A HIDDEN PARAMETER NETWORK THAT EXPLAINS TOPOLOGICAL PROPERTIES OBSERVED IN NEOCORTEX

MAX-PLANCK-GESELLSCHAFT

Felipe Yáñez*, Daniel Udvary, Marcel Oberlaender

Max Planck Group: In Silico Brain Sciences, Center of Advanced European Studies and Research, Bonn, Germany

* felipe.yanez@caesar.de @yanezlang

caesar
center of advanced european studies and research

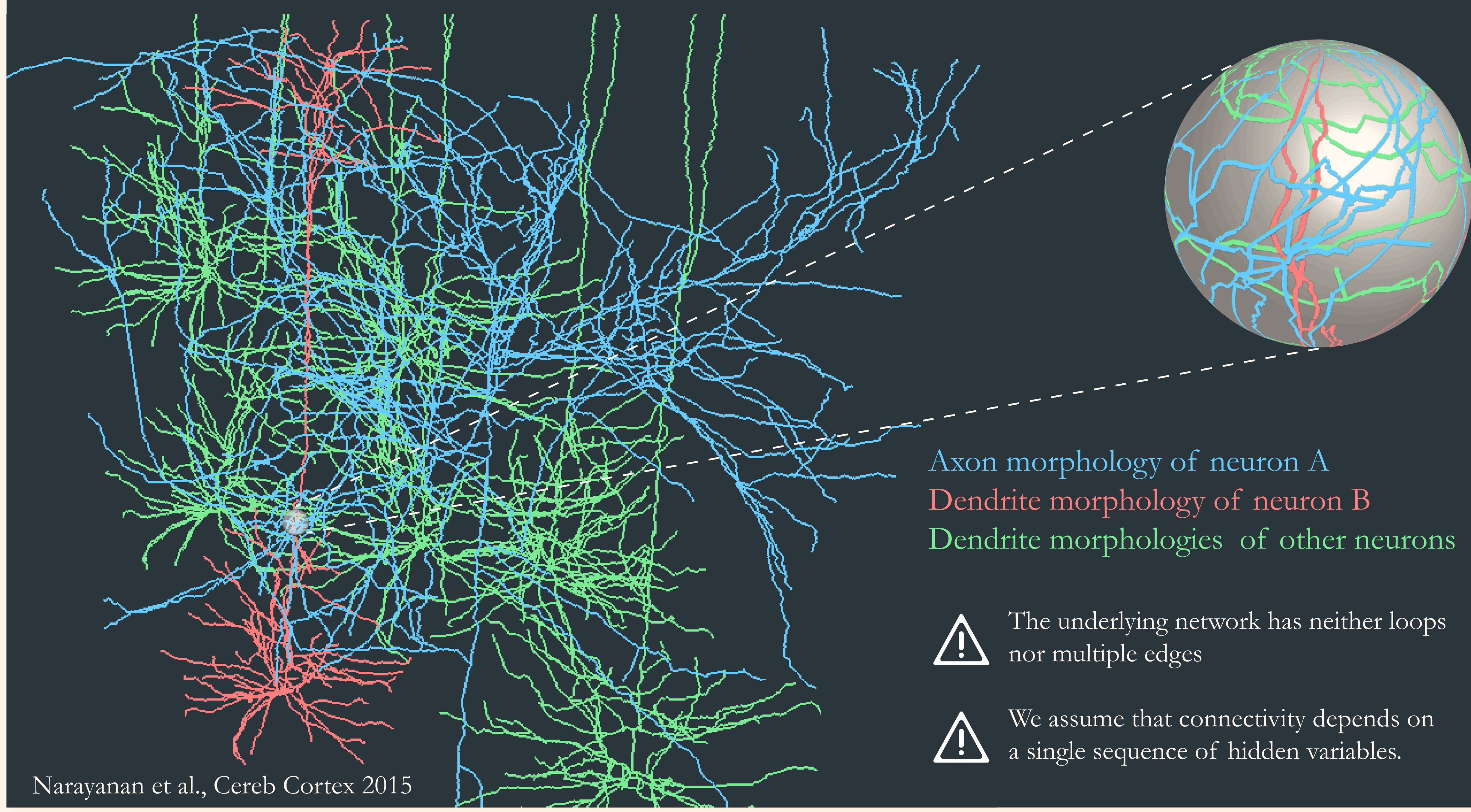
SUMMARY

* Neurons are characterized by independent hidden variables controlling the establishment of synaptic connections between pairs of neurons.

* The fact that we do not allow our model to have neither loops nor multiple edges makes the network disassortative.

* The distribution of the neuropil (i.e., hidden variables) completely determines the non-random topology of the network.

HIDDEN PARAMETER NETWORK MODEL DEFINITION



Narayanan et al., Cereb Cortex 2015

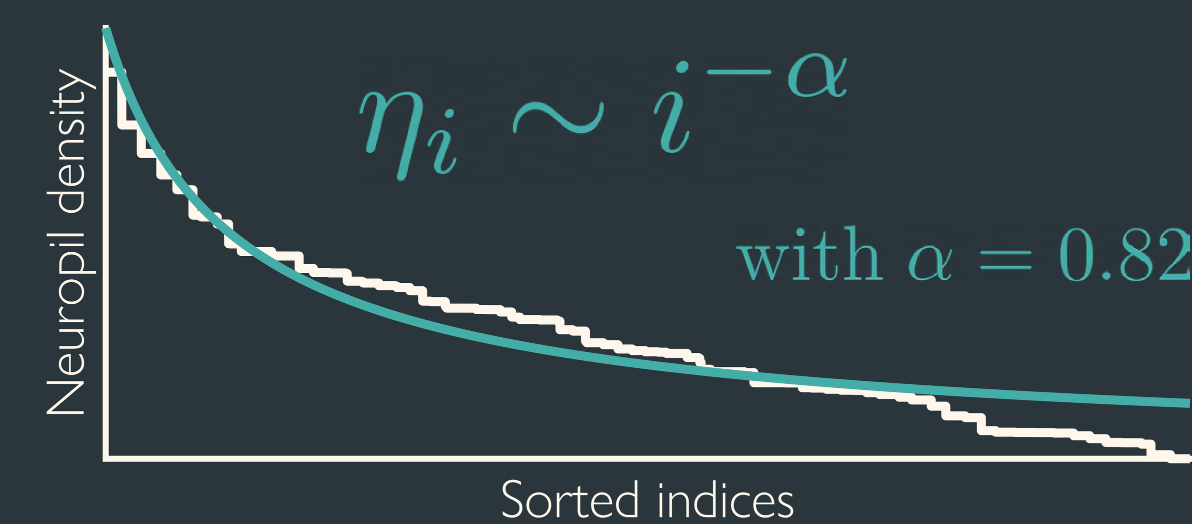
The underlying network has neither loops nor multiple edges

We assume that connectivity depends on a single sequence of hidden variables.

Connectivity rule:

$$p(i,j,\theta) = \frac{\eta_i^{\theta_1}\eta_j^{\theta_2}}{(N\langle\eta\rangle)^{\theta_3}}$$

Using the empirical distribution of axonal boutons as an independent sequence of hidden variables



SPARSE NETWORK FOR $\theta = 1$

Average degree of the network for large N:

$$\langle k\rangle = N\sum_{i,j}\rho(\eta_i)p(i,j,\theta)\rho(\eta_j)$$

$$= \frac{N}{N^{\theta_3}\langle\eta\rangle^{\theta_3}}\sum_i\frac{\eta_i^{\theta_1}}{N}\sum_j\frac{\eta_j^{\theta_2}}{N}\,.$$

For $\theta = \mathbf{1}$, we have a sparse network with

$$\langle k\rangle = \langle\eta\rangle\,.$$

SCALE-FREE PROPERTY

For $\theta = \mathbf{1}$, the connectivity rule is

$$p(i,j) = \frac{\eta_i\eta_j}{N\langle\eta\rangle}\,.$$

The degree distribution now reads

$$P(k) = \sum_i g(k|\eta_i)\rho(\eta_i)$$

$$= Ak^{-\left(1+\frac{1}{\alpha}\right)}$$

$$\sim k^{-\gamma} \quad \text{with } \gamma = 2.22\,.$$

STRUCTURAL DISASSORTATIVITY

Measuring degree correlations:

$$k_{nn}(k) = 1 + \frac{1}{P(k)}\sum_i g(k|\eta_i)\rho(\eta_i)\sum_j \bar{k}(\eta_j)p(\eta_j|\eta_i) = \frac{\langle k^2\rangle}{\langle k\rangle}\,.$$

Technically uncorrelated because we did not impose degree correlations.

The structural cutoff in simple networks is $k_{sc}(N) \sim (\langle k\rangle N)^{1/2}$ and the cutoff of a scale-free network with $\gamma < 3$ is $k_{max} \sim N^{\frac{1}{\gamma-1}}$, thus

$$\frac{1}{\gamma-1} = \alpha = 0.82 > \frac{1}{2}\,.$$

Because of η_i, our network develops structural disassortativity, similar to the topology observed experimentally in the neocortex.