A network model of the neocortex

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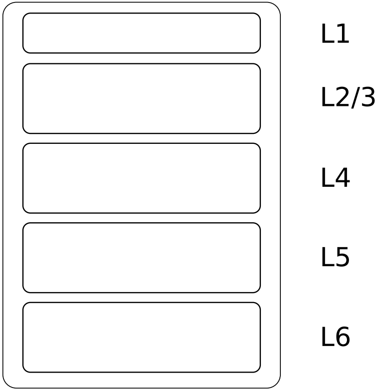
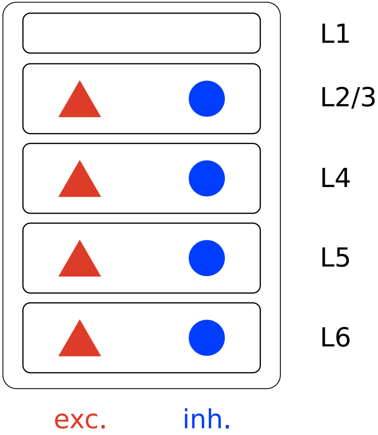
Layered structure



Layered structure



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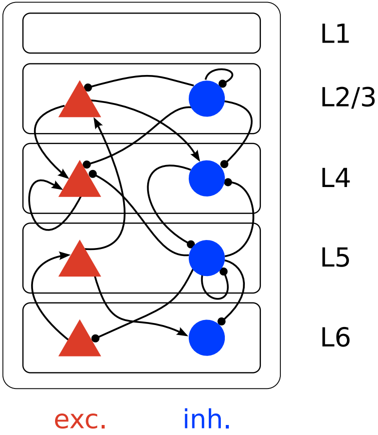

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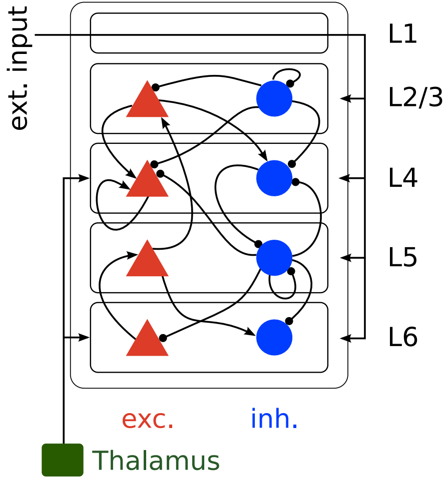
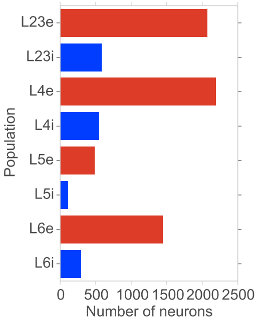


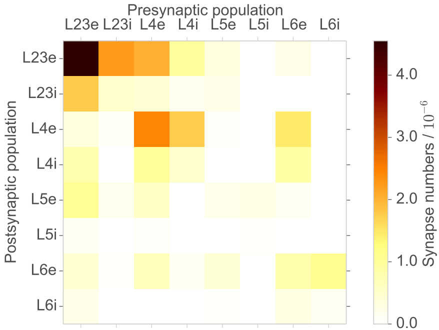
Network parameters

Parameter specification	
Total population size	$\approx 80,000$
Total synapse number	$\approx 0.3 \cdot 10^9$
Neuron model	Leaky integrate-and-fire
Synapse model	Exponential-shaped postsynaptic currents
Rel. inh. synaptic strength	$g = -4.0$

Network parameters



(a) Population size



(b) Synapse numbers

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Neuron depolarization

Membrane potential V_i at timescale τ_m follows

$$\tau_m \dot{V}_i(t) = -V_i(t) + RI_i(t)\,. \tag{1}$$

The model goes from a deterministic description,

$$RI_i(t) = \tau_m \sum_j J_{ij} \sum_k \delta(t - t_j^k - D) \tag{2}$$

to a statistical one:

$$RI_i(t) = \mu(t) + \sigma(t)\sqrt{\tau}\eta_i(t) \tag{3}$$

Here, $\eta_i(t)$ is uncorrelated gaussian white noise.

Self-consistent solution in 2D model

Firing rate ν of each neuron obeys

$$\frac{1}{\nu} = \tau_{rp} + 2\,\tau_m \int_{\frac{V_r-\mu}{\sigma}}^{\frac{\theta-\mu}{\sigma}} e^{u^2}\left(1+\mathrm{erf}(u)\right)\,\mathrm{d}u \tag{4}$$

with average input

$$\mu = \tau_m C\,J\,(1-\gamma g)\,\nu \quad + \tau_m C\,J\,\nu_{ext} \tag{5}$$

and fluctuations

$$\sigma^2 = \underbrace{\tau_m C\,J^2\left(1+\gamma g^2\right)\,\nu}_{\text{local}} + \underbrace{\tau_m C\,J^2\,\nu_{ext}}_{\text{external}}\,. \tag{6}$$

Goals

1. Reconstruct the original model in *pynest*

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2. Develop a mean field model for firing rates

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2. Develop a mean field model for firing rates

3. Compare network model with mean field model

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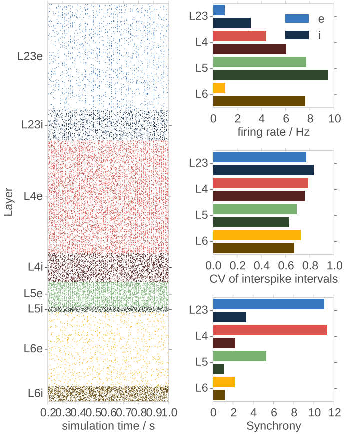
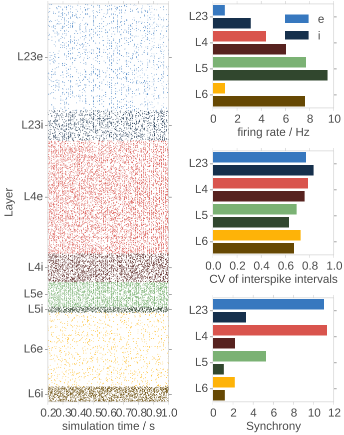
Compare SLI and pynest implementations

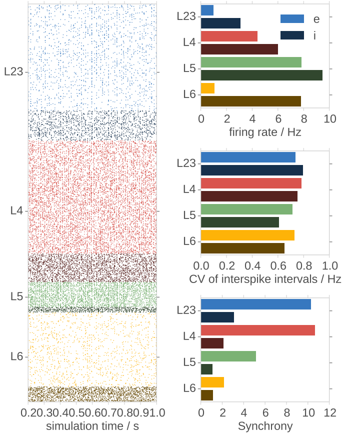


(a) SLI

Compare SLI and pynest implementations

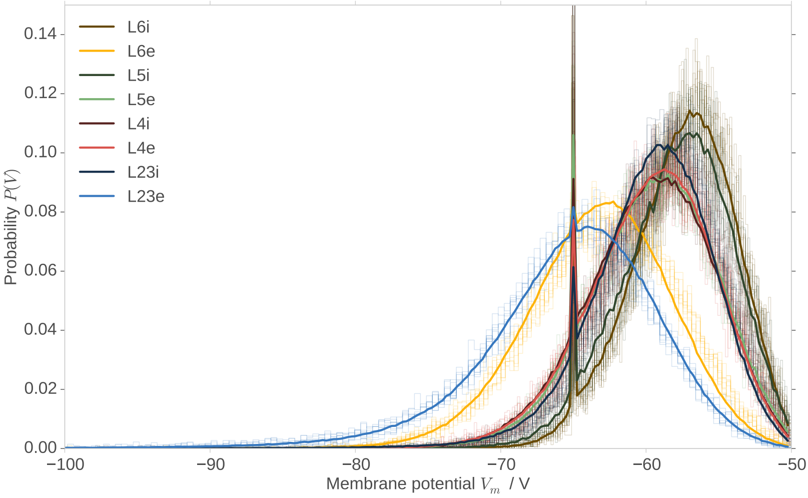


(a) SLI

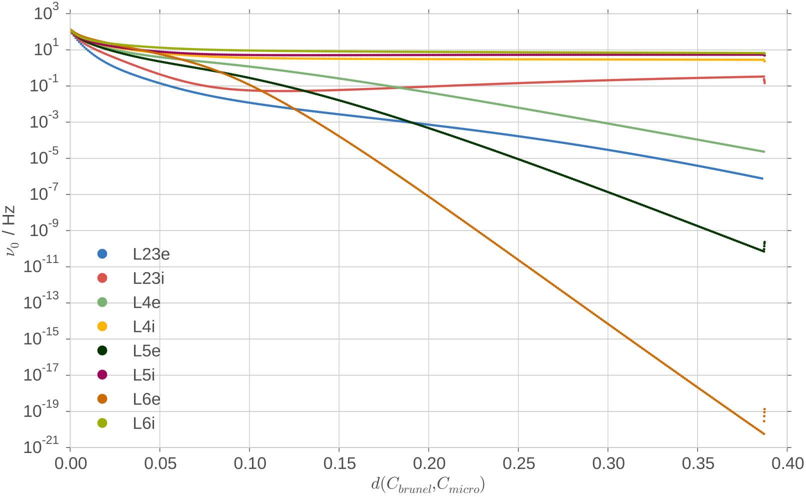


(b) Pynest

Membrane potential distribution



Current state of the numerical approach



Take home

Mean field model would be great to understand the dynamics

... but ...

turns out to be quite instable in large parameter spaces.

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with average input

$$\mu = \tau\, C\, J\,(1-\gamma g)\,\nu \quad + \tau\, C\, J\,\nu_{ext} \tag{8}$$

and fluctuations

$$\sigma^2 = \underbrace{\tau\, C\, J^2\left(1+\gamma g^2\right)\,\nu}_{\text{local}} + \underbrace{\tau\, C\, J^2\,\nu_{ext}}_{\text{external}}\;. \tag{9}$$

Extension to higher dimensions

For neuron i in population a,

$$\frac{1}{\nu_a} = \tau_{rp} + 2\,\tau_m \int_{\frac{V_r-\mu_a}{\sigma_a}}^{\frac{\theta-\mu_a}{\sigma_a}} e^{u^2}\,(1+\mathrm{erf}(u))\;\mathrm{d}u \tag{10}$$

with average input

$$\mu_a = \tau_m \sum_{b\in\text{pop.}} C_{ab}\,J_{ab}\,\nu_b + \tau\,C_{a,ext}\,J_{a,ext}\,\nu_{ext} \tag{11}$$

and fluctuation

$$\sigma_a{}^2 = \tau_m \sum_{b\in\text{pop.}} C_{ab}\,J_{ab}{}^2\,\nu_b + \tau_m\,C_{a,ext}\,J_{a,ext}{}^2\,\nu_{ext} \tag{12}$$

Extension to higher dimensions

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$$\frac{1}{\nu_a} = \tau_{rp} + 2\,\tau_m \int_{\frac{V_r-\mu_a}{\sigma_a}}^{\frac{\theta-\mu_a}{\sigma_a}} e^{u^2}\,(1+\mathrm{erf}(u))\,\mathrm{d}u \tag{13}$$

with average input

$$\boldsymbol{\mu} = A_I\boldsymbol{\nu} + A_{ext}\boldsymbol{\nu}_{ext} \tag{14}$$

and fluctuation

$$\boldsymbol{\sigma}^2 = B_I\boldsymbol{\nu} + B_{ext}\boldsymbol{\nu}_{ext} \tag{15}$$