Machine Learning Optimization of Parameters for Biophysical Stochastic Model of Auditory Nerve Stimulation

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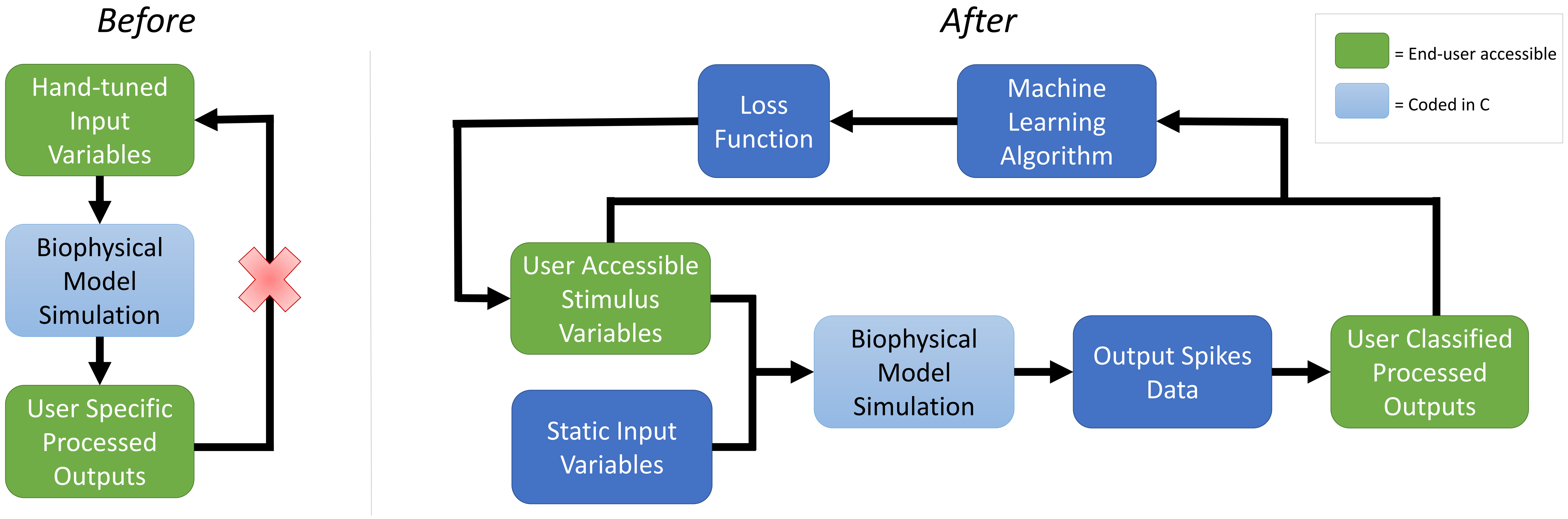
Abstract

Cochlear implant function is dependent on injected current depolarizing auditory nerve fibers. Our group previously developed a stochastic, biophysical simulation of a population of electrically stimulated auditory nerve fibers (Imennov & Rubinstein 2009), providing novel insights into cochlear implant function and a test bed for signal processing strategies. While the parameters in this model correspond to empirically measured quantities, construction of the original model required hand-tuning of these parameters within the experimentally observed range to produce the desired simulation behavior.

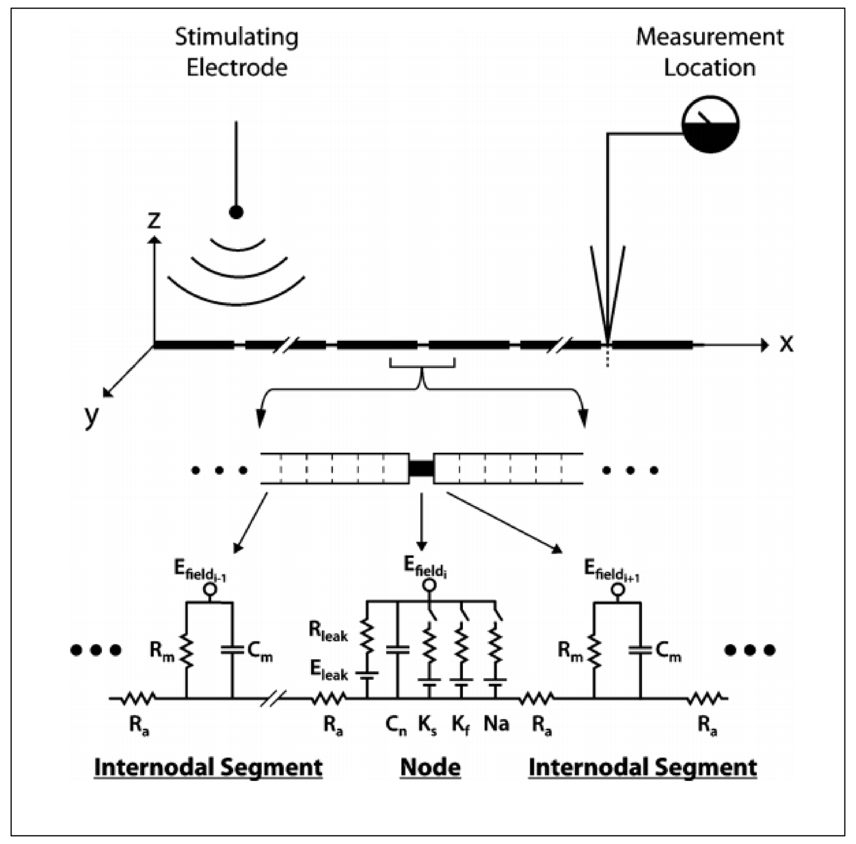
I have built a Python based computational wrapper that interfaces with this biophysical model at both the front and back ends that is both user and machine accessible, creating for the possibility of cross-user collaboration and machine learning. Our next steps will be to close the loop between these inputs and outputs using particle swarm optimization to enable machine tuning of model parameters which correspond to physiological attributes. This automated tuning will speed up the incorporation of new features into the model and enable parameter sensitivity analysis.



Biophysical Model

Segmented Cable Model of Auditory Nerve Stimulus

- Electrode and fiber properties correspond explicitly to empirically measurable quantities but can be manipulated to model pathology
- Membrane potential changes calculated via implicit solution of differential equations describing circuit model
- Electrophysiological output parameters generated from by extracting spiking data from fiber potential data



Imennov & Rubinstein 2009

Computational Wrapper

User Accessibility – Achieved by providing straightforward user template that compiles non-static input variables into Labels and Options classes. The rest of the computational wrapper remains rigid and independent of end-user access.

User Manipulability – Achieved by providing user with an accessible function to experimentally scan across up to three non-static input parameters. Can be scaled to easily accommodate larger experiments.

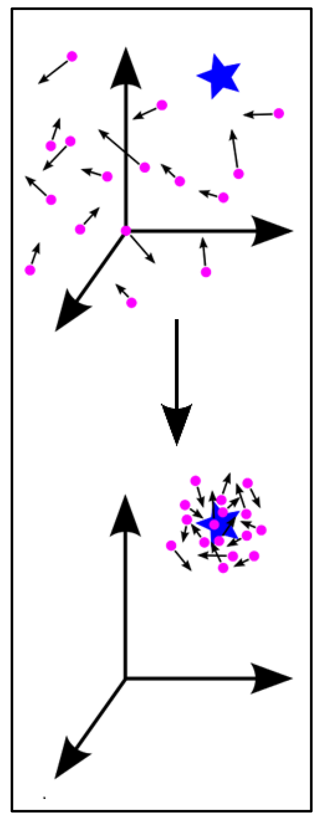
Machine Learning Accessibility – Achieved by automated development of two Numpy module databases, input and output respectively, which can be selectively refined for machine learning algorithms.

Collaborativeness – Achieved by development of uniform experimental object classes and a database library allowing for successive data compiling, sharing, and mining.

Machine Learning

Particle Swarm Optimization

- Requires input matrix of stimulus parameters of interest, output matrix of the measures of fitness, and ideal output values
- Iteratively operates the Python wrapper until specified error between simulation output and ideal values reaches threshold by optimizing stimulus parameters
- Inconsistent localization of a given stimulus parameter indicates non-correlation between parameter and specified output measurements



Becker 2013

Conclusions

- Provides a versatile and accessible model for all researchers interested in auditory function
- Provides the framework for machine learning approach to optimization of similar biophysical models
- Potential to develop ideal stimulus parameters to improve functionality of cochlear implants

Acknowledgements

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