# VESICLE: Volumetric Evaluation of Synaptic Interfaces using Computer Vision at Large Scale

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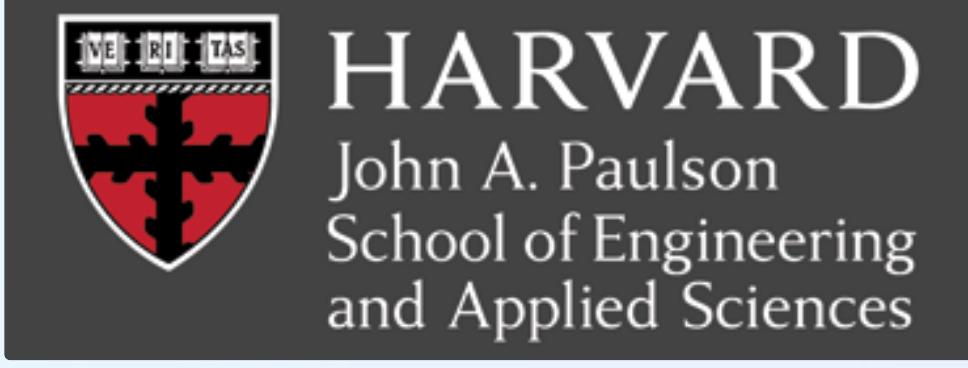
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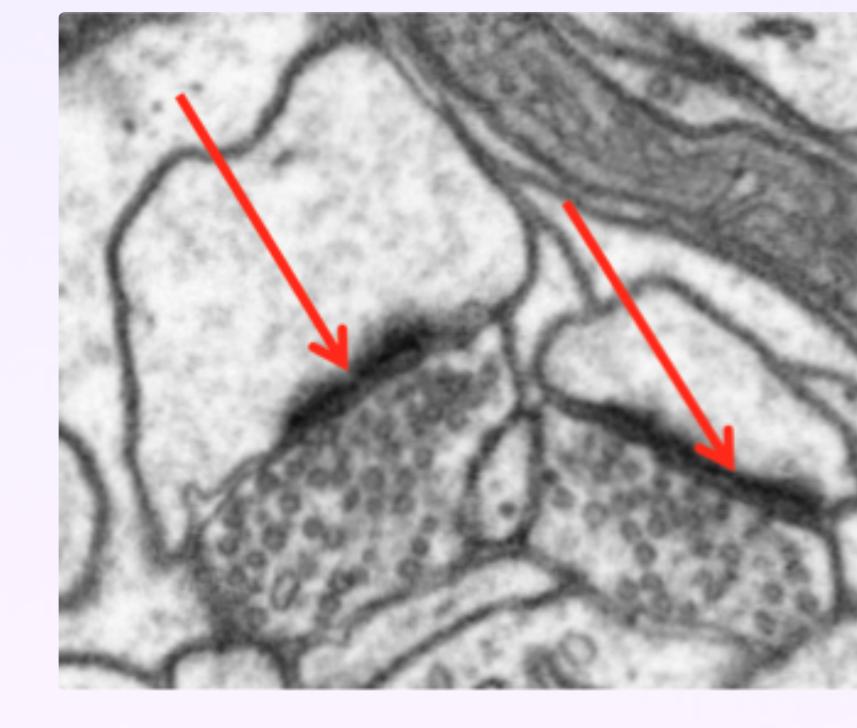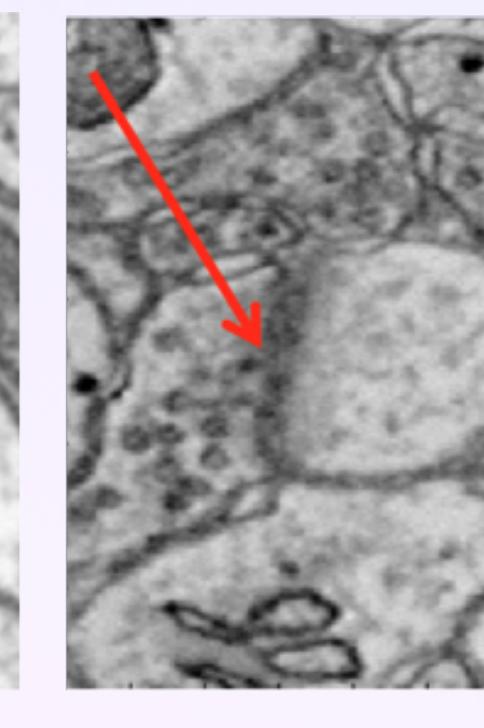
Challenge

▸ Large high-resolution volumes of neural tissue offer new frontiers for brain mapping
▸ This field promises rapid advances in biofidelic algorithms and healthcare
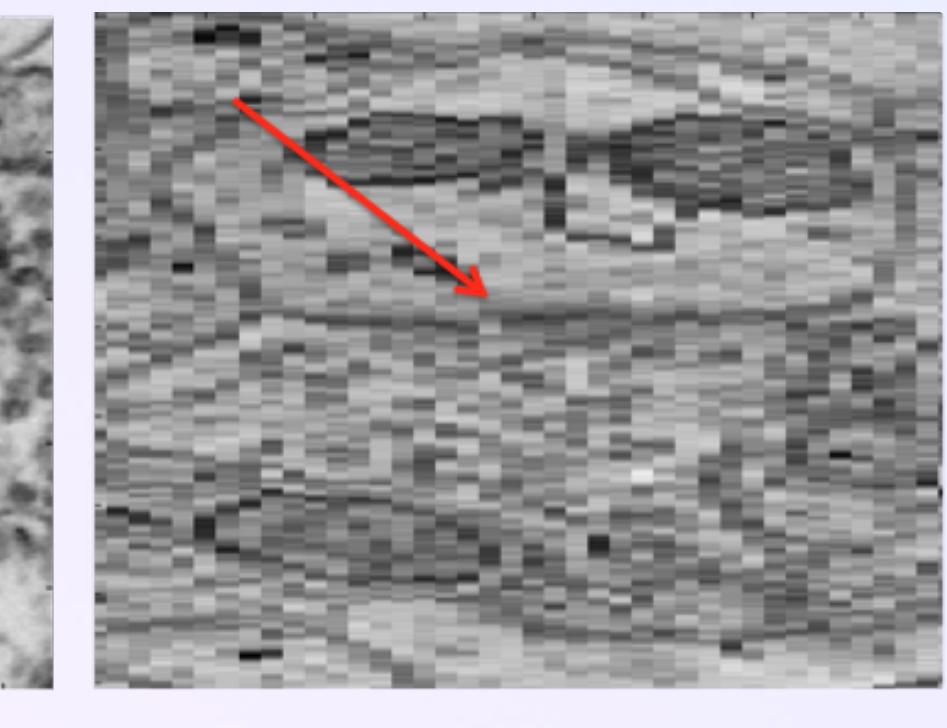
▸ Synapses are an integral part of these circuits and represent the communication point between cells
▸ Current methods are insufficient for high-throughput anisotropic, non-poststained data

Isotropic, poststained FIBSEM data

Anisotropic, non-poststained SEM data (XY slice, in imaging plane)
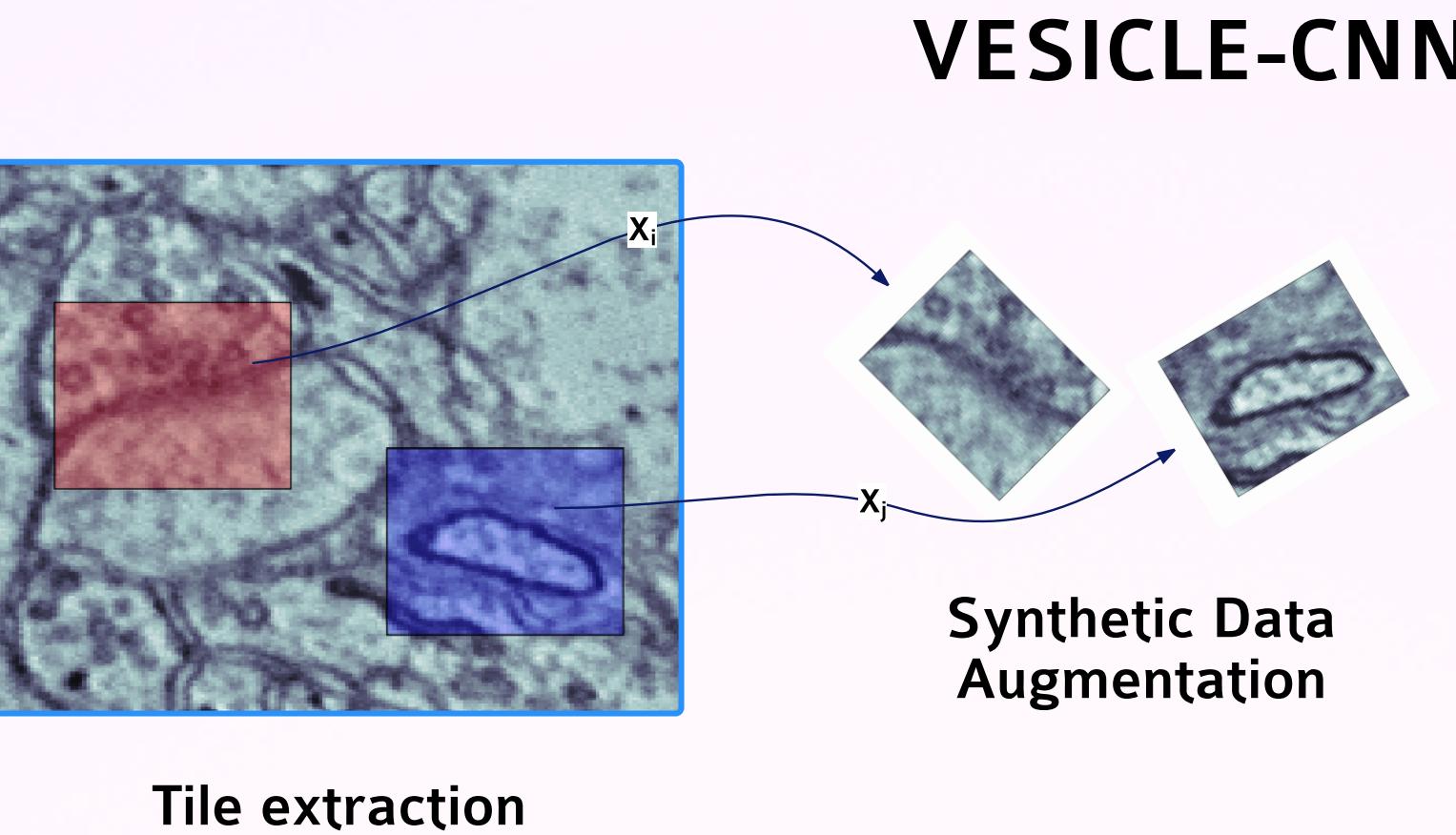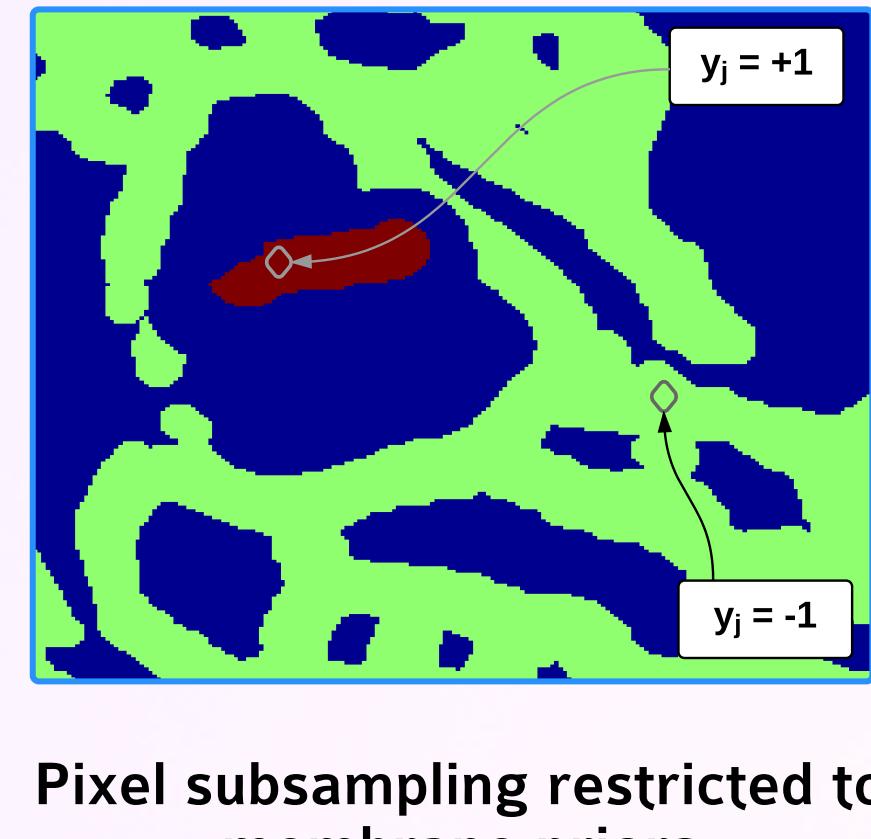
Anisotropic, non-poststained SEM data (XZ cross-section)
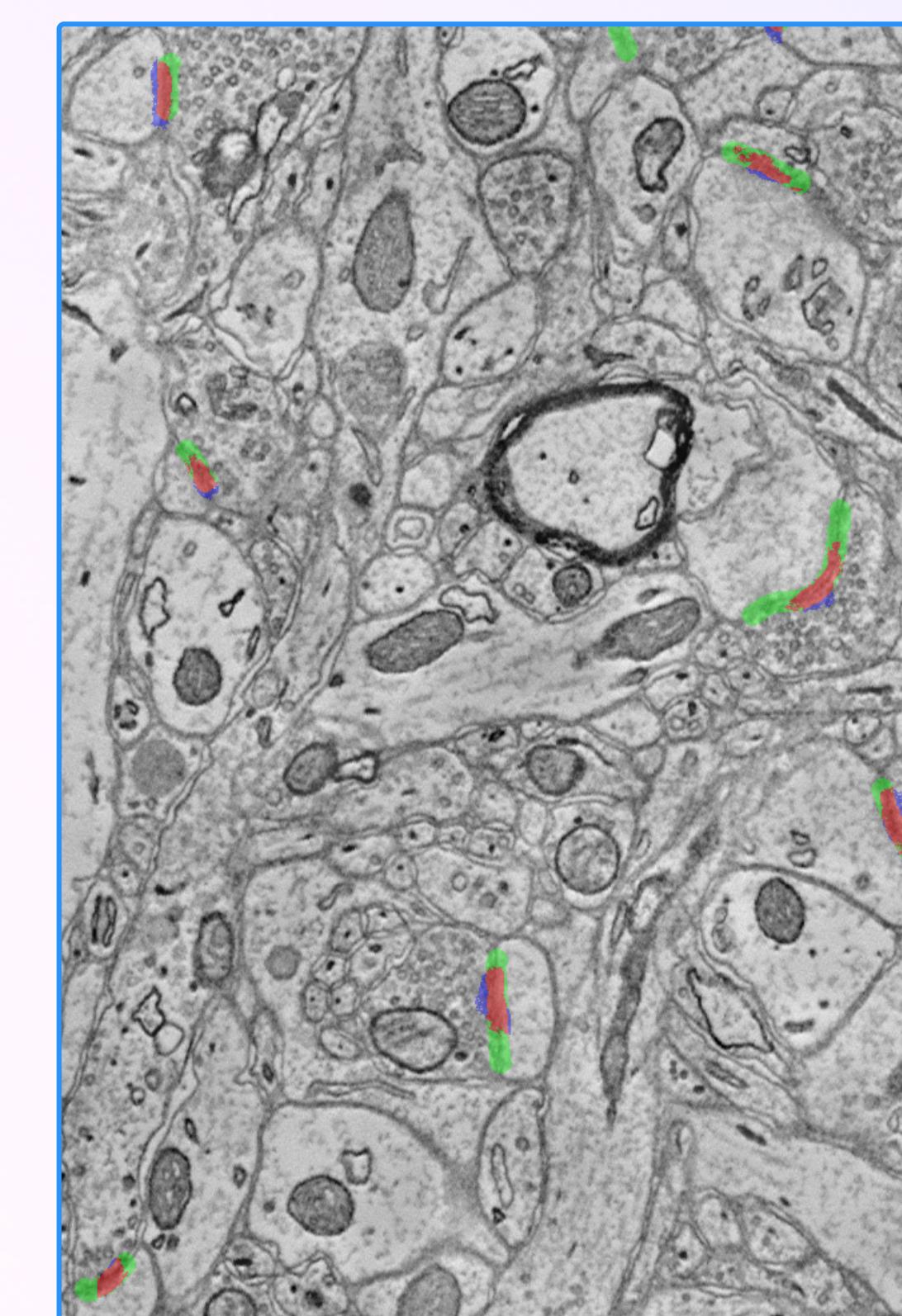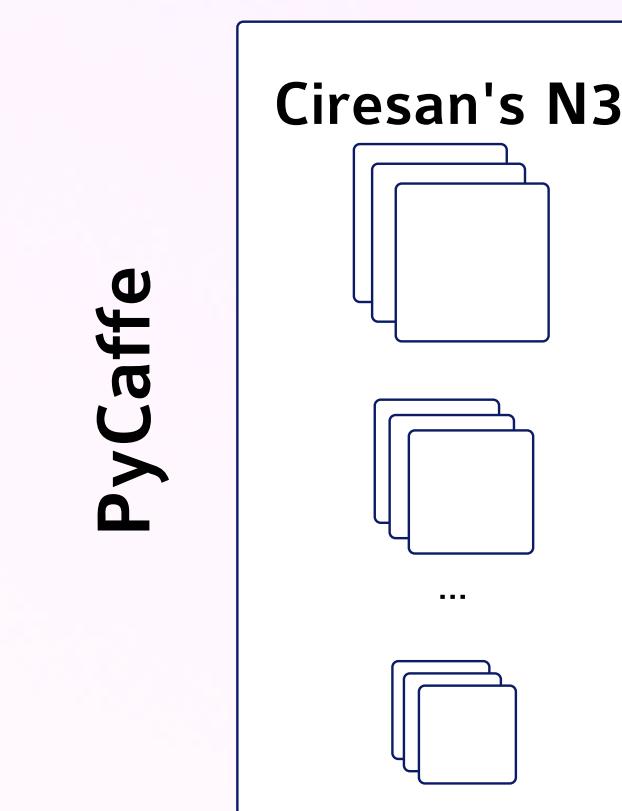
Action

▸ Our methods explicitly leverage biological context
▸ We provide two different approaches (performance/scalability tradeoffs)
  ▸ VESICLE-CNN: deep learning classifier
 ▸ VESICLE-RF: lightweight Random Forest approach

Raw Image data (left), High probability membrane pixels (top right), True Synapses (bottom right)

Pixel subsampling restricted to membrane priors

VESICLE-CNN

Tile extraction

Synthetic Data Augmentation

Ciresan's N3

PyCaffe
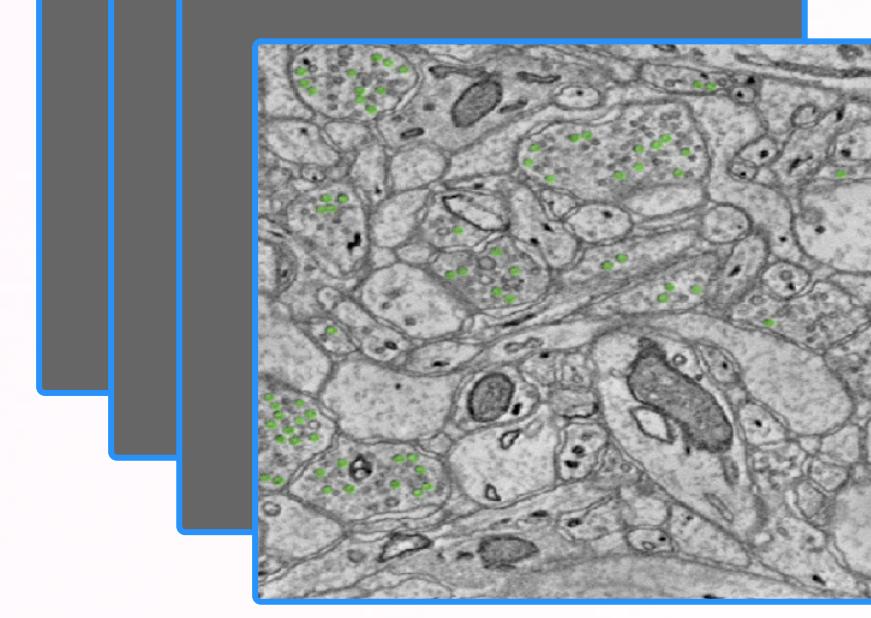
We adopt and re-implement the pixel-level convolutional neural network classification approach of [3] suitably adapted for synapse detection.

VESICLE-RF
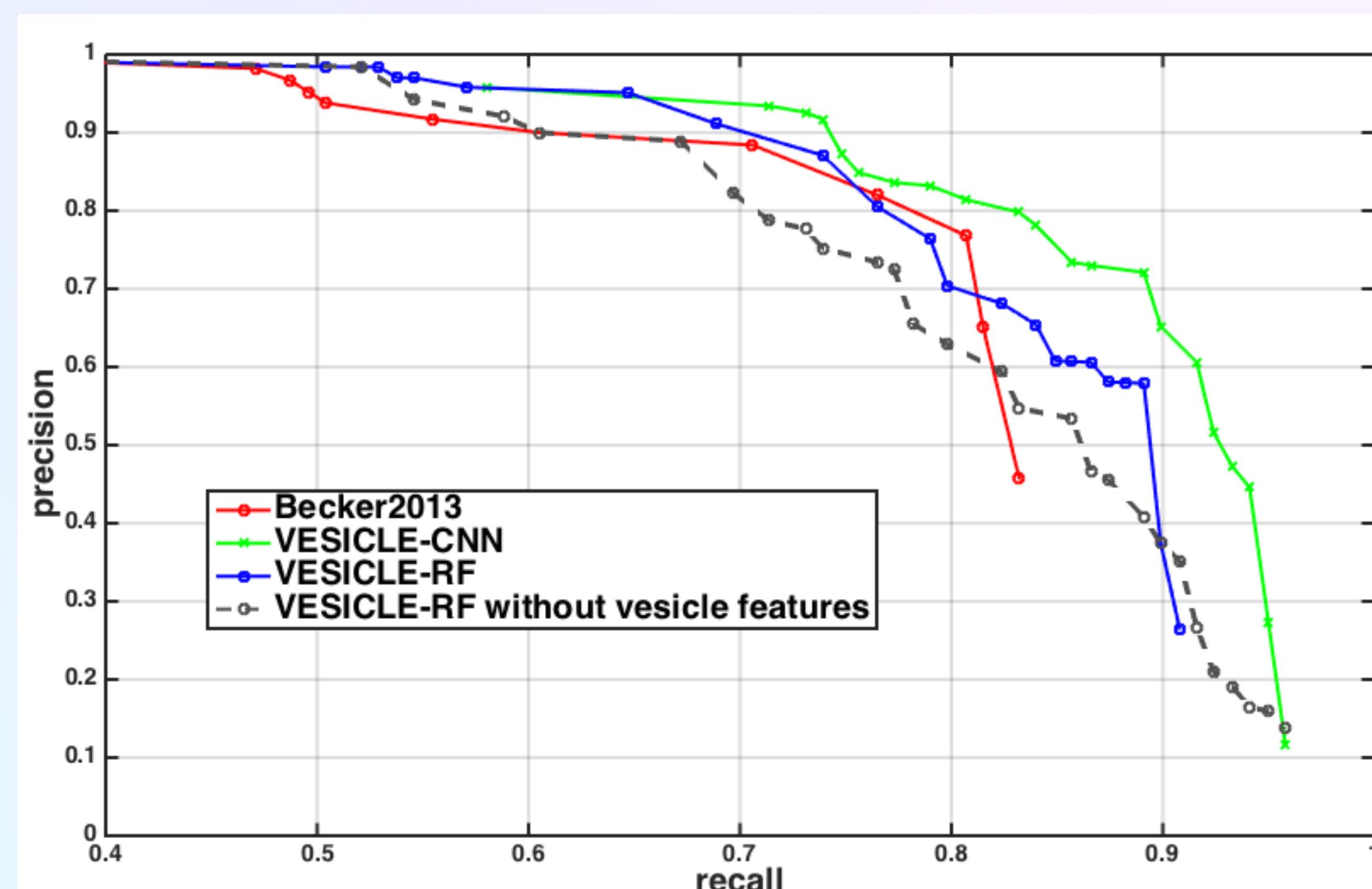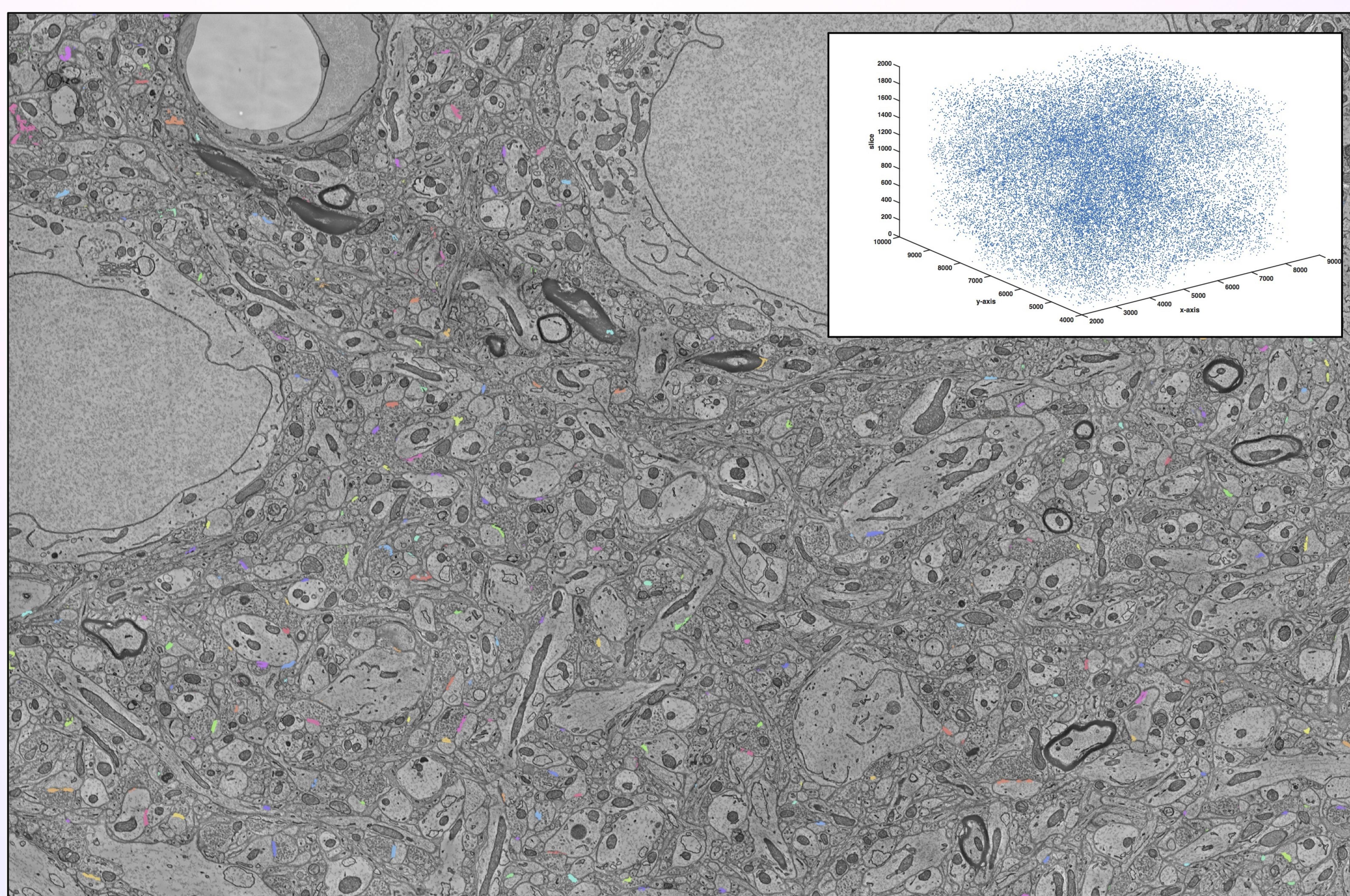
Table 1: Description of features used in VESICLE-RF; data transforms are summarized using different kernel bandwidths: $\theta_0 : [5, 5, 1]$, $\theta_1 : [15, 15, 3]$, $\theta_2 = [25, 25, 5]$, $\theta_3 = [101, 101, 5]$, θ_4 = minimum vesicle distance.

Data Transform	Box Kernel
Intensity	θ_0, θ_1
Local Binary Pattern	θ_0
Image Gradient Magnitude	θ_1, θ_2
Vesicles	$\theta_2, \theta_3, \theta_4$
Structure Tensor	θ_1, θ_2

We leverage biological context to compute image transformations. One such channel identifies neurotransmitter-containing vesicles, which provide a strong indication of synaptic connections. These channels are summarized into ten features, using box kernels of different sizes.

Classifier probabilities are thresholded and grouped into contiguous objects. Precision-recall curves are computed by sweeping over thresholds, synapse size and persistence limits.

Resolution

▸ Our classifiers provide state of the art performance
▸ Found ~50,000 synapses in 60,000 cubic microns (220 GB on disk) of electron microscopy data
▸ Proof of concept scalability test detected 11.6 million synapses in a 20 teravoxel poststained data volume


VESICLE-RF and VESICLE-CNN significantly outperform prior state-of-the art, particularly at high recall rates. The choice of method and operating point depends on application and speed/performance tradeoffs.
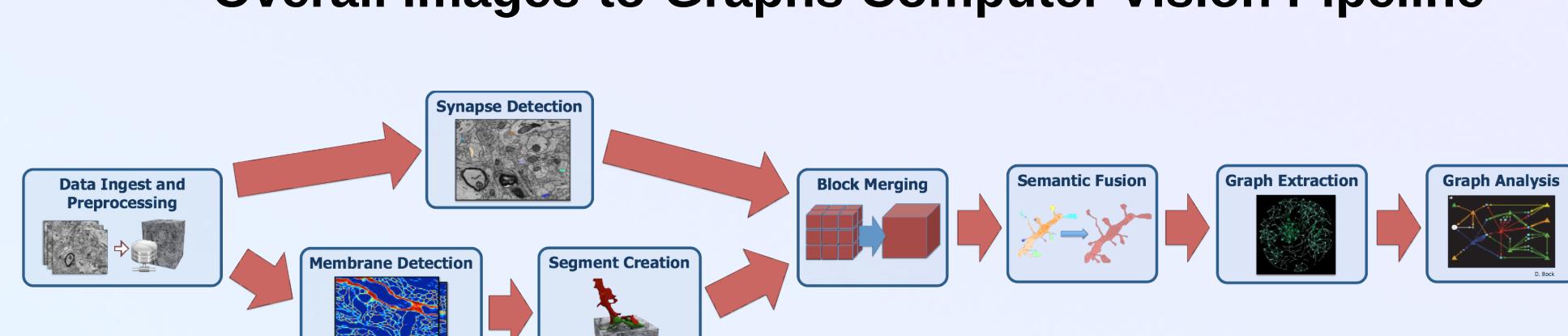
Visualization of large scale synapse detection results; we found a total of 50,000 putative synapses in our volume. An XY slice showing detected synapses is shown, and a point cloud of the synapse centroids are also visualized (inset).

Code and data are open source, and available at: openconnecto.me/vesicle

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Overall Images-to-Graphs Computer Vision Pipeline

[1] Carlos Becker, Karim Ali, Graham Knott, and Pascal Fua. Learning context cues for synapse segmentation. IEEE Transactions on Medical Imaging, 32(10):1864–1877, 2013. ISSN 02780062. doi: 10.1109/TMI.2013.2267747.
[2] William Gray Roncal, Dean M Kleissas, Joshua T Vogelstein, Priya Manavalan, Kunal Lillaney, Michael Pekala, Randal Burns, R Jacob Vogelstein, Carey E Priebe, Mark A Chevillet, and Gregory D Hager. An Automated Images-to-Graphs Framework for High Resolution Connectomics. Frontiers in neuroinformatics 2015, pages 1–13.
[3] DC Dan Ciresan, Alessandro Giusti, Luca M LM Gambardella, and Jürgen Schmidhu- ber. Deep neural networks segment neuronal membranes in electron microscopy im- ages. In Advances in neural information processing systems, pages 2843–2851, 2012.
[4] Davi Bock, Wei-chung Allen Lee, Aaron M Kerlin, Mark L Andermann, Greg Hood, Arthur W Wetzel, Sergey Yurgenson, Edward R Soucy, Hyon Suk Kim, and R Clay Reid. Network anatomy and in vivo physiology of visual cortical neurons. Nature, 471 (7337):177–182, 2011. ISSN 0028-0836. doi: 10.1038/nature09802.