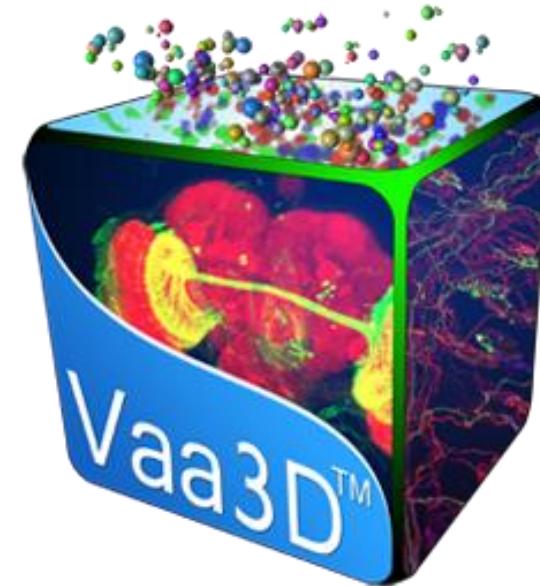


How to visualize various biodata via Vaa3D



Xin Chen

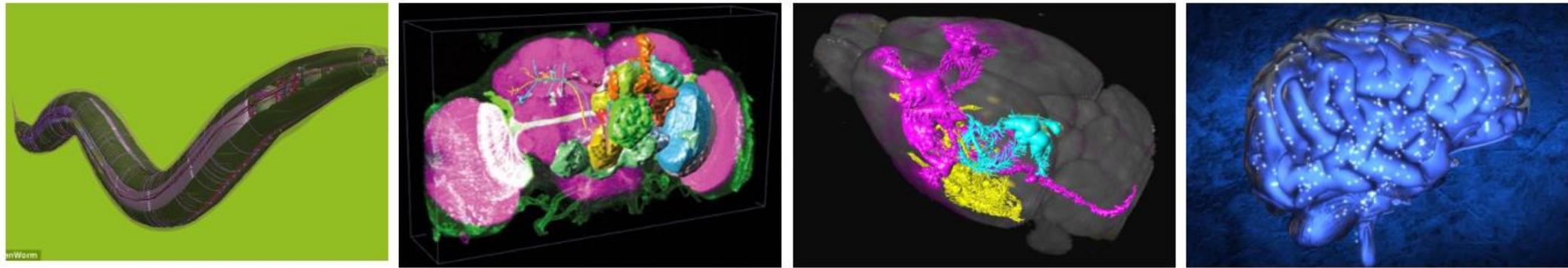
Institute for Brain and Intelligence

10/18/2021

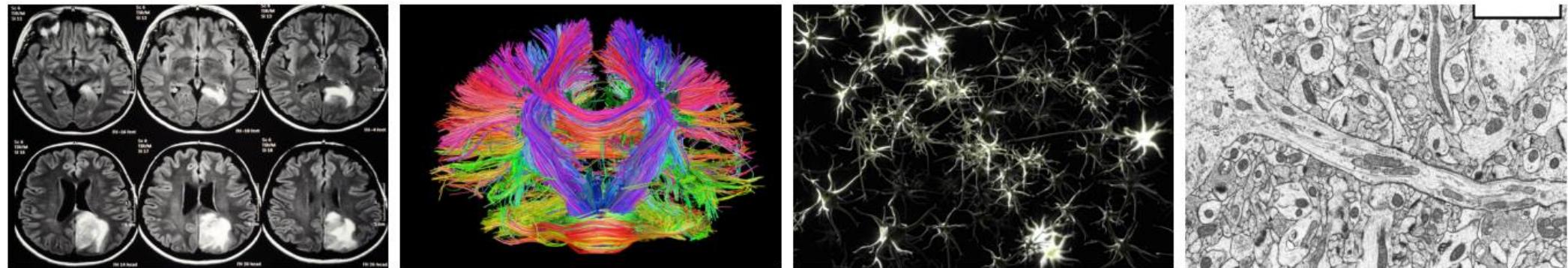


Biodata – various, complicated, containing valuable information

Various species



Various resolution



Various imaging modalities

Various data types, formats, etc.

Vaa3D – 3D Visualization-Assisted Analysis

Visualization

Various-scale (small and large, e.g. terabyte voxel) multidimensional (3D/4D/5D) bioimage

- Tri-view
- 3D viewer – 3D/4D/5D bioimage
- TeraFly – bioimage with unlimited size
- TeraVR – immersive

Data Types

- 3D color image stacks

- Tiff stack (.tif, .tiff)
- Zeiss LSM (.lsm)
- MRC (used for electron microscopy images) (.mrc)
- Vaa3D's raw file (.v3draw, .raw, *.v3dpbd, *.vaa3dpbd) (The PBD files are compressed raw files)
- Any other image formats (e.g. jpeg, PNP, BMP, ...) supported by LOCI Bioformats Java library (through a Vaa3D-bioformats plugin, see the plugin pages)

- 5D time series of color image stacks

- Each time point saved as a separate file (end with suffix like 000.tif, 001.tif, ...)
- Each time point saved as a single slice of a 3D image stack of whatever formats Vaa3D supports (e.g. tiff, or Vaa3D's raw)

- 3D irregular shaped surfaces

- Wavefront .OBJ files
- Vaa3D's surface format (.v3ds)

- 3D neuron structures or any relational data that can be described as a graph

- SWC file (.swc)
- Enhanced SWC file (*.eswc)

- 3D point cloud

- .apo file (a simple CSV format with fixed number of columns)

- 3D landmarks

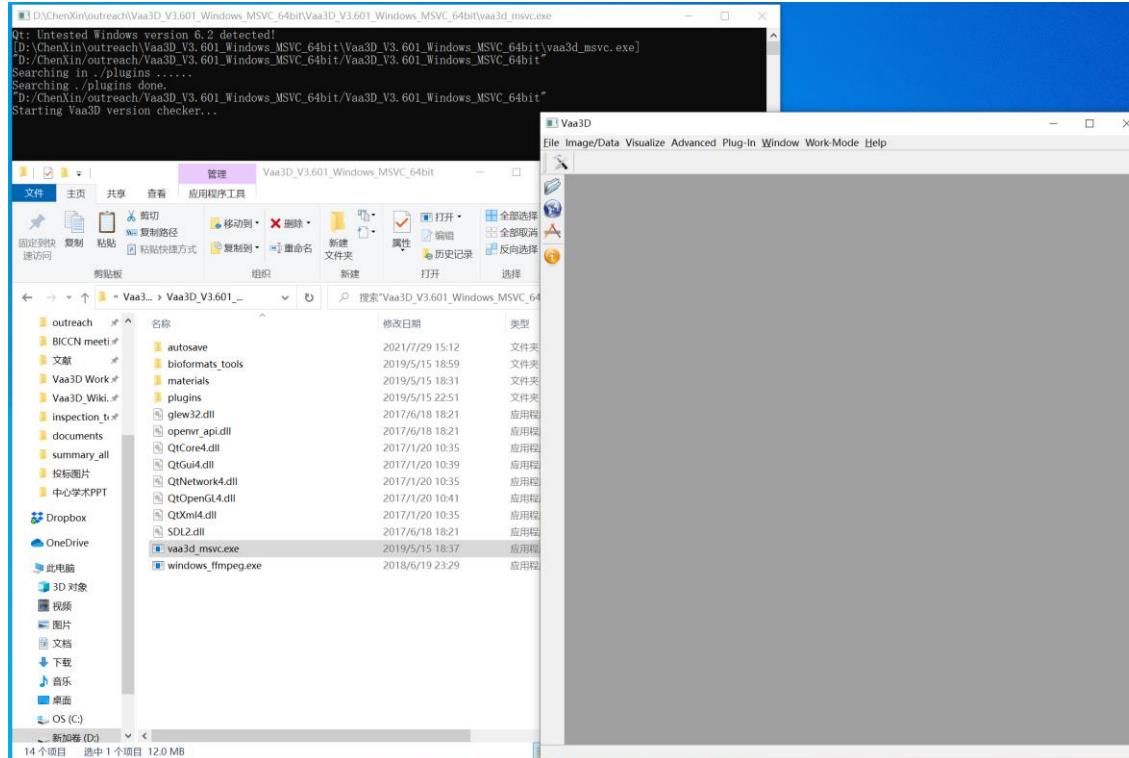
- .marker (indeed a simple CSV format)
- .csv

- Linker files

- linker files (.ano) that enables opening many data files of different types easily
- atlas files (.atlas) for managing colocalized/registered image files

Data Types

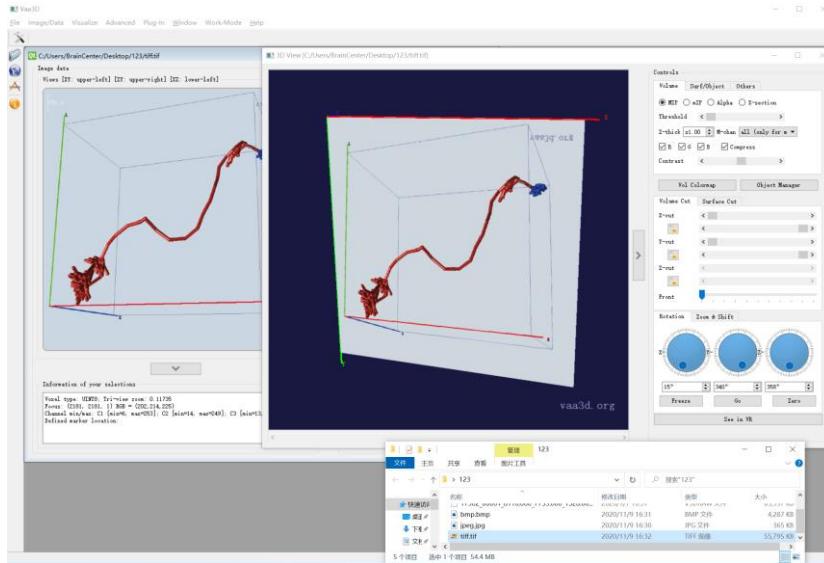
Vaa3D: main interface



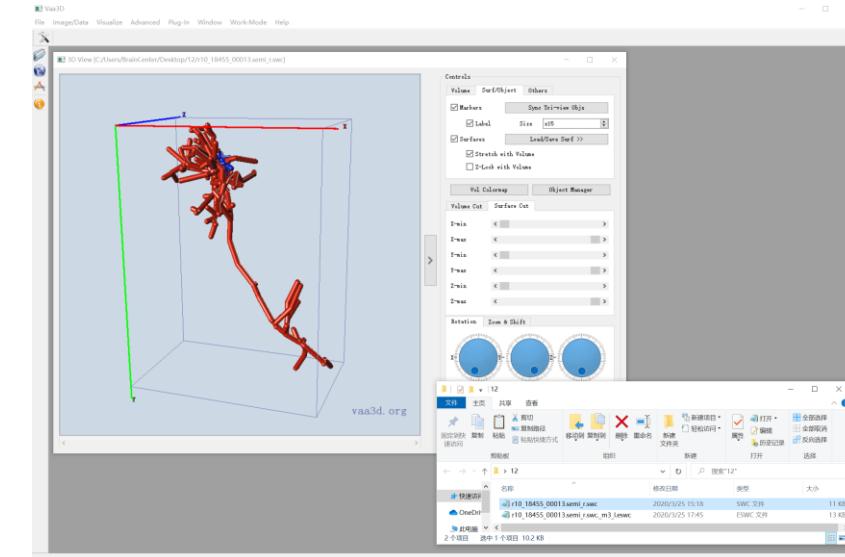
The screenshot shows the "Help Information" window of the Vaa3D application. The window title is "vaa3d_msvc". The main content area is titled "Supported file types". A red box highlights the "TIF, .TIFF, .LSM (Tiff and LSM stacks)" section. Below it, a list of supported file types is provided with their descriptions:

- TIF, .TIFF, .LSM (Tiff and LSM stacks)
a simple raw file which supports 8-bit unsigned char, 16-bit unsigned short, 32-bit single-precision float 4D image stacks.
- RAW (Vaa3D's RAW), .V3DRAW (Vaa3D's RAW), .VAA3DRAW (Vaa3D's RAW), .v3dpbd (Vaa3D's RAW with compression)
- TIF (Series 2D tiff section)
- SWC
reconstructed neurons or other relational data which can be described as a graph.
- APO
point cloud file used in WANO to describe the cells and any other image objects.
- .VAA3DS, .OBJ
surface object files. OBJ file is ASCII description of surface objects, which will be slow in opening but can be read by other software; VAA3DS is binary representation of surface and much faster to load.
- .AN0
the linker file which contains file names of other heterogeneous files.
- MARKER
the landmark recording file (which is just a plain csv file with a specified format).
- ATLAS
the linker file which contains a list of image-stack file names that can be opened using the atlas manager.
- PC_ATLAS
the linker file which contains a list of point cloud files names for the point cloud atlas.
- ZIP
on Mac and Linux the .zip files of the above Vaa3D file formats can be opened automatically.

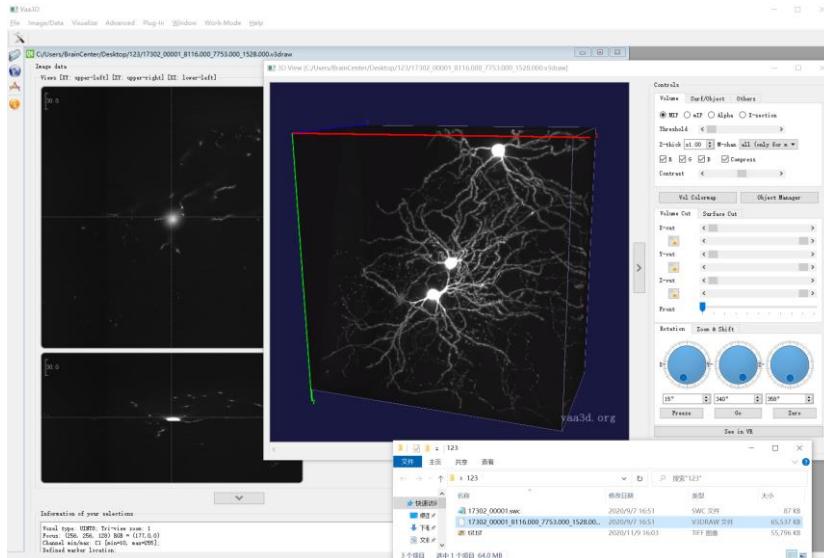
Tiff stack (.tif, .tiff)



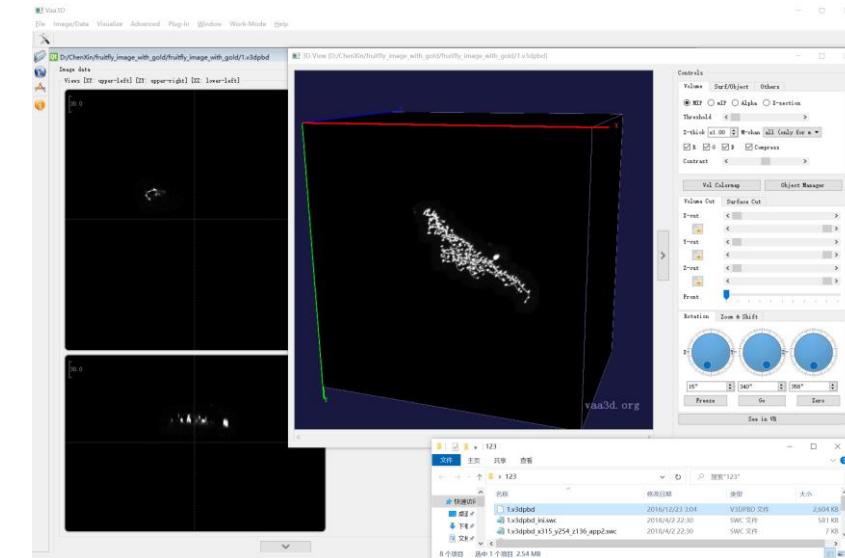
SWC file (.swc)



Vaa3D's raw file (.v3draw)

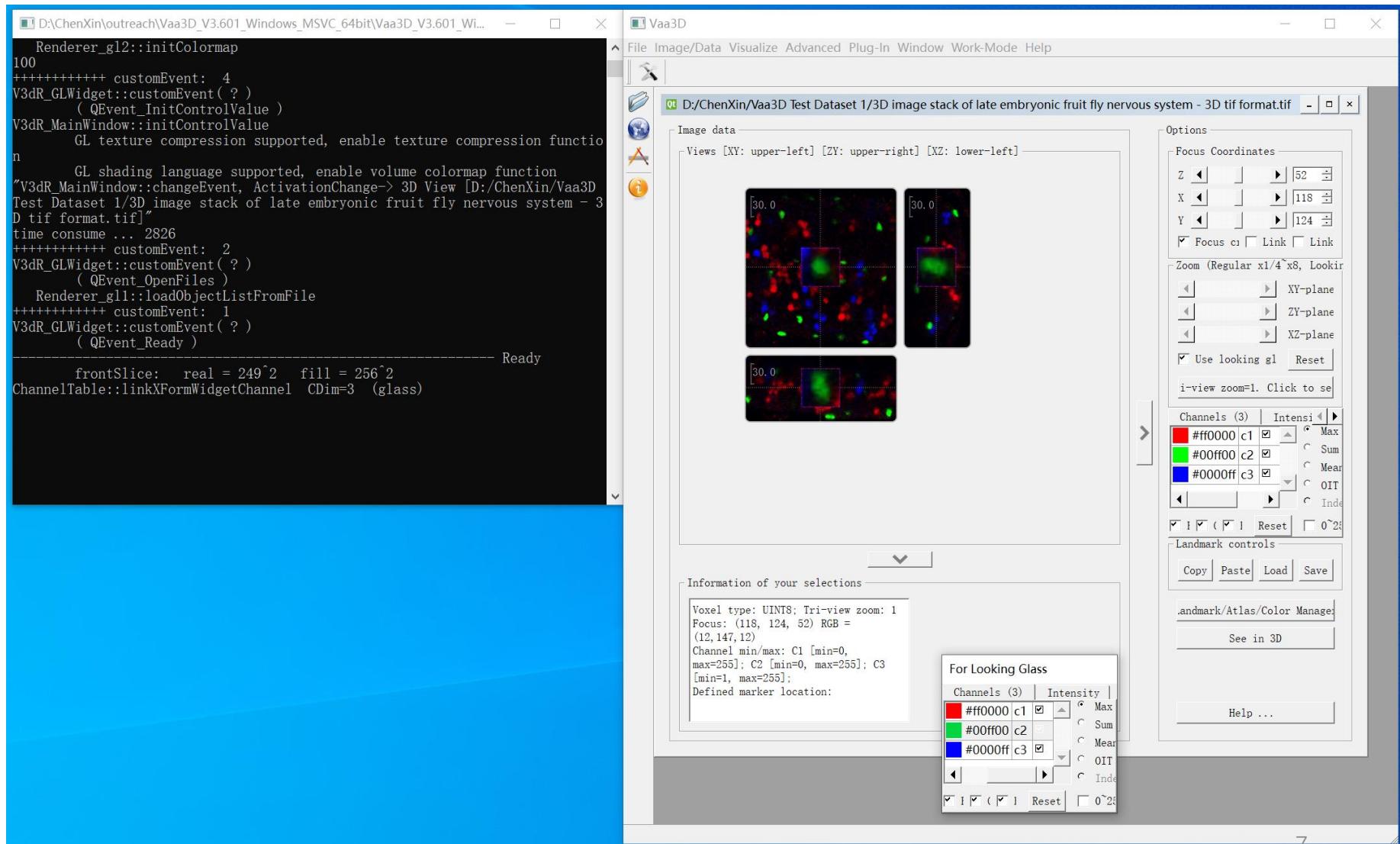


Vaa3D's raw file (*.v3dpbd)



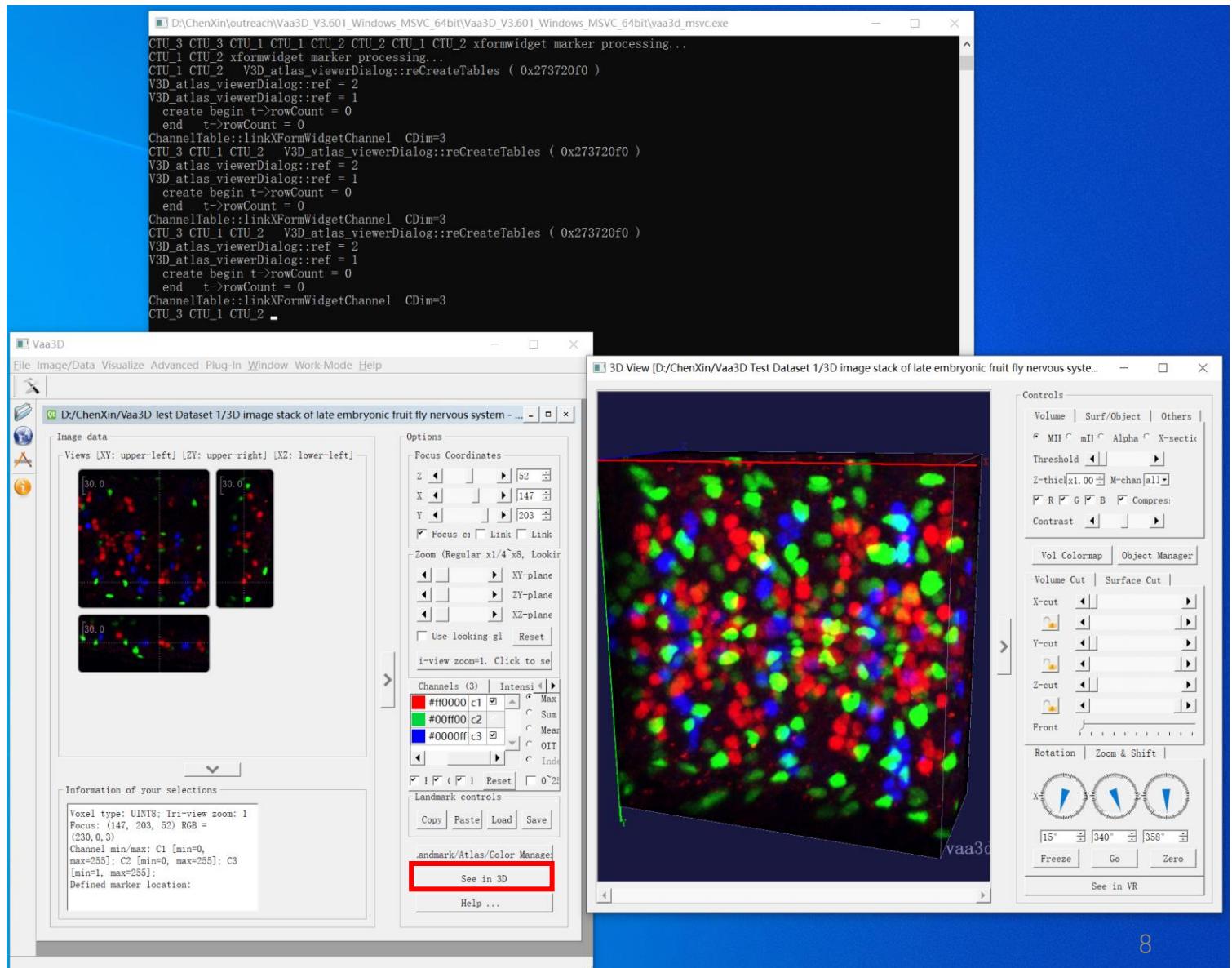
Tri-view

3 orthogonal views
Focus coordinates
Zoom
Looking Glass
Intensity
Landmarks
Atlas
Color channels
.....



3D Viewer

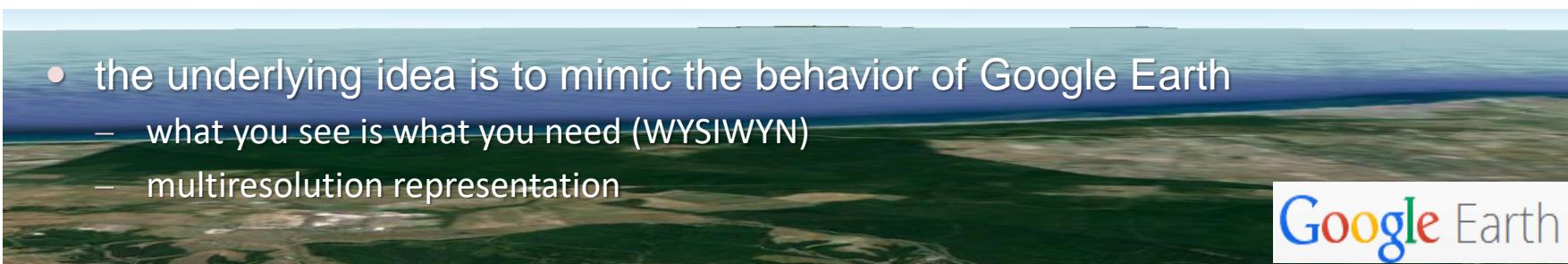
MIP (Maximal intensity projection)
mIP (minimal intensity projection)
Alpha blending
Cross-sectional view
Threshold
Z-thick
Contrast
Channel
Surf/Object
Volume Colormap
Object Manager
Volume Cut
Surface Cut
Rotation, Zoom, Shift
.....



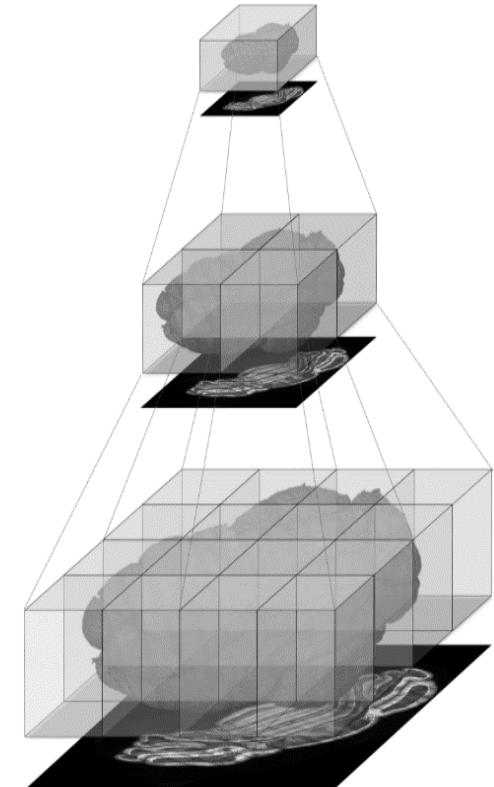
Vaa3D-TeraFly: Overview

TeraFly extends the Vaa3D software to cope with (potentially) **unlimited** sized bioimage even on laptops with a limited amount of system memory (≤ 4 GB) and video card memory (≤ 1 GB)

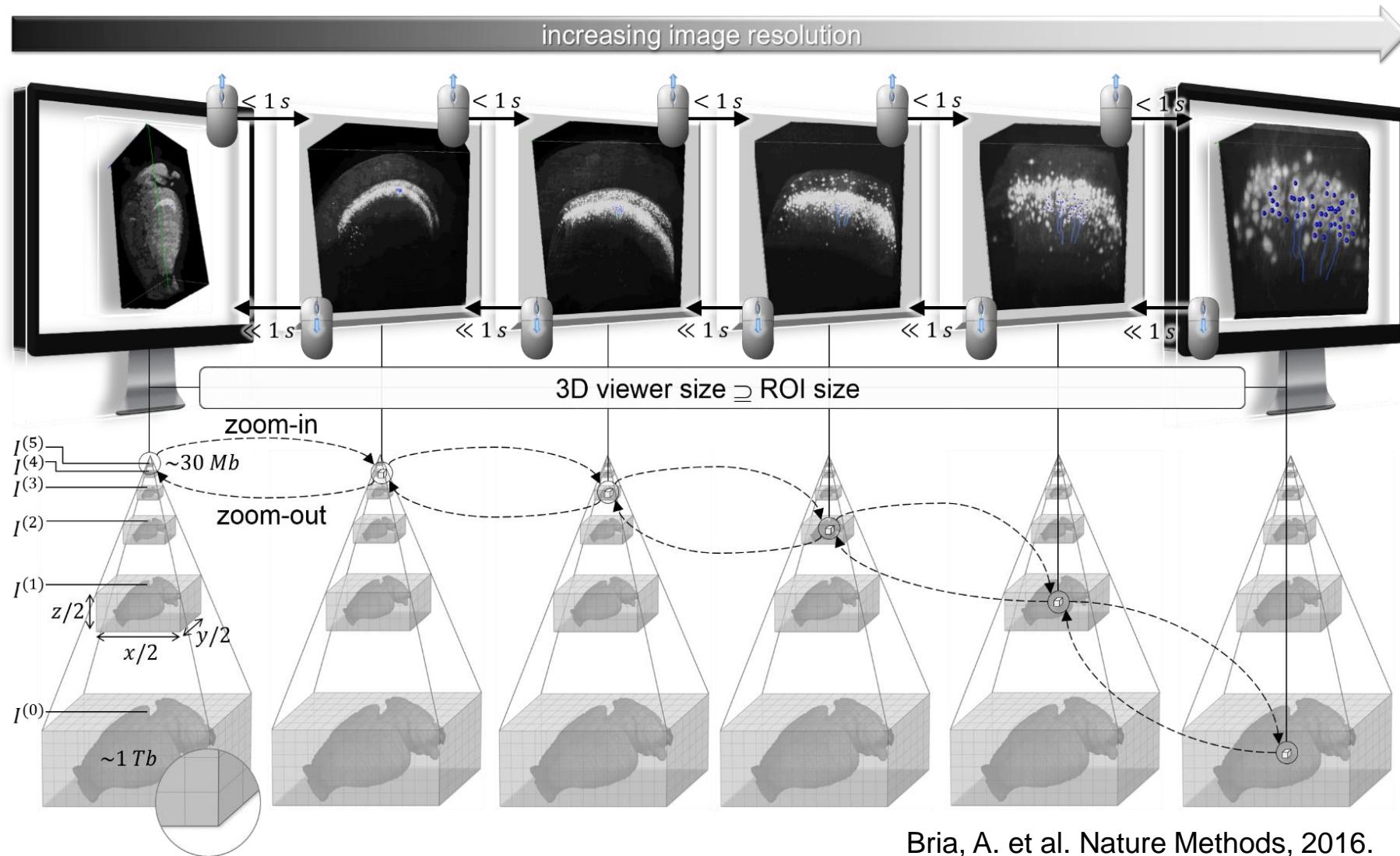
- fast rendering/visualization of **3/4/5D terabyte**-scale microscopy images
- **instant** zoom-in/out with mouse-scroll
- visualization-assisted **annotation** of 3D objects at different scales
- image format conversion tool (**TeraConverter**) included



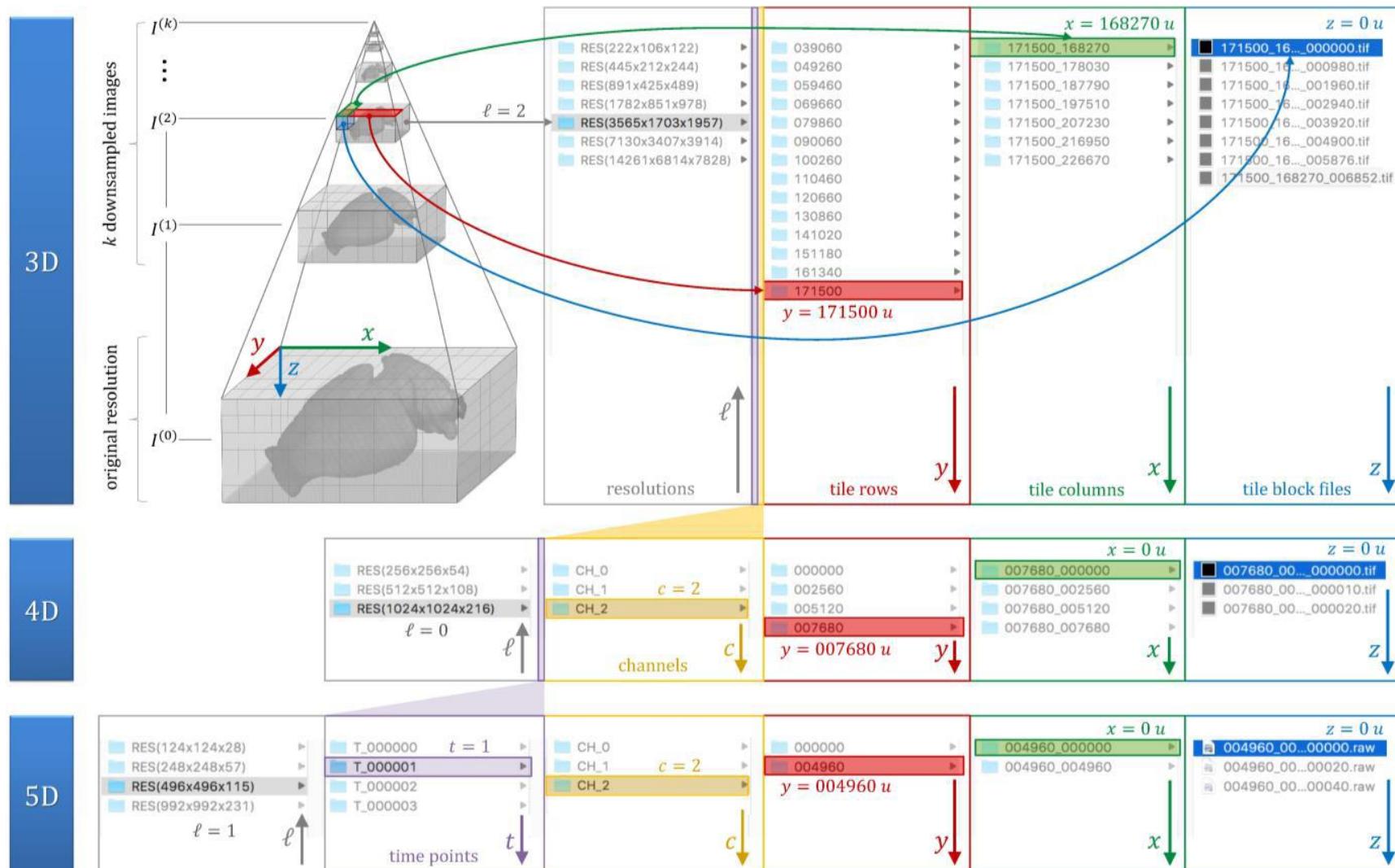
- the underlying idea is to mimic the behavior of Google Earth
 - what you see is what you need (WYSIWYN)
 - multiresolution representation



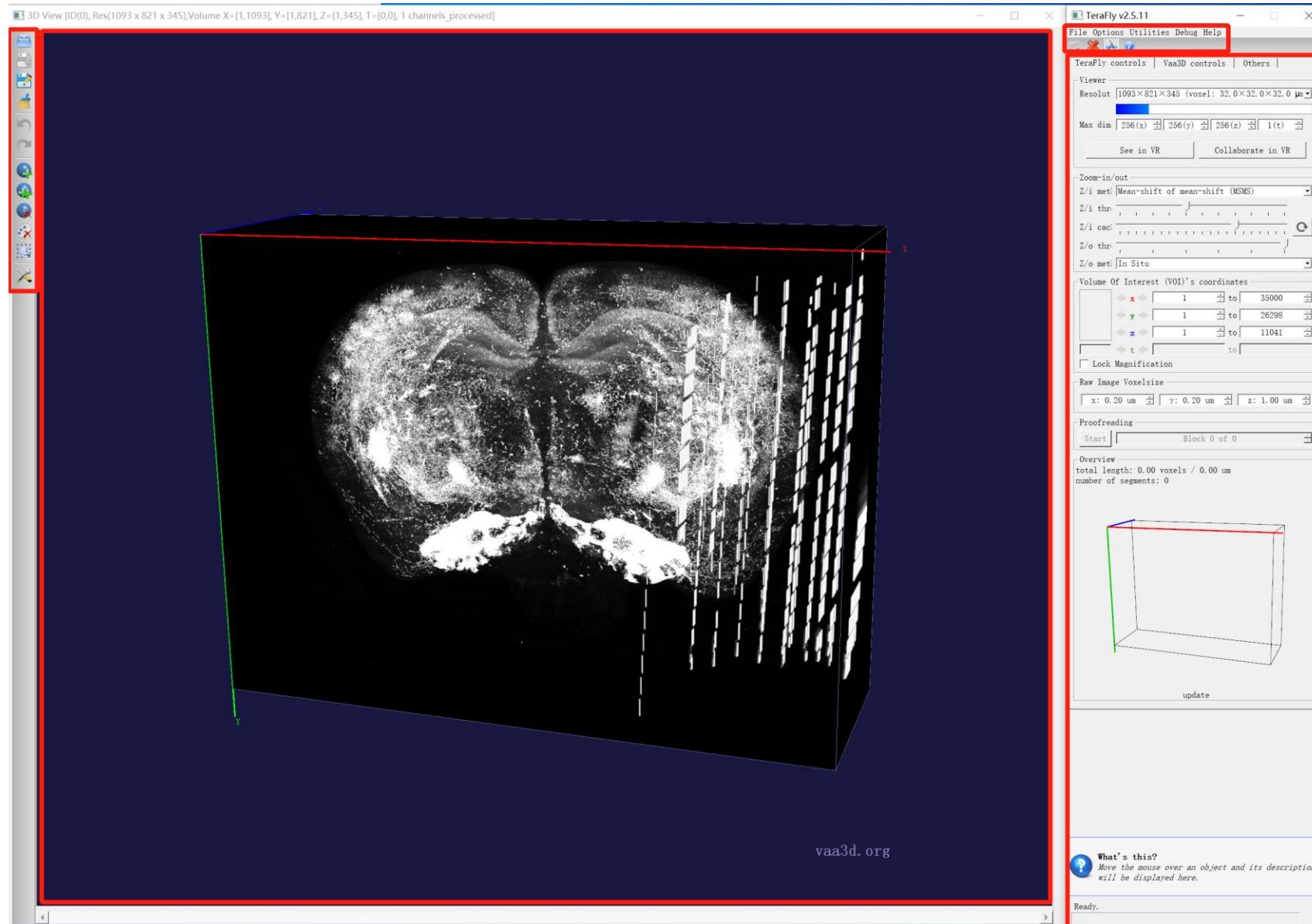
Vaa3D-TeraFly: Architecture



Vaa3D-TeraFly: Schema of 3D-5D Formats



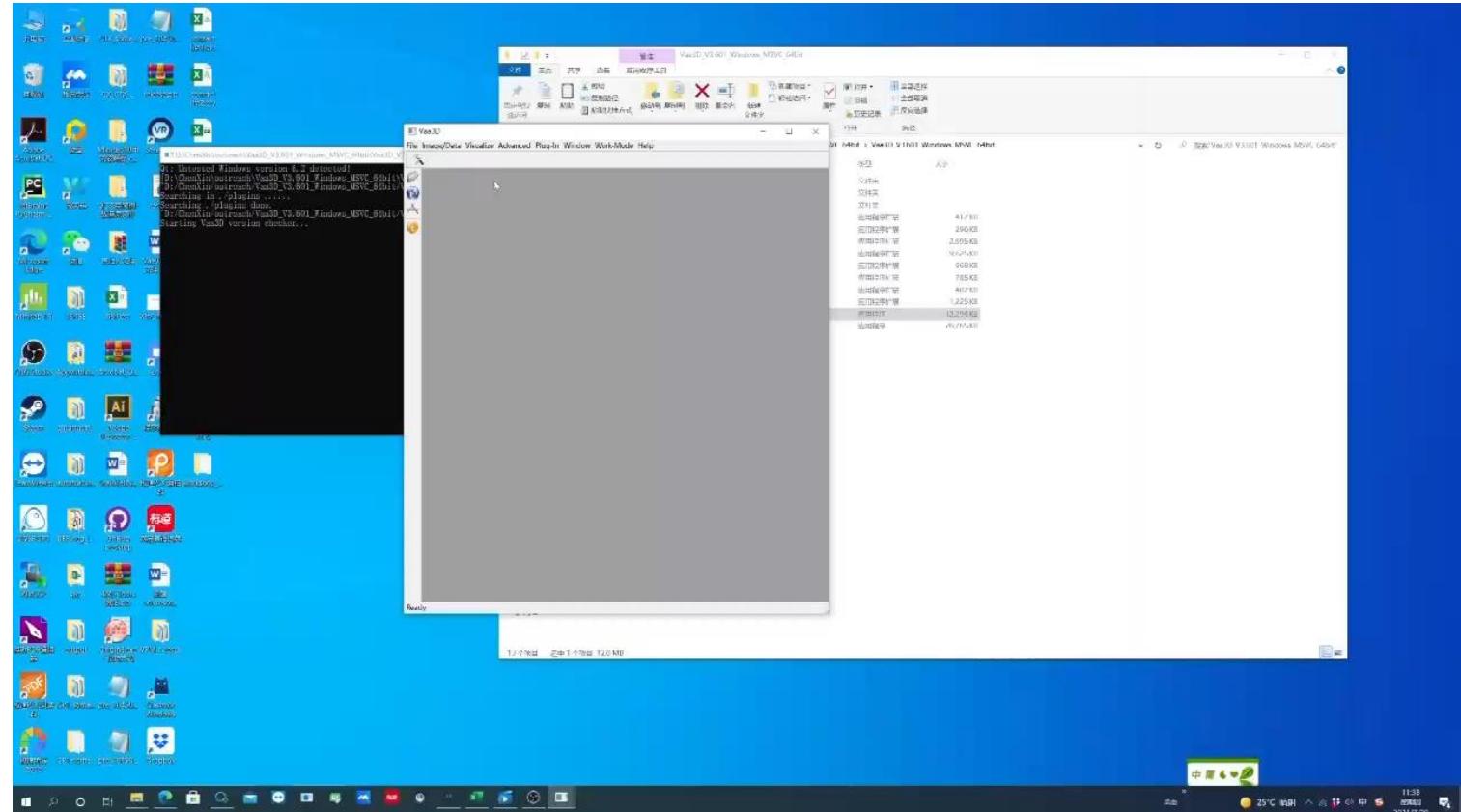
Vaa3D-TeraFly: User Interface



TeraConverter and TeraFly

Generate TeraFly data format:
“Advanced”, “Big-Image_Data”,
“TeraConverter”, “Step 1: Import
volume from:”, “Step 2: Convert
volume to:”, “Start”

**Visualize the TeraFly data
format generated:** “Advanced”,
“Big-Image_Data”, “TeraFly”,
“File”, “Open TeraFly Image (3-
5D)”, “RES(.....)”, “OK”, zoom
in/out, rotate
Adjust the control panel such as
shift, resolution, Z-thick, contrast,
Volume Cut, Surface Cut



TeraVR

Integrate immersive and collaborative 3-D visualization, interaction, and hierarchical streaming of teravoxel – scale images.



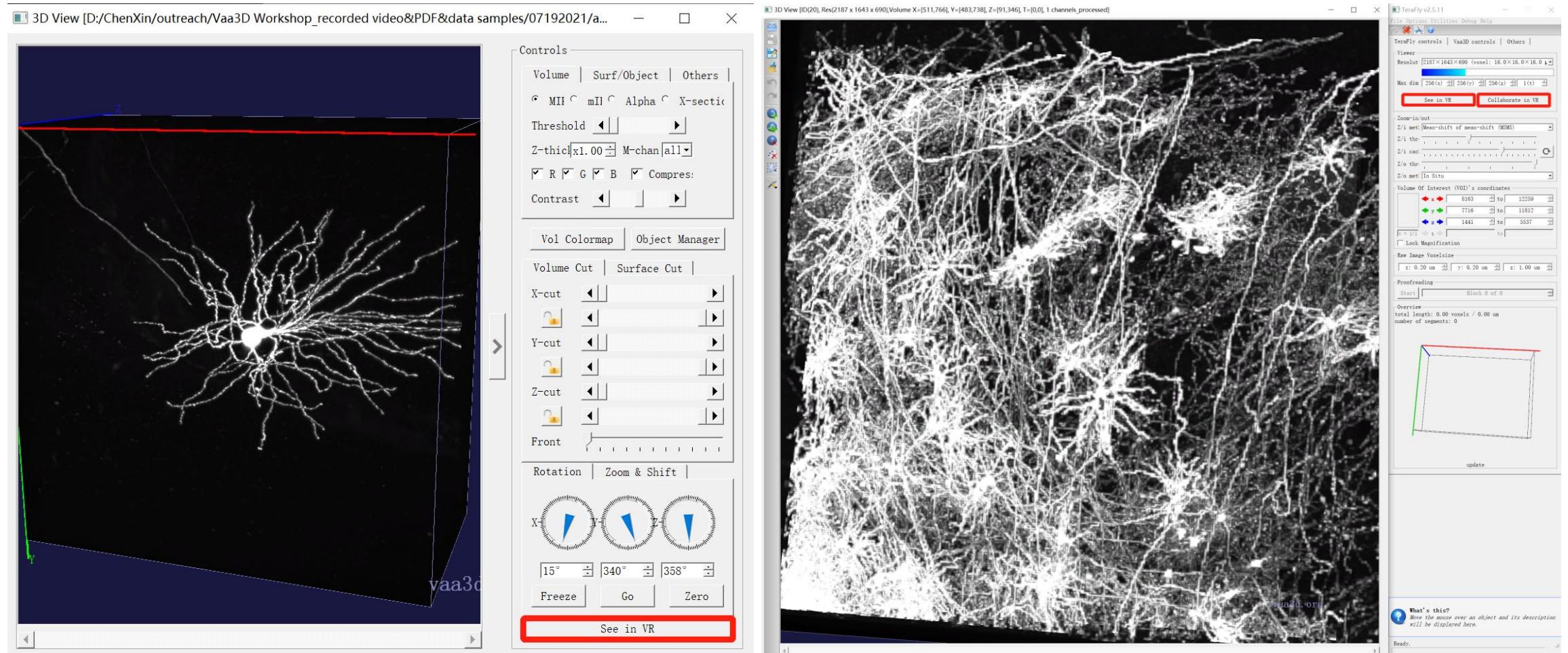
Wang, Y. et al. Nature Communications, 2019.

TeraVR

TeraVR (single user): see in VR

VR-Farm (multiple users): collaborate in VR

MR-Farm (multiple users)



TeraVR



Summary

Vaa3D – 3D Visualization-Assisted Analysis

Visualize various multidimensional (3D/4D/5D) biodata

- Tri-view
- 3D viewer – 3D/4D/5D bioimage
- TeraFly – bioimage with unlimited size
- TeraVR – immersive

Extended readings

More details can be found in the below papers:

- Peng, H., Ruan, Z., Long, F., Simpson, J.H. & Myers, E.W. V3D enables real-time 3D visualization and quantitative analysis of large-scale biological image data sets. *Nat. Biotechnol.* 28, 348-353 (2010). DOI:10.1038/nbt.1612
- Peng, H., Bria, A., Zhou Z., Iannello, G. & Long, F. Extensible visualization and analysis for multidimensional images using Vaa3D. *Nat. Protoc.* 9, 193-208 (2014). DOI:10.1038/nprot.2014.011
- Peng, H., Tang, J., Xiao, H., Bria, A., et al. Virtual finger boosts three-dimensional imaging and microsurgery as well as terabyte volume image visualization and analysis. *Nat. Commun.* 5, 4342 (2014). DOI:10.1038/ncomms5342
- Bria, A., Iannello, G., Onofri, L. & Peng, H. TeraFly: real-time three-dimensional visualization and annotation of terabytes of multidimensional volumetric images. *Nat. Methods* 13, 192-194 (2016). DOI:10.1038/nmeth.3767
- Wang, Y. et al. TeraVR empowers precise reconstruction of complete 3-D neuronal morphology in the whole brain. *Nat. Commun.* 10, 3474 (2019). DOI:10.1038/s41467-019-11443-y

Thank you!