Scalable Multicenter Normative IEEG Atlas: Harnessing Epilepsy Databases for Translational Science

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Background

- The rise of large-scale electrophysiology and neuroimaging data offers new potential for data-driven neuroscience, but few frameworks can **scale analyses** across multiple institutions or adapt in real time.
- Normative iEEG atlases help localize seizures and guide surgical planning, but current versions are limited by sparse, static, and siloed datasets.

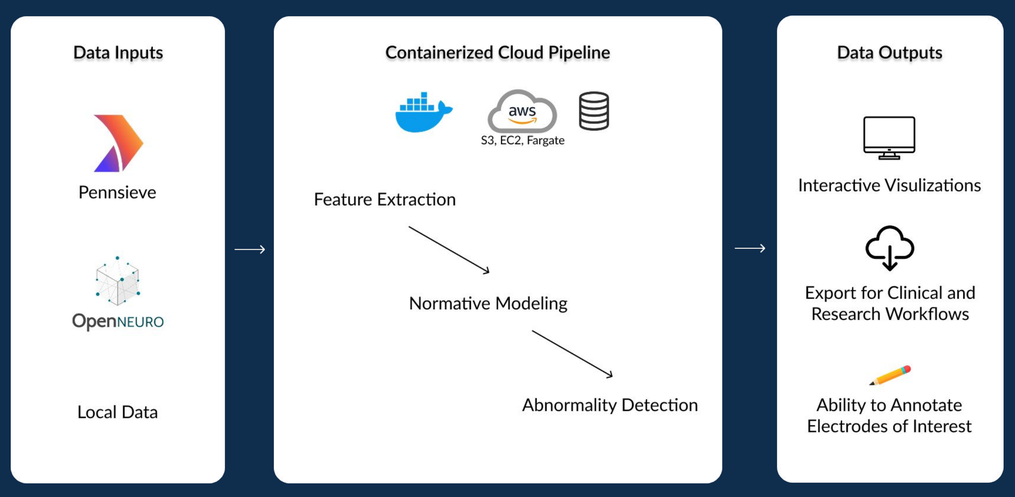
We introduce: ***Neuronova**, a **cloud-native iEEG atlas** built to integrate multicenter data in **real time** and power large-scale **normative modeling**.*

- In doing so, we explore:
  a. **How to connect tools to epilepsy databases**
  b. **How to scale tools to learn and adapt as more data becomes available**
  c. **How to deploy these tools in individual patients to improve clinical care**

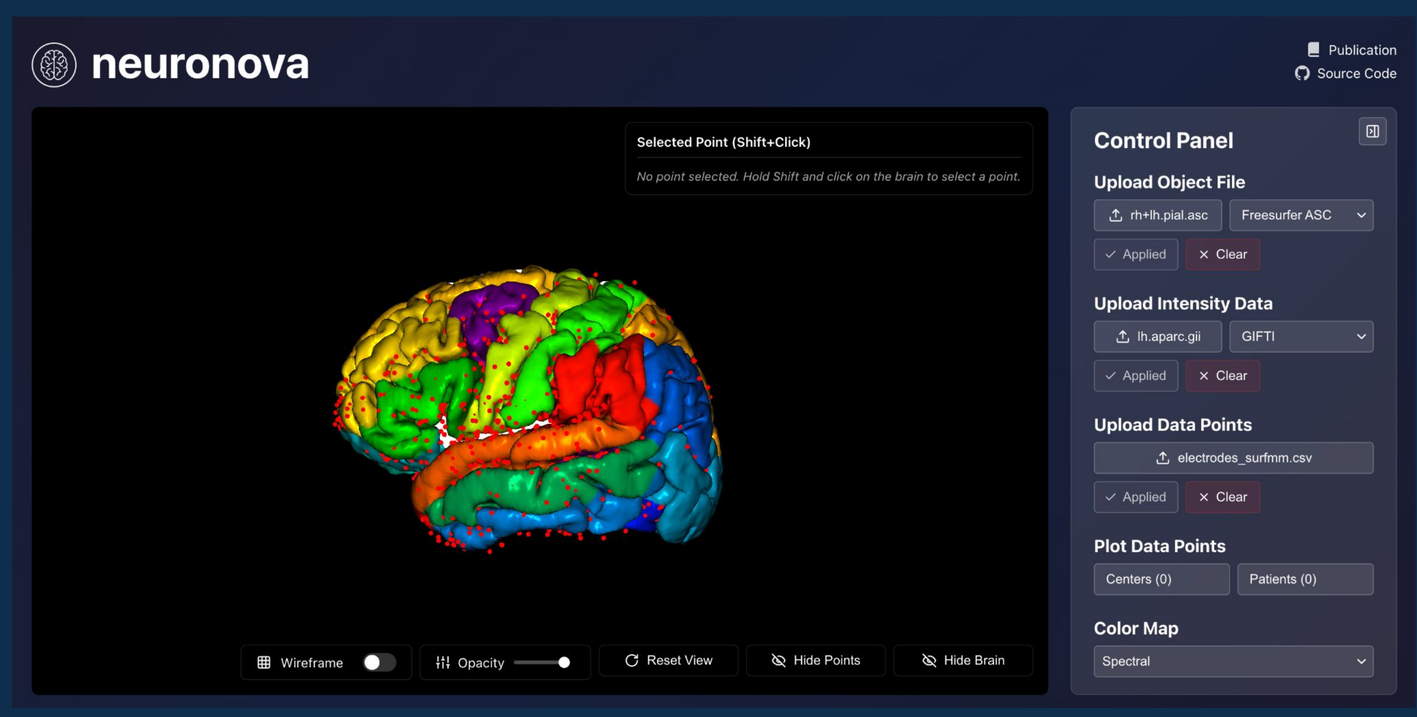
Methods

System Architecture

- Cloud-based, containerized platform using Docker and hosted on AWS
- Connects directly to Pennsieve and OpenNeuro through REST APIs
- An interactive frontend built on BrainBrowser enables 3D visualization of z-scores overlaid on anatomical models and backend using Python Flask



Multicenter Electrode View with Anatomical Brain Region Mapping



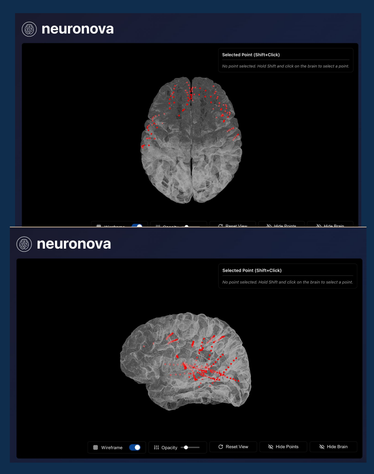
Users can explore electrode data by brain region, enabling focused analysis of specific anatomical areas across patients.

Results

Connecting tools to EEG databases:

- Neuronova integrates over **30,000 electrodes from 400+ patients**, with data harmonized across HUP, MNI, UCSF, MUSC, Emory, and public repositories.
- Data are standardized in BIDS-iEEG format and co-registered to MNI space for consistent, region-specific analysis.
- We incorporated 1,772 clinically normal channels from the MNI dataset as a normative control cohort.

Implanted electrodes can be viewed on standardized on MNI Brain



Population-level normative mapping reveals important ROI

Red is a **positive** deviation. Blue is a **negative** deviation. Larger points mark electrodes with abnormal feature values, highlighting potential regions of interest for seizure localization.

Scaling tools and feature extraction:

Our pipeline automatically computes the following features through a pipeline that runs in cloud using Docker containers:

- **Time-domain**: amplitude, variance
- **Frequency-domain**: bandpower across canonical EEG bands, entropy, Catch22 metrics

Z-Scores can be displayed for different features for each patient of interest

Deploying tools to improve clinical care

- Clinicians can view patient-specific electrode abnormalities in real time, aligned against a growing normative reference.
- The platform offers interactive z-score maps, regional overlays, and feature-based sorting to support event annotation and patient-specific interpretation in a population context.

Conclusion

- **Neuronova** offers the first scalable, cloud-native iEEG atlas capable of real-time normative modeling across centers and patient populations.
- Implications include enabling reproducible, automated analysis of new patient data without manual reruns with the goal of supporting both population-level discovery and personalized decision support.

References

Bernabei, J. M., Sinha, N., Arnold, T. C., Conrad, E., Ong, I., Pattnaik, A. R., Stein, J. M., Shinohara, R. T., Lucas, T. H., Bassett, D. S., Davis, K. A., & Litt, B. (2022). Normative intracranial EEG maps epileptogenic tissues in focal epilepsy. *Brain, 145*(6), 2075–2087. https://doi.org/10.1093/brain/awab480

Hamilton, L. S., Chang, D. L., Lee, M. B., & Chang, E. F. (2014). A spatial map of onset and spread of epilepsy from intracranial EEG. Frontiers in Neuroinformatics, 8, 89. https://doi.org/10.3389/fninf.2014.00089

See presentation on June 5, 2025 between 15:20 to 16:50 pm for live demo!