Probabilistic Synapse Detection in Array Tomography

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Challenge

- Unsupervised automatic detection of specific synaptic subtypes with confidence values using array tomography data

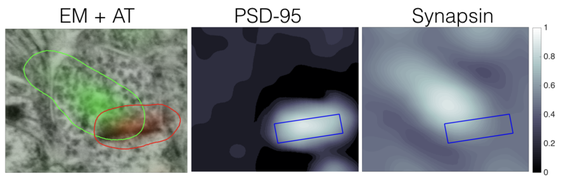


Figure 1: Left: PSD-95 (red) and Synapsin (green) data overlaid on EM data. Center: PSD-95 IF image. Right: Synapsin IF image. Synaptic cleft marked in blue.

Background

- **What is a Synapse?**

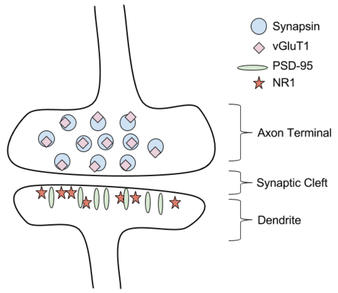


Figure 2: Molecular architecture of a excitatory PSD-95 expressing synapse depicted in a simplified cartoon form

- **Array Tomography (AT) Pipeline**

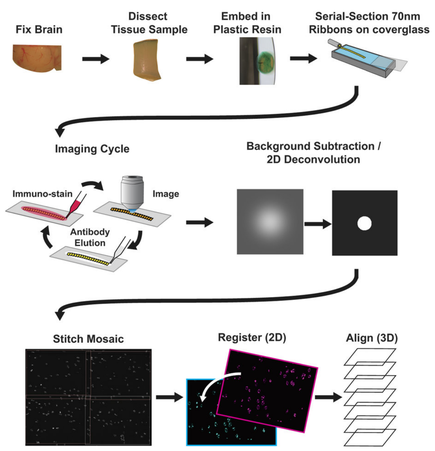
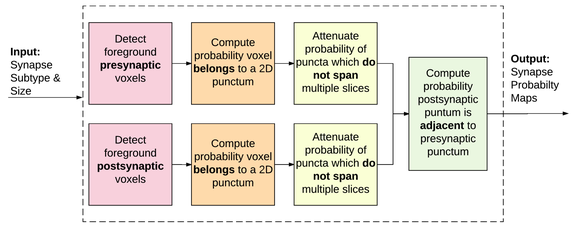


Figure 3: Array Tomography Methodology [6]

Action

- **Overview of Proposed Method**



- **Step 1: Foreground Probability**

$$p_B(x,y,z) = \frac{1}{\sigma_B\sqrt{2\pi}} \int_{v(x,y,z)}^{\infty} e^{\frac{-(t-\mu_B)^2}{2\sigma_B^2}} dt. \quad (1)$$

$$p_F(x,y,z) = 1 - p_B(x,y,z). \quad (2)$$

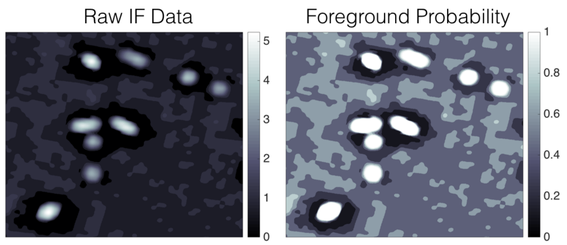


Figure 4: (Left) Logarithm of the IF raw data. (Right) Foreground probability map. Slices of the PSD-95 antibody of size 5.268×5.827 μm.

- **Step 2: 2D Puncta Probability.**

$$p_P(x,y,z) = \prod_{i=x-W}^{x+W} \prod_{j=y-W}^{y+W} p_F(i,j,z), \quad (3)$$

W is the expected size of a punctum.

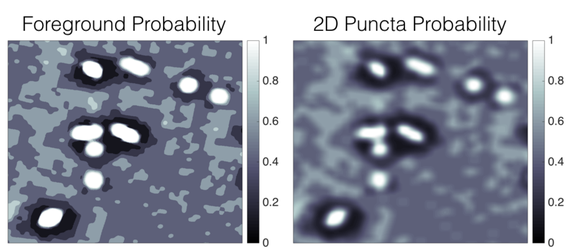


Figure 5: (Left) Probability map. (Right) Probability map of each pixel belonging to a 2D punctum.

- **Step 3: 3D Puncta Probability**

$$f(x,y,z) = \exp\left\{ -\sum_{j=j_{start}}^{j=j_{end}} [p_P(x,y,z) - p_P(x,y,z+j)]^2 \right\} \quad (4)$$

$$p_{3DP}(x,y,z) = p_P(x,y,z) f(x,y,z), \quad (5)$$

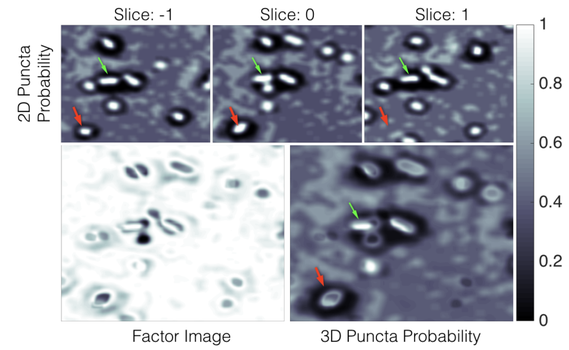


Figure 6: **Top:** Three consecutive slices of the 2D puncta probability. **Bottom:** Factor image given by Eq. (4) (left) and the corresponding 3D puncta probability (right) of the center slice in the top row. Each image is a cutout of size 2261×2501 pixels or $5.268 \times 5.827 \mu m$.

- **Step 4: Presynaptic and Postsynaptic Puncta Adjacency.**

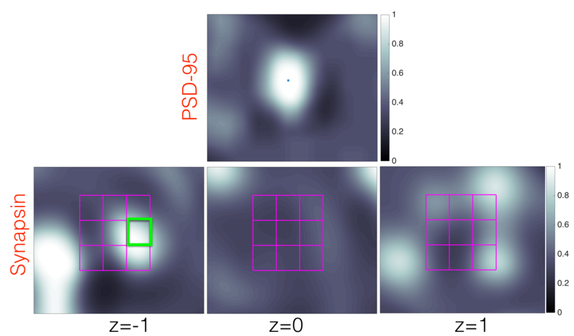


Figure 7: **First row:** cutout of PSD-95 Punctum with center pixel highlighted. **Second row:** synapsin cutouts with the search grid overlaid.

Resolution

- **Result:**

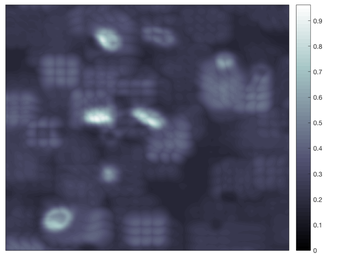


Figure 8: Output probability map, each pixel's intensity value represents to the probability of it belonging to a synapse.

	Excitatory				Inhibitory			
	EM		IF		EM		IF	
Dataset	Precision	Recall	Precision	Recall	Precision	Recall	Precision	Recall
KDM-SYN-120905	0.88	0.91	0.90	0.93	-	-	-	-
KDM-SYN-140115	0.92	0.94	0.93	0.95	0.82	0.81	0.91	0.91

Figure 9: Precision and recall values on conjugate array tomography data

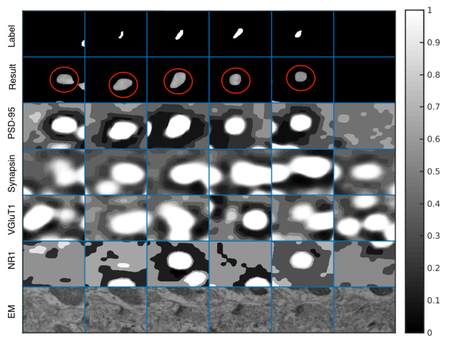


Figure 10: Synaptogram showing IF data for an EM identified synapse. Each 'block' is $1.221\mu m \times 1.233\mu m$.

Acknowledgments

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