Conductance-Based Integrate-and-Fire Models

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A conductance-based model of Na+ and K+ currents underlying action
An alternative approach was to simplify the process of action potential generation by representing the neuron as an integrate-and-fire (IAF) device (see Ashik 1993). In this case, the neuron produces an action potential when its
Figure 1: Comparison of action potential generation in Hodgkin-Huxley and pulse-based models. A train of spikes was generated by injecting a depolarizing current pulse (2 nA) in a single compartment model (area of 15,000 \( \mu \text{m}^2 \); \( \bar{g}_{Na} = 30 \text{ ms/cm}^2 \); other parameters as in equation 2.1). The time course of the rate constants (\( \alpha_m, \beta_m, \alpha_h, \beta_h, \alpha_n, \) and \( \beta_n \)) and state variables (\( m, h, \) and \( n \)) is shown for each panel. In the Hodgkin-Huxley model (left panel), rate constants undergo sharp transitions when a spike occurs. Approximating these transitions by pulses (right panel) led to a simplified representation of spike-generating mechanisms (threshold of \( -53 \text{ mV} \), pulse duration of 0.6 ms, rate values as in equation 4).

The basis of the simplified model is to approximate the time course of the
given threshold. For example, $a$ will be assigned a position $p$ if $a < P$.
Here, $t_0$ is the time at which the pulse began, and $m(t_0)$, $h(t_0)$, and $n(t_0)$ are the values of $m$, $h$, and $n$ at that time.
Hodgkin-Huxley
Figure 4: Comparison of simplified and original Hodgkin-Huxley models using simulations of circuits of neurons. Left panel: Model of spindle oscillations in a network of 16 thalamic neurons. Eight thalamocortical (TC) cells projected to 8 thalamic reticular (RE) neurons using AMPA-mediated contacts, whereas RE cells contacted themselves using GABA_A receptors and TC cells using a mixture of GABA_A and GABA_B receptors. Each neuron had Na^+, K^+, Ca^+, and cationic voltage-dependent currents described by Hodgkin-Huxley-type equations, whose parameters were obtained from voltage-clamp and current-clamp...
Table 1: Computational Performance of Different Methods for Generating Action Potentials.

<table>
<thead>
<tr>
<th>Method</th>
<th>NEURON (relative CPU time)</th>
<th>Minimal C Code (relative CPU time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>DEo</td>
<td>0.32</td>
<td>0.45</td>
</tr>
<tr>
<td>PB</td>
<td>0.25</td>
<td>0.17</td>
</tr>
<tr>
<td>IAF</td>
<td>0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Note: A single-compartment cell comprising passive currents, 1 nA injected current, and a model for action potentials was simulated. Different models for action potentials were: DE: Hodgkin-Huxley model described by differential equations; DEo: same equations solved using optimized algorithms; PB: pulse-based model; IAF: simple integrate-and-
formance of IAF models (see Table 1). However, this increase of efficiency could be minimal in the case of network simulations where action potentials represent only a small fraction of the computation time. On the other hand.
Destexhe, A., Mainen, Z., & Sejnowski, T. J. (1994b). Synthesis of models for excitable membranes, synaptic transmission and neuromodulation using a