Talk 3.6

Representation and Computation in Natural Vision

(NGA NSF 0423031 FY 04)

S. Geman
Brown University

E. Bienenstock
Brown University

M. Paradiso
Brown University

D. Sheinberg
Brown University

Biological vision systems outperform state-of-the-art computer vision systems in almost all vision tasks. At any given detection rate, biological vision systems are far more selective than artificial systems. We are studying the hypothesis that this selectivity can be traced to cortical micro-circuitry, whereby local correlations signal details about the arrangements of perceived parts. There are four principal thrusts to our research effort: (1) Experiments with a computer vision system designed to exploit the hypothesized biological mechanism. A demonstration system for reading Massachusetts license plates performs at a high read rate (>98% of plates read correctly) with no false detections; (2) Experiments with small networks of *nonlinear* integrate-and-fire neurons designed to demonstrate *circumstantial* correlation of activities. Simulated complex cells signal the alignment of their targets through high correlation, and the signal is "read out" through significant increase in firing of postsynaptic neurons; (3) Multi-unit recordings from monkey V1 designed to reveal coding of bar alignments across complex cells. Data is now being collected from a four-electrode multidrive and being analyzed for evidence of the predicted circumstantial correlation; (4) Multi-unit recordings from monkey IT for the purpose of exploring the possible relationships between inter-cellular correlations and perception. Several new statistical techniques have been developed and have revealed highly reliable spike counts following stimulus onset, and some evidence has been found for circumstantial correlation across units.

Publications

1. S. Geman and M. Johnson. Probability and statistics in computational linguistics, a brief
review. In: Mathematical foundations of speech and language processing. Ed. Mark Johnson, Sanjeev Khudanpur, Mari Ostendorf, and Roni Rosenfeld, Springer, New York, 2004, 1-26.

2. S. Geman. Invariance and selectivity in the ventral visual pathway. Submitted.

3. A. Amarasingham, T.-L. Chen, S. Geman, M. Harrison, and D. Sheinberg. Spike count
variability and the Poisson Hypothesis. *Journal of Neuroscience*, January 18, 2006, 26(3):801:809.

4. Y. Jin and S. Geman. Context and hierarchy in a probabilistic image model. Proceedings of the 2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'06).

5. M. Harrison and S. Geman. Compositional feature detectors. Technical Report, Division of
Applied Mathematics, Brown University, 2003.

6. A. Amarasingham, T.-L. Chen, S. Geman and M. Harrison. Notes on a Spike Count Vari-
ability Test. Technical Report, Division of Applied Mathematics, Brown University, 2003.

7. Matthew Harrison and Stuart Geman. An exact jitter method using dynamic programming.
Technical Report, Division of Applied Mathematics, Brown University, 2004.

8. Anderson B, Harrison MT and Sheinberg DL (in press). A Multielectrode Study of IT in the Monkey: Effects of Grouping on Spike Rates and Synchrony. *NeuroReport*.

9. Singer J and Sheinberg DL (in press). Holistic processing unites face parts across time. *Vision Research*.

10. Paradiso MA, Blau S, Huang X, MacEvoy SP, Rossi AF, and Shalev G (in press) Lightness, filling-in, and the fundamental role of context in visual perception. *Progress in BrainResearch*.

11. Wei Wu, Yun Gao, Elie Bienenstock, John P. Donoghue, and Michael J. Black, (2005).
Bayesian Population Decoding of Motor Cortical Activity Using a Kalman Filter. *Neural*
Comp, 18: 80-118.

12. Archibald R, OKeefe T, Bienenstock E, and Sanes JN (2005). Predicting leftward and rightward hand movements with EEG on single-trials. Program No. 401.12. 2005 Abstract
Viewer/Itinerary Planner. Washington, DC: Society for Neuroscience, 2005. Online.

13. Harrison, M., Geman, S., and Bienenstock, E. Using Statistics of Natural Images to Facilitate Automatic Receptive Field Analysis, Division of Applied Mathematics, Technical Report, 2004.

14. Gao, Y., Kontoyiannis, I. and Bienenstock, E., Division of Applied Mathematics, TechnicalReport, 2004.