Neuroprothetik Exercise 5
Multicompartment Model

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1. Create a Multicompartment Model

Change the point neuron model from the last exercise to a multicompartment model consisting of 100 Compartments. Use the backward Euler method to solve the arising system of differential equations. The parameters are given in the Appendix.

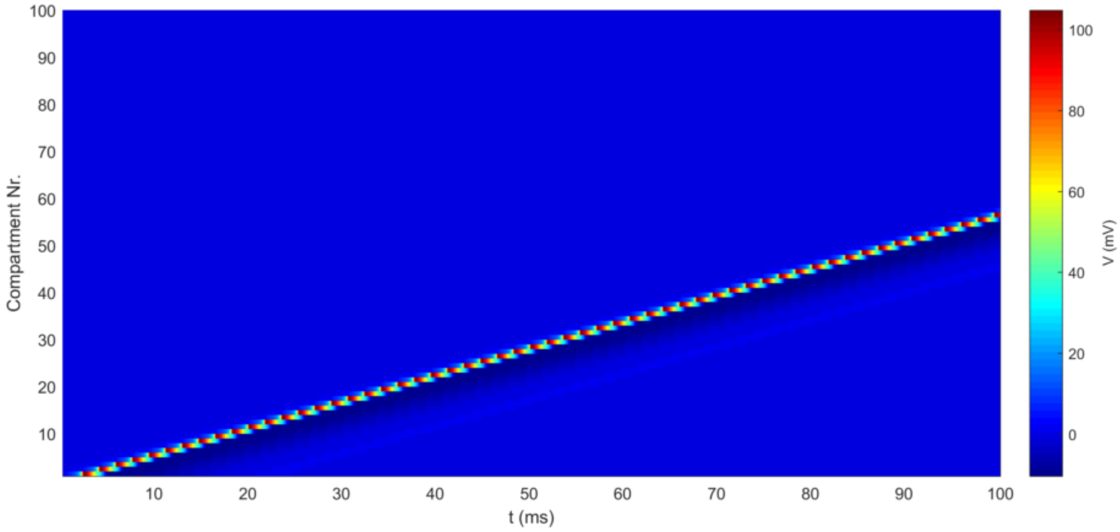
2. Experiments

Run 100 ms long simulations ($\Delta t = 25\,\mu$s should be sufficient) at $6.3\,°C$ with the following settings.

1. Stimulate the axon at the first compartment with a rectangular 5 ms long pulse with an amplitude of $10\,{}^{\mu A}/_{cm^2}$. Visualize how the action potential propagates along the axon.
2. Stimulate the axon with the same pulse as above but at compartment 20 and simultaneously at compartment 80. Explain the resulting propagation profile and its origin.
3. Explore the different parameters of the model and find out which would affects the speed of action potential propagation.

3. Solution

Here you can see how the resulting plots should look like. This is just to give you an idea if your results are valid.



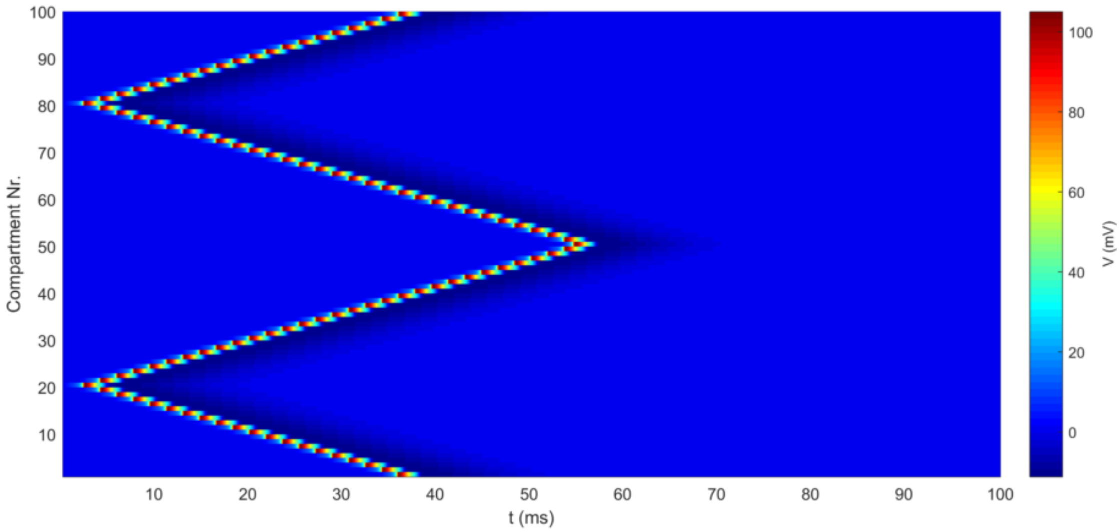


Abbildung 1: Top: Propagation of the action potential over the different compartments for stimulation at compartment 1. Bottom: Same for simultaneous stimulation at compartments 20 and 80. The colorbar shows the color coding of the action potential values.

A. Equations and Constants

All units are given as in the original publication. Hodgkin and Huxley obviously had no idea about SI units but if you use all units as given and ms for the time axis, all numbers can be used without conversions.

General equations:

$$i_{ion} = i_{Na} + i_K + i_L$$
$$V = V_i - V_e - V_{rest}$$

Ionic currents:

$$i_{Na} = \bar{g}_{Na} m^3 h (V - V_{Na}) \qquad i_K = \bar{g}_K n^4 (V - V_K)$$
$$\frac{dm}{dt} = [\alpha_m(1-m) - \beta_m m]k \qquad \frac{dn}{dt} = [\alpha_n(1-n) - \beta_n n]k$$
$$\frac{dh}{dt} = [\alpha_h(1-h) - \beta_h h]k \qquad i_L = \bar{g}_L(V - V_L)$$

Temperature correction (T in °C):

$$k = 3^{0.1(T-6.3)}$$

Rate equations (V in mV):

$$\alpha_m = \frac{2.5 - 0.1V}{e^{(2.5-0.1V)} - 1} \qquad \beta_m = 4e^{-V/18}$$
$$\alpha_n = \frac{0.1 - 0.01V}{e^{(1-0.1V)} - 1} \qquad \beta_n = 0.125e^{-V/80}$$
$$\alpha_h = 0.07e^{-V/20} \qquad \beta_h = \frac{1}{e^{(3-0.1V)} + 1}$$

Constants

Conductances in $^{\mathrm{mS}}/_{cm^2}$			
$\bar{g}_{Na} = 120$	$\bar{g}_K = 36$	$\bar{g}_L = 0.3$	
Resting potentials in mV			
$V_{Na} = 115$	$V_K = -12$	$V_L = 10.6$	$V_{rest} = -70$
Other constants			
$c = 1\,^{\mu\mathrm{F}}/_{\mathrm{cm}^2}$	$\rho_{axon} = 0.1\,\mathrm{k\Omega cm}$	$r_{axon} = 2 \cdot 10^{-4}\,\mathrm{cm}$	$l_{comp} = 0.1 \cdot 10^{-4}\,\mathrm{cm}$