

Signatures of signal and noise in a model of PO map formation

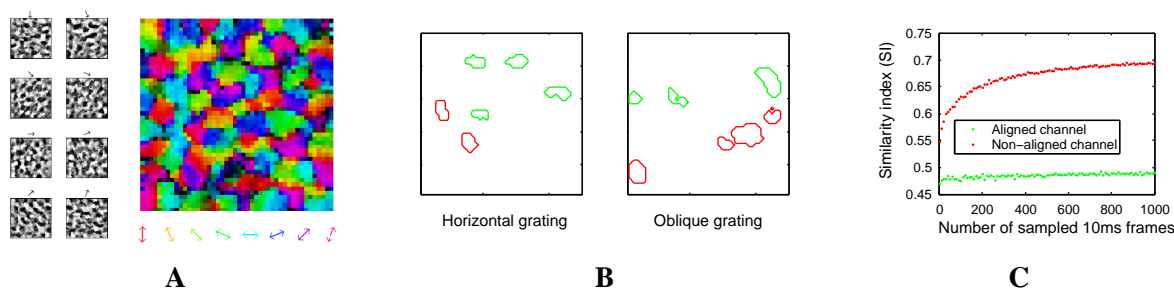
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It has been proposed that early in cortical development, orientation maps emerge from (electrical) pattern formation [1]. To explore this possibility, we have built a large-scale neuromorphic model of early V1 that consists of a two-layer network of recurrently-connected silicon neurons with short-range excitation and long-range inhibition [2]. The neurons in our network receive isotropic afferent inputs. When the recurrent feedback is tuned to be sufficiently strong, bump-like patterns of neural activity form across the network; these bumps, which are seeded by random component heterogeneity, serve as the scaffold of the map (Fig. A). Similar to animal maps, our chip has smoothly changing orientation domains (because the bumps have spatial extent) that repeat at regular intervals (because the bumps are periodic).

Here, we show that the way in which a bump aligns itself to the stimulus (in a 10ms frame) determines whether that bump contributes to robust selectivity. First, we identify a bump (defined as a contiguous region of activity in a frame), and measure its axis of orientation (when fit to an ellipse). Next, bumps are segregated into an aligned channel, which corresponds to bumps that are parallel with the stimulus (Fig. B, green), and a non-aligned channel, which corresponds to all other bumps (Fig. B, red). Finally, we compare the similarity index (SI) between the converged PO map (created from a long experiment) with PO maps created by sampling frames from the aligned channel (Fig. C, green) and the non-aligned channel (Fig. C, red); a SI of 1 indicates the PO maps are identical, whereas a SI of 0.5 indicates random maps.

Our results show that aligned bumps do not contribute to orientation selectivity (noise) while non-aligned bumps provide robust selectivity (signal). We believe this relationship exists because aligned bumps are driven by direct stimulation and are therefore equally active for all orientations (non-selective). Non-aligned bumps, on the other hand, are driven by recurrent interactions, which can be orientation selective due to biases introduced by the network's unique scaffold. We propose that activity imaged from early V1 should be analyzed in a similar manner to determine if electrical pattern formation plays an important role in map development.



A Different gratings elicit different bump patterns, resulting in a PO map. B Aligned (green) and non-aligned (red) bumps in a 10ms frame. C Similarity between map from A and channel-specific maps.

References

- [1] Intracortical origin of visual maps. U. Ernst et al. *Nature Neuroscience*, 4(4):431-436, 2001.
- [2] Dynamic computation in a recurrent network of heterogeneous silicon neurons, P. Merolla and K. Boahen, *IEEE International Symposium on Circuits and Systems*, pp 4539-4542, 2006.