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NASA-Ames/Stanford Center of Excellence
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Progress Report
12/1/93-11/30/94

Brian A. Wandell (Principal Investigator)
Psychology Department, Stanford University
Stanford, California 94305-2130

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(NASA-CR-194329) [OVERVIEW OF RESEARCH IN PROGRESS AT THE CENTER OF EXCELLENCE] Progress Report, 1 Dec. 1993 - 30 Nov. 1994 (Stanford Univ.) 20 p

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Introduction

The Center of Excellence (COE) was created nine years ago to facilitate active collaboration between the scientists at Ames Research Center and the Stanford Psychology Department. Significant interchange of ideas and personnel continues between Stanford and participating groups at NASA-Ames; the COE serves its function well.

The COE continues to foster an exchange of ideas and technology between research scientists at Ames Research Center and Stanford. Dr. Mosier has completed her work through the Center organization but will continue to work as a scientist at Ames. Dr. Heeger, who was a research scientist at Ames Research Center will continue to participate in the Center as a member of the Stanford faculty.

A new postdoctoral student, Dr. Beutter, support by the Center, is working in Dr. Stone's Laboratory at ARC. Although Dr. Perrone has taken a tenure-track position at the University of Waikato and is no longer directly supported by the Center, he will continue to collaborate actively with Dr. Stone and Dr. Beutter in their Center activities.

This progress report is organized into sections divided by project. Each section contains a list of investigators, a background statement, progress report, and a proposal for work during the coming year.

As in previous years, apart from the project-specific funding requests, there are some funding needs that are common to all of the Stanford projects. The main expense in this area is support for a fraction of Ms. Ruby's salary to serve as a coordinator and administrator of the Center's activities.

We are grateful for the research support this grant offers us at Stanford. Funds from the Center grant have been extremely helpful in supporting a number of projects over the last nine years. As a glance at the budget will show, funding for Center projects at Stanford only supports a fraction of the true costs of most of our research projects. These projects also depend on support derived from other sources, including corporate and other governmental sponsors. We selected the on-campus research projects in this proposal, by identifying those projects that are closely connected to the research mission of our colleagues at Ames Research Center. Not all of these projects are directly funded by this grant; but all of the projects do rely on the computational and administrative infrastructure the grant provides.

1 Algorithms for development and calibration of visual systems

The investigators on this section are A. Ahumada and A. Tabernero.

1.1 Background

Unlike geometrically precise and relatively stable sensors on chips, the human retina provides an irregular and unstable input system that must be calibrated by the visual system. We are developing models for the calibration process with the goal of understanding the human visual system development and function and the goal of providing this self-calibration property to remote systems suffering degradation in space.

1.2 Progress

We have been studying the properties of algorithms for the development/calibration of the simple cells of the visual cortex. Others have claimed that the cells can arise from a "clean slate" by purely associative learning principles. We have shown that the irregular sampling of the retina prevents such models from working alone, but shows that in combination with simple prewiring and translation-invariance learning, associative learning models can then construct units with cortex-like receptive fields.

1.3 Proposed Work

During the next year we plan to focus on the two features of the cortical cell calibration algorithm that have little biological plausibility. We plan to try to replace the competitive algorithm of Sanger with the anti-Hebbian competitive algorithm of Barlow and Foldiak, which uses symmetric inhibitory connections among output units instead of assuming all the units are in a linear hierarchy in which each unit inhibits all the units below it. Also, in previous work, we have assumed that the inputs to receptive fields wrapped around, so that we could ignore the effects of receptive field edges. Preliminary work in one dimension shows that frequency localization is not ensured by anti-Hebbian competition unless there is size variation in the windows of competing units. In this case the small units select high spatial frequencies and conversely. We plan to extend these investigations to the two dimensional case.

1.4 Section References

1. A. J. Ahumada, Jr., A. Tabernero, "Development of a translation-invariant image representation", OSA Annual Meeting Technical Digest, Vol. 23, Optical Society of America, Washington, D.C., pp. 130-131, 1992.

2. A. J. Ahumada, Jr., A. Tabernero, "Developing a translation-invariant cortex transformation from an irregular retina", Investigative Ophthalmology and Visual Science, Vol. 34, No. 4 (ARVO Suppl.), p. 707, 1993.

2 Visually optimized image compression

The investigators on this section are A. Ahumada and A. Watson.

2.1 Background

Image compression has many applications in aeronautics and space. The JPEG standard has made DCT image compression the most popular choice for lossy compression. We have been developing methods for minimizing the visibility of DCT artifacts. The loss of the Galileo probe main antenna has led to the decision to use DCT image compression to increase the number of pictures that will be returned.

2.2 Progress

A general method has been developed for keeping DCT quantization errors below visible thresholds, based on models of human thresholds and the display viewing parameters. It also allows the matrices to be customized for the color space in which the images are compressed. A method has also been developed to optimize the quantization matrix for a particular image. Using this method, matrices were found for particular examples of simulated Galileo imagery and different levels of compression. Assembly language routines for the Galileo's RCA1802 processor were developed to allow for a large number of quantization matrices to be used if necessary.

2.3 Proposed Work

We have begun work on developing methods to reduce the DCT quantization artifacts after the images come back. We have found methods that can improve originally smooth images, and we are trying to improve them so that they work with simulated Galileo imagery and with the quantization matrices that will be used.

2.4 Section References

1. A. J. Ahumada, Jr., H. A. Peterson, "Luminance-Model-Based DCT Quantization for Color Image Compression", B. E. Rogowitz, J. P. Allebach, and S. A. Klein, editors, Human Vision, Visual Processing, and Digital Display III, Proc. 1666, SPIE, Bellingham, WA, pp. 365-374, 1992.

2. A. J. Ahumada, Jr., "Computational Image Quality Metrics: A Review", in J. Morreale, ed., Society for Information Display International Symposium Digest of Technical Papers, Volume 24, SID, Playa del Rey, CA 1993.

3. H. A. Peterson, A. J. Ahumada, Jr., and A. B. Watson, "The Visibility of DCT Quantization Noise", in J. Morreale, ed., Society for Information Display International Symposium Digest of Technical Papers, Volume 24, SID, Playa del Rey, CA 1993.

3 Evaluation of advanced piloting displays

The investigators for this section are A. Ahumada, A. Watson, D. Heeger, C. Null.

3.1 Background

The development of advanced displays for all-weather and window-less aircraft is a high priority of the NASA aeronautics program. This development needs computational evaluation to allow more alternatives to be considered.

3.2 Progress

Review papers were written on the extraction of multiple dimensions from quality assessment data and the types of metrics that have been developed for image compression and halftoning.

3.3 Proposed Work

Work will begin on the development and validation of image quality metrics that can evaluate the ability of displays to communicate the presence of obstructions and the ability to provide pilots with the motion cues necessary for situational awareness.

3.4 Section References

1. R. A. Martin, A. J. Ahumada, Jr., J. O. Larimer, "Color matrix display simulation based upon luminance and chromatic contrast sensitivity of early vision", B. E. Rogowitz, J. P. Allebach, and S. A. Klein, editors, Human Vision, Visual Processing, and Digital Display III, Proc. 1666, SPIE, Bellingham, WA, pp. 336-342, 1992.

2. J. B. Mulligan, A. J. Ahumada, Jr., "Principled Halftoning Based on Models of Human Vision", B. E. Rogowitz, J. P. Allebach, and S. A. Klein, editors, Human Vision, Visual Processing, and Digital Display III, Proc. 1666, SPIE, Bellingham, WA, pp. 109-121, 1992.

3. D. C. Foyle, A. J. Ahumada, J. Larimer, B. T. Sweet, "Enhanced/Synthetic Vision System: Human Factors Research and Implications for Future Systems", Enhanced Situation Awareness for Retrofit and Advanced Cockpit Design, SP-933, SAE, 1992.

4 Spectral Representations of Color

The investigators for this section are B. Wandell, H. Zabrodsky (Stanford), D. Marimont (Xerox Palo Alto Research Center), J. Farrell (Hewlett-Packard Laboratories), and A. Ahumada (NASA-Ames Research Center).

4.1 Background

We have been exploring a novel approach to color by trying to understand and control the information acquired and displayed by devices, and the visual pathways acquired and interpreted by the visual pathways, in terms of the spectral properties of surfaces and illuminants. Our approach differs from the classic approach within color science in which all concepts are formulated in terms of the photopigment absorptions in the human eye.

Our research includes computational and psychophysical experiments. One group of experiments has been devoted to calibrating modern color devices such as scanners and printers. These devices are part of an information management system. A second group of experiments is aimed at analyzing the factors that control color appearance in human observers. Since our studies are all based on a consideration of the spectral properties of devices and observers, we have been able to track the information flow between devices and observers as a unified system.

A list of papers supported by the grant that illustrate our approach is included the reference section.

4.2 Progress Report

Marimont and Wandell completed two papers this year. One appeared in the *J. Optical Society* summarizing their work on efficient representations of surface and illuminant functions. A second is under review at the *J. Optical Society* on the topic of axial chromatic aberration in the human eye.

Poirson and Wandell completed a paper on how color appearance depends on spatial pattern. The paper is due to be published in the December issue of the *J. Optical Society.*

Chichilnisky and Wandell completed a paper on the effects of large field adaptation on the gain of the photoreceptors. The paper was accepted by *Vision Research* and will appear next year.

Farrell and Wandell completed a conference paper and a journal paper on the properties of color scanners.

Finally, Brainard, Wandell and Chichilnisky completed an invited review on the topic of spectral representations for the journal *Current Directions in Psychological Science.*

4.3 Proposed Work

Color appearance depends strongly on the spatial pattern of the object. Patterns at high spatial frequencies appear desaturated. We only experience saturated colors in response to low frequency stimulation.

To predict the color appearance of a point in an image requires, then, that we understand the relationship between the spatial pattern and color appearance. A significant amount of the change in color appearance of a pattern is due to *axial chromatic aberration.* Axial chromatic aberration is the wavelength dependent optical defocus.

This year we will carry out computational and psychophysical experiments to evaluate the influence of pattern effects on natural images. We plan to integrate our basic results on chromatic aberration and color appearance into software for display applications. Specifically, we will be working on halftoning color images and resizing monitor windows.

We will implement methods for creating halftoned color images that minimize a new group of color metrics. The color metrics will be designed to include the color differences that take into account the substantial effects of chromatic aberration and spatial pattern selectivity of the human color mechanisms. We are in a good position to develop these metrics based on the experimental measurements and computational experiments we have performed over the last several years.

We plan to move our calculations from simple patterned gratings into predictions based on natural images. Our experiments in this area will serve two purposes. First, our measurements and application software will be a resource for organizations who need assistance in developing color management tools, including industry and government. Second, our attempts at building demonstrations will clarify the directons we should pursue in the next round of basic research we carry out.

These experiments will be carried out partly at Stanford and partly at Hewlett-Packard Laboratories. Our colleagues at Hewlett-Packard are designing a new experimental apparatus for evaluating halftone images. We request support for one post-doctoral fellow to help us implement the software and carry out the computational and psychophysical experiments. We anticipate that she will spend 20% of her time on campus and 80% of her time at Ames Research Center and with our industrial partners.

4.4 Section References

1. D. Brainard, B. Wandell, and E. Chichilnisky. Color constancy: From physics to appearance. *Current Directions in Psychological Science*, 1993 (in press).
2. J. Farrell, J. Meyer, R. Motta, B. Wandell, and E. Chichilnisky. Sources of scanner calibration errors. In *IS&T's Eight International Congress on on Advances in Non-impact Printing Technologies*, 1992.
3. J. E. Farrell and B. A. Wandell. Scanner linearity. *Journal of Electronic Imaging*, 2(3):225–230, 1993.
4. D. Marimont and B. Wandell. Linear models of surface and illuminant spectra. *J. Opt. Soc. Am. A*, 11:1905–1913, 1992.
5. A. B. Poirson and B. A. Wandell. The appearance of colored patterns: pattern-color separability. *J. Opt. Soc. Am. A*, page in press, Nov., 1993.
6. B. Wandell. Color appearance: The effects of illumination and spatial resolution. *Proc. Nat. Acad. Sci.*, November, 1993.

5 Perception of Motion in Man and Machine

The investigators in this section are D. Heeger and D. Hoffman.

5.1 Background

We have been pursuing two goals in our study of visual motion perception. The first goal is to develop computer programs for analyzing motion in image sequences. The second is to develop models of the biological mechanisms for motion processing.

As we move and explore the environment, the visual stimulation in our eyes is constantly changing. Somehow we are able to perceive the spatial layout of the scene and to discern our movement through space. It is well-known, from both psychophysical and neurophysiological experiments, that the visual system has mechanisms that are specifically suited for analyzing motion, and that human observers are capable of recovering accurate information about the world (e.g., three-dimensional trajectory, relative distance, shape) from motion in images.

Pilots obviously depend on these abilities (for example when landing aircraft), so an understanding of visual motion perception is of great interest. In addition, a machine vision system capable of motion perception, a "smart camera" that senses motion and depth, would be extremely useful. For example, such a machine vision system could warn pilots about the presence of obstacles (e.g., during nap-of-earth flight), or warn them about other moving objects. Ultimately, motion perception by machine vision will be an important component of fully autonomous navigation systems, e.g., for autonomous flight, for mobile robots like the proposed Mars rover, and for undersea robotic exploration.

5.2 Progress

A paper by Heeger (in press, *J. of Neurophysiology*) presents a model that explains the motion selective responses of neurons in the primary visual cortex (V1) of the brain.

A review paper by Heeger, on the behavioral consequences of the response properties of these V1 neurons, has been submitted to the journal *Current Directions in Psychological Science.*

A paper by E. Simoncelli (Univ. of Penn.) and D. Heeger was presented at the Assoc. for Research on Vision and Ophthalmology Annual Meeting. The paper describes a computational model for human motion perception that accounts for a variety of behavioral data. In particular, the model provides a good fit to measurements of the perceived speed and direction of moving texture patterns, and the model is consistent with human motion transparency phenomena.

5.3 Proposed Work

In the primate brain, there is a well-defined anatomical pathway that appears to be specialized for visual motion analysis. The first stage in this motion pathway involves a subset of the neurons in V1. Information passes from there to visual area MT, where nearly all of the neurons are selectively responsive to moving stimuli. We have started developing a computational model of the response properties of MT neurons. Although this work is just beginning, we have already succeeded in simulating a number of published physiological results. More importantly, our theoretical work has given rise to several testable predictions. We plan to complete the development of this MT model and use it to fit data on MT cell responses. We also plan to combine this physiological model with the psychophysical/behavioral model (above) to yield a single unified model for human velocity perception.

Our model of the early stages of human motion perception makes several specific (as yet untested) predictions about how people should judge the contrast and the velocity of a moving pattern. For example, the model predicts that the perceived contrast and perceived speed of a texture patch should depend (in a particular way) on the contrast of the background. We are planning an extensive series of behavioral experiments to test these predictions.

Finally, we are beginning to develop a machine vision system for autonomous (and semi-autonomous) mobile robotics. The primary operational requirements of this vision system are that it: (1) construct and maintain a free-space map for safe vehicle motion through its environment, (2) detect and track other moving objects, and (3) operate sufficiently rapidly. We plan to begin this project this year. Our first goal will be to develop a robust computer system that precisely and accurately tracks the motion of an object (or feature) in a video image sequence. We are in a good position to succeed in this effort based on our experience over the last several years developing motion analysis algorithms.

5.4 Section References

1. M Carandini and D J Heeger. Normalization with shunting inhibition explains simple cell response phase and integration time. *Inv Opthal. and Vis. Sci.*, 34:907, 1993.

2. M Carandini, D J Heeger, and J A Movshon. Amplitude and phase of contrast responses in lgn and v1. *Soc. Neurosic. Abstr., part I*, 19:628, 1993.

3. M Carandini, D J Heeger, and J A Movshon. Contrast and the temporal properties of the responses of lgn and v1 neurons. *Perception (supplement)*, 22:43, 1993.

4. D J Heeger. Modeling simple cell direction selectivity with normalized, half-squared, linear operators. *Journal of Neurophysiology*, in press, 1993.

5. D J Heeger. The representation of visual stimuli in primary visual cortex. *Current Directions in Psychological Science*, submitted, 1994.

6. E P Simoncelli and D J Heeger. A computational model for representation of image velocities. *Inv Opthal. and Vis. Sci.*, 34:975, 1993.

6 Automation and Decision Making

The investigator in this section is K. Mosier.

6.1 Background

Crew performance, decision making, and interaction with automation have been the topics of Mosier's research during the past year. One of the goals of the NASA Strategic Behavior/Workload Management Program was to develop standardized procedures for constructing Figures of Merit (FOMs) that describe minimal criteria for flight task performance, as well as summarize overall performance quality. Such a measure could be utilized for evaluating flight crew performance, for assessing the effectiveness of new equipment or technological innovations (e.g., TCAS or Datalink), or for measuring performance at a particular airport.

6.2 Progress

As part of the requirements of this program, Dr. Mosier (together with Dr. Greg Zacharias of Charles River Analytics) did an in-depth analysis of two of the flight crews from a previously conducted simulator study. The objective was to demonstrate a methodology for creating performance Figures of Merit. The analysis included a detailed time line of activities, accompanied by subjective workload ratings and aircraft parameter data. Results of this analysis were presented at the biannual Symposium on Aviation Psychology. The methodology is currently being expanded and applied to an ongoing simulator study, and utilized to evaluate crew problem-solving and decision-making strategies, as well as other aspects of performance.

Dr. Mosier was also involved this past year in a project to design a decision-making training module for Trans World Airlines. Dr. Mosier worked with the TWA training department to construct a course that would reflect current thinking in decision making strategies in naturalistic environments.

Dr. Mosier's current work is concerned with the interaction of air crews with automated decision aids. We have begun a program of research to investigate the tendency to rely heavily - almost blindly - on these aids, and to comply with their demands even in the face of contradictory evidence from other system indicators. She is beginning this effort by identifying the conditions under which this "automation bias" is likely to occur, and ways of counteracting it.

6.3 Section References

1. Mosier, K., & Zacharias, G. Flight Performance Measurement Utilizing a Figure of Merit (FOM). Proceedings of the 1993 International Symposium of Aviation Psychology.

2. Chaired panel discussion at the 37th Annual Meeting of the Human Factors and Ergonomics Society: Resource Management in the Highly Automated Airspace System. Scheduled panel members included Earl Wiener (Univ. of Miami), Bob Helmreich (NASA/UT), Vic Riley (Honeywell), and Alan Price (Delta). Presented in panel: Who (or What) Is Doing the Managing in Resource Management?

3. Presented to FLT/FLR with Dr. Linda Skitka, Southern Illinois University at Edwardsville, Oct. 19: Automated Decision Aids and Accountability for Decisions.

4. September 20-23. Briefed Paul Schutte, NASA Langley, on proposed research for NASA HSR program. With other Ames researchers, met with Paul, Susan Infield (Boeing), and Jack Dwyer (Douglas) to discuss high-speed research agenda.

5. January 8, 1993. Briefed P-3 Squadron VP-39 at Moffett on Crew Resource Management: Evolution and New Directions, addressing the evolution of the concept, present applications in industry, and future issues and trends. (with Jay Shively).

7 Motion Information Used For Navigation and Control

The investigators for this section are L. Stone, B. Beutter and J. Perrone.

7.1 Background

The importance of vision in vehicle control is well established. What is not so clear is how the visual information required to control a moving car, spacecraft or aircraft is extracted and processed by the human brain. Last year, Dr. Perrone, then supported by the Center, proposed a new approach to solving this problem (Perrone, 1992). His model of human self-motion perception was designed to explain human performance in self-motion tasks while using the design principles of primate visual cortex.

7.2 Progress

Self-Motion Modeling. This year, Drs. Stone and Perrone have extended the model to extract relative depth information as well as self-motion parameters (heading and rotation). They have shown that this new algorithm can extract relative depth maps from flow-field information using only those signals known to exist in the primate brain (Perrone and Stone, 1992a). Because humans stabilize their eyes as they move through their environment, they refined the model so that its performance is tuned to those flow fields generated under such real-world conditions (Perrone and Stone, 1992b, Stone and Perrone, 1994). Finally, Stone and Perrone have also performed a number of psychophysical experiments to test the model. They have demonstrated that the dominant model in the field (Rieger and Lawton, 1985) cannot explain human performance while their refined model does indeed do so over a wide range of conditions (Stone and Perrone, 1993; Perrone and Stone, 1994). In addition to these results, they have continued their interaction with neurophysiologists at the Laboratory of Sensorimotor Research at NIH. They now have preliminary physiological recordings in MST that directly support their model (Duffy and Wurtz, 1993).

MT modeling. The present version of our self-motion model uses theoretical MT neurons as their input. In an effort to extend the model to include lower level inputs, Dr. Perrone has developed a model of the projection from V1 to MT. Simulations of his algorithm show that the model is able to mimic the direction and speed tuning properties of real MT neurons using combinations of neurons known to exist in V1 (Perrone, 1994).

Dr. Beutter, who spent his first few months at ARC setting up a human psychophysics lab, has begun a study of how well humans can estimate 2-D motion. Given that this estimation process is thought to be performed by the V1-MT pathway, his results should provide constraints and/or validation for the modeling efforts. In particular, he has recently found, in collaboration with Dr. Jeffrey Mulligan of ARC, that the final estimation of direction is influenced by the shape of the viewing window (Beutter et al., 1994). This exciting new result shows that models that do not explicitly consider the integration of velocity information across space cannot explain human motion perception.

7.3 Proposed Work

Extending the human self-motion model. Stone and Beutter will combine the the V1-MT and MT-MST models into a single more complete model of the motion processing pathways in the primate brain that are thought to underly self-motion perception.

They will continue the psychophysical validation process by examining the effect of the translation and rotation rates on the accuracy of human performance in heading judgment tasks. It is critical to determine the limits of human ability in these tasks, as it has become clear that under some circumstances humans are unable to extract accurate heading from visual information alone (Royden et al., 1992).

In collaboration with Dr. Richard Krauzlis of the National Eye Institute at NIH, they will extend his model of pursuit eye movements to include a more biologically realistic visual *front-end*. They will then examine whether or not this new combined model can better explain human eye movements.

V1-MT modeling. Stone and Beutter will examine the human ability to extract accurate estimates of 2D velocity and measure how well humans can determine both the speed and direction of motion of both single gratings and plaids composed of several gratings, this will help us to understand how the lower-level motion information available in V1 is further processed in MT to generate a final 2D motion percept. These results will be used to evaluate the V1-MT model.

In these pyschophysical experiments, Stone and Beutter will also simultaneously record the eye- movements generated by the visual stimuli which will allow them to examine the relationship between eye movements and motion perception. Furthermore, the eye-movement measurements will be used to evaluate the pursuit model.

7.4 Section References

1. Perrone, J.A. Model for the computation of self-motion in biological systems, JOSA A, 9: 177-194 (1992).

2. Perrone, J.A. and Stone, L.S. A possible role for the speed tuning properties of MT cells in the recovery of depth from motion, Invst. Opthalmol. & Vis. Sci. 33 : 1141 (1992a)

3. Perrone, J.A. and Stone, L.S. Using the properites of MT neurons for self-motion estimation in the presence of eye-movements, Perception 21 (Suppl 2) : 64

(1992b)

4. Perrone, J.A. and Stone, L.S. A model of self-motion estimation within primate extrastriate visual cortex, submitted to Vis. Res. (1994)
5. Rieger J.H. and Lawton D.T., Processing differential image motion, JOSA A 2: 354-360 (1985)
6. Perrone, J.A. and Stone, L.S. Human heading perception cannot be explained using a local differential motion algorithm, Invst. Opthalmol. & Vis. Sci. 34 : 1229 (1993)
7. Duffy, C.J. and Wurtz, R.H. Soc. for Neurosci. abstr. In press (1993)
8. Perrone, J.A. Simulating the speed and direction tuning of MT neurons using spatio temporal tuned V1-neuron inputs submitted to Invst. Opthalmol. & Vis. Sci. 35 (1994)
9. Beutter, B.R., Stone, L.S., and Mulligan, J.B. The Barber-Plaid Illusion, submitted to Invst. Opthalmol. & Vis. Sci. 35 (1994)
10. Royden C.S., Banks, M.S., and Crowell, J.A. The perception of heading during eye movements, Nature 360: 583-585 (1992)

Budget Justification

We have divided the budget into two components, following the precedent in previous submissions. One reflects research done at Stanford and the second research being carried at out Ames Research Center.

On-Campus: Personnel

Our request for on-campus activities includes the following.

First, Ms. Ruby serves as principal administrator for the grant. Over the last nine years, she has spent a considerable amount of her time preparing budgets and overseeing the paper work involved in arranging staff appointments, travel reimbursements, and other administrative duties. She has been an extreme able administrator, highly regarded by those at Stanford and Ames Research Center. In addition, she is now quite expert in handling the COE administrative requirements. We request funds to pay fifteen percent of her salary.

Second, we are requesting funds for twenty percent time post-doctoral fellow to assist in the work on spectral representations of color. We hope to be able to hire Dr. Hagit

Zabrodsky, an expert in computational vision and color. Dr. Zabrodksy recently received her Ph.D. from the Hebrew University in Jerusalem. Dr. Zabrodsky will spend eighty percent of her time working at Ames Research Center.

Third, David Hoffman is a Ph.D. graduate student in the Computer Science Department at Stanford, working with Prof. Heeger to develop a computer system fortracking motion in video image sequences. Most of Hoffman's funding is provided by a fellowship from the Hertz Foundation. We are requesting funds to cover the remaining fraction of his tuition for the academic year.

On Campus: Other Expenses

We request 500 dollars to defray the charges for phones, postage and photocopying during the year. We are also requesting a fifteen percent RAship for David Hoffman during the summer quarter.

On Campus: Travel

We request travel funds to cover airfare for one trip for Dr. Zabrodsky to the annual vision meeting (ARVO) that takes place in Sarasota, Florida.

Off-Campus: Personnel

The main portion of the off-campus budget supports the 80% salary for Dr. Zabrodsky who will be working both at Stanford and at Ames Research Center. Money to cover hourly graduate students to work with Dr. Ahumada and Dr. Watson is requested. Dr. Beutter is listed, as well, but no additional funds are requested. We have adequate funds to pay his salary until May 1994, at which time we expect he will be paid directly from funds at Ames Research Center.

Off Campus: Travel

We request funds for Beutter and Zabrodsky to travel to the ARVO meetings in Sarasota, Florida.

Off Campus: Other Expenses

We request five hundred dollars to support miscellaneous costs for telephone, postage, mailing, journal reprints, and other related costs for all members of the Center. Minor charges for student expenses such as dues and subscriptions are also included.

COE/NCC 2-307 1993-94
Wandell, November 1993

STANFORD ON-CAMPUS BUDGET

12/01/93 - 11/30/94

PERSONNEL:		
Ruby, J.A. (Admin Assistant, 15%)	4,460	
Zabrodsky, H. (Postdoctoral fellow, 20%)	4,000	
Hoffman, D. (Graduate student summer stipend, 15%)	1184	

	9,644	
Staff benefits @ 30.7%	2,961	
		12,605
TRAVEL		
• Zabrodsky -		
Sarasota, FL: ARVO Meeting Rtrip airfare		542
OTHER EXPENSES:		
Hoffman, D. (3 qtrs graduate student tuition)		3,834
	Total Direct Costs	16,981
	MTDC (minus tuition)	13,147
	I.D.C. @ 61%	8,020
	TOTAL DC & IDC	$ 25,001

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COE/NCC 2-307 1993-94
Wandell, November 1993

STANFORD ON-CAMPUS BUDGET

12/01/93 - 11/30/94

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jan/wandell/grants/nasa.center/coe.93-94/budget.on

COE/NCC 2-307 1993-94
Wandell, November 1993

NASA-AMES OFF-CAMPUS BUDGET

12/1/93 - 11/30/94

PERSONNEL:			
Zabrodsky, H [Postdoctoral fellow, 80%]	16,000		
Hourly Graduate students	8,340		
Beutter, Brent [Postdoctoral Fellow, 100%] Funded amt (incl SB + IDC) 92-93 = $53,916 Amt spent 5/18/93-11/30/93 = $29,274	-0-		

	24,340		
Staff Benefits @ 30.7%	7,472		
			31,812
TRAVEL:			
• Beutter -			
Sarasota, FL: ARVO			
Rtrip airfare	542		
6 days per diem @ $87	522		
local travel	50		
		1,114	
• Zabrodsky -			
Sarasota, FL: ARVO			
6 days per diem @ $87	522		
local travel	50		
		572	
			1,686
OTHER EXPENSES			
Reprints, photocopy, postage, phone		500	
Student Aid/Expenses (dues, subscriptions)		100	
			600
		Total Direct Cost	34,098
		I.D.C @ 37.61%	12,824
		TOTAL DIRECT & INDIRECT	46,922