FINAL PRODUCTIVITY REPORT

Context-Sensitive Visual Processing: Segmentation and Grouping, Visual Search, and 3-D Surface Perception

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13. ABSTRACT *(Maximum 200 words)*
Psychophysical experiments in visual search, texture segregation, motion segmentation, lightness perception on 3-D surfaces, and the perception of heading have been designed, executed, and analyzed. Data from these experiments and others has been used to refine parameter selection for the Boundary Contour System model of early human vision and its application to image processing. Mingolla has obtained a security clearance and consulted with Dr. Allen Waxman's group at MIT Lincoln Laboratory on night vision and image processing. Mingolla continues to work in modeling (neural architectures for brightness perception, illusory contours, figure/ground segmentation, search for targets in clutter, motion perception) and image processing (segmentation or enhancement of SAR and LADAR imagery).

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Item 1: Overview of Progress

Psychophysical experiments in visual search, texture segregation, motion segmentation, lightness perception on 3-D surfaces, and the perception of heading have been designed, executed, and analyzed. Data from these experiments and others has been used to refine parameter selection for the Boundary Contour System model of early human vision and its application to image processing. Mingolla has obtained a security clearance and consulted with Dr. Allen Waxman's group at MIT Lincoln Laboratory on night vision and image processing. Mingolla continues to work in modeling (neural architectures for brightness perception, illusory contours, figure/ground segmentation, search for targets in clutter, motion perception) and image processing (segmentation or enhancement of SAR and LADAR imagery).

Item 2: Summary of Research Finding: Induced motion and visual stability in an optic flow illusion

Investigators: Christopher Pack and Ennio Mingolla

(a) Description of finding: When an expansion flow field of moving dots is overlapped by planar motion, observers perceive an illusory displacement of the focus of expansion (FOE) in the direction of the planar motion (Duffy & Wurtz, 1993, Vision Research, 33, 1481-1490). The illusion may be a consequence of induced motion, wherein an induced component of motion relative to planar dots is added to the motions of expansion dots to produce the FOE shift. Such a process could be mediated by local, "center-surround" receptive fields. Alternatively, the effect could be due to a higher-level process which detects and subtracts large-field planar motion from the flow field. We probed the mechanisms underlying this illusion by adding varying amounts of rotation to the expansion stimulus, and by varying the speed and size of the planar motion field. The introduction of rotation into the stimulus produces an illusory shift in a direction perpendicular to the planar motion. Larger FOE shifts were perceived for greater speeds and sizes of planar motion fields, although the speed effect saturated at high speeds. While the illusion appears to share a common mechanism with center-surround induced motion, our results also point to involvement of a more global mechanism that subtracts coherent planar motion from the flow field. Such a process might serve as a means of maintaining visual stability during eye movements.

(b) Significance: Besides being important to the fundamental understanding of mechanisms for computing heading and maintaining visual stability during eye movements, an understanding of this illusion may be important in any task involving rapid navigation guided by artificial displays. This illusion is highly "cognitively impenetrable," in the sense that it is experienced even if the observer is aware in advance of the conditions of the display. As a result, it may make an unwelcome appearance in a variety of situations, including the use of "head up" displays, which can superimpose imagery from one modality (e.g. an artificial sensor) with another modality (including a natural view through a windshield). A detailed understanding of the origins of the illusion can aid the design of techniques for mitigating its effects.

(c) Figures: Three color figures on paper and transparencies are attached to this report.

(d) Manuscript: A copy of Pack, C. and Mingolla, E. Induced motion and visual stability in an optic flow illusion. **Technical Report CAS/CNS-97-008**, Department of Cognitive and Neural Systems, Boston University is attached to this report.

Item 3: Productivity Report: April 1, 1994 to June 30, 1997

(a) Published papers:

Grossberg, S., Mingolla, E., and Williamson, J., Synthetic aperture radar processing by a multiple scale neural system for boundary and surface representation. *Neural Networks* (Special Issue on Automatic Target Recognition), 1995, **8**(7/8), 1005-1028.

Gove, A., Grossberg, S., and Mingolla, E., Brightness perception, illusory contours, and corticogeniculate feedback. *Visual Neuroscience*, 1995, **12**, 1027-1052.

Pessoa, L., Mingolla, E., and Neumann, H., A contrast- and luminance-driven multiscale network model of brightness perception. *Vision Research*, 1995, **35**, 2201–2223.

Pessoa, L., Beck, J., and Mingolla, E., Perceived texture segregation in chromatic element-arrangement patterns: High intensity interference. *Vision Research*, 1996, **36**(12), 1745-1760.

Pessoa, L., Mingolla, E., and Arend, L., The perception of lightness in 3-D curved objects. *Perception and Psychophysics*, 1996, **58**(8), 1293-1305.

Grossberg, S., Mingolla, E., and Ross, W.D., Visual brain and visual perception: How does the cortex do perceptual grouping? *Trends in Neurosciences*, 1997, **20**(3), 106-111.

(b) Papers in press:

Bressan, P., Mingolla, E., Spillmann, L., and Watanabe, T., Neon color spreading: A review. *Perception*, in press.

Chey, J., Grossberg, S. and Mingolla, E., Neural dynamics of motion grouping: From aperture ambiguity to object speed and direction. *Journal of the Optical Society of America A*, in press.

Chey, J., Grossberg, S., and Mingolla, E., Neural dynamics of motion processing and speed discrimination. *Vision Research*, in press.

Neumann, H., Pessoa, L., and Mingolla, E., A neural network architecture of brightness perception: Non-linear contrast detection and geometry-driven diffusion. *Image and Vision Computing*, in press.

Ross, W.D. and Mingolla, E., Recent progress modeling neural mechanisms of form and color vision. Invited article for a special issue of the *Journal of Image and Vision Computing*, in press.

(c) Technical reports:

Cunningham, R.K., Beck, J., and Mingolla, E., Approaching visual search in photo-realistic scenes. **CAS/CNS-96-034**. Department of Cognitive and Neural Systems, Boston University.

Oddo, S., Beck, J. and Mingolla, E., Texture segregation in chromatic element-arrangement patterns. **CAS/CNS-97-004**. Department of Cognitive and Neural Systems, Boston University.

Pack, C. and Mingolla, E., Induced motion and visual stability in an optic flow illusion. **CAS/CNS-97-008**. Department of Cognitive and Neural Systems, Boston University.

Lidén, L. and Mingolla, E. Monocular occlusion cues alter the influence of terminator motion in the barber pole phenomenon. **CAS/CNS-97-012.** Department of Cognitive and Neural Systems, Boston University.

Grossberg, S., Mingolla, E., and Pack, C., A neural model of attentive visual navigation by cortical area MST: Heading and time-to-contact. **CAS/CNS-97-15**. Department of Cognitive and Neural Systems, Boston University.

(d) Book chapters published:

Grossberg, S., Mingolla, E., and Williamson, J., A multiple scale neural system for boundary and surface representation of SAR data. In **Proceedings of the IEEE workshop on neural networks for signal processing**, New York, 1995.

Lesher, G.W. and Mingolla, E., Neural models of illusory contour perception. In M.A. Arbib (Ed.), **Handbook of brain theory and neural networks**. Cambridge, MA: MIT Press, 1995, pp. 481-483.

Mingolla, E., Neural mechanisms of brightness perception and visual search. Invited article in **Proceedings of the world congress on neural networks**, Washington, **2**, 901–904. Hillsdale, NJ: Erlbaum Associates, 1995.

(e) Book chapters in press:

None.

(f) Patent activity:

None.

(g) Presentations:

Categorical behavior without symbolic processing in brightness perception. Presentation at the Second Annual Symposium in Honor of Gaetano Kanizsa, Trieste, Italy, October, 1994.

A multiscale network model of brightness perception. Invited lecture at the International School in Biocybernetics of Vision: Integrative Mechanisms and Cognitive Processes, Ischia, Italy, October, 1994.

Recent results in emergent visual segmentation. Invited lecture at the International School in Biocybernetics of Vision: Integrative Mechanisms and Cognitive Processes, Ischia, Italy, October, 1994.

Categorical behavior in brightness perception. Colloquium presented at the Harvard University Department of Psychology, November, 1994.

Searching for the units of visual search. Colloquium presented at the Istituto de Neurofisiologia, CNR, Pisa, Italy, June, 1995.

Neural mechanisms of brightness perception and visual search. Invited presentation to the World Congress on Neural Networks, Washington, DC, July, 1995.

Grouping effects in double target search (with William D. Ross and Norma Mejia-Monasterio). European Conference on Visual Perception, Tubingen, Germany, August, 1995.

Brightness perception, illusory contours, and binocular corticogeniculate feedback. Colloquium presented at the Fakultaet fur Informatik, Universitaet Ulm, Germany, August, 1995.

A multiple scale neural system for boundary and surface representation of SAR data (with S. Grossberg and J. Williamson). Presentation at the IEEE Workshop on Neural Networks for Signal Processing (NNSP), Cambridge, Massachusetts, September, 1995.

A cortical architecture for real and illusory contour processing in Areas V1 and V2 (with S. Grossberg and W.D. Ross). Presentation at the annual meeting of the Society for Neuroscience, San Diego, California, November, 1995.

Recent results in early visual processing. Invited presentation at the International Workshop on Soft Computing in Industry, Muroran, Hokkaido, Japan, April, 1996.

Discussant for session on Lightness and Shading at the Fifth Hans-Lukas Teuber Symposium, MIT, Cambridge, Massachusetts, October, 1996.

Neural circuits for perceptual grouping. Colloquium presented to the Ohio State University Psychology Department, March, 1997.

Visual search. Invited presentation to the International Conference on Vision, Recognition, and Action: Neural Models of Mind and Machine, Boston, MA, May, 1997.

Perceptual grouping. Invited presentation to Cambridge Basic Research, Cambridge, MA, July, 1997.

(i) Transitions:

Transition 1: Pacific Sierra Research has developed Forward Looking Infrared Radar (FLIR) Minimal Temperature Resolvable Difference (MRTD) evaluation software based in part on the PI's prior work. The aim of the software is to emulate human perceptual responses to low-fidelity FLIR imagery, in order to automate FLIR calibration. In Phase I of an SBIR contract to the Army Test Center at Huntsville, success rates in classifying prototype targets as detectable or not by human operators ranged from 96% to 100%, as described in:

> Burroughs, E.E. Jr., Moe, G.O., Lesher, G.W., and Merrill, J.W.L., Automated MRTD using boundary contour system, custom feature extractors, and fuzzy ARTMAP. Presented at the 17-21 April, 1995, AeroSense Conference of the SPIE, Orlando, Florida.

Point of contact:	Gordon Moe
	Pacific Sierra Research Corporation, Arlington, VA
Phone:	703-527-4975

Transition 2: The PI has obtained a security clearance and begun consulting with Dr. Allen Waxman's group at the MIT Lincoln Laboratory on night vision and image processing. Dr. Waxman's group has implemented a number of neurally-inspired algorithms based on the PI's modeling work with Stephen Grossberg on image segmentation and surface representation. The PI has made several visits to Dr. Waxman's lab to discuss algorithms and parameter adjustments for processing night vision imagery, SAR, and infrared imagery. Dr. Waxman's group continues to use/extend the PI's work for (1) multiresolution speckle reduction in SAR imagery; (2) off-system (darkness) processing for shadow noise cleaning in SAR imagery; and (3) opponent-color processing of multispectral (three bands) IR imagery for target enhancement in industrial/urban environments. Items (1) and (2) are for an Air Force sponsor; item (3) is supported by ONR.

Point of contact:	Dr. Allen Waxman
	MIT Lincoln Laboratory, Lexington, MA
Phone:	617-981-2056

Transition 3: The PI was also PI of a Navy-sponsored subcontract to Boston University from HNC, Inc., to develop improved segmentation algorithms for LADAR image segmentation for automatic target classification. Improvements in edge localization, grouping

across incomplete data, and speed-up of image processing algorithms are being developed at Boston University for transition to the Navy via HNC.

Point of contact:	Dr. Robert Hecht-Nielsen
	HNC Software, Inc., San Diego, CA
Phone:	619-546-8874

(j) Training:

Robert Cunningham	doctoral student	U.S. Citizen
Matthew Giamporcaro	doctoral student	U.S. Citizen
Allen Gove	doctoral student	U.S. Citizen
Seungwoo Hwang	doctoral student	not U.S. Citizen
Lars Liden	doctoral student	U.S. Citizen
Christopher Pack	doctoral student	U.S. Citizen
Luiz Pessoa	doctoral student	not U.S. Citizen
Harald Ruda	doctoral student	not U.S. Citizen

(k) Honors:

Invited to join the editorial board of *Applied Intelligence*, 1996.

(l) Equipment purchased (Year 1):

One Macintosh Powerbook 540C, including 16 megabyte memory upgrade and bundled software. Cost: $6948.