

Visualization of high-dimensional scientific images for annotation tools

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Introduction

- ▶ **Motivation/Challenges:**

- ▶ Multi-dimensional imaging captures complex data beyond human perception.
- ▶ Task-specific approaches ensure relevant information is emphasized.

- ▶ **Common Requirement:**

- ▶ Annotate multi-dimensional data based on human perception
- ▶ Make visualization compatible with existing annotation tools (e.g., Computer Vision Annotation Tool (CVAT)).

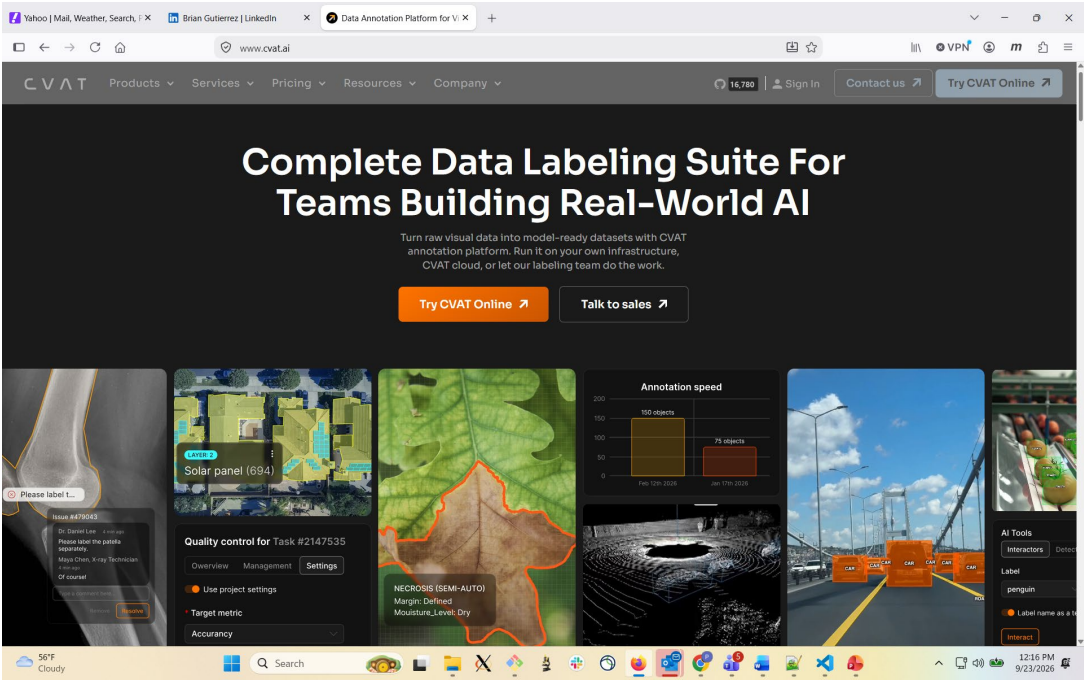
- ▶ **Problem Statements:**

- ▶ Create multiple visual representations of multi-dimensional images for human visual consumption.
- ▶ Design evaluation metrics for selecting the optimal representation given a task.

Examples of Existing Annotation Tools: Computer Vision Annotation Tool (CVAT)

<https://www.cvat.ai/>

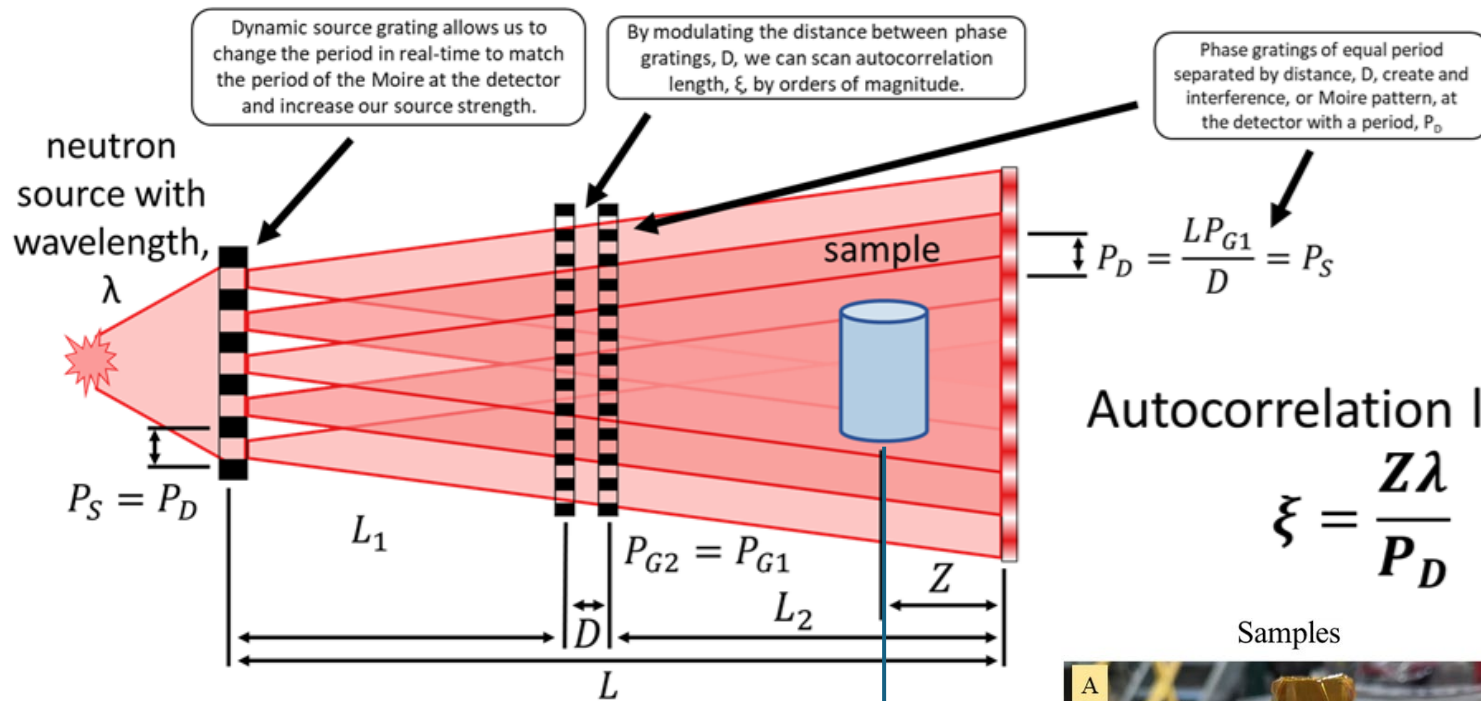
Tool	Primary Use Case	Format Support	Installation
CVAT	Video & Complex Images	COCO, YOLO, TFRecord	Docker / Cloud
Label Studio	Multi-modal (Img/Txt/Aud)	JSON, CSV, COCO	Python / Docker
LabelImg	Bounding Boxes	YOLO, PascalVOC	Local (Python)
Labelme	Polygons/Masks	JSON	Local (Python)
VIA	Quick sketches	JSON, CSV	Browser (No install)



Annotations to Create Ground Truth Image Segments

Interferometry: INFER - Neutron Interferometric Microscopy of Small Forces and Hierarchical Structures

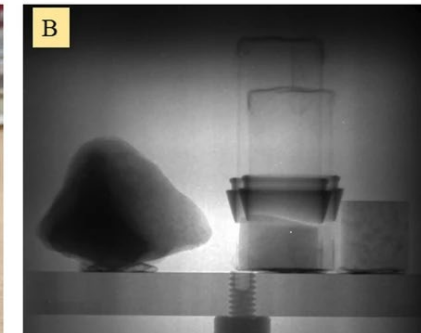
[Project webpage](#)



Samples



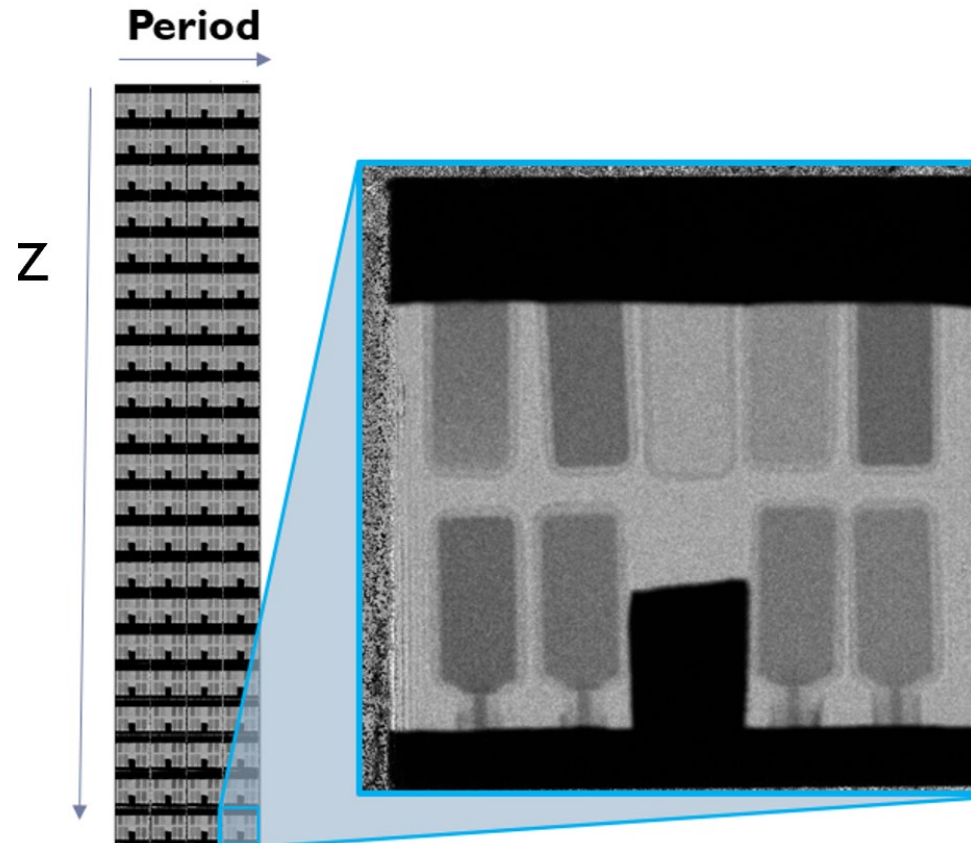
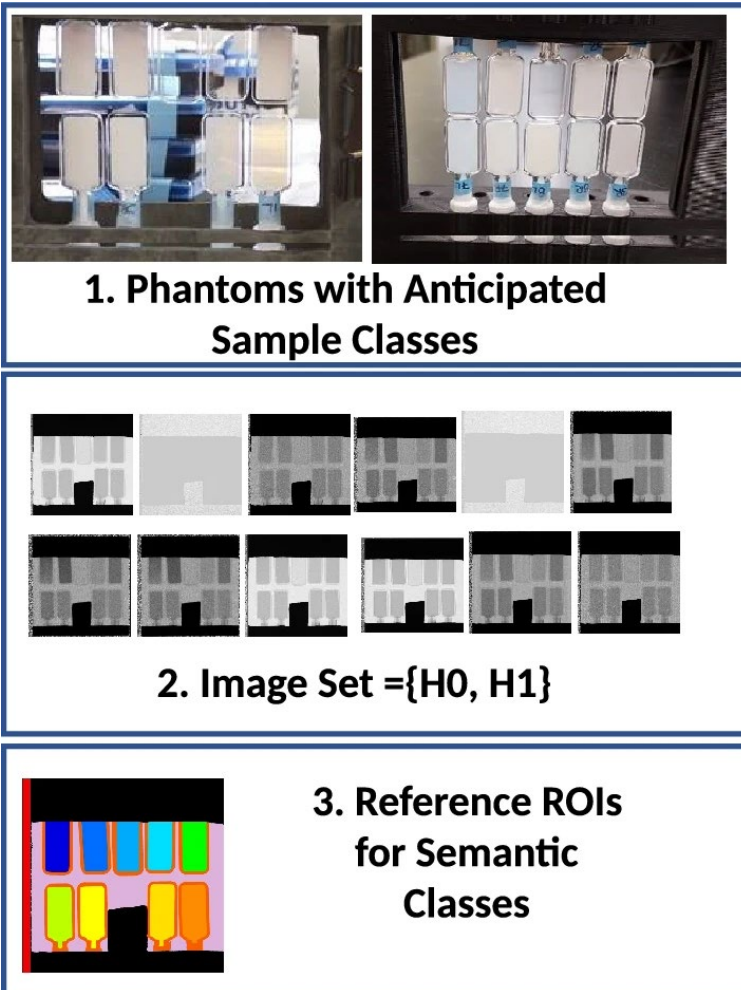
Image Acquisition



One image for each configuration of Z , λ , and P_D

Specific Dataset: Overview

INFER Neutron Imaging



Data Dimensions:
Spatial (x, y), Z, Period P_D
= (1942, 1942, 21, 4)

Specific Dataset: Access

General Task: Visualize high-dimensional images for manual segmentation tasks where the segments are defined by the homogeneity of high-dimensional attributes.

Access to data downloads: [Data dissemination webpage](#)

(1) Measured Intensities for 84 autocorrelation values: A sample with polystyrene (PS) beads with varying radii in Deuterium Oxide suspensions acquired at ORNL HFIR)

[tar.gz file download \(1.5 GB\)](#)

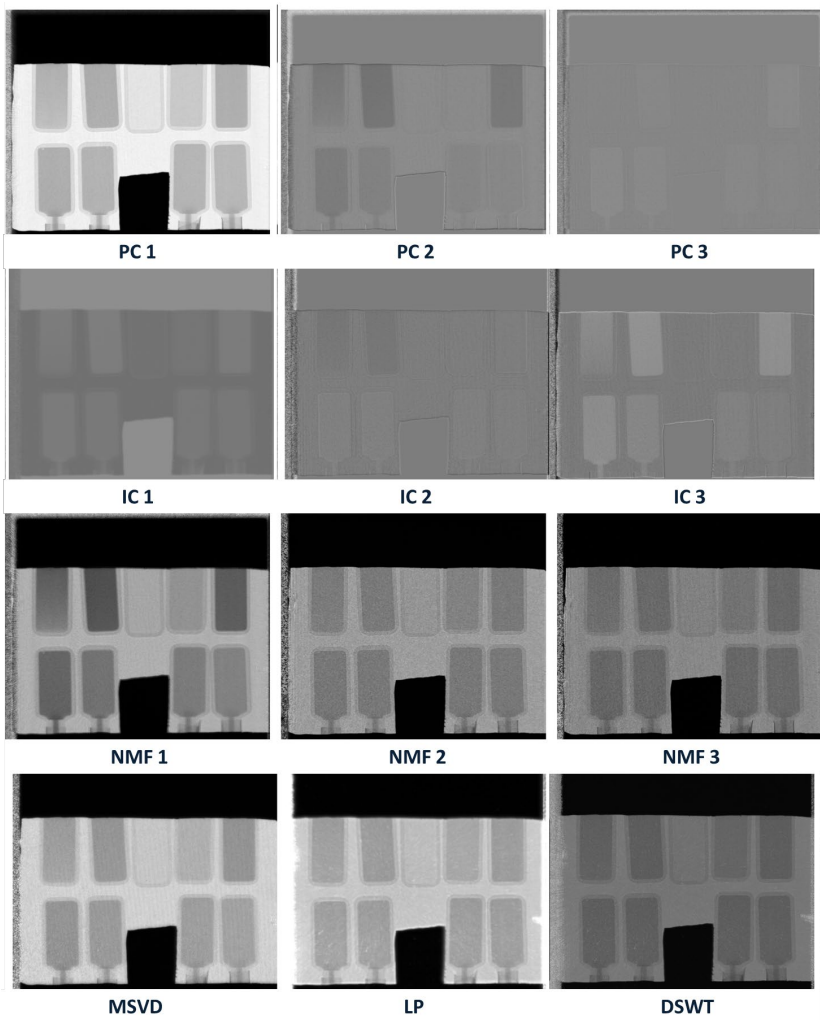
(2) Manual Mask: 1 manually annotated mask with pixel-level annotations of 13 classes for the PS dataset (1)

[tar.gz file download \(52 KB\)](#)

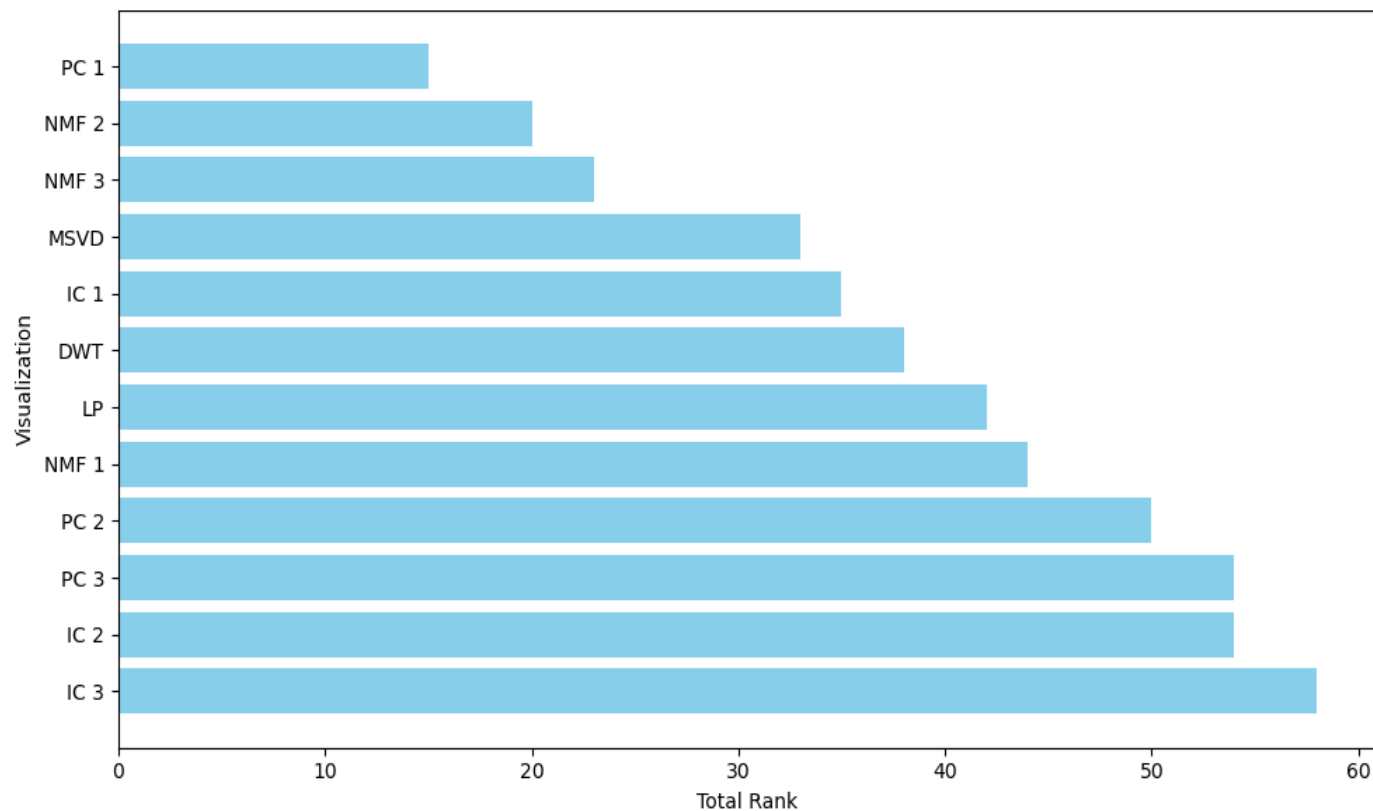
Projections to Lower-Dimensions

METHOD	DESCRIPTION
PCA (Principal Component Analysis)	Decomposes the images into orthogonal components, each representing a direction of maximum variance.
ICA (Independent Component Analysis)	Extracts statistically independent components from the images.
NMF (Non-negative Matrix Factorization)	Factorizes the images into parts-based components.
MSVD (Multiscale Singular Value Decomposition)	Decomposes the images into singular vectors across multiple scales.
LP (Laplacian Pyramid)	Decomposes images into multi-level pyramids, separating high-frequency (details) and low-frequency (structures) components.
DWT (Discrete Wavelet Transform)	Decomposes images into wavelet sub-bands, representing different frequency components.

Examples of Projections



**Rank Analysis of Visualizations
(Lower is Better)**



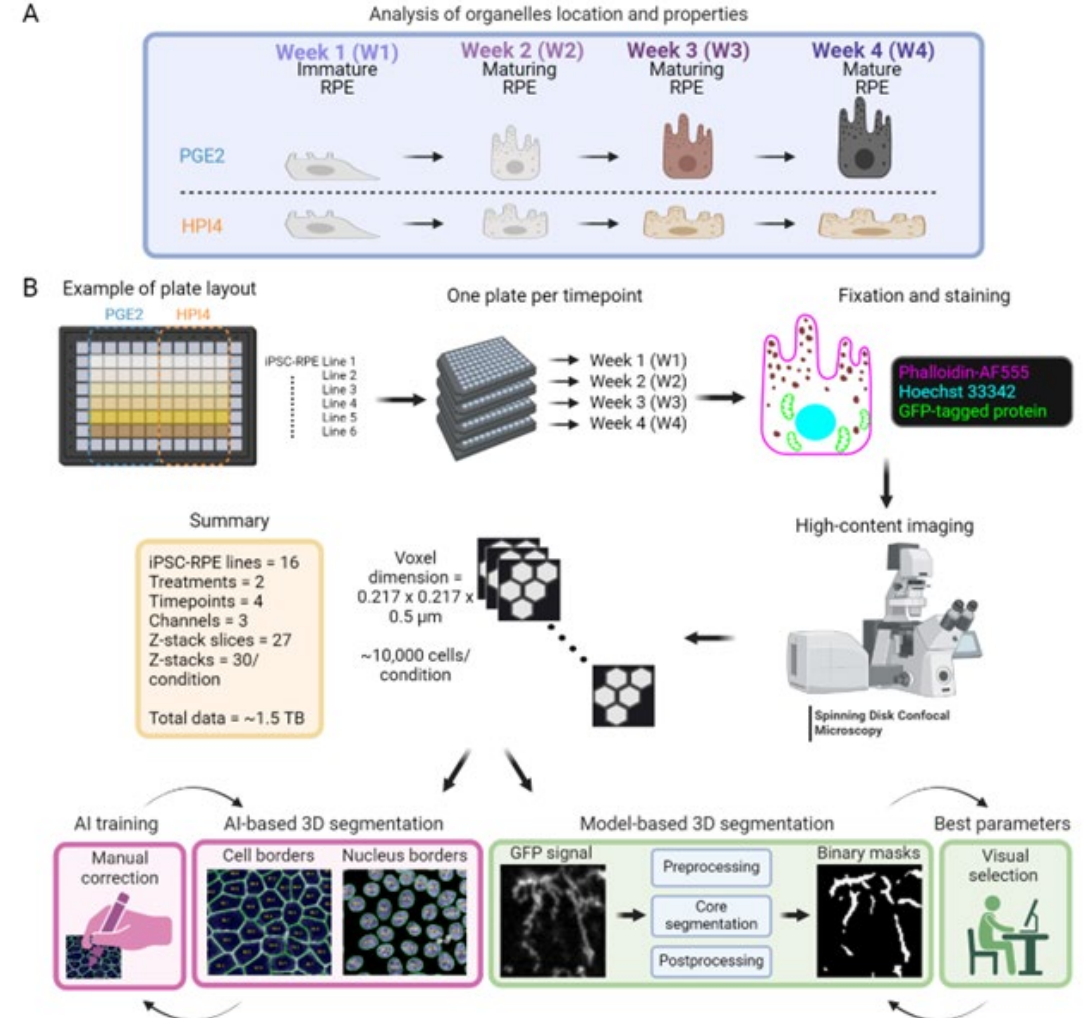
Annotations to Create Ground Truth Clusters

Quantify 3D Characteristics of Human Retinal Pigment Epithelium

A 3D Subcellular Map of Human Retinal Pigment Epithelium Using Quantitative Confocal Fluorescent Microscopy



- ACTB (actin filaments)
- CETN2 (centrioles)
- CTNNB1 (adherens junctions)
- DSP (desmosomes)
- FBL (nucleolus)
- GJA1 (gap junctions)
- LAMP1 (lysosomes)
- LC3B (autophagosomes)
- LMNB1 (nuclear envelope)
- MYH10 (actomyosin bundles)
- RAB5 (endosomes)
- SEC61B (ER)
- SLC25A17 (peroxisomes)
- ST6GAL1 (Golgi apparatus)
- TOM20 (mitochondria)
- Z01 (TJP1 tight junction protein)



Specific Dataset: Access

[Download webpage](#)

[Interactive viewing of 2TB of images](#)

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Frame 1 / 27

▼ Layer selection

Layer: Actin

▼ Layer composition

☐

 Organelle

☐

 DNA

☐

 CellMembrane

☐

 Actin_Seg

☐

 DNA_Seg

☐

 Organelle_Seg

▼ Display info

Cursor info

Image coords:

Screen coords:

Intensity:

Field of view info

Zoom: 74.14 %

X (top left): -195

Y (top left): -57

Width: 1667

Height: 1198

▼ Screen recording

📷 Take a snapshot of the screen

🔴 Start recording

Options

Include scalebar: ☐

Include timestamp: ☐

Timestamp location: Top left

▼ Filtering

☒ Enabled

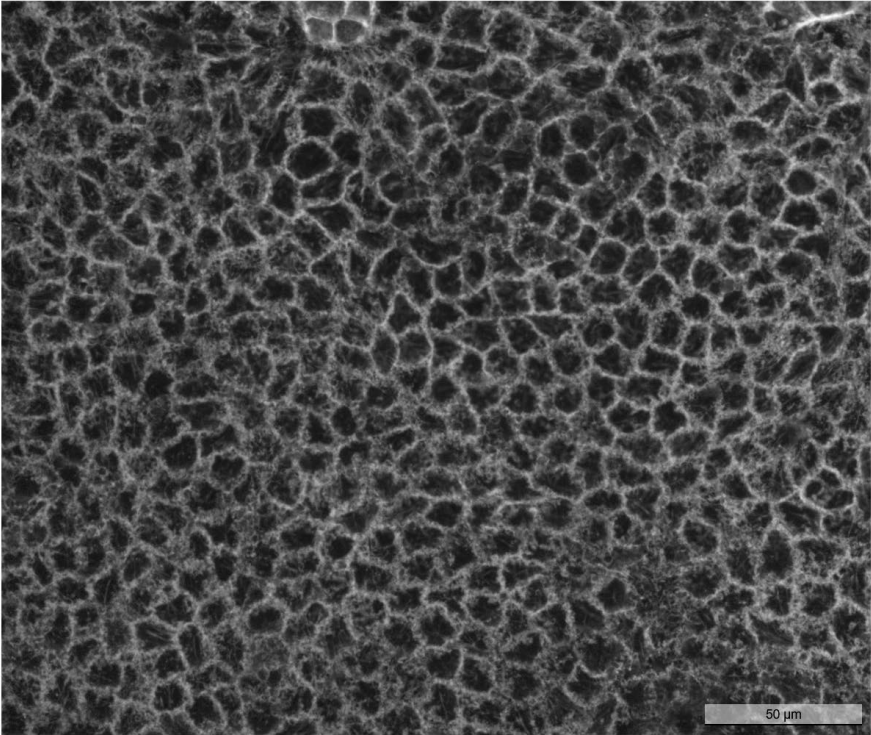
Modify filters

Exposure: 45

▼ Connectivity analysis

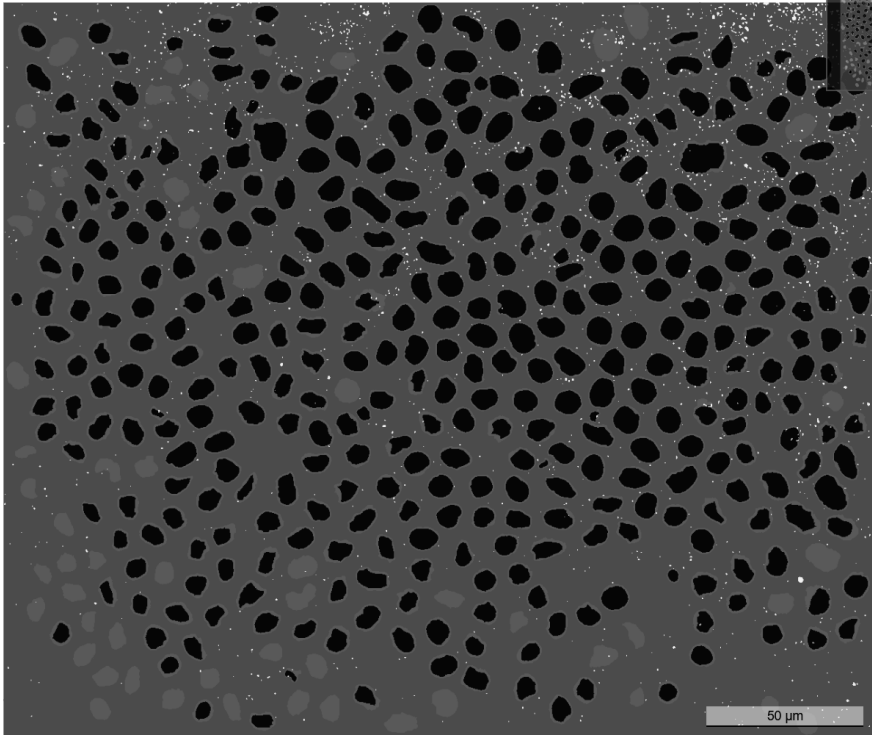
Run analysis

Measured Images



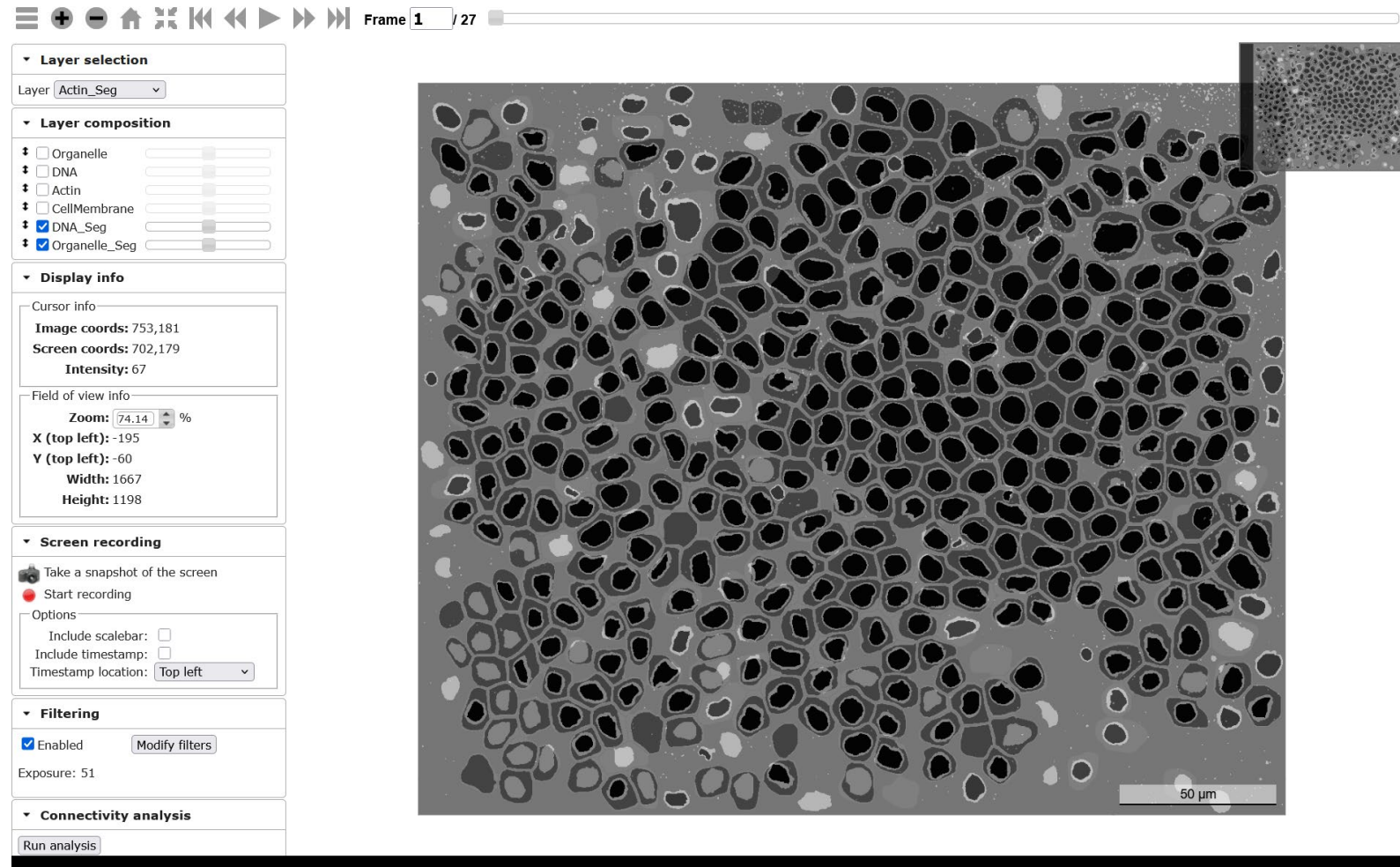
Frame 1 / 27

Segmented Images



Specific Dataset: Task

The task for annotators is to cluster cells for which organelles around each nucleus have similar distributions.

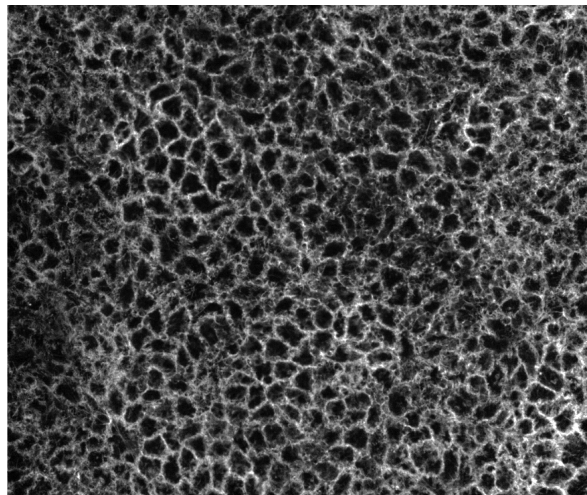


Display: Cell Boundary with DNA and Organelle

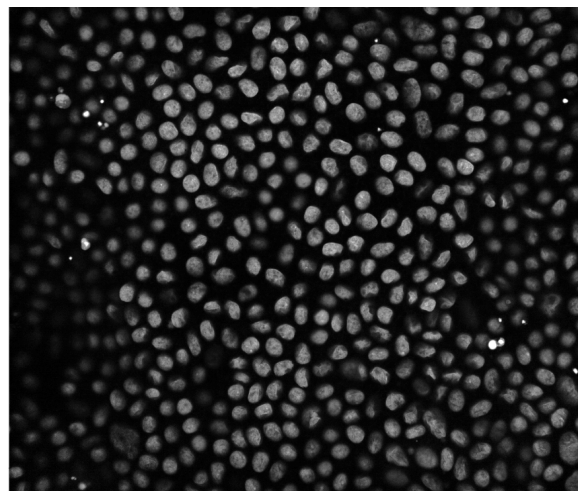
Task: Inspection of distributions of organelles around DNA in each cell

https://isg.nist.gov/deepzoomweb/view/image/P1W2TOM_E02_F001

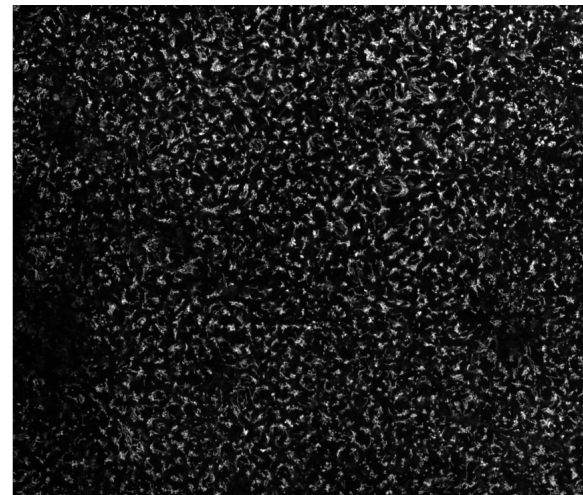
Intensity



actin

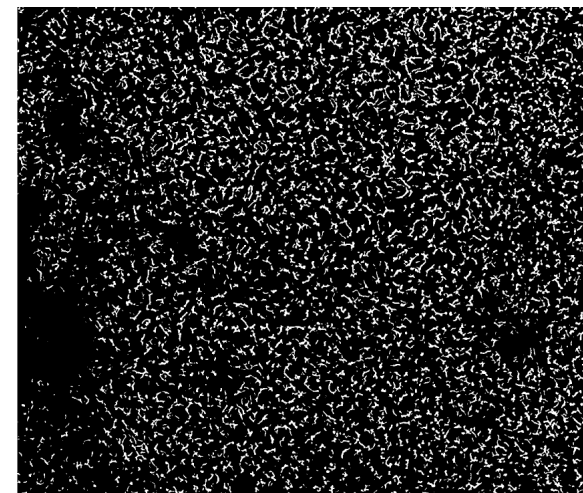
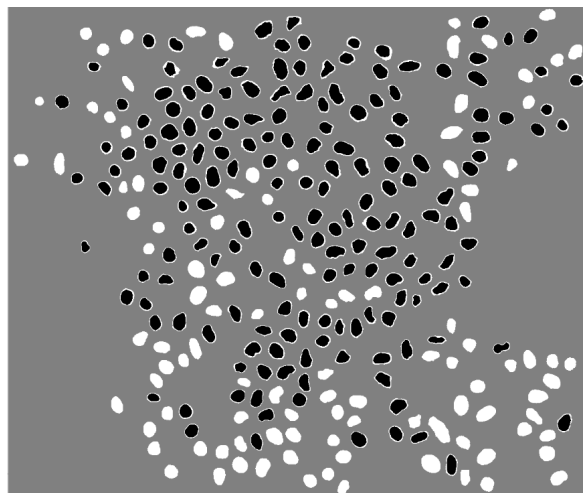
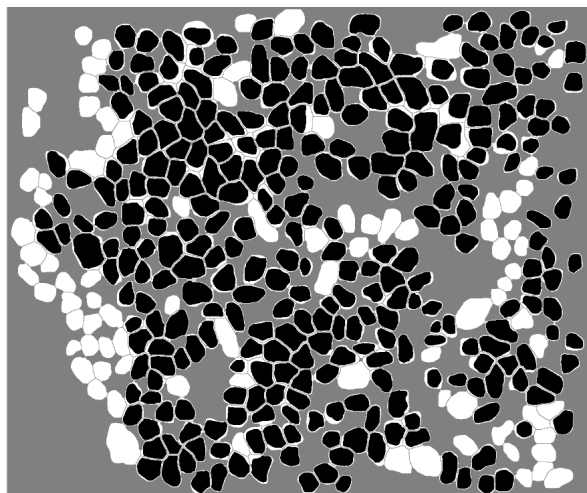


nucleus



organelles

Segmentation



Relevant Literature

- Material science project using neutron imaging:
 - Project webpage: <https://www.nist.gov/programs-projects/interferometry-infer-neutron-interferometric-microscopy-small-forces-and>
 - Download webpage: <https://isg.nist.gov/deepzoomweb/data/inferSegmentation>
 - Sathe, P.S., Wolf, C.M., Kim, Y. *et al.* Data-driven simulations for training AI-based segmentation of neutron images. *Sci Rep* **14**, 6614 (2024). <https://doi.org/10.1038/s41598-024-56409-3>
- Biology project using fluorescent confocal microscopy:
 - Project webpage: <https://isg.nist.gov/deepzoomweb/data/RPEmap>
 - Downloads: <https://isg.nist.gov/deepzoomweb/data/RPEmap>
 - Visualization: <https://isg.nist.gov/deepzoomweb/resources/csmet/pages/RPEmap/RPEmaplinks.html>
 - Davide Ortolan, Sathe Pushkar, Andrei Volkov, Dominik Reichert, Sheldon Sebastian, Arvydas Maminishkis, Nicholas J. Shaub, Jorge Ferrari, Nyusha Lin, Gianluca Pegoraro, Carl G. Simon Jr., Ruchi Sharma, Peter Bajcsy, and Kapil Bharti, "AI Driven 3D Subcellular RPE Map Discovers Cell State Transitions in Establishment of Apical/Basal Polarity", *Nature npj Artificial Intelligence*, npj Artif. Intell. 2, 20 (2026). <https://doi.org/10.1038/s44387-026-00074-6>