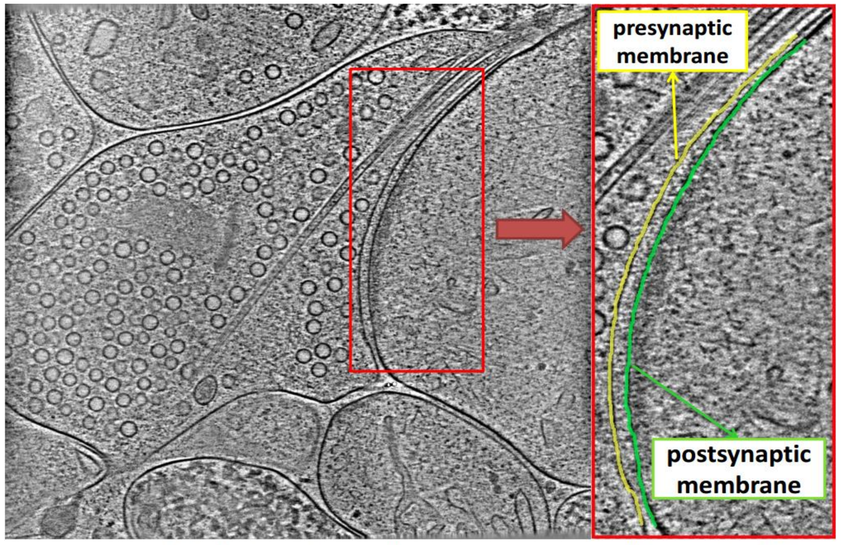
Accurate Segmentation of Synaptic Cleft with Contour Growing Concatenated with A ConvNet

Shaobo Min, **Xuejin Chen***, Hongtao Xie, Zheng-Jun Zha, Guoqiang Bi, Feng Wu, Yongdong Zhang
National Engineering Laboratory for Brain-inspired Intelligence Technology and Application

Introduction

Electron micrographs are obtained by electron tomography, which can visualize the native environment of neurons.

Our target is to localize the synaptic cleft regions, which play an important role in neurotransmission.

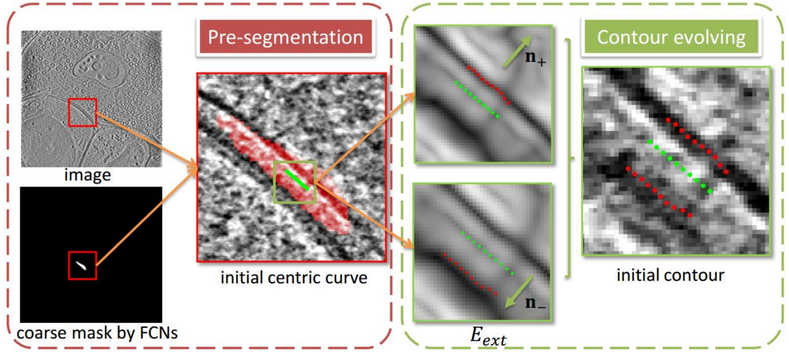


(a) electron micrograph (b) synaptic cleft

Key Contributions

- We propose an effective framework to accurately segment synaptic cleft regions in electron micrographs;
- A novel updating strategy of active contours is developed, which is more robust and effective for accurate extraction of synaptic cleft regions.

Proposed Algorithm



Pipeline:

- A FCN-style network provides a coarse segmentation mask, which gives an initial curve (green line) for evolving.
- The initial curve is respectively evolved along two opposite directions to trace boundaries for the two membranes.
- Two curves synchronously grow to localize the whole synaptic cleft region (encircled by the red solid curves).

Curve Evolving:

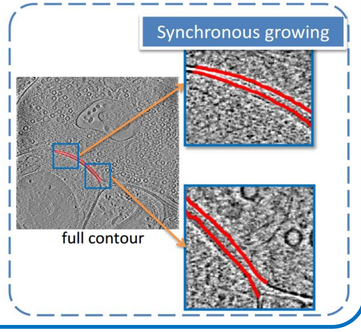
$$x_{t+1} = (A + \gamma I)^{-1}(x_t + E_{ext}(x_t, y_t)n_x)$$
$$y_{t+1} = (A + \gamma I)^{-1}(y_t + E_{ext}(x_t, y_t)n_y)$$

A is the pentadiagonal matrix, E_{ext} is gradient vector flow filed, and (n_x, n_y) are the normal.

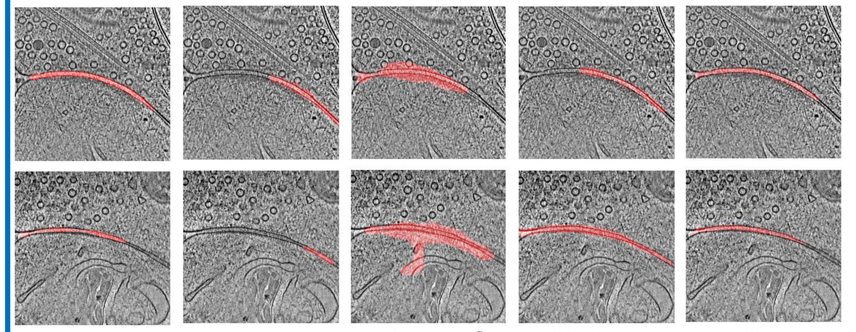
Synchronous Growing:

We formulate the growing process as iteratively searching a piece of line of length l and unit vector v_l:

$$\underset{l,v_i}{\operatorname{argmin}} \sum_{i=0}^{l} E_{ext}(iv_l + q) - \rho v_q \cdot v_l$$
$$s.t. \;\; v_q \cdot v_l > \tau$$



Experiments



Results produced by state-of-the-art segmentations methods and our model. The red regions in input images are the ground truth, while the others are predicted target regions.

Methods	Pixel Accu.	mean IOU
Contour Growing+FCN	0.9956	0.6339
Contour Growing+U-net	0.9962	0.7720
Contour Growing+DeepLab	**0.9974**	**0.7848**
Contour Growing+PSPNet	0.9961	0.7683

Comparing segmentation results with state-of-the-art methods.

Methods	Pixel Accu.	mean IOU
FCN [11]	0.9923	0.5258
U-net [17]	0.9939	0.6359
DeepLab [18]	0.9951	0.7164
PSPNet [19]	0.9949	0.7195
FCN+GVF	0.9724	0.6145
FCN+balloon	0.9794	0.6345
FCN+CG (ours)	**0.9974**	**0.7848**

Contour growing with various pre-segmentations.

Conclusion

We propose a two-step method for extracting synaptic cleft regions in cryo-electron tomography. With the initial curves from an FCN, we design a contour growing algorithm to localize the accurate contours by curve evolving and growing. Instead of GVF, the proposed updating strategy for contour evolving is more robust.