HUMAN VISION PARADOX IMPLICATES RELAXATION MODEL*

LBL-6469

F. S. Montalvo
Computer Science and Applied Mathematics
Lawrence Berkeley Laboratory
Berkeley, California 94720

The dual role of edges as boundaries and as periodic groupings is supported by human experimental findings. A relaxation model (Zucker, et al., 1975) based on line detectors can underlie both mechanisms. The existence of these edge operators (Mubel and Wiesel, 1962) and parallel interactions has strong neurophysiological support.

Edges or discontinuities in intensity play two roles: 1) as outlines of boundaries between regions and 2) as uniform texture within regions. In this context, one can assume an equivalence between texture detection and spatial frequency/orientation operators. Bajcsy (1973), for example, has successfully used measures of spatial frequency and directionality as a concise and complete description of texture. Other approaches to texture segmentation also take into account a dual role for edges. Marr's (1975) terminology for the two ways that lines interact is in *curvilinear and theta aggregations*. Lines grouped into boundaries rely on continuation of contour while lines grouped into uniform texture rely on similarity of orientation and spacing for their enhancement and definition.

In addition to having utility in computer vision there is experimental evidence that human vision uses the dual role of edges in organizing the visual scene. An experiment by Frome and Levinson (1975) produces opposite results depending on whether a subject is asked to adjust the shape or the spacing of a row of squares. The experiment is this. Subjects look at a vertical sine-wave grating for a few minutes. Then they look at a row of squares whose size and spacing (spatial frequency) is somewhat smaller (higher) than the size and spacing (spatial frequency) of the bars in the sine-wave grating. Size (spatial frequency) contrast (Blakemore and Sutton, 1969) predicts that the squares in the row will appear narrower (*higher* in spatial frequency). However when subjects are asked to adjust the height of the row before and after adaptation to make the figures look square, the height is increased after adaptation to compensate for a *wider* (*lower* spatial frequency) appearance. In the same experiment, when subjects are asked to adjust the spacing (spatial frequency), the squares appear more *narrow*ly spaced (*higher* spatial frequency).

How does one resolve the paradox of wider size but higher spatial frequency? One does not have to resort to spatial frequency detectors operating independently of outline continuity detectors preliminary to shape detection. All that is necessary is a distribution of edge operators of various sizes and orientations and relational constraints (in relaxation network terminology) or facilitory connectivity (in neural network terminology) such that segments that line up to form continuous contours facilitate each other and bars of a given width, w, facilitate same-sized, parallel bars at a distance 2w away. After adaptation to a grating the interconnections for that particular spatial frequency and orientation are less strong. Thus, perception of frequencies slightly higher than the adapting frequency will be biased *away* from the adapting frequency, toward even higher frequencies, and vertical contours will be less distinct than horizontal contours. These effects are all in the general class of feature contrast effects modeled by Montalvo (1976). If we assume that less distinct contours appear shorter, as some computational experiments (Zucker, 1975) would indicate, then squares after adaptation to vertical contours should appear squat. Human experimental evidence does show that longer contours are more easily detected (Thomas, 1976). The converse, however, has not yet been verified.

In any case, if we accept such an explanation for the paradox two conclusions important to image processing can be made: 1) the intensity of contours can affect shape qualitatively, and 2) local interactions between edge operators can support two different kinds of global organization simultaneously in the same network.

References

R. Bajcsy, "Computer description of textured surfaces," *Proc. of 3rd IJCAI*, August 1973, 572-579.

C. Blakemore and P. Sutton, "Size adaptation: a new aftereffect," *Science*, 166, 1969 245-247.

F. Frome & J. Z. Levinson, "Shifts in perception of size after adaptation to gratings,11," Paper presented at the 1975 meeting of the Assoc, for Res. in Vis. & Opthal.

D.H. Hubel $ T.N. Wiesel, "Receptive fields, binocular interaction and functional architecture in cat's visual cortex," *J. Physiol*. *160*, 1962, 106-154.

D. Marr, "Analyzing natural images," MIT AI Lab. Memo 334, 1975.

F.S. Montalvo, "Aftereffects, adaptation, and plasticity: a neural model for tunable feature space," Tech. Report 76-4, Camp. 6 Info. Sci. Dept., Univ. of Massachusetts, 1976.

J.P. Thomas, "The one-dimensional nature of spatial summation," The IV Symposium on Sensory Systems Physiology: Info. Proc. in Vision. Pavlov Inst, of Physiol, of the USSR Acad, of Sci., Leningrad, November, 1976.

S.W. Zucker, R.A. Hummel, A. Rosenfeld, "Applications of relaxation labeling, 1: line and curve enhancement," Tech. Report 419, Comp. Sci. Center, Univ. of Maryland, 1975.

---

*Work performed under the auspices of the Energy Research and Development Administration.