Second FIPPA Check-in

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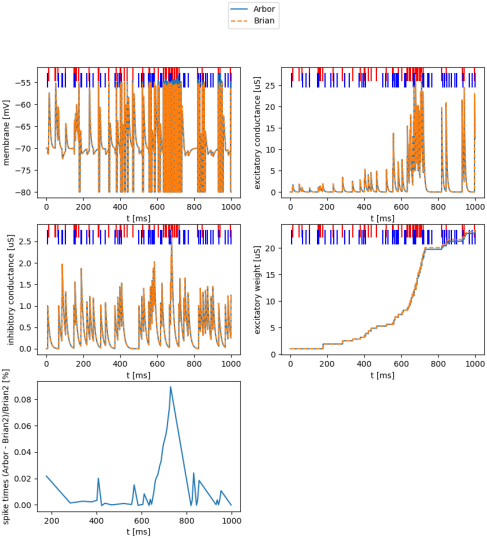
M18 internal milestone

- Description: Extension of Arbor for initial support of plasticity and beta-release of code
- Means of verification: Arbor running with test plasticity rules
- Achieved: yes
- Summary of achievement: Together with the Arbor core developers, functionality was added to Arbor that allows for spike/event driven plasticity rules. This allows to evaluate spike timing dependent plasticity (STDP) as well as event driven homeostasis. In addition, the FIPPA team contributed to the overall development of Arbor and the Arbor GUI.
- Person who validated the MS achievement: Nora Abi Akar
- Proof of achievement: `https://github.com/tetzlab/FIPPA`

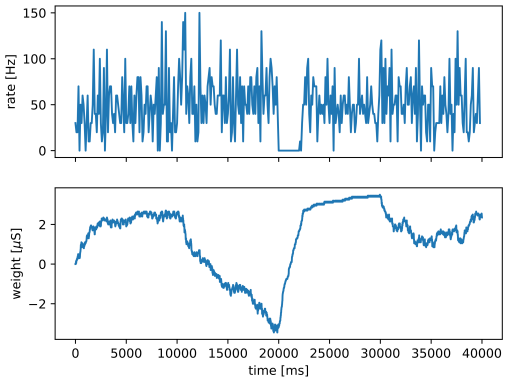
`https://drive.ebrains.eu/smart-link/bc68d0df-25e8-4133-ac52-a2f69eec5c97`

Proof of achievement: STDP



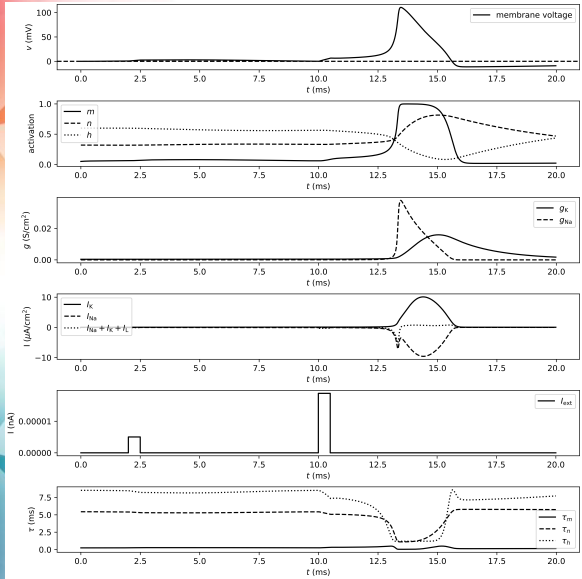
- Single STDP synapse driven by Poisson input stimulates a LIF neuron
- Comparison between Brian2 and Arbor

Proof of achievement: event based homeostasis



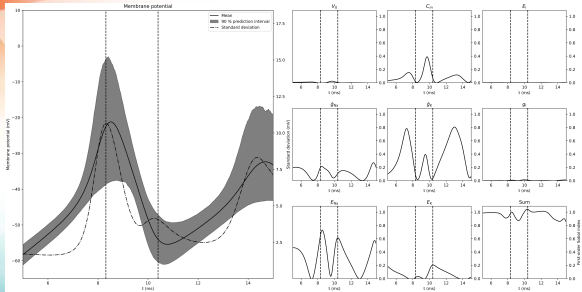
- Two poisson stimuli are connected to a neuron, one with a varying rate and the other with a fixed rate
- The synaptic weight from the varying rate stimulus to the neuron is fixed, the synaptic weight from the fixed rate stimulus to the neuron is plastic and tries to keep the neuron at a firing rate that is determined by the parameters of the plasticity rule

Misc: Hodgkin-Huxley Approximated



- Hodgkin-Huxley neuron simulation with approximations for gating variable steady-states and time constants

Misc: Hodgkin-Huxley Sensitivity Analysis



- Reproduction of: “Uncertainty Propagation in Nerve Impulses Through the Action Potential Mechanism”, Valderrama et al. `https://doi.org/10.1186/2190-8567-5-3`

Next steps

- Implementation of “Organization and priming of long-term memory representations with two-phase plasticity” (`https://doi.org/10.1101/2021.04.15.439982`) in Arbor (Jannik)
- Implementation of axial diffusion of ions (“Arbor team” with Sebastian); `https://github.com/arbor-sim/arbor/issues/1651`

Diffusion

Spatial spreading of specific signaling molecules is determined by the balance between diffusion and inactivation rate: how far active molecules can diffuse before they are inactivated. In the simplest model assuming one dimensional diffusion of the molecules along the dendrite, the spatial profile of activity C is given as a function of the distance from the stimulated spine (x) and time (t) as

$$\partial C(t,x)/\partial t = D_{\text{eff}}\left(\partial^2 C/\partial x^2\right) - C/\tau,$$

where D_{eff} is the effective diffusion coefficient of the signaling molecule and τ is the time constant of the decay of molecular activity (50). At the steady state ($t \rightarrow \infty$), C can be described as

(Yasuda, 2017)

- Both the neuron and its synapses need to have access to C