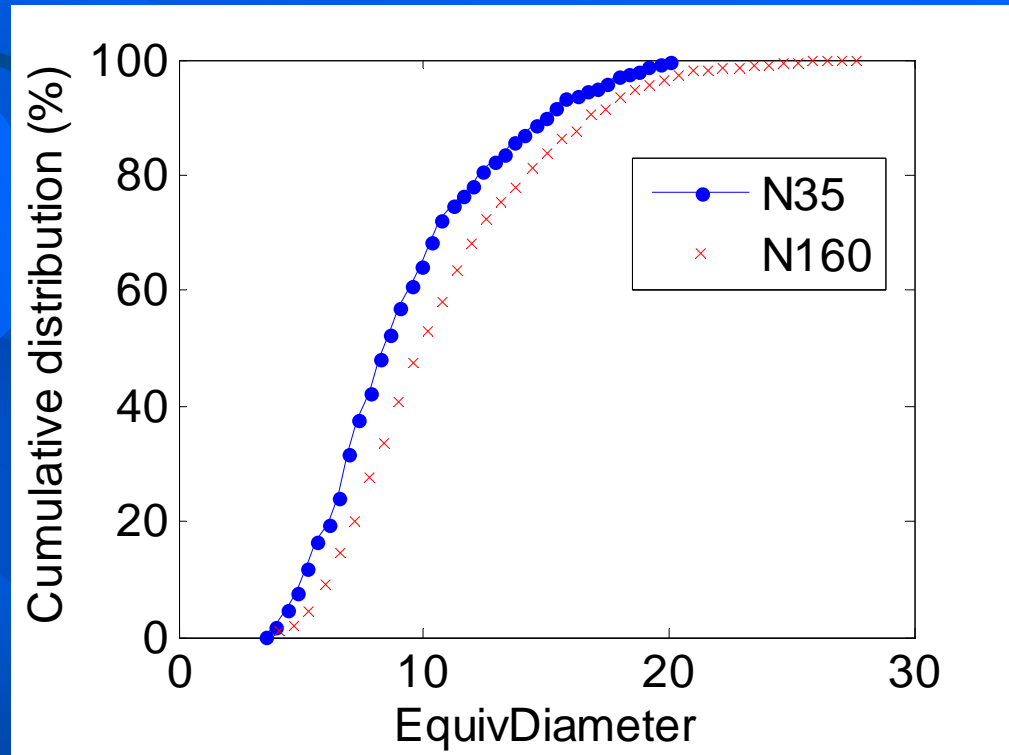
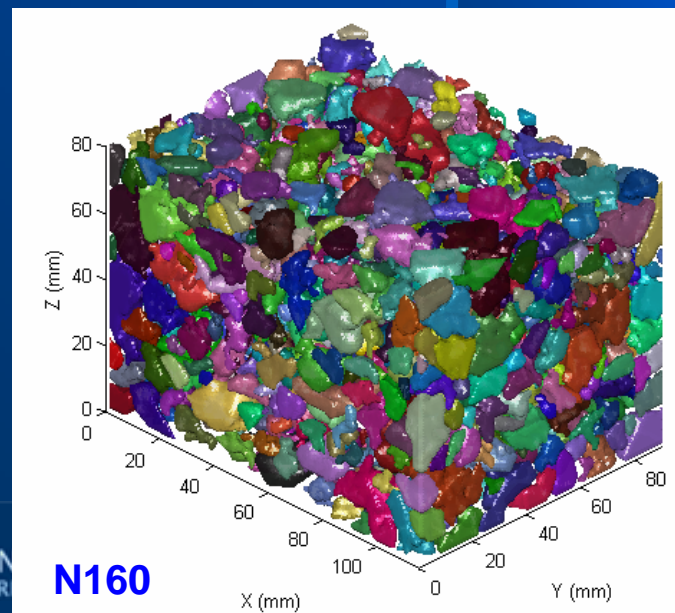
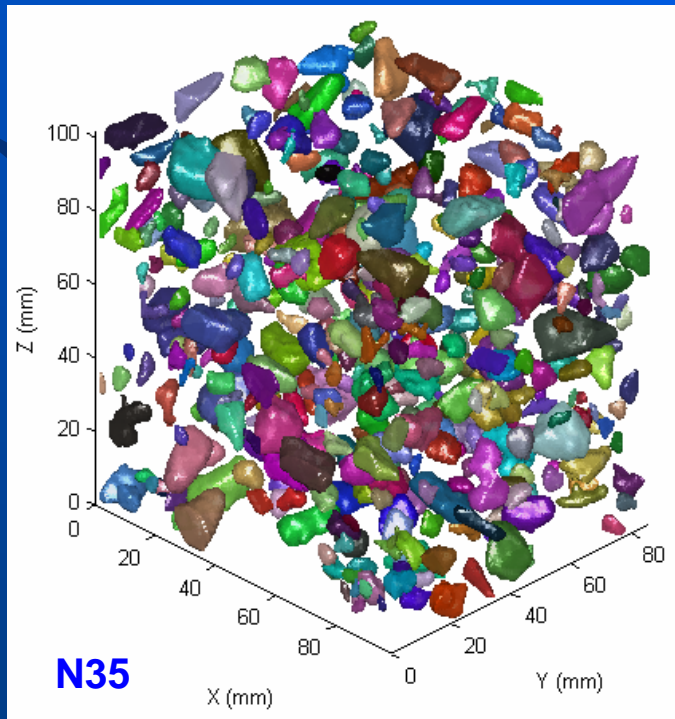
Calculation of contact points



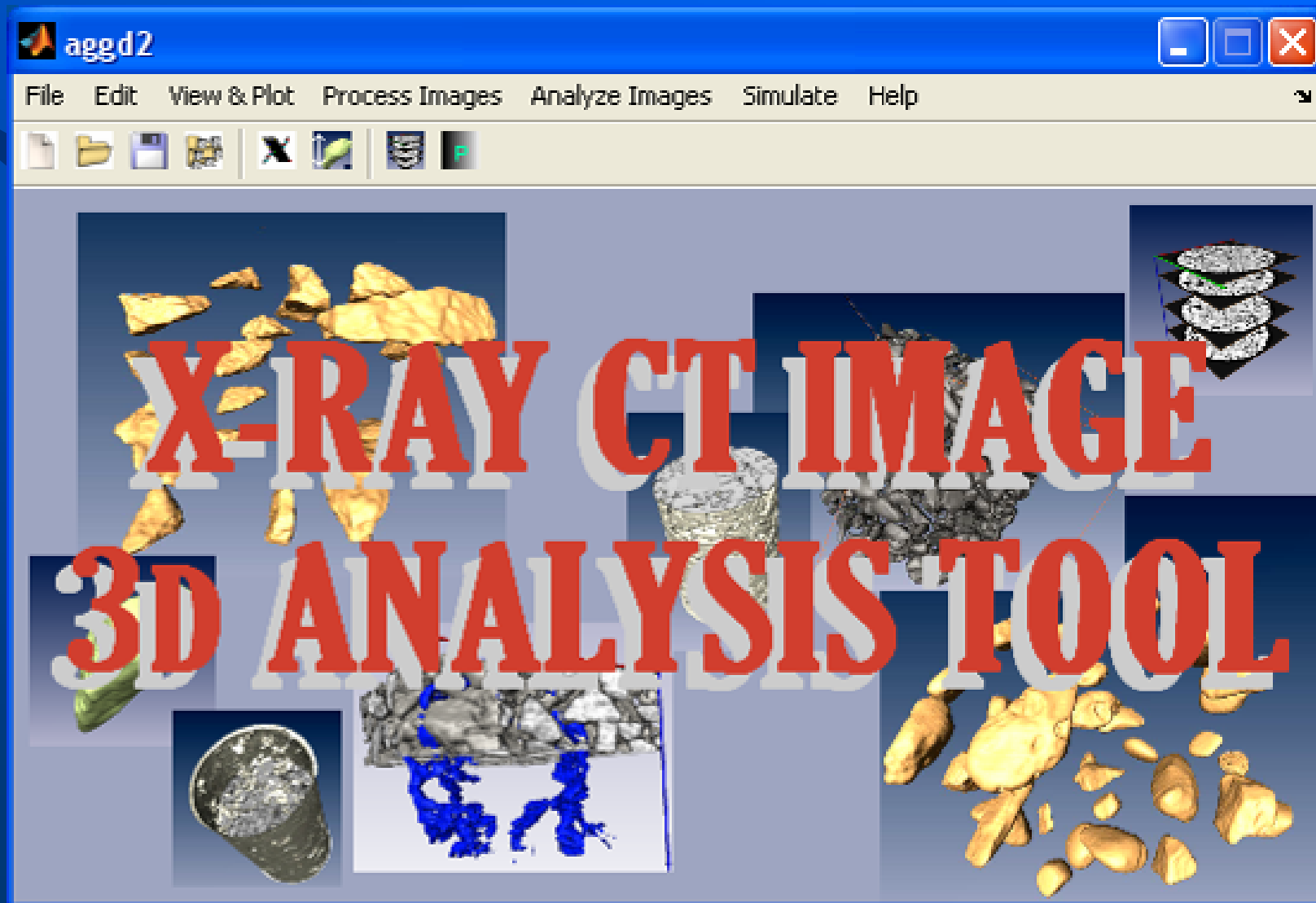
Example calculations



Example calculations

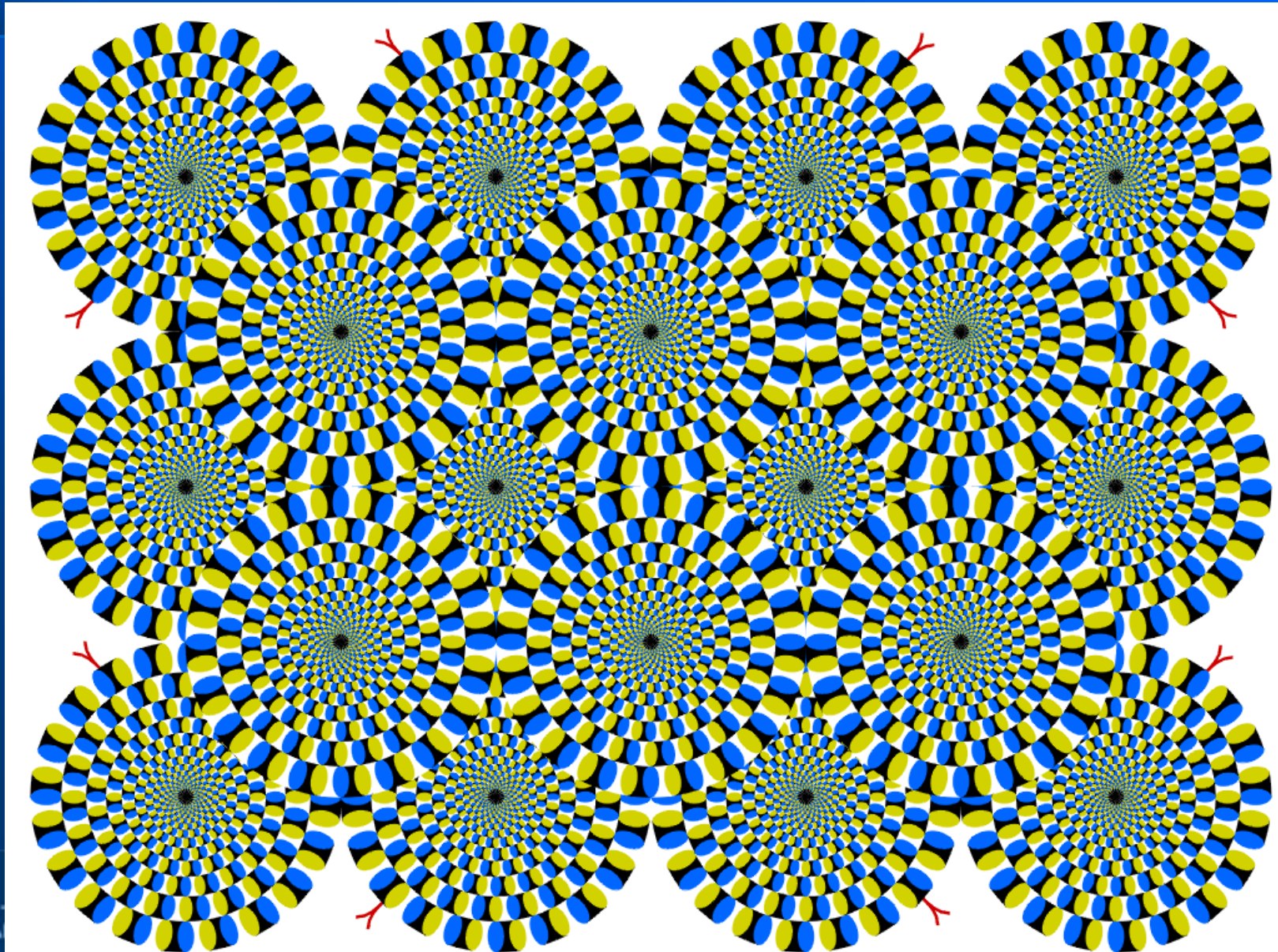


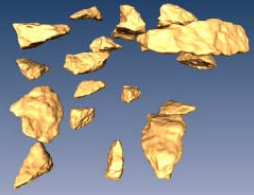
X-ray CT Image 3D Analysis Tool



Thank You!

Try to catch the rotating snake with your eye!





The End

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