

# Computational Neuroscience Homework 9

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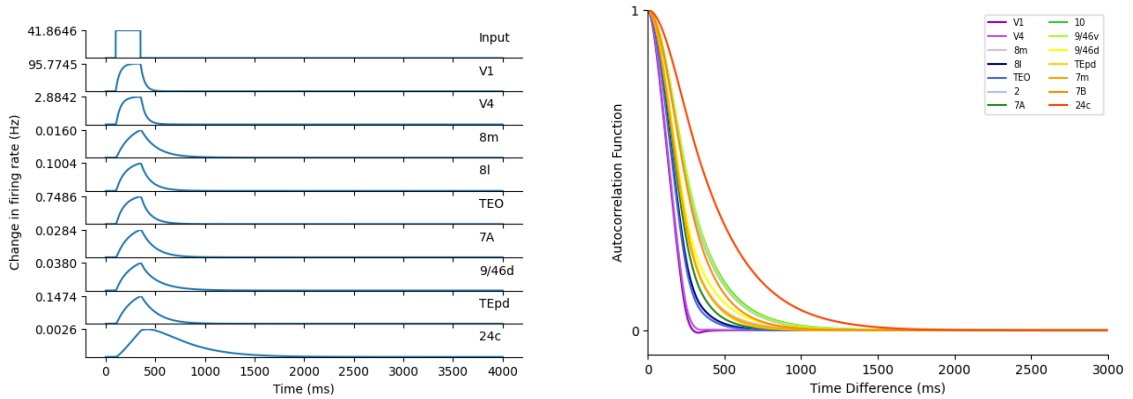
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Based on inter-areal connectivity data, a dynamical model was developed for a multiregional macaque monkey cortex [1]. The model was built in the following way: a) the model structure was constrained by anatomical data, b) each local area was described by a canonical local circuit model with an excitatory neural population and an inhibitory neural population, c) spine count per neuron was used as a proxy of excitatory input strength, which displayed a macroscopic gradient along the cortical hierarchy.

Firstly we simulate the model with the reference parameter values and save the time series of the excitatory neural population  $r_{E,k}(t)$  from each cortical area  $k$ . Then we compute the autocorrelation function of  $r_{E,k}(t)$ :

$$ACF_k(\tau) = \frac{\langle (r_{E,k}(t') - \langle r_{E,k}(t') \rangle) (r_{E,k}(t+t') - \langle r_{E,k}(t+t') \rangle) \rangle}{\langle (r_{E,k}(t') - \langle r_{E,k}(t') \rangle)^2 \rangle} \quad (1)$$

where  $\langle x(t) \rangle$  denotes the time average of  $x$ . Figure 1 describes the pulse propagation and the  $ACF_k(\tau)$  for the 14 areas. Then we fit each with either a single exponential function  $\exp(-t/\tau_k)$  or a weighted sum of two exponentials  $w_{k,1} \exp(-t/\tau_{k,1}) + w_{k,2} \exp(-t/\tau_{k,2})$  with  $w_1 + w_2 = 1$ , in which case  $\tau_k = w_{k,1}\tau_{k,1} + w_{k,2}\tau_{k,2}$ . Figure 2 plots  $\tau_l$  against the hierarchical position  $i$  of area  $k$ , where the color matches Figure 1. Unlike the paper, the model system does not show a clear hierarchy of time constants, and the range is in  $[0.175s, 0.376s]$ [1].

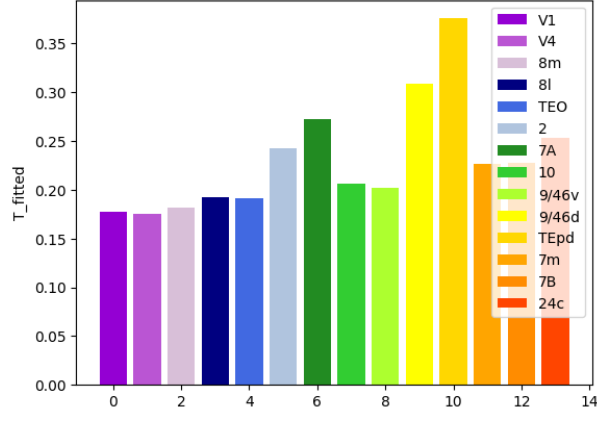


**Figure 1:** A pulse of input to area V1 is propagated along the hierarchy (left) and autocorrelation of area activity in response to white-noise input to V1 (right).

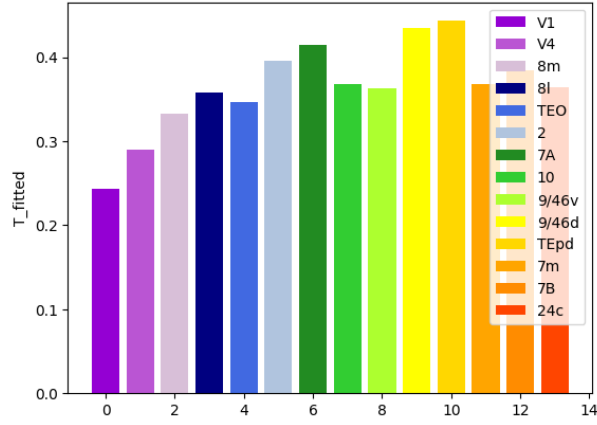
Next, we make the macroscopic gradient of synaptic excitation absent in the model, meaning when  $h_i$  is replaced by a constant equal to its average over all areas  $i$ , and observe the change on time constants. Specifically, we use:

$$(1 + \eta h_i) w_{EE} \nu_E^i + \mu_{EE} \sum_{j=1}^N FLN_{ij} \nu_E^j \quad (2)$$

for the excitatory population, and similarly for the inhibitory population. After the change, we notice the time constants in general increase and the new range is in  $[0.243s, 0.443s]$ . Also, qualitatively speaking, it becomes more evenly distributed in value across various regions.



**Figure 2:** The dominant time constants in various areas of the network extracted by fitting exponentials to the autocorrelation.



**Figure 3:** Reproduce of Figure 2 with the same  $h_i$  value across all areas  $i$ .

## References

- [1] Rishidev Chaudhuri et al. “A Large-Scale Circuit Mechanism for Hierarchical Dynamical Processing in the Primate Cortex”. In: *Neuron* 88.2 (2015), pp. 419–431. ISSN: 0896-6273. DOI: <https://doi.org/10.1016/j.neuron.2015.09.008>. URL: <https://www.sciencedirect.com/science/article/pii/S0896627315007655>.