A computational model of binding by temporal synchrony in visual area V1

The problem

How do neurons in the early visual system group themselves into meaningful perceptual units such as contours, parts, and objects?

Background

Cells in Visual area V1 (primary visual cortex) in the brain are organized into hypercolumns of neurons (Hubel & Wiesel, 1962) that are sensitive to contrasts in conjunctions of properties such as phase (bars vs edges), orientation, opponent color channel.

Neurons in V1 that represent the same contour have been shown to fire in synchrony with each other, and fire in synchrony with neurons that represent different contours (Gray & Singer, 1989). Sine (Edges) Cosine (Bars)

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Hyperscolumns are arranged in a retinotopic hexagonal lattice across the model’s 400 px wide circular visual field. Each hypercolumn contains filter neurons tuned to conjunctions of color channel, phase, scale, and orientation. 3 color channels: red-green, blue-yellow, black-white 3 spatial scales: 16 px, 32 px, 64 px

Lateral timing connections between neurons in the same and adjacent hyperscolumns influence the timing of firing:

- Neurons are likely to be on the same contour have positive timing connections to help them fire together.
- Neurons are unlikely to be on the same contour have negative timing connections to help them fire out of phase.

Neurons near vertices (neuron C) may serve to help them coordinate synchrony at vertices and over longer distances.

Filter neuron response

Input image with parametric primitives

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Conclusions

- Lateral connections in our simulated V1 establish synchrony of firing between nearby neurons on the same contour (neurons A & B) and asymptotically firing between neurons on separate contours (neurons A & D).
- Synchrony between distant neurons along the same contour (neurons A & C) is difficult to establish with only V1 neurons.
- Neurons near vertices (neuron C) fire in a less regular pattern, possibly due to conflicting signals from neighboring neurons.
- Top-down influences from V2 (and higher visual areas) may serve to coordinate synchrony at vertices and over longer distances.

Cross-correlograms

Electrode locations

References


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