Characterizing Hierarchical Computation in Primary Visual Cortex (V1)  
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I. Machine learning to predict neural activity

Nonlinear models of [single] V1 neurons

- ULN cascade models like the Nonlinear Input Model (NIM) [2] and others [3-4] can identify many stimulus features that a given neuron is sensitive to.

- ULN cascade can in principle represent any combination of inputs (with enough LN subunits, but...)

- In practice, number of subunits that can be fit is data-limited.

II. Computational Scaffold Network

The “structure” of V1 neuron computation

- Each layer is composed of 3/4 excitatory and 1/4 inhibitory units
- Number of cells (N) = 8

- Example L5/6 neurons

- The “structure” of V1 neuron computation derives from inhibition in deeper layers.

- Putative inhibitory inputs are derived from deeper levels of the scaffold, suggesting it is more computationally complex (and likely not easily captured by simpler models).

- The scaffold network reveals complex structure of V1 neuron computation across nearly all neurons. Such models significantly outperform less complex models.

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- The model predicts a plausible array of size-tuning, which derives from inhibition in deeper layers.

Conclusions

1. Machine learning approaches offer the opportunity to capture nonlinear computations performed by V1 neurons significantly better than current models, but what they produce is difficult to interpret on the level of system-level computation.

2. The computational scaffold network offers a new conception of neural function in the context of hierarchical computation, as an alternative to descriptions based on feature detection.

3. The scaffold network reveals complex structure of V1 neuron computation across nearly all neurons. Such models significantly outperform less complex models.

Properties of [putative] inhibition

- Inhibitory connections from the scaffold to V1 neurons robustly derives from deeper levels, across different scaffold configurations.

- Size tuning

Deep inhibition should have a wider spread, suggesting it could be result in size-tuning. Although this was not experimentally tested, we generated model data for different stimulation apertures at different widths, relative to each cell’s RF location.

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