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IMAGE PROCESSING FOR VISION: AN EQUIPMENT REQUESTS TO  
DOD(U) MASSACHUSETTS INST OF TECH CAMBRIDGE W RICHARDS  
19 FEB 87 AFOSR-TR-87-0463 AFOSR-83-0266

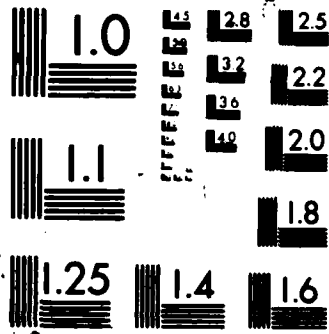
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19 ABSTRACT (Continue on reverse if necessary and identify by block number) The report lists items of scientific instrumentation acquired under the DoD University Research Instrumentation Program. These items, used for basic research on human vision, include an image processor and associated color display monitors, a computer disk drive, a computer magnetic tape storage, and a color video camera.			
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ITEM: DoD Instrumentation Grant Fiscal and Scientific Final Report.  
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GRANT SCOPE: Image Processing for Vision  
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GRANT PERIOD: June 15, 1983 - January 17, 1985 (extension)  
M.I.T. OSP #: 93874

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Attached find the final Fiscal and Scientific reports for our DOD-University  
Instrumentation Program grant (AFOSR-83-0266)

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I. DoD INSTRUMENTATION GRANT FINAL FISCAL REPORT  
Image Processing for Vision (AFOSR-83-0266)

1. Introduction

Under the terms of our DOD-University Research Instrumentation Program grant (AFOSR-83-0266), this final report details the equipment actually acquired on the grant (and the 6 month extension period). A FINANCIAL STATUS REPORT is attached.

All the equipment specified has been purchased with minor modifications and is in active use in support of our research. We feel that the goals of the grant have successfully met.

2. Equipment actually acquired.

Figure 1 shows the current logical configuration of our equipment. The equipment acquired under this grant is outlined. Below we list the items from the grant approval letter, and detail the equipment acquired and the cost.

(1) Image Processor. Estimated Cost: 63,000

Equipment Name -----	Manufacturer -----	Cost ----
RDS-3000 Image Processor	Adage, Inc.	64,845.00
RDS-3000 Upgrade	Adage, Inc.	8,737.00
Two 7211 Color Display Monitors	Conrac, Inc.	3,780.00
		TOTAL: 77,362.00

Special circumstances: (1) For some increase in price, we acquired an image processor that was more comprehensive and advanced than originally proposed. In addition, during the grant extension period, we used the remaining funds to upgrade the RDS-3000 system. This upgrade increased its performance and provided new functionality (matrix multiplication) for image processing. (2) The color monitors were not purchased as part of a package from Adage, because the cost and performance of the Conrac monitors are better. (3) Total cost sharing (donations) on these items is \$18,793.00

(2) Disk Drive. Estimated Cost 29,590

Equipment Name -----	Manufacturer -----	Cost ----
450 MB Disk Drive	Fujitsu, Inc.	10,500.00
Disk Drive Controller	Emulux, Inc.	6,386.00
		TOTAL: 16,886.00

Special circumstances: (1) Instead of the DEC disk originally specified, we purchased a newer drive that has more storage capacity and costs less. The funds saved on this item are used on other items.

(3) Magtape Drive. Estimated Cost 10,735

Equipment Name -----	Manufacturer -----	Cost ---
TFS Magnetic Tape System	Aviv, Inc.	8,287.50

Special circumstances: (1) The originally specified tape drive had some problems. In order to get going quickly, we accepted a different tape drive that had slightly lower performance and cost. (2) Cost sharing (donation) on this item is \$2,500.00. The funds saved on this item are used on other items.

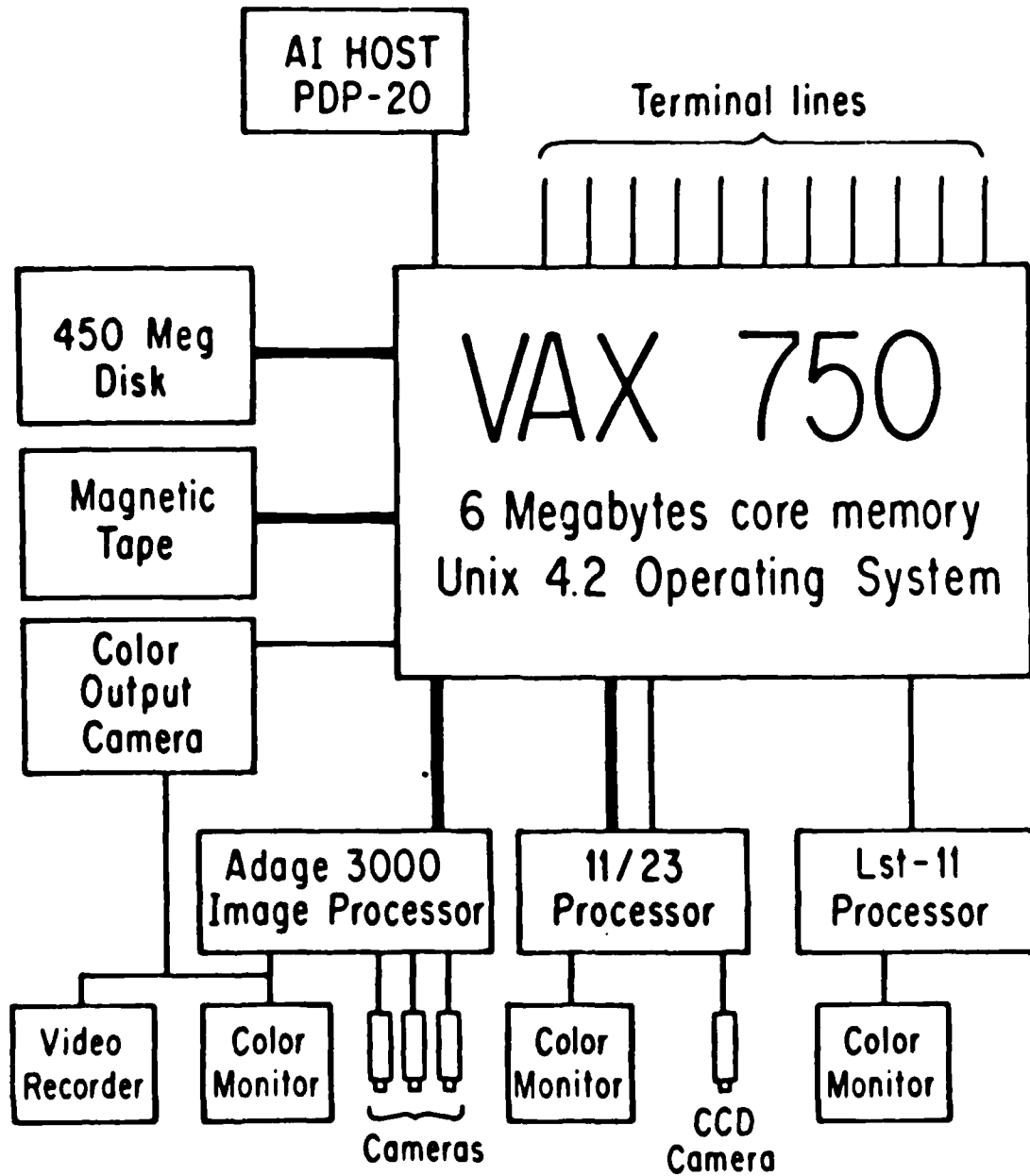
(4) Color Film Camera. Estimated Cost 8,675

Equipment Name -----	Manufacturer -----	Cost ---
Color Video Output Camera	Matrix Instruments	9,225.50

Special circumstances: (1) For slightly more money we purchased an extra camera back (for slides) for this camera. This greatly increases the functionality of this output camera. Cost sharing (discount) on this item was about \$2,000.00.

SHIPPING COSTS:	238.52
	-----
FUNDS REMAINING:	0.00

## Logical Structure of Equipment



The general logical structure of our equipment is shown in this diagram. The equipment purchased under the terms of this grant is indicated with a bold outline. The VAX 750 is the host machine for this equipment. The Adage 3000 and the two PDP-11's each provide local intelligence for an image processing "work station".

## II. DoD INSTRUMENTATION GRANT FINAL SCIENTIFIC REPORT Image Processing for Vision (AFOSR-83-0266)

Under the terms of our DOD-University Research Instrumentation Program grant (AFOSR-83-0266), this final report details the research projects on which the acquired equipment has been used. A REPORT OF INVENTIONS AND SUBCONTRACTS is attached.

### 1. Research Projects Using this Equipment.

#### (a) Research Work Described in the Proposal.

Since only 40% of the equipment funds requested were approved, the goals of the proposal had to be reduced. In particular, the LISP machine, a VAX 11/750, an Array Processor and the Ethernet were not approved. The lack of this equipment precluded most of the proposed cooperative program with Prof. Graybiel (in neuroanatomy) and Prof. Bizzi (neuro-motor control).

However, the main goal of the proposal (and much of the work at this lab), the "automatic extraction of image features suitable for low-level object recognition", has been greatly advanced by the equipment grant. We expect that the results of this work will have wide applicability.

The equipment has been used on the following research projects:

- Vision Algorithms and Psychophysics. Whitman Richards, et. al.

This AFOSR grant studies the computational algorithms that might be used in "low level" or "early" vision, i.e. image interpretation that is not driven by any particular problem domain. As an example of these algorithms, consider the problem of finding simple shapes or defining colored areas in an image. The goal is to ultimately have automatic processing and interpretation (understanding) of a natural visual scene.

The equipment is used to implement and test algorithms for finding these kinds of features in images. The computational demand is tremendous, and was nearly impossible before this equipment grant.

This kind of research will have broad applicability in visual guidance, machine vision, medical, scientific, and remote sensing areas, as well as benefiting our understanding of human vision.

- Codon Theory Implementation. W. Richards, D. Hoffman, B. Dawson

As part of this grant and other proposals, we are attempting to extract certain elemental curved contours from images. These elements are called "codons", in part because they can be grouped into strings of elements much the way nucleic acids are grouped in the DNA genome.

The equipment is again used to perform the computation necessary to test



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these theories, and to display images and the results of processing. See, for example: "Representing Shapes for Visual Recognition", Ph.D. thesis by D.D. Hoffman, M.I.T. 1983.

• Pyramid Computation. B. Dawson, G. Treese and S. True

Many image processing and understanding algorithms require the image to be sorted into features at different scales (a "scale-space" representation). One method of doing this is the Gaussian Pyramid scheme of Burt and Adelson. (See, for example: "The Laplacian Pyramid as a Compact Image Code", by P.J. Burt and E.H. Adelson, IEEE Transactions on Communications, vol. COM-31, No. 4, April 1983). On our old equipment, these calculations on a single image could take as long as 40 minutes. On new equipment the entire algorithm takes about 17 seconds! In addition to transporting the algorithms to the new equipment, we have examined and improved the basic algorithms in many places.

• Blob Finding. B. Dawson and G. Treese

A "blob" is our term for a located but as yet undifferentiated object. We must first find potential objects in a scene before we can specify what they are, or find their parts. Starting with the Gaussian Pyramid representation of an image, we threshold to find areas that are lighter or darker than the background. These blobs (potential objects) are then characterized by their location, size, shape, and structural relationship with other blobs. Finally, the entire set of blobs (across the image and across scales) is reduced by applying knowledge (rules) about the structure of the environment and the required internal consistency of the blob set. These blobs are then used as the basis for other algorithms, such as implementing the codon theory. See, for example, "Computing Curvature from Images" by B. Dawson and G. Treese, Proc. SPIE, Vol. 504, Nov. 1984.

b) Other Work of Interest that Uses the Equipment.

• Using Color to Find Material (Object) Changes. J. Rubin & W. Richards.

While it seems obvious that color could be used to tell when the material in an image changes (e.g. apples vs. oranges), in fact there are many problems in simply doing this. For example, what if the illumination is strongly colored? What about shadow across the objects? Rubin and Richards have developed a method of reliably making some assertions about material changes given a color change. The equipment has been used to psychophysically test consequences of this method. See, for example, "Color Vision: Representing Material Categories", by J.M. Rubin and W.A. Richards, M.I.T. A.I. Memo No. 764, 1984.

• Models of Specularity and Reflectance. A. Bobick

We use the gloss (shine) and specularity (highlights) of objects to make inferences about the shape, extent and composition of the objects. For example, we may use these characteristics to guess if an object is metallic or plastic in composition. Bobick has studied (and found lacking) many of the standard computer graphic models of reflectance for simulating the surfaces of objects. Currently we are using the equipment to ask how we make guesses as to material composition based on reflection and specularity.

• A Method of Displaying Volumes of Rotation. D. Steigerwalt.

As part of Steigerwalt's undergraduate thesis at M.I.T., he developed a general program for displaying volumes of revolution, given various lighting, reflectance, and observation information, on the equipment. This will be used in our psychophysical studies of the perception of material types given limited information.

• The Computer Modeling of Water Waves. W. Richards

A beginning effort to model ocean waves is under way. This has been done for various flight simulators, but our concern here is to understand the physics that underlies our perception of realistic images. Once the perceptually relevant physical variables have been isolated, we then can explain how, in principle, these variables can be recovered from images. The graphics display thus provides a critical tool needed for the first step in understanding how we "know" that a textured surface is indeed "water".

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