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Barrio: Customizable Spatial Neighborhood Analysis and Comparison for Nanoscale Brain Structures - Supplementary Material -

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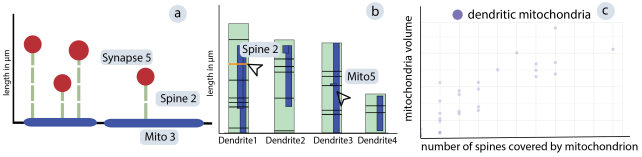

Figure 1: ***Analysis views generated for ST3: Mitochondric spine coverage.*** *(a) to (c): low-, medium-, high-cardinality comparison views. (a) detailed spine visualization for a single dendrite based on a lollipop chart. Each lollipop encodes the length (bar height) and volume (circle size) of a spine and indicates its position in relation to the mitochondria (blue horizontal bars) of the dendrite, (b) dendrite abstraction showing one green bar per dendrite. We depict spines as horizonal lines with their vertical position indicating their position along the dendrite and mitochondria (blue). (c) scatter plot of 26 mitochondria, showing their spine coverage.*

1. Case Study: Mitochondria Analysis

Below, we describe the third scenario subtask of the "Mitochondria Analysis" case study described in the paper.

1.1. Mitochondric Spine Coverage (ST3)

Domain Goal: In the final scenario subtask, the scientist wanted to study the relationship between dendritic spines and mitochondria. Spine coverage is defined as a mitochondrion being present in the cell region right below the neck of a spine. Spines often develop synapses, which are big energy consumers. Therefore, knowing more about mitochondria close to spines plays a vital role in understanding metabolic processes. Furthermore, the presence of mitochondria might influence spine plasticity, which in turn may influence fission/fusion dynamics of mitochondria.

Visualizations: Fig. 1 shows the visualizations for analyzing dendritic spines. For *low-cardinality* comparisons we developed a customized spine visualization based on lollipop charts and integrated it into Barrio. We abstract the dendrite to a straight horizontal line in 2D (see Fig. 1a), inspired by Neurolines [AABS*14]. Next, we encode the mitochondrion position (blue shapes) within the dendrite and represent spines and their lengths as green vertical lines. The red circle on the top of the spine represents a synapse, and its radius encodes the spine's surface area to volume ratio, which gives an intuition of the spine's shape. This view provides a detailed analysis of the dendrite's morphology (i.e., mitochondria positions, spine locations, and synapse sizes). In the *medium-cardinality* comparison mode, each dendrite is represented as a vertical rectangle (Fig 1b), allowing the comparison of up to a dozen dendrites in a single visualization. The height of the rectangle represents the length of the dendrite and the positions of the mitochondria within that dendrite are visualized through the smaller blue rectangles. Spine positions are indicated as black horizontal lines. For *high-cardinality* comparisons, the scientist defined a scatterplot in the ADF file (Fig 1c). Each data point corresponds to an individual mitochondrion. The horizontal axis encodes the number of spines covered by this mitochondrion, and the vertical axis encodes the mitochondrion's volume.

Interactive Analysis: The domain expert started by analyzing multiple mitochondria and dendrites and immediately observed that spines usually develop with mitochondria coverage. To follow up on this initial insight, he selected six mitochondria to compare them. In a particular case, he observed two mitochondria that overlapped in the dendrite. He speculated that these two mitochondria might initially have been a single mitochondrion that split into two parts. He pointed out that he wants to use Barrio in the future to analyze whether regions of overlapping mitochondria develop more spines. When switching to the scatterplot visualization, our collaborator immediately spotted a linear dependence between the mitochondria volume and the number of spines covered, which was a new finding for him. This observation indicates that mitochondria coverage plays a vital role in spine development.

2. Examples of Analysis Definition Files

In this section, we give two examples of analysis definition files (ADFs). Figure 2 shows the ADF used in the case study. It defines three scenario subtasks that all use mitochondria as target types. Figure 3 gives an example of an ADF comparing two data sets

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Figure 2: ***The analysis definition file (ADF)*** *for the case study "Mitochondria Analysis" specifies three scenario subtasks (ST1: Synaptic neighborhood of mitochondria, ST2: Mitochondria placement, and ST3: Spine coverage of mitochondria). Each scenario subtasks supports visual comparison at three comparison cardinalities by defining a specific visualization method for each level. Each visualization method is defined by a set of parameters and data mapping.*

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Figure 3: ***An example of an analysis definition file with multiple data sources and synapses as target types.*** *The analysis scenario "Relation of synapses and mitochondria" defines one scenario subtask (ST1: Surrounding mitochondria) and uses synapses as target types. In this task, scientists can compare synapses of two different data sets to investigate neuronal development over time.*

("mouse2" and "mouse3"). Here, the analysis scenario defines only one scenario subtask using synapses as target types. More details and information about supported visualization types and a detailed documentation can be found on our website [VCG22].

3. High-Resolution Figures

Below, we provide high-resolution versions of the figures in our paper (see Fig. 4, Fig. 5, Fig. 6, Fig. 7, and Fig. 8).

References

[AABS*14] AL-AWAMI A., BEYER J., STROBELT H., KASTHURI N., LICHTMAN J. W., PFISTER H., HADWIGER M.: NeuroLines: A Subway Map Metaphor for Visualizing Nanoscale Neuronal Connectivity. *IEEE Transactions on Visualization and Computer Graphics 20*, 12 (2014), 2369–2378. doi:10.1109/TVCG.2014.2346312. 1

[VCG22] VCG: Barrio Documentation, 2022. last accessed: 04/17/2022. URL: https://github.com/VCG/Barrio/wiki. 3

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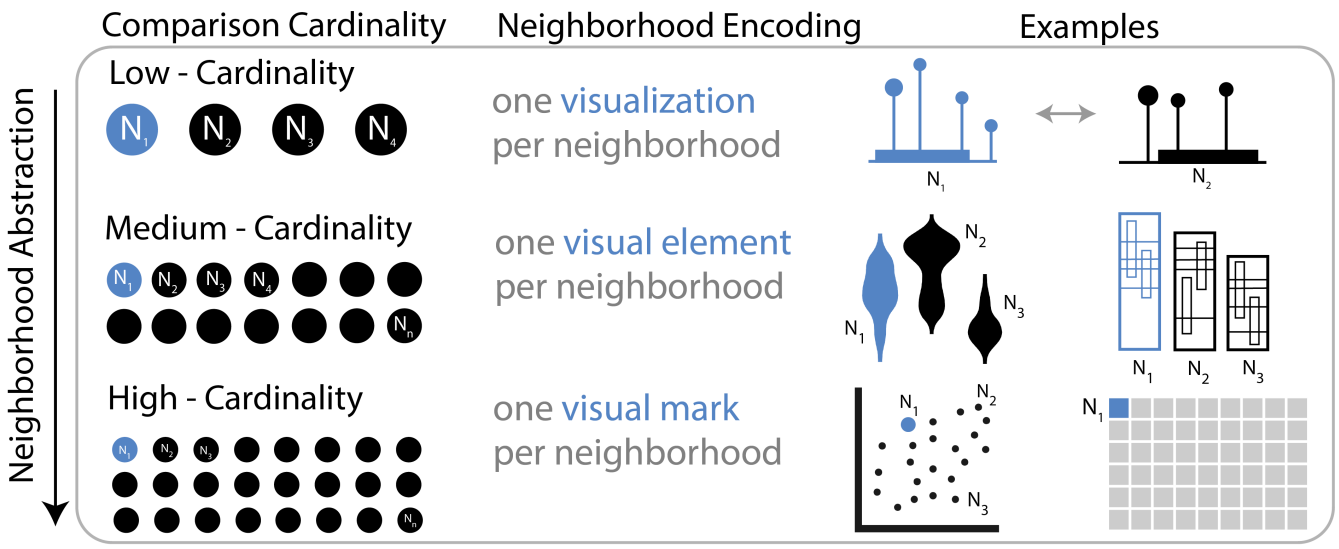

Figure 4: *High resolution version of Figure 5 in the paper.* ***Scalable comparisons*** *at three different cardinalities. Low-cardinality comparisons (top row) analyze a small number of spatial neighborhoods and use juxtaposed small multiples. Medium- and high-cardinality comparisons support increasingly larger numbers of neighborhoods and encode a single neighborhood as a single visual element (i.e., a violin in a violin plot) or a single visual mark (i.e., a dot in a scatterplot), respectively.*

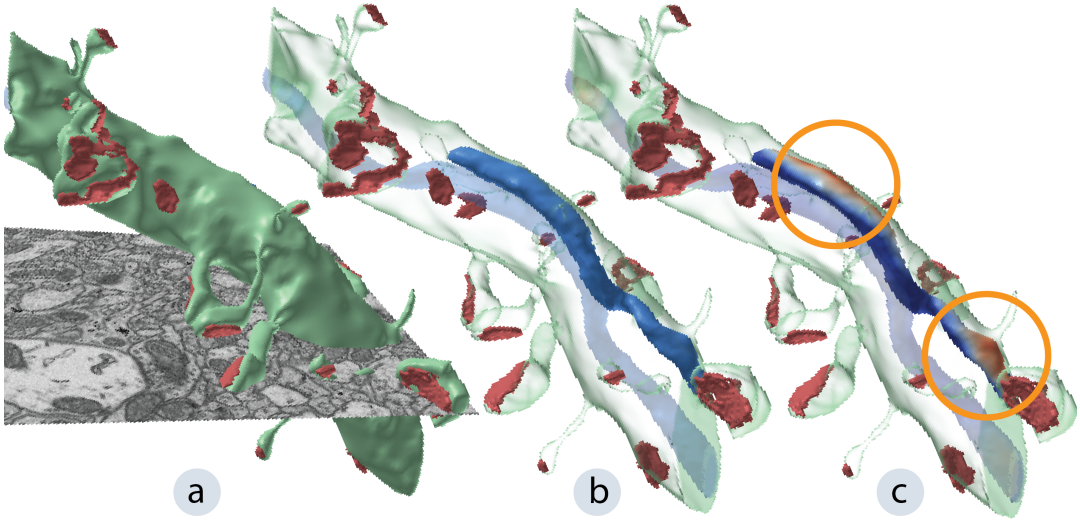

Figure 5: *High resolution version of Figure 6 in the paper.* ***Detailed 3D neighborhood view.*** *The dendrite (green) and close synapses (red). (a) 2D slice overlay of the original EM data to show biological context. (b) Silhouette enhancing and semi-transparent surface rendering to highlight how enclosed mitochondria (blue) are positioned within the dendrite. (c) Color-coding of a mitochondrion showing the distance between the mitochondrion and its surrounding cell membrane.*

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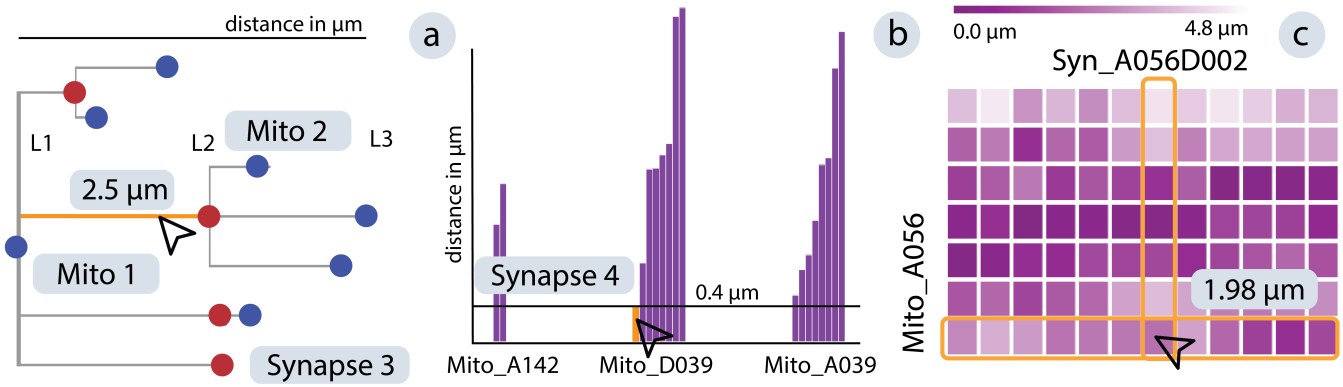

Figure 6: *High resolution version of Figure 7 in the paper.* ***Analysis views generated for ST1: Synaptic neighborhood of mitochondria.*** *(a) to (c): low-, medium-, and high-cardinality comparison views. (a) distance tree for mitochondrion 'Mito 1' showing its surrounding synapses (red) and their closest mitochondria (blue), (b) bar chart showing three mitochondria and the spatial distance of their surrounding synapses, (c) distance matrix of all mitochondria and their neighboring synapses.*

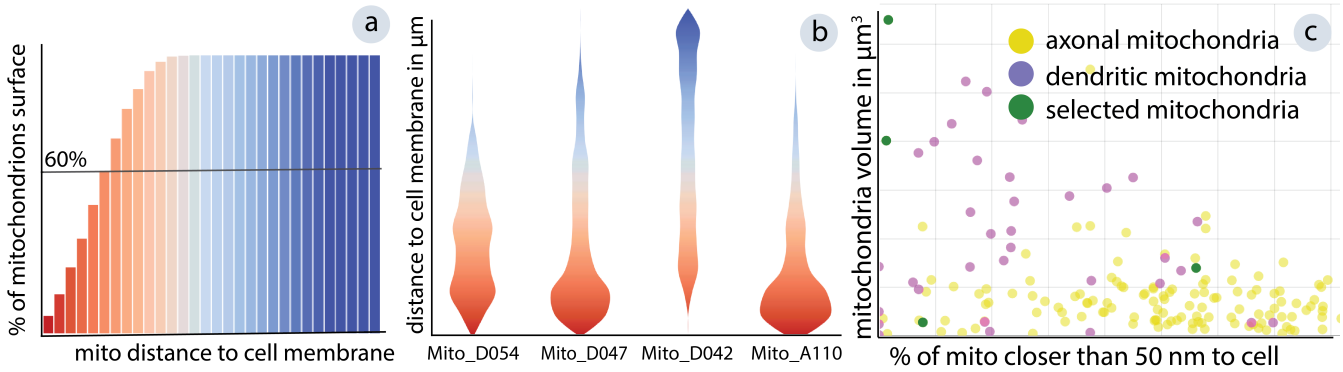

Figure 7: *High resolution version of Figure 8 in the paper.* ***Analysis views generated for ST2: Mitochondria placement.*** *(a) to (c): low-, medium-, high-cardinality comparison views. (a) cumulative histogram showing the percentage of a single mitochondrion's surface that is within a certain distance to the surrounding cell membrane (red means close, blue means far), (b) violin plots for four mitochondria, each showing the distance distribution of the mitochondrion's surface to the surrounding cell membrane (color and vertical position encode the distance, the width of the plot encodes the number of surface points with that distance), (c) scatter plot showing many mitochondria (dots) and their volume correlated to their distance to the cell membrane.*

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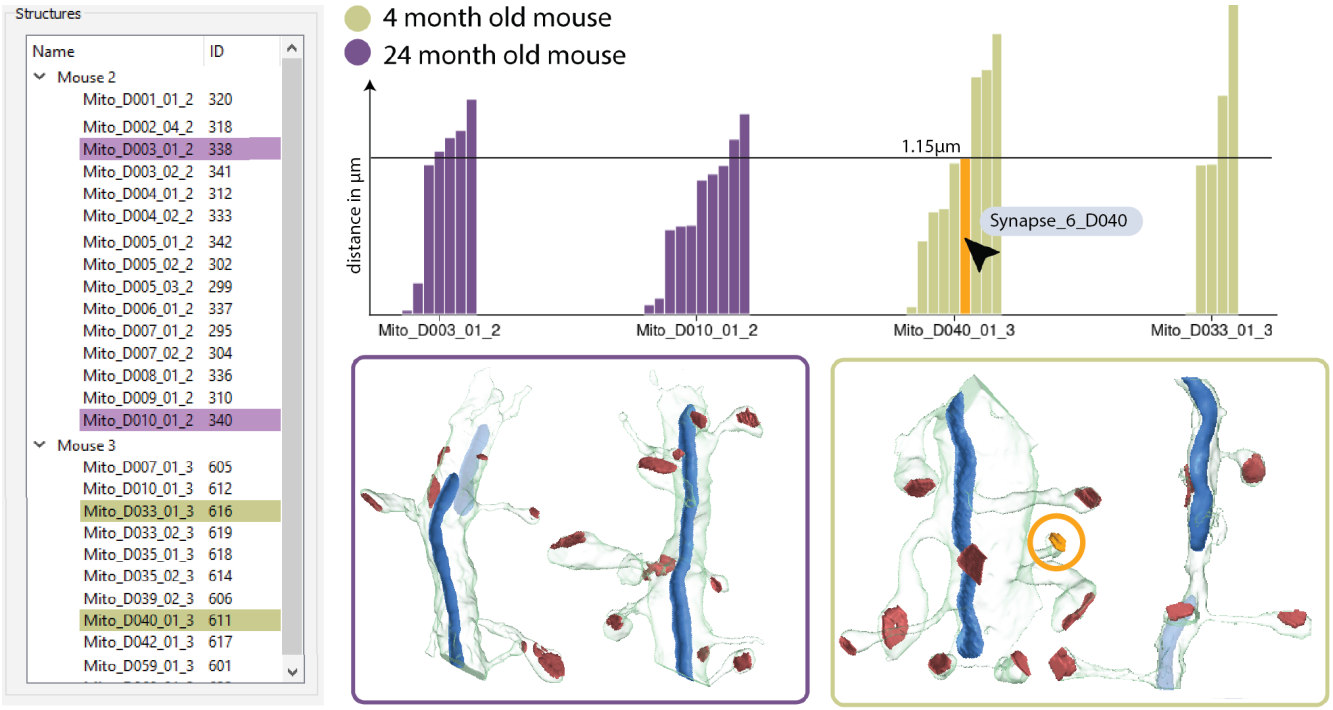

Figure 8: *High resolution version of Figure 9 in the paper.* ***Comparing synapse locations in two different mouse data sets (purple and green).*** *The 3D views show the four selected mitochondria neighborhoods. Grouped bars show the distances between mitochondria and their neighboring synapses. Hovering over a bar highlights the corresponding synapse in the 3D neighborhood view (orange). The young mouse (green, right) exhibits a* wider *mitochondria-synapses distance bandwidth than the adult mouse (purple, left), indicating synaptic pruning over time.*

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