Janelia Research Campus - Open Science Software Initiative

Proposal: VVD Viewer

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BACKGROUND

The VVD Viewer[1] was developed by Takashi Kawase and Hideo Otsuna as a fork of Flourender. VVD is an open source volumetric visualization application comparable feature-wise to commercial software such as Imaris and Amira. It supports multi-channel 3D and 4D volume data and polygon meshes, larger-than-memory imagery, arbitrary clipping planes, and many visualization adjustments.

The code underlying VVD's visualization system is based on state-of-the-art Vulkan API and currently runs on Windows and macOS systems. Vulkan is a lower-level graphics and compute API that allows developers much greater control and further optimization. VVD was recently migrated from OpenGL to Vulkan, which increased the rendering speed four-fold. Importantly, once OpenGL ceases to be supported on Mac, VVD will be the only option for large-scale 3d visualization, as all other major volumetric viewers are built on OpenGL.

VVD is currently mostly used within Janelia by neurobiologists for viewing fluorescent-stained confocal and TB scale light-sheet samples. It is often used to verify EM-LM correspondence, by loading both LM imagery and EM skeletons in a single overlaid 3d view. Critically, VVD's support for large imagery allows visualization of expansion microscopy (ExM) data sets.

In addition to rendering, VVD also offers functionality for segmentation. Users can paint 3D masks using add, subtract and diffuse brushes on top of the signals.The 3D painting segmentation is mainly used for extracting neurons. Extracted neurons are used for figures, movies and Color MIP Search. VVDViewer also has a gray value thresholding based on automatic segmentation. The function is used to train a machine learning based 3D neuronal segmentation "PatchPerPix" (Ref. 13: Lisa M et.al.) by PTR. Also, it was used for machine learning training of presynaptic signal 3D segmentation in ExM data by Ding Sherry (E.x SciCompSoft) and Josh Lillvis (Dickson Lab).

Janelia labs currently relying on VVD include the Rubin Lab, Jayaraman Lab, Aso Lab, Stern Lab, Card Lab, Huston Lab, Keller Lab, PTR and Kellerman Lab. In addition, it is used around the world

[1] https://github.com/JaneliaSciComp/VVDViewer

by labs who have left or are leaving Janelia, such as Ito Lab, Lee Lab, Dickson Lab, and others. It is also used by some collaborators of these labs, Scott Lab (Berkeley), Murthy Lab (Princeton). For a list of papers that have referenced VVD, see the section at the end of this proposal.

CHALLENGES

The focus of VVD development has been to solve specific problems for labs at Janelia. Although it is open-source code, it lacks documentation and tutorials (not user-friendly), which are necessary to transform it into a successful Open Science project. Additionally, VVD's functionality is currently not exposed as an API (not developer-friendly), which limits its use for other developers.

PROPOSED SOLUTIONS (User-friendliness - 3.5 FTE mo)

Website (0.5 FTE mo)

We plan to update the current website for VVD, hosted on GitHub, to guide new users through download, installation, and basic usage of VVD. The website will also serve as a hub for linking to videos showing VVD's capabilities, facilities for bug reporting, as well as relevant publications and data.

User manual (2.0 FTE mo)

The biggest bottleneck to widespread usage of VVD is the lack of documentation and tutorials. Currently, the main developers personally train potential new users. While this approach worked for a small, Janelia-internal user-base, it inhibits further growth. We will develop a comprehensive user manual for VVD to make it easier for new users to use the software without personalized assistance.

Linux build (1.0 FTE mo)

VVD currently works well on macOS and Windows. A Linux build would complete VVD's portability and make it capable of being used by anyone. We will also automate builds with GitHub Actions.

PROPOSED SOLUTIONS (Developer-friendliness - 6.0 FTE mo)

Modular C++ API (3.0 FTE mo)

Inspired by BigDataViewer, we will refactor VVD's API to improve modularity and enable its usage as a library and not just a standalone application. Others should be able to write a C++ program, import the VVD library, and spawn a VVD window with a single line of code to visualize their in-memory data. We will provide examples of such usage to inspire community usage of this new library.

Python/Java bindings to C++ API (3.0 FTE mo)

Given that most scientific programming is happening in Python and Java, we will develop bindings to allow these environments to call the VVD library. To support large images and virtually created datasets, we will use call-back APIs that allow VVD to request data in small blocks (similar to Neuroglancer and BigDataViewer). In Python, we plan to be able to provide function calls that allow visualization of numpy arrays as well as datasets stored on disk. For Java, we plan to use the Java Native Interface (or similar) to expose calls that use primitive Java arrays as well as ImgLib2 cell images in addition to datasets stored on disk. Time permitting, we plan to develop Fiji and Napari plugins for end-users.

REQUIRED SKILL SET

In order to develop intuitive documentation, website presence and tutorials we plan to make use of scientific writing services. A dedicated person will coordinate documentation and website creation and consult with the main developers. Additionally, Gerry Rubin volunteered to help develop and test the documentation.

The implementation of Linux builds as well as the API and Python/Java bindings requires dedicated developers. We propose that Takashi Kawase will implement most of the code with help from Hideo Otsuna, Konrad Rokicki and Stephan Preibisch.

ESTIMATED IMPACT

VVD is a powerful 3D/4D Viewer that was developed for Janelia labs that has the unique capability of supporting larger-than-memory datasets. To the best of our knowledge, VVD is the only open-source project that is able to handle such data right now. We expect that addressing user-friendliness will allow many biologists outside and within Janelia to use VVD efficiently in their research.

We think that addressing VVD's developer-friendliness would encourage many developers to use VVD in their code. This would also have the effect that more people might contribute to maintenance and extension of the source code. Additionally, a solid technical foundation would set the stage for further feature development in support of the 4DCP research direction.

So far, fifteen papers have referenced VVD Viewer:

1. Two Brain Pathways Initiate Distinct Forward Walking Programs in Drosophila. Salil S Bidaye, Meghan Laturney, Amy K Chang, Yuejiang Liu, Till Bockemühl, Ansgar Büschges, Kristin Scott. ***Neuron.*** 2020 Nov 11;108(3):469-485.e8. doi: 10.1016/j.neuron.2020.07.032. Epub 2020 Aug 20.

2. Controlling motor neurons of every muscle for fly proboscis reaching. Claire E McKellar, Igor Siwanowicz, Barry J Dickson, Julie H Simpson. ***eLife***. 2020 Jun 25;9:e54978. doi: 10.7554/eLife.54978.

3. Distributed control of motor circuits for backward walking in Drosophila. Kai Feng, Rajyashree Sen, Ryo Minegishi, Michael Dübbert, Till Bockemühl, Ansgar Büschges, Barry J Dickson. ***Nature Commun***. 2020 Dec 2;11(1):6166. DOI: 10.1038/s41467-020-19936-x.

4. Circuit and Behavioral Mechanisms of Sexual Rejection by Drosophila Females. Fei Wang , Kaiyu Wang , Nora Forknall, Ruchi Parekh, Barry J Dickson. ***Curr Biol.*** 2020 Oct 5;30(19) DOI: 10.1016/j.cub.2020.07.083.

5. Conservation and divergence of related neuronal lineages in the Drosophila central brain. Ying-Jou Lee, Ching-Po Yang, Rosa L Miyares, Yu-Fen Huang, Yisheng He, Qingzhong Ren, Hui-Min Chen, Takashi Kawase, Masayoshi Ito, Hideo Otsuna, Ken Sugino, Yoshi Aso, Kei Ito, Tzumin Lee. ***eLife***. 2020 Apr 7;9:e53518. DOI: 10.7554/eLife.53518.

6. Spatial readout of visual looming in the central brain of Drosophila. Mai M Morimoto, Aljoscha Nern, Arthur Zhao, Edward M Rogers, Allan M Wong, Mathew D Isaacson, Davi D Bock, Gerald M Rubin, Michael B Reiser. ***eLife***. 2020 Nov 18;9:e57685 doi: 10.7554/eLife.57685.

7. TwoLumps Ascending Neurons Mediate Touch-Evoked Reversal of Walking Direction in Drosophila. Rajyashree Sen, Kaiyu Wang, Barry J.Dickson. ***Curr Biol.*** 2019 Dec 4337-4344 https://doi.org/10.1016/j.cub.2019.11.004

8. Proprioceptive input to a descending pathway conveying antennal postural information: Terminal organisation of antennal hair field afferents. JensGoldammer, VolkerDürrb. ***Arthropod Structure & Development*** Volume 47, Issue 5, September 2018, Pages 465-481 https://doi.org/10.1016/j.asd.2018.07.001

9. Transsynaptic mapping of Drosophila mushroom body output neurons. Kristin M Scaplen, ProfileMustafa Talay, John D Fisher, Raphael Cohn, Altar Sorkaç, ProfileYoshinori Aso, ProfileGilad Barnea, ProfileKarla R Kaun ***eLife***. 2021 Feb 11;10:e63379. doi: 10.7554/eLife.63379.

10. Transneuronal Dpr12/DIP-δ interactions facilitate compartmentalized dopaminergic innervation of Drosophila mushroom body axons. Bavat Bornstein, Idan Alyagor, Victoria Berkun, Hagar Meltzer, Fabienne Reh, Hadas Keren-Shaul, Eyal David, Thomas Riemensperger, Oren Schuldiner. ***EMBO J***. 2021 Jun 15;40(12):e105763. doi:10.15252/embj.2020105763. Epub 2021 Apr 13.

11. Neural Network Organization for Courtship Song Feature Detection in Drosophila. Christa A. Baker, Claire McKellar, Aljoscha Nern, Sven Dorkenwald, Barry J. Dickson, Mala Murthy ***BioRxiv*** 2020 doi: https://doi.org/10.1101/2020.10.08.332148

12. Neural Changes Underlying Rapid Fly Song Evolution. Yun Ding, Joshua L. Lillvis, Jessica Cande, Gordon J. Berman, Benjamin J. Arthur, Min Xu, Barry J. Dickson, David L. Stern. ***BioRxiv*** 2017 doi: https://doi.org/10.1101/238147.

13. PatchPerPix for Instance Segmentation. Peter Hirsch, Lisa Mais, Dagmar Kainmueller. ***Computer Vision – ECCV 2020.*** Springer International Publishing

14. Color depth MIP mask search: a new tool to expedite Split-GAL4 creation. Hideo Otsuna, Masayoshi Ito, Takashi Kawase. ***BioRxiv*** 2018 doi: https://doi.org/10.1101/318006

15. Classification and genetic targeting of cell types in the primary taste and premotor center of the Drosophila brain. Gabriella R. Sterne, Hideo Otsuna, Barry J. Dickson, Kristin Scott. ***eLife*** 2021 doi: 2021 10.7554/eLife.71679