Xolotl: A Fast and Comprehensible Neuronal Simulator

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ABSTRACT

`xolotl` is an open-source neuronal simulator written in `C++` with `MATLAB` wrappers. Complex models and networks can be designed efficiently using an intuitive language tightly coupled to the object-based architecture of the underlying `C++` code. Models are specified by adding conductances to compartment objects. The structure is modular, serialized, and searchable, permitting high-level programmatic control over nearly all features of the models. `C++` templates are provided for developing new conductances, compartments, and integration schemata. `xolotl` readily implements parallel-processing on multicore processors and high-performance computing clusters. It also includes a customizable graphical user interface ('puppeteer') for rapid prototyping and hand-tuning conductances in real-time. In addition, `xolotl` comes packaged with a powerful optimization toolbox (`procrustes`) for optimizing any model parameters accessible in the `xolotl` tree. The modular structure and accessibility to all parameters, variables, and dynamics of the model network in `MATLAB` facilitate interoperability with other specifications (viz. `NeuroML, SBML`), simulators (viz `NEURON, Brian, NEST`), and web-based applications (viz. `Geppetto`). `xolotl` is freely available at `https://github.com/sg-s/xolotl`. This tool provides rapid implementation and fast simulation of neuronal models while permitting full control over every aspect of the network and integration.

Keywords: simulator, MATLAB, C++, xolotl, conductance-based, computational, keyword, keyword

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Figure 1. `xolotl` readily implements voltage clamp. (A) Cartoon of a cell with potassium conductance with experimentally-fixed voltage. (B) Structure of `xolotl` object in A. (C) Code snippet depicting integration under voltage clamp. (D-E) Current response to steps in voltage from a holding potential of $V_m = -60$ mV. (F) Current-voltage relation of the steady-state current ($t = 400$ ms) indicating a reversal potential of $E = -80$ mV and no inactivation. (G) Conductance-voltage relation at steady-state takes the form of a sigmoid. (H) Sigmoids of the form $m(V)^n$ fit to the model data indicating that $n = 4$ is the best fit. (I) R^2 correlation of the sigmoid fits at various powers where $n = 4$ is an exact fit.

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DATA AVAILABILITY STATEMENT

The datasets [GENERATED/ANALYZED] for this study can be found in the [NAME OF REPOSITORY] [LINK].

REFERENCES

[Dataset] LastName1, A., LastName2, A., and LastName3, A. (2011). Data title. doi:10.000/55555

LastName1, A., LastName2, A., and LastName3, A. (2013). Article title. *Frontiers in Neuroscience* 30, 10127–10134. doi:10.3389/fnins.2013.12345

Name, A. (1993). *The title of the work* (The city: The name of the publisher)

Name, C., Surname, D., and LastName, F. (1996). The title of the work. In *The title of the conference proceedings*, eds. E. Name1 and E. Name2 (The name of the publisher), 41–50

Surname, B. (2002). The title of the work. In *The title of the book*, ed. E. Name (The city: The name of the publisher). 201–213

Surname1, H. (2010). *The title of the work* (Patent country: Patent number)

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