AI Models for Neuron Segmentation: A Comparative Study

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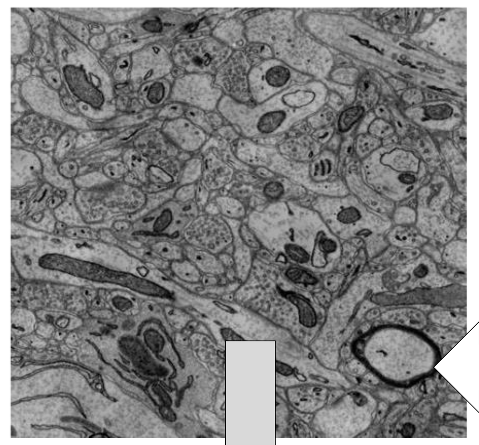
PRECS Phenotypic Plasticity Research Experience for Community College Students

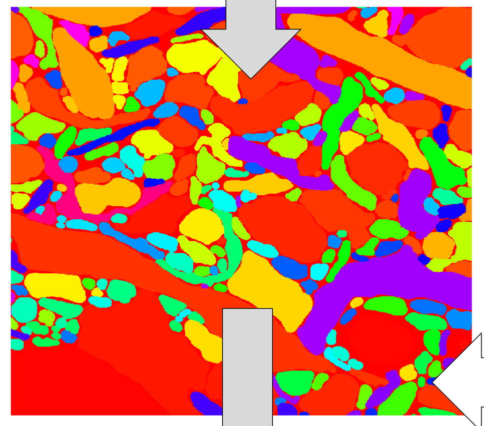
Project Goal:

- Electron microscopy (EM) provides scientists at The Schroeder Laboratory with a variety of biological insights into neural networks and synapses.
- However, due to the substantial data generated from the biological specimens being analyzed, the process of manual cell segmentation is labor-intensive and time-consuming.
- This project assesses and optimizes three different open-source machine learning models. Our objective is to determine which model delivers the highest efficiency, precision, and ease of use for our laboratory needs.

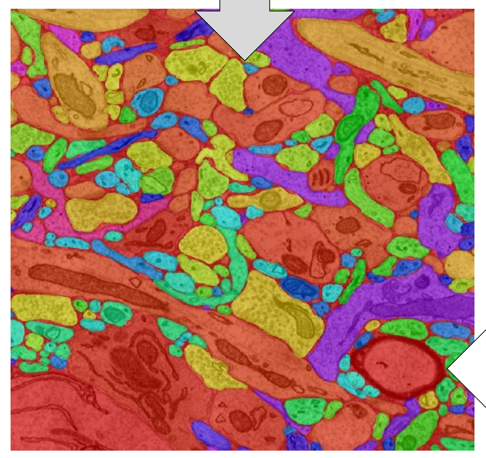
Cell Segmentation:



This is a picture of neurons taken by an electron microscope. The individual neurons must be segmented.



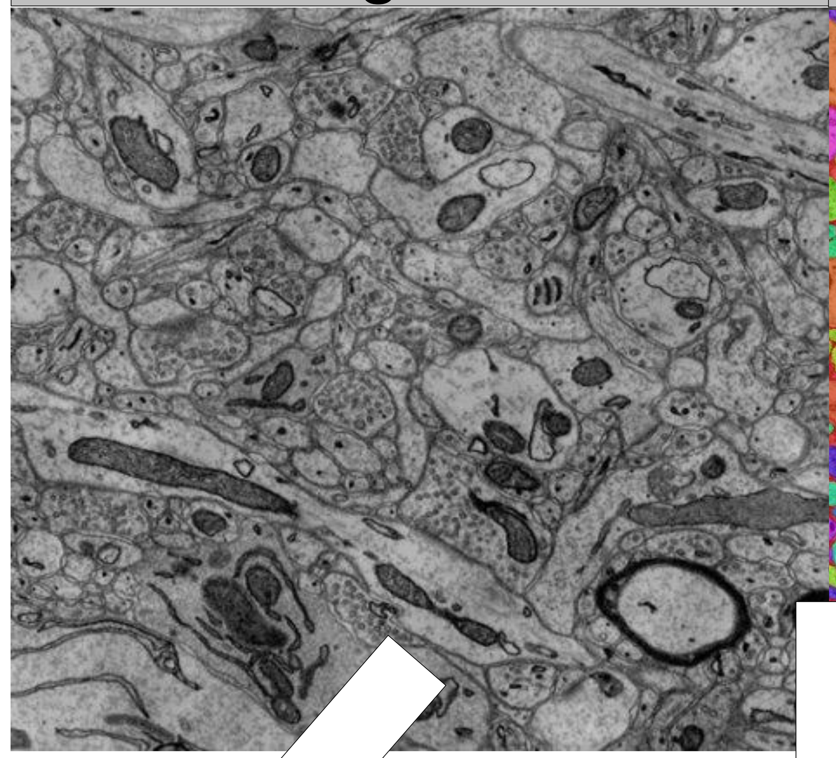
These are neuron labels, or *masks*. Creating masks can take hours to months to complete, They must be hand drawn, for thousands of images.



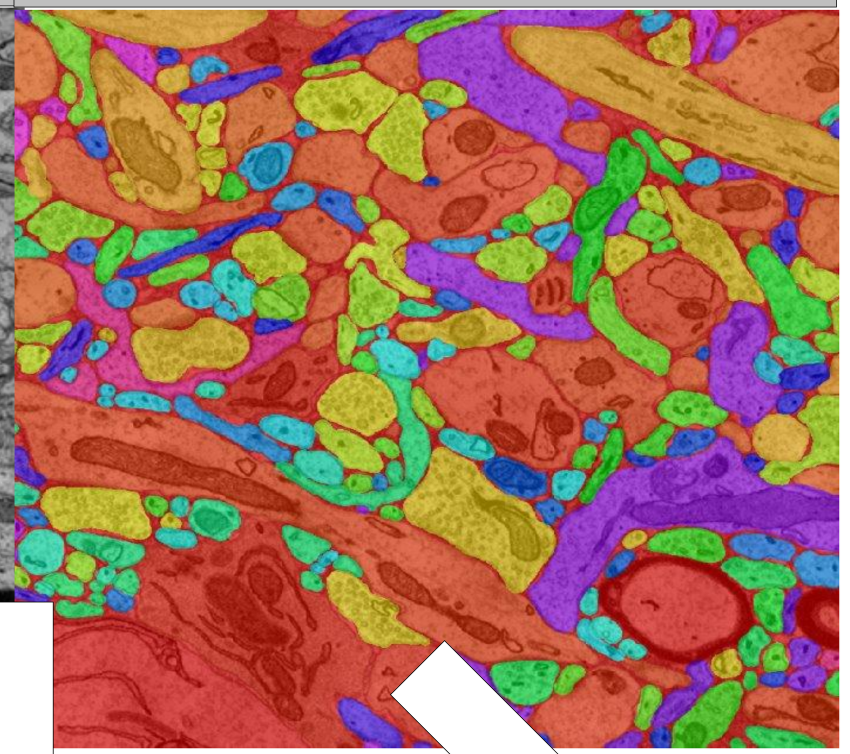
The final image shows the overlay of neuron masks over the segmented class, in this case, the neuron.

Current Segmentation Models:

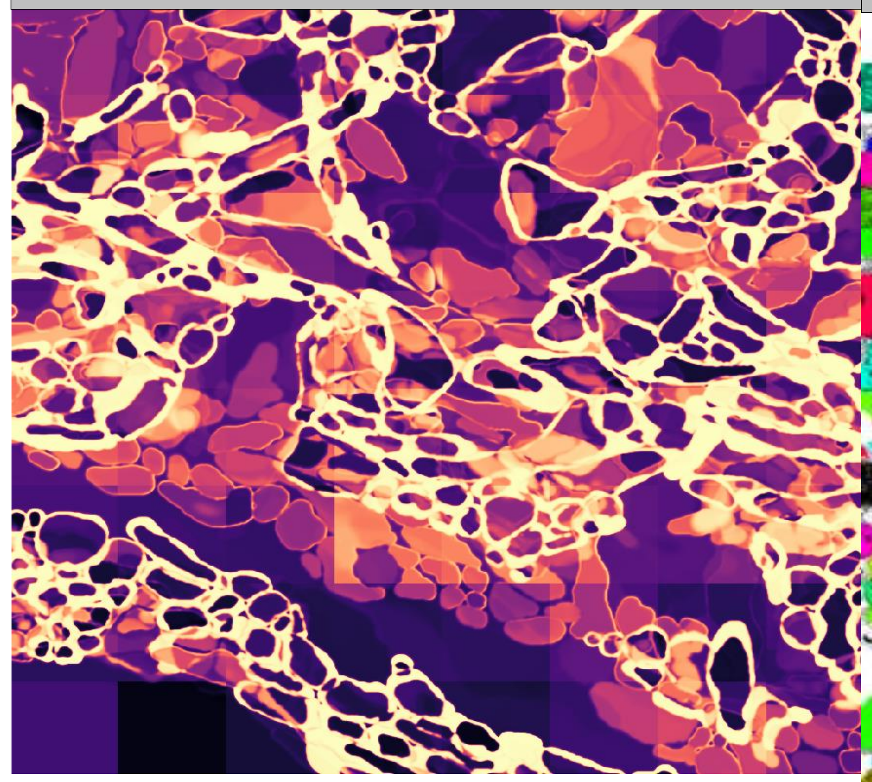
Raw Image of Neurons



Ground Truth



3D-UNet Model

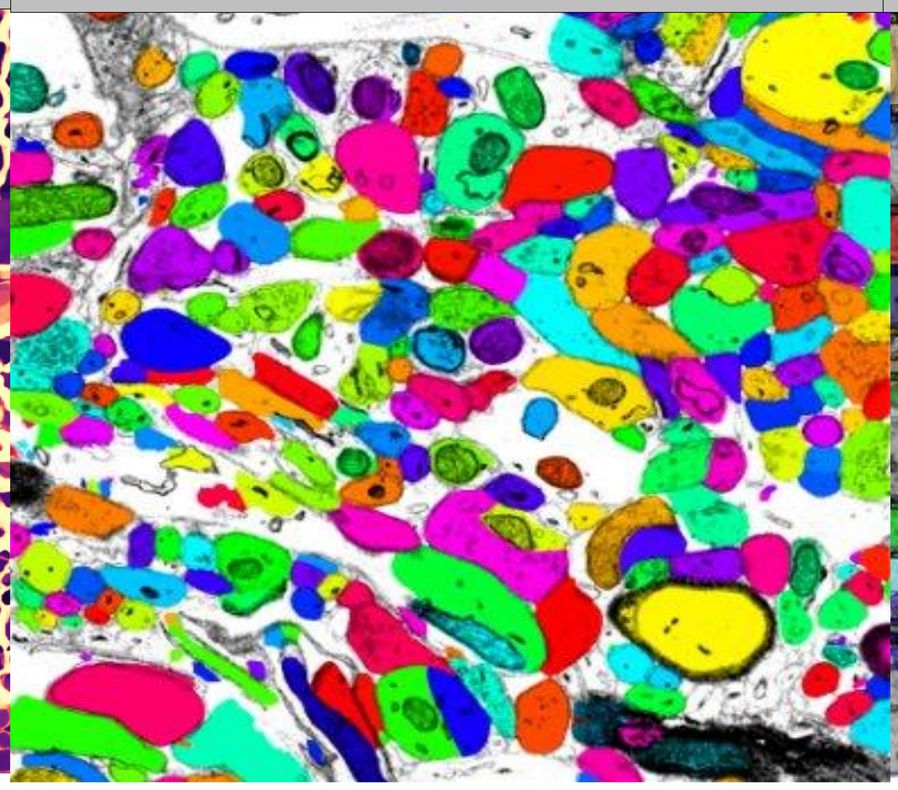


3D-UNet Metrics:

Training Accuracy =
Value: 0.9904 at step 500
Training Loss =
Value: 0.4809 at step 1000
Validation Accuracy =
Value: 0.8838 at step 1000
Validation Loss =
Value: 0.4709 at step 1000
Final Accuracy score = 88.38%

Ease of use = Intermediate

Cellpose Model

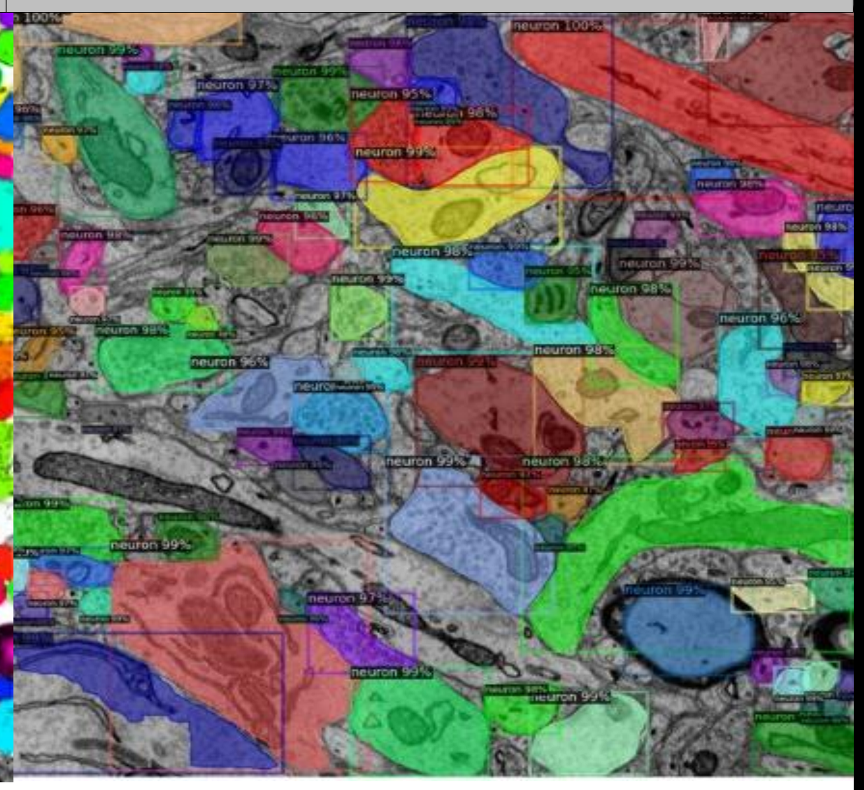


Cellpose Metrics:

Cellpose did not provide us with metrics.

Ease of use = Easy

Detectron2 Model



Detectron2 Metrics:
(Metrics for validation set, 10 images)

Average Accuracy = 90.30%
Average Precision = 26.35%
Average Recall = 28.20%
False Negatives = 8.14%
False Positives = 12.18%

Ease of use = Challenging

Conclusions:

- **3D-UNet**: Achieved 88.38% accuracy but had high validation loss, suggesting overfitting.
- **Cellpose**: User-friendly but lacks direct performance metrics.
- **Detectron2**: High accuracy (90.30%) but low precision (26.35%) and recall (28.20%), indicating many false positives and negatives.

While 3D-UNet and Detectron2 are promising, improvements in precision and recall are needed.

Future Work:

- Cellpose: The 3d version of Cellpose should be used if it displays metrics.
- 3DUnet: More time should be spent on a watershed algorithm.
- Detectron2: Augmentation should be added, and more time should be spent exploring and adjusting the hyperparameters.

References:

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