Scientific Visualization 101

Image Segmentation and 3D Analysis

KAUST Visualization Core Lab
Ronell Sicat

KAUST
VISUALIZATION
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This workshop is being live-streamed and recorded.

What are you interested in learning today?

- I am interested in learning foundational techniques of **image segmentation** and **3D analysis**
- To create meaningful and accurate **visual representations** of complex datasets, enhancing the ability to communicate findings.
- The basic of using **Avizo**, **measuring** dimensions, and **transform** a Avizo file to a CAD file (if possible)
- Segment CT scans and MRI to obtain real data **3D models**
- How to analyze and segment **biological images**
- How to segment and analyse **pores** space from a **rock**
- Image segmentation using **Deep Learning** and Machine Learning data analysis.

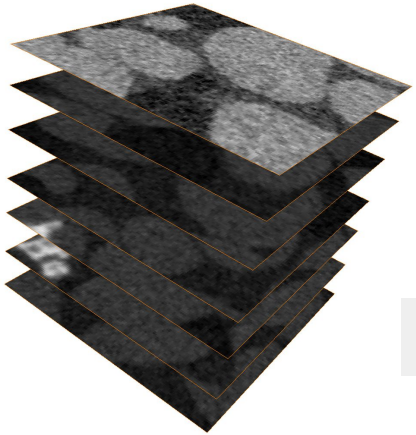
How can I use Avizo to

visualize
process
segment
analyze
transform

my data?

Overview

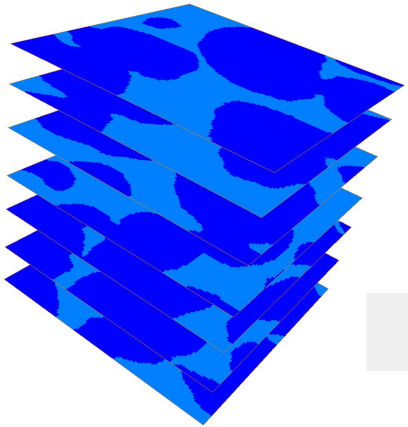
image stack



e.g., 16-bit images
(tiff, png, jpeg)

segmentation

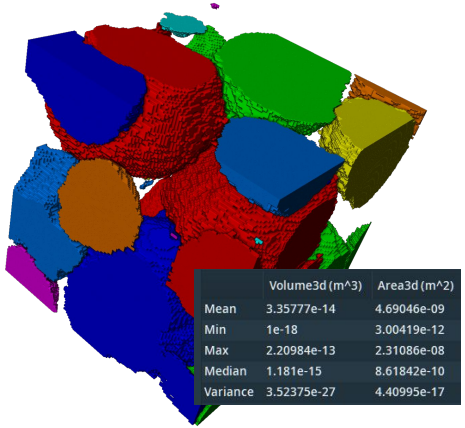
label images



e.g., 8-bit images
(tiff, png)

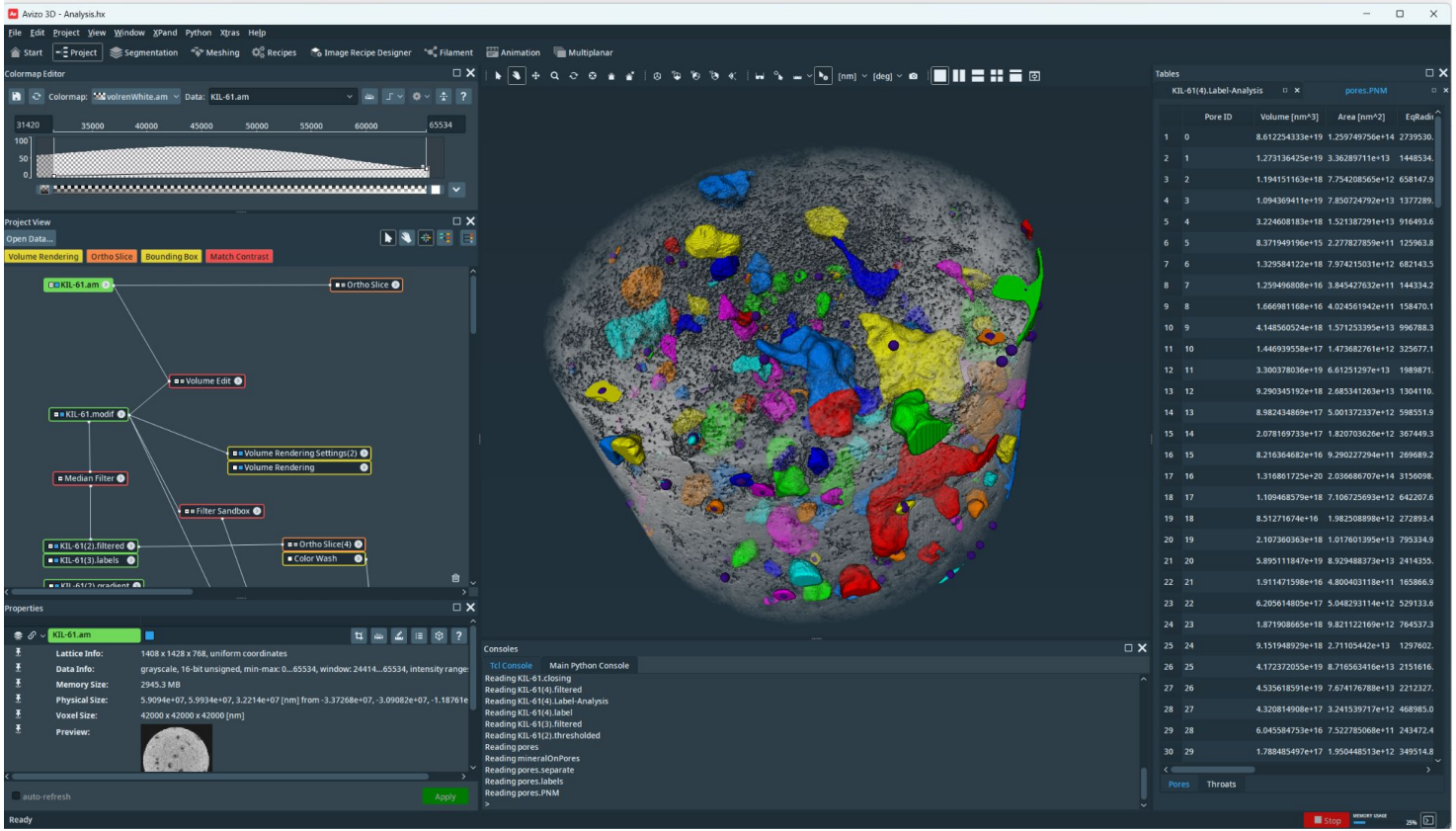
analysis

analysis results



e.g., tabular data
(csv, excel)

Avizo 2024.1


Avizo 3D - Analysis.hx
File Edit Project View Window XPand Python Xtras Help
Start Project Segmentation Meshing Recipes Image Recipe Designer Filament Animation Multiplanar
Colormap Editor
Project View
Open Data...
Volume Rendering Ortho Slice Bounding Box Match Contrast
KIL-61.am
Ortho Slice
Volume Edit
KIL-61.modif
Volume Rendering Settings(2)
Volume Rendering
Median Filter
Filter Sandbox
KIL-61(2).filtered
KIL-61(3).labels
Ortho Slice(4)
Color Wash
Properties
Lattice Info: 1408 x 1428 x 768, uniform coordinates
Data Info: grayscale, 16-bit unsigned, min-max: 0...65534, window: 24414...65534, intensity range:
Memory Size: 2945.3 MB
Physical Size: 5.9094e+07, 5.9934e+07, 3.2214e+07 [nm] from -3.37268e+07, -3.09082e+07, -1.18761e
Voxel Size: 42000 x 42000 x 42000 [nm]
Preview:
auto-refresh
Apply
Ready
Consoles
Tcl Console
Main Python Console
Reading KIL-61.closing
Reading KIL-61(4).filtered
Reading KIL-61(4).Label-Analysis
Reading KIL-61(4).label
Reading KIL-61(3).filtered
Reading KIL-61(2).thresholded
Reading pores
Reading mineralOnPores
Reading pores.separate
Reading pores.labels
Reading pores.PNM
Tables
KIL-61(4).Label-Analysis
pores.PNM
Pore ID Volume [nm^3] Area [nm^2]
1 0 8.612254333e+19 1.259749756e+14 2739530.
2 1 1.273136425e+19 3.36289711e+13 1448534.
3 2 1.194151163e+18 7.754208565e+12 658147.9
4 3 1.094369411e+19 7.850724792e+13 1377289.
5 4 3.224608183e+18 1.521387291e+13 916493.6
6 5 8.371949196e+15 2.277827859e+11 125963.8
7 6 1.329584122e+18 7.974215031e+12 682143.5
8 7 1.259496808e+16 3.845427632e+11 144334.2
9 8 1.666981168e+16 4.024561942e+11 158470.1
10 9 4.148560524e+18 1.571253395e+13 996788.3
11 10 1.446939558e+17 1.473682761e+12 325677.1
12 11 3.300378036e+19 6.61251297e+13 1989871.
13 12 9.290345192e+18 2.685341263e+13 1304110.
14 13 8.982434869e+17 5.001372337e+12 598551.9
15 14 2.078169733e+17 1.820703626e+12 367449.3
16 15 8.216364682e+16 9.290227294e+11 269689.2
17 16 1.316861725e+20 2.036686707e+14 3156098.
18 17 1.109468579e+18 7.106725693e+12 642207.6
19 18 8.51271674e+16 1.982508898e+12 272893.4
20 19 2.107360363e+18 1.017601395e+13 795334.9
21 20 5.895111847e+19 8.929488373e+13 2414355.
22 21 1.911471598e+16 4.800403118e+11 165866.9
23 22 6.205614805e+17 5.048293114e+12 529133.6
24 23 1.871908665e+18 9.821122169e+12 764537.3
25 24 9.151948929e+18 2.71105442e+13 1297602.
26 25 4.172372055e+19 8.716563416e+13 2151616.
27 26 4.535618591e+19 7.674176788e+13 2212327.
28 27 4.320814908e+17 3.241539717e+12 468985.0
29 28 6.045584753e+16 7.522785068e+11 243472.4
30 29 1.788485497e+17 1.950448513e+12 349514.8
Pores
Throats
Stop

KAUST **V**isualization Core **L**ab (KVL) Introduction

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12 CORE LABS

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- DEEP LEARNING

Ronell Sicat

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Scientific Visualization | Large-scale Images and Vo… | Augmented/Virtual Reality | Segmentation

TITLE	CITED BY	YEAR
A novel multi-scale µCT characterization method to quantify biogenic carbonate production V Chandra, R Sicat, F Benzoni, V Vahrenkamp, V Bracchi Geoscience Frontiers 15 (6), 101883		2024
Advancing Membrane Technology: Ordered Macroporous ZIF-67 as a Filler in Mixed Matrix Membranes for Enhanced Propylene/Propane Separation D Poloneeva, SJ Datta, R Sicat, R Khairova, L Garzon-Tovar, A Bavykina, … Small, 2309127	1	2024
Natural variation in salt-induced changes in root: shoot ratio reveals SR3G as a negative regulator of root suberization and salt resilience in Arabidopsis MR Ishka, H Sussman, Y Hu, MD Alqahtani, E Craft, R Sicat, M Wang, … bioRxiv, 2024.04. 09.588564		2024
Multivariate Probabilistic Range Queries for Scalable Interactive 3D Visualization A Ageeli, A Jaspe-Villanueva, R Sicat, F Mannuss, P Rautek, M Hadwiger IEEE Transactions on Visualization and Computer Graphics 29 (1), 646-656	1	2022
Real-Time Visualization of Large-Scale Geological Models With Nonlinear Feature-Preserving Levels of Detail R Sicat, M Ibrahim, A Ageeli, F Mannuss, P Rautek, M Hadwiger IEEE Transactions on Visualization and Computer Graphics 29 (2), 1491-1505	2	2021
Virtual reality framework for editing and exploring medial axis representations of nanometric scale neural structures D Boges, M Agus, R Sicat, PJ Magistretti, M Hadwiger, C Calì Computers & Graphics 91, 12-24	11	2020
Virtual environment for processing medial axis representations of 3D nanoscale reconstructions of brain cellular structures D Boges, C Calì', PJ Magistretti, M Hadwiger, R Sicat, M Agus Proceedings of the 25th ACM Symposium on Virtual Reality Software and …	2	2019
Immersive environment for creating, proofreading, and exploring skeletons of nanometric scale neural structures D Boges, C Cali, PJ Magistretti, M Hadwiger, RB Sicat, M Agus Eurographics Association	3	2019
DXR: A toolkit for building immersive data visualizations R Sicat, J Li, J Choi, M Cordeil, WK Jeong, B Bach, H Pfister IEEE transactions on visualization and computer graphics 25 (1), 715-725	201	2018
Drawing into the AR-CANVAS: Designing embedded visualizations for augmented reality B Bach, R Sicat, H Pfister, A Quigley Workshop on Immersive Analytics, IEEE Vis 4	51	2017
The hologram in my hand: How effective is interactive exploration of 3D visualizations in immersive tangible augmented reality? B Bach, R Sicat, J Beyer, M Cordeil, H Pfister IEEE transactions on visualization and computer graphics 24 (1), 457-467	270	2017
Comparative Visual Analysis of Structure-Performance Relations in Complex Bulk-Heterojunction Morphologies A Aboulhassan, R Sicat, D Baum, O Wodo, M Hadwiger Computer Graphics Forum 36 (3), 329-339	7	2017
Large-Scale Multi-Resolution Representations for Accurate Interactive Image and Volume Operations RB Sicat		2015
Sparse PDF Volumes for Consistent Multi-Resolution Volume Rendering R Sicat, J Krueger, T Moeller, M Hadwiger IEEE	39	2014

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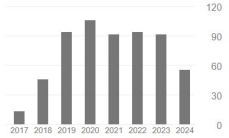

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Co-authors — EDIT

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Professor of Computer Science, …

RESEARCH ARTICLE

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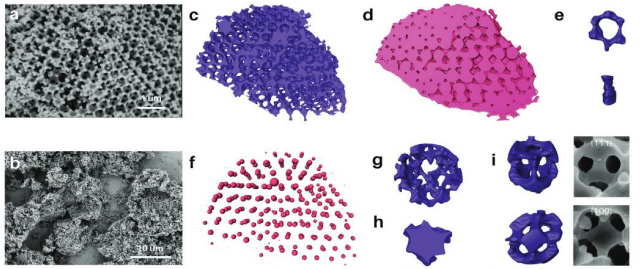
Advancing Membrane Technology: Ordered Macroporous ZIF-67 as a Filler in Mixed Matrix Membranes for Enhanced Propylene/Propane Separation

Daria Poloneeva, Shuvo Jit Datta, Ronell Sicat, Rushana Khairova, Luis Garzon-Tovar, Anastasiya Bavykina, Mohamed Eddaoudi, and Jorge Gascon**



OM-ZIF-67 particles at low magnification. c) Surface-rendered olume. e) Surface-rendered parts of OM-ZIF-67: pore aperture ts of OM-ZIF-67 particle: g) missing pillar and h) missing pore. ding SEM images.

ntages of this type of membrane, e.g. modification of a [1] to make it more similar to a polymer to increase the affin- face functionalization to improve compatibility,[4] and par- orphology modification, such nanoparticles[5] 2D sheets,[6] particles,[7] etc.

additional challenge, the lack of processability in the man- e of these composite membranes, was recently overcome cessing MOFs through a porous liquid (PL) state.[8] We

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Contents lists available at ScienceDirect

Geoscience Frontiers

journal homepage: www.elsevier.com/locate/gsf

Research Paper

A novel multi-scale µCT characterization method to quantify biogenic carbonate production

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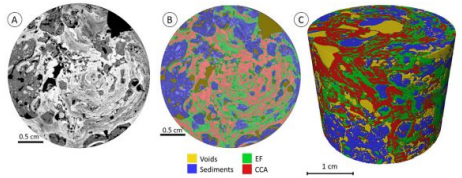
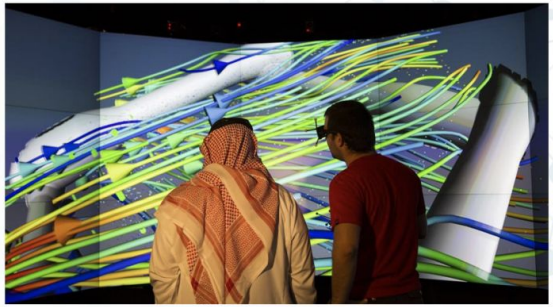
Foraminifera
µCT



RCT greyscale cross-section (A) and its corresponding labelled image (B) segmented into voids, sediments, EF and CCA. (C) of voids, sediments, EF and CCA from the ground-truth segmentation method applied to the sub-volume HRCT image of the

KVL offers state-of-the-art **visualization facilities**

ZONE 1/2 DISPLAY WALLS: 2D/3D Analytics



CUBES VR

ZONE 5 VR

AR/VR HMDs

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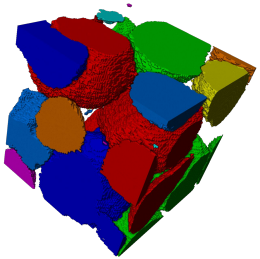
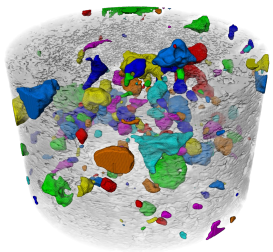
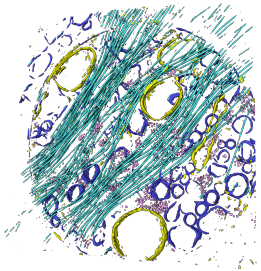
Schedule

- 10 mins: Overview
- 20 mins: Introduction to Avizo
- 10 mins: **Break**
- 40 mins: Basic Segmentation and Analysis
- 10 mins: **Break**
- 30 mins: Advanced Segmentation and Analysis

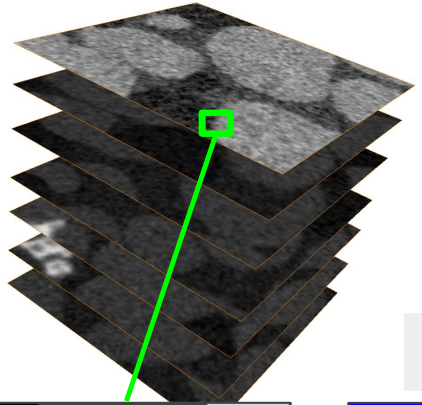


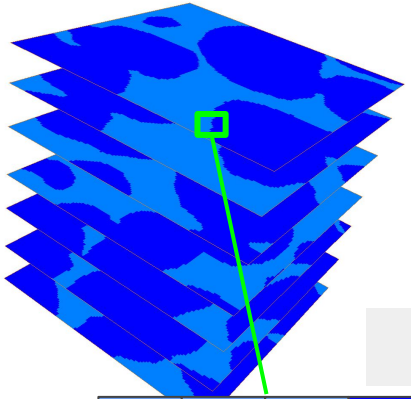
Introduction to Avizo

Important concepts

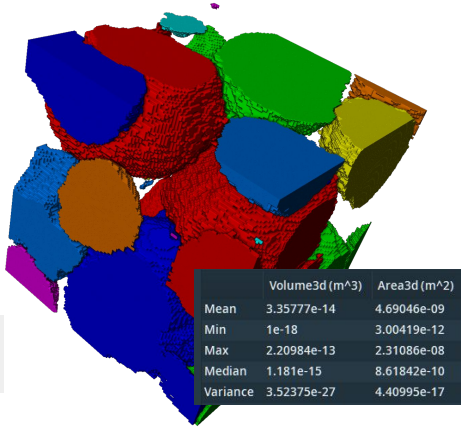
image stack



label images

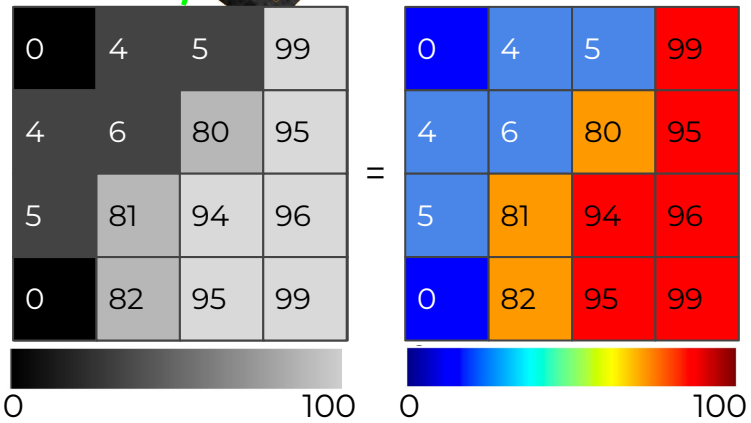


analysis results



segmentation

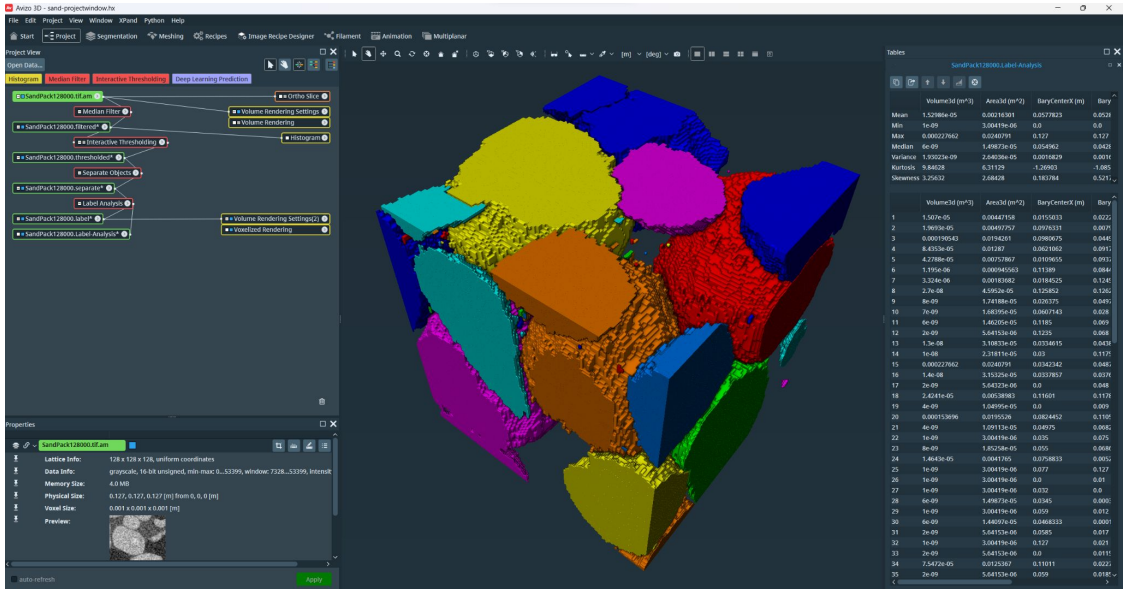
analysis



	air	sand
count	7	9
fraction	0.44	0.56

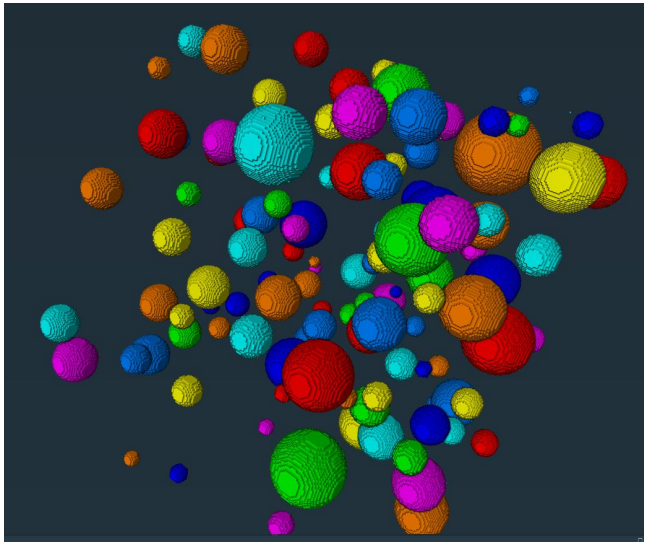
Demo: Sand - Avizo Basics on Project Window

- Orthoslice
- Volume Rendering
- Interactive Thresholding
- Filter Sandbox
- Median Filter
- Voxelized Rendering
- Separate Objects
- Label Analysis
- Export Table
- Screenshots
- Animations

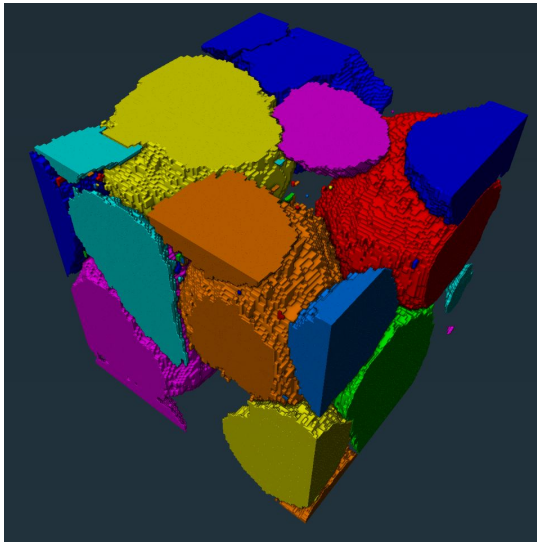


Try it out!

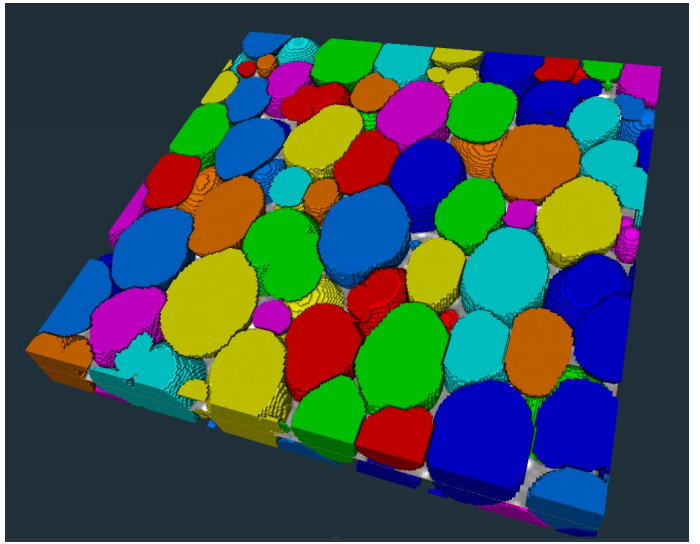
Hint: filter sandbox, median filter, interactive thresholding, separate objects, label analysis



easy - pheres



intermediate - sand



advanced - foam

10-minute Break

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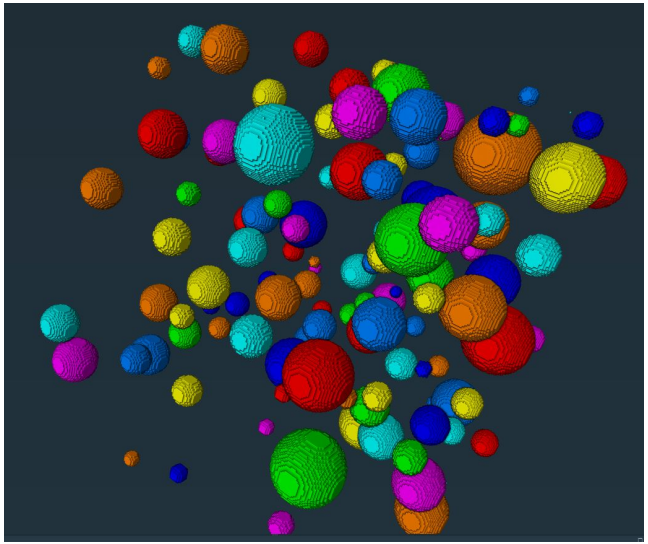
Data Download

https://wiki.vis.kaust.edu.sa/training/scivis/2024/segmentationintro

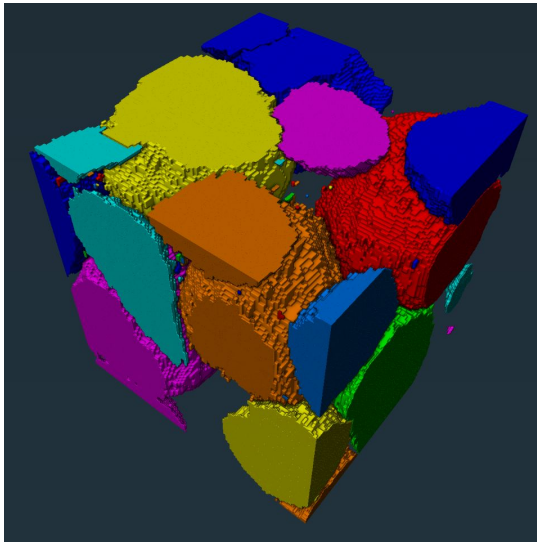
Basic Segmentation and Analysis

Try it out!

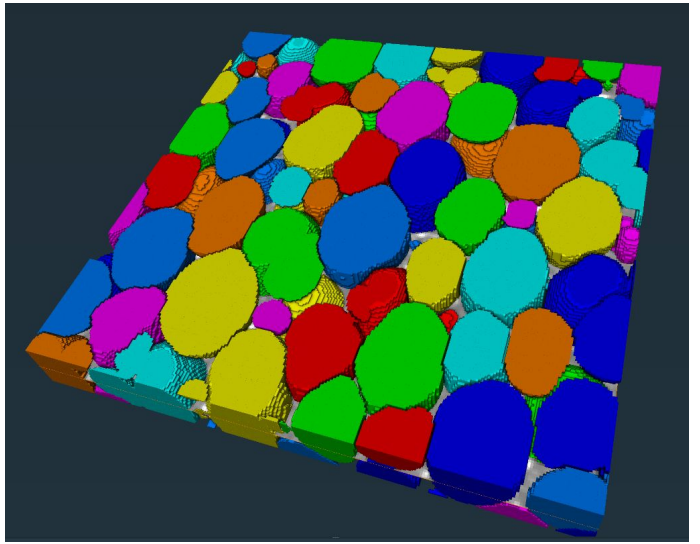
Hint: filter sandbox, median filter, interactive thresholding, separate objects, label analysis



easy - pheres

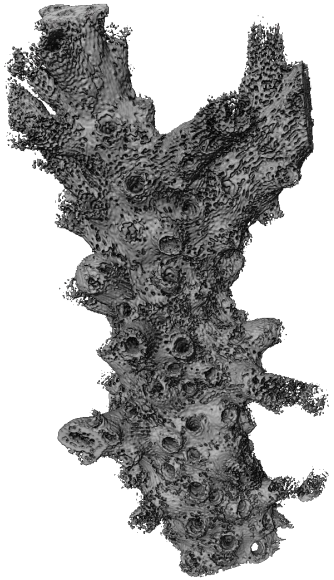


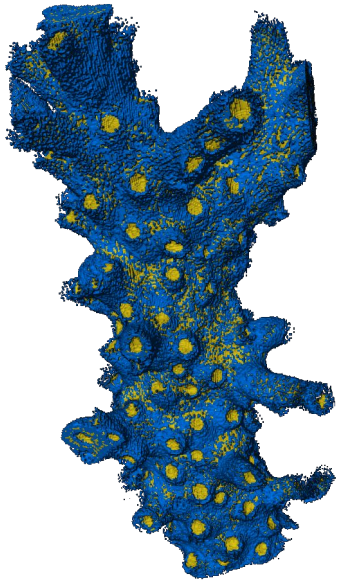
intermediate - sand

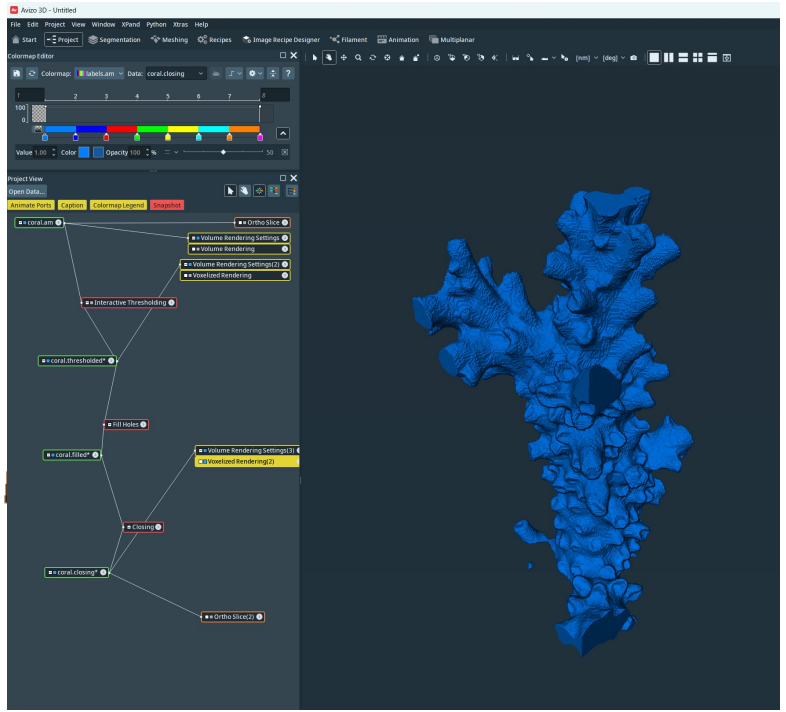


advanced - foam

Hands-on: CT of Coral (measure, surface area, conversion to 3D model)

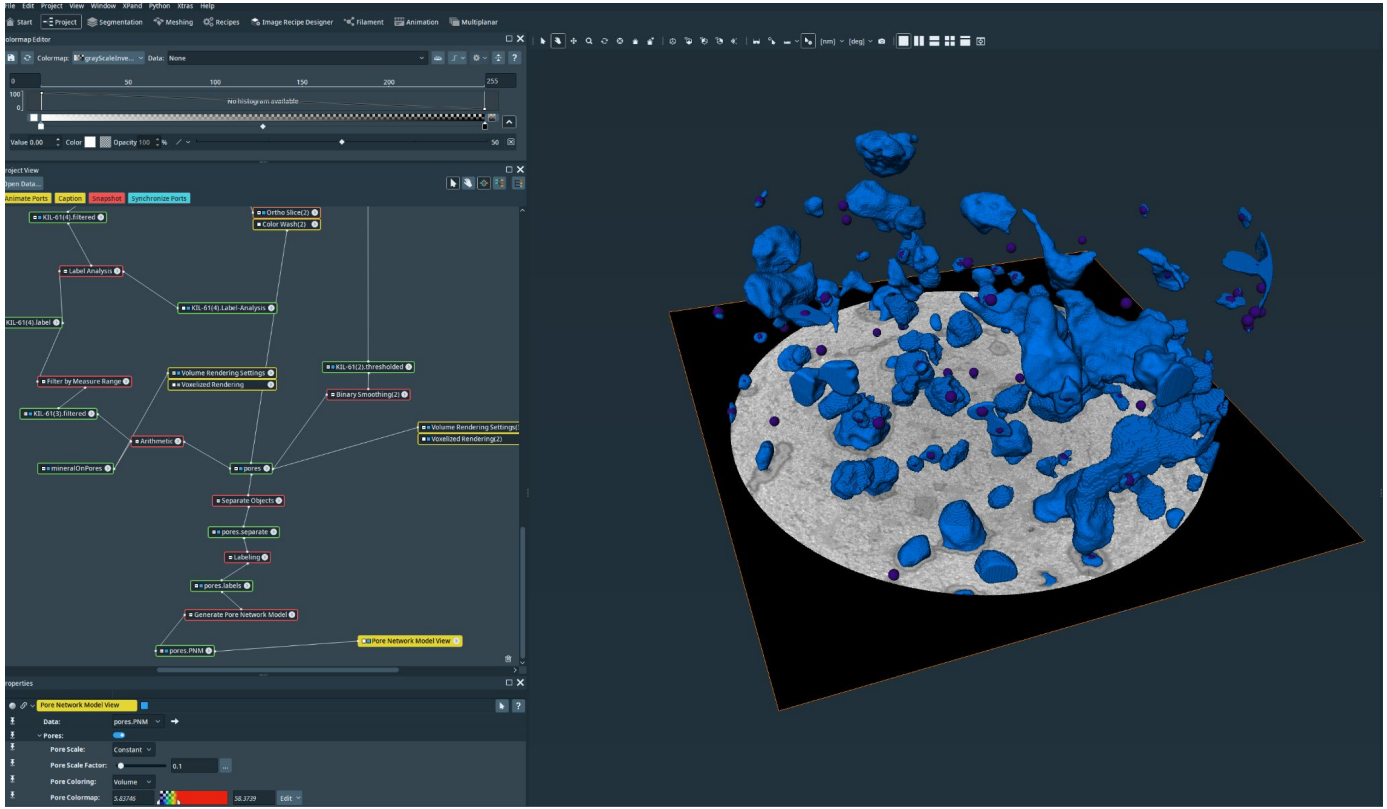




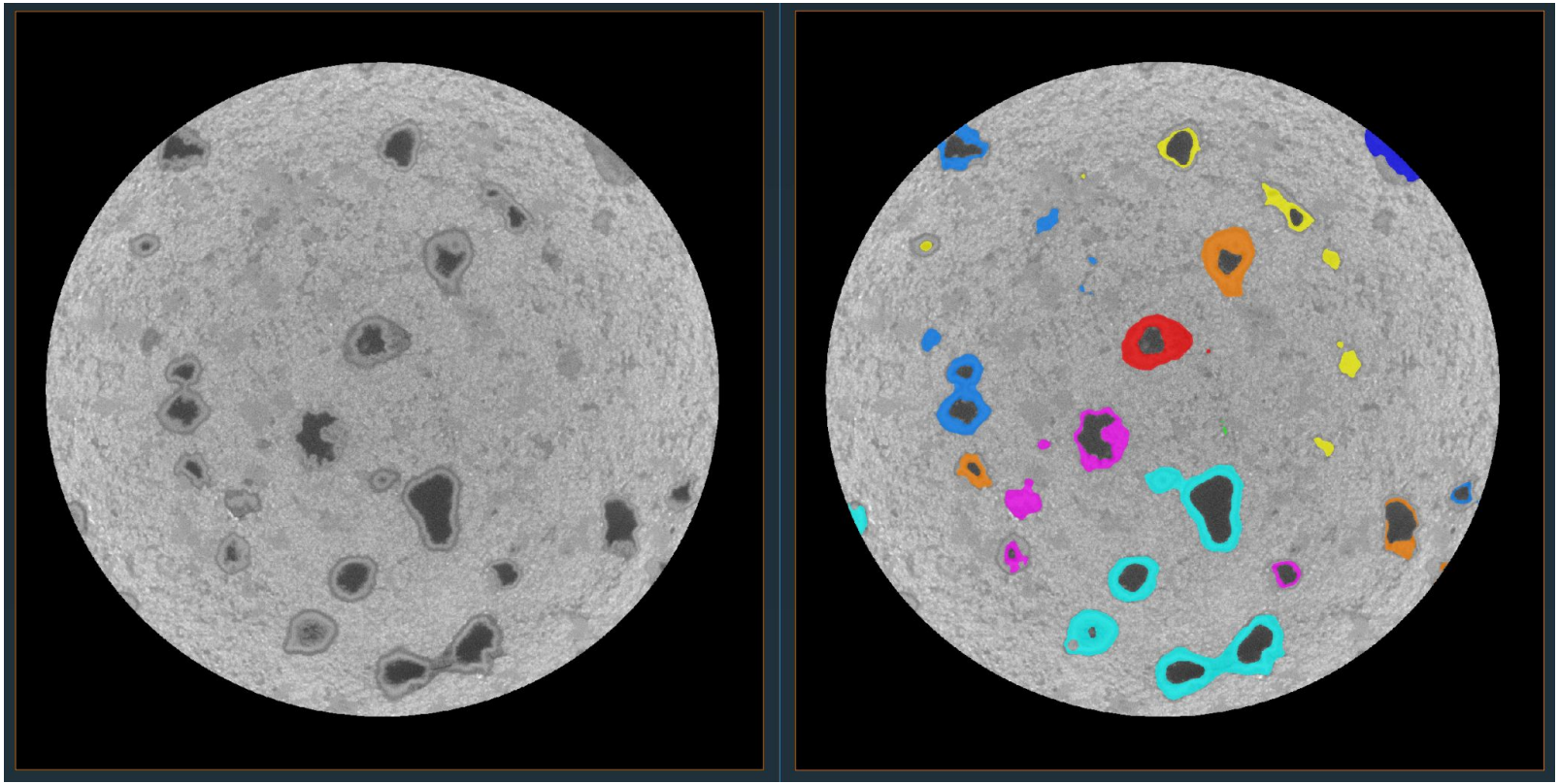


data c/o Eleonora Re and Domingo Sanchez

Hands-on: CT of **basalt** core (pore network analysis)



Hands-on: CT of **basalt** core (pore reduction)



10-minute Break

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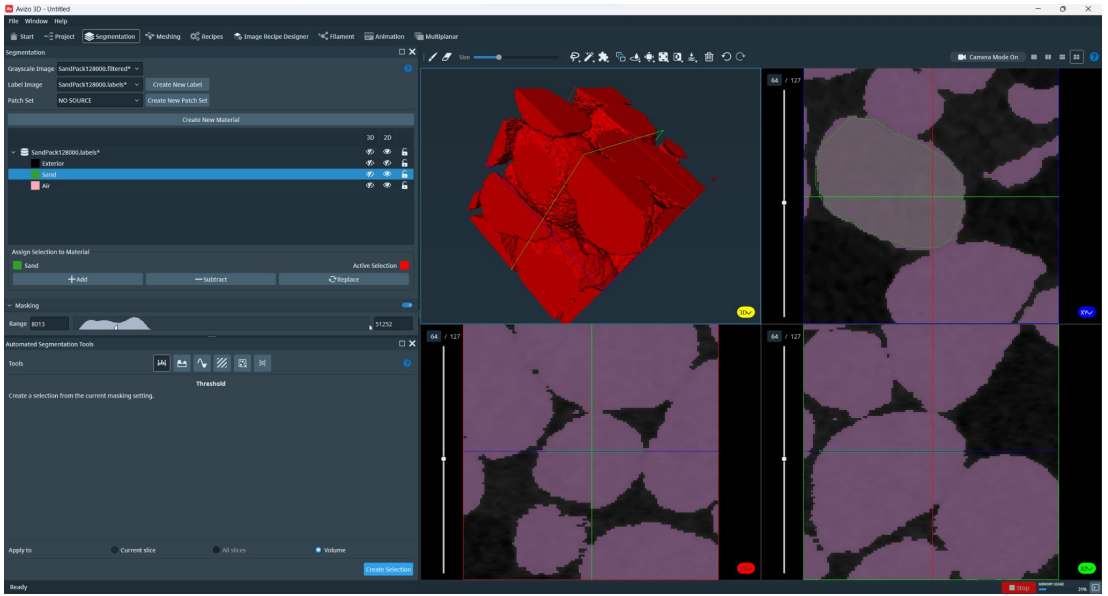
KVL wiki

Advanced Segmentation and Analysis

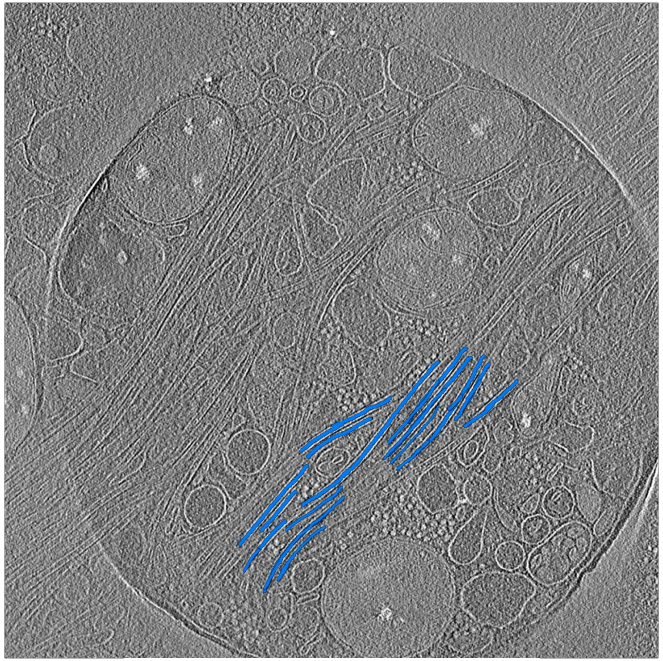
Demo: Sand - Segmentation Workroom

- Set input data (filtered)
- Create new label
- Create new materials
- Create and add selections to material:
  - Using brush
  - Using threshold tool

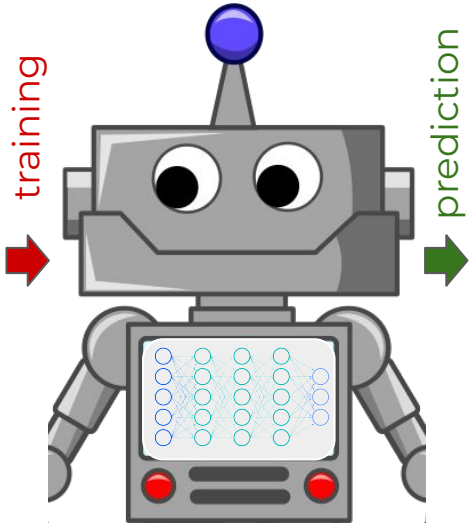


Important AI concepts

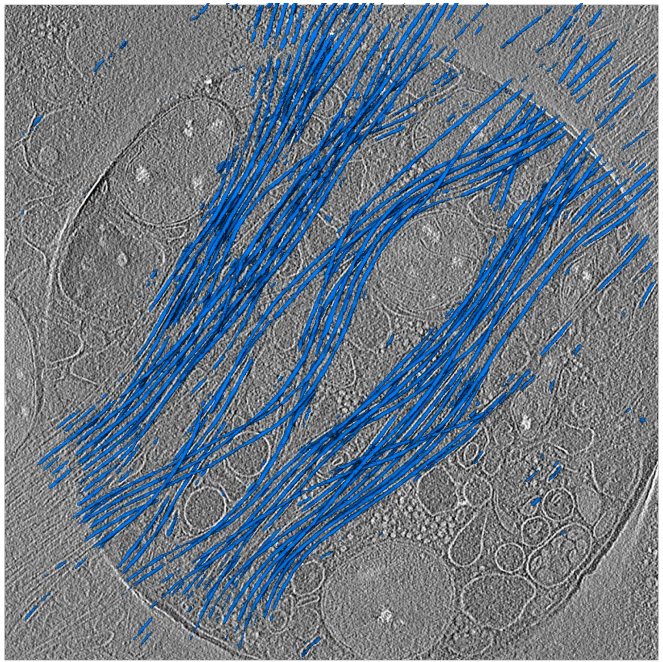
We can use **deep learning models** for segmentation.



human segmentation



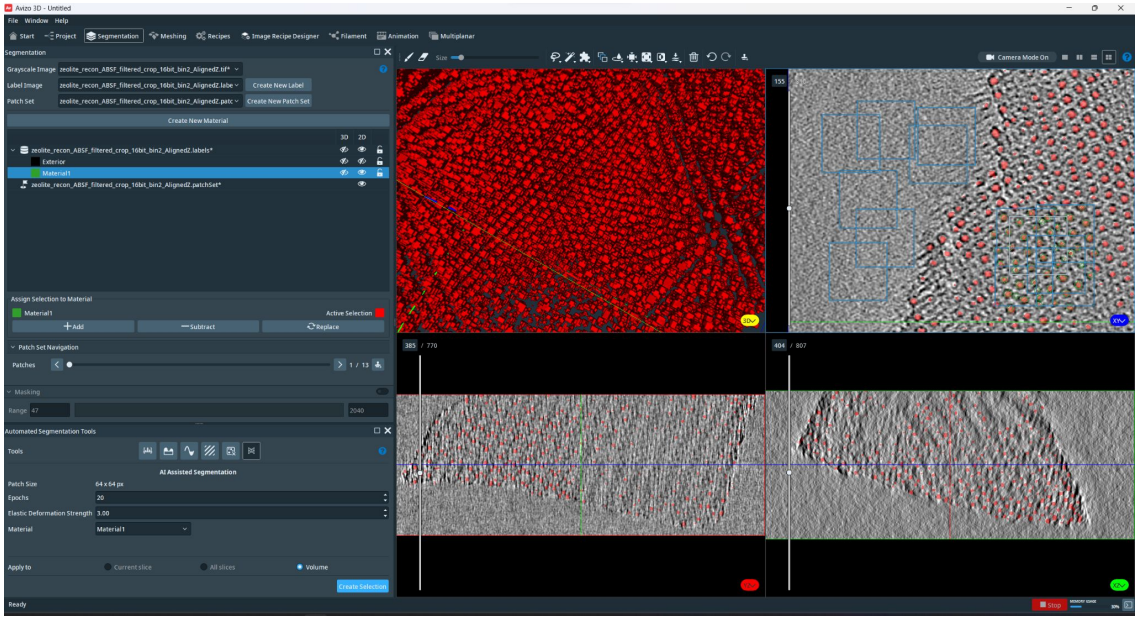
deep learning model
(AI)



AI segmentation

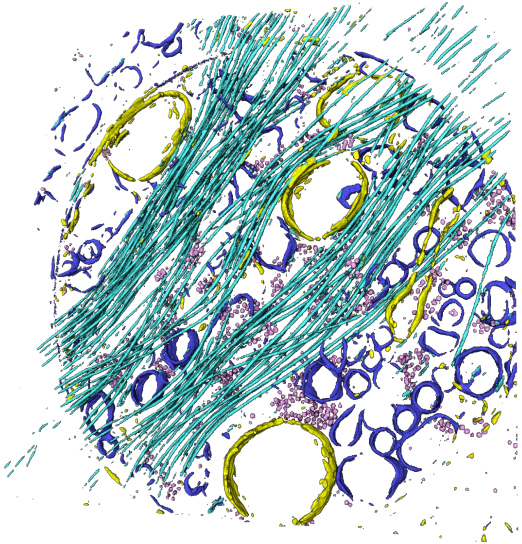
Demo: Zeolite - Segmentation Workroom

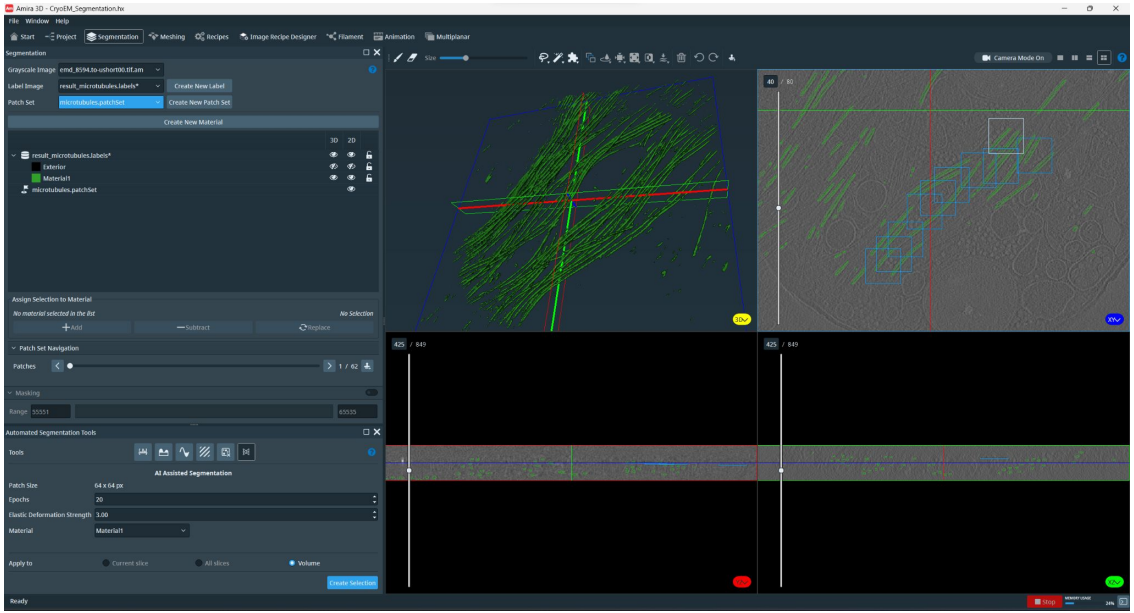
- Set input data
- Create new label
- Create new materials
- Add selections to material using brush
- Create new patch set
- Add patches for fore/background
- Create/add selection using AI tool
- Tweak parameters and iterate



data c/o Georgian Melinte ([Parsapur et. al, 2023](#))

Hands-on: CryoEM - Segmentation Workroom





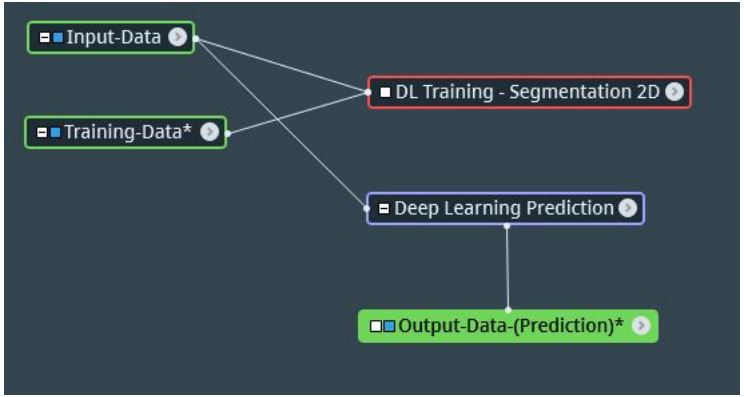
See CryoEM folder in datasets. Input data is CryoEM/CryoEM_Segmentation-files/emd_8594.to-ushort00.tif.

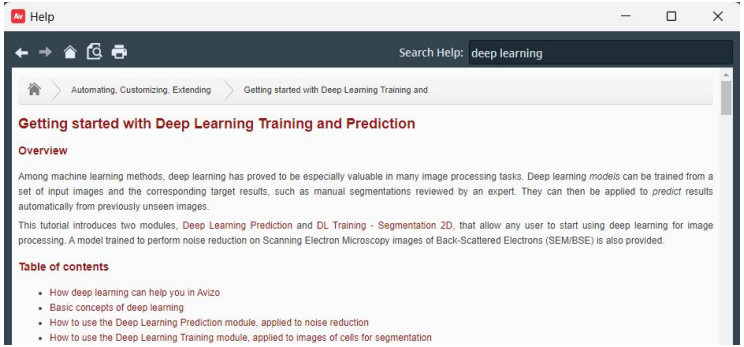
https://xtras.amira-avizo.com/xtras/ai-assisted-tool-for-cryoem-segmentation

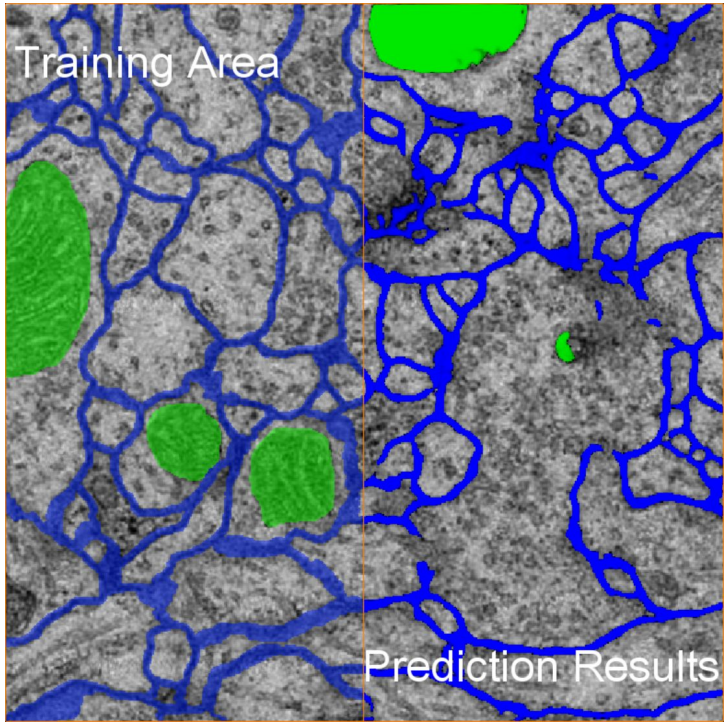
Workflow recommendation

- Inspect data (orthoslice, volume rendering, histogram)
- Filter data to denoise or improve features:
  - Median filter, Bilateral filter, Non-local means filter, Unsharp Masking
- Try simple segmentation tools in Avizo:
  - Thresholding, Watershed, Texture Classification
- Try AI segmentation in Avizo
- Try AI segmentation in ilastik
- Try Pixel Classification in ilastik
- Try Deep Learning Training/Prediction in Avizo
- Try other tools
- Worst case: manual segmentation
- Not sure? Contact **help@vis.kaust.edu.sa**.

Deep Learning Training/Prediction in Avizo



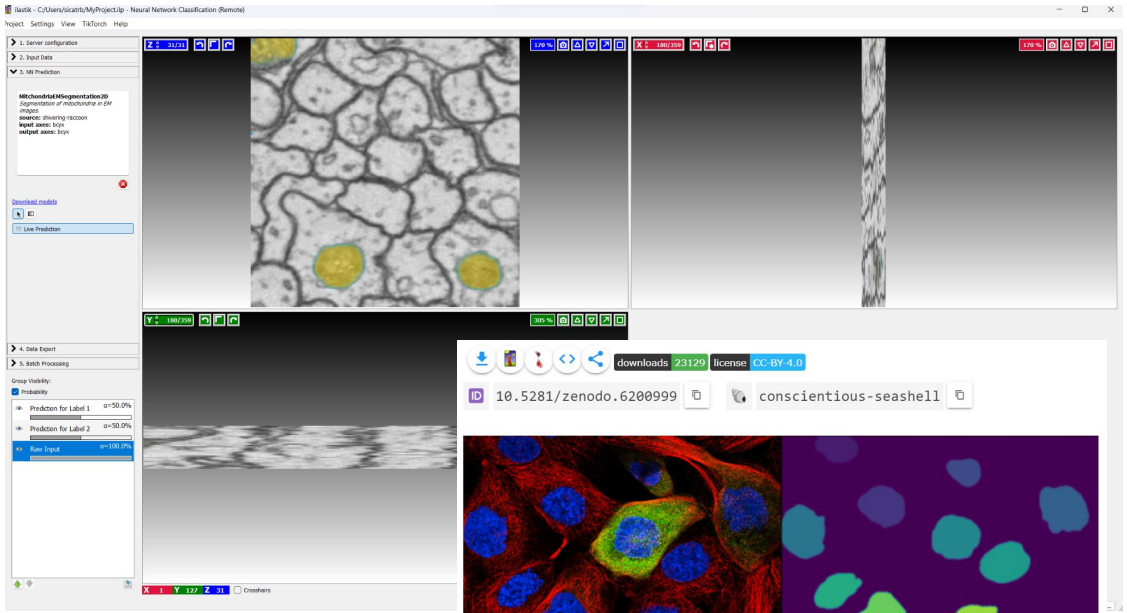




https://xtras.amira-avizo.com/xtras/getting-started-with-deep-learning-training

Other segmentation tools

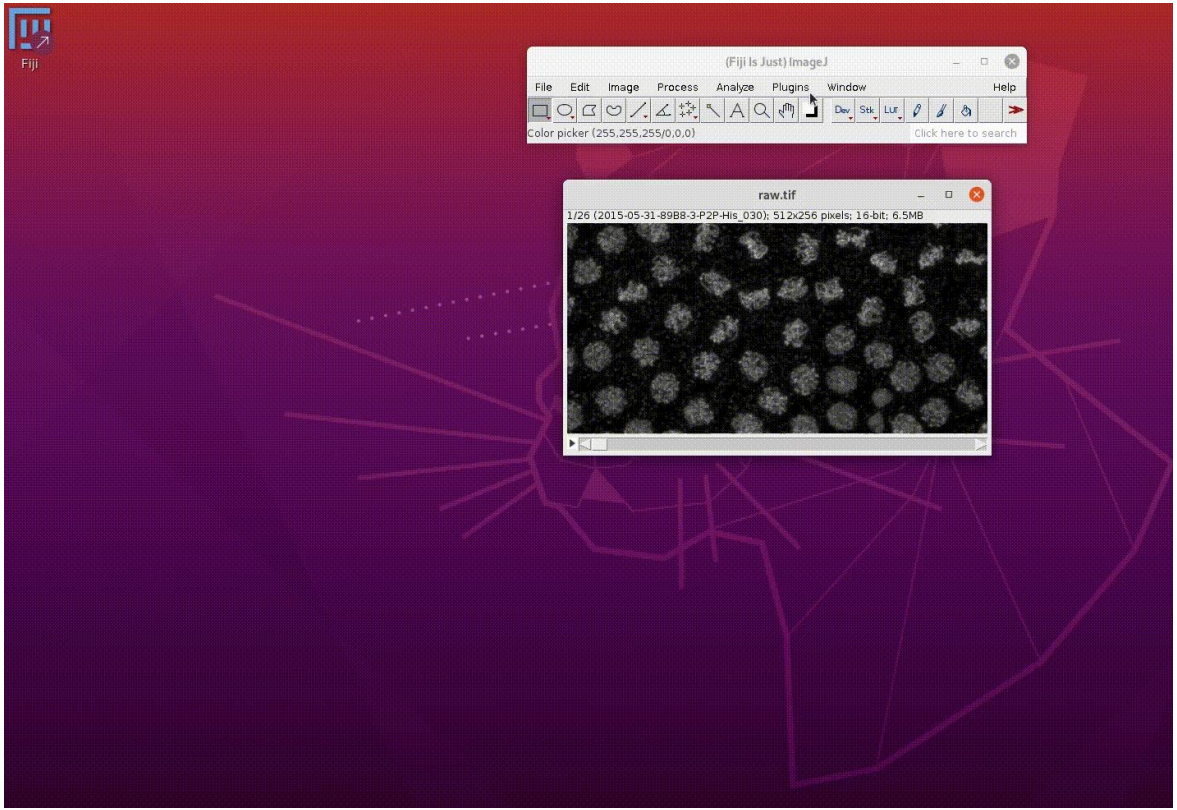
- **ilastik**
- Fiji
- Matlab
- OpenCV
- TensorFlow
- PyTorch



Contributors: Hao Xu Wei Ouyang

Other segmentation tools

- ilastik
- **Fiji**
- Matlab
- OpenCV
- TensorFlow
- PyTorch



Manual segmentation

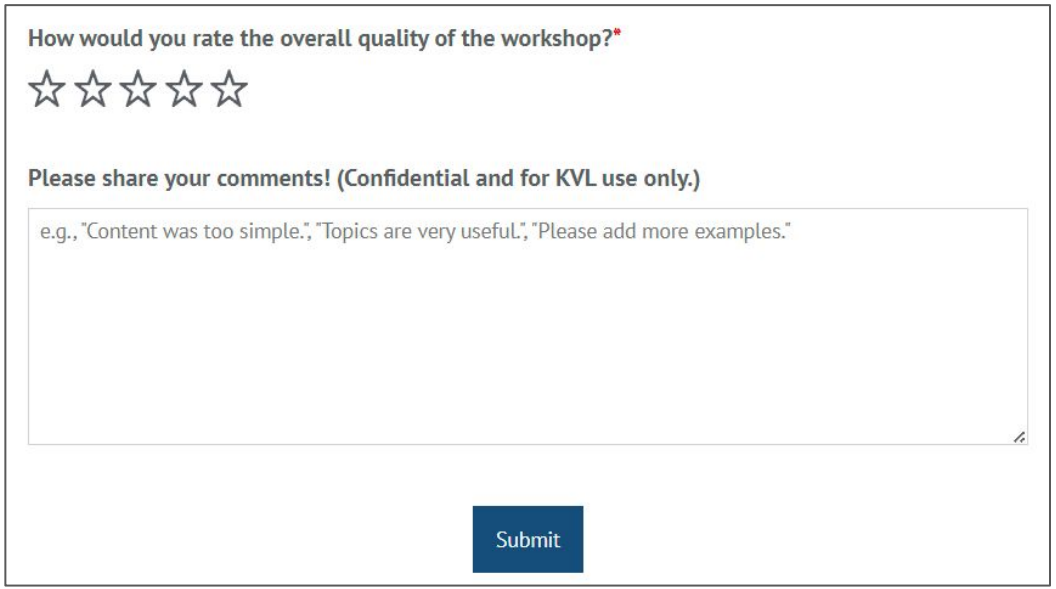
Book “Vive” facility at https://wiki.vis.kaust.edu.sa/booking.

Thank you!

wiki.vis.kaust.edu.sa

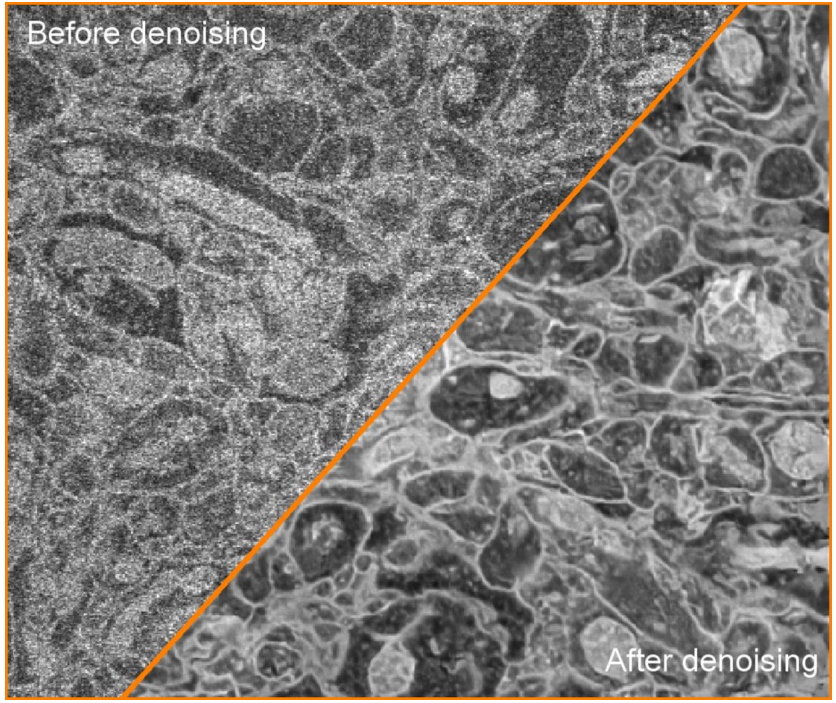
help@vis.kaust.edu.sa

feedback form

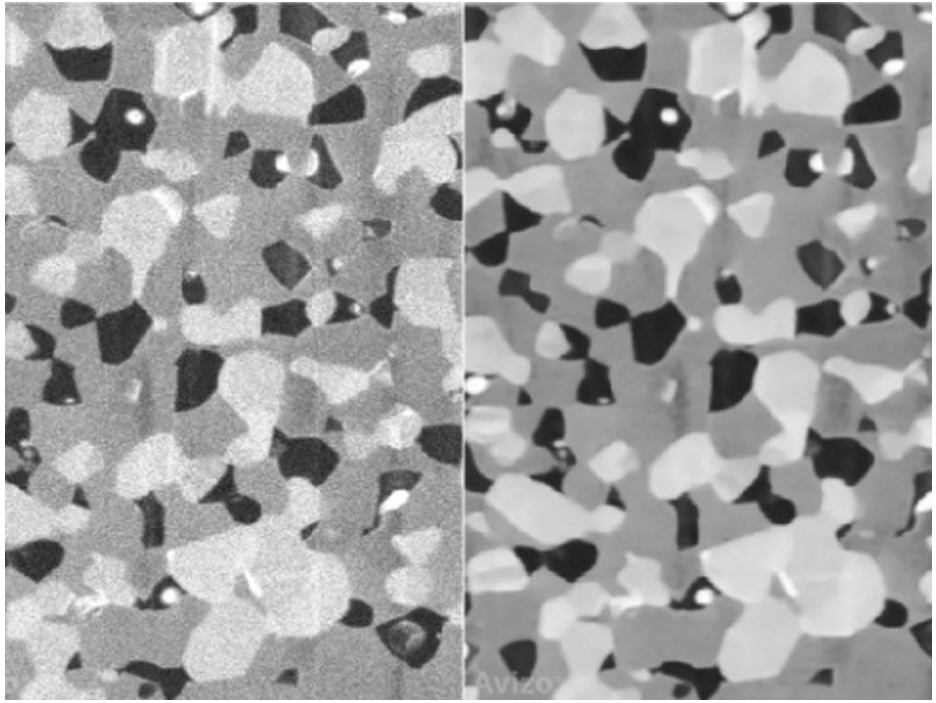


End

Denoising using Deep Learning



https://xtras.amira-avizo.com/xtras/bse-sem-denoiser



Noise to Void