Weizmann Institute of Science
Dept. of Applied Math and CS

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Tuesdays, 9am, FGS rm. 3

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Features of Visual Representation

1 Purpose of the seminar

Systems of receptive fields (RFs) are probably the most prominent and ubiquitous computational mechanism employed in biological information processing, and, in particular, in vision. A natural question suggested by the hierarchy of RF types found in the visual pathway is, what is it good for? It may seem that the answer is to be found, jointly, in the many models of visual function based on population coding of various stimulus qualities, especially as some of these models draw explicit parallels between the representations they employ and the RFs found in biological vision. However, mere invocation of the idea of population coding, if not accompanied by a computational (in the sense of Marr, 1982) statement of what it is that the visual system does with its representations, simply begs the question:

> At all levels of the visual system, complex objects appear to be coded by the activity of populations, or networks, of cells, and the representation of a particular object may be widely distributed throughout one or more visual areas. That said, the goal of the anatomical pathway for object recognition becomes less obvious. The photoreceptors are a population of cells, for example, and they are necessarily capable of coding, by their population response, any conceivable stimulus. Why are subsequent populations needed? (Desimone and Ungerleider, 1989, p.268).

A number of recent works that do address the computational problem of representation tend to employ information-theoretic terms such as redundancy reduction and efficient coding (Field, 1994; Daugman, 1988; Atick, 1992). This seminar series will survey and compare the different computational characterizations of the features of visual representation, and will discuss the relevance of the proposed approaches to the problem of representing 3D shape.

2 Schedule

1. Feb. 21 introduction: the problem of understanding sensory coding (Barlow, 1979a)
2. Feb. 28 information preservation (Linsker, 1988; Linsker, 1990; Daugman, 1988) [**Yasuto T.**]
3. Mar. 7 reconstructibility (Bialek et al., 1991); the single-neuron doctrine (Barlow, 1972) [**Yuval S.**]
4. Mar. 14 reconstruction (Barlow, 1979b); redundancy reduction (Barlow, 1990) [**Jonathan S.**]
5. Mar. 21 wavelets (Strang, 1989; Simoncelli and Adelson, 1990) [**Uri P.**]
6. Mar. 28 statistics of natural images (Field, 1987; Field, 1994) [**Kalanit G-S.**]
7. Apr. 4 information theory (Atick and Redlich, 1992; Atick, 1992) [**Maxim K.**]
8. Apr. 11 dimensionality reduction (Intrator, 1992; Intrator et al., 1992; Intrator and Gold, 1993) [**Ariel BP.**]
9. Apr. 18 – PASSOVER VACATION –
10. Apr. 25 clustering by distal characteristics (Weiss and Edelman, 1995; Duvdevani-Bar and Edelman, 1995) [**Alexei S.**]
11. May 2 what makes a good feature (Richards and Jepson, 1992; Freeman, 1993) [**Sharon D.**]
12. May 9 faces (Rhodes, 1988; Edelman et al., 1992; Lando and Edelman, 1994) [**Mattew B., Svetlana G.**]
13. May 16 – ARVO –
14. May 23 – ARVO –
15. May 30 plastic features (Richards, 1982; Herrnstein, 1984; Spitzer et al., 1988) [**Yael K.**]
16. June 6 natural 3D shapes (Fujita et al., 1992; Tanaka, 1992; Tanaka, 1993; Kobatake and Tanaka, 1994) [**Alumit I.**]
17. June 13 generalization in feature spaces (Shepard, 1987) [**Ovadya M.**]

3 Prerequisites

Familiarity with the basic concepts and methods of computational vision will be assumed throughout the series. Understanding of the case studies from psychophysics and neurobiology will require, in addition to that, an introductory-level knowledge of the structure and function of the primate visual system.

4 Requirements for credit

The only way to obtain credit for participation in this seminar will be to give a presentation. It will be possible to share some of the assigned topics between several participants, each of whom will be responsible for the presentation of a part of the material. People planning to take the seminar for credit are urged to contact Shimon Edelman[1] to set the date and the topic of their talk.

5 Guidelines

Here is a short collection of guidelines that would help you in preparing a more useful seminar presentation:

- Use transparencies; this will save you lots of handwaving at the blackboard. 25-30 transparencies usually fill an hour.
- Practice on a friend, and time yourself. Pick a friend who has never heard of the topic of your presentation, and see if your message comes across.
- Take your time to explain the authors' motivation and starting assumption.
- Present your critical evaluation of the results and the conclusions (in more than a few sentences).
- Put your topic in a perspective relative to the entire series.

References

Atick, J. J. (1992). Could information theory provide an ecological theory of sensory processing? *Network*, 3:213–251.

Atick, J. J. and Redlich, A. N. (1992). What does the retina know about natural scenes? *Neural Computation*, 4:196–210.

Barlow, H. (1990). Conditions for versatile learning, helmholtz's unconscious inference, and the task of perception. *Vision Research*, 30:1561–1571.

Barlow, H. B. (1972). Single units and sensation: a neuron doctrine for perceptual psychology. *Perception*, 1:371–394.

Barlow, H. B. (1979a). The past, present and future of feature detectors. In Albrecht, D., editor, *Lecture Notes in Biomathematics*, volume 44, pages 4–32. Springer, Berlin.

Barlow, H. B. (1979b). Reconstructing the visual image in space and time. *Nature*, 279:189–190.

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Bialek, W., Rieke, F., de Ruyter Van Steveninck, R. R., and Warland, D. (1991). Reading a neural code. *Science*, 252:1854–1857.

Daugman, J. G. (1988). An information-theoretic view of analog representation in the striate cortex. In Schwartz, E. L., editor, *Computational Neuroscience*, pages 403–423. MIT Press.

Desimone, R. and Ungerleider, L. (1989). Neural mechanisms of visual processing in monkeys. In Boler, F. and Grafman, J., editors, *Handbook of Neuropsychology*, volume 2, pages 267–299. Elsevier, Amsterdam.

Duvdevani-Bar, S. and Edelman, S. (1995). Representation by Chorus of Prototypes. Cs-tr, Weizmann Institute of Science. in preparation.

Edelman, S., Reisfeld, D., and Yeshurun, Y. (1992). Learning to recognize faces from examples. In Sandini, G., editor, *Proc. 2nd European Conf. on Computer Vision, Lecture Notes in Computer Science*, volume 588, pages 787–791. Springer Verlag.

Field, D. J. (1987). Relations between the statistics of natural images and the response properties of cortical cells. *Journal of the Optical Society of America*, A 4:2379–2394.

Field, D. J. (1994). What is the goal of sensory coding? *Neural Computation*, 6:559–601.

Freeman, W. T. (1993). Exploiting the generic view assumption to estimate scene parameters. In *Proceedings of the 3rd International Conference on Computer Vision*, pages 347–356, Washington, DC. IEEE.

Fujita, I., Tanaka, K., Ito, M., and Cheng, K. (1992). Columns for visual features of objects in monkey inferotemporal cortex. *Nature*, 360:343–346.

Herrnstein, R. J. (1984). Objects, categories, and discriminative stimuli. In Roitblat, H. L., Bever, T. G., and Terrace, H. S., editors, *Animal Cognition*, pages 233–261, Hillsdale, NJ. Erlbaum.

Intrator, N. (1992). Feature extraction using an unsupervised neural network. *Neural Computation*, 4:98–107.

Intrator, N. and Gold, J. (1993). Three-dimensional object recognition in gray-level images: the usefulness of distinguishing features. *Neural Computation*, 5:61–74.

Intrator, N., Gold, J. I., Bülthoff, H. H., and Edelman, S. (1992). Three-dimensional object recognition using an unsupervised neural network: understanding the distinguishing features. In Moody, J., Hanson, S. J., and Lippman, R. L., editors, *Neural Information Processing Systems*, volume 4, pages 460–467. Morgan Kaufmann, San Mateo, CA.

Kobatake, E. and Tanaka, K. (1994). Neuronal selectivities to complex object features in the ventral visual pathway of the macaque cerebral cortex. *J. Neurophysiol.*, 71:856–867.

Lando, M. and Edelman, S. (1994). Generalization from a single view in face recognition. submitted.

Linsker, R. (1990). Perceptual neural organization: some approaches based on network models and information theory. *Ann. Rev. Neurosci.*, 13:257–281.

Linsker, R. (March 1988). Self-organization in a perceptual network. *IEEE Computer*, 21:105–117.

Marr, D. (1982). *Vision*. W. H. Freeman, San Francisco, CA.

Rhodes, G. (1988). Looking at faces: first-order and second-order features as determinants of facial appearance. *Perception*, 17:43–63.

Richards, W. (1982). How to play twenty questions with nature and win. A.I. Memo No. 660, Artificial Intelligence Laboratory, Massachusetts Institute of Technology.

Richards, W. and Jepson, A. (1992). What makes a good feature? A.I. Memo No. 1356, Artificial Intelligence Laboratory, Massachusetts Institute of Technology.

Shepard, R. N. (1987). Toward a universal law of generalization for psychological science. *Science*, 237:1317–1323.

Simoncelli, E. P. and Adelson, E. H. (1990). Subband transforms. In Woods, J. W., editor, *Subband image coding*, chapter 4, pages 143–192. Kluwer Academic.

Spitzer, H., Desimone, R., and Moran, J. (1988). Increased attention enhances both behavioral and neuronal performance. *Science*, 240:338–340.

Strang, G. (1989). Wavelets and dilation equations: a brief introduction. *SIAM Review*, 31:614–627.

Tanaka, K. (1992). Inferotemporal cortex and higher visual functions. *Current Opinion in Neurobiology*, 2:502–505.

Tanaka, K. (1993). Column structure of inferotemporal cortex: "visual alphabet" or "differential amplifiers"? In *Proc. IJCNN-93*, Nagoya.

Weiss, Y. and Edelman, S. (1995). Representation of similarity as a goal of early visual processing. *Network*, 6:19–41.