NeuroLines

A Subway Map Metaphor for Visualizing Nanoscale Neuronal Connectivity

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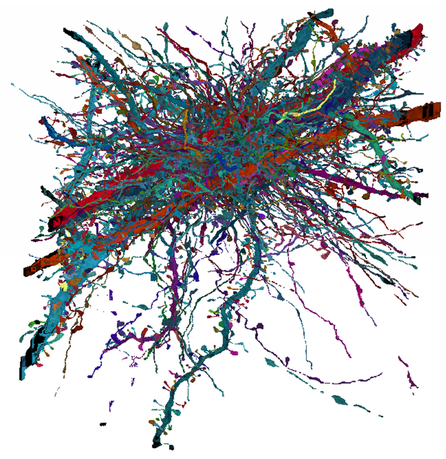
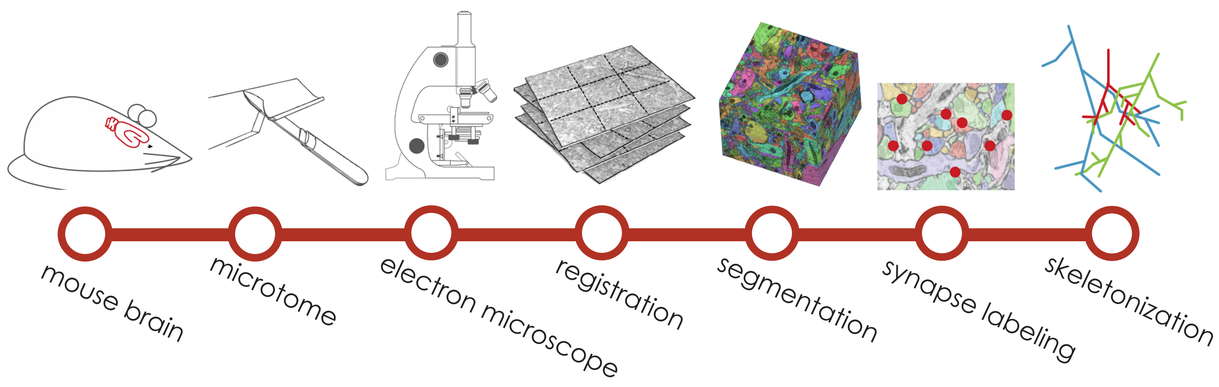
Abstract

We introduce NeuroLines, a novel tool designed for visualizing neuronal morphology and connectivity at the nanoscale level. NeuroLines uses a subway map metaphor to abstract the topology of 3D brain tissue data into a multi-scale, relative distance-preserving 2D visualization. This allows domain scientists to conduct an interactive analysis of neurons and their connectivity. Nanoscale connectomics attempts to reverse-engineer the wiring diagram of the brain. This task, coupled with the task of analyzing the detailed connectivity of neurites (axons, dendrites), is crucial to understanding the brain, its development and pathologies. However, the main challenge with such tasks is the enormous scale, complexity and visual clutter of nanoscale connectivity. This makes it difficult for existing visualization techniques to render such data in a meaningful way. NeuroLines offers a scalable visualization platform that can interactively render thousands of neurites in an uncluttered fashion, paired with interactive features to support the detail analysis of neuronal connectivity.



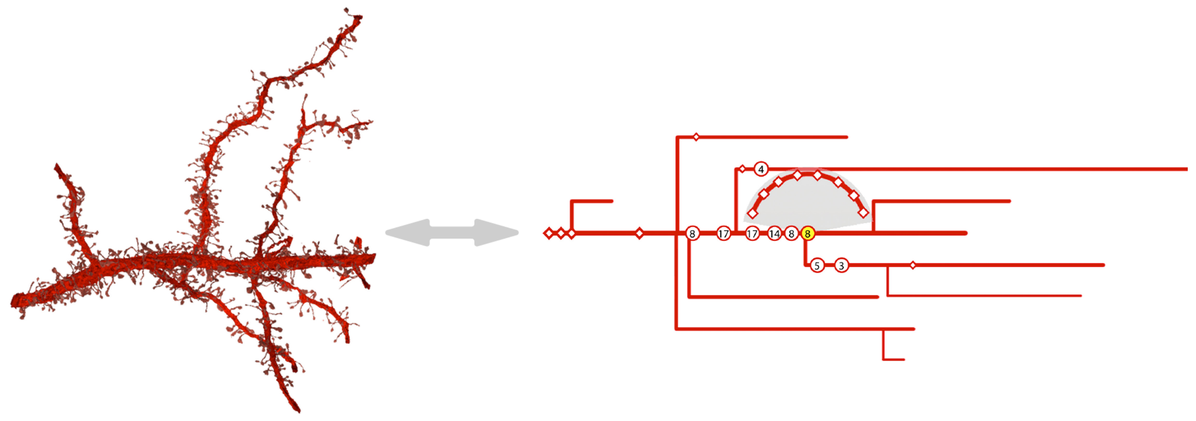
Standard large scale volume visualization of segmented neurites. The neurites are entangled producing a cluttered visualization.

Workflow



After slicing and imaging the tissue block, registration, segmentation, and synapse labeling are performed. The segmented neurites are then skeletonized, which forms the basis for subsequent interactive visualization and analysis in NeuroLines.

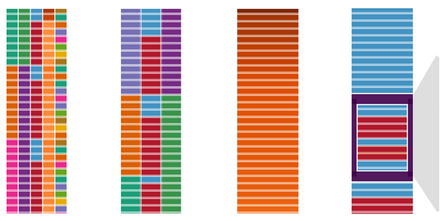
Visual Encoding



We abstract the original 3D structure and topology of neurites segmented in nanoscale brain tissue data into a 2D subway map visualization that preserves topology and relative distances. Left: Volume rendering of a dendrite. Right: NeuroLines abstraction of the same dendrite, represented as a subway line to more clearly show branches, clusters of synapses in proximity and individual synapses as stations along the line.

System Overview

Navigation Bar



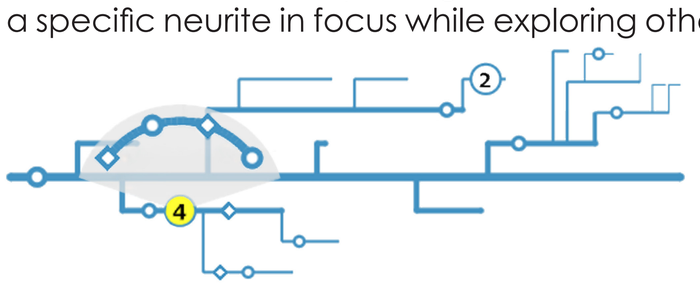
The current sorting of neurites is depicted in the navigation bar by colorcoding the sorting criteria according to neurite attributes. Multicriteria sorting according to user preference. Neurites can also be color-coded with a single attribute regardless of the sorting criteria. The navigation bar also displays a slidable focus window, which is linked directly to the neurite overview for navigation.

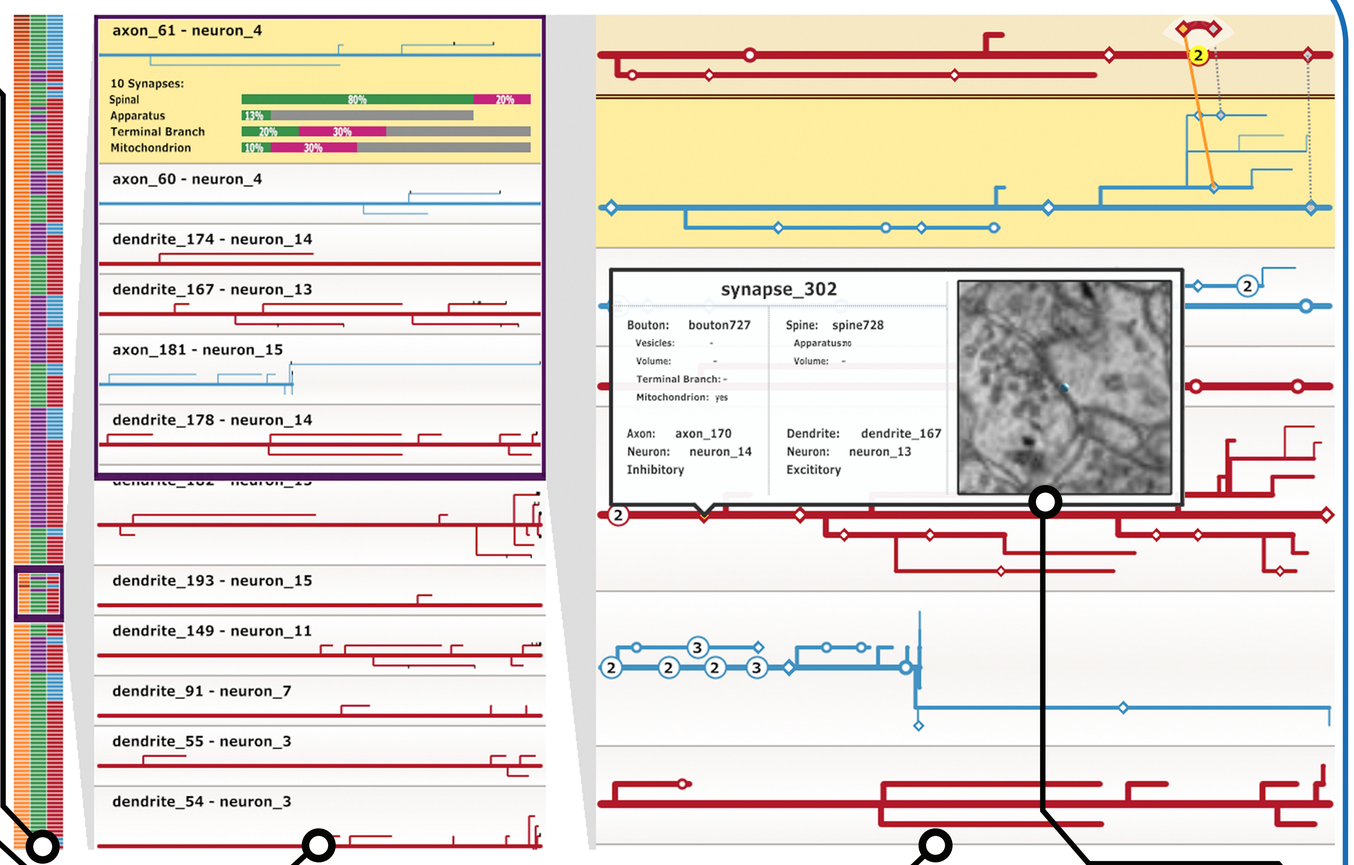
Neurite Overview

Allows inspecting all neurites at a medium level of abstraction and provides detailed statistics of a selected neurite and its synapses (e.g., percentage of spinal vs. non-spinal synapses).

Workspace

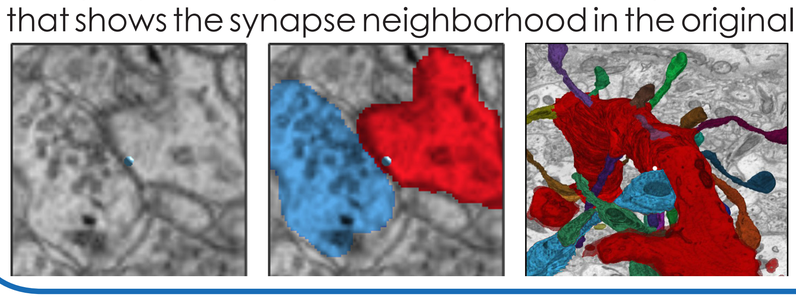
Allows the inspection of neurites at a detailed level of abstraction. Individual synapses are shown as diamonds (spinal) or circles (non-spinal); synapses overlapping in screen space become clusters that can be fanned out. This view also allows pinning of a neurite in the workspace to keep a specific neurite in focus while exploring others.





Synapse Analysis

The synapse analysis view shows detailed synapse information and a 2D inset view that shows the synapse neighborhood in the original electron microscopy volume.



The 2D inset view allows users to toggle the display of segmentation information, and is linked with a 3D volume visualization for futher exploration.

http://people.seas.harvard.edu/~jbeyer/neurolines.html

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