Segmentation subject to Stitching Constraints: Finding Many Small Structures in a Large Image

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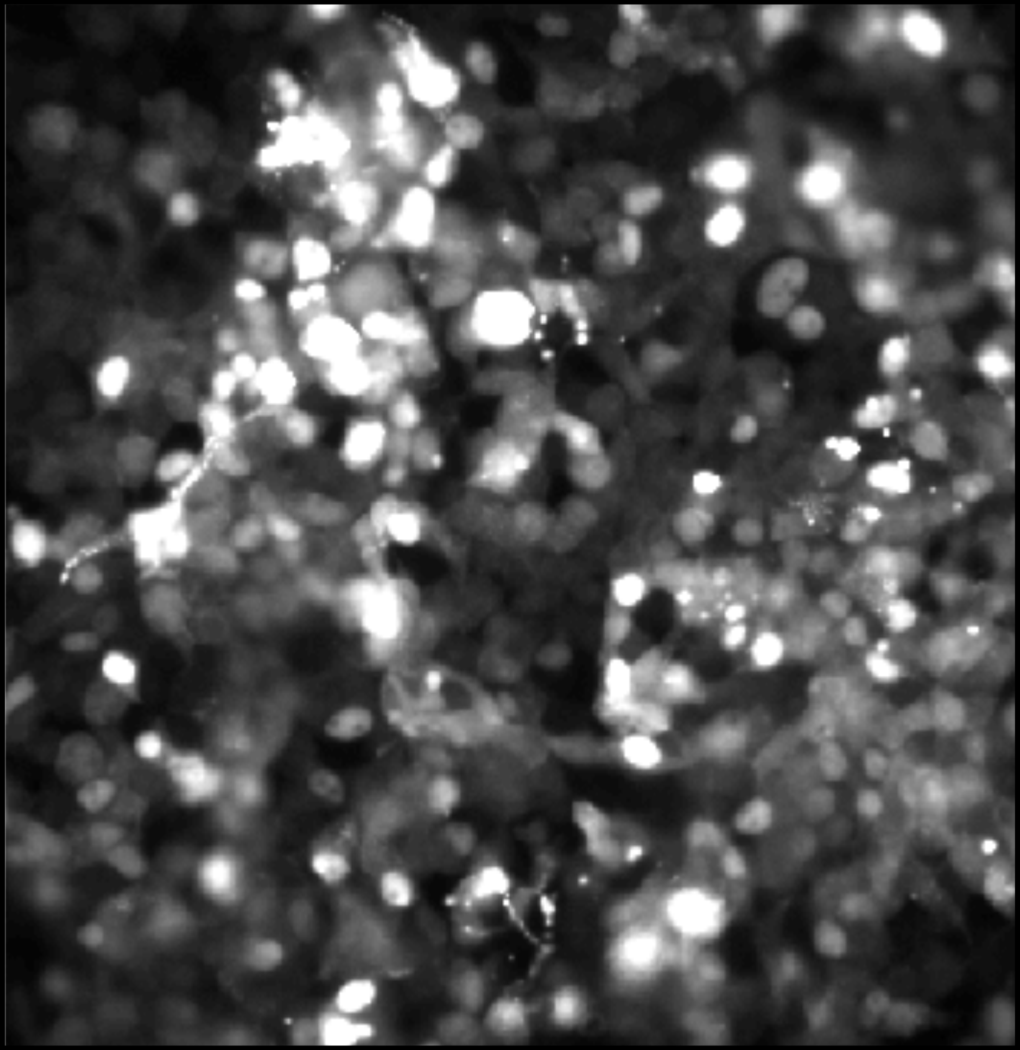
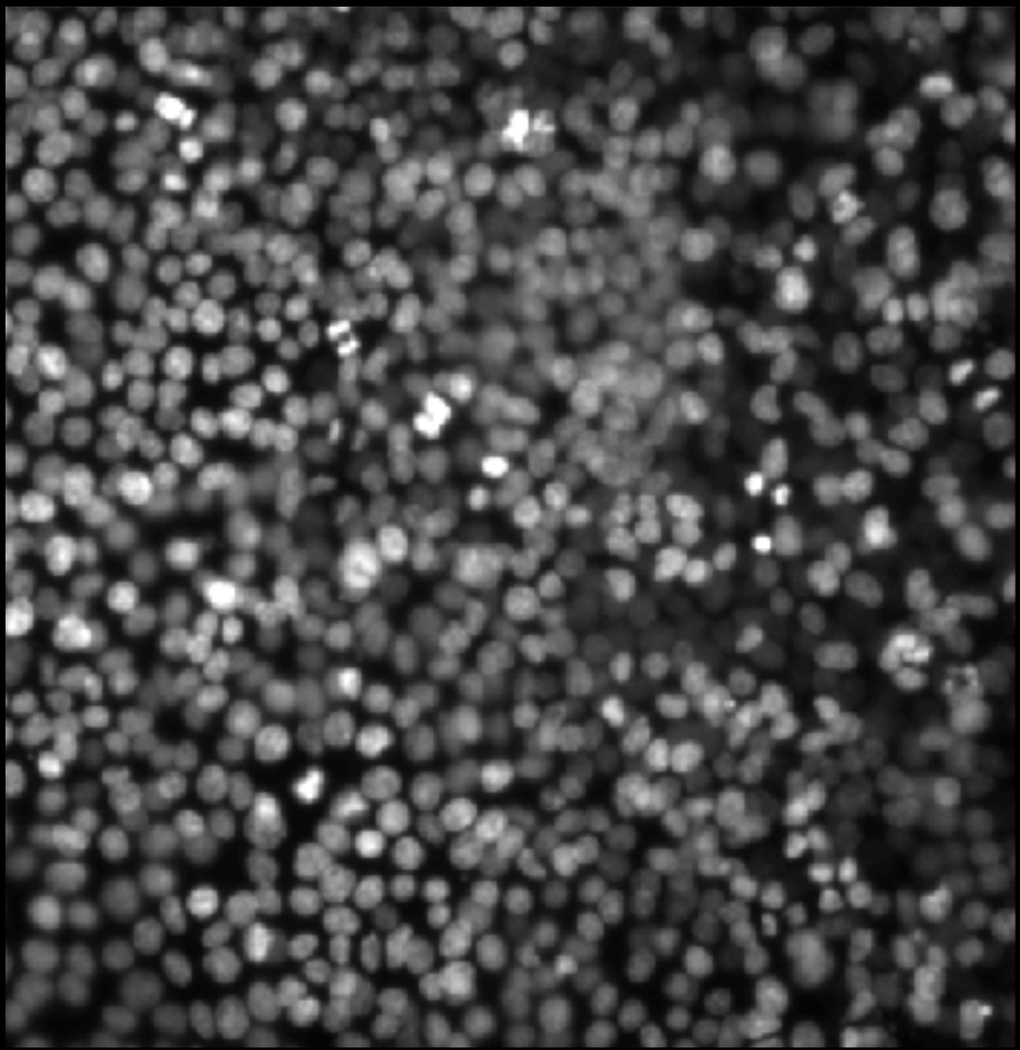
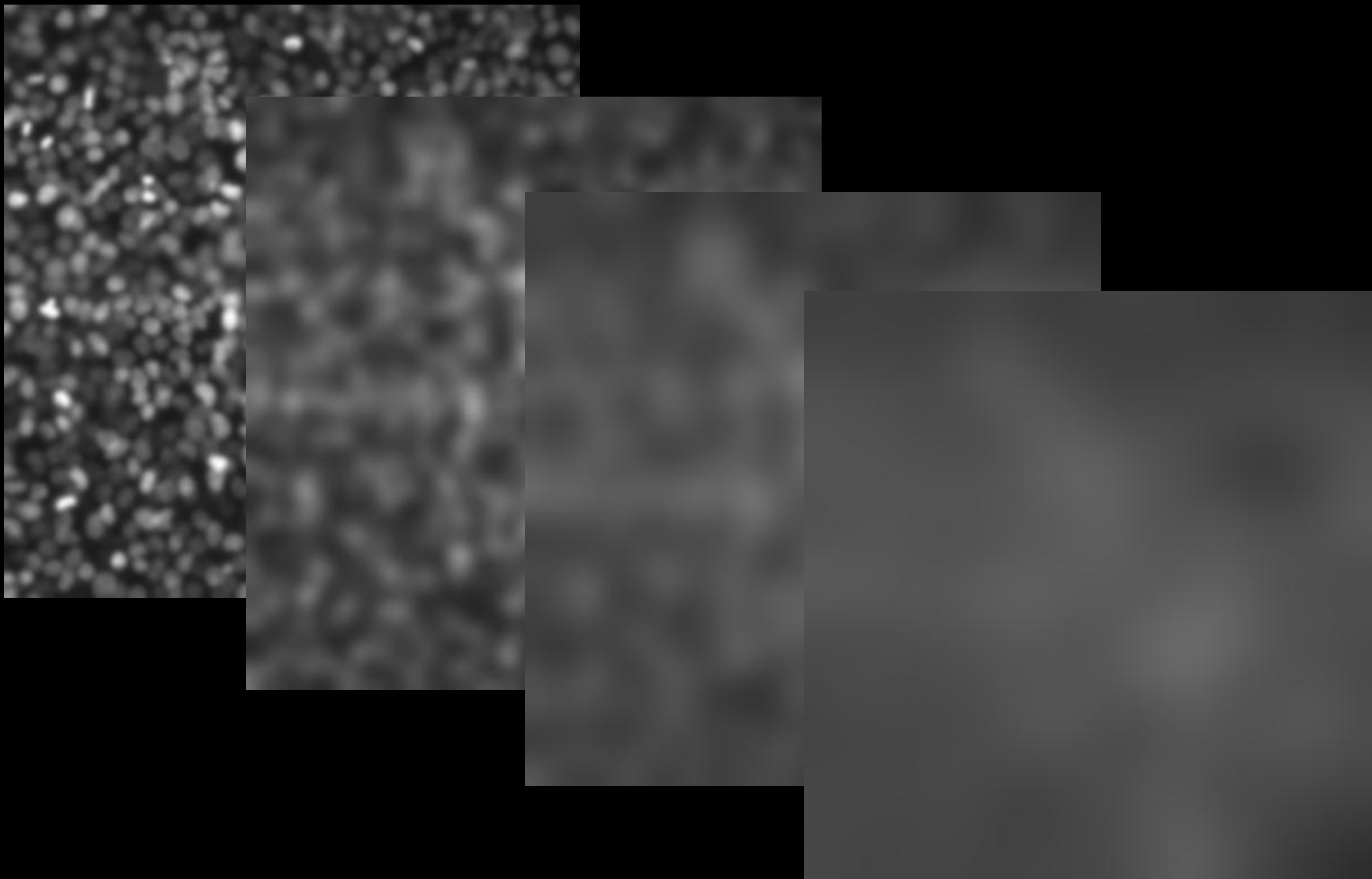
Goal: Segment Many Small Regions in a Large Image



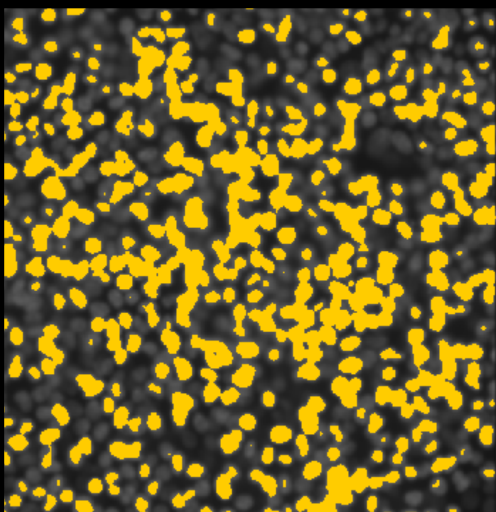


[Image Courtesy: Nisha Sosale at UPenn]

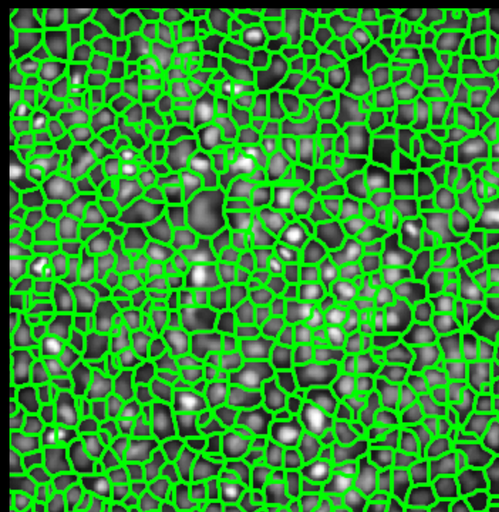
Dilemma: Segmentation Complexity vs. Granularity



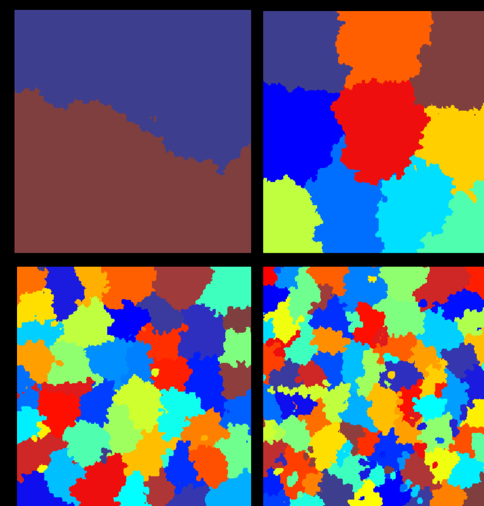
Challenge: Efficiency vs. Robustness



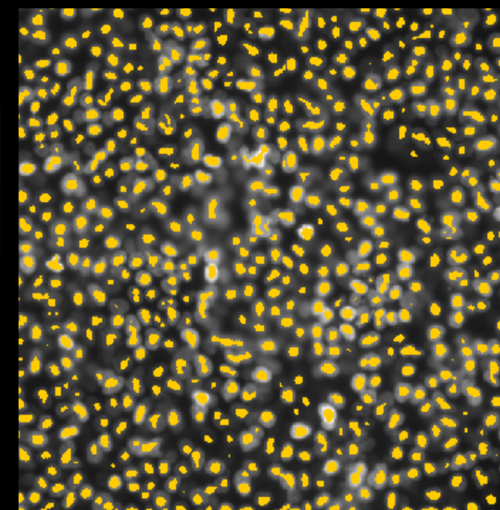
K-means



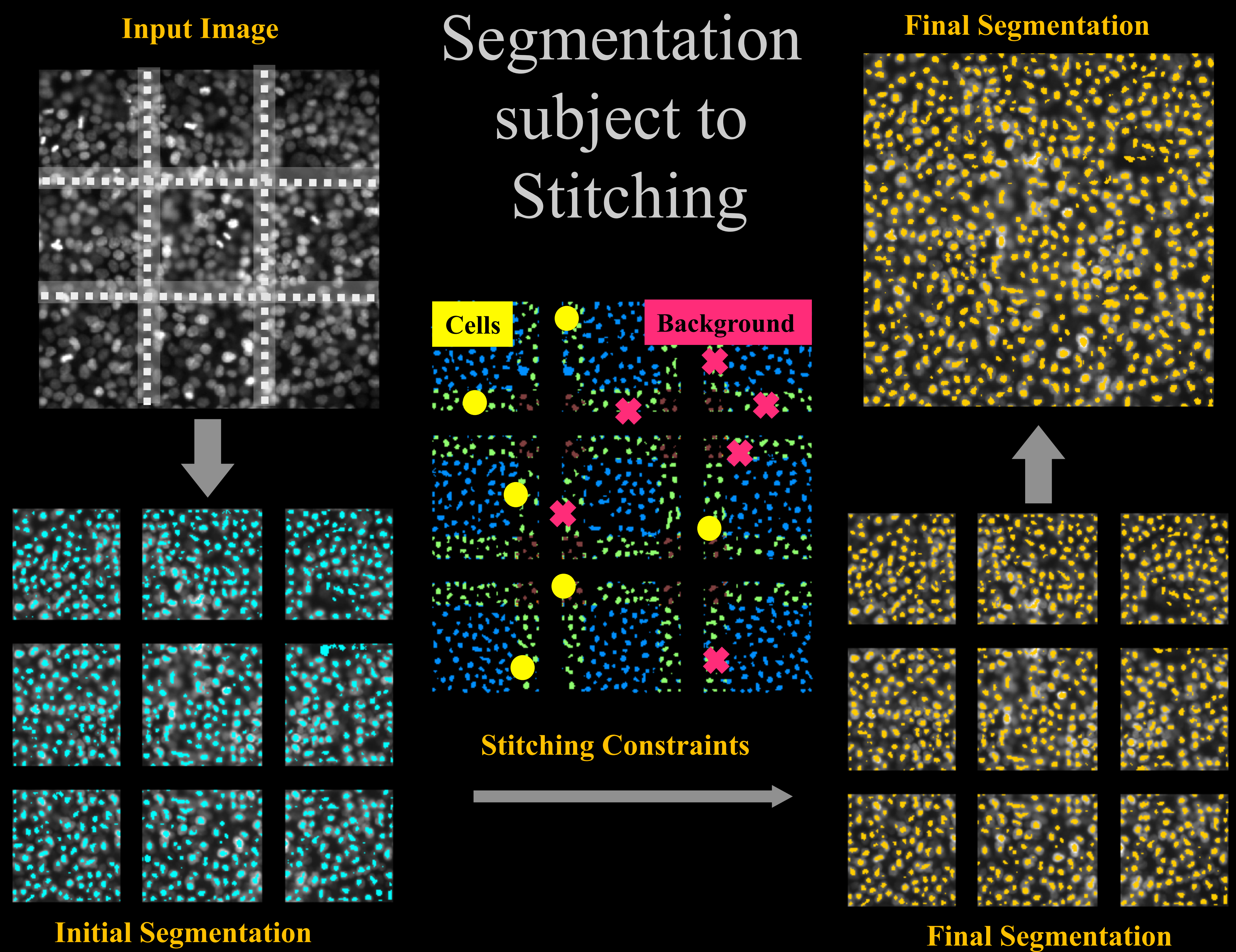
Watershed



Normalized Cuts

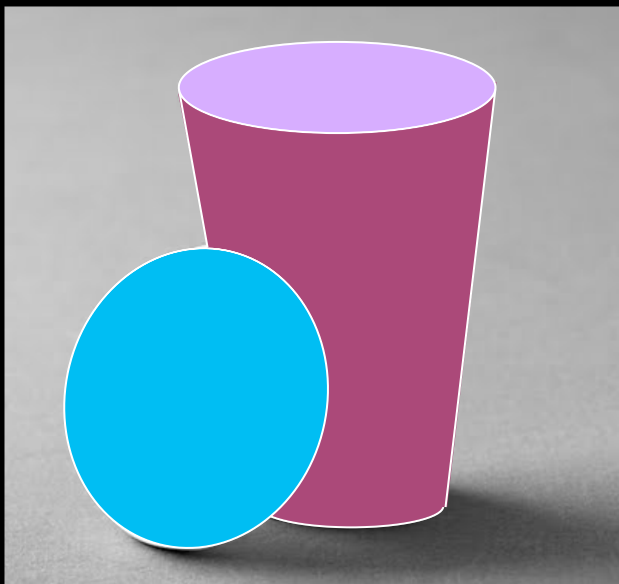


Our Result

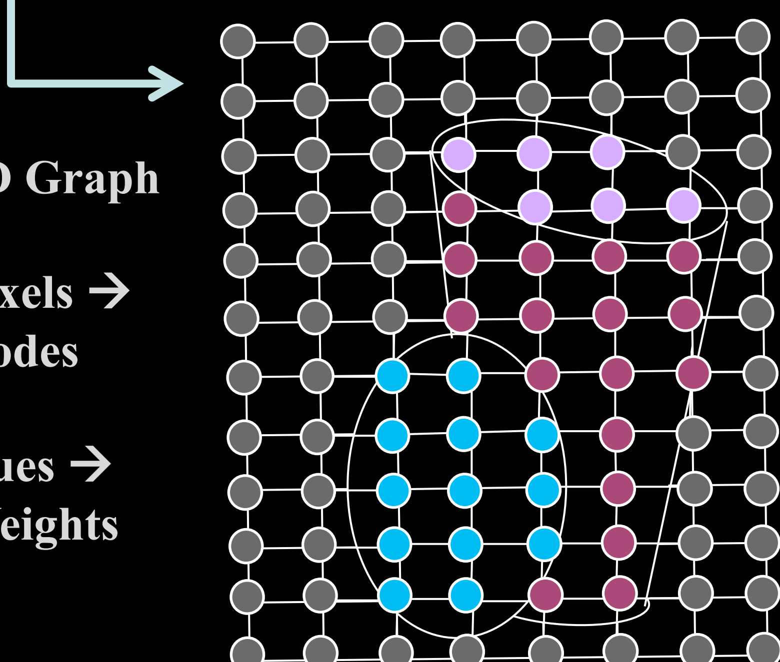


Input Image
Segmentation subject to Stitching
Final Segmentation
Cells
Background
Stitching Constraints
Initial Segmentation
Final Segmentation

Spectral-Graph Partitioning by Normalized Cuts



$$G^{region} = < V^{region}, W^{region} >$$



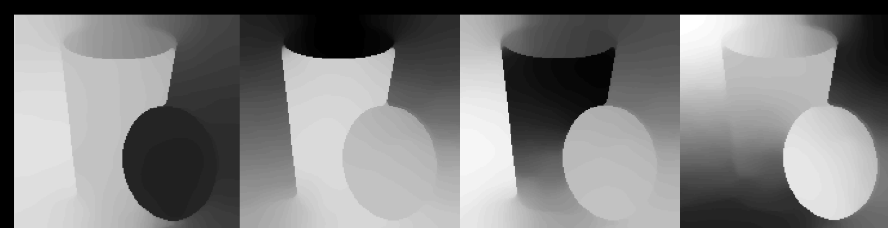
2D Graph

Pixels → Nodes

Cues → Weights

Partition graph so that similarity within group is large and similarity between groups is small

Optimal solution given by the eigenvector of (W, D)



[Shi, Malik '97]

Constrained Segmentation with Two Kinds of Cues

$$\max \varepsilon = \frac{\text{within-group similarity}}{\text{total degree of similarity}} + \frac{\text{between-group dissimilarity}}{\text{total degree of dissimilarity}}$$

maximize $\quad \varepsilon(X) = \sum_{g=1}^{2} \frac{\boxed{X_g^T W X_g}}{X_g^T D X_g}$

subject to $\quad \boxed{X \in \{0,1\}^{n\times 2}, X 1_2 = 1_n}$

$\quad U^T X = 0$

$X = \boxed{\text{grouping indicator}}$

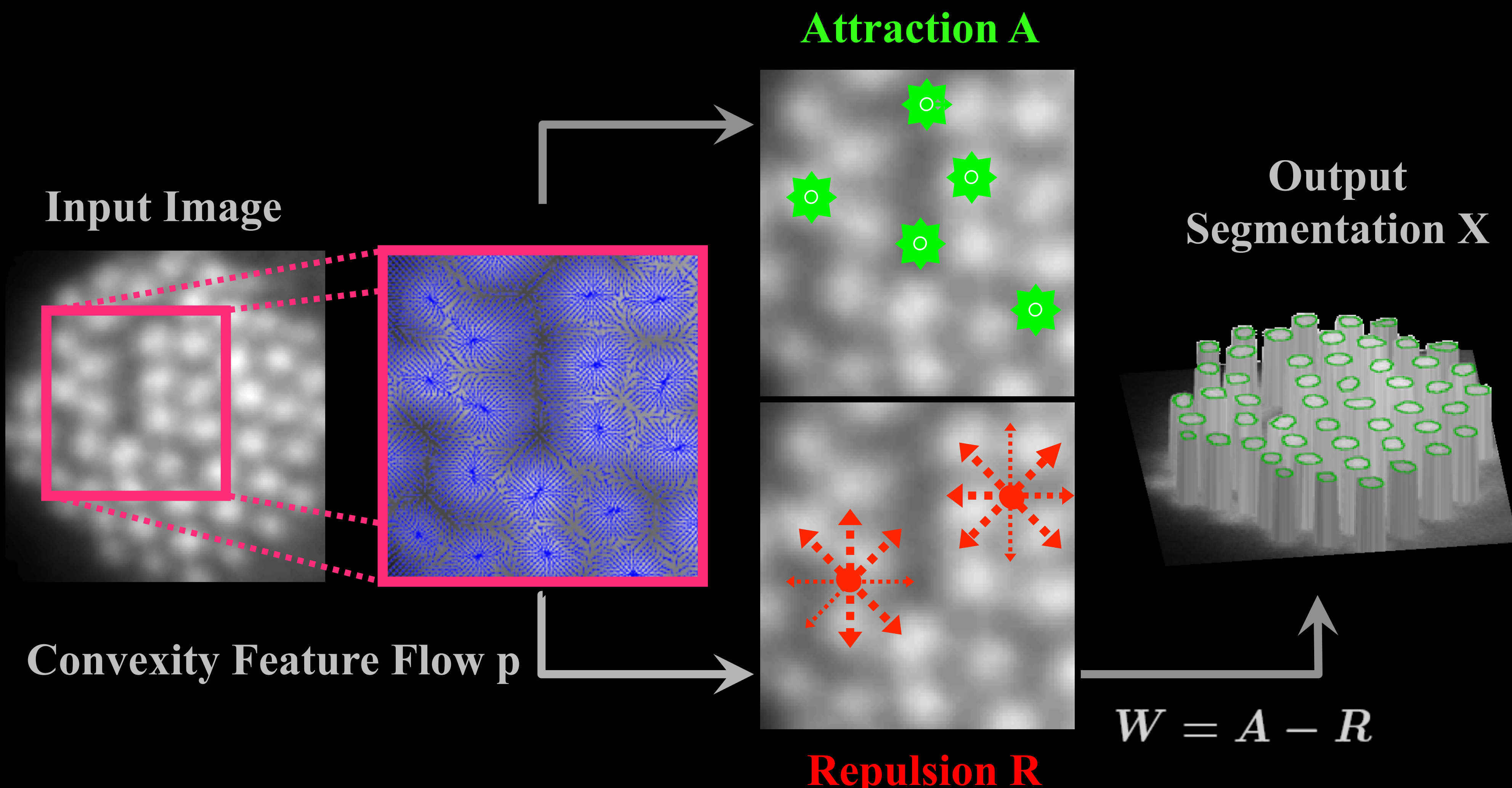
$W = \boxed{\text{weight matrix}}$

$U =$ pairwise constraint matrix

$D_W =$ diagonal *degree* matrix

$\mathbf{1}_n = \boldsymbol{n} \times \mathbf{1}$vectors of 1's

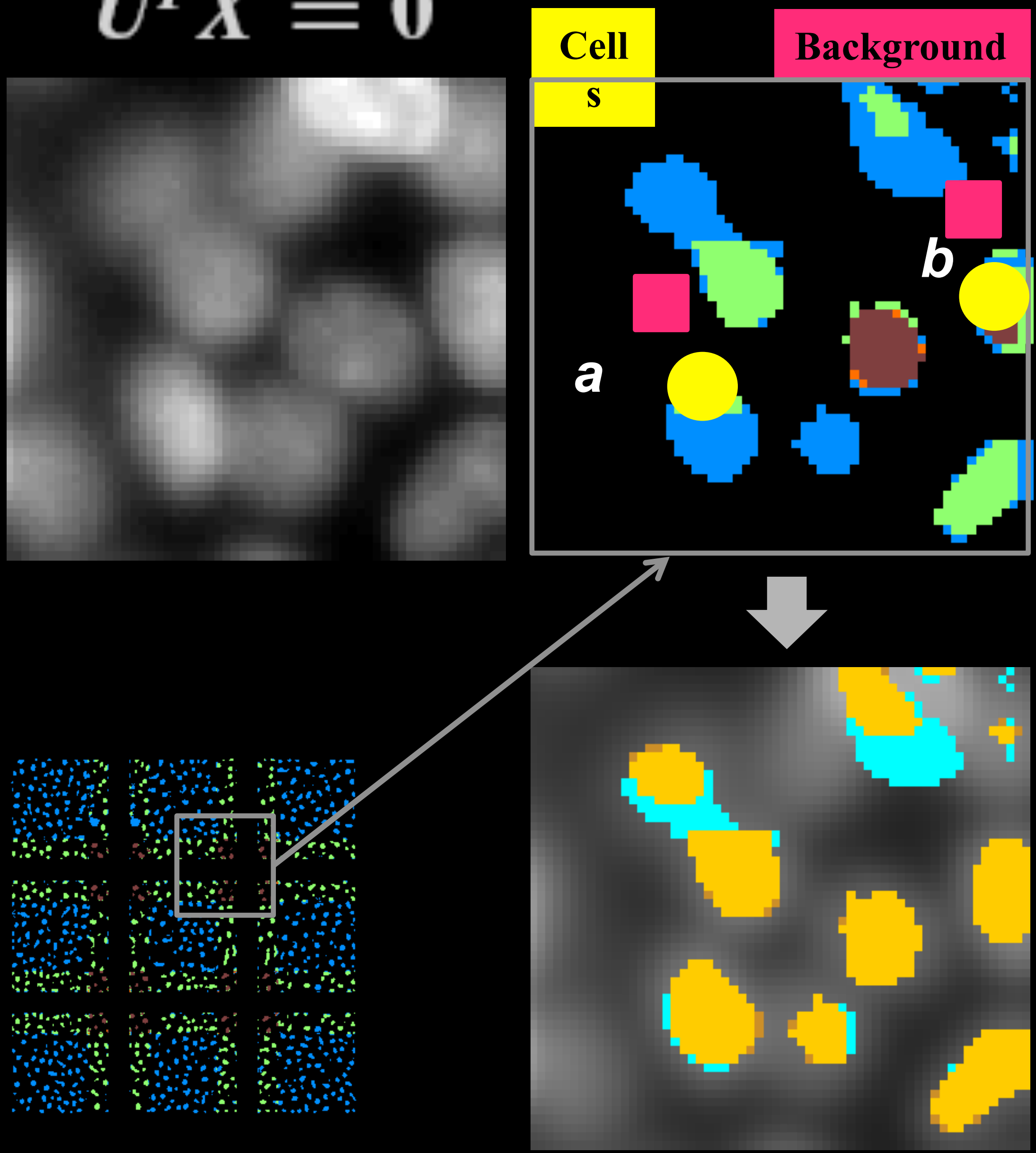
Weight W: Short-range Attraction, Long-range Repulsion



[Finding Dots, CVPR 2010]

Stitching Constraints U in the Solution Space

$$U^T X = 0$$



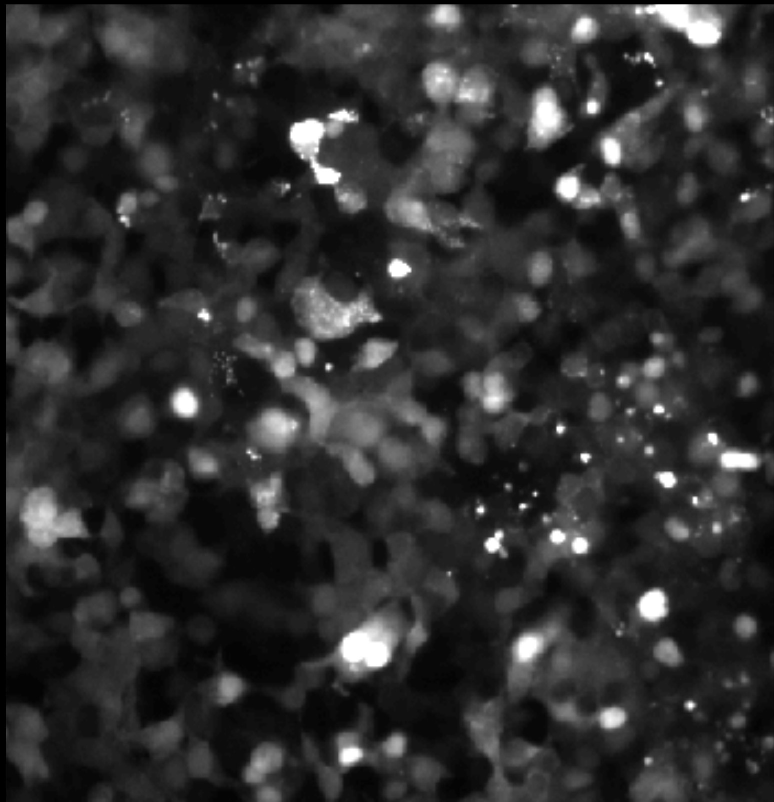
a and *b* belong to the same region

$$X(a,:) = X(b,:)$$

k-th constraint

$$U(a,k) = 1$$

$$U(b,k) = -1$$



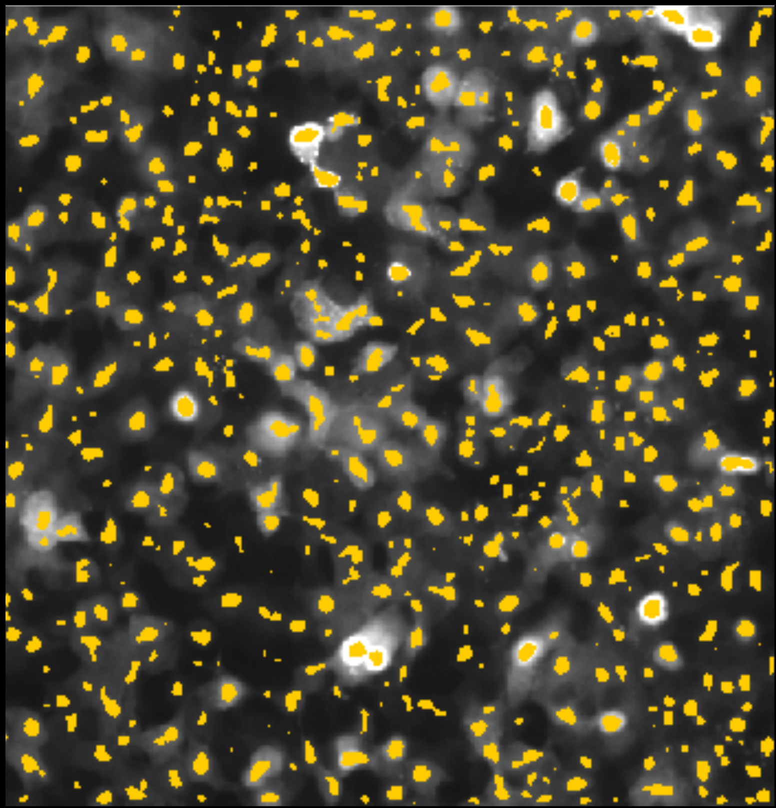
Results

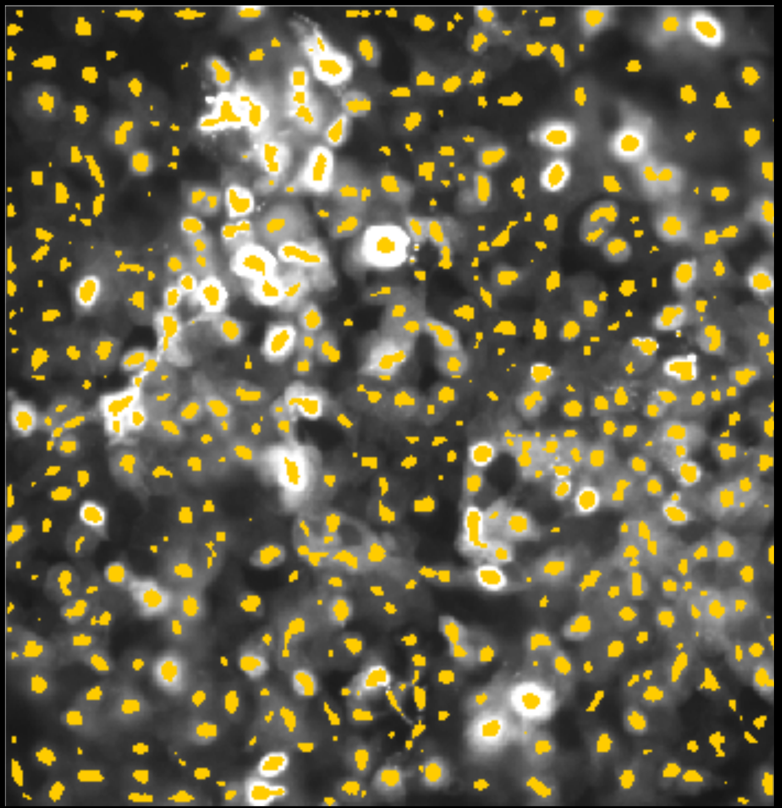
Running time = 1 s

Patch = 256 x 256

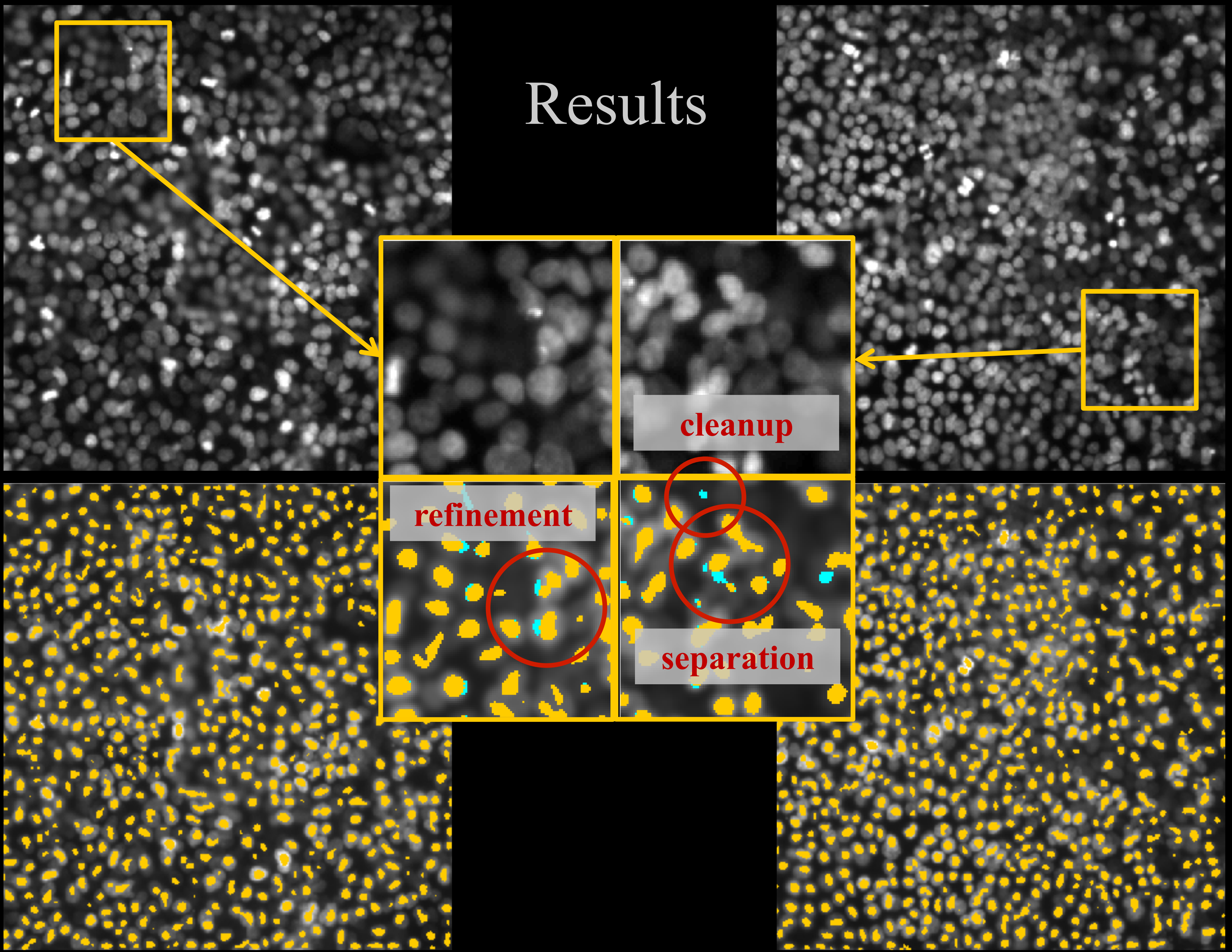
Dot = 15 x 15

Overlap = 20 pixels

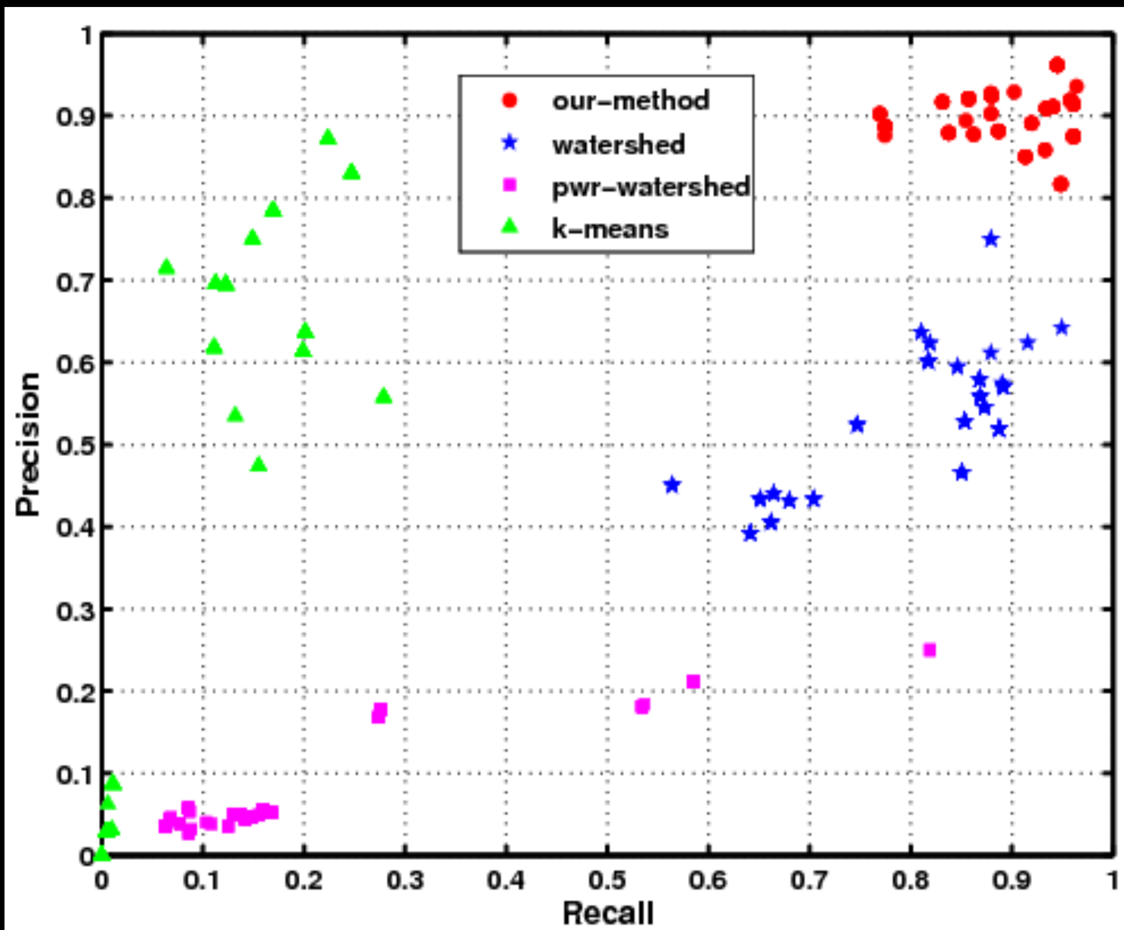




Results



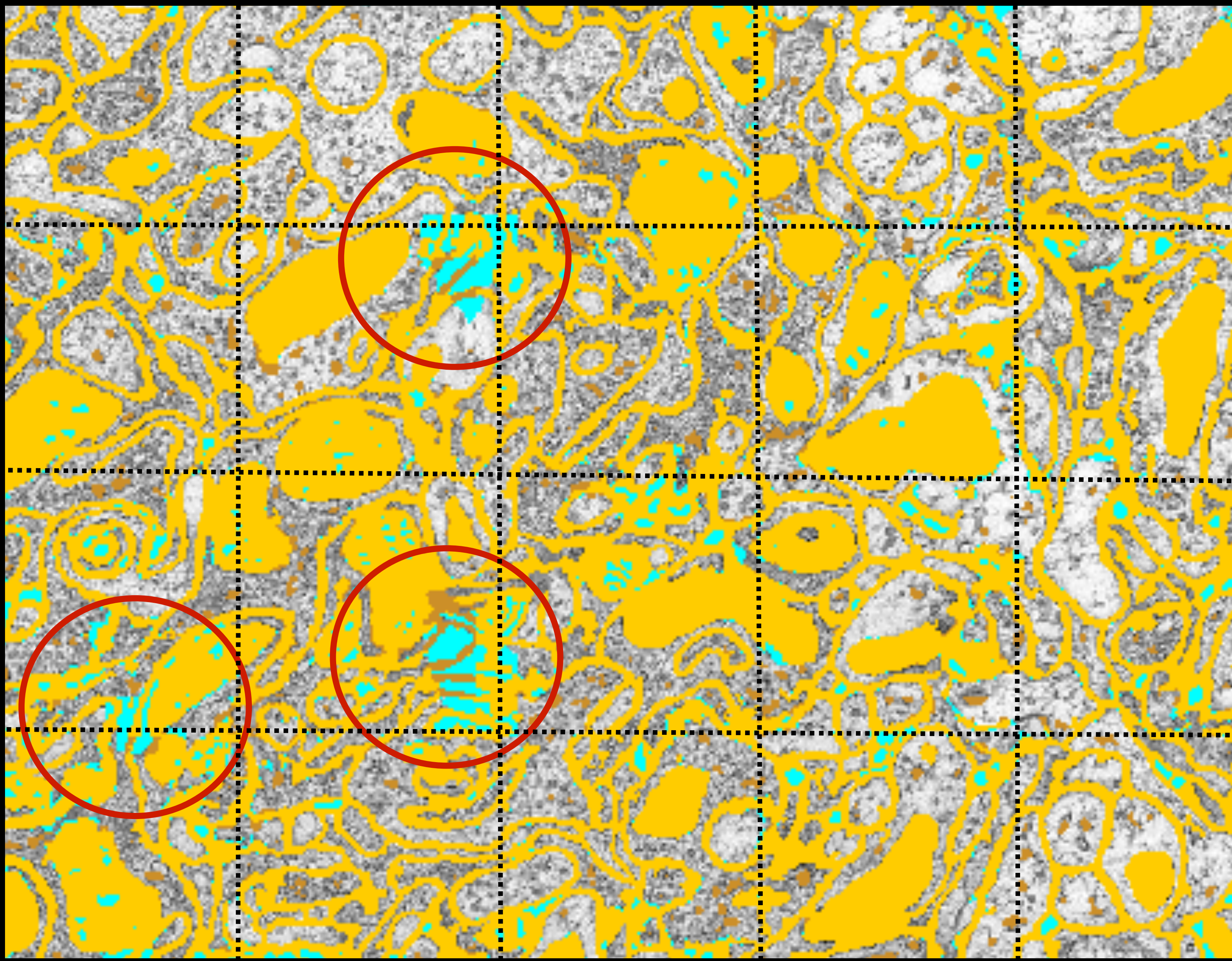
Cells Benchmark Results



Precision:
Proportion of true dots among all segments

Recall:
Proportion of segments among all the true dots

Constraint Propagation: More than Simple Stitching!



[Image Courtesy: Janelia Farm]

Conclusions

• Segmenting small/thin structures in a large image faces a scale dilemma between image size and segment size

• We resolve this in spectral graph theory by decoupling the two sizes in constrained patch segmentation

• Segmentation subject to stitching constraints goes beyond simple stitching

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