08:44:49 OCA PAD AMENDMENT - PROJECT HEADER INFORMATION 11/03/89

Active

Project #: E-21-672
Center # : R6362-0A0

Cost share #:
Center shr #:

Rev #: 1
OCA file #:
Work type : RES

Contract#: ECS-8705109
Prime #:

Mod #: AMENDMENT 01

Document : GRANT
Contract entity: GTRC

Subprojects ? : N
Main project #:

Project unit: EE Unit code: 02.010.118
Project director(s):
MERSEREAU R M EE (404)894-2913
SCHAFER R W EE (404)-

Sponsor/division names: NATL SCIENCE FOUNDATION / GENERAL
Sponsor/division codes: 107 / 000

Award period: 870801 to 900131 (performance) 900430 (reports)

Sponsor amount	New this change	Total to date
Contract value	0.00	90,000.00
Funded	0.00	90,000.00
Cost sharing amount		128,200.00

Does subcontracting plan apply ?: N

Title: ENG. RES. EQUIP.:VIDEO DIGITIZING & DISPLAY SYS.

PROJECT ADMINISTRATION DATA

OCA contact: David B. Bridges 894-4820

Sponsor technical contact

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Sponsor issuing office

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WASHINGTON, DC 20550

Security class (U,C,S,TS) : U
Defense priority rating :
Equipment title vests with: Sponsor

ONR resident rep. is ACO (Y/N): N
NSF supplemental sheet
GIT X

Administrative comments -
AMENDMENT 01 EXTENDS THE TERMINATION DATE TO 1/31/90 (NCE); ALL OTHER TERMS REMAIN THE SAME;

GEORG~ INSTITUTE OF TECHNOLOGY
OFFICE ~~ CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 08/14/90

Project No. E-21-672 Center No. R6362-0A0

Project Director MERSEREAU R M School/Lab ELEC ENGR

Sponsor NATL SCIENCE FOUNDATION/GENERAL

Contract/Grant No. ECS-8705109 Contract Entity GTRC

Prime Contract No. ____

Title ENG. RES. EQUIP.:VIDEO DIGITIZING & DISPLAY SYS.

Effective Completion Date 900131 (Performance) 900430 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	N	
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments ____

Subproject Under Main Project No. ____

Continues Project No. ____

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	N
GTRC	Y
Project File	Y
Other	N
	N

E-21-672

APPENDIX VII

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Georgia Institute of Technology School of Electrical Engineering Atlanta, Georgia 30332-0250	Instrumentation, Sensing & Measurement	ECS-8705109
	4. Award Period From 8/1/87 To 1/31/90	5. Cumulative Award Amount $90,000

6. Project Title
Engineering Research Equipment Grant: Video Digitizing and Display System

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

A system for quantizing and displaying video signals was purchased. The system is capable of capturing, digitizing, and storing 30 seconds of black and white video signals (512 x 512 frames, 30 frames/second). It is also capable of capturing, digitizing, processing and displaying single frame color images. This equipment enables the researchers in the Digital Signal Processing Laboratory to extend their research on speech and image coding to the area of low and medium bit-rate video coding, and also to look at some important problems in computer vision. Matching funds were used to fund part of the system, purchase a video tape recorder to store coded sequences, and to provide maintenance for the equipment for its first two years.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM: Check (✓)	Approx. Date
a. Abstracts of Theses					
b. Publication Citations					
c. Data on Scientific Collaborators					
d. Information on Inventions					
e. Technical Description of Project and Results					
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Russell M. Mersereau		7-31-90

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1.2 Budget 2

1.3 Difficulties Encountered 2

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Appendix A

1 Introduction

The Digital Signal Processing Laboratory at the Georgia Institute of Technology has been actively involved in research in methods and applications of digital signal processing for almost twenty years. During this period the group has grown significantly. It currently contains nine faculty members and nearly fifty doctoral students. The research interests of the group are varied, emcompassing general algorithms for digital signal processing, speech coding, speech recognition, radar signal processing, knowledge-based signal processing, image and video coding, image enhancement, computer vision, signal reconstruction from partial information, and computer architectures for optimally implementing signal processing algorithms.

In the course of performing this research a computing facility consisting of workstations and minicomputers connected by an Ethernet network has been developed which is accessible, highly interactive, and well-suited to performing research in speech and image processing. The primary shortcoming of the facility was its lack of a capability for the input and output of real-time video signals. This was a severe limitation to the conduct of research in problems involving moving imagery. This equipment grant addressed that need.

1.1 Specific Equipment Needs

The current computing facility in the DSP Laboratory consists of workstations and minicomputers. All of these use the UNIX operating system operating in an XWINDOWS environment. The workstations are distributed among offices and laboratories, and storage for user files is also distributed throughout the system. The majority of the programming is performed using the C language although other high-level languages are also used. It is important that the video I/O system function in this envoronment and be accessible to all of the users. Furthermore because of research needs, the video system should be programmable but make use of libraries of special purpose routines to implement common tasks efficiently. The programming environment should resemble the other workstations on the network (i.e. it should support UNIX, XWINDOWS, and the C language.)

A copy of the specific request for bids is included in Appendix A. The salient features of the system as proposed are summarized below:

- The capability to capture and display 512 × 512 black and white images at 30 frames/sec.
- The ability to store up to 500 frames of 512 × 512 B/W imagery.
- A VME interface for connection to the network.
- A minimum of 500 Mbytes of program storage.

- The ability to digitize and display 512 × 512 color still images.
- High resolution 1024 × 1024 color monitor for still images.
- The ability to be interfaced to a video tape recorder to accept and record full-color video sequences on a frame-by-frame basis.
- Expandability to be able to accept and display full-color video in the future.
- Built-in functionality for performing common image processing functions (e.g. convolution with small masks, image subtraction, zooming, panning, morphological operations, etc.) was desirable provided that it did not come at the expense of the other capability and fell within the overall budget.

1.2 Budget

The amount requested for this equipment was $154,400. Georgia Tech agreed to match this request with sufficient funds to cover maintenance. The actual amount that was granted was $90,000 from NSF with a $128,200 matching contribution from Georgia Tech. We were later able to supplement this with an additional equipment grant of $12,933 from Georgia Tech that was used to purchase the video tape recorder system. Therefore, the total amount that was available for the entire system including its maintenance for the first three years was $231,133.

1.3 Difficulties Encountered

A number of difficulties were encountered that delayed the purchase of the equipment. First, because the budget was limited, it was necessary to select the features of the desired system carefully and to omit those that were not necessary to its primary purpose. A sudden rapid increase in the cost of semiconductor memory chips (which obviously are a key component of such a system) occured during this time. The effect of this was that none of the original bids fell within the budget. This necessitated redrafting the specifications and having the system rebid. This added to the overall delay. Finally, the low bidder had difficulty in configuring the system to meet the system requirements. While they were eventually able to do so, the system was delivered late. It did not arrive and go into use until October 1989–nine months after the expiration of the original grant. This necessitated our request for a no-cost extension of the grant until Jan. 1990.

2 Equipment Purchased

This section provides a technical description of the complete system that was purchased.

2.1 Description

The complete system is shown in Figure 1. As is apparent from that figure, there are in fact two distinct subsystems—one which performs real-time video acquisition and storage and one which functions as an image processing workstation. The various components are described below.

- Visual Information Technologies, Inc. (VITec) image computer package 10-IS003-1. This includes the VITec image processing computer which can process and display 1280 × 1024 true color images (32 bits per pixel), 10 Mbytes of image memory, and a 19 inch 1280 × 1024 color monitor. ($26,175)
- SUN 3/160 Workstation with 4 Mbytes of memory, an 1152 × 900 black and white monitor, 1/4 in cartridge tape subsystem, with C, NFS, SUN, and FORTRAN licences. ($22,780)
- Fujitsu 2382 1 Gbyte large capacity disk with a Xylogics 735 SMD VME Disk controller. This disk is capable of operating at a 3.0 Mbyte/sec transfer rate. ($13,313)
- Data Translation DT1458 high resolution frame grabber with auxilliary frame processor. ($10,200)
- Imaging Technologies Image Processor. This system incorporates the integration of the real-time acquisition subsystem. ($12,750)
- Applied Memory Technology High Speed Disk. This disk is capable of storing 30 seconds of black and white video. ($48,750)
- Sony BVU-950 video tape recorder. This operates with a U-matic format and a resolution of 340 TV lines with an NTSC input/output, a signal to noise ratio in excess of 50 dB and a computer controlled interface. ($10,490)
- Sony BKU-901 time-base corrector for interfacing the recorder above. ($3,356)

The total cost of the hardware listed above was $147,814.

2.2 Maintenance Provisions

Maintenance on the complete system is fairly expensive. The total cost for maintenance on the Sun processor, Imaging Technologies Image processor, ViTec processor, and the

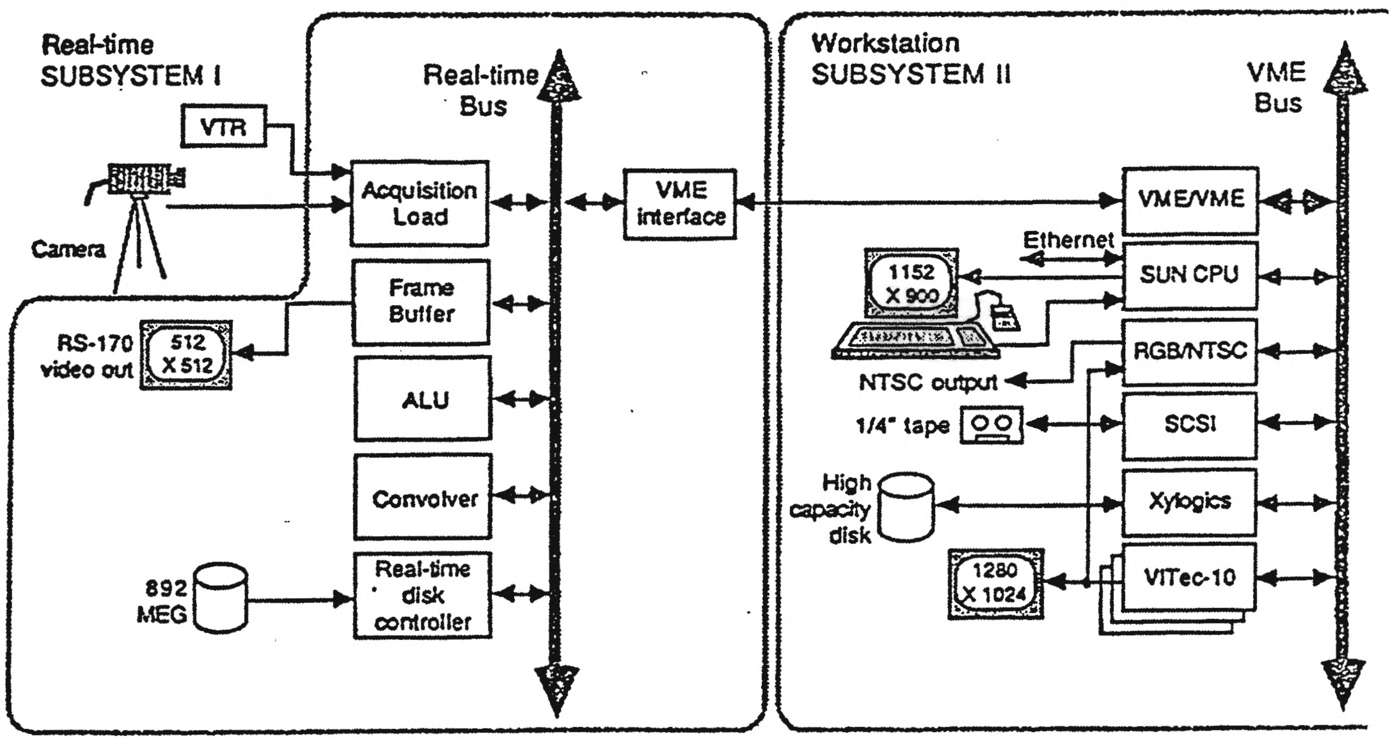

Figure 1: The video workstation as finally purchased.

two disks is approximately $25,000 per year, to be paid out of the Georgia Tech matching funds. A one-year maintenance contract with Visual Information Technologies Inc (VITec) has been purchased and remaining matching funds are available to extend this coverage for a second year. In addition, the Digital Signal Processing Laboratory has as part of its staff, two research engineers, two research scientists, and one technician whose primary responsibility is the maintainance and service of the computing environment (both hardware and software).

3 Research Being Performed on the System

Even though this grant was for the purchase of equipment, it nonetheless seems appropriate to indicate how this equipment is being used. Since the system's installation in October 1989 a number of research projects have begun to make use of it. These represent the first of what is expected to be a large number of projects in the areas of image coding, image restoration, computer vision, and multiprocessor architecture. Very brief descriptions of these projects follow.

3.1 Video Coding

The group has a long history of research in the areas of speech and image coding. While the system can be and is being used to display coded still imagery, the primary motivation for its purchase was to permit the extension of our coding research into video sequence coding. Three projects in this general area have already begun. These are summarized briefly below.

3.1.1 Video Subband Coding

Subband coding has been successfully applied to the coding of speech and single frame images and it is currently being applied to the coding of video. The primary advantage of these coders is the fact that they exploit the limitations of a human observer, so that encoding errors are either not perceived or are less objectionable that with other types of coding distortions for coders operating at the same moderate bit rate. There are a number of issues associated with extending these ideas to video sequences but the foremost among these is simply being able to handle the large amount of data that is involved at video frame rates. Furthermore since these coders exploit the properties of a human observer it is essential that the coded imagery be presented to test subjects in real-time. This is research that would not even be attempted without the video I/O system provided under this grant. Applications of this research include video conferencing and multi-media data processing and storage.

3.1.2 Information Preserving Coders

The coders described in the previous subsection greatly reduce the number of bits required to represent the video sequence at the expence of a reduction in quality. In application such as high-definition television, and medical imaging it is often required that no distortion be introduced into the data. Obviously these coders operate at a higher bit rate. Nonetheless, these applications are important and the need for methods to reduce the number of bits required to represent the imagery is still present. One of our doctoral students is looking at methods for information-preserving coding. The approach that he is using makes use of simple reversible signal processing operations conbined with arithmetic coding of the residual signals. The video system will be used both for its display and input capability as well as its computational power.

3.1.3 Variable Sampling Rate Coding

The approach here exploits the fact that the local nature of an image sequence is generally nonhomogeneous. Therefore, adaptive techniques are probably necessary to obtain good coding results. This approach operates in the spatio-temporal domain. Its main focus is in the design of nonuniform sampling patterns for 2-D or 3-D subimage blocks. Nonrecursive and recursive partitioning schemes are being investigated for subimage decomposition. The reconstruction of the sampled imagery is then accomplished by various interpolation methods. It is well known that the human visual system is less sensitive to noise in areas or high spatial activity or rapid motion. Since the sampling structure is a direct measure of the activity within a subimage, the samples can be adaptively scalar or vector quantized. Preliminary results with this approach appear to compare favorably with transform coding.

3.2 Motion Estimation and Segmentation

Two projects have been begun in the area of image segmentation and motion estimation in video sequences. The approach in the second of these looks particularly promising although it was developed for a particular medical application. We hope to expand it into a framework for more general computer vision systems.

3.2.1 Edge Tracking

In many important problems involving motion analysis the scene can be modeled as foreground objects consisting of well-defined segments moving in front of a stationary or uniformly moving background. Identifying the segments of such a scene is greatly aided it motion estimates are available. Conversely the task of motion estimation is aided if the segments have been identified. Our approach, therefore, it to tackle the two problems simultaneously. Moving edges in the image are identified and their motion is estimated. Motion estimates are then used to refine the segmentation and so on.

This particular research uses the storage capability and functionality of the new equipment to facilitate handling the large number of data samples involved.

3.2.2 Knowledge-Based Video Segmentation

A doctoral thesis was completed which resulted in the development of a system for automatic boundary detection of time-varying magnetic resonance images of the beating heart. The goal of the project was to automatically find, track and measure the inner and outer walls of the left ventricle of the beating heart to ascertain cardiac function and quantify the degree of coronary artery disease. This resulted in a system for knowledge-based image sequence analysis that made extensive use of fuzzy logic and the Dempster-Shafer theory of evidence. The system synthesized measurements from several different knowledge sources and used knowledge that it learned to optimize the flow of subsequent information for more efficient use of limited computational resources.

3.3 Anticipated Research

The approach used in the cardiac image sequence analysis system described above is applicable to more general problems in computer vision and we anticipate appliying it to some of these problems. This is not a trivial extension because the cardiac problem was highly constrained and this structure kept the total computational requirements reasonable. In more general contexts the system itself must impose structure and be more efficient in its use of knowledge to formulate and test hypotheses. This work will make extensive use of the video I/O system, both for data input and for image processing. It will make use of the rest of the computer network for the extensive statistical calculations that must be performed.

APPENDIX A

Georgia Institute of Technology

School of Electrical Engineering

TO: Procurement Office

FROM: Electrical Engineering, Dr. R. M. Mersereau

PURCHASE ORDER NUMBER:

CLASSIFICATION: Equipment

The following is a specification for an image processing workstation to be used for research. The image processing workstation will consist of special purpose image processing hardware interfaced to a general purpose workstation. The required features of the system are:

Image Processing requirements

- Spatial Processing
- User-defined kernel sizes
- Real-time logical and arithmetic operation
- Real-time recursive 3x3 convolutions
- Region of Interest (ROI) processing
- Morphological processing
- Interactive processing modes
- Interactive, Menu-driven image processing software
- 8Mb of Image Memory

Image Display requirements

- 512x512 True Color (R, G, B) display
- Programmable Cursor and text fonts

- Hardware interpolated and replicated zoom
- Interactive Zoom, Roam and Scroll
- Independent X, Y, Zoom and Scroll
- NTSC video output

The NTSC output must be compatible with the Sony BVU-950 VTR.

Image Storage/Retrieval requirements

- Real-time digital video disk storage for at least 500 frames of greyscale video
- 8-bit greyscale video rate (30 Frame/Second) acquisition/display
- 8Mb of Image memory

The system must be capable of acquiring/displaying 500, 512x512 frames of video in real-time (30 frames/second). This requires a transfer rate of at least 7.9Mb/second for greyscale and 23.6Mb/second for color. The real-time capability is required for greyscale and must be capable of being upgraded to color.

Image Acquisition requirements

- Greyscale acquisition in real-time (30 frames/second)
- Capable of being upgraded to True Color
- Direct input of camera, CCD and VTR
- Digital or Analog input
- Programmable gain and offset levels
- Inline look-up-tables and ALU
- Real-time frame averaging
- Region-of-Interest acquisition/preprocessing
- Real-time logic and arithmetic operations during acquisition

Software Development Environment requirements

- Berkeley 4.3BSD based operating system
- Interactive image processing commands

- Access to Image Processing driver level software
- Image processing software utility libraries for C
- Object oriented Image Processing software
- C and FORTRAN compilers for the general purpose workstation
- X-Window software version X11R2 must be available
- Must be able to run SUN Network File System (NFS) software

The SUN-NFS software run's on at least 40 vendors computers. This does not constitute a "sole source" requirement. The Berkeley 4.3BSD, X-Windows and NFS software is needed for compatibility with existing systems on which are currently running this software. The X11R2 software is available from MIT and several workstation vendors. The general purpose workstation must be able to act as a client system under X11R2. If the workstation has a separate display from the image processing system, an X11R2 server must be capable of running on this system. This is not a requirement for an X11R2 software deliverable but a requirement for the capability to run the software.

Workstation requirements

- 32 bit Workstation with 4Mb of memory and Floating Point Co-Processor
- 2.0 or greater MIPs operation
- At least 800Mb of disk storage and tape backup
- Ethernet (Thin or twisted-pair not acceptable)

Maintenance Information

A cost estimate for hardware maintenance for a period of three years following delivery of the system (including any warranty period) should be provided. The hardware maintenance should include board-level support for the hardware and a hot-line service for diagnostic assistance. Board-level support means that a defective board will be replaced at no or a substantially reduced cost. If this option is not available then the solution which would include this should be quoted.

A cost estimate for software maintenance should also be included. This should include bug-fixes, documentation updates, and software release updates.

This system must allow for a wide variety of image processing research and because of the complexity of the system, all of the components must be purchased from a single vendor or system integrator. We will also need to review the bids before a decision is made.