

Vaa3D is the Right Tool for Big Biodata Visualization and Analysis

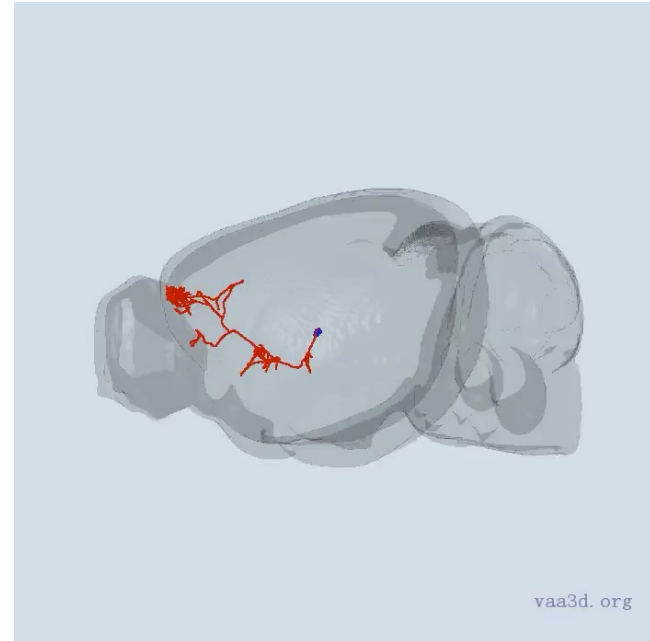
A brief walkthrough of the software

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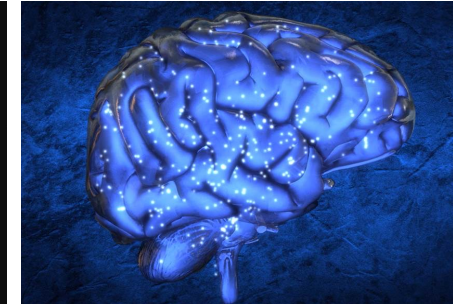
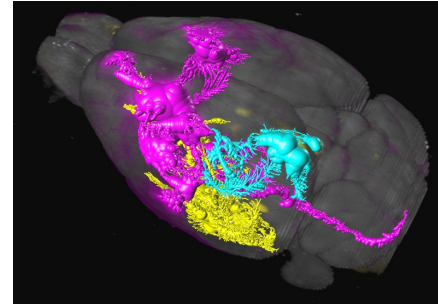
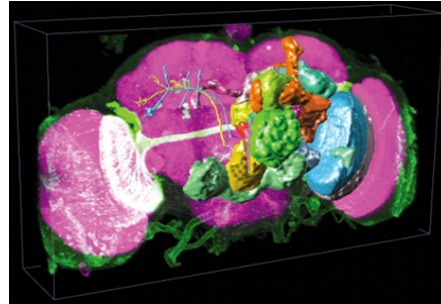
School of Comp. Eng. & Sci.,
Shanghai University

2021-06-21

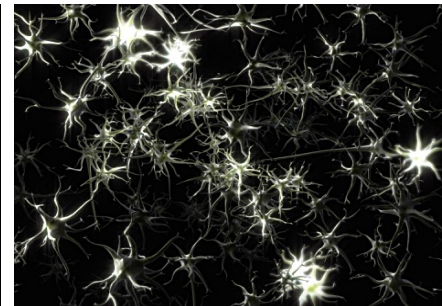
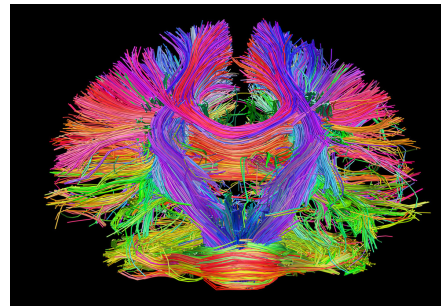
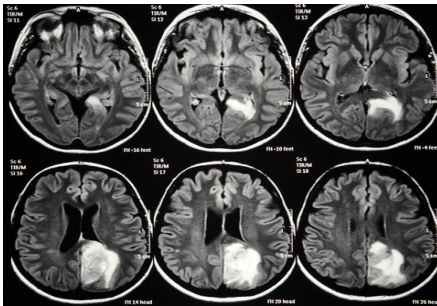


Big Biodata – big, complicated, while containing valuable information

- Various species



- Various resolution



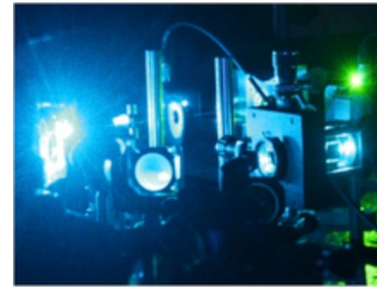
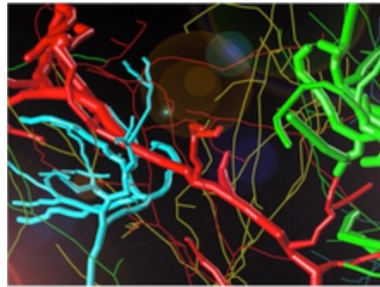
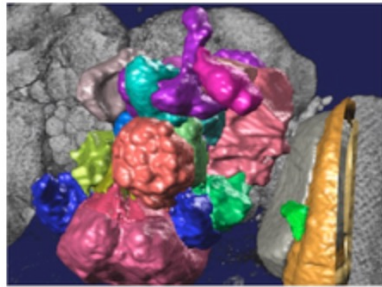
- Various imaging modalities
- Various data types, formats, etc.

The bottleneck lies in visualization/computation/analysis, rather data generation.

Vaa3D Homepage: www.vaa3d.org

Vaa3D

'Vaa3D' is short for the "3D Visualization-Assisted Analysis" software suite. This term was first used in a [2010 Nature Biotech article \(DOI: 10.1038/nbt.1612\)](#). The software has been featured in [HHMI News](#), [Allen Institute News](#), [Nature Methods Highlights](#) and [Science News](#), among others. This software is currently maintained by both HHMI - Janelia Research Campus and the Allen Institute for Brain Science, and is used in a number of projects worldwide.



A Swiss Army knife for exploring big big image data

FAST

Vaa3D visualizes and explores big 3D/4D/5D images with giga-voxels and even tera-voxels, within seconds or sub-seconds!

COOL

Vaa3D extracts complex surface objects from images, and performs comprehensive analyses such as brain connectome mapping.

EXTENSIBLE

100+ plugins for image acquisition, microsurgery, data management and analysis, and massive-scale pipelining.

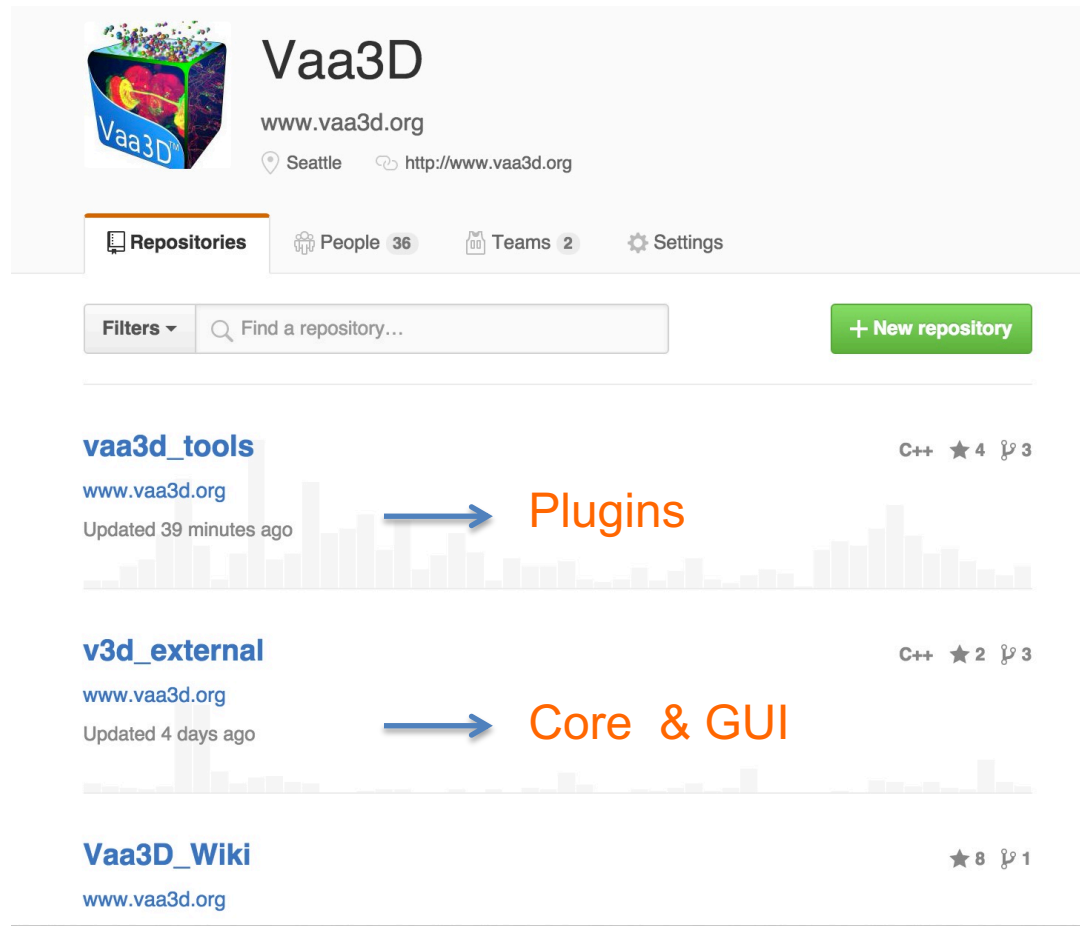
LICENSE

Downloads

- [Binary releases](#)
- [Plugins](#)
- Source code and documentation
 - [Code Repo](#)
 - [GitHub Docs](#)

- [Related tools](#)

Vaa3D Source Code: <https://github.com/Vaa3D>



Vaa3D
www.vaa3d.org
Seattle <http://www.vaa3d.org>

Repositories People 36 Teams 2 Settings

Filters Find a repository... [+ New repository](#)

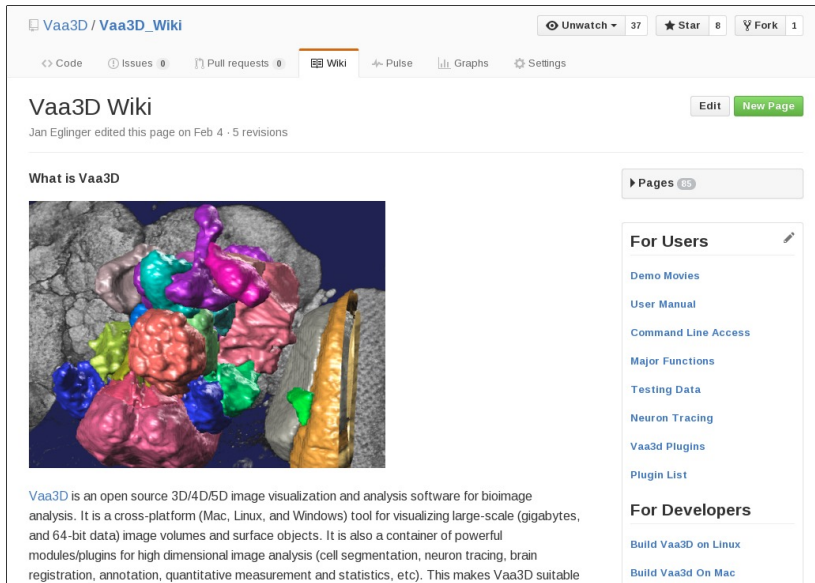
vaa3d_tools C++ ★ 4 🍴 3
www.vaa3d.org
Updated 39 minutes ago → **Plugins**

v3d_external C++ ★ 2 🍴 3
www.vaa3d.org
Updated 4 days ago → **Core & GUI**

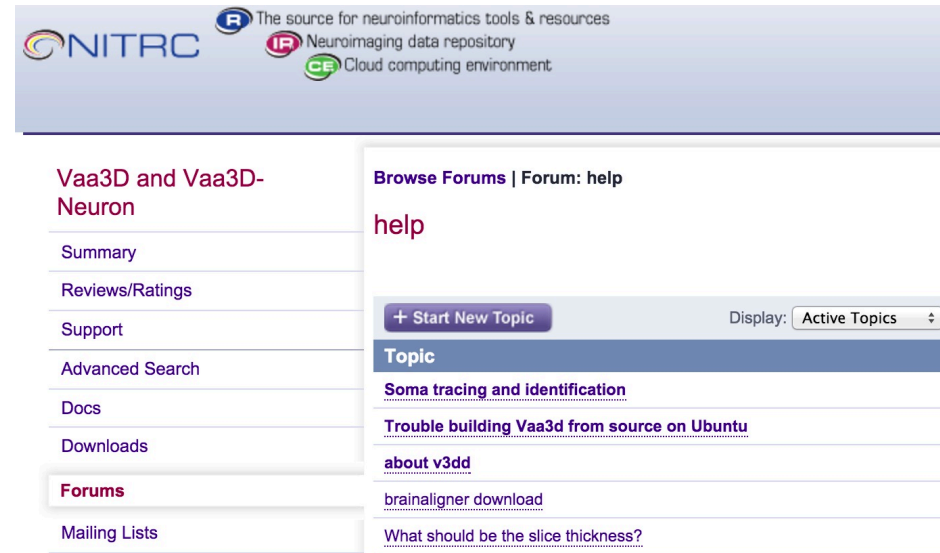
Vaa3D_Wiki ★ 8 🍴 1
www.vaa3d.org

Executables: https://github.com/Vaa3D/Vaa3D_Wiki/wiki/Download-Vaa3D-executables

The Vaa3D community



The screenshot shows the GitHub Wiki page for Vaa3D. At the top, it displays the repository name 'Vaa3D / Vaa3D_Wiki' and navigation options like 'Code', 'Issues', 'Pull requests', 'Wiki', 'Pulse', 'Graphs', and 'Settings'. The main heading is 'Vaa3D Wiki' with an 'Edit' button and a 'New Page' button. Below the heading, it states 'Jan Eglinger edited this page on Feb 4 · 5 revisions'. The content area is titled 'What is Vaa3D' and features a 3D visualization of a brain slice with various colored regions (red, green, blue, yellow, orange) representing different structures. To the right of the image is a sidebar with a 'Pages' section containing a list of links: 'Demo Movies', 'User Manual', 'Command Line Access', 'Major Functions', 'Testing Data', 'Neuron Tracing', 'Vaa3d Plugins', and 'Plugin List'. Below this is a 'For Developers' section with links to 'Build Vaa3D on Linux' and 'Build Vaa3d On Mac'.

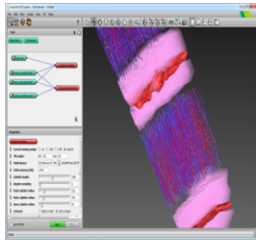


The screenshot shows the NITRC forum page for Vaa3D. At the top, there is a header with the NITRC logo and the text 'The source for neuroinformatics tools & resources'. Below the header, there are three circular icons: 'R' for Neuroimaging data repository, 'IP' for Neuroimaging data repository, and 'CE' for Cloud computing environment. The main content area is titled 'Vaa3D and Vaa3D-Neuron' and includes a 'Browse Forums | Forum: help' link. The page is organized into several sections: 'Summary', 'Reviews/Ratings', 'Support', 'Advanced Search', 'Docs', 'Downloads', 'Forums', and 'Mailing Lists'. The 'Forums' section is highlighted in red. To the right of the main content, there is a 'help' section with a '+ Start New Topic' button and a 'Display: Active Topics' dropdown menu. Below this, there is a 'Topic' section with a list of topics: 'Soma tracing and identification', 'Trouble building Vaa3d from source on Ubuntu', 'about v3dd', 'brainaligner download', and 'What should be the slice thickness?'.

- More Vaa3D resources & wiki page:
https://github.com/Vaa3D/Vaa3D_Wiki/wiki/Vaa3D-Wiki
- Please send your Vaa3D related questions to the Vaa3D help forum hosted at NITRC.org

Why Vaa3D?

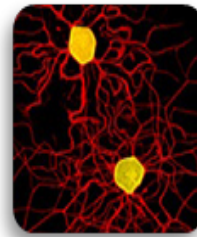
- Commercial tools



Amira



Imaris



NeuroLucida



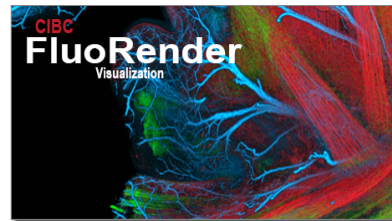
Matlab

...

- Free or open-source tools



ImageJ



Fluorender



Icy



ilastik

...



3 Enabling technologies of Vaa3D



Immersive visualization



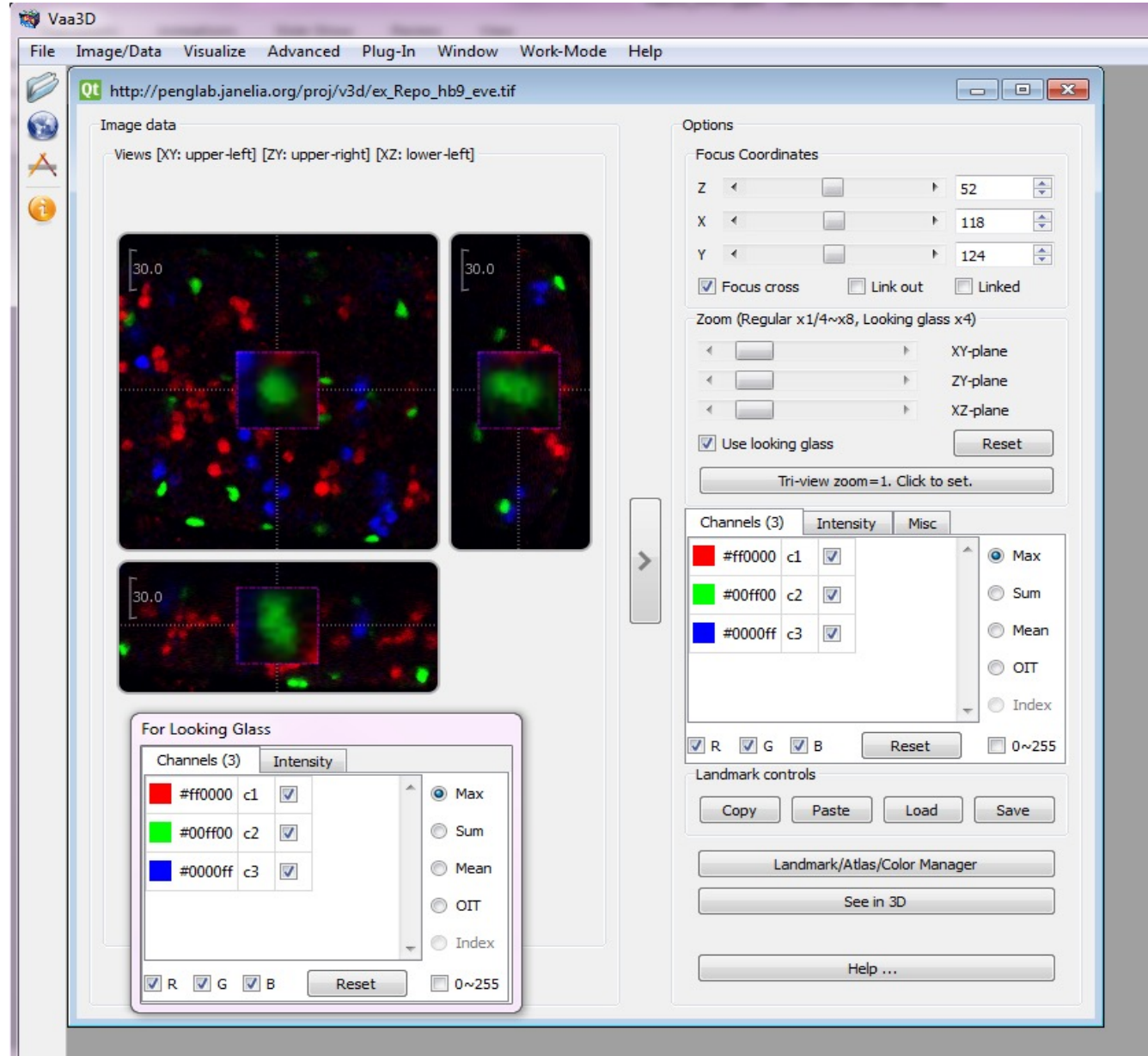
Intuitive annotation



Out-of-core handling of big data

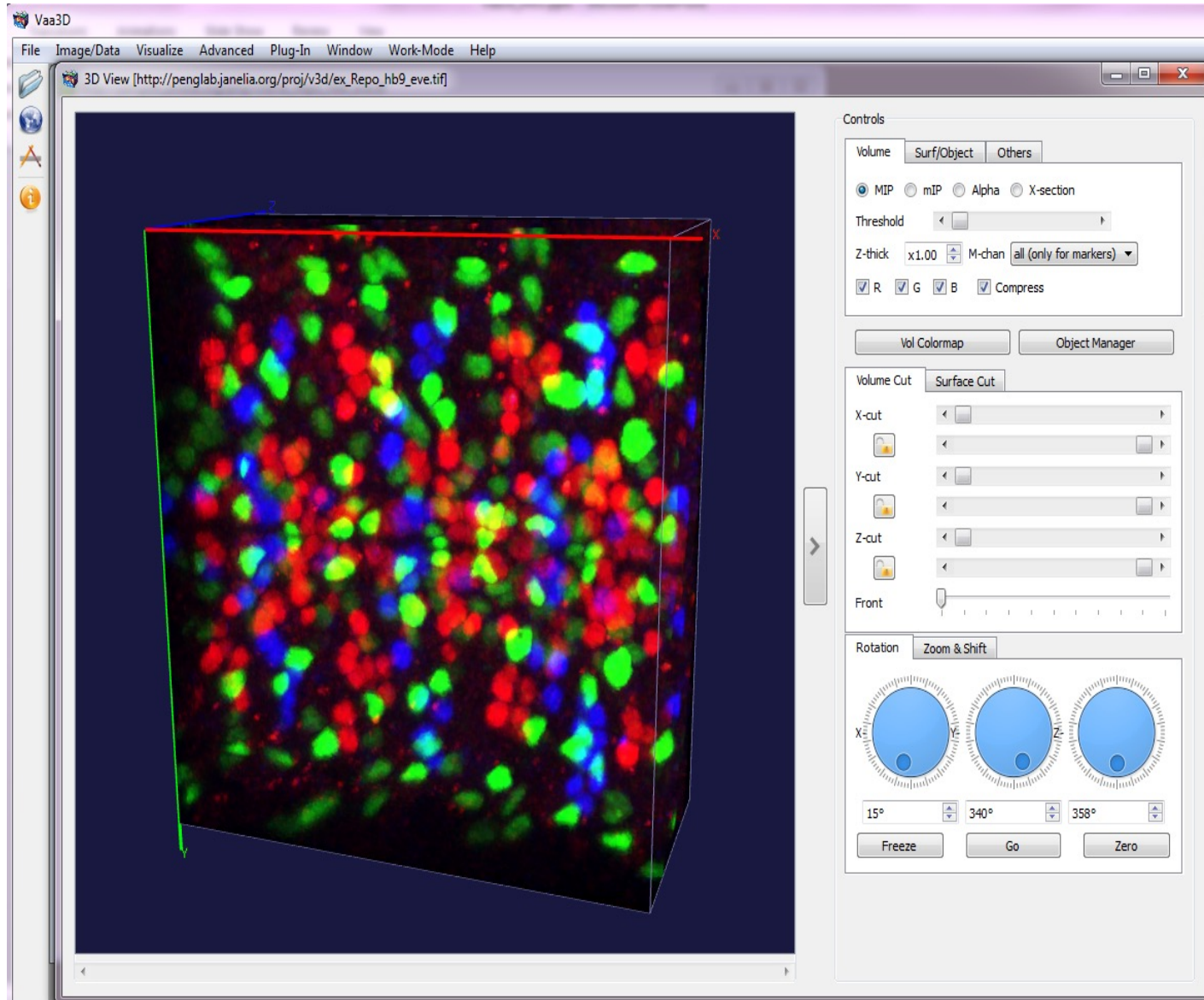
Tri-view

- 3 orthogonal views
- Looking Glass
- Channel
- Landmarks
- Atlas

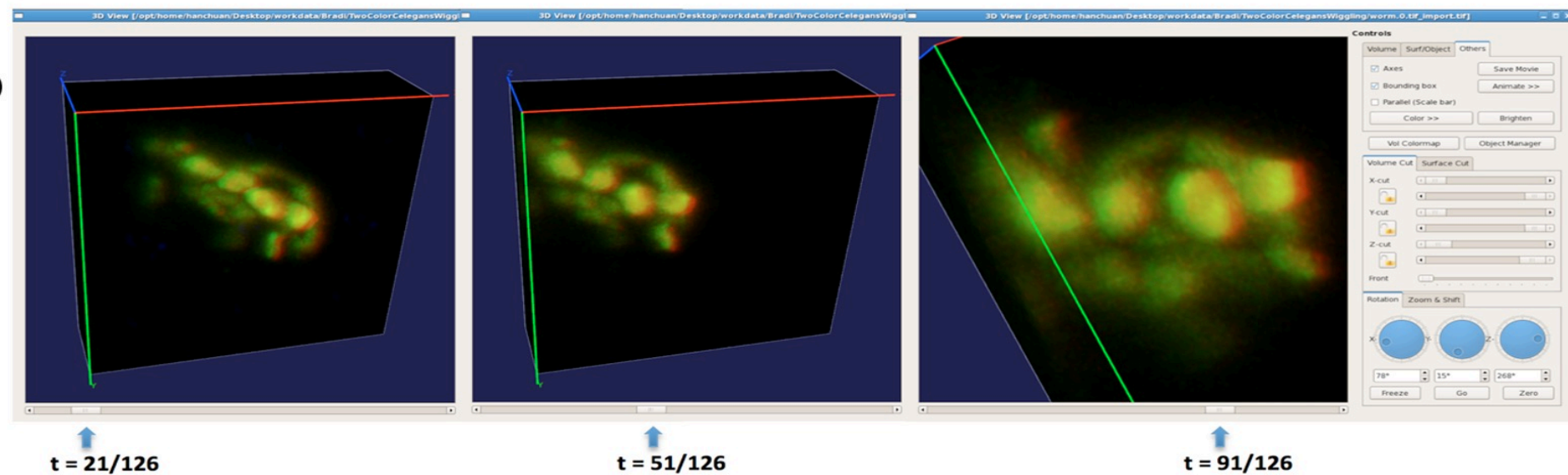
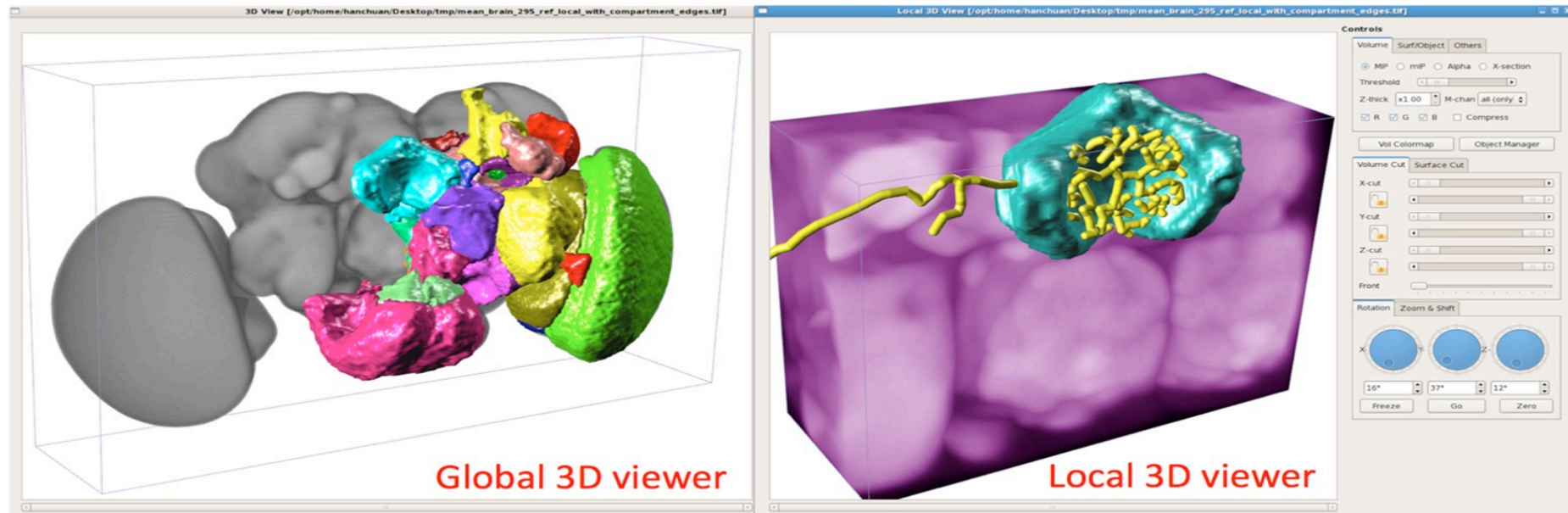


3D Viewer

- MIP
- Alpha
- Color map
- Volume Cut
- Zoom, Rotate, Pan
- Annotation
- Different surface objects

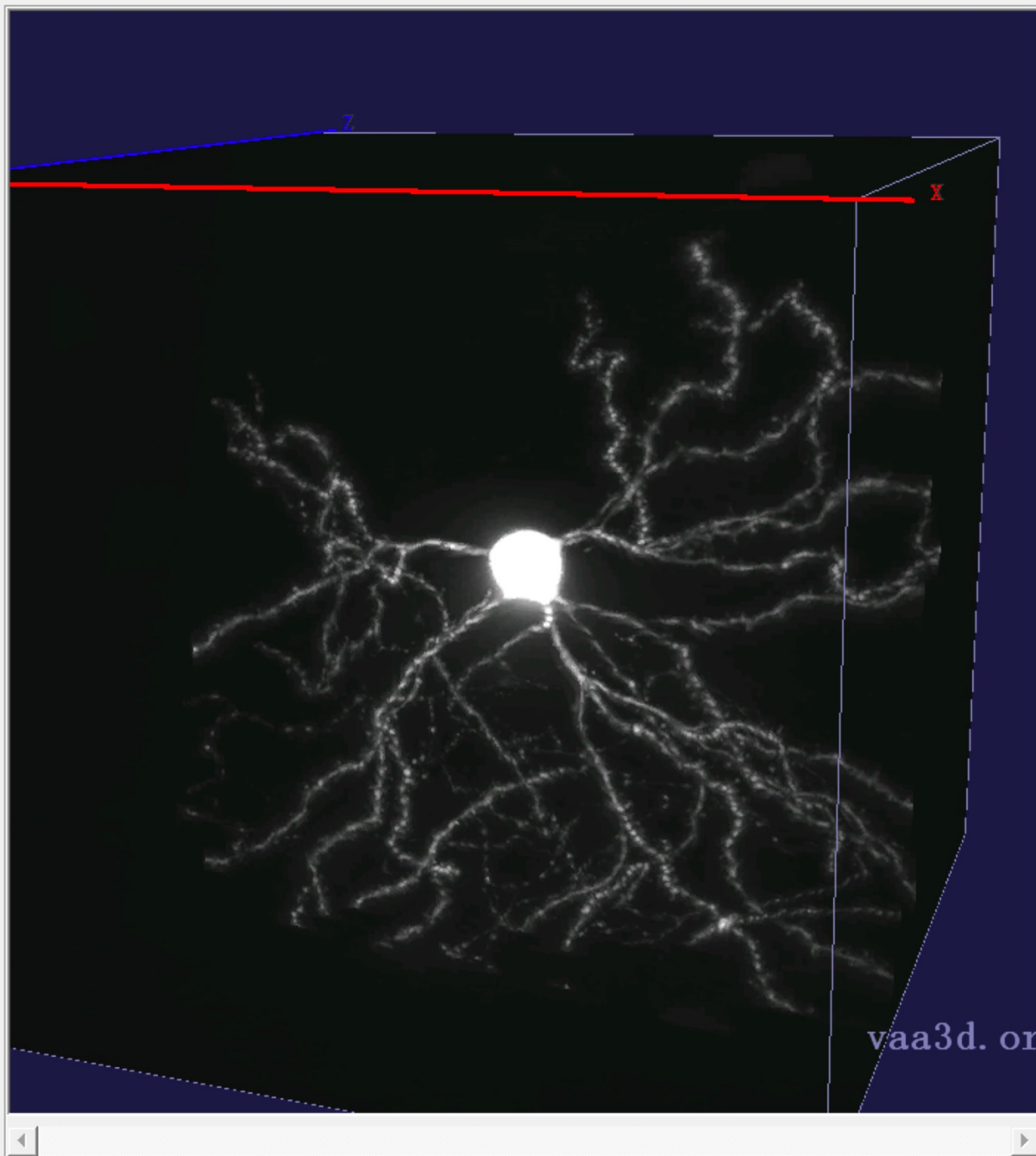


Generalized 5D data (XYZ-C-T) and surface object visualizer



TeraVR: an extension for immersive visualization





Controls

Volume | Surf/Object | Others |

MIP mIP Alpha X-section

Threshold

Z-thick M-chan

R G B Compress

Contrast

Vol Colormap | Object Manager

Volume Cut | Surface Cut |

X-cut

Y-cut

Z-cut

Front

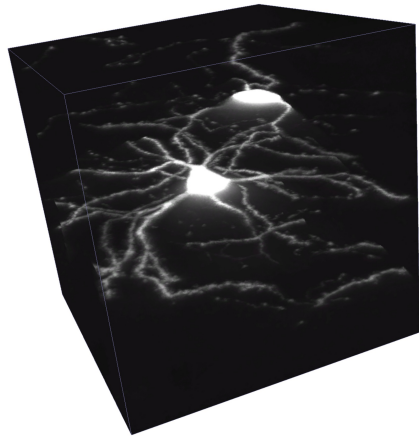
Rotation | Zoom & Shift |

X

Freeze | Go | Zero

See in VR

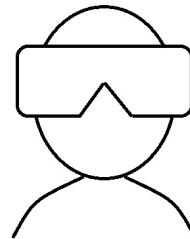
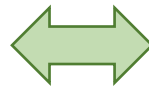
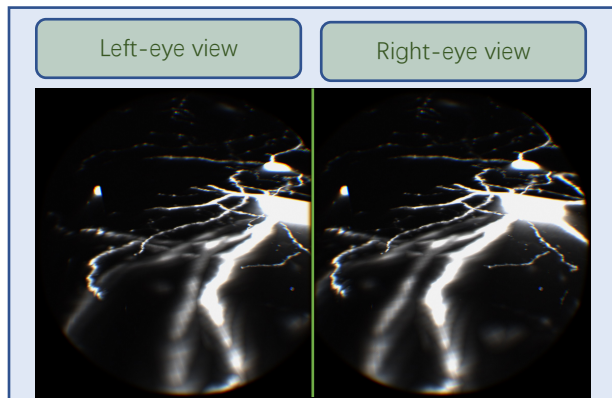
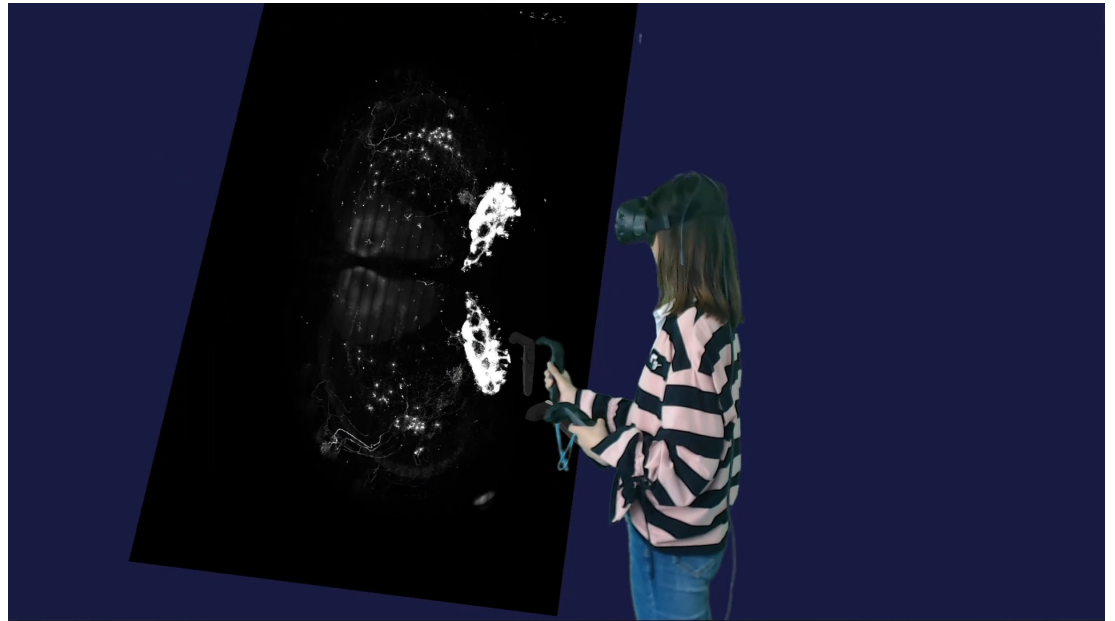
VR-based neuron reconstruction



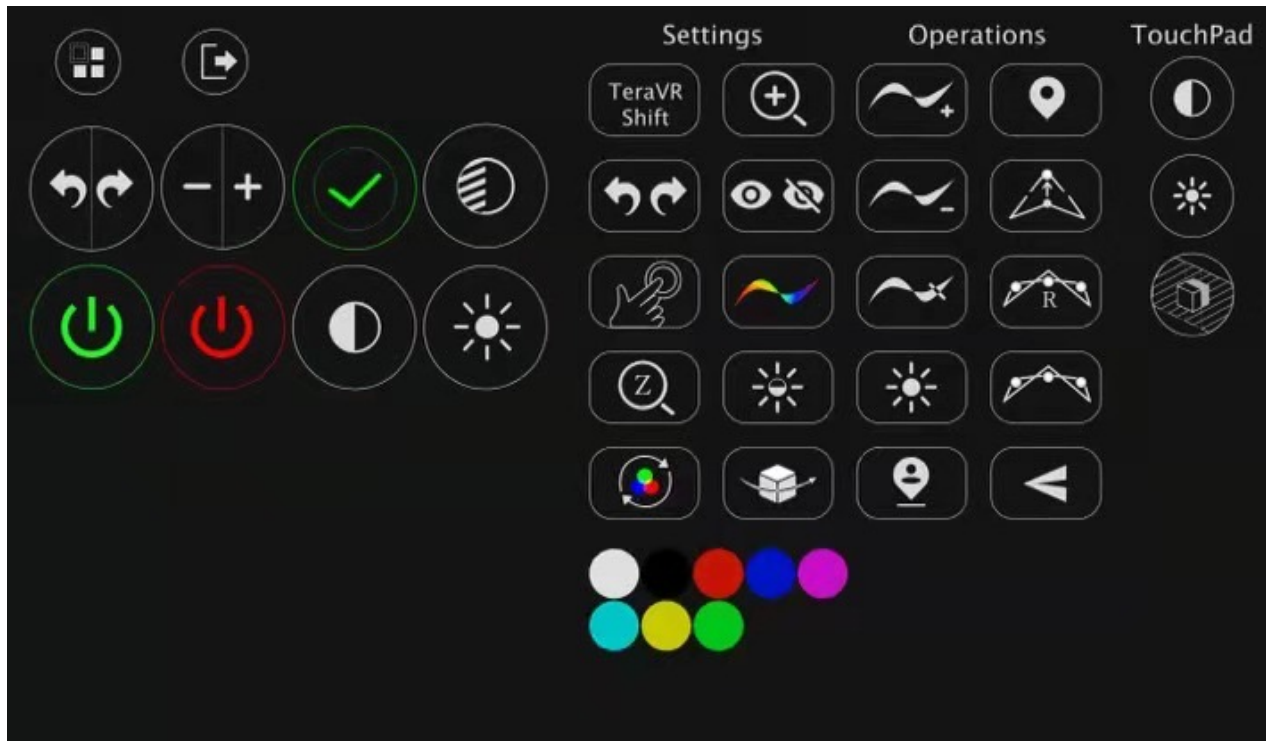
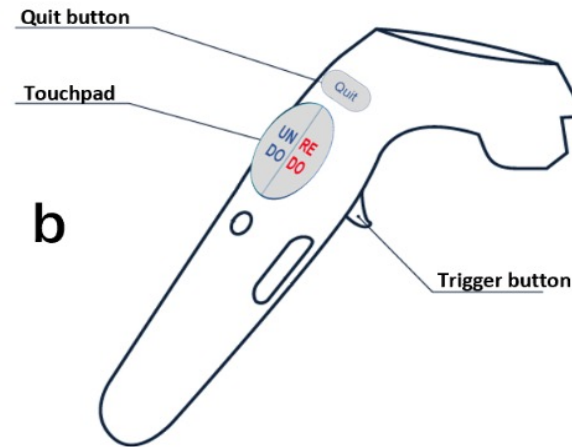
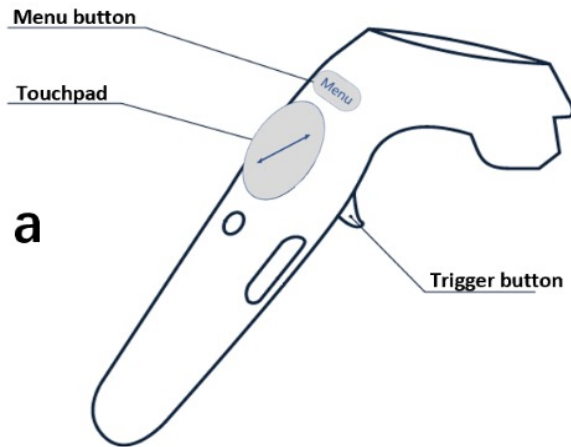
Position,
orientation,
transformation



Stereo
rendering
result



Comprehensive toolbox



3 Enabling technologies of Vaa3D



Immersive visualization



Intuitive annotation



Out-of-core handling of big data

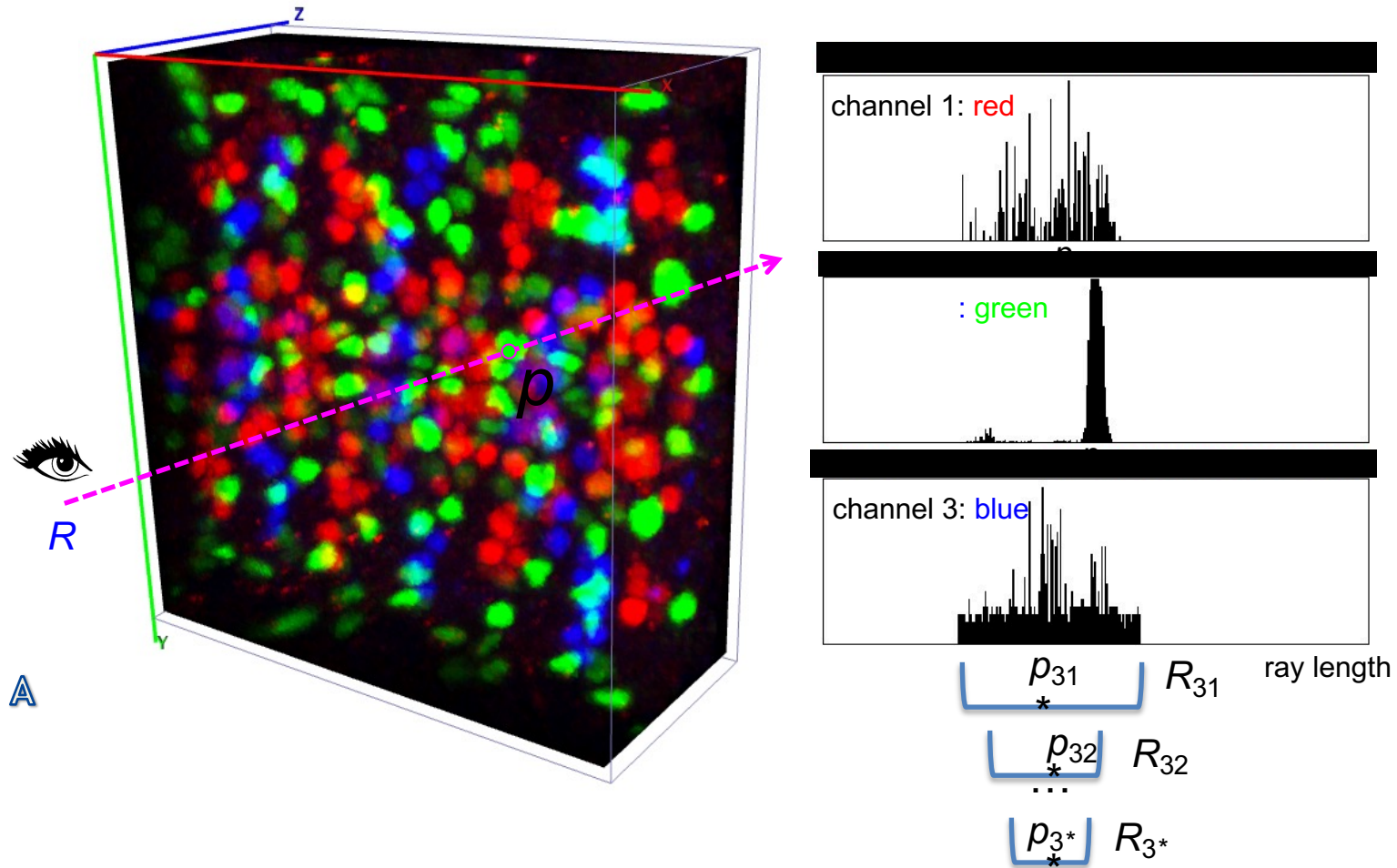
3D Random Access Powered by Virtual Finger

- A family of 3D-WYSIWYG ('what you see in 2D is what you get in 3D') computer algorithms that map users' inputs in the 2D plane of a computer screen to the 3D locations of biological entities



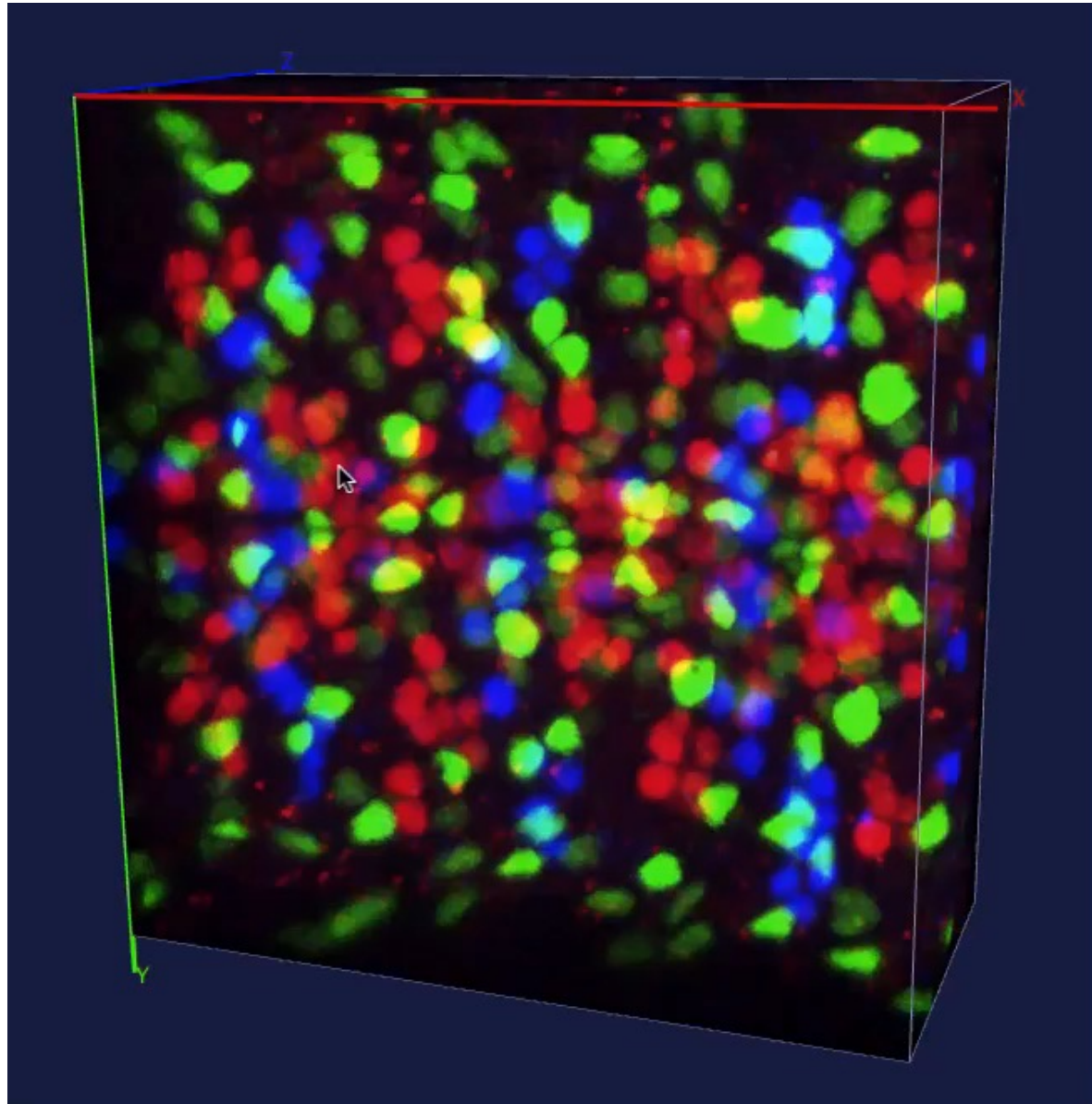
* Peng, H. et al, "Virtual finger boosts three-dimensional imaging and microsurgery as well as terabyte volume image visualization and analysis", Nature Communications 5, 2014

One-click 3D Pinpointing

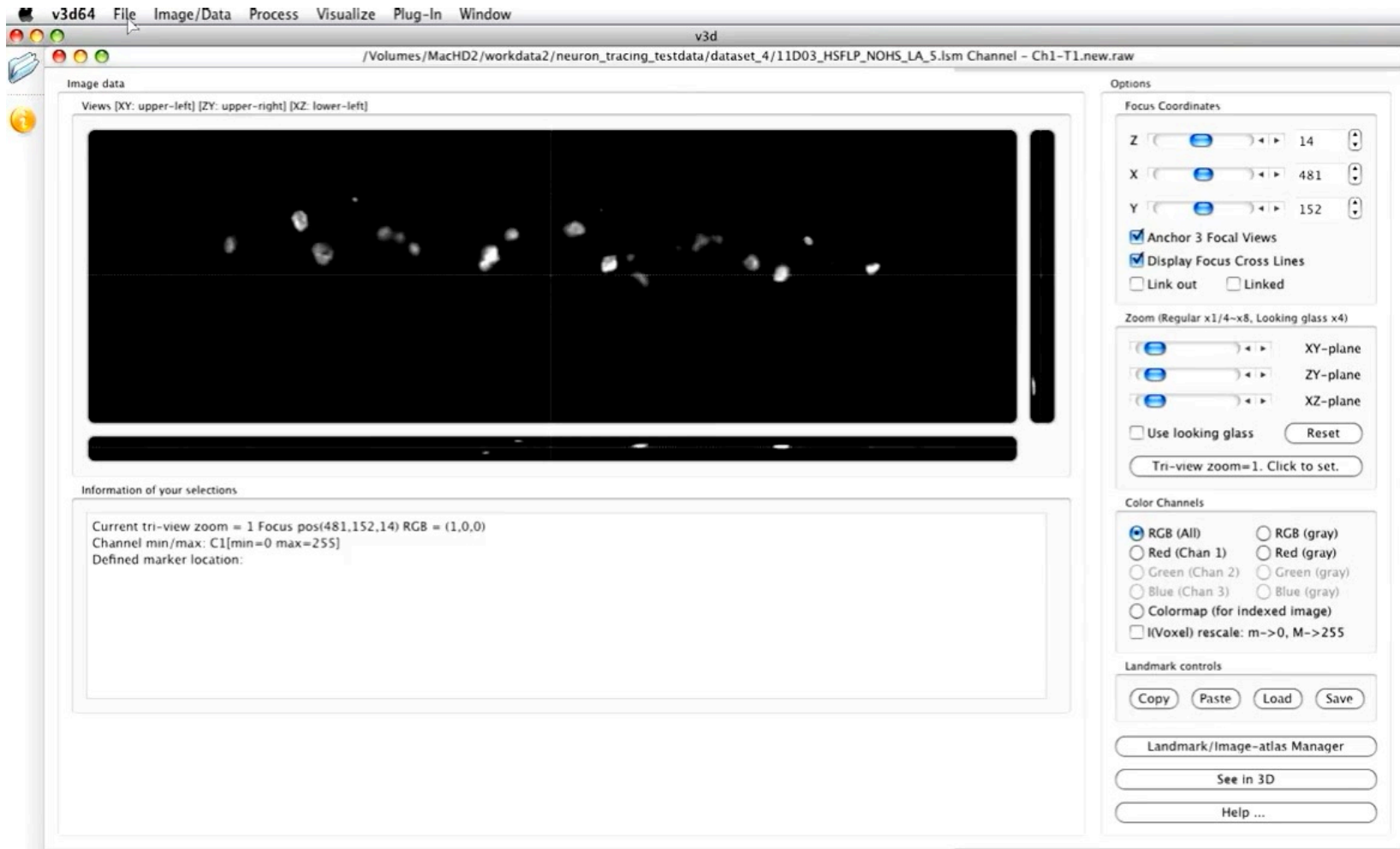


The most probable location on A is estimated by applying the **mean-shift** algorithm on the intensity distribution along the shooting ray. It can be used for quick manual **cell-counting** or for **quantitatively profiling** the voxel intensity along the straight line segment connecting two markers.

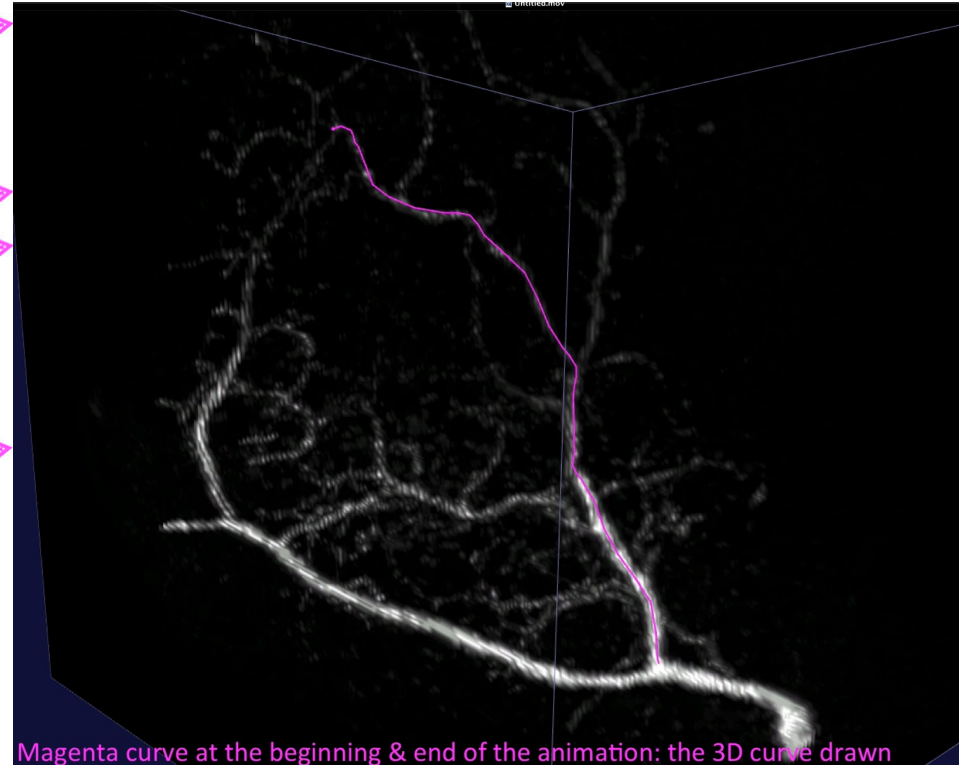
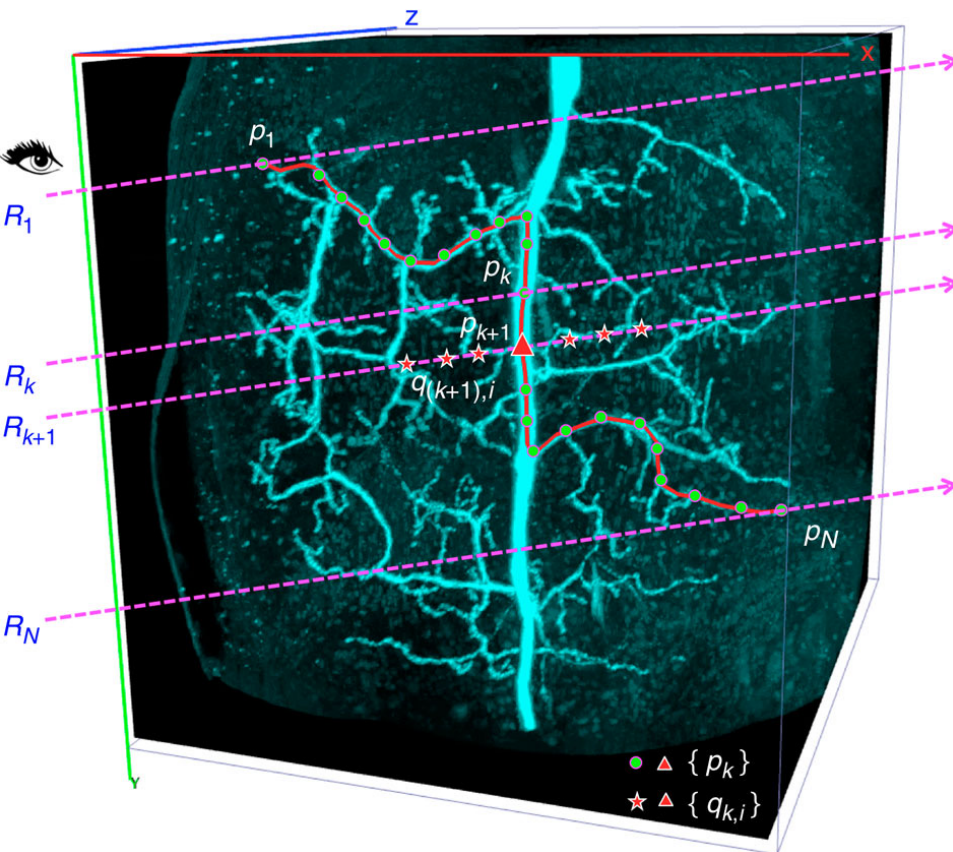
One-click 3D Pinpointing



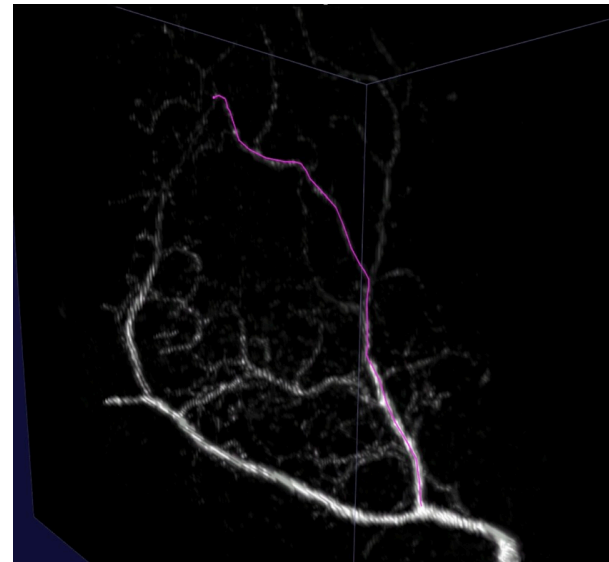
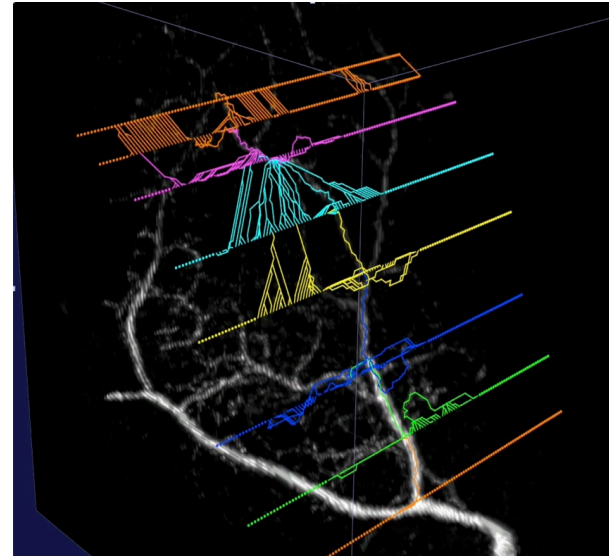
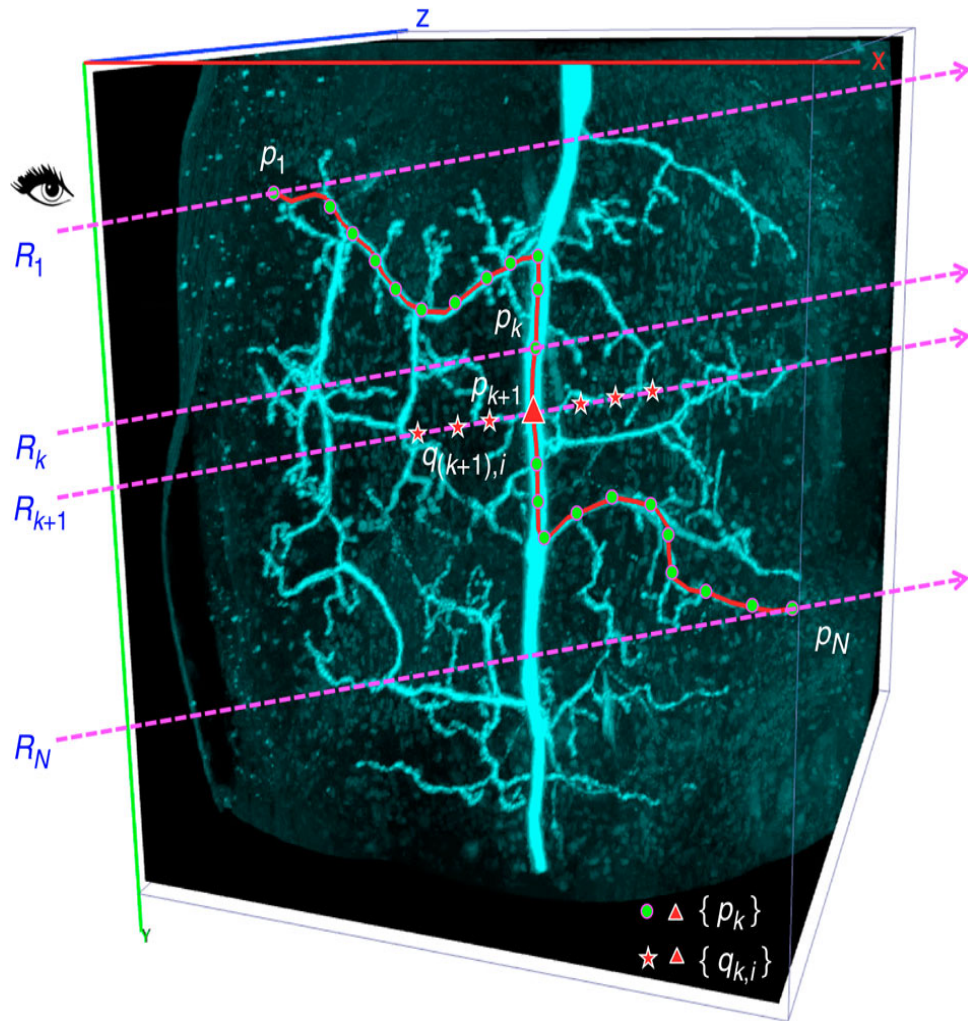
Vaa3D: 1-mouse stroke 3D curving (1/2)



Vaa3D: 1-mouse stroke 3D curving (2/2)



One-Stroke Curve Generation



Global minimum cost path via shortest paths for all consecutive rays.

3 Enabling technologies of Vaa3D



Immersive visualization



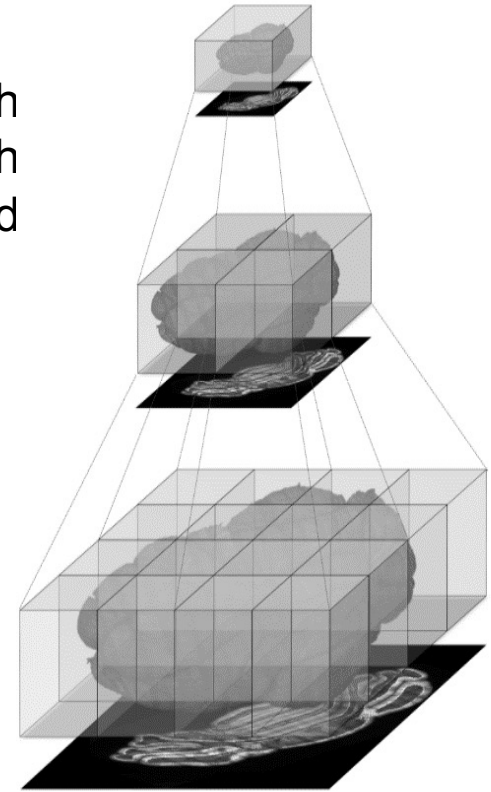
Intuitive annotation



Out-of-core handling of big data

Vaa3D-TeraFly (1/4): Overview

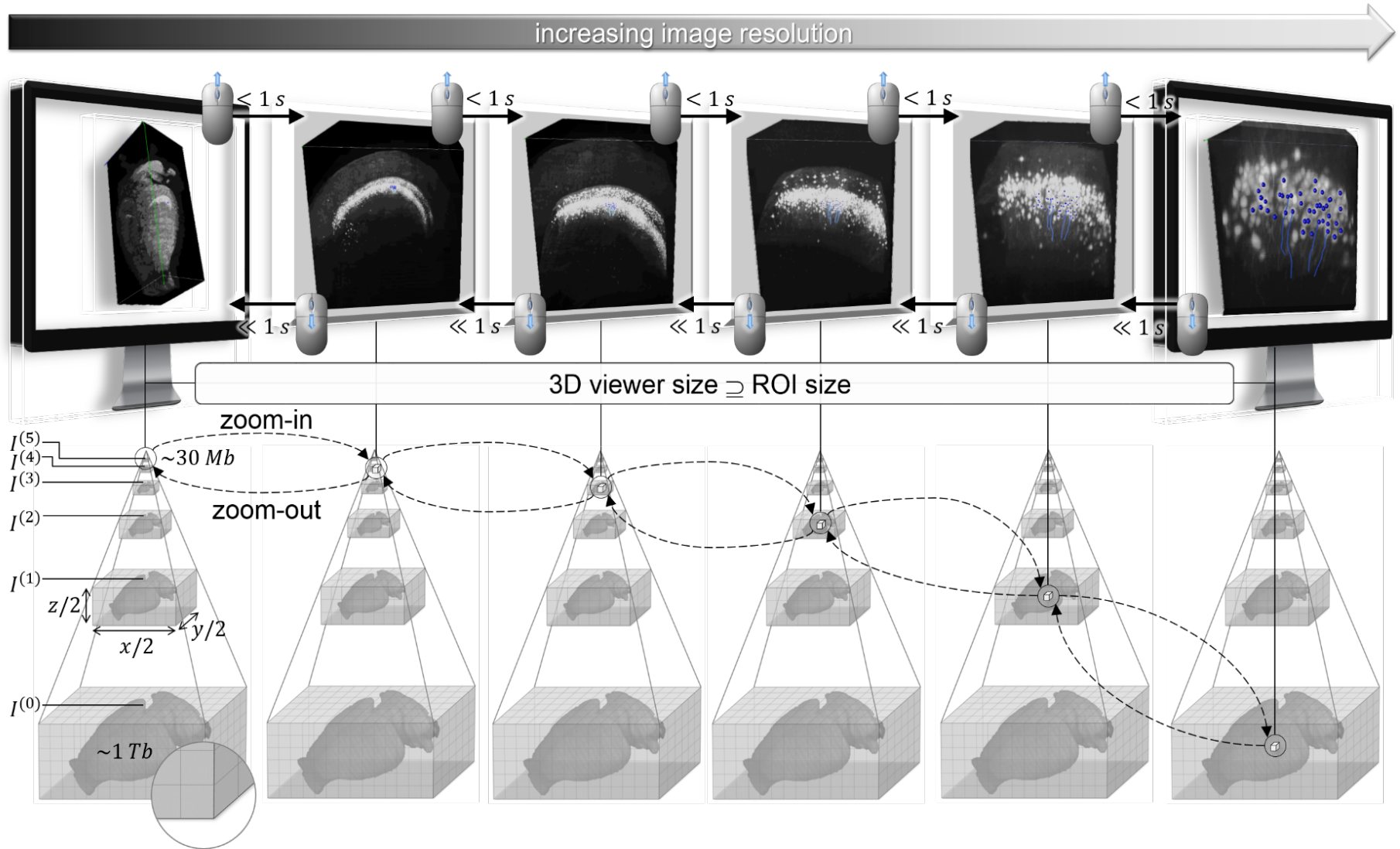
- **TeraFly** extends the Vaa3D software to cope with (potentially) **unlimited** sized bioimages even on laptops with a limited amount of system memory (≤ 4 GB) and video card memory (≤ 1 GB)
 - fast rendering/visualization of **3/4/5D TeraByte**-scale microscopy images
 - **instant** zoom-in/out with mouse-scroll
 - visualization-assisted **annotation** of 3D objects at different scales
 - **proofreading** tools
 - image format conversion tool (**TeraConverter**) included



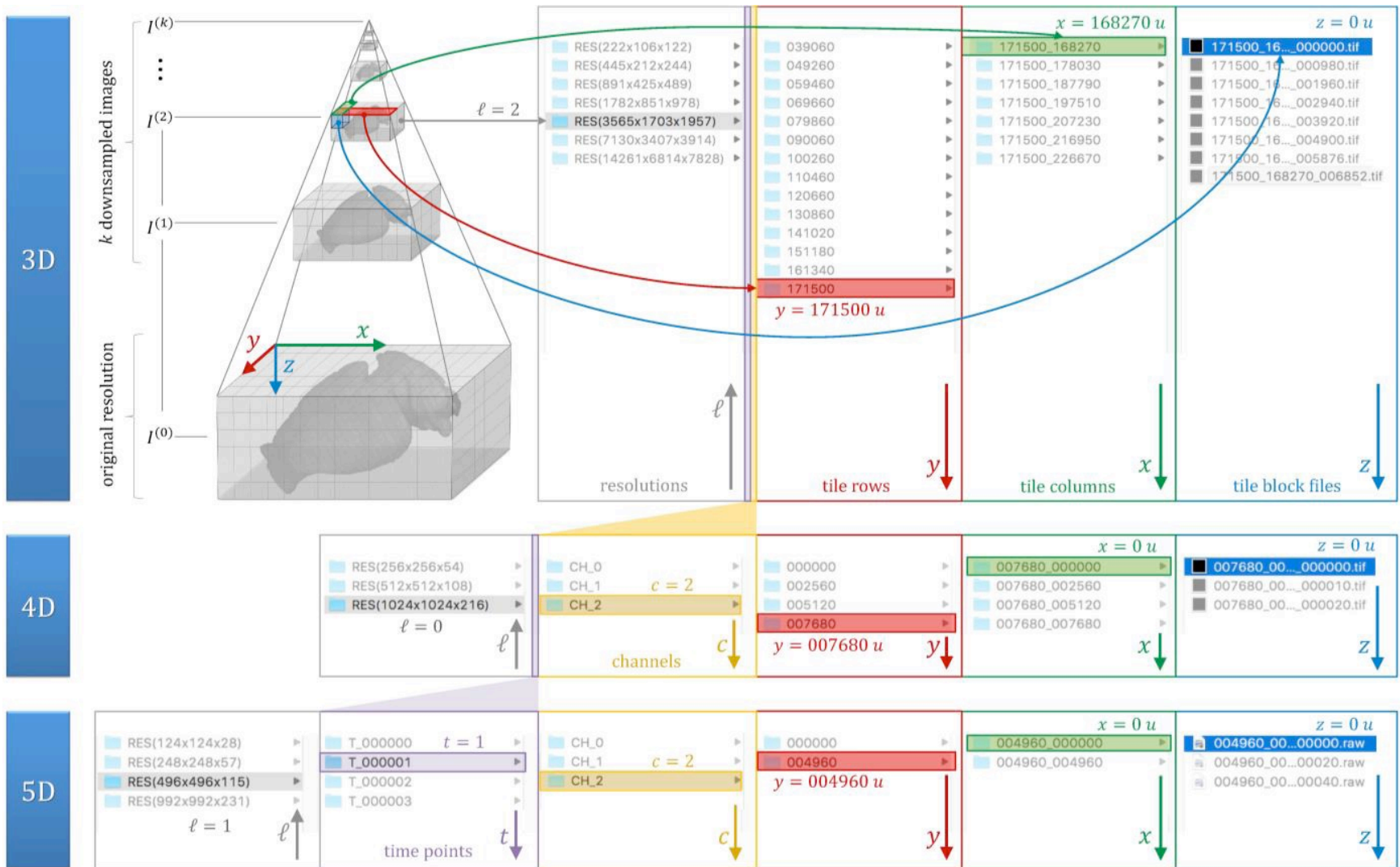
- the underlying idea is to mimic the behavior of Google Earth
 - what you see is what you need (WYSIWYN)
 - multiresolution representation



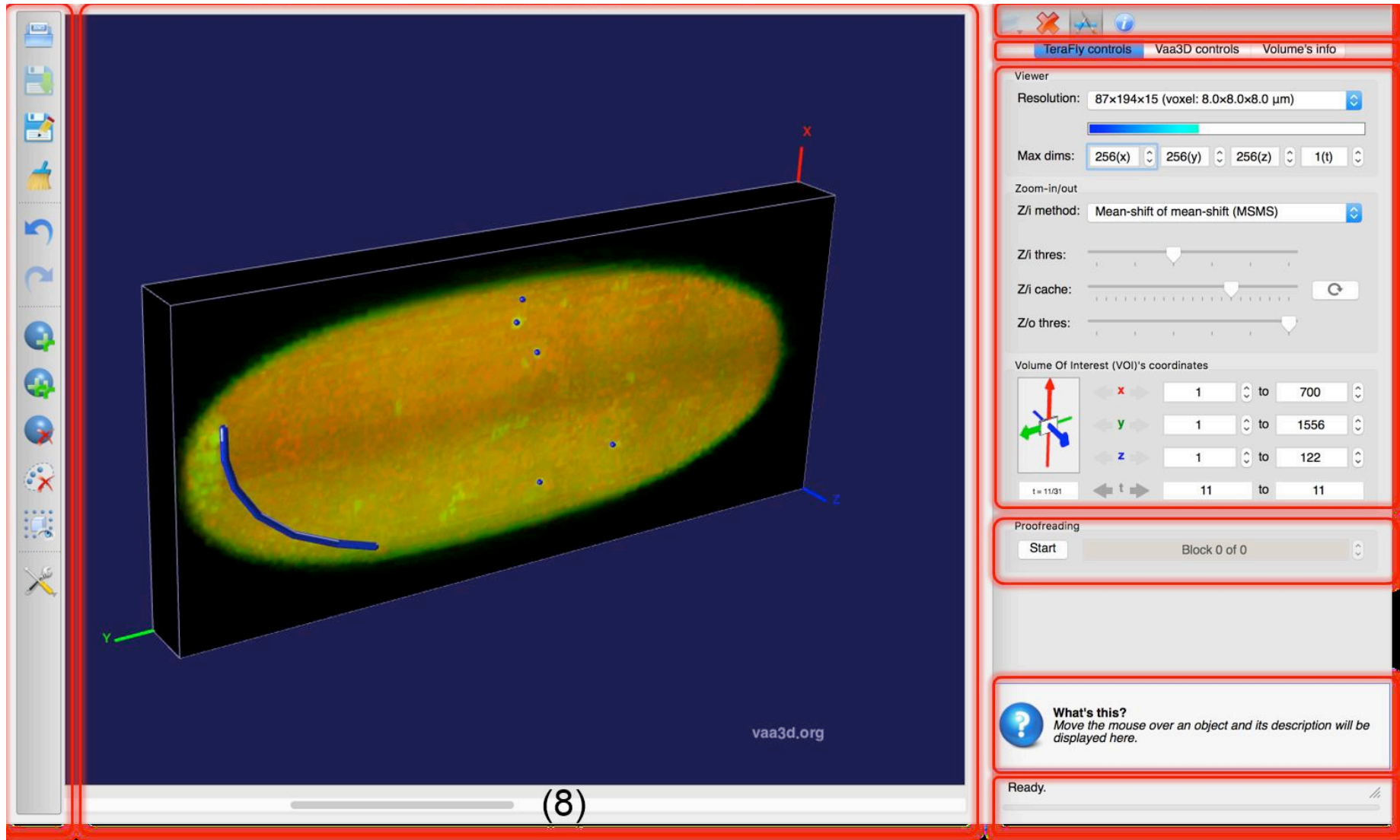
Vaa3D-TeraFly (2/4): Architecture



Vaa3D-TeraFly (3/4): Schema of 3D - 5D Formats



Vaa3D-TeraFly (4/4): User Interface

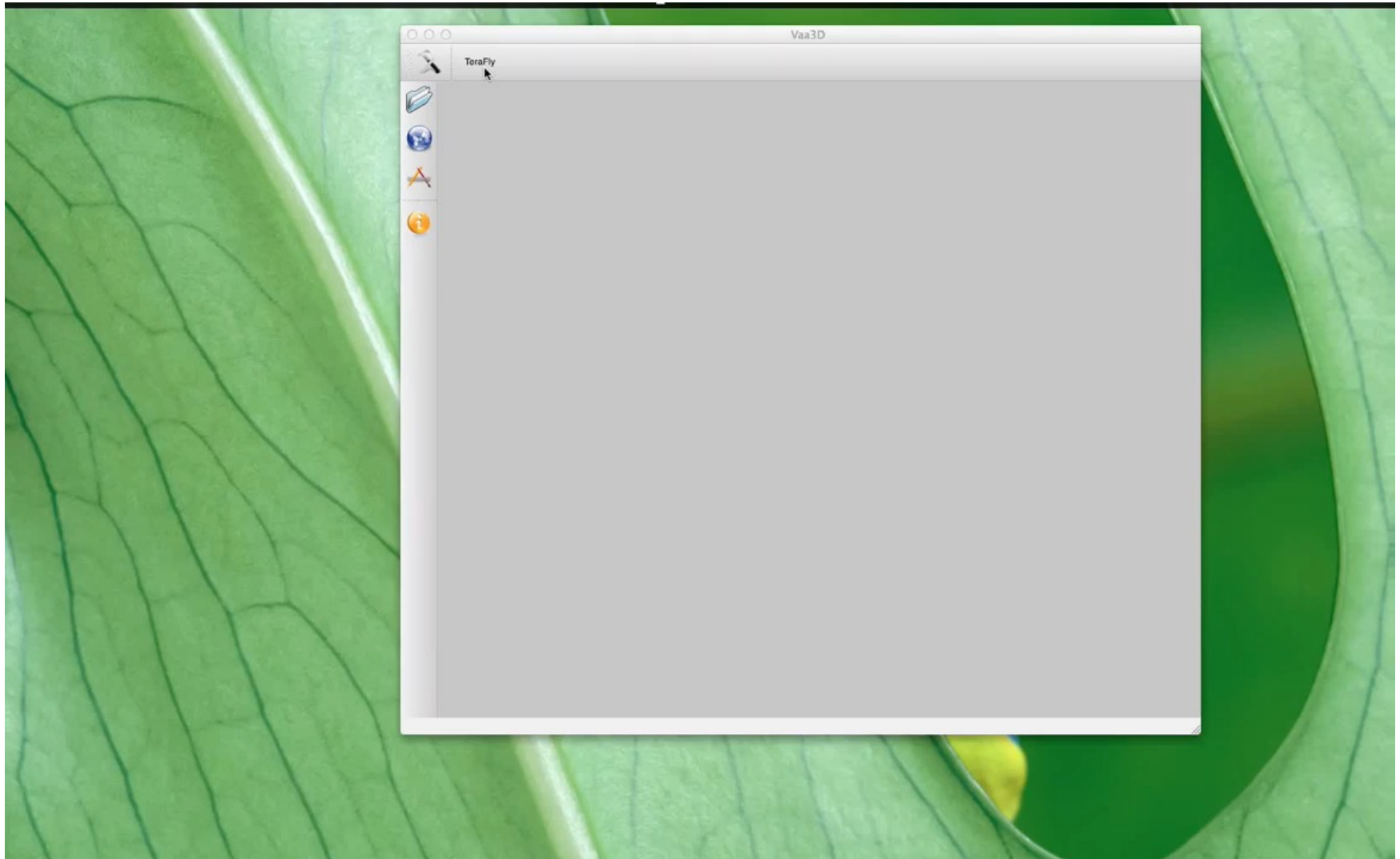


The image displays the Vaa3D-TeraFly user interface. The main window shows a 3D volume rendering of a biological specimen, likely a cell or tissue, with a blue line indicating a path or structure. The volume is rendered in a yellowish-green color. The interface includes a toolbar on the left with various icons for file operations, navigation, and rendering. The right panel contains several control sections:

- TeraFly controls**: Includes tabs for "TeraFly controls", "Vaa3D controls", and "Volume's info".
- Viewer**: Shows resolution (87x194x15 voxel: 8.0x8.0x8.0 μm) and a color scale bar.
- Max dims**: Controls for maximum dimensions (256(x), 256(y), 256(z), 1(t)).
- Zoom-in/out**: Includes a "Z/i method" dropdown set to "Mean-shift of mean-shift (MSMS)".
- Z/i thres**: A slider for Z/i threshold.
- Z/i cache**: A slider for Z/i cache with a refresh button.
- Z/o thres**: A slider for Z/o threshold.
- Volume Of Interest (VOI)'s coordinates**: A 3D coordinate system and input fields for x (1 to 700), y (1 to 1556), z (1 to 122), and t (11 to 11).
- Proofreading**: A "Start" button and a "Block 0 of 0" indicator.
- What's this?**: A help section with a question mark icon and text: "Move the mouse over an object and its description will be displayed here."
- Ready.**: A status bar at the bottom right.

The URL "vaa3d.org" is visible in the bottom right corner of the main window. A red box highlights the entire interface. The number (8) is in the bottom center.

Vaa3D-TeraFly: Basic Usage



Vaa3D-TeraFly: 5D image visualization

The screenshot displays the Vaa3D-TeraFly v0.9.996 software interface. The main window, titled "3D View [ID(0), Res(124 x 124 x 28), Volume X=[1,124], Y=[1,124], Z=[1,28], T=[0,9], 2 channels_processed]", shows a 3D visualization of a biological specimen with green and red channels. The interface is divided into several control panels:

- Volume Controls:** Includes tabs for "Surf/Object" and "Others". Options include MIP (selected), mIP, Alpha, and X-section. A Threshold slider is present. Z-thick is set to x1,00 and M-chan to all (only fo). Checkboxes for R, G, and B are checked, and Compress is unchecked. Buttons for "Vol Colormap" and "Object Manager" are available.
- Volume Cut:** Features "Surface Cut" and "Volume Cut" tabs. Sliders for X-cut, Y-cut, and Z-cut are shown. A "Front" slider is also present.
- Rotation and Zoom & Shift:** Includes three rotation dials for X, Y, and Z axes. Current rotation values are 26°, 18°, and 355°. Buttons for "Freeze", "Go", and "Zero" are provided.
- Viewer Controls:** Includes a "Volume's Info" tab. The "Viewer" section shows Resolution: 124x124x28 (voxel: 8.0x8.0x8.0 μm). Max dims are 256 (X), 256 (Y), 128 (Z), and 10 (t). "Zoom-In/out" controls include a "Z/i method" dropdown (Foreground (1 marker)), "Z/i thres" and "Z/i cache" sliders, and a "Z/o thres" slider.
- Volume Of Interest (VOI) coordinates:** A 3D coordinate system shows X (1 to 992), Y (1 to 992), and Z (1 to 231) ranges. Time (t) is set to 0/9.
- Proofreading:** Includes a "Start" button and a "Block 0 of 0" indicator.
- Help Panel:** A "What's this?" section with a question mark icon and the text: "Move the mouse over an object and its description will be displayed here." Below it is a "Ready." status bar.

More Functions of Vaa3D

- **Segmentation**
 - globular objects (cell bodies, nuclei, bouton)
 - fibrous objects (neurons)
 - Irregular shaped (brain compartments)
- **Registration**
 - global (affine, rigid), local (non-rigid, elastic)
 - Feature point detection, matching
 - Generate of warping field
 - Cutting plane restacking along curve
- **Classification**
 - Image [region] classification
 - Feature calculation
 - Neuron structure comparison & categorization
- **5D Data management**
 - 3D landmarking
 - Proof-reading
 - Manage images and associated meta data
 - Manage large image archive, e.g. aligned images & atlas files
- **~300 user-developed plugins**

Extended reading

More details of the techniques covered in this talk can be found in the below paper:

- Vaa3D platform, *Nature Biotechnology* 2010, *Nature Protocols* 2014
- Virtual finger, *Nature Communications* 2014
- TeraFly, *Nature Methods* 2016
- TeraVR, *Nature Communications* 2019

Thank you!

Acknowledgements go to our developers, collaborators, and the user community.

