Large-Scale Mitochondria Segmentation

Overview

1. Motivation
2. Problem Statement
3. Challenges
4. Related Work
5. Method
6. Post-processing
7. Results

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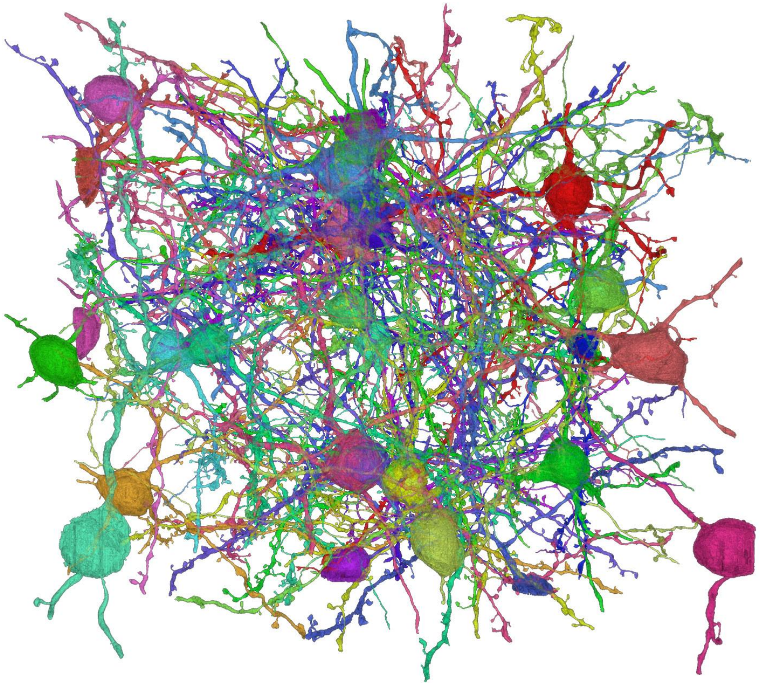
Connectomics



Need for Connectomics

1. Correlation between neuron wirings with
    a. Cognition
    b. Intelligence
    c. Consciousness
2. How memory is stored
3. Evolution of wirings with age
4. Diseases

Mitochondria

1. Powerhouse of the cell
2. Responsible for
    a. Neuronal development [1]
    b. Developmental Brain Diseases[1]
3. Relevant mitochondria features
    a. Morphology
    b. Number density
    c. Dysfunctionality and more

[1]*Geurim Son and Jinju Han*, "Roles of mitochondria in neuronal development" in BMB Reports 2018.

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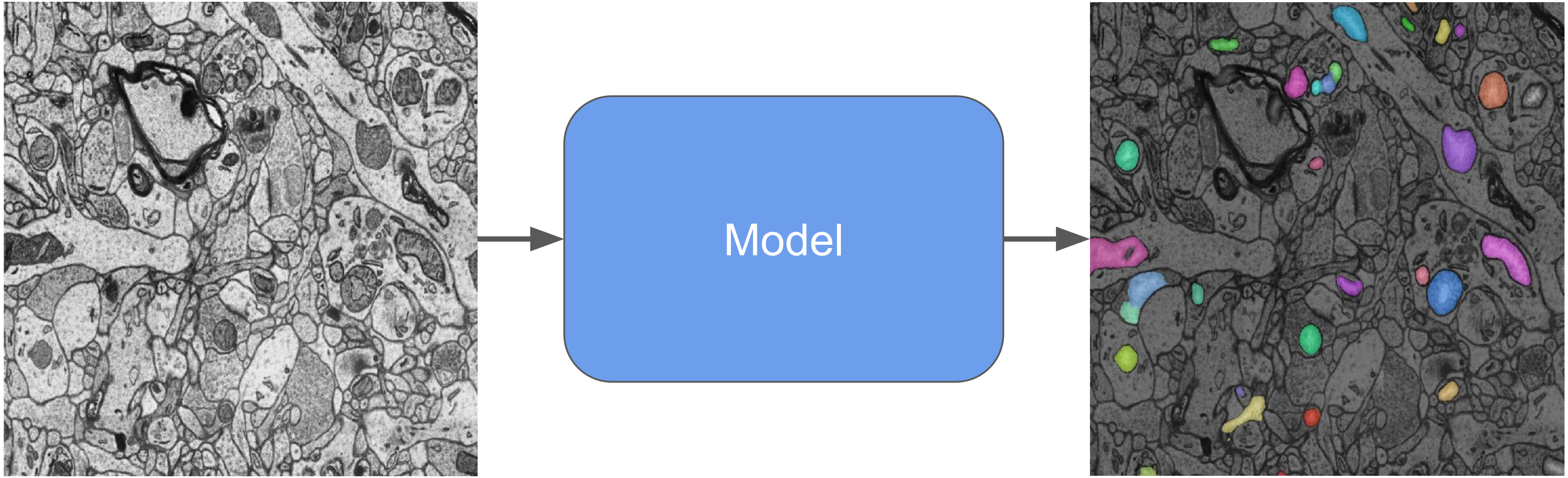
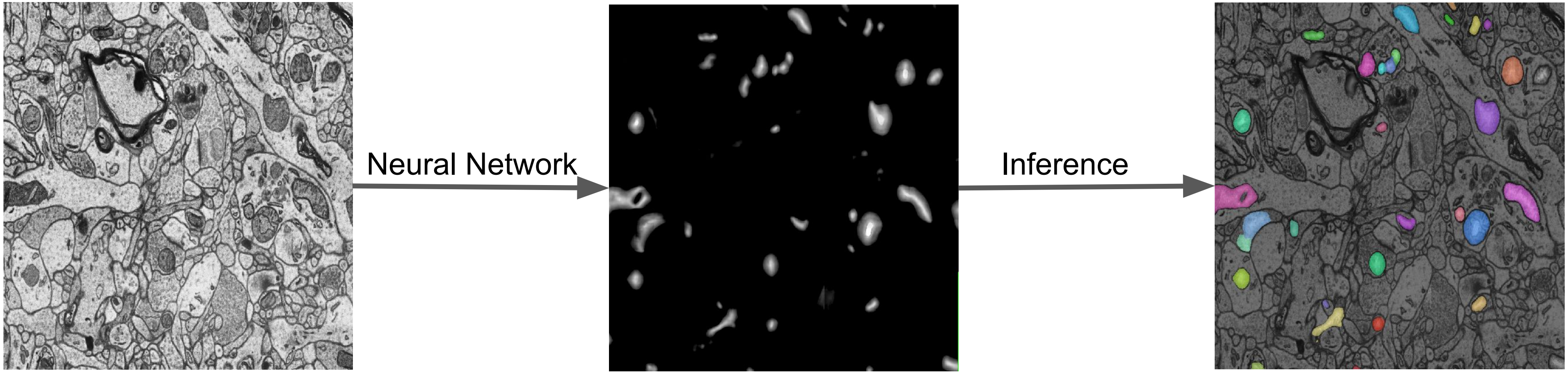
Mitochondria Segmentation



EM Image

Segmentation Map

Mitochondria Segmentation



EM Image

Intermediate
Representation

Segmentation
Map

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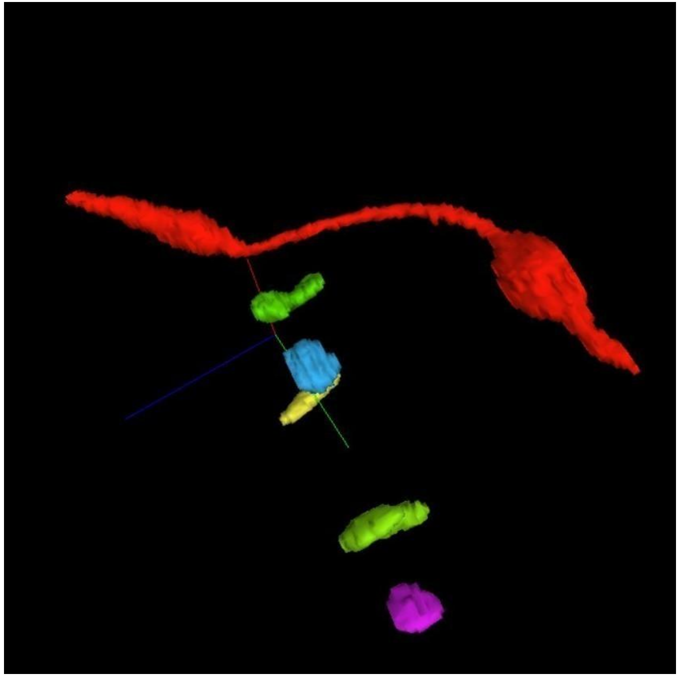
Challenges

1. Non-convex Morphology
2. Mitochondria in close vicinity
3. Annotated data and Generalization
    a. Training data: 1x6Kx4Kx300
    b. Test data: 49X4KX4KX1K



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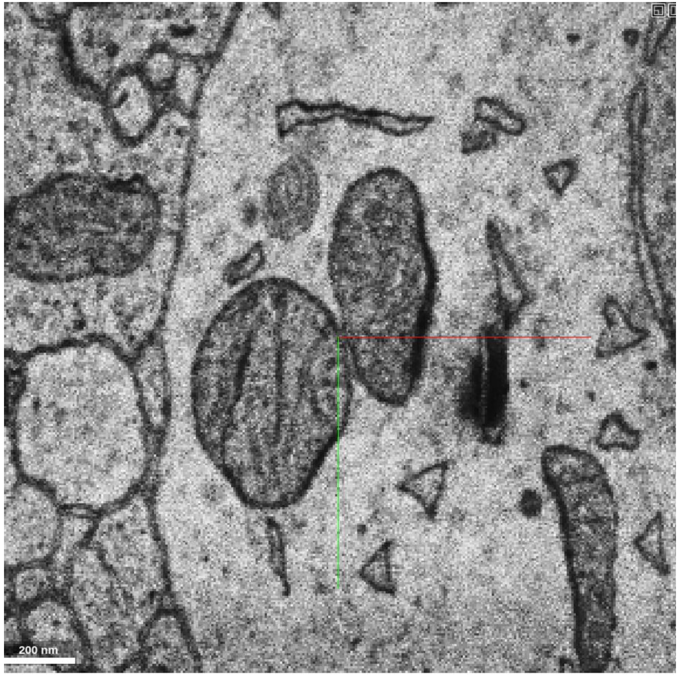

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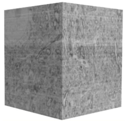
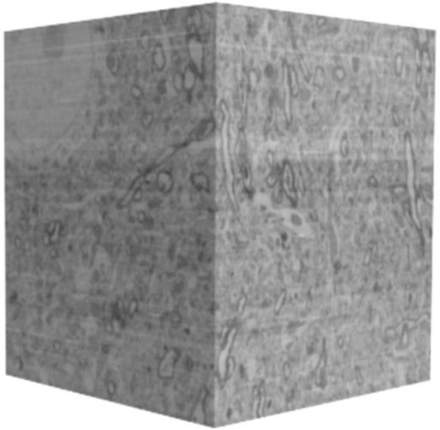
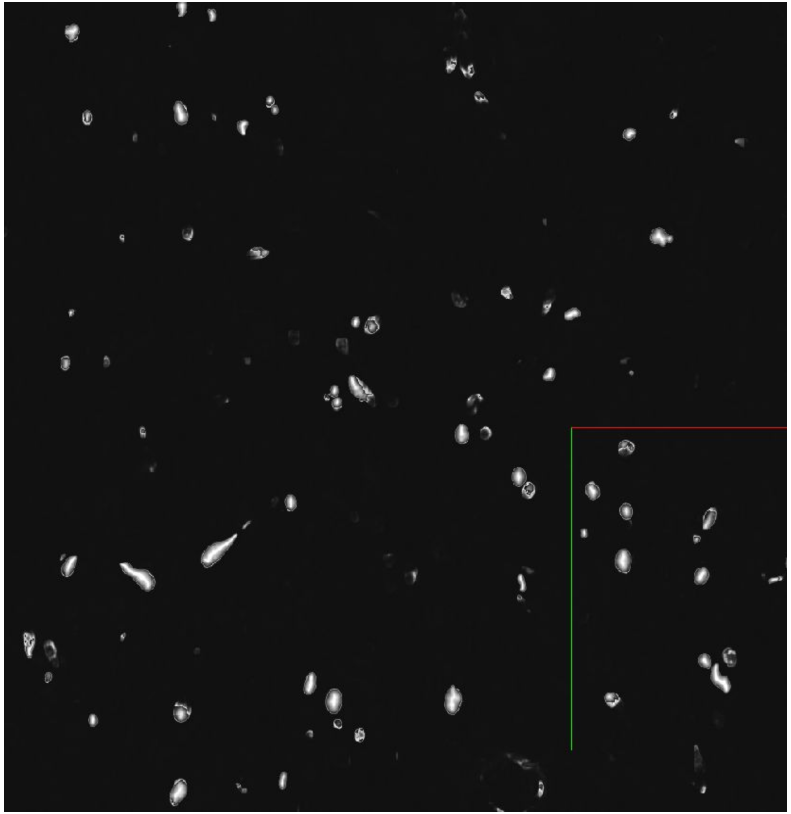


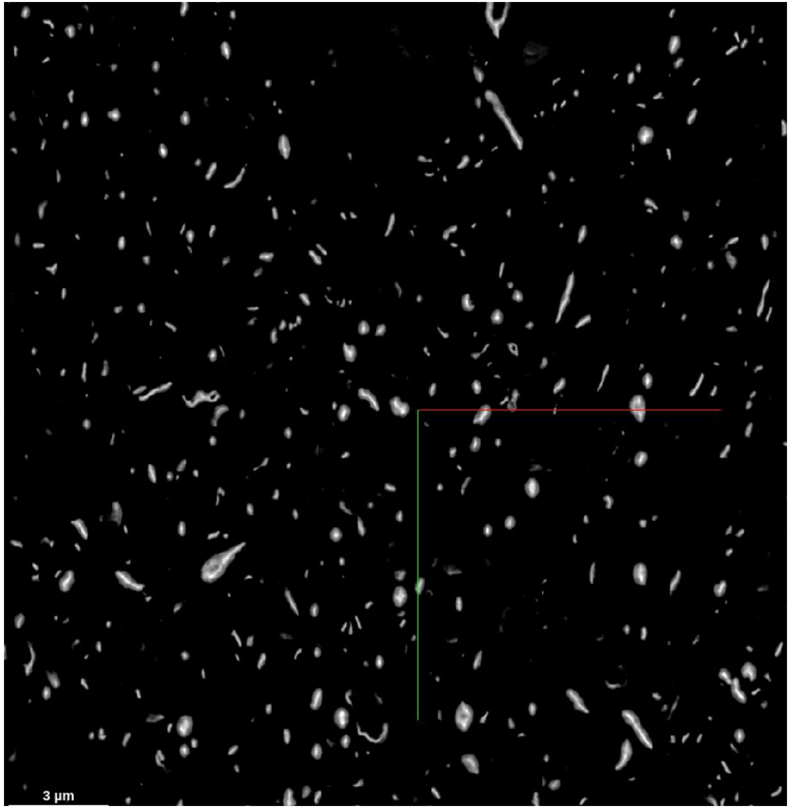
Train



Test



Output



Expected Output

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Related Work

1. Boundary Prediction
    a. Distance Transform
    b. Seed Generation
    c. Flood filling rule
    d. False merges
2. Deep Watershed[2]
    a. Discretized watershed maps with the boundaries at the same level
    b. Cut at specific energy level
    c. Poor connectivity

[2] *M. Bai and R. Urtasun*, “Deep Watershed Transform for Instance Segmentation“. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pages 5221–5229, 2017. 2, 3, 5

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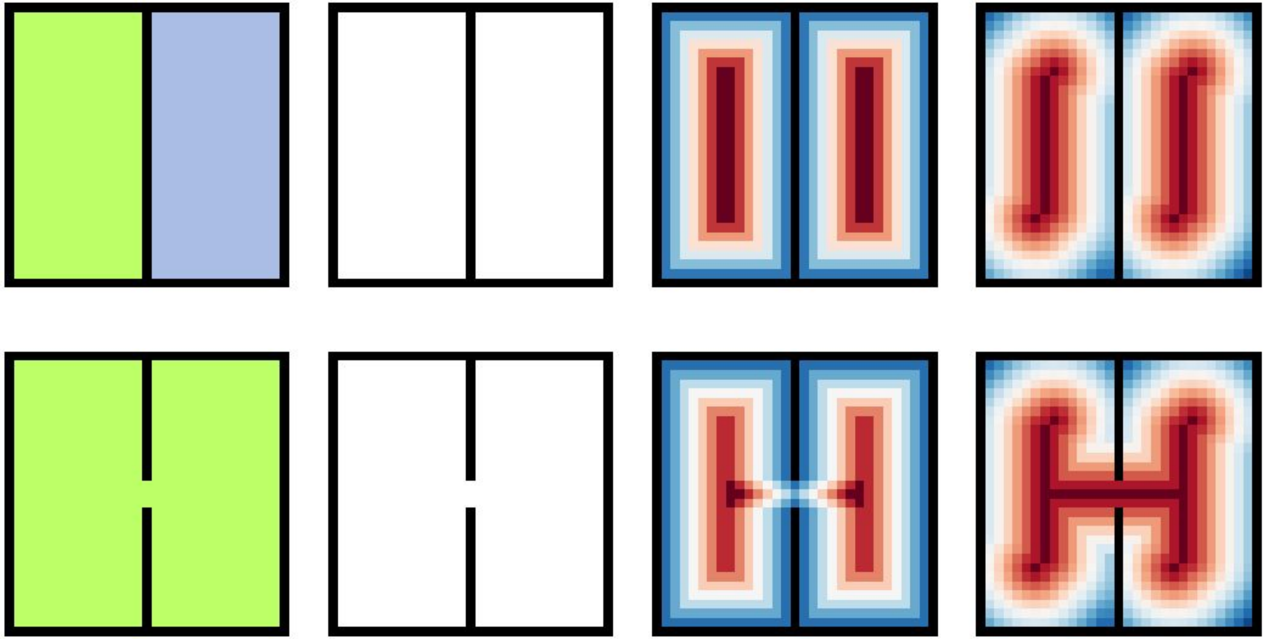
Connectivity-Aware Watershed Energy

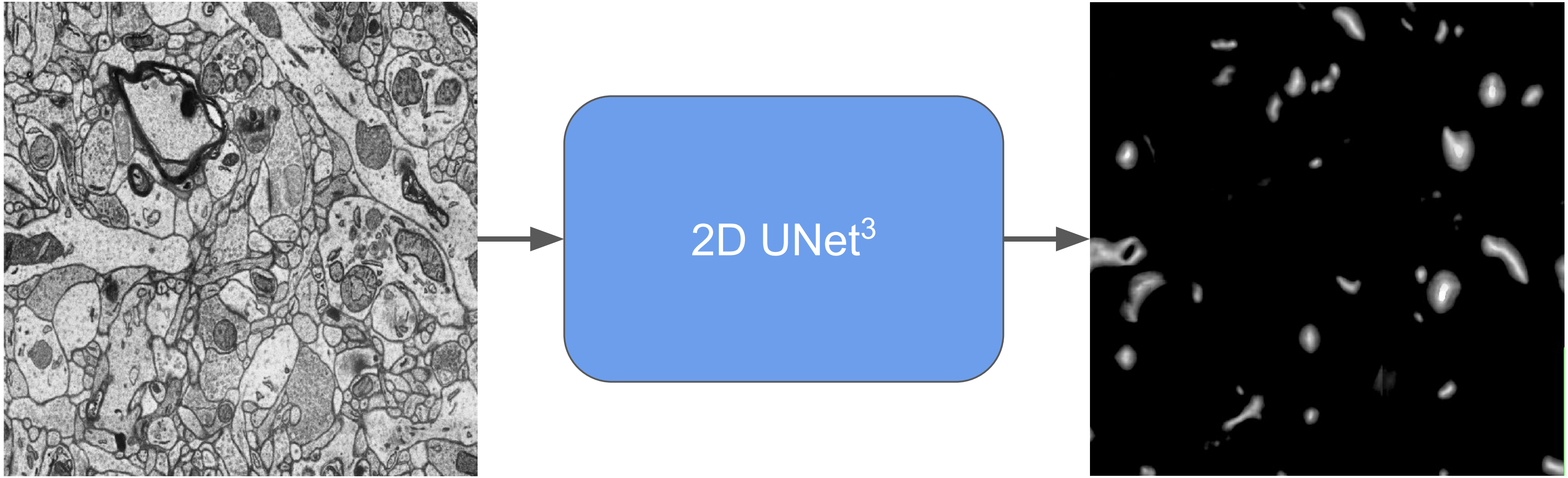
1. Ground Truth -> Energy Map
   a. Recursive erosion of boundary pixels
   b. Distance transform using skeleton pixels
   c. Normalization of distance transform
2. Track changes in connectivity
   a. Augment model with loss functions
   b. More weight for keypoints (skeleton ends and branch points) in loss function

Connectivity-Aware Watershed Energy



(a) Instance Masks | (b) Edge $L^2 = 0.06$ | (c) DWT $L^2 = 0.09$ | (d) **Ours** $L^2 = \mathbf{0.19}$

Connectivity-Aware Watershed Energy

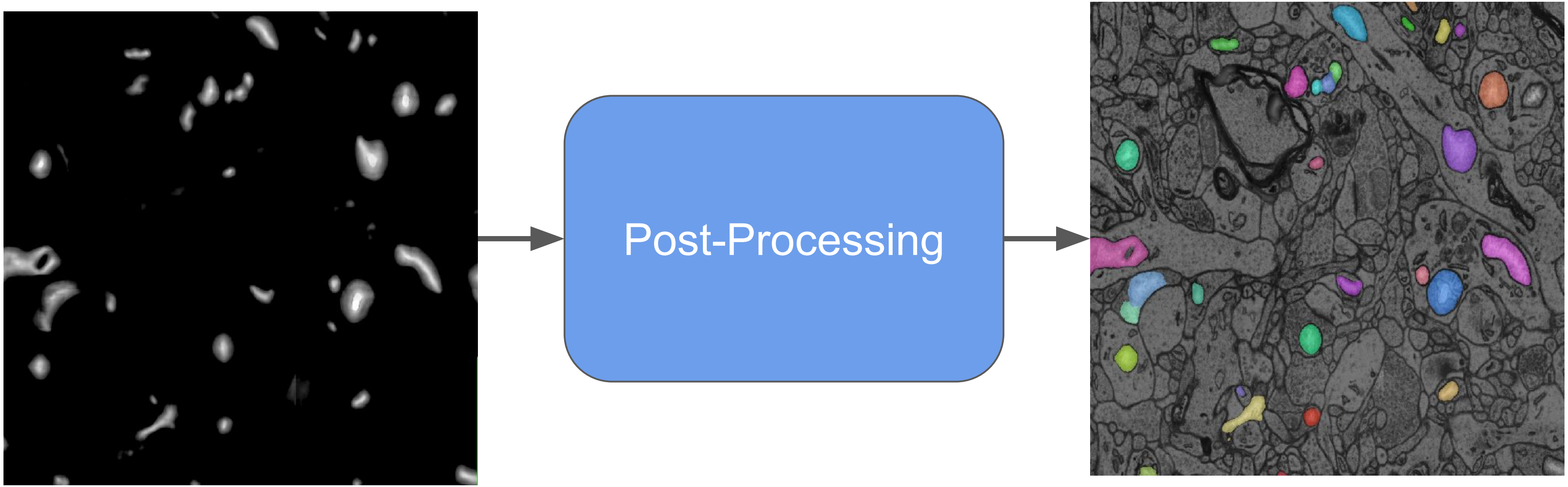


EM Image

Distance Transform Map
(Energy Map)

[3]*O. Ronneberger and P.Fischer and T. Brox*, “U-Net: Convolutional Networks for Biomedical Image Segmentation” in MICCAI 2015, vol. 9351, pp. 234-241, 2015

Connectivity-Aware Watershed Energy



Distance Transform Map
(Energy Map)

Segmentation Map

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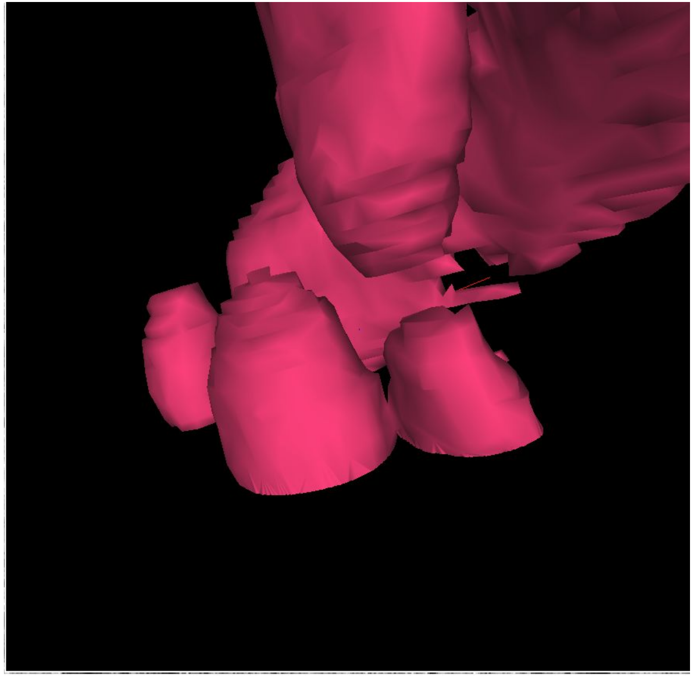
Previous Approaches

1. Connected Components
   a. False Merges
2. CC with Binary Erosion/Dilation
   a. False Splits
3. Watershed
   a. Oversegmentation



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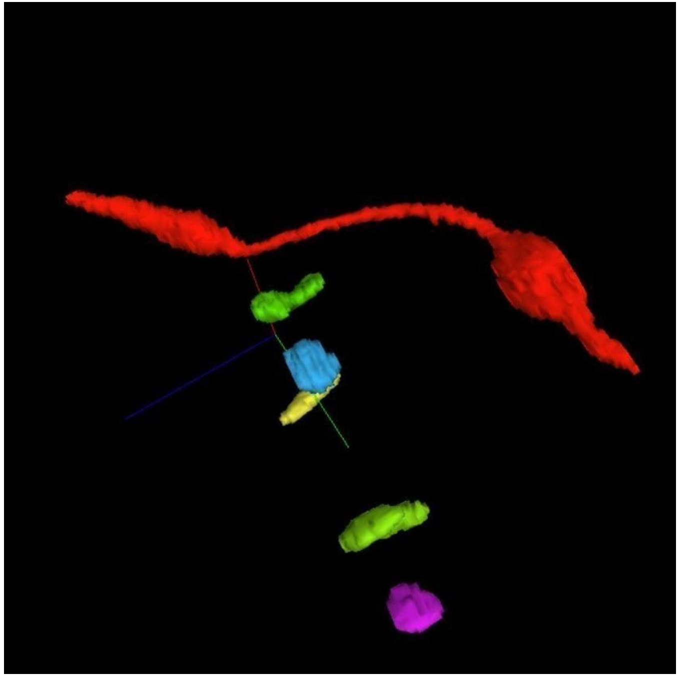

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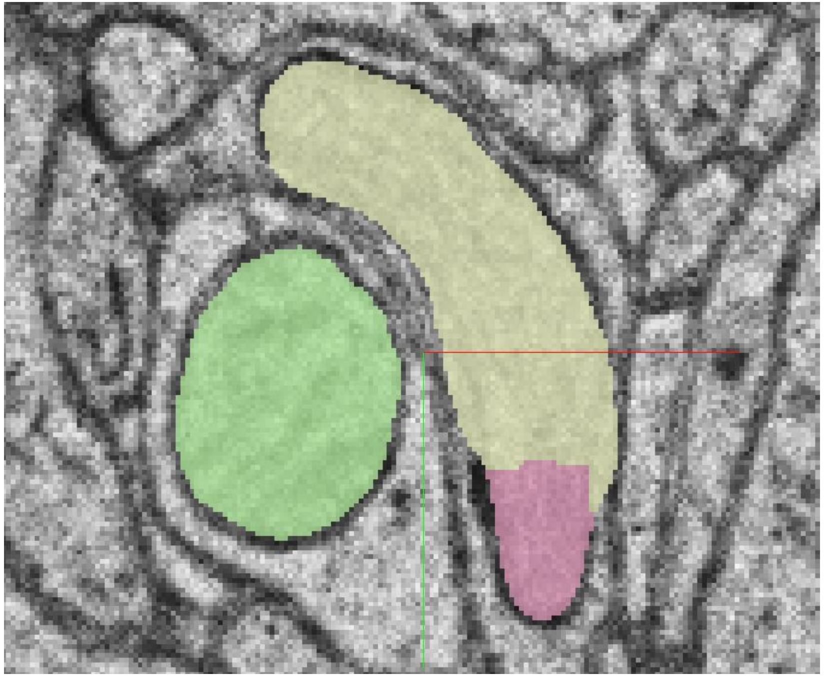
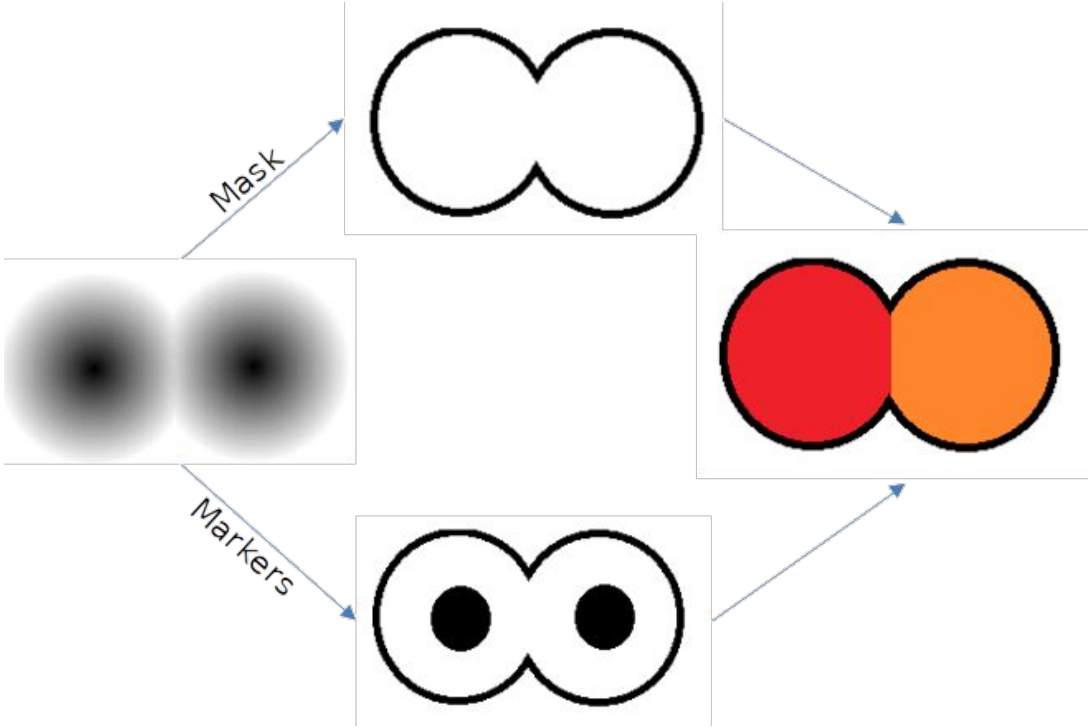


Marker Generation for Watershed

1. Threshold Energy Map
    a. Marker generation
2. Binarize CC output
    a. Mask Generation
3. Watershed



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Results (Annotated Cell Body)

Matching Criteria: > 0.8 IoU

	True Positives	False Positives	False Negatives
Initial Prediction	49	12	20
After Error Correction	59	12	10

Precision/Recall (by pixel): 94% / 96%