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PixelMap: An Application for Flexible Electrode Selection on Neuropixels Probes

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Abstract

PixelMap is a browser-based application for creating custom channelmaps for Neuropixels probes that respects electrode wiring constraints. Neuropixels probes, widely used for high-density neural recordings, have more physical electrodes than can be used for simultaneous recording because they contain fewer analogue-to-digital converters (ADCs) than data lines. Each ADC is hard-wired to several electrodes, creating complex interdependencies where selecting one electrode makes others unavailable. PixelMap provides an installation-free, browser-based interface for researchers to design arbitrary recording configurations that meet their experimental requirements while satisfying these hardware constraints. The tool generates IMRO (IMec Read Out) files compatible with SpikeGLX, the most common acquisition software for Neuropixels recordings.

Statement of need

Neuropixels probes have revolutionised systems neuroscience by enabling simultaneous recordings from hundreds of neurons across multiple brain regions at any depth (Beau et al., 2021, 2025; Bondy et al., 2024; Jun et al., 2017; Steinmetz et al., 2021; Ye et al., 2025). However, configuring these probes presents challenges. Limited by the number of integrated analogue-to-digital converters (ADCs), Neuropixels probes contain 960–5120 electrodes but can only record from 384–1536 channels simultaneously (Table 1). Users must therefore select a subset of electrodes to activate for each recording, a "channelmap". Researchers often need to create custom channelmaps to target specific brain regions, and sometimes must adjust them rapidly based on feedback from ongoing recordings. Because the electrode-to-ADC wiring follows complex, probe version-dependent patterns, manual channelmap design is error-prone and time-consuming.

SpikeGLX is the most common acquisition software for Neuropixels recordings and uses the `.imro` file format to encode channelmaps. While SpikeGLX provides tools to edit channelmaps, it requires a desktop app, comes with limited preset channelmaps, and does not easily allow selection of fully arbitrary electrode geometries.

PixelMap addresses these needs by:

1. **Being available on any machine installation-free**: The tool is available both as a web application at https://pixelmap.pni.princeton.edu and as a Python package.
2. **Visualising wiring constraints interactively**: When users select electrodes, the interface immediately shows which other electrodes become unavailable (marked in black) due to shared ADC lines, preventing invalid configurations.
3. **Supporting arbitrary electrode geometries**: Users can select electrodes by choosing from common preset geometries, entering electrode ranges as text for reproducibility, directly

clicking or dragging on the probe visualization, or loading pre-existing `.imro` files. These four selection methods are fully intercompatible and can be combined. For instance, a SpikeGLX `.imro` file can be loaded as a starting point, and selection boxes used to further refine the channelmap geometry.

Probe Version	Physical Channels	Simultaneously Recordable Channels
Neuropixels 1.0	960	384
Neuropixels 2.0 (single shank)	1,280	384
Neuropixels 2.0 (4-shank)	5,120 (1,280 per shank)	384
Neuropixels 2.0 Quad Base	5,120 (1,280 per shank)	1,536

Table 1: Number of physical and simultaneously addressable electrodes across Neuropixels probe versions.

Software design

PixelMap is implemented in Python using HoloViz Panel (Yang et al., 2022) for the web interface, providing an interactive and responsive user experience. The software architecture consists of three main components.

First, the **wiring maps** at `./wiring_maps/*.csv` are hand-built CSV files describing the electrode-to-ADC mappings for each supported probe type. They were adapted from files provided by IMEC (Neuropixels manufacturer - downloadable here).

Second, the **core logic** at `./backend.py` implements the constraint-checking algorithms that validate electrode selections against probe-specific wiring maps. This handles the complex mapping between physical electrodes and ADC channels for different probe types (Neuropixels 1.0, 2.0 single-shank, and 2.0 four-shank so far). Hash tables (Python dictionaries) are used to query incompatible electrode pairs with O(1) complexity and improve performance.

Finally, the **graphical user interface** at `./gui/gui.py` was built with HoloViz Panel. The interface provides real-time visualisation of the probe layout with electrode colour-coded based on their selection state (available in grey, selected in red, or unavailable in black). The interface supports the abovementioned four selection modes, including Bokeh-based interactive click-selection and box-selection to select or deselect electrodes. User interactions trigger immediate recalculation of available electrodes based on the current selection state. This design ensures users receive instant feedback about constraint violations, preventing invalid configurations before file generation.

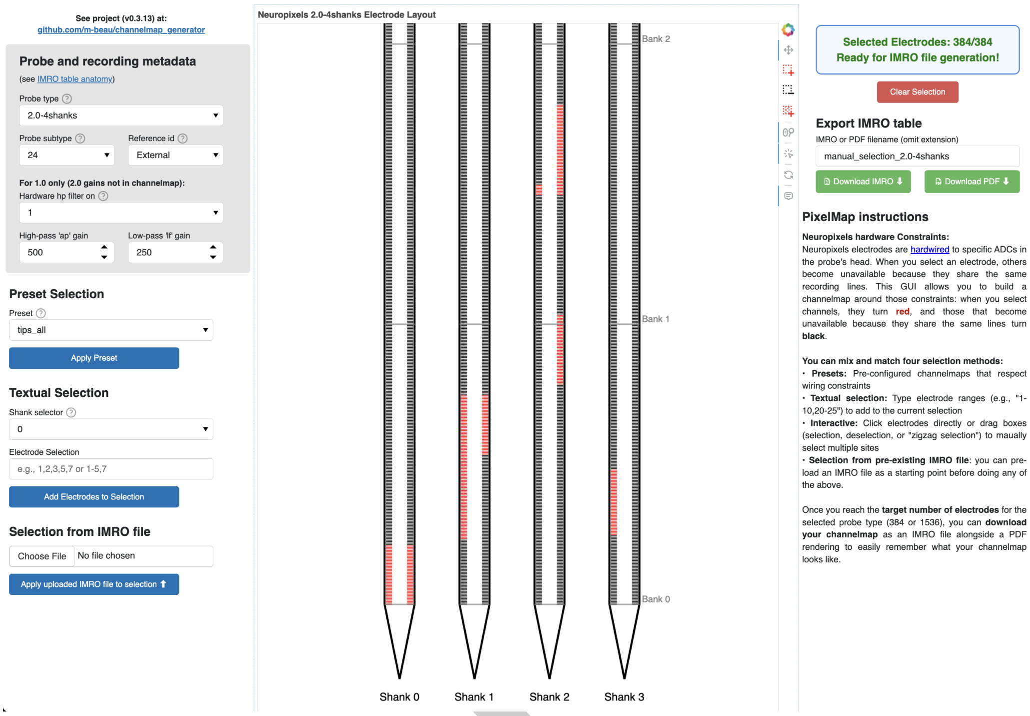

Figure 1: PixelMap's browser-based graphical user interface.
Center: Main panel featuring the probe's physical layout with one or four shanks that exhibit the 960 (Neuropixels 1.0) or 1,280 (Neuropixels 2.0) physical electrodes/shank to be selected. Electrodes available for selection are light grey, selected electrodes turn red, and electrodes that become unavailable due to hardware wiring constraints turn black. In this example, 384 electrodes have been selected (matching the maximum simultaneous recording capacity), with a distributed pattern across multiple banks, illustrating that PixelMap allows selection of arbitrary channelmap geometries.
Left: panel to input probe metadata (also part of `.imro` files) as well as three methods of electrode selection: preset geometries, manual textual input of electrode ranges, and pre-loading an existing `.imro` file. These three methods of electrode selection can be mixed together with an interactive click-and-drag box selector and deselector.
Right: electrode status indicator that turns green to confirm the selection is complete and is ready for IMRO file generation. Users can export their configuration via the "Download IMRO" button for direct use in SpikeGLX or save a PDF visualisation to easily remember the geometry of the corresponding `.imro` file in the future. Below the status indicator are PixelMap's instructions.

Installation and Usage

PixelMap can be used through:

1. **Web application**: Available at https://pixelmap.pni.princeton.edu for immediate use without installation.
2. **Local installation**: Via pip (`pip install .`) or uv (`uv run cmap_gui`) from the cloned GitHub repository.
3. **Docker container**: Users can download the image used for the website and run the container locally.
4. **Programmatic API**: Python scripts can directly call `generate_imro_channelmap()` for batch processing or integration into analysis pipelines.

For more details, see the project repository at https://github.com/m-beau/channelmap_generator.

The software includes an automated test suite with 41 tests covering hardware constraint validation, all preset configurations, IMRO file generation for all supported probe types, and end-to-end workflows. Tests run automatically via GitHub Actions continuous integration on every code change, ensuring software reliability. See the repository's `tests/` directory for details.

Research impact statement

PixelMap addresses a practical bottleneck in Neuropixels experimental workflows. As users of Neuropixels probes since 2019 (Beau et al., 2021, 2025; Bondy et al., 2024; Kostadinov et al., 2019; Steinmetz et al., 2021), we identified the need for an alternative to existing solutions for channelmap generation (see Statement of Need). The tool has been adopted by experimentalists across multiple institutions for planning recordings, as evidenced by community engagement on the project repository (16 stars as of January 2025).

AI usage disclosure

AI-assisted technologies used: Claude (Anthropic) via Claude Code. AI assistance was used for (1) optimization suggestions and documentation improvements (docstrings, code comments) in `backend.py`, (2) initial scaffolding of the HoloViz Panel GUI architecture in `gui/gui.py`, (3) manuscript grammatical and syntactical review. AI was not used for project conceptualization, core algorithm design, electrode wiring map construction – these built on the authors' experience writing software for Neuropixels (Beau et al., 2021). App hosting infrastructure was designed independently of AI assistance.

Author Contributions

	Maxime Beau	Christian Tabedzki	Carlos D. Brody
Conceptualisation	X		
Backend and GUI	X		
App hosting		X	
Supervision and funding			X

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