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Predicting neuronal activity with an adaptive exponential integrate-and-fire model

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An adaptive Exponential Integrate-and-Fire (aEIF) model [1] was used to predict activity of cortical neurons. This model is a leaky Integrate-and-Fire which has in the voltage equation an additional exponential term [2] describing early activation of voltage-gated channels combined with a second variable introduced in the model to allow for subthreshold and spike frequency adaptation [3].

Previously, we used the aEIF model to predict the membrane potential of pyramidal neurons under random current injection [4]. Moreover, similarly to the Izhikevich model [3], we know that the model can mimic more complicated firing patterns, that is, the model can reproduce spike trains of a detailed conductance-based model under standard electrophysiological paradigms [1].

Here, we reproduce several firing patterns of mainly interneurons from the EPFL microcircuit database [5]. The aEIF model was used to reproduce the firing pattern of the different electric classes of neurons under standard electrophysiological input regime. We studied nine classes among which Delayed Initiation Spiking, Burst Spiking, Fast Adapting or Non-Adapting Spiking [6] and compared simulation of the aEIF model (with 9 parameters) to a Hodgkin-and-Huxley model with 6 different ion channels.

Moreover, we wondered whether the model can be fitted directly to experimental data. We successful fitted the aEIF model to recordings of a Layer-II-III cells with different firing properties.

In summary, we found different areas of the parameter space corresponding to these specific classes. That is, the aEIF model includes an additional mechanism that can be tuned to model spike-frequency adaptation as well as burst activity. The exponential term allows one to model specific behaviors such as delayed spike initiation and offers flexibility at the level of the threshold mechanism. At the moment a large part of the tuning is done manually. However, once our automatic parameter fitting procedure is in place, we expect that clustering in parameter space could contribute to an automatic neuron classification.

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