Layer 2/3 Is A Neural Multigrid: Information Maximization In A Local Network Explains V1 Hypercolumn Formation

James Kozloski, Charles C. Peck, Guillermo A. Cecchi, A. Ravishankar Rao

IBM T.J. Watson Research Center, Yorktown Heights,NY 10598

One of the most striking feature of primate V1 is a topographic ordering of receptive fields. Previous models of topographic map formation (e.g., [1]) pose topography as a constraint on receptive-field formation. Optimization techniques maximize information between visual inputs and outputs [2], and produce receptive fields strikingly similar to those in V1, but not topography. Neural network implementations of infomax [3] require fully connected lateral networks, which the cortex does not possess. While the density of lateral connections in layer 2/3 surpasses all other connection classes [4], a local, patchy connectivity pattern is still observed [5]. A model of infomax in 2/3 must therefore explain how this optimization can be implemented in a local network. We hypothesized that topography might emerge naturally from such a model.

Here we present a neural multigrid that approximates infomax in a locally connected network, and embeds optimal receptive fields in a phase-independent topographic map. Our approach allows for a 66% reduction in the density of lateral connections, and yields a network topology similar to that observed in layer 2/3. We conclude that two key features of layer 2/3, 1) local, patchy synaptic connectivity and 2) topography, together serve the same goal: information maximization in a biologically constrained network.

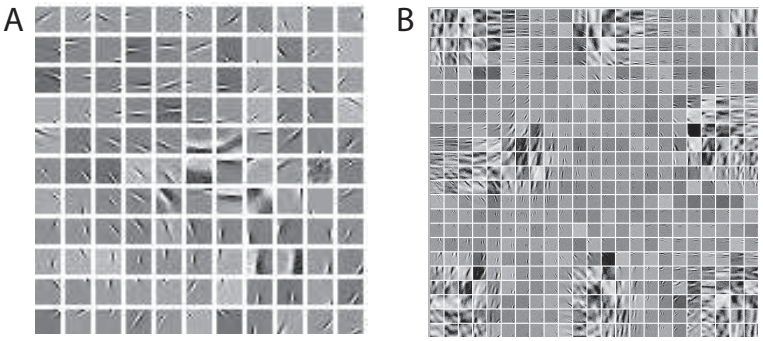

Figure 1: A. Neural multigrid maps optimal filters. B. Local network yields hypercolumns.

Acknowledgments
We thank Ralph Linsker and John Wagner for many helpful discussions.

References

[1] Kohonen, T. (1997), Self-Organizing Maps, Berlin: Springer-Verlag.
[2] Bell, A. J. & Sejnowski, T. J. (1995) "An information-maximisation approach to blind separation and blind deconvolution," Neural Computation, 7:1129-1159.
[3] Linsker, R. (1997) "A local learning rule that enables information maximization for arbitrary input distributions," Neural Computation, 9:1661-1665.
[4] Binzegger T., Douglas R.J. & Martin KA (2004) J. Neurosci. 24(39):8441-8453
[5] Angelucci, A., Levitt, J.B., Walton, E.J.S., Hupe, J.M., Bullier, J. & Lund, J.S. (2002) Circuits for local and global signal integration in primary visual cortex, J. Neurosci. 22 86338646.