Make Sense of .swc Files: Information Extraction via Vaa3D Platform

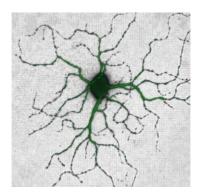


Shuxia Guo

June 28th, 2021

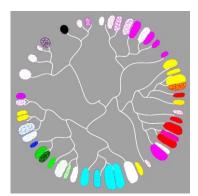


Key Questions in Neuroscience





(morphology, physiology, gene expression, locations, ...)



• Where neurons come from and how they change over time? (lineage, neuron growth/pruning/aging/plasticity,...)

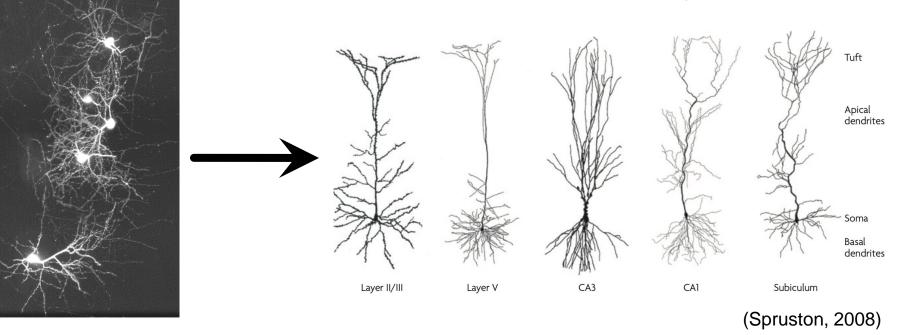


How neurons connect and work together?

(connectivity/connectome/networks, information processing, dynamics, behaviors, ...)



Key Questions in Neuroscience



Dendritic morphology



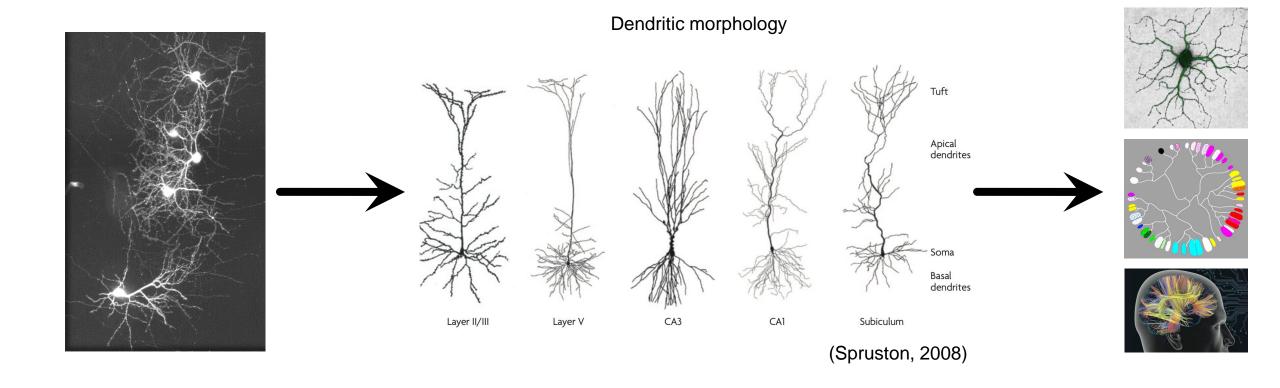
.swc files

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	1	2	4	5	6	7	8
data type	Sample number	Structure Identifier	x position	y position	z position		parent sample
1	starting from '1',	<pre>Standardized swc files (www.neuromorpho.org) - 0 - undefined 1 - soma 2 - axon 3 - (basal) dendrite 4 - apical dendrite 5+ - custom A lot of data does not conform exactly to this standard however e.g. CNIC data - 0 - undefined 1 - soma 2 - axon 3 - (basal) dendrite 4 - apical dendrite 5 - fork point 6 - end point 7 - custom VNED data - seems to be standard, but uses 10 - related to soma ? Gulyas data - each number represents structure with same diameter. Other data has been observed with -1 - also possibly related to soma ?</pre>	given in 'radius' i thicknes microme the few f	microme s half the s, also give eters (note	dendrite ven in e this is or vhich use	ne of	The sample number. Connectivity is expressed with this value. Parent samples should appear before any child samples.



Key Questions in Neuroscience



• Quantify/characterize neuron morphologies



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File Image/Data Visualize Advanced Plug-In Window Work-Mode Help

Plug-in manager Re-scan all pluging

Recently used plugins

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Most used plugins Clear used plugins history _Vaa3D_plugin_creator adaEnhancement AllenApps app2WithPreinfo app3

celegans cell_counting color_channel compare_swc consensus data_IO data_type findCrossBranch

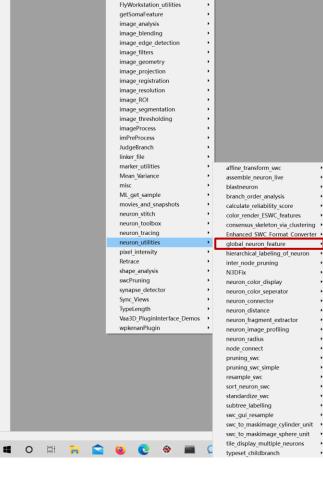
A toolkit to edit swc files

- Pre-process, e.g., sort, pruning, resampling, connector...
- Confidence score of each tracing point
- Distance between neurons
- Extract fragments from a reconstruction
- Affine transform to a reference swc

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• global_neuron_feature

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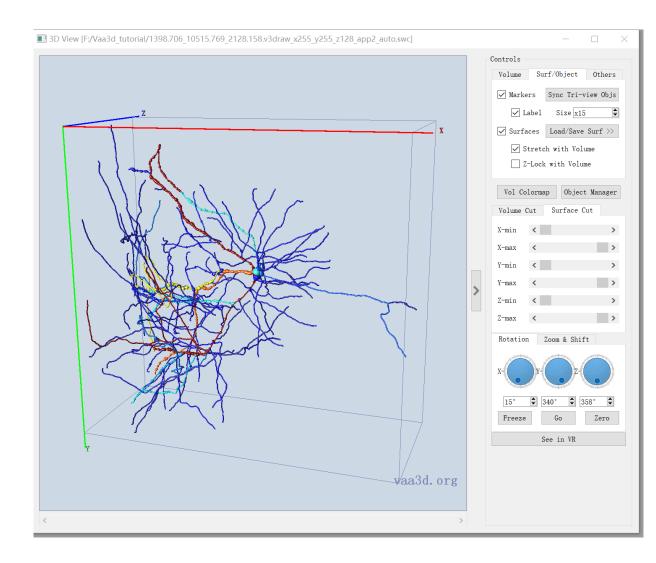


L-Measure Features

- Number of Nodes
- Soma Surface
- Number of Stems
- Number of Bifurcations
- Number of Branches
- Number of Tips
- Overall Width
- Overall Height
- Overall Depth
- Average Diameter
- Total Length

- Total Surface
- Total Volume
- Max Euclidean Distance
- Max Path Distance
- Max Branch Order
- Average Contraction
- Average Fragmentation
- Average Parent-daughter Ratio
- Average Bifurcation Angle Local
- Average Bifurcation Angle Remote
- Hausdorff Dimension

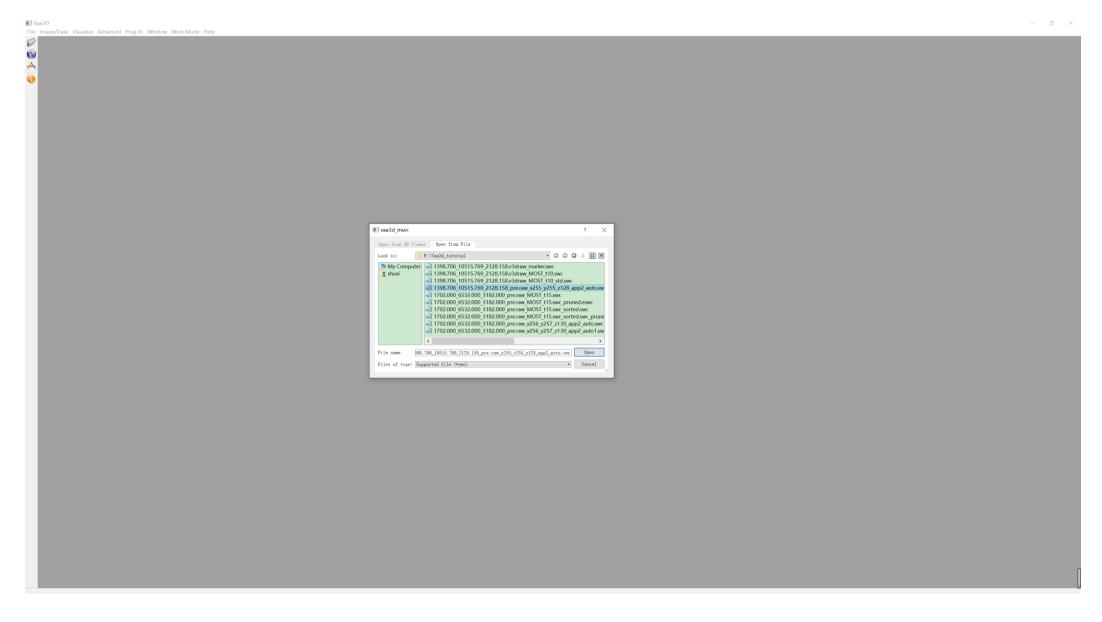






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🔳 Vaa3D File Image/Data Visualize Advanced Plug-In Window Work-Mode Help

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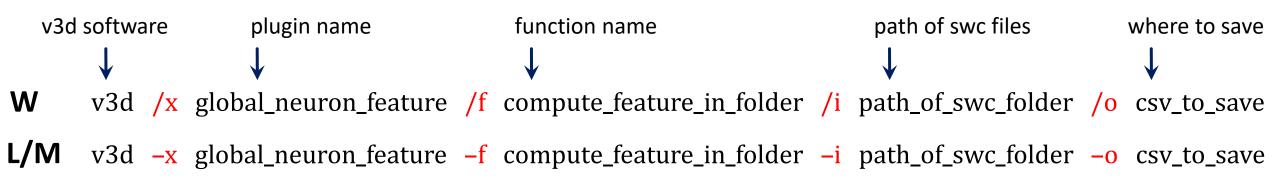
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Run Functions Via Command Line



Global Features Via Command Line



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.swc files

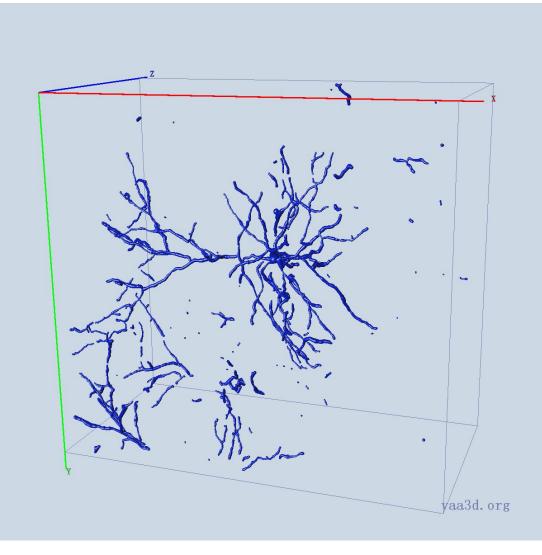
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Pre-process .swc Files

- not saved in the order of root-branches
- more than one roots
- not well-connected tree (i.e., there are gaps)
- small branches

• sort \rightarrow prune





swc_to_maskimage_sphere_unit

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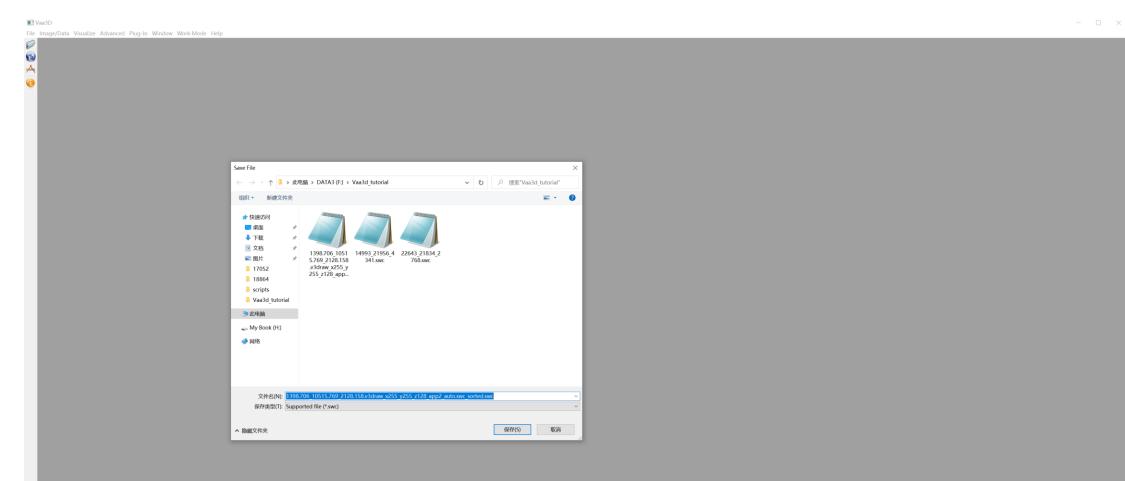
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Example Result

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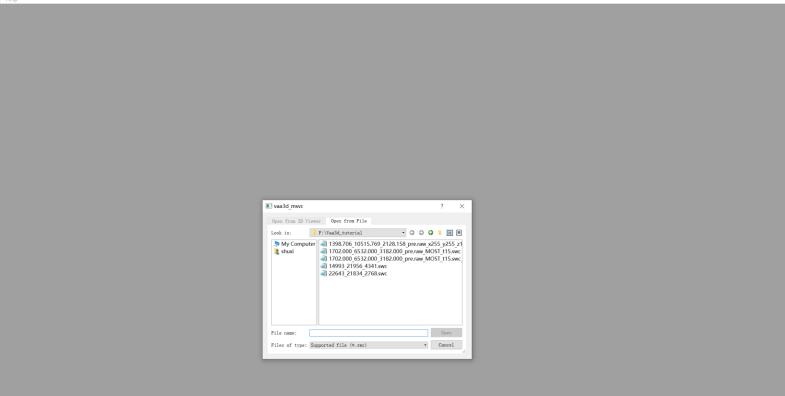
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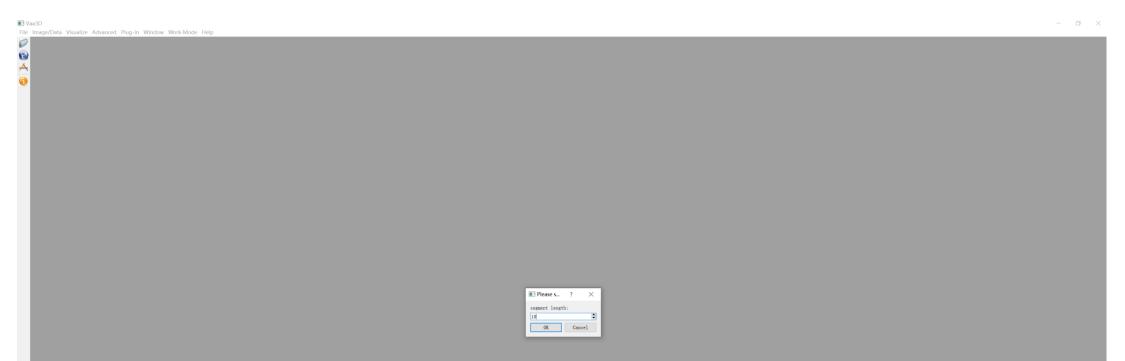
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Vaa3D
 File Image/Data Visualize Advanced Plug-In Window Work-Mode Help

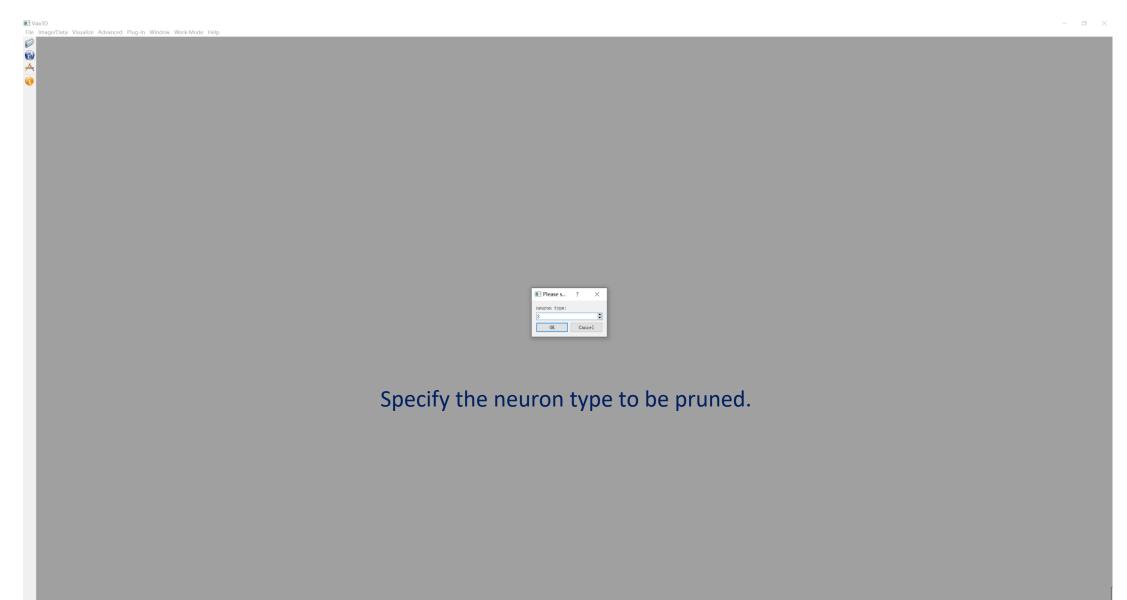


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Length threshold: segments shorter than this threshold will be removed.







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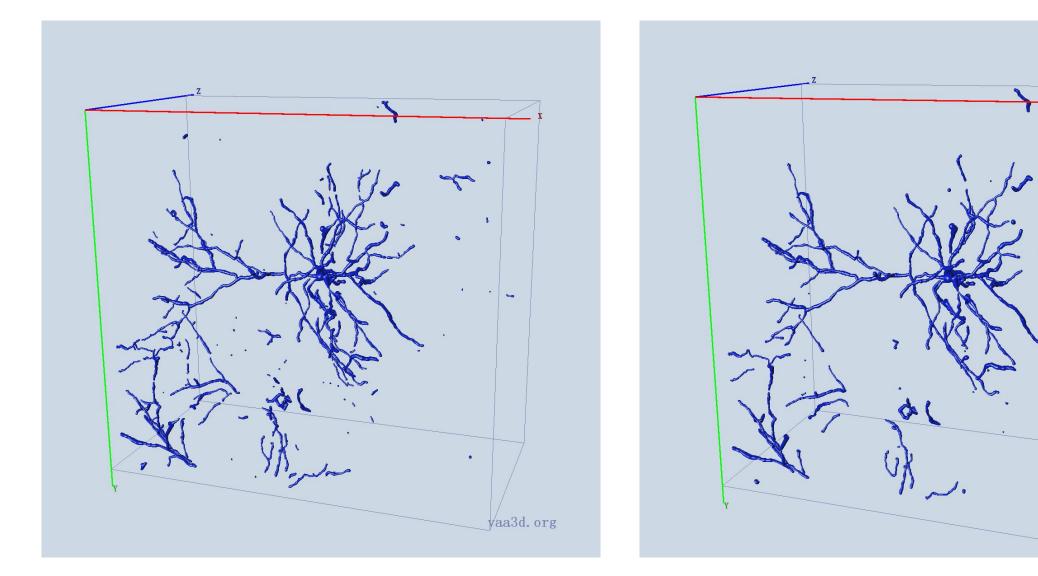
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 📰 图片 * 17052 18864 📕 scripts Vaa3d tutorial 🗢 此电脑 🥪 My Book (H:) 🔮 网络 文件名(N): 1702.000_6532.000_3182.000_pre.raw_MOST_t15.swc_sorted.swc_pruned.swc 保存类型(T): Supported file (*.swc) 保存(S) 取消 ▲ 隐藏文件夹

- 0 ×



Results





pruned

vaa3d.org

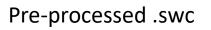
Global Features

Vaa3D				- 5 X
File Image/Data Visualize Advanced				
Ø	Plug-in manager			
8	Re-scan all plugins			
Å	Recently used plugins			
	Most used plugins Clear used plugins history	·		
	_Vaa3D_plugin_creator			
	adaEnhancement	•		
	AllenApps app2WithPreinfo			
	app3			
	calculate_2images_overlap_shift			
	celegans			
	cell_counting	,		
	color_channel	•		
	compare_swc	•		
	consensus	•		
	data_IO	•		
	data_type	•		
	findCrossBranch	•		
	FlyWorkstation_utilities			
	getSomaFeature			
	image_analysis image_blending			
	image_edge_detection			
	image_filters			
	image_geometry	,		
	image_projection			
	image_registration	•		
	image_resolution	•		
	image_ROI	•		
	image_segmentation	•		
	image_thresholding	•		
	imageProcess	•		
	imPreProcess			
	JudgeBranch			
	linker_file marker_utilities	affine transform swc		
		annie_transionn_swc		
		assemble_neuron_live blastneuron		
		branch_order_analysis		
	movies and snapshots	 calculate_reliability_score 		
		color_render_ESWC_features		
	neuron_toolbox	consensus_skeleton_via_clustering +		
		Enhanced_SWC_Format_Converter +		
		global_neuron_feature		
		hierarchical_labeling_of_neuron		
		inter_noue_pruning	Help	
	shape_analysis swcPruning	N3DFix		
	synapse_detector	fiedron_color_display		
		neuron_color_seperator neuron_connector		
		neuron_distance		
	Vaa3D_PluginInterface_Demos	neuron_fragment_extractor		
	wpkenanPlugin	neuron_image_profiling		
		neuron_radius +		
		node_connect +		
		pruning_swc •		
		pruning_swc_simple		
		resample_swc +		
		sort_neuron_swc		
		standardize_swc		
		subtree_labelling swc_gui_resample		
		swc_to_maskimage_cylinder_unit		
		swc_to_maskimage_sphere_unit		

Global Features

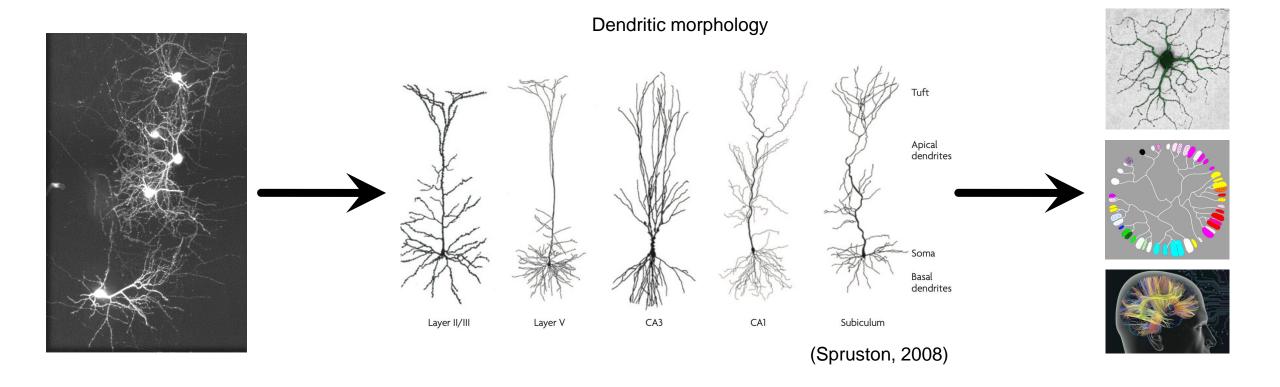
🔳 vaa3d_msvc	×
Global features of the neuron:	
<pre>number of nodes soma surface number of stems number of bifurcations number of branches number of tips overall width overall height overall depth average diameter total length total surface total volume max euclidean distance max path distance max branch order average contraction average fragmentation average parent-daughter ratio average bifurcation angle local average bifurcation angle remote Hausdorff dimension</pre>	
	ОК







Key Questions in Neuroscience

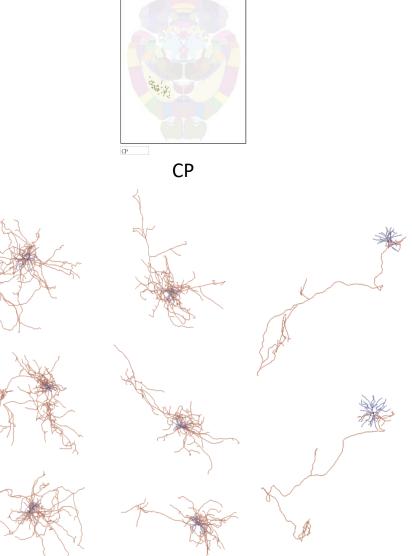


• Quantify/characterize neuron morphologies



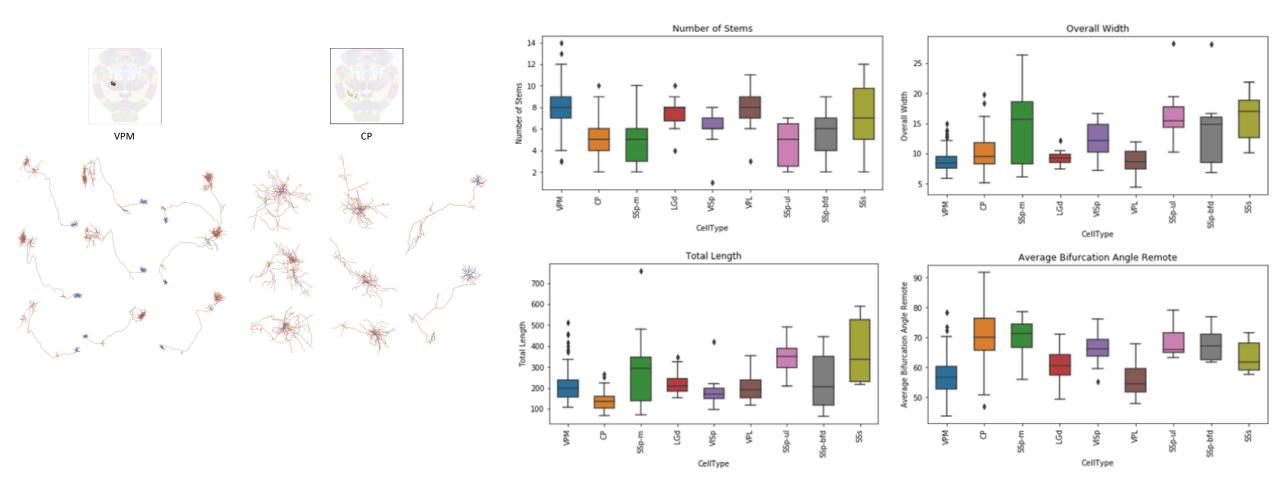
Single Neurons

VPM VPM

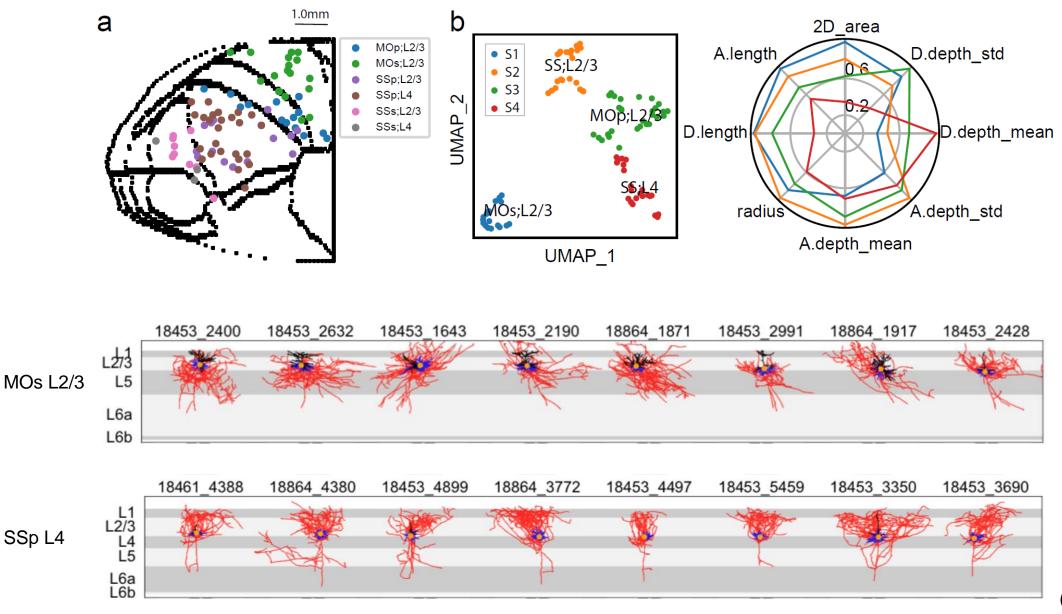




Morphological Features



Local Arborization Patterns of Cortical L2/3/4 IT Neurons



10 × 1

(Peng et al, 2020)

Automatic Quality Control

features after initial screening Number of Tips Overall Width **Overall Height Overall Depth** Total Length Max Branch Order Number of Stems Number of Bifurcatons Number of Branches Max Euclidean Distance Max Path Distance Average Contraction

Tolerance Interval Plot for Number of Tips

95% Tolerance Interval At Least 95% of Population Covered

Statistics

Normal

Nonparametric

Achieved Confidence

Normality Test

237

53.401

15.141

21.207

85.595

29.000 93.000

95.4%

3.688

0.005

Ν

Mean

StDev

Lower

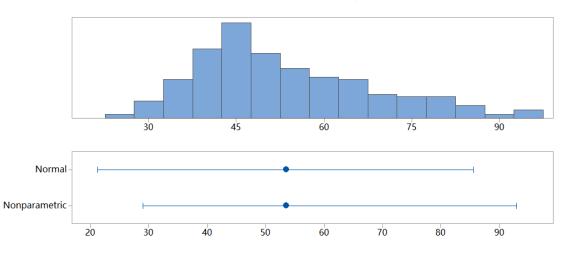
Upper

Lower

Upper

AD

P-Value <



Normal Probability Plot



Summary

- To calculate morphological features of a reconstruction
- To sort and prune .swc files as preprocessing steps

• Brief showcase where we can make use of the morphological features



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File	Imag
Ø	

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File Image/Data Visualize Advanced Plug-In Window Work-Mode Help

Plug-in manager Re-scan all pluging

Recently used plugins

calculate_2images_overlap_shift

FlyWorkstation utilities getSomaFeature image_analysis image_blending image edge detection image_filters

image_geometry

image_projection image registration image_resolution

image_ROI image_segmentation image thresholding imageProcess

imPreProcess JudgeBranch linker file marker utilities

Mean Variance

ML get sample

neuron stitch

neuron toolbox

neuron_tracing

neuron utilities

pixel intensity

shape_analysis

synapse detector

Vaa3D_PluginInterface_Demos

swcPruning

Sync Views

TypeLength

wpkenanPlugin

Retrace

movies and snapshots

misc

Most used plugins Clear used plugins history _Vaa3D_plugin_creator adaEnhancement AllenApps app2WithPreinfo app3

celegans cell counting color channel compare swe consensus data IO data_type findCrossBranch

A toolkit to edit swc files

- Pre-process, e.g., sort, pruning, resampling, connector...
- Confidence score of each tracing point •
- Distance between neurons

....

- Extract fragments from a reconstruction
- Affine transform to a reference swc

	pruning_swc_simple
	resample_swc
	sort_neuron_swc
	standardize_swc
	subtree_labelling
	swc_gui_resample
	swc_to_maskimage_cylinder_unit
	swc_to_maskimage_sphere_unit
	tile_display_multiple_neurons
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affine transform swc

assemble_neuron_live

branch_order_analysis

global neuron feature

inter node pruning

neuron color display

neuron connector

neuron distance

neuron_color_seperator

neuron fragment extractor

typeset childbranch

neuron image profiling neuron radius node connect pruning swc

N3DFix

calculate reliability score

color render ESWC features

consensus skeleton via clustering >

Enhanced_SWC_Format_Converter

hierarchical_labeling_of_neuron

blastneuron

10×1

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