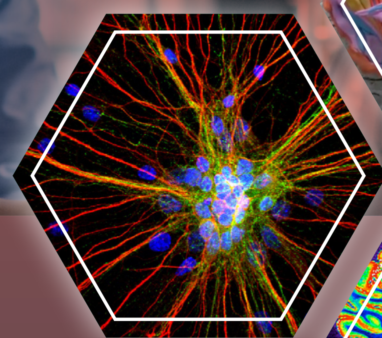
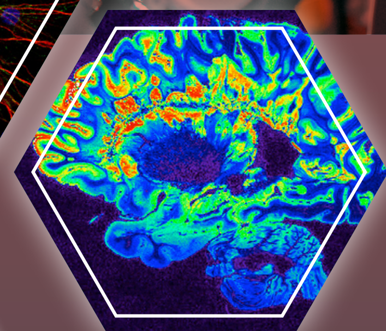
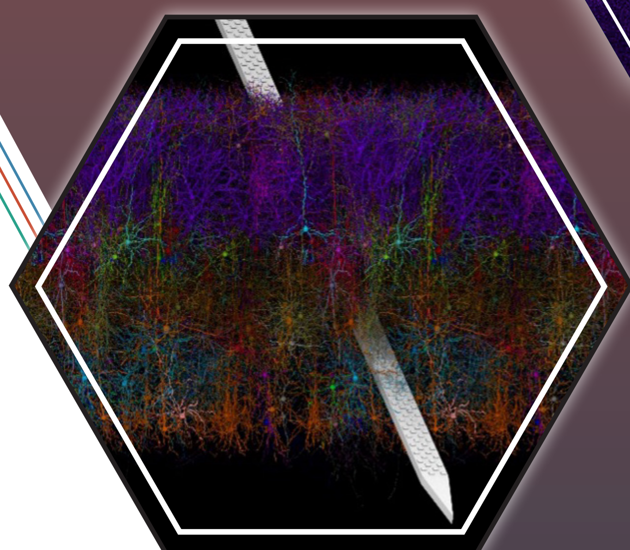
NOVEMBER 2023

Toolmakers Newsletter

Special Software Issue







ISSUE 12

In this issue

www.braininitiative.org

BRAIN INITIATIVE ALLIANCE

Welcome Back to the Toolmakers Newsletter!

Welcome to the fourth and final *Brain Research Through Advancing Innovative Neurotechnologies®* (BRAIN) Initiative Alliance Toolmakers Newsletter of 2023!

In this issue, we feature four pieces of software that are making it easier to store, share, visualize, synchronize, convert, and analyze neuroscience data: PET2BIDS by Anthony Galassi; BCI2000 by Dr. Peter Brunner; the Data Archive for the BRAIN Initiative (DABI) by Dr. Arthur Toga; and Brain Modeling Tools: Brain Modeling Toolkit (BMTK), SONATA, Visual Neuronal Dynamics (VND) by Dr. Anton Arkhipov. Let's dive in and learn about how these types of software are innovating research from the scientists who work with them!

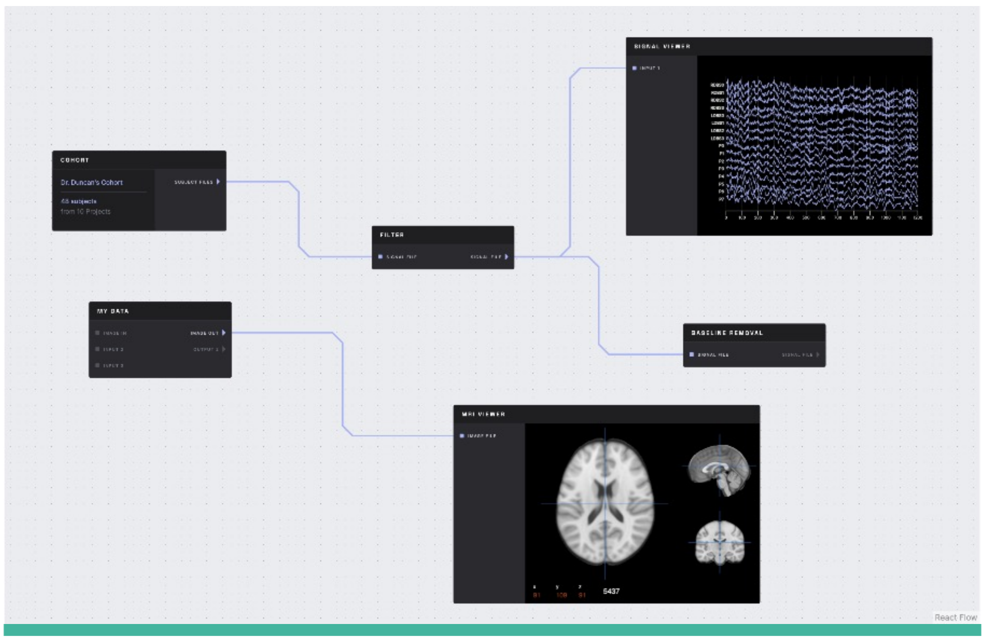


Image: A view of DABI-TOOL, a DABI data analysis toolkit. Credit: DABI, 2023.

> "New tools and new knowledge should be shared broadly to maximize the value of scientific progress stemming from the BRAIN Initiative and to seed new paths of inquiry. BRAIN supports innovators working to bridge the gap between their labs or companies and the broader neuroscience community. Dissemination is a key priority of our program, and we are proud to see these software tools being featured for the research community."
>
> — *Dr. Natalie Trzcinski, Program Director, National Institute of Neurological Disorders and Stroke (NINDS)*

On the front cover: Top Right Hexagon: An image still from a video of the C. elegans brain, including every nerve and muscle fiber, being reconstructed by serial-section electron microscopy. Credit: Daniel Witvliet, University of Toronto and Harvard University, 2020. **Top Central Hexagon:** Four-week-old rat cortical neurons labeled for dendrites (red), axons (green), and nuclei (blue). Credit: Karthik Krishnamurthy, Davide Trotti, Piera Pasinelli, Thomas Jefferson University, 2020. **Bottom Right Hexagon:** A pseudo-colored image of high-resolution gradient-echo MRI scan of a fixed cerebral hemisphere from a person with multiple sclerosis. Credit: Govind Bhagavatheeshwaran, Daniel Reich, National Institute of Neurological Disorders and Stroke, National Institutes of Health, 2016. **Bottom Central Hexagon:** "Model of Mouse V1 With A Neuropixels Probe" image taken with Visual Neural Dynamics (VND). Credit: University of Illinois at Urbana-Champaign Theoretical and Computational Biophysics Group, 2023.

PET2BIDS – Anthony Galassi

PET2BIDS is a library built to support positron emission tomography (PET) data conversion into the Brain Imaging Data Structure (BIDS) as a part of the OpenNeuroPET project, a collaborative data sharing project built off of the successful OpenNeuro platform (in case you missed it: Learn more about OpenNeuro in the November 2022 newsletter). Since its launch in 2015, BIDS has grown rapidly and been adopted by several major neuroscience databases. BIDS provides a standardized way of organizing, naming, and formatting neuroimaging files. This way, BIDS supports data standardization while also promoting FAIR (findable, accessible, interoperable, and reusable) data principles. PET is a non-invasive imaging method that uses radioactive material to diagnose a variety of diseases, including cancer and brain disorders. PET imaging also helps understand physiological changes that are linked to neuropsychiatric disorders to improve treatment methods.

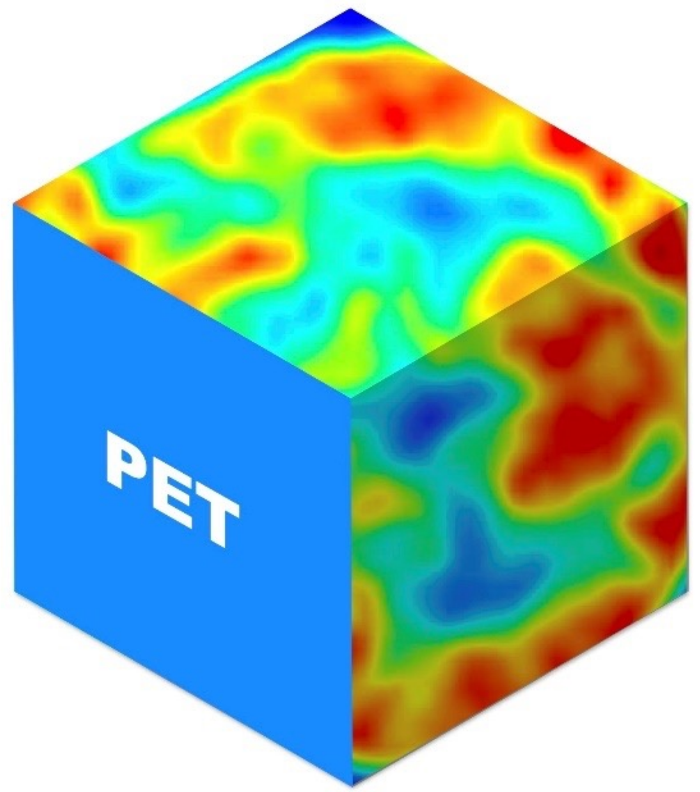


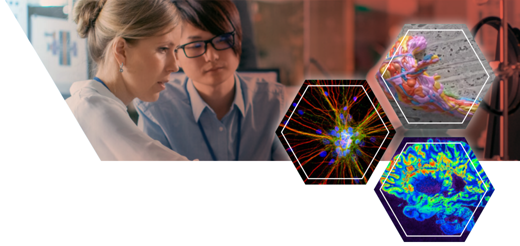
Image: The PET2BIDS logo. Credit: PET2BIDS, 2023.

Researchers at the National Institute of Mental Health (NIMH), part of the National Institutes of Health, created PET2BIDS with optimal data sharing in mind, either openly through OpenNeuro or publicly through Public-nEUro. Curating PET data can be difficult, but software like this helps researchers quickly convert large amounts of imaging data without needing to spend time doing manual data input or worrying about losing critical data components. Additionally, the uniform file structure granted by BIDS makes it easier to analyze neuroimaging data from different studies and parts of the brain. Making PET data easily searchable and comparable allows researchers to replicate experiments in the future to target new discoveries. “BIDS conversion remains a tricky subject for many,” says Anthony Galassi, a computer programmer at NIMH in the Molecular Imaging Branch working with PET2BIDS and OpenNeuro. “PET2BIDS does its best to make the conversion process more palatable for users.”

PET2BIDS takes image data files (e.g., PET ECAT or DICOM file formats) and uses coding tools, such as Dcm2niix, Nibabel, and Matlab, to convert them into a file structure that is BIDS-compliant. PET metadata is often stored as JSON files, and PET2BIDS updates JSON files to ensure that all metadata is consistent and meets BIDS standards. PET2BIDS also supports text file or spreadsheet conversion to BIDS by changing tabular data formats (e.g., xls, xlsx, csv, PMOD) into JSON files or blood.tsv files.

The OpenNeuroPET team working on PET2BIDS is in the process of developing a few tools to complement the PET data converted with PET2BIDS. To stay up to date with PET2BIDS and how to use it with PET datasets, visit the PET2BIDS website.

> “PET2BIDS is designed to support others whether they be researchers, toolmakers, or data curators by shaping PET data into BIDS which is crucial for sharing, analysis, and study. BIDS allows for rapid analysis, anonymization, and a de-duplication of work at all aspects of research.”
>
> — *Anthony Galassi*



BCI2000 – Dr. Peter Brunner

The National Center for Adaptive Neurotechnologies (NCAN) at the Washington University School of Medicine in St. Louis studies brain-computer interface (BCI) rehabilitation as one of its core technology research and development (TR&D) projects. For nearly two decades, NCAN and its partners have been developing and improving BCI2000, a standardized, open-source BCI software platform. BCI2000 works with adaptive neurotechnologies to acquire and process data from electrophysiological experiments and to translate those signals in real time for visualization, analysis, and direct neural feedback.

BCI2000 is highly customizable, operating well with a wide range of experimental models and data acquisition devices. "The application scenarios for BCI2000 range from simple stimulus presentation with simultaneous multi-modal recordings of electrophysiology and behavior, to complex neuromodulation experiments and interventions in which electrical stimulation is delivered in real time based on specific neural activity or behaviors," says Dr. Peter Brunner, a technology research and development leader at NCAN and Associate Professor at Washington University School of Medicine in St. Louis. BCI2000's supported input types include extracranial (EEG) and intracranial electroencephalographic (iEEG) activity, electromyographic (EMG) activity, and behavioral data from movement sensors, eye trackers, audio, video, and more. The BCI2000 system can also link with external tools like robotic arms and stimulation devices.

> "We are actively supporting laboratories in adapting BCI2000 for their research and in disseminating their experiments to other BRAIN Initiative laboratories. These efforts are transforming BCI2000 into a core service for multi-center electrophysiological research."
>
> — *Dr. Peter Brunner*

Four modules comprise the BCI2000 system: source (to acquire brain signals), signal processing (to process brain signals), user application (an experimental paradigm), and operator interface (an investigator's user interface). These modules communicate with each other to handle data import and export, enabling a smooth data flow and rapid experimental design prototyping.

Image: The BCI2000 logo. Credit: BCI2000, 2023.

BCI2000's amenable properties, functionality, and general-purpose architecture have made it a central component of BCI research. Currently, the software has more than 6,000 users around the world and over 2,300 publication citations. BCI2000 was created to be an easily accessible, adaptive system to support TR&D, and the NCAN team plans to continue developing it for clinical and translational uses. To do so, the team is working to create interfaces to third-party applications to accelerate the development and dissemination of adaptive neurotechnology experiments. BCI2000 is freely available, and scientists interested in using it can download its source code and instructions on the BCI2000 website.

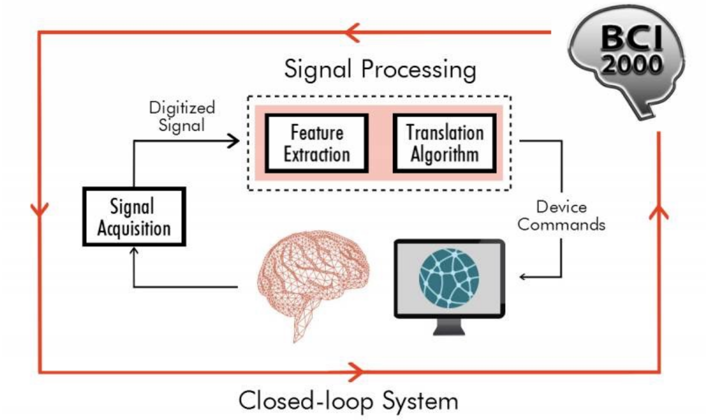


Image: How BCI2000 helps with different software needs. Credit: National Center for Adaptive Neurotechnologies, 2023.

Data Archive for the BRAIN Initiative (DABI) – Dr. Arthur Toga

The Data Archive for the BRAIN Initiative (DABI) is a large, open access archive that hosts human and non-human research data. DABI is web accessible, easily searchable, HIPAA-compliant, and compatible with data analysis tools including its own analysis platform, DABI TOOL, which helps users preprocess and analyze data.

Image: The Data Archive for BRAIN Initiative (DABI) logo. Credit: Laboratory of Neuro Imaging, University of Southern California, 2023.

DABI was developed in 2018 at the Laboratory of Neuro Imaging (LONI) at the University of Southern California (USC) and the University of Texas Southwestern Medical Center by Drs. Arthur Toga, Dominique Duncan, and Nader Pouratian to help BRAIN Initiative-funded researchers organize and analyze large amounts of neurodata. Since then, DABI has grown to host over ten terabytes of data, and it continues to increase—the LONI has allocated petabytes of data storage for DABI. Dr. Toga, director of the LONI, says that invasive neuroelectrophysiology encompasses much of their data, with many data partners researching deep brain stimulation (DBS) optimization.

The data stored in DABI is used to study a variety of disorders and mechanisms. For example, DABI's DBS datasets include subjects with obsessive compulsive disorder, epilepsy, autism spectrum disorder, posttraumatic stress disorder, and more. This data helps study how DBS treatment provokes response and helps track disease progression. Other DABI datasets use technologies like local field potential to study movement response in the motor cortex, electrocorticography for pre- and post-operative imaging, or intracranial electroencephalography for recording and visualization.

What sets DABI apart from other neuroscience data archives is the ability to accept data from many different formats and modalities. DABI also makes data sharing incredibly easy and user-friendly. Scientists who store and share data in DABI maintain total control of who can access their data and conditions for using it. "We work with our data providers to ensure that data sharing is simple and does not strain their time and resources further," says Dr. Toga, "one of the ways we accomplish that is by providing three different types of storage: centralized, federated, and cloud-based." Centralized data gets stored on USC neuroimaging servers, while federated data gives DABI access to the data provider's server(s). Cloud-based data allows data sharing through Box, Inc.

DABI accepts data from all neuroscience projects even if they are not funded by the NIH BRAIN Initiative. Scientists interested in storing their data in DABI can learn more about the advantages of DABI and apply to upload on the DABI website.

> "We believe that the best way to ensure data longevity is through reuse and, therefore, providing a platform that allows for multi-study, multi-modality, and multi-tool analyses is a model that leads to success."
>
> — *Dr. Arthur Toga*

Brain Modeling Tools: Brain Modeling Toolkit (BMTK), SONATA, Visual Neuronal Dynamics (VND) – Dr. Anton Arkhipov

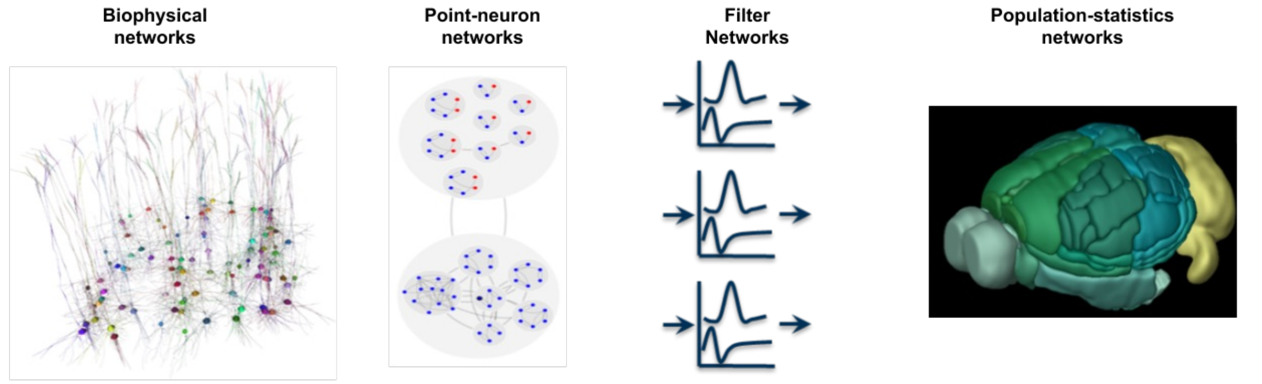


Image: Examples of brain modeling available though the Brain Modeling Toolkit (BMTK). Credit: Allen Institute, 2023.

The Brain Modeling Toolkit (BMTK), SONATA, and Visual Neuronal Dynamics (VND) comprise a suite of tools that complement each other when building complex models of brain circuits. While all the tools play different roles, together, they help scientists efficiently study the inner workings of complex brain circuits, identify brain activity patterns, and ultimately, better understand brain diseases and how to treat them. As Dr. Anton Arkhipov, an investigator at the Allen Institute, says, “It is important to be able to incorporate more of the brain’s complexity and biological details into our models,” which is what BMTK, SONATA, and VND allow their users to do.

The BMTK is a piece of software that uses Python to work with neural network models of varying sizes and resolutions. It was developed by the Allen Institute as a tool to independently build, simulate, and analyze brain models. SONATA is an open data file format used to store modeling details. SONATA file contents can be used by many software programs that study circuit mechanisms. The SONATA file format was developed by the Allen Institute in partnership with the Blue Brain Project at the École polytechnique fédérale de Lausanne. Last, VND is a visualization tool that can show three-dimensional renderings of brain network models for simulation and analysis. VND is produced by the University of Illinois at Urbana-Champaign’s Theoretical and Computational Biophysics Group in collaboration with the Allen Institute.

Between the three tools, SONATA is the backbone that connects BMTK and VND. When models are created in BMTK, they get stored in SONATA data format. SONATA is essential for saving model specifications and data input or output. Stored output activity can be used for analysis and gets brought to life through VND’s visualization and animation capabilities.

> “I hope that our tools can help the community to achieve the dream of accurate simulations of large brain networks and ultimately the whole brain, which can have tremendous consequences for science, medicine, and bioengineering.”
>
> — *Dr. Anton Arkhipov*

With the amount of available biological neuroscience data increasing every day, it is imperative that tools like these give scientists the opportunity to standardize, visualize, analyze, and share data. Stay tuned—BMTK and VND have more functions being added to help create additional functionality and modifications. To learn more about each tool, visit the BMTK, SONATA, and VND websites.

Excited by the potential of the tools in this issue?! Stay tuned for our next issue and explore more products of BRAIN Initiative discoveries in our Toolmakers’ Resources page!