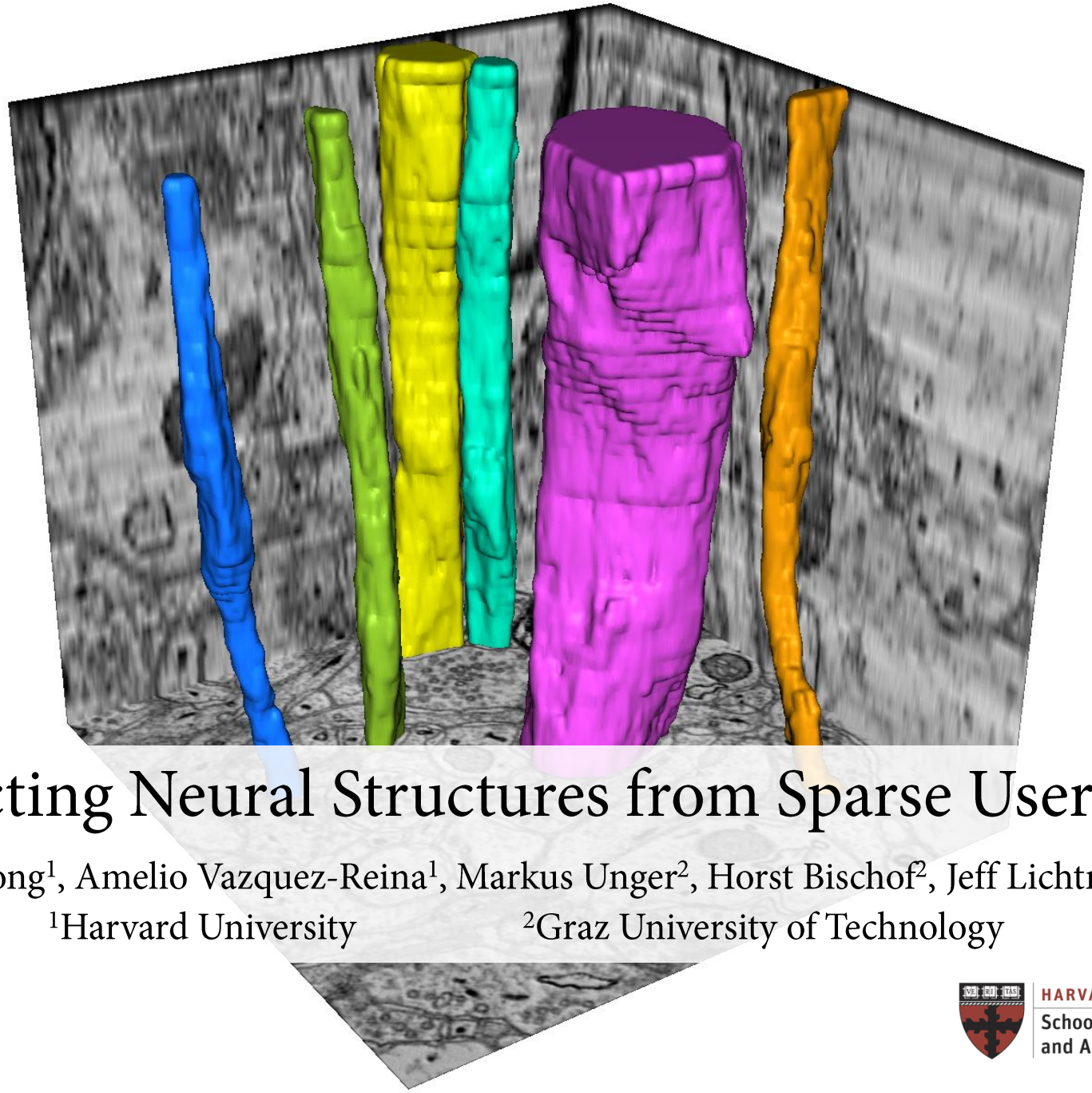


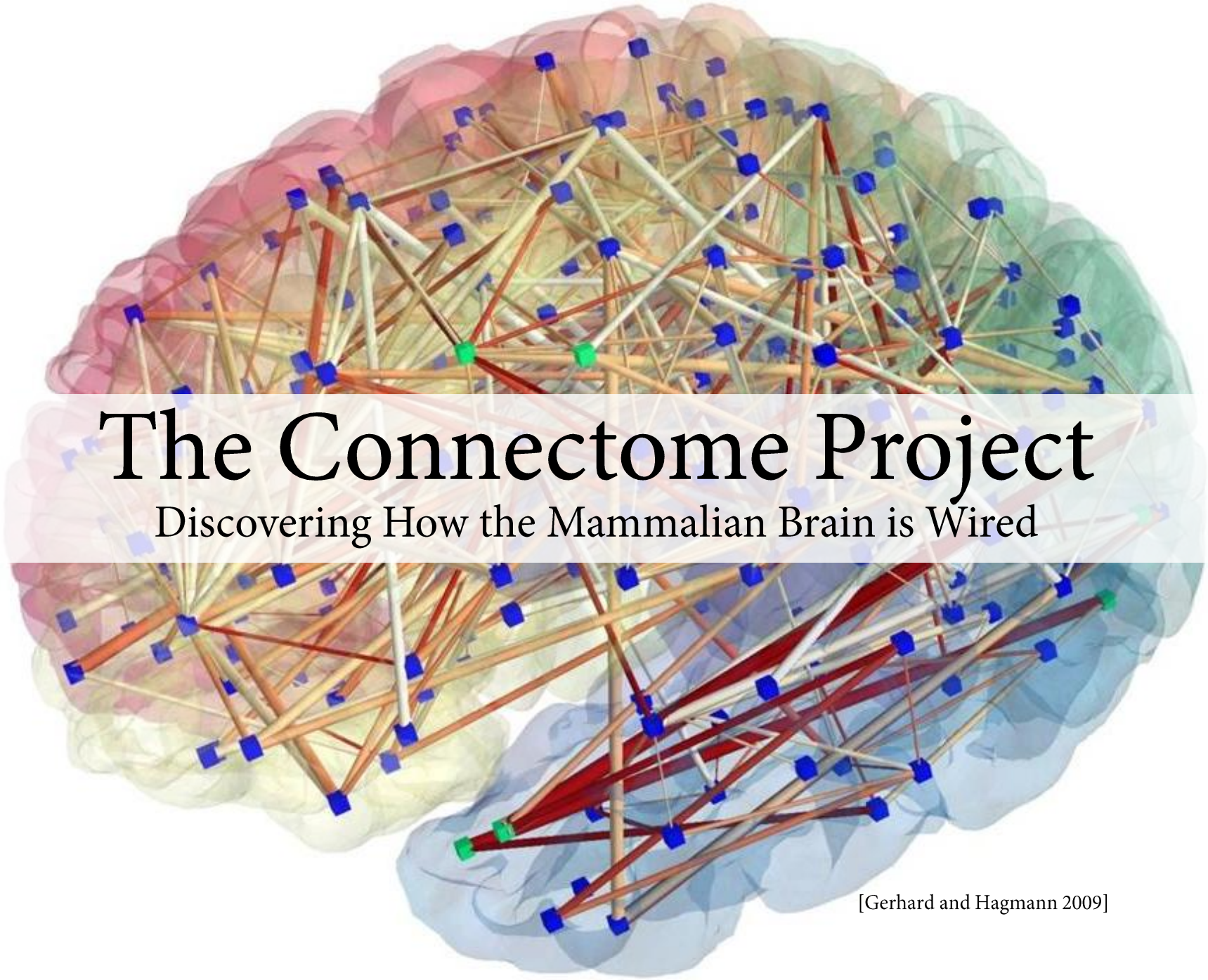
Reconstructing Neural Structures from Sparse User Scribbles

Mike Roberts[1], Won-Ki Jeong[1], Amelio Vazquez-Reina[1], Markus Unger[2], Horst Bischof[2], Jeff Lichtman[1], Hanspeter Pfister[1]

[1]Harvard University [2]Graz University of Technology

HARVARD School of Engineering and Applied Sciences

TU Graz

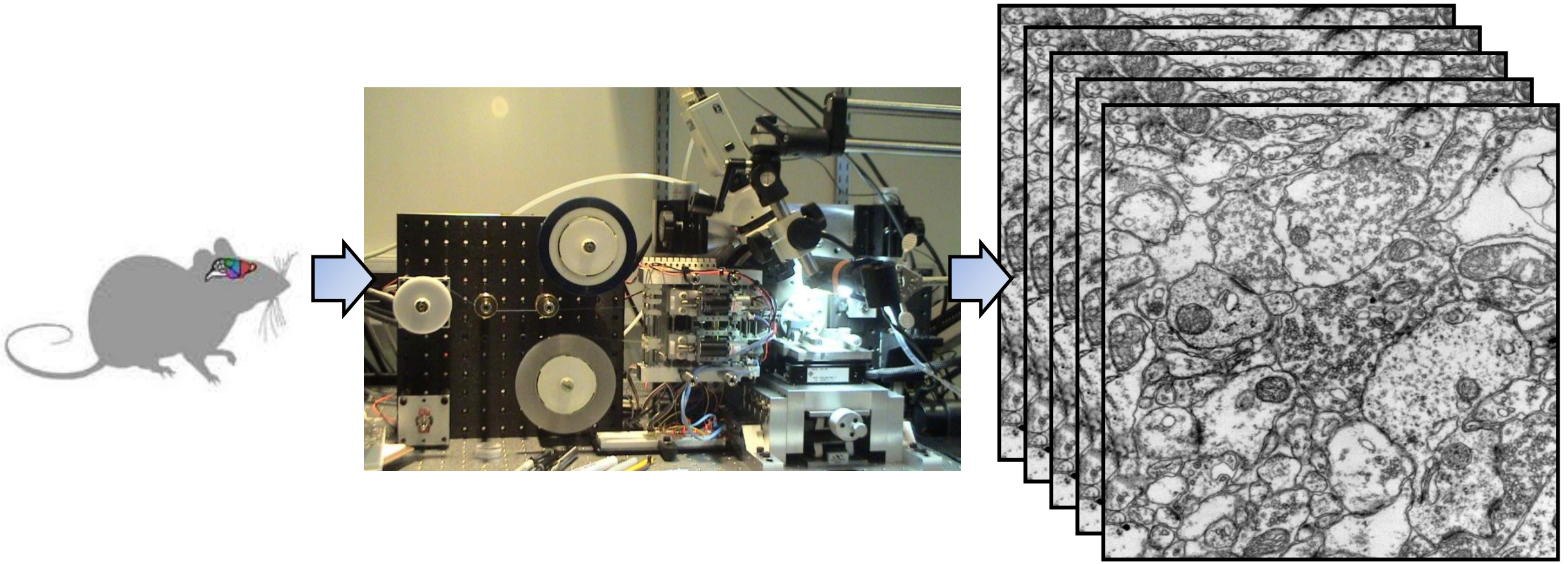


The Connectome Project

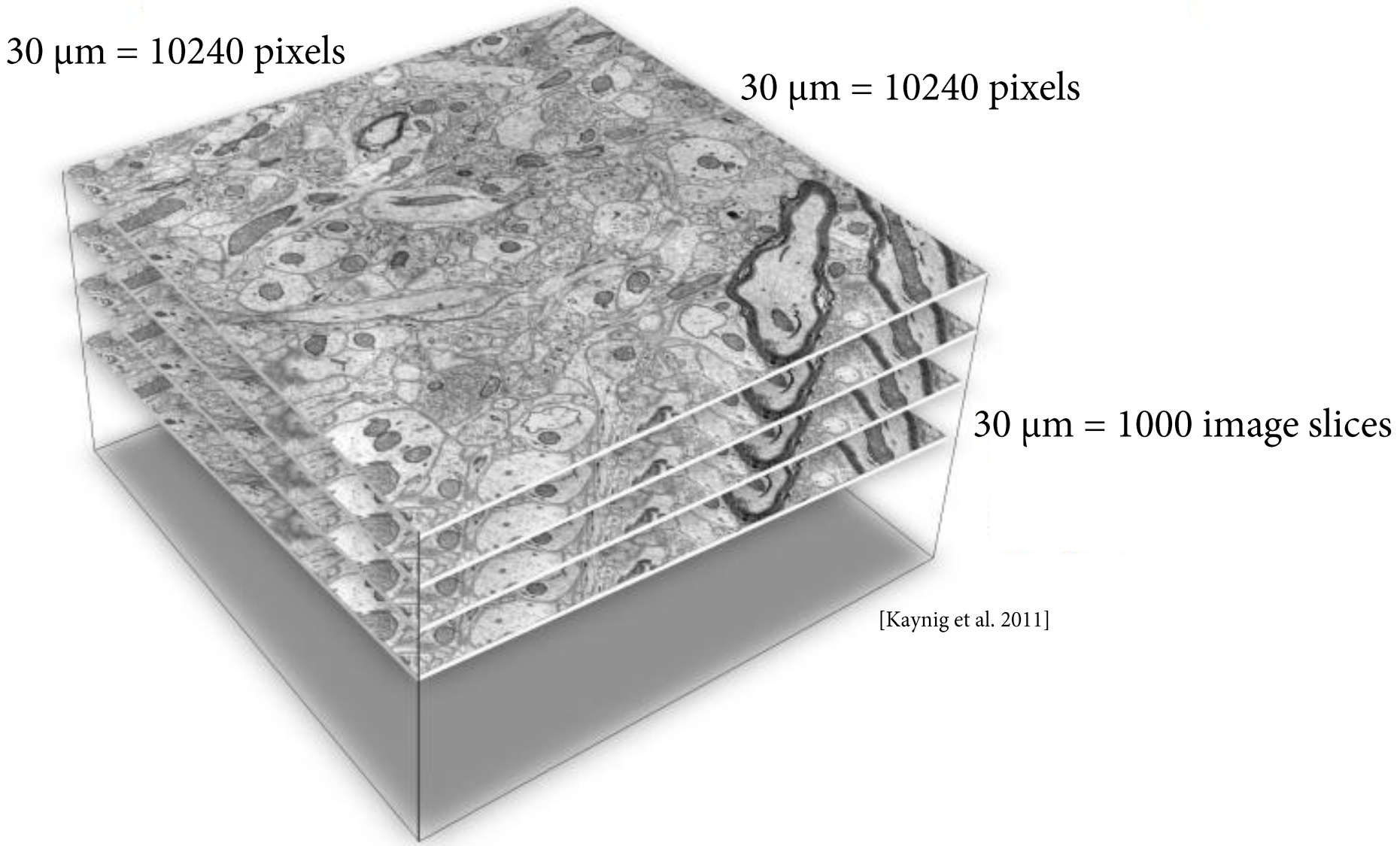
Discovering How the Mammalian Brain is Wired

[Gerhard and Hagmann 2009]

Data Acquisition

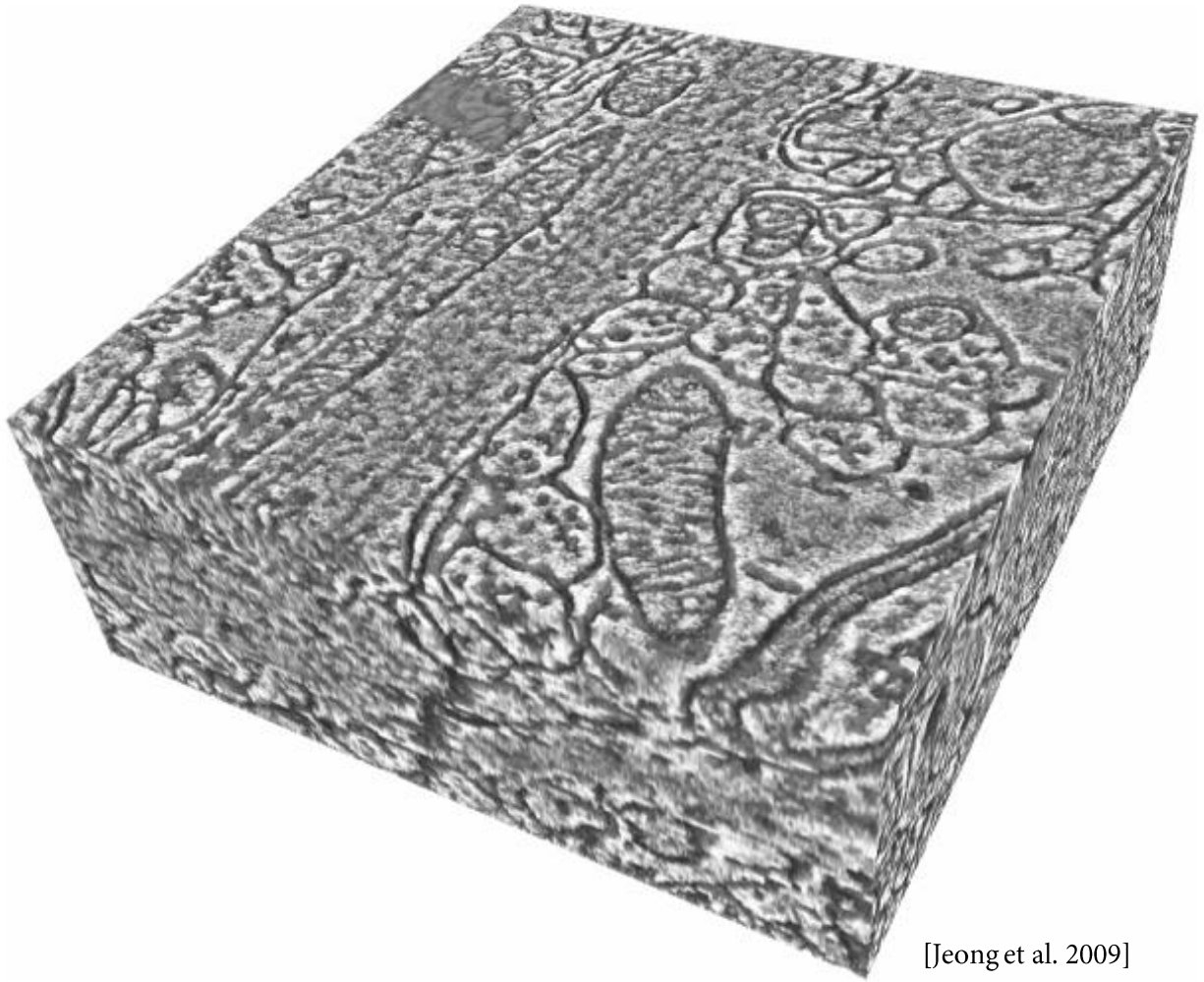


[Hayworth 2006]

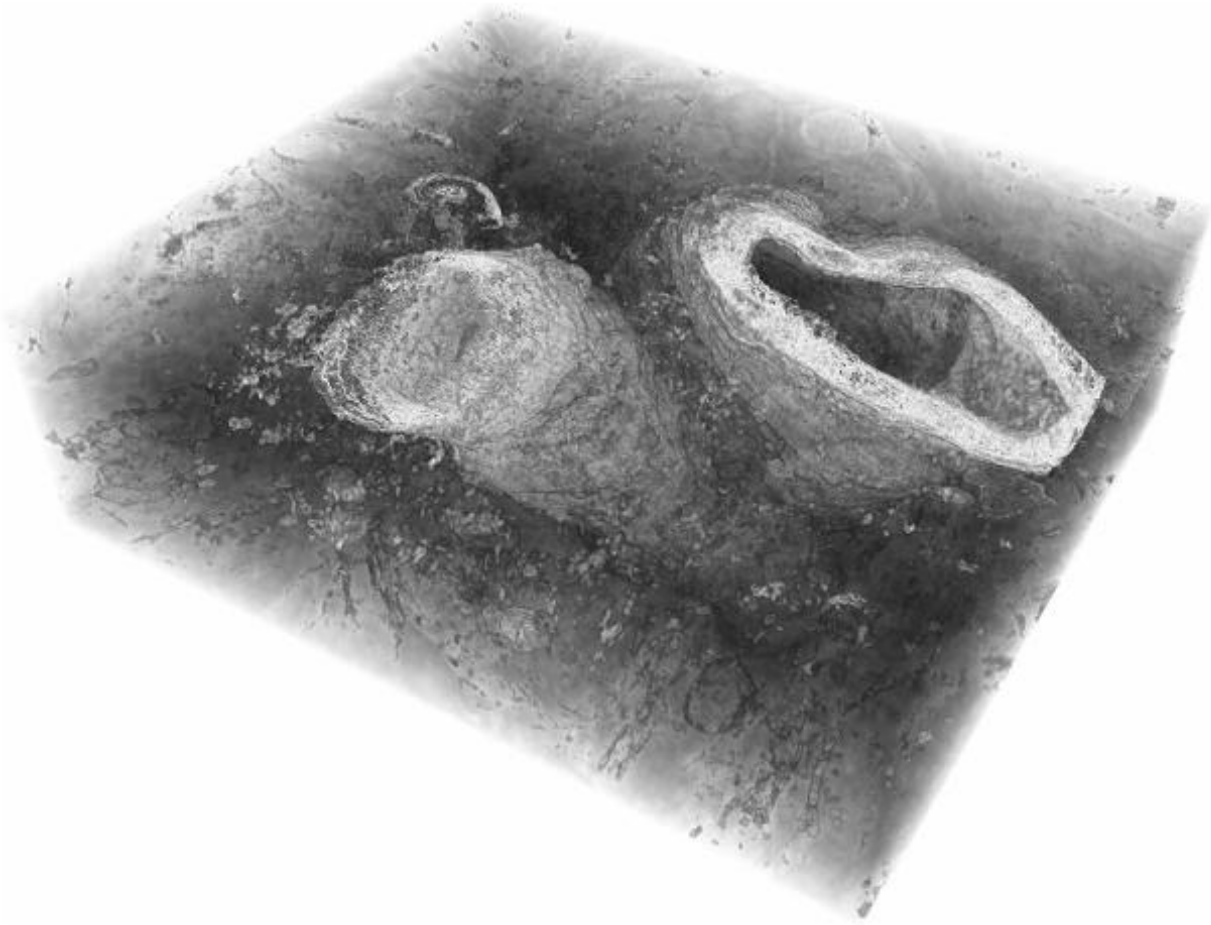


[Kaynig et al. 2011]

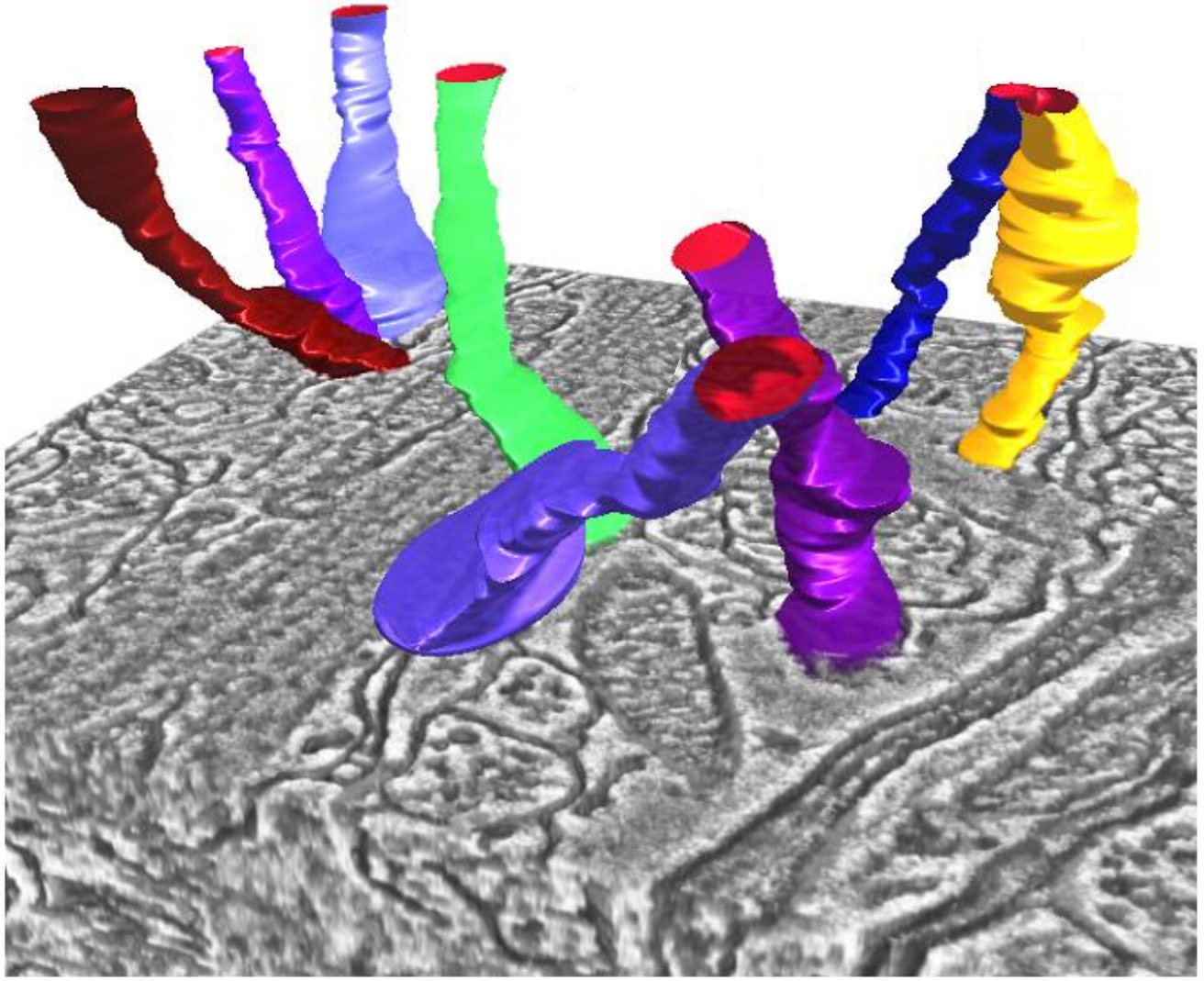
Connectome data is hard to visualize.



[Jeong et al. 2009]



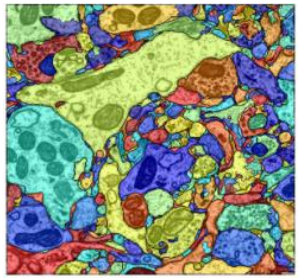
Segmentation is essential.



[Jeong et al. 2009]

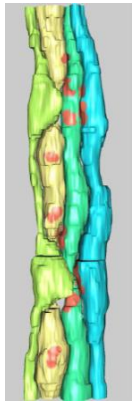
Previous Work

Fully Automatic:

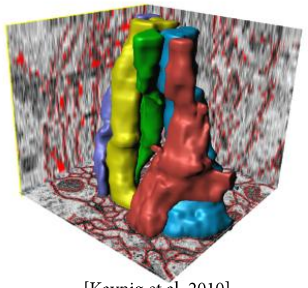


[Vazquez-Reina et al. 2011]

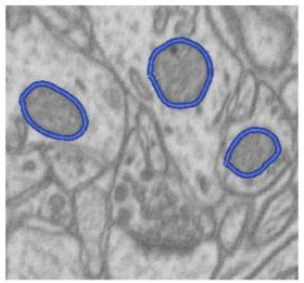
[Jain et al. 2010]



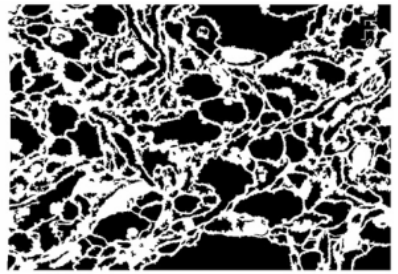
[Jurrus et al. 2010]



[Kaynig et al. 2010]



[Lucchi et al. 2010]



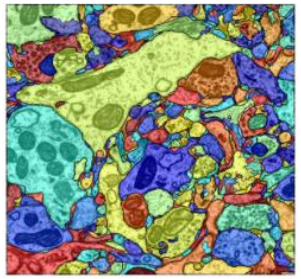
[Mishchenko et al. 2009]

[Venkataraju et al. 2009]

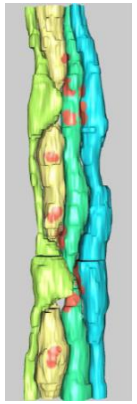
[Andres et al. 2008]

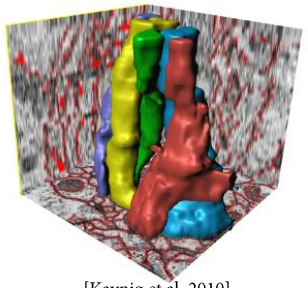
Previous Work

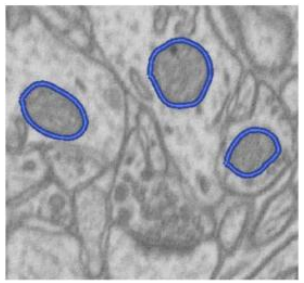
Fully Automatic:

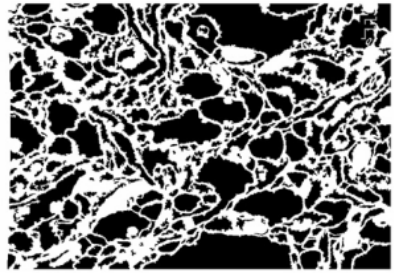

[Vazquez-Reina et al. 2011]


[Jain et al. 2010]


[Jurrus et al. 2010]


[Kaynig et al. 2010]

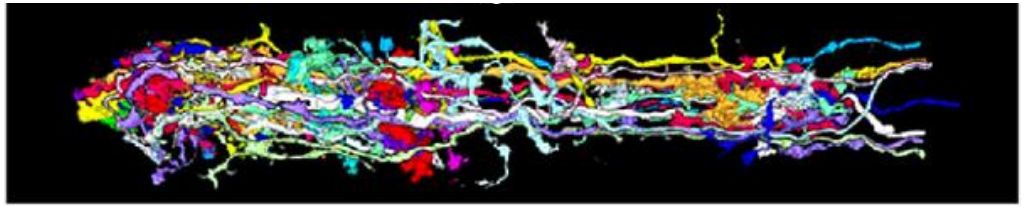

[Lucchi et al. 2010]

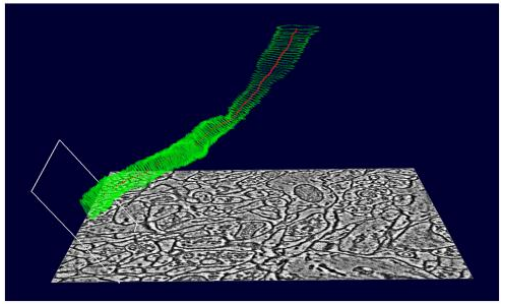

[Mishchenko et al. 2009]

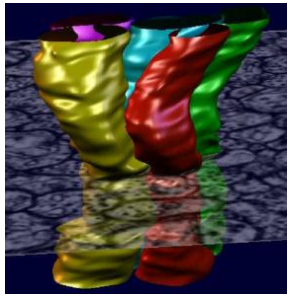

[Venkataraju et al. 2009]

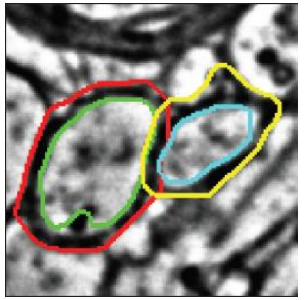

[Andres et al. 2008]

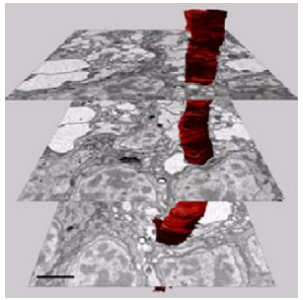
User-Assisted:


[Chklovskii et al. 2010]


[Jeong et al. 2009]


[Pan et al. 2009]

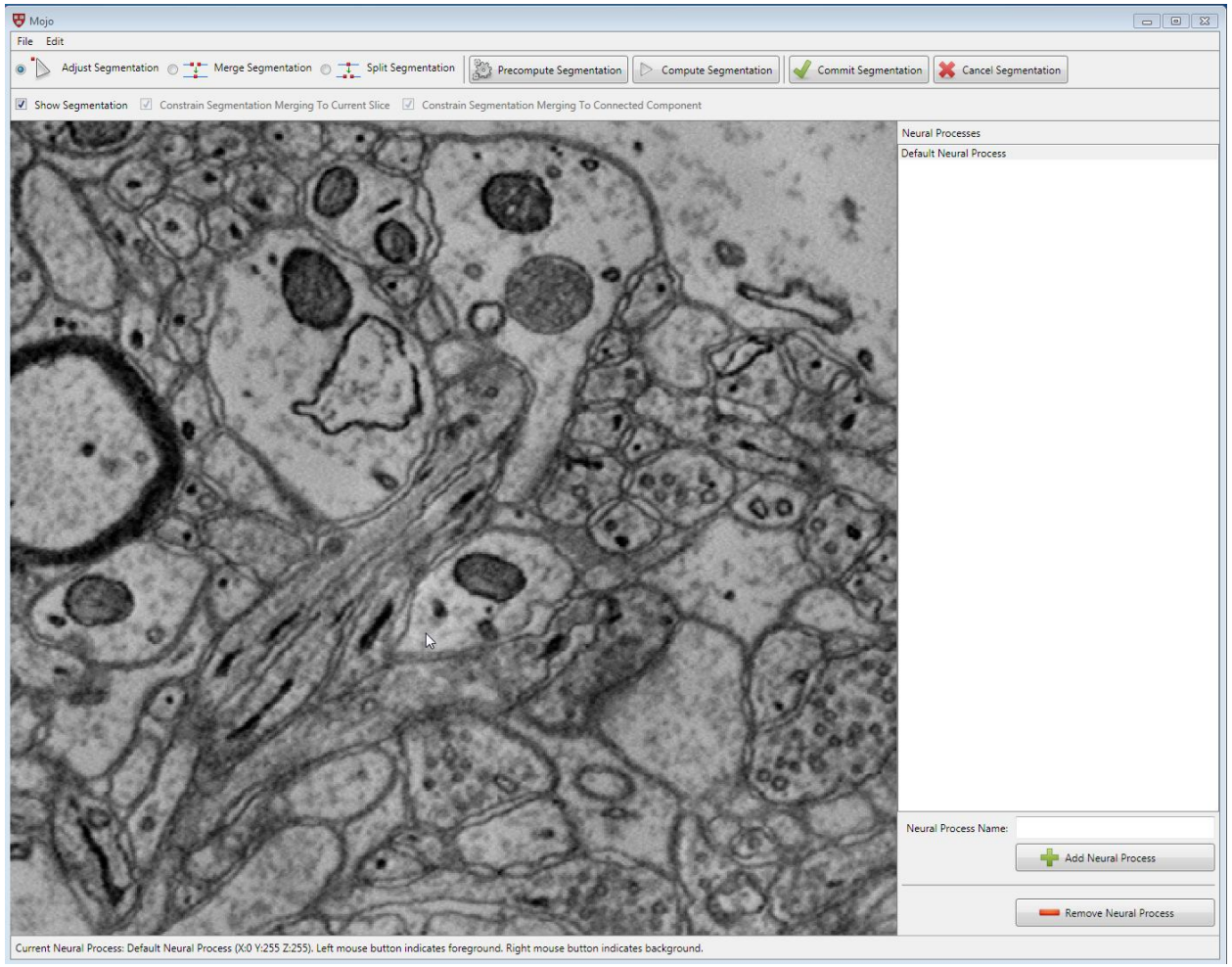

[Vazquez-Reina et al. 2009]


[Macke et al. 2008]

Our Goals

better accuracy, less user interaction

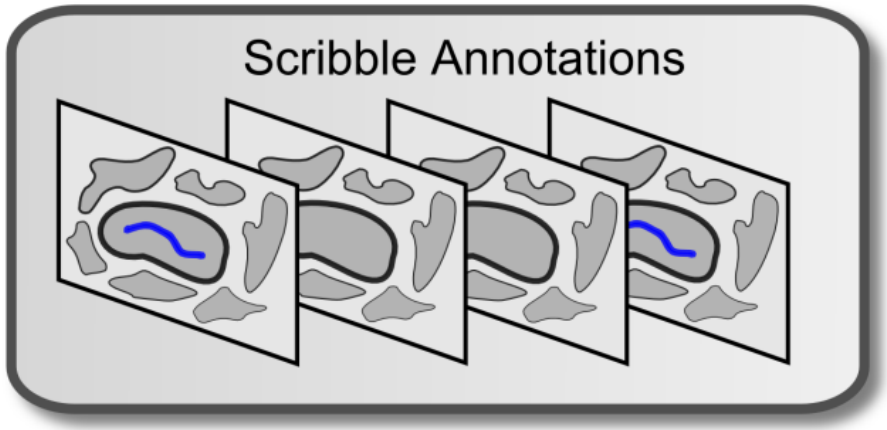
Demo



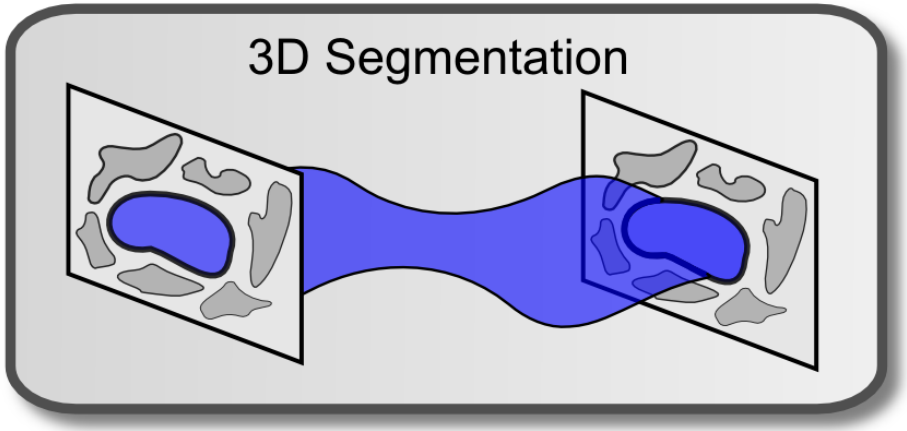
512×512×50 mouse hippocampus

Our Method

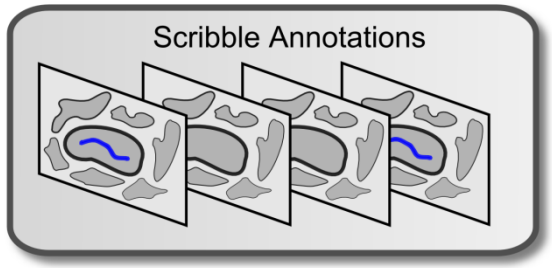
Input:



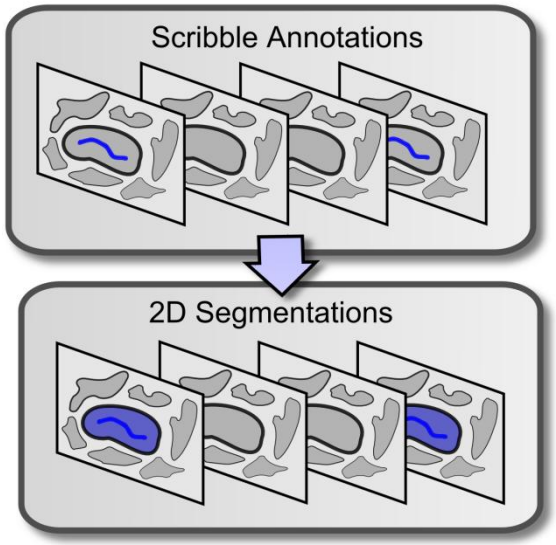
Output:



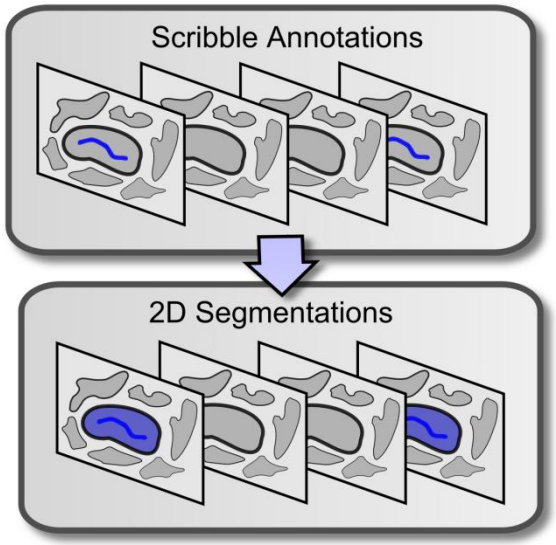
Our Method



Our Method

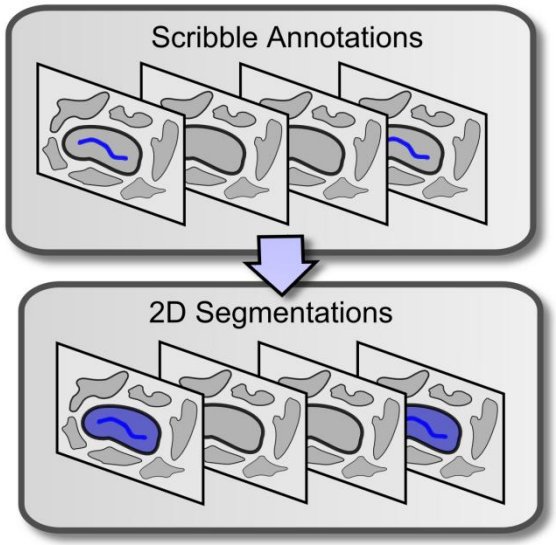


Our Method



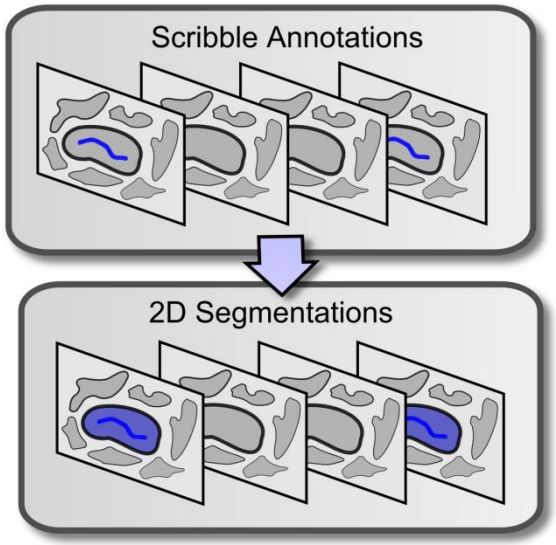
$$\underset{u_i}{\operatorname{argmin}} \int_{\mathbf{x} \in \Omega_i} \left(g_i |\nabla u_i| + f_i u_i \right) d\mathbf{x}$$

Our Method



$$\underset{u_i}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega_i} \left(g_i|\nabla u_i| + f_i u_i\right) d\mathbf{x}$$

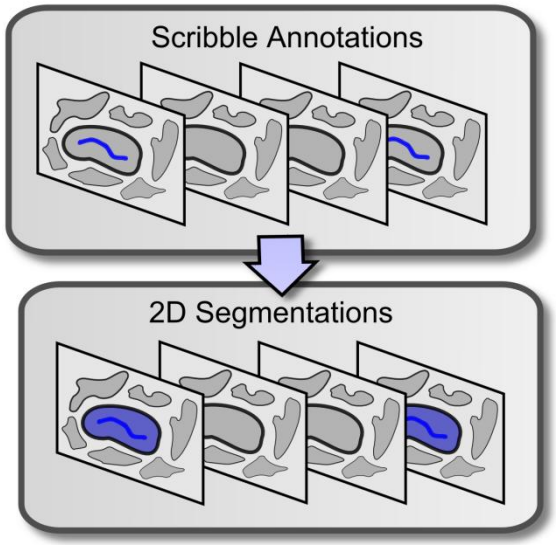
Our Method



$$\underset{u_i}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega_i} \left(g_i|\nabla u_i| + f_i u_i\right) d\mathbf{x}$$

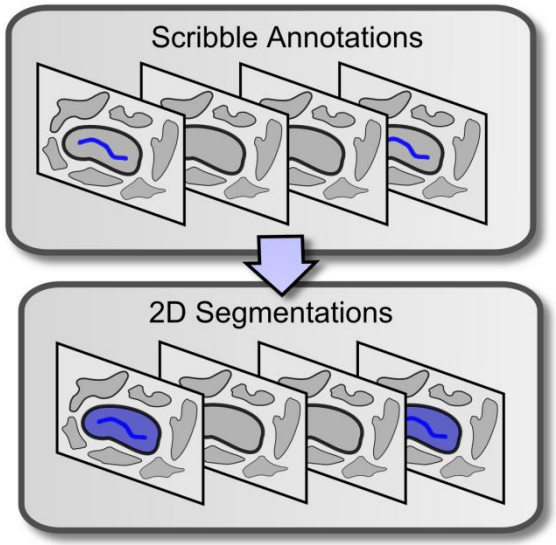
Penalize segmentation boundaries that don't lie on strong image edges.

Our Method



$$\underset{u_i}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega_i} \left(g_i |\nabla u_i| + f_i u_i \right) d\mathbf{x}$$

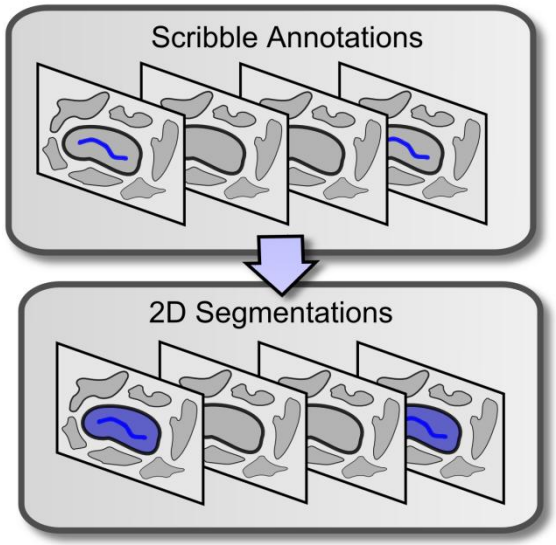
Our Method



$$\underset{u_i}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega_i} \left(g_i |\nabla u_i| + f_i u_i \right) d\mathbf{x}$$

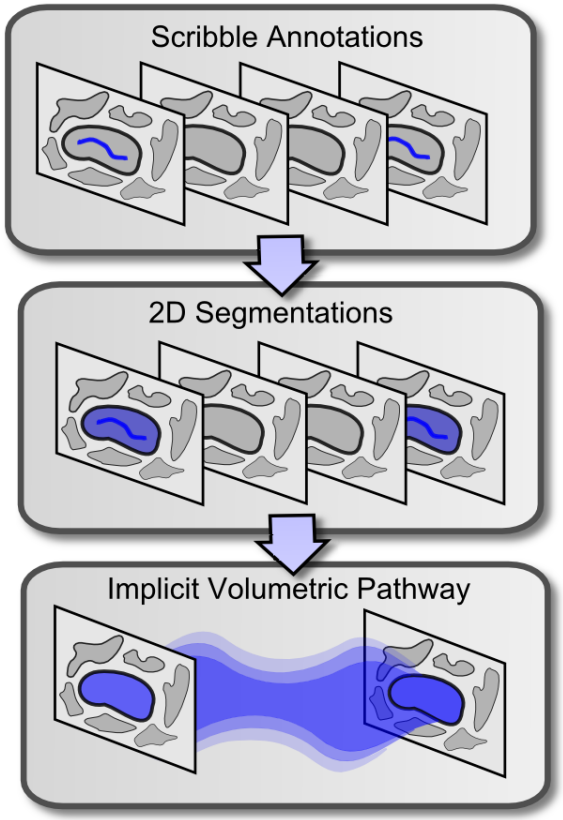
Penalize segmented regions that don't match scribble annotations.

Our Method

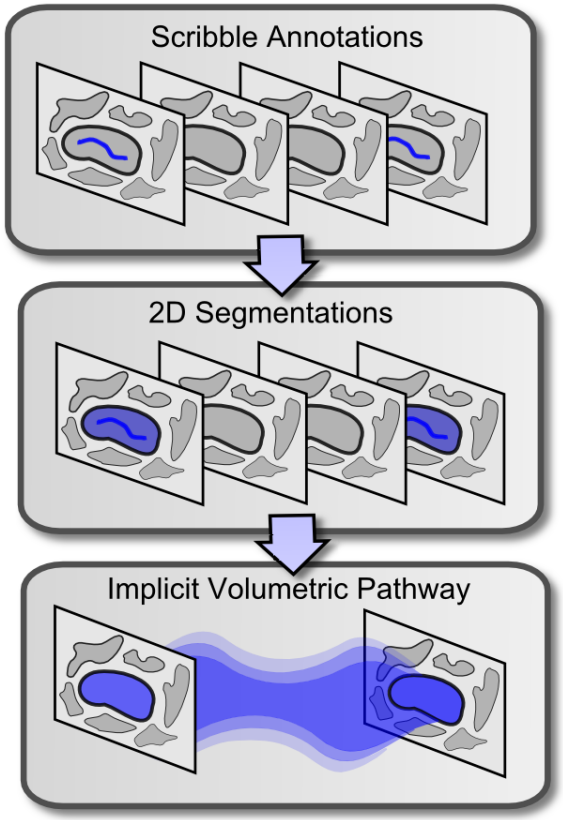


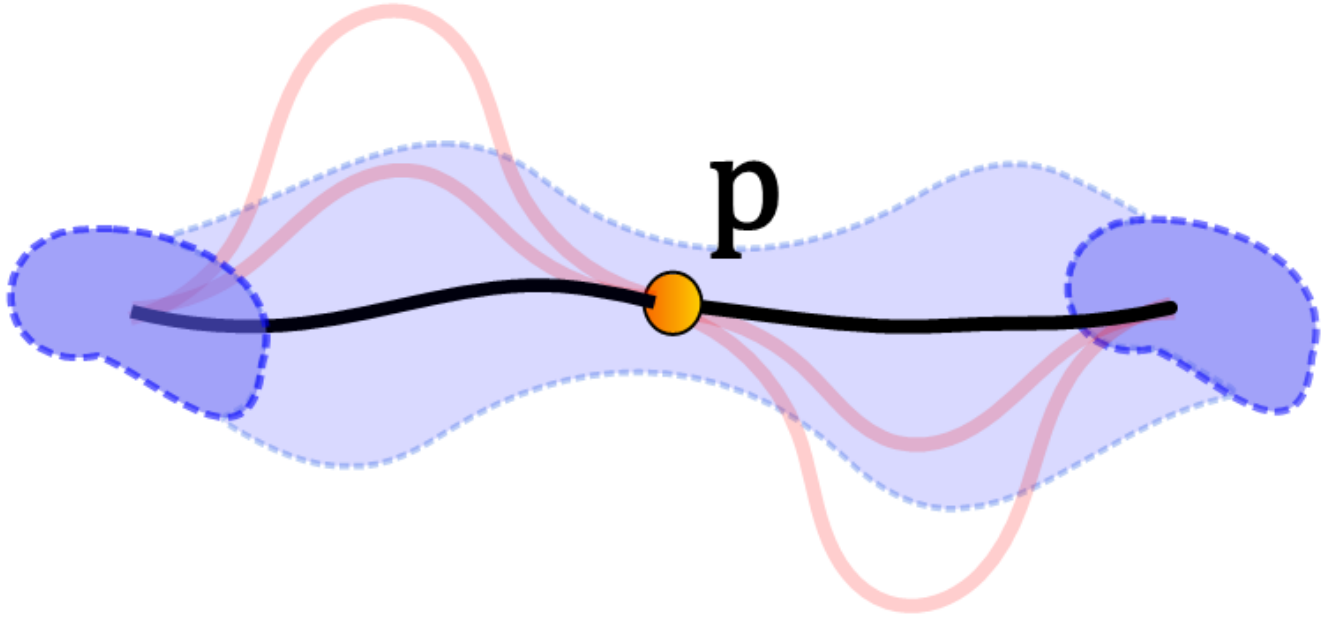
Use 2D segmentations as **hard constraints** on the 3D segmentation.

Our Method


Scribble Annotations
2D Segmentations
Implicit Volumetric Pathway

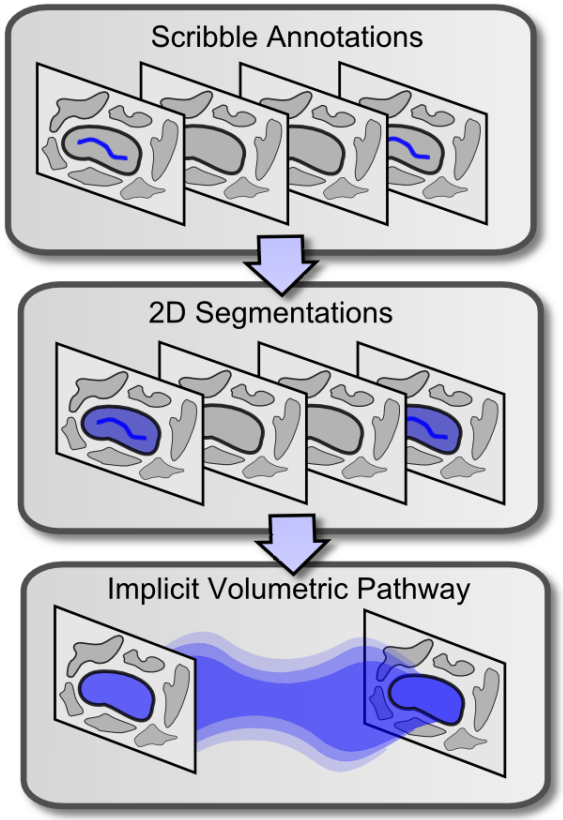
Our Method

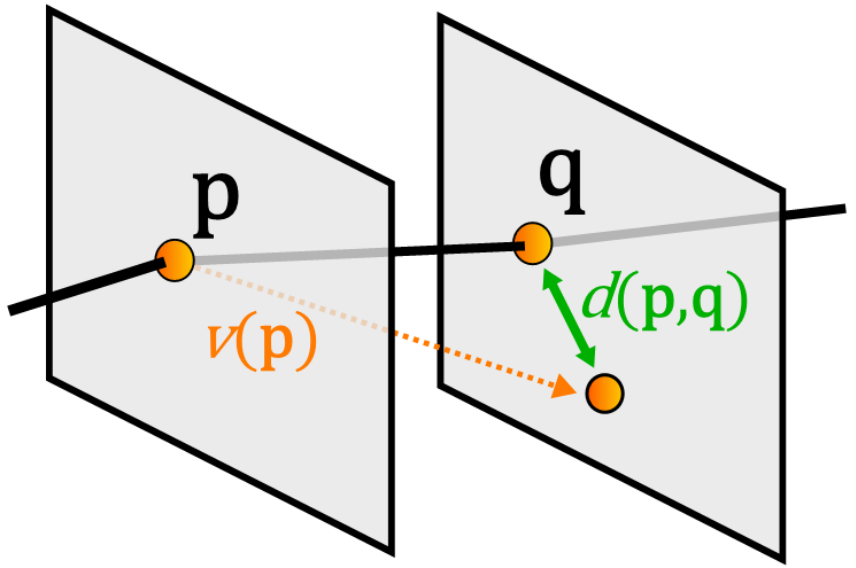




Define the *cost* of each pixel **p** as the length of the shortest path connecting the 2D segmentations via **p**.

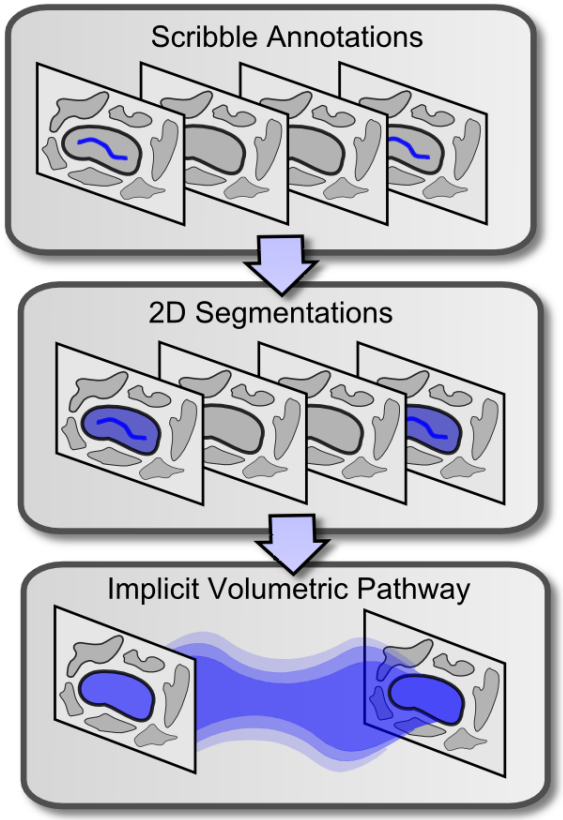
Our Method





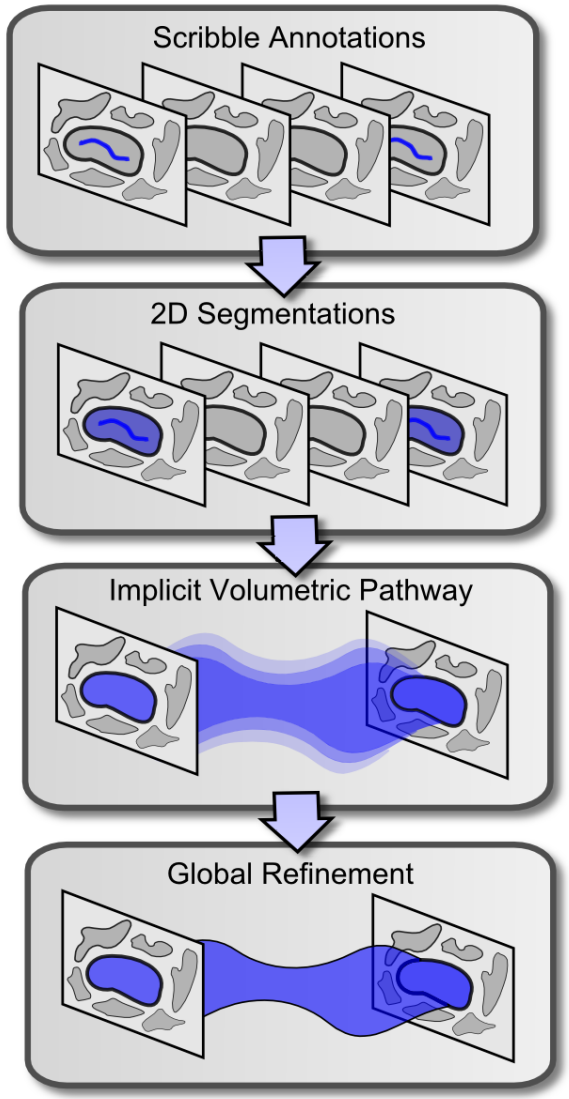
Model the distance between pixels **p** and **q** on adjacent image slices based on the dense optical flow between slices.

Our Method



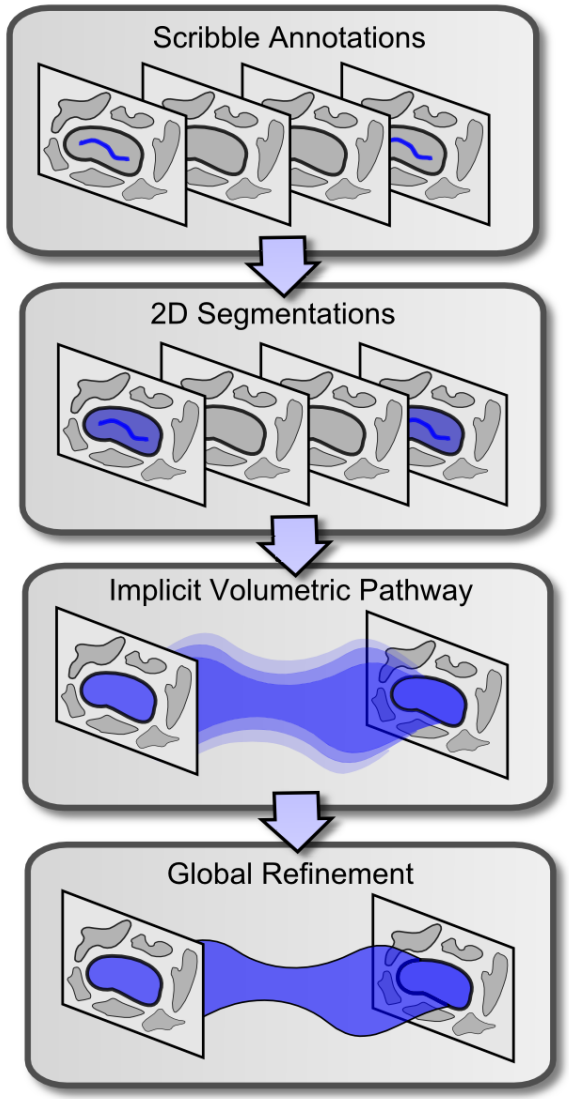
Use pixels with low costs as **soft constraints** on the 3D segmentation.

Our Method



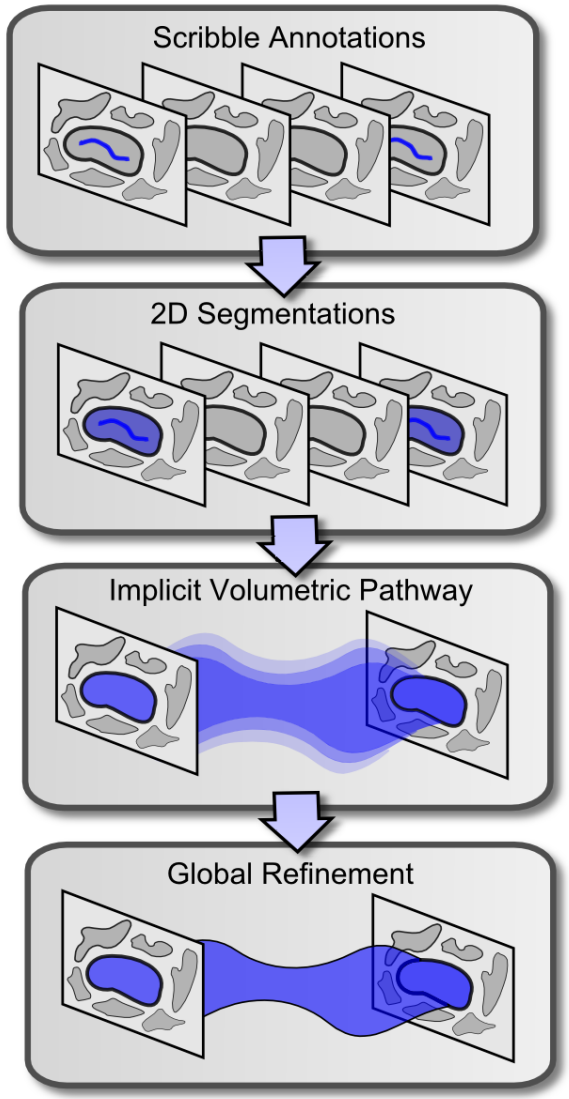
$$\underset{u}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega} \left(g|\nabla^{\mathrm{xy}} u| + |\nabla^{\mathrm{z}} u| + f u\right) d\mathbf{x}$$

Our Method



$$\underset{u}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega} \left(g|\nabla^{\mathrm{xy}} u| + |\nabla^{\mathrm{z}} u| + f u \right) d\mathbf{x}$$

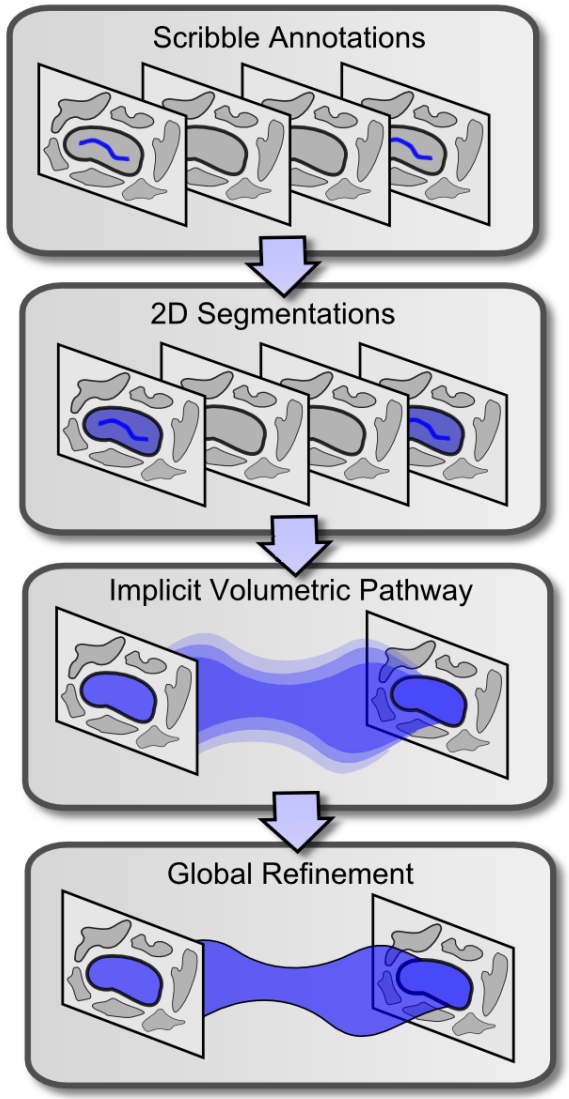
Our Method



Penalize segmentation boundaries that don't lie on strong image edges.

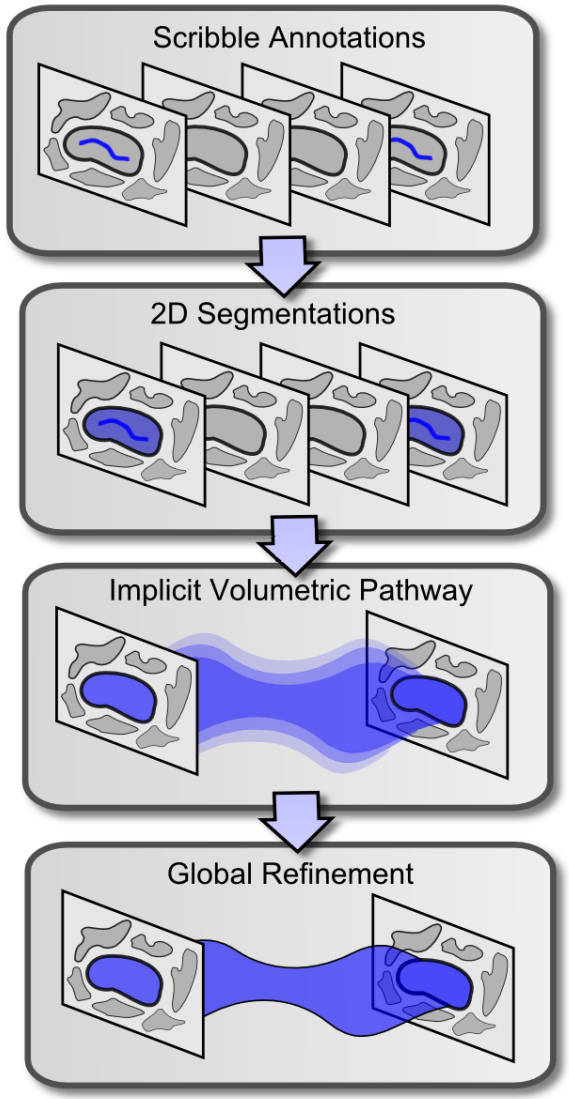
$$\underset{u}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega} \left(g\left|\nabla^{\mathrm{xy}} u\right| + \left|\nabla^{\mathrm{z}} u\right| + f u \right) d\mathbf{x}$$

Our Method



$$\underset{u}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega} \left(g|\nabla^{\mathrm{xy}} u| + |\nabla^{\mathrm{z}} u| + f u\right) d\mathbf{x}$$

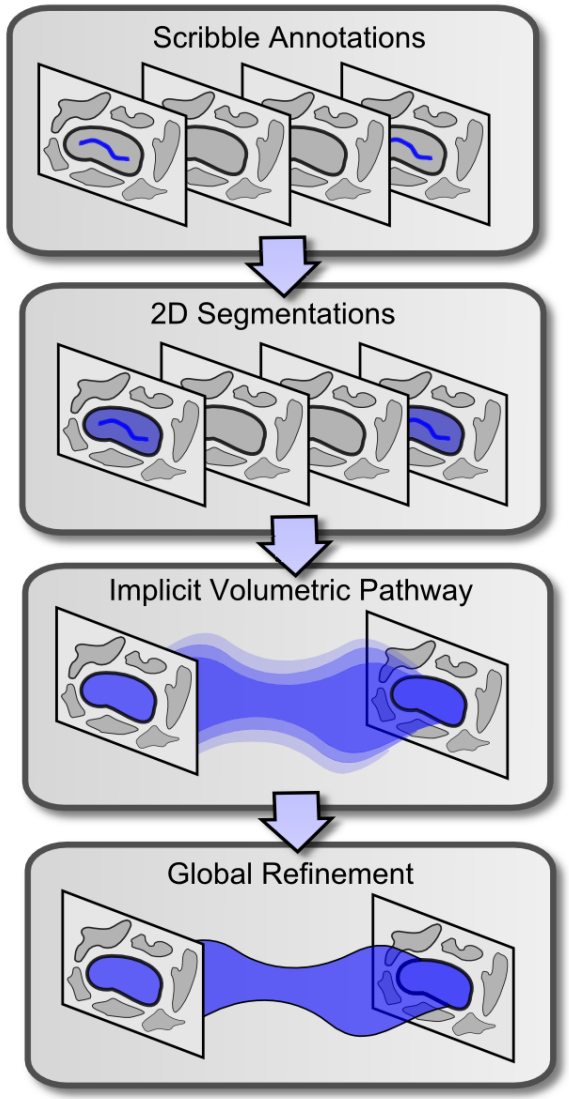
Our Method



Penalize changes in the segmentation from slice to slice.

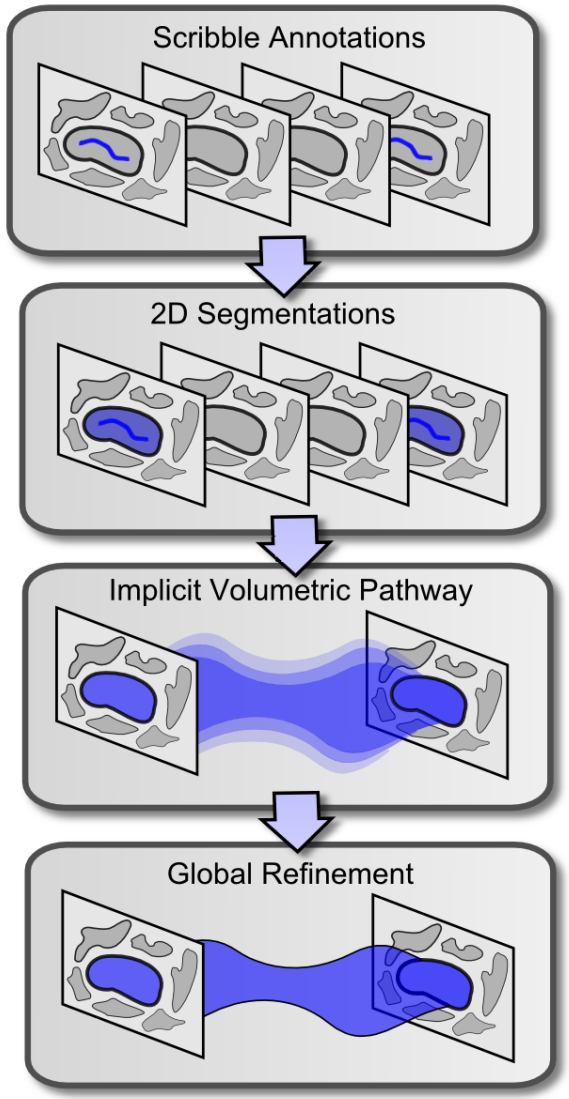
$$\underset{u}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega} \left(g|\nabla^{\mathrm{xy}} u| + |\nabla^{\mathrm{z}} u| + f u\right) d\mathbf{x}$$

Our Method



$$\underset{u}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega} \left(g|\nabla^{\mathrm{xy}} u| + |\nabla^{\mathrm{z}} u| + \boldsymbol{f u}\right) d\mathbf{x}$$

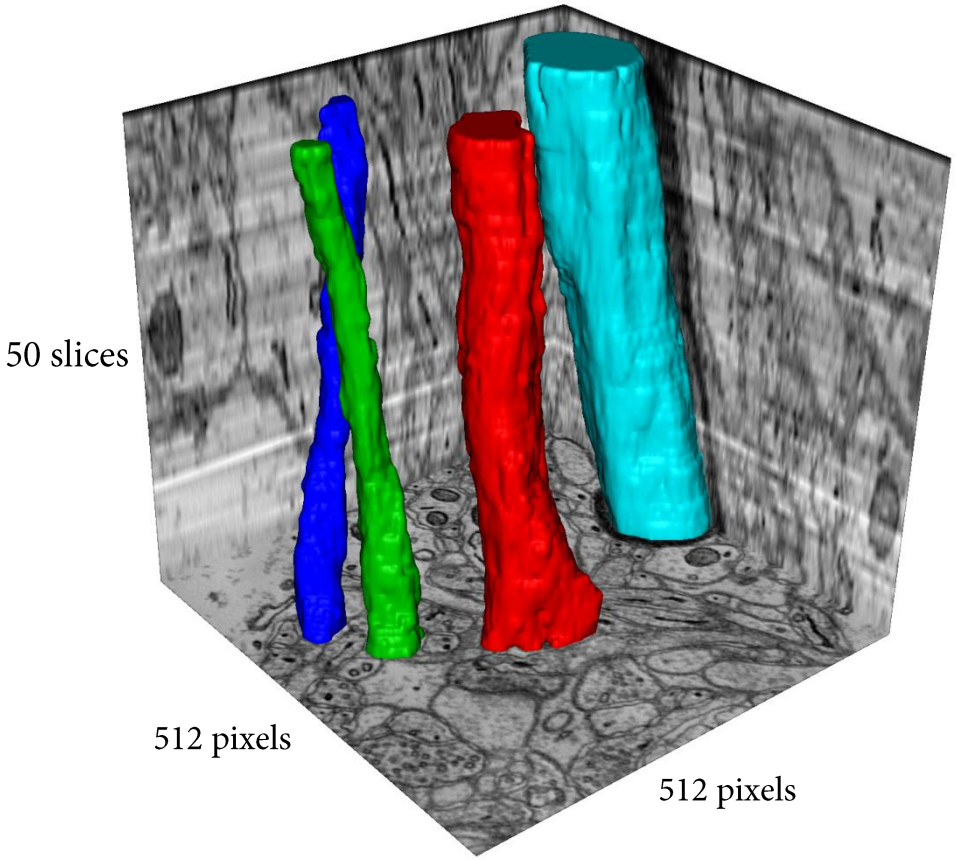
Our Method

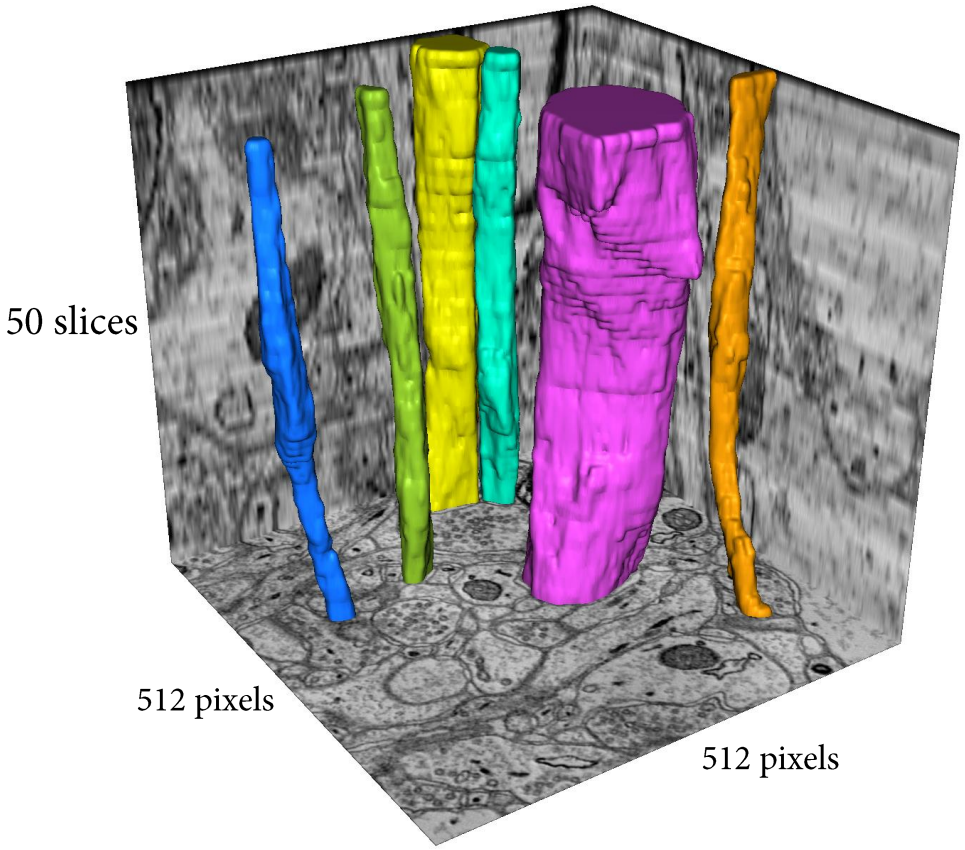


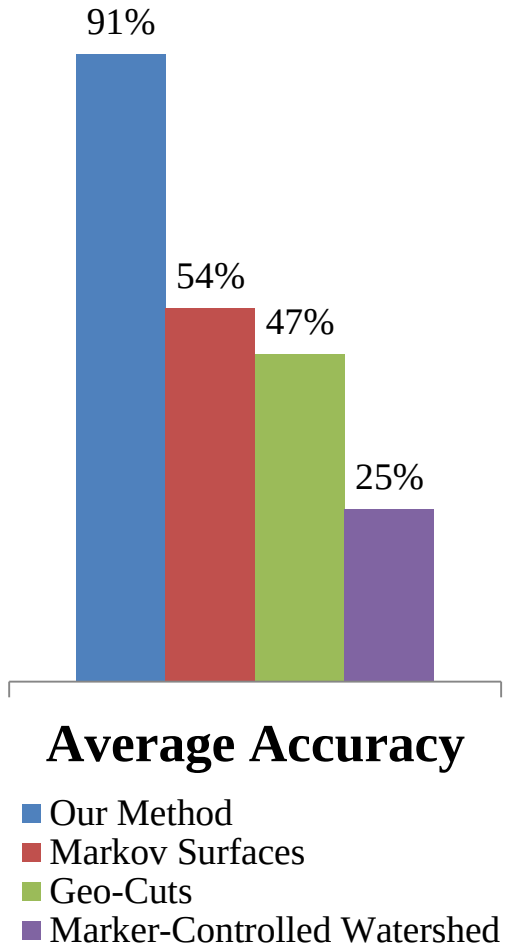
Penalize segmented regions that don't match the hard and soft constraints.

$$\underset{u}{\operatorname{argmin}} \int_{\mathbf{x}\in\Omega} \left(g|\nabla^{\mathrm{xy}} u| + |\nabla^{\mathrm{z}} u| + f u\right) d\mathbf{x}$$

Results


50 slices
512 pixels
512 pixels

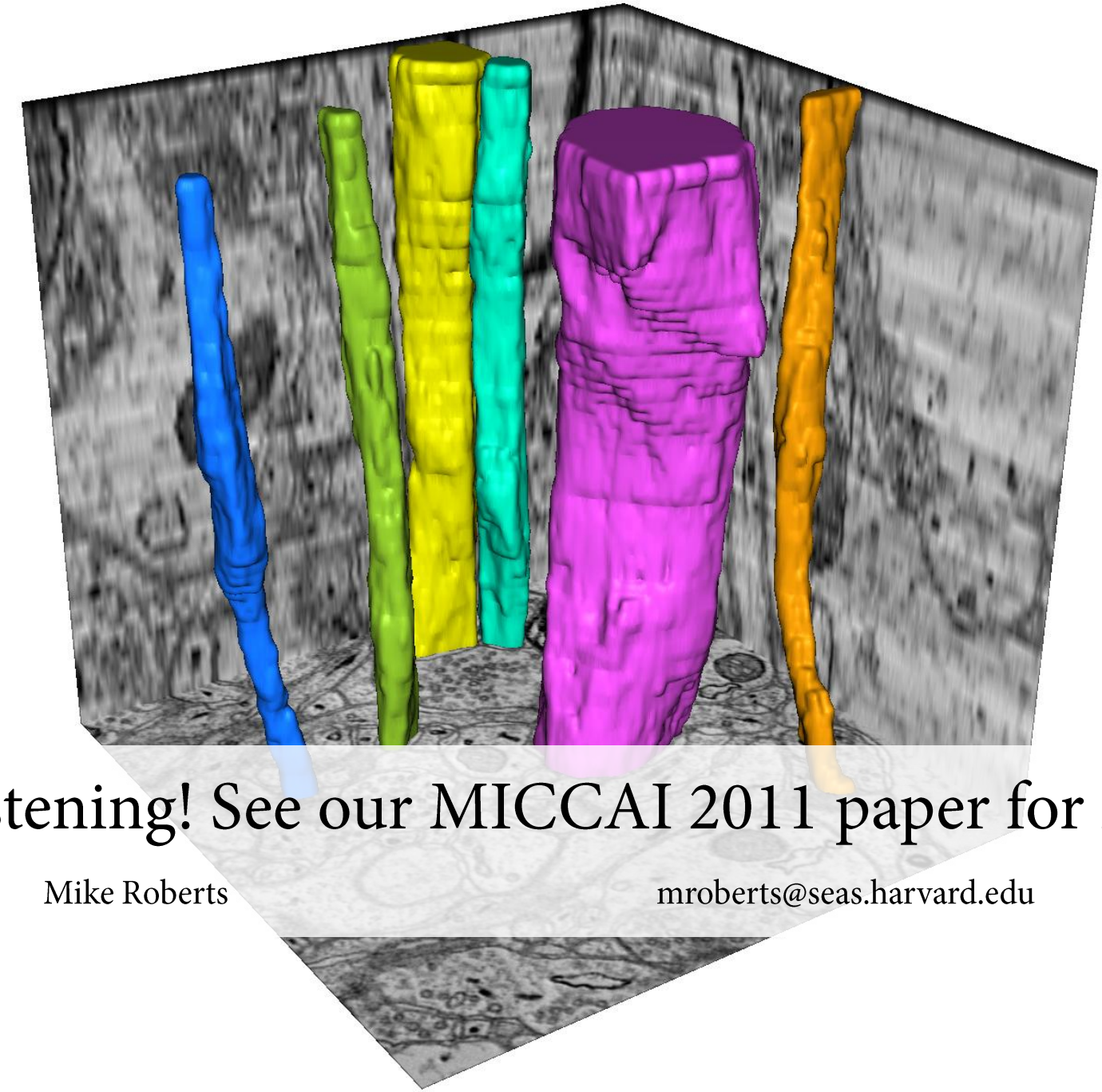

50 slices
512 pixels
512 pixels


91%
54%
47%
25%
Average Accuracy
Our Method
Markov Surfaces
Geo-Cuts
Marker-Controlled Watershed

Our Goals

✓ ✓

better accuracy, less user interaction



Thanks for listening! See our MICCAI 2011 paper for more details.

Mike Roberts mroberts@seas.harvard.edu