

The Graphics, Visualization, and Usability Center

Georgia Institute of Technology

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A. INTRODUCTION AND GOALS

Graphics, Visualization, and Usability (GVU) is an interdisciplinary area which draws its intellectual foundations from Computer Science, Psychology, Industrial and Systems Engineering, and Computer Engineering, and which has application to any use of computers to graphically convey information to users. Typical applications are computer aided design, scientific and business data visualization, multimedia, computer-supported cooperative work, computer-based teaching, image understanding, medical imaging, and user interface design.

The GVU Center has three missions: education, service, and research. In our educational role, we teach the principles and methods of computer graphics, visualization, and usability to members of the academic community ranging from undergraduate students to graduate students and faculty. Center members teach dozens of courses and seminars among the wide offering of relevant courses listed in Section F. A set of continuing education short courses (Section G) are provided to assist practitioners to stay abreast of current developments. Our service mission is carried out through the Scientific Visualization Lab, a joint undertaking with Information Technology (the campus-wide computer service), to provide state of the art computer graphics hardware and software capabilities to the entire Georgia Tech community. Over 150 faculty, graduate students and staff use the visualization lab's facilities. Our research, described in Section B, spans the areas of realistic imagery, computer-supported collaborative work, algorithm animation, medical imaging, image understanding, scientific data visualization, animation, user interface software, usability, adaptive user interfaces, multimedia, stereo graphics, virtual environments, image quality, and expert systems in graphics and user interfaces. The twenty faculty and staff who are actively developing the lab's programs are drawn from Psychology, Mechanical Engineering, Office of Interdisciplinary Programs, Physics, Mathematics, Information Technology, and the College of Computing. An active seminar series and brown-bag lunches brings us together every week to discuss current research topics.

By integrating these three missions together in a single unit, the Center is developing a highly interactive and collaborative environment where researchers unfamiliar with computer graphics can come for help in integrating scientific visualization into their research work, graphics experts and graduate students can share their knowledge with one another and find new and interesting problems on which to work, and students can learn in a melting pot of closely-related ideas and collaborations between researchers from multiple disciplines. This intellectually-stimulating environment, complemented by over 40 workstations and other pieces of equipment and over 3000 square feet of newly-renovated lab space, provides a paradigm for the use of interactive computer graphics systems which will be necessary for engineering and scientific research in the 21st century.

B. CURRENT RESEARCH PROJECTS

The many research projects being conducted by our members are briefly described. Many are sponsored by governmental agencies and corporations, while others represent embryonic research projects.

B.1. Three-dimensional Computer Graphics

Computer-Aided Curve & Surface Design

On account of its versatility and speed, one method currently being used for computer-aided geometric design is that of refined sub-division. Sub-division methods operate on an initial set of control points, which can be thought of as the vertices of a control polyhedron. These methods recursively refine the polyhedron by sub-dividing it into sub-polyhedra, and the limiting union of all the tiny polyhedra fit together to form the desired curve or surface. This project involves a new parallel IFS algorithm for implementing these refinement schemes, and generating the limiting curve or surface.

Project members: Marc Berger, Kevin Leeds
Sponsors: NSF

Stereoscopic Computer Graphics

Stereoscopic Computer Graphics (SCG) images add the stereopsis cue to the standard monocular depth cues by presenting to each eye of an observer a different view of the image. Presentation methods involve a time multiplexed scheme in which a liquid crystal modulator (LCM) polarization encodes the two images and then linear or circular polarizers allow only the correct image to reach each of the viewer's eyes. Due to the wide applicability of SCG, much of this research is done jointly with other engineers and application scientists at Georgia Tech. Issues that are currently being investigated include: development of algorithms for rendering SCG images; determination of tasks and applications for which SCG is appropriate; and examination of visual perception and computer-human interaction issues in SCG.

Project Members: Larry Hodges, Steve Adelson, Shane McWhorter
Sponsor: StereoGraphics Inc.

Distributed Virtual Environments

The goal of a distributed virtual environment is to present imagery at each node that is realistic enough to ensure that a visualization or training task is accomplished effectively while minimizing the cost of equipment. Any implementation of a distributed virtual environment will potentially consist of nodes with quite different capabilities. We should assume that nodes are highly heterogeneous. They may differ in terms of purpose, network characteristics, computing power, and display type. The obvious implication is that the visual fidelity of the representation of the simulated environment will vary across nodes. We are examining visualization and training implications when dealing with nodes having different resolutions, available colors, network capabilities, and display modes.

Project Members: Larry Hodges, Steve Adelson, Shane McWhorter

TABLE OF CONTENTS

A.	INTRODUCTION AND GOALS	1
B.	CURRENT RESEARCH PROJECTS	2
C.	GVU CENTER MEMBERS	21
D.	FACULTY PROFILES	25
E.	COMPUTING FACILITIES	29
F.	ACADEMIC COURSES	31
G.	SHORT COURSES	36
H.	RECENT GROUP PUBLICATIONS (affiliated members in bold type)	38
I.	GENERAL INFORMATION	51

B.2. User Interface Software

User Interface Designer's Aide

The user-computer interface is often the major impediment to successful use of interactive computer graphics systems. Design of the interface is often thought of as art rather than science, and suffers from lack of formalisms, models, tools, and methodical design approaches. Slowly, the design process is becoming more structured, and more formal tools are becoming available.

The objective of this project is to create a User Interface Design Environment (UIDE), a knowledge-based system to assist in user interface design and implementation. At the heart of UIDE is a representation of the conceptual design of a user interface. The design includes: the class hierarchy of objects which exist in the system, properties of the objects, actions which can be performed on the objects, units of information required by the actions, and pre- and postconditions for the actions. The conceptual design and related information is used to: check the interface design for consistency and completeness, transform the knowledge base, and hence the user interface it represents, into a different but functionally equivalent interface via transformation algorithms, evaluate the interface design with respect to speed of use, generate intelligent run-time help to the end-user, and produce a printed description of the design in the Interface Definition Language (IDL) which is a formal language developed to present the conceptual design of the user interface in a structured and readable form. Several UIDE sub-projects are:

Compositional Model of Human-Computer Dialogues

Presently, there is no clearly defined model of dialogue styles -- what constitutes a dialogue style, what makes one style different from another, and how different styles interact. Such a model is needed for development of a user interface design tool that (1) supports a broad range of user interfaces and (2) allows for easy transitions from one user interface design to another. We are developing a compositional model of human-computer dialogues that meets the two requirements and can serve as a basis for a user interface design tool allowing a user interface designer to easily explore different designs. The compositional model views a user interface as a composition of primitives from a finite set, structured in a specific way; the exact structure and primitives used depend on the application for which a user interface is being built, and on a desired dialogue style. The model assumes a knowledge-based approach; both the application semantics knowledge and the user interface domain knowledge are utilized to model dialogues and to facilitate navigation in a design space. The navigation, transitions from one design to another, is done by applying a set of transformation controlling different aspects of user interfaces.

Project Members: Srdjan Kovacevic, Jim Foley
Sponsors: National Science Foundation

Attaching Pre- and Postconditions to Widgets

Widgets are objects on the screen with which the user interacts (i.e. windows, menus, buttons, sliders, etc.). A widget can be enhanced to have preconditions that determine its status and postconditions that are asserted when certain actions are performed on the widget. One set of preconditions is used to determine if the widget is visible and the other determines if it is enabled. Postconditions are used for each functionally different action on the widget. Attaching pre- and postconditions to widgets provides several useful features,

such as selectively enabling of controls, rapid prototyping, and automatic generation of explanations and help text.

Project Members: Martin Frank, Jim Foley
Sponsor: Sun Microsystems

Automatic Application of Graphical User Interface Application Style Guidelines

User interface design is becoming increasingly easy. New tools allow interactive design of the interface by laying out user interface controls on the screen. To help the designer building consistent user interfaces, a lot of style guidelines have been written down. The objective of this project is to study the feasibility of automatically applying style guidelines to menus and pop-up windows. The automation of design rules means that users of lay-out tools will be assisted in following the style guides, and that new consistent user interfaces can be created more quickly.

Project members: Mark Gray, Jim Foley
Sponsor: Sun Microsystems

Intelligent SX/Tools

Our objective is to develop user interface representations and a runtime user interface architecture which facilitates adaptive interfaces and adaptive on-line help at run time. To achieve this objective, we investigate various factors which should be quantified to dictate adaptive behaviors. These factors are based on application tasks, user expertise on various tasks in a particular application, history of user's task patterns, user errors, user's stage of understanding various parts of on-line help, etc. A user model based on these factors will be developed and used to vary adaptive behaviors, which range from reorganizing interface structure, to making often-used tasks easier to achieve, to varying levels of detail and speed of delivery in on-line help presentations. Integrated verbal and animated help is the primary help presentation style, with detail varying according to individual users. We are also investigating means for the user to control and customize the adaptive behaviors..

Project members: Noi Sukaviriya, Todd Griffith, Hans de Graaff, Jim Foley
Sponsor: Siemens

Next-generation User Interfaces

Very recently, much progress has been made toward evolving user interfaces to more "direct manipulation"-oriented interactions, thus simplifying their use. We seek to push this work further by adding animation and sound to user interfaces. Animation is important because it demonstrates the dynamics of an interface and the underlying software. By illustrating smooth changes between states, rather than sudden abrupt actions, an interface preserves context and fosters user understanding. The use of sound touches an untapped dimension of user interfaces as well. Utilizing audio feedback, much as we do in everyday life, should make user interfaces convey more information and become easier to work with. Our work here focuses on user interface development tools, and how to incorporate animation and sound into the tools in a simple, consistent manner.

Project Members: John Stasko

B.3. Data and Program Visualization

Stereo Visualization/Animation Tools

The objective of this research is to develop interactive stereo visualization and animation tools for manipulating and analyzing complex atomic, molecular, or other data. These tools are especially focused toward visualizing data that can be represented as 3D structures (atomic spheres, molecular clusters, flexible tubes for chain molecules, etc.). Not much work has been done on strategies for visualizing the dynamics of these systems compared with, for example, vector or scalar flow fields for fluid dynamics. Our aim is to develop interactive and user-friendly paradigms for allowing the users to visualize the data related to the motion and the properties of these complex assemblages. To make our tools as flexible and easy-to-use as possible, we are working on implementing a rich interface that will offer the user a variety of means to navigate through his data. In addition to the standard pop-up menus, button boxes and sliders, more sophisticated control peripherals will also be incorporated into the user interface, such as the "Spaceball" which provides the user with six degrees of freedom in manipulating the data.

Project Members: Lina Karam, Bill Ribarsky

Visual Debugging

Algorithm animation, the use of dynamic graphics to illustrate programs and their behaviors, has been used primarily as an instructional aid to date, but we are exploring ways to use algorithm animation techniques as aids for program development and debugging. Data structure display systems, one of the other areas of program visualization, have been used as debugging aids in the past. Unfortunately, they have the restriction that their views only involve generic data, and do not include visualizations of the program's semantics and abstractions. Our work in this area seeks to supplement traditional debuggers with operations that will allow users to quickly and easily create application-specific animated program views. Users should not have to write any graphics design code. Rather, they should be able to create graphical program views using simple commands, buttons, menu selections, and direct manipulation graphics editing.

Project Members: John Stasko

Sponsor: NSF

Visualization of Parallel Programs

Developing, testing, and debugging parallel programs is intrinsically far more difficult than sequential programs. This project seeks to create a comprehensive visualization system for viewing the semantics, data, and operations of a variety of parallel application programs. We are focusing on views of the actual program entities and actions, as opposed to views of the state of the parallel computation (performance visualization). The project has two primary foci: 1) gathering and organizing information about the application program's activities, and 2) developing an animation framework for designing and displaying the parallel program views.

Project Members: John Stasko, William Appelbe, Eileen Kraemer

Visualization of Object-Oriented Programs

Previous attempts to graphically describe or document object-oriented programs have all suffered from the fact that the visualizations were static. Object-oriented programs, however, are quite dynamic. We are attempting to develop a visual prototyping environment for C++ that exhibits execution components such as message passing and instance creation via animation scenarios. A developer will invoke commands for designing classes, objects, methods, etc. Our tool will show the corresponding animation actions and generate associated C++ code templates. In essence, the tool will be like a simplified "visual programming" system. These animated code design scenarios will be able to be saved and replayed later as well. This capability would be useful as a documentation aid, for example, to illustrate how a system will work to managers. The future extension of this work will be to automatically provide animated visualizations of C++ programs during their executions. This type of system would be critical for software understanding, particularly for code designed elsewhere that must be adopted or incorporated locally.

Project Members: John Stasko

Three-Dimensional Software Visualization

In this project, we are exploring ways to present programs and animations using three-dimensional computer graphics. The target areas are both automatically generated canonical program views and highly abstract, user-designated algorithm animations. We are currently developing the Polka-3D system, which supports simplified design and implementation of 3D algorithm animations. This system will be useful for illustrating both parallel programs and algorithms which manipulate three-dimensional data. We are also exploring how audio cues and multimedia methods can be used to present and explain software.

Project Members: John Stasko, Joe Wehrli

Interactive Stereo Visualization/Animation of Data

The objective of this research is to develop interactive stereo visualization and animation tools for manipulating and analyzing complex atomic, molecular, or other data. These tools are especially focused toward visualizing data that can be represented as 3D structures (atomic spheres, molecular clusters, flexible tubes for chain molecules, etc.). Not much work has been done on strategies for visualizing the dynamics of these systems compared with, for example, vector or scalar flow fields for fluid dynamics. Our aim is to develop interactive and user-friendly paradigms for allowing the users to visualize the data related to the motion and the properties of these complex assemblages. To make the interactive environment as rich and flexible as possible, we are also exploring the use of more sophisticated control peripherals such as the "Spaceball" and dataglove. Eventually stereoscopy, these devices, and others (such as head-mounted displays) will be integrated to produce virtual environments with which users can go on voyages of discovery through their data.

Project Members: Lina Karam, Bill Ribarsky

Visualization of Complex, Multiparametric Dynamical Systems

The focus of this research is the visualization of complex data from large scale simulations or observations of big collections of interacting objects (e.g., atoms or molecules) or of other systems analyzed on the atomic scale. There are few methods for representing the interplay between the many parameters, such as the forces acting on individual atoms, in data from these large scale simulations or observations. Methods derived here will give researchers insights into the mechanisms that propel dynamic processes and into the often obscure interrelationships between properties. Our approach is to develop visual representations of the parametric data and their mutual relations and then develop interactive tools for binding or associating the representations with the data. The challenge in developing visual representations will be to see how far the human eye-brain system can be pushed in comprehending massively complex sets of images. The objective will be to develop easily discernible visual patterns that expert viewers can recognize and methods for "rotating" between sets of parameters in the parameter space to discover relations.

Project Members: Bill Ribarsky, Robert Minsk
Sponsor: National Science Foundation

Customized Visual Data Representations

Researchers analyzing large datasets usually have neither the time nor the expertise to do their own graphics programming. Yet standard methods of visualizing data should often be tailored, or entirely new representations used, to achieve, in an effective and efficient manner, understanding of the data. Furthermore, the most creative analysis is an interactive process where the researcher refines her visualizations based on what she sees. We are developing programmerless, interactive methods to allow the researcher to construct glyphs, choose attributes, and then bind them to data. The binding patterns, ranges of change for an attribute, and numbers or types of attributes can be changed at will by the user. The results of changes will be propagated automatically to the visual representation thus allowing a quick, iterative approach to finding the best depictions of the data. In addition we are designing these methods in a flexible, data-driven environment allowing user-defined filtering and manipulation and efficient instancing of thousands of glyphs and their attributes (e.g., pseudo-colored spheres representing positions and properties of each atom in a large collection). In their general form, these methods can build visual representations that are very rich and would subsume most current visualizations; they will also allow construction of untried representations or combinations of representations.

Project Members: Bill Ribarsky, Lina Karam, Robert Minsk

B.4. Image Understanding

Image Understanding Environments

Over the past twenty-five years, several different software environments have been developed to support and integrate image understanding activity. These have now evolved into integrated systems of considerable computational and representational power, reflecting the range of problems researchers in computer vision deal with and incorporating much of what has been learned about machine vision. These systems are referred to as Image Understanding Environments (IUEs). We are currently developing an Image Understanding Environment to coordinate Image Understanding work at Georgia Tech and are working in areas concerned with object oriented methodologies and facilities for cooperative work.

Project Members: Daryl Lawton, Mary Ann Frooge, Chang Zeng
Sponsor: DARPA and ADS

Interactive Model Based Vision for Telerobotic Control

Many of the difficult issues in model based vision concern control and hypothesis management. To aid in the development of autonomous systems, Lawton is developing interactive model based vision systems. These have the same underlying architecture as an autonomous system, but are controlled by a human. This framework has many exciting implications. The interactive system provides a rich set of protocols for programming the autonomous vision system. Scripts obtained with the interactive system can be used for the transfer of interpretation expertise, especially in areas such as biomedicine. We can also restrict the presentation of imagery to the human to get detailed protocols for psychological study. A current project is developing an interactive vision system for the control of a telerobot where there is limited communication bandwidth. The human will quickly provide a high level interpretation of a scene that can be used for short term autonomous functioning of a telerobot.

Project Members: Daryl Lawton, Warren Gardner
Sponsor: US Army Human Engineering Laboratory and ADS

Model-Based Vision System

Model-based vision concerns the use of world knowledge to interpret imagery. Fundamental issues concern such things as: how to represent models, preferably as hierarchies of physically and geometrically based constraints; how to index into a potentially enormous data base of models during interpretation; and how to perform model to image matching, inference, and optimization. Lawton's current work involves building model-based vision systems for several domains, extending the general architecture used previously for outdoor robot landmark extraction and matching. Current projects underway include one for the analysis of pulmonary embolism (along with researchers in nuclear medicine at Emory Medical School), one for dynamic cardiac images (along with Dr. Norberto Ezquerro of the Medical Informatics Center at Georgia Tech), and one for outdoor robotics. Other efforts are planned for the inspection of chickens and the automatic interpretation of electron density maps obtained from X-ray diffraction imagery.

Project Members: Daryl Lawton, Norberto Ezquerro, Warren Gardner
Sponsors: Georgia Tech Research Institute and Georgia Tech/Emory Medical Consortium

Basic Vision Research

Of particular importance is perceptual processing for extracting environmental and symbolic information from images for the control of real-time behavior. This involves three primary areas: motion analysis, perceptual organization, and the incorporation of active sensing strategies into vision. Earlier work in motion analysis was concerned with processing restricted cases of motion for which robust solutions are possible; real-time motion analysis using a content-addressable parallel processor; and techniques for the immediate extraction of motion parameters from the differential properties of optic flow fields at occlusion boundaries. Current work is concerned with the psychophysical and practical implications of these approaches and also with the direct extraction of occlusion boundaries. It may be unnecessary to use motion analysis to determine an exact depth map or egomotion parameters. A wide range of motor activity and cues for directing attention depend only on extracting and representing the relative depth of surfaces and the image-registered location of occlusion boundaries. Perceptual organization is fundamental to the extraction of information for model based recognition and for determining landmarks used in qualitative navigation. Current work involves extending a hierarchical rule-based grouper.

Project Members: Daryl Lawton, Warren Gardner
Sponsor: DARPA, NASA

B.5. Medical Informatics

3D Fusion of Multimodality, Multidimensional Medical Information

Decision-making processes in medicine typically require the integration of several types of information in a meaningful, reliable, and efficient manner. In medical imaging problems, this integration involves voluminous amounts of data, thereby presenting a formidable problem in the representation, display, and interpretation of multidimensional information. A multidisciplinary and interinstitutional project is underway aimed at facilitating the integration of different imaging modalities, using methods based on computer vision, image synthesis, and graphics and visualization techniques. The objective is to develop a unified methodology with which to objectively and accurately integrate the diverse types of sparse and noisy data, which will allow interactive and animated manipulations of the fused information, and which will support interpretive decision-making at higher levels of abstraction. Emphasis is placed both on objective, quantitative representations as well as on subjective, qualitative representations of multimodal information. The methodology is presently being realized through the integration of information from coronary angiography and cardiovascular nuclear medicine imaging. Other modalities (magnetic resonance imaging, X-ray CT, etc.) are also investigated.

Project members: Norberto Ezquerro (PI), John Peifer, and faculty members from Emory University.

Sponsors: National Institute of Health (NIH), Emory-Georgia Tech Biomedical Technology Research Center (E-GT BTR Center)

Interactive Real-time Manipulation and Visualization of 3-D Cardiac Magnetic Resonance Images

Magnetic Resonance Imaging allows the capture of the structural characteristics of dynamic organs such as the heart. A physician can acquire a set of cross-sectional images along any axis of the heart as well as over the cardiac cycle. The resultant set of images is too large for a clinician to view sequentially and fuse mentally into a three-dimensional dynamic structure. This work involves the design of computer graphic tools to visualize large sets of cardiac data. Our approach is to perform a lossless transformation of the Cardiac MRI images into graphical objects in order to manipulate and display them in a virtual 3D space. Cross-sectional images are processed to remove all data extraneous to heart muscle. The images are displayed and oriented so that they are a true representation of the sampled organ. The representation is animated by looping through the set of images taken over the cardiac cycle. This base of functionality is augmented with graphical display and manipulation techniques such as stereoscopic display and virtual manipulation devices. We believe that this work will result in the creation of useful tools for structuring and visualizing large amounts of detailed physiological data.

Project Members: Larry Hodges, Yves Jean, Steve Adelson, Roderic Pettigrew (Emory Medical School)

Sponsor: NSF

Model-Based Vision in Medical Imaging

The model-based vision paradigm has shown to be one of the most promising approaches for solving problems involving the analysis and understanding of complex imagery. The approach emphasizes the use of explicit object, sensor, and phenomenological models to

aid in these tasks. Efforts are under way to develop model-based strategies to represent, recognize, and interpret static and dynamic (motion) imagery; emphasis is placed on the use of hierarchical data structures and groupings, semantic networks, structural and causal knowledge, and geometric and temporal models to guide low-level vision operations. At present, the anatomical and physiological information contained in images of the beating heart are being investigated to analyze, characterize, and interpret structure and function using coronary cineangiography. In another project, the structural and dynamical properties of mandibular joints are being studied using magnetic resonance imaging.

Project Members: Daryl Lawton, Norberto Ezquerra, and members of Emory University School of Medicine.

Sponsors: Georgia Tech Bioengineering Center and NIH

Knowledge-Based Interpretation of Medical Images

Knowledge-based approaches to medical decision-making have usually involved diagnostic problems of a textual nature. In this research program, however, the emphasis is placed on visual rather than purely numeric or textual information, involving the diagnosis of heart disease using cardiovascular nuclear medicine images. The objective of this research is to develop a methodology to assist in decision-making tasks associated with interpreting these images, emphasizing the development and implementation of methods for processing visual data, reasoning with uncertainty, representing medical knowledge symbolically, and inferring structural information from physiological function. An object-oriented approach is used, coupled with rule- and frame-based representation methods. User-interaction issues are also investigated in order to allow the knowledge-based system to not only provide decision support, but also to play a more comprehensive consultative and tutorial role in the overall decision-making process.

Project Members: Norberto Ezquerra (PI), Rakesh Mullick, Victor Maojo, Fernando Martin, and Emory University researchers.

Sponsor: NIH

Visualization of Medical Imagery

Biomedical structures and functions are complex, dynamic systems that are sometimes difficult to understand geometrically even when studied through scanning or imaging systems. To this end, research efforts are directed toward developing and exploring visualization techniques to facilitate the understanding of such structures and functions. The overall objective is to develop a unified methodology that can accept as input data that are discrete, noisy, and sparse, and provide an architecture that can support interactive visual displays as well as higher-level interpretive processes. This methodology incorporates elements of: (a) low-level vision for extracting salient features from imagery and reconstructing 3D geometric models from limited views; (b) interactive graphics and visualization methods for rendering manipulable models of structures and functions of interest; and (c) animation techniques to visualize dynamic processes. Current efforts are aimed at realizing this methodology with medical imagery.

Project Members: Norberto Ezquerra (PI), John Peifer, and Emory University researchers

Sponsors: NIH and E-GT BTR Center

Visual Reasoning in Diagnostic Radiology

This project explores the decision-making processes employed by humans to detect, recognize, and diagnose possible diseases in chest X-rays. The goal is to investigate the interrelationships between models of visual perception on one hand, and models of problem solving on the other, in order to construct a model of visual reasoning that may aid in understanding the decision-making process employed by experienced radiologists. As the model is constructed, increasing emphasis will be placed on developing a computational model that will serve to highlight, guide, or extract the salient visual information in the images with dynamic interaction with the user. The computational model will be implemented in a fully interactive fashion such that it can guide inexperienced (or less experienced) radiologists in the visual decision-making process.

Project Members: Ron Arkin, Erika Rogers, Norberto Ezquerro; in collaboration with members of the Radiology Department of Emory University.
Sponsor: E-GT BTR Center

Connectionist Approaches to Medical Image Processing

In many instances, prior knowledge is not available concerning the specific contents and meaning of an image. However, certain constraints and expectations may guide the interpretation of such imagery. Connectionist techniques may be a useful paradigm for understanding this type of image information, where artificial neural network (ANN) models may be explored for discovering patterns inherent in the imagery. Initial investigations center on seeking ANN models to not only classify patterns in medical images, but to predict new images as output. One eventual goal is to interpret and relate connectionist models with respect to explicit knowledge representation models. Preliminary results have been obtained with cardiovascular nuclear medicine images to predict heart functions.

Project Members: Norberto Ezquerro (PI), Alejandro Pazos, Fernando Martin and Victor Maojo (visiting postdoctoral fellows)
Sponsors: Georgia Tech Bioengineering Center; Government of Spain; and Junta de Galicia (Spain)

B.6. Multimedia and Collaborative Work

Multimedia On-line Help

A previous UIDE related predecessor of this project is Cartoonist, a system which provides an automatic support of runtime context-sensitive animated help dynamically generated from UIDE representations. One of the purposes of the multimedia help project is to combine this kind of help with speech audio narrating animated help, and to test the utility of this form of multimedia help.

The main objective of this project is to investigate the effectiveness of various mappings from help information to different multimedia presentation configurations. Applying human information processing theory and human factor principles, the information-media mappings in the study are selected to maximize the information transfer from help presentation to users. A combination of text, static graphics, speech audio, video, and context-sensitive animation are being investigated as media for help presentation; specific information types studied include definitive, procedural, and troubleshooting. A prototype multimedia help system is implemented as part of the project using UIDE representations and a part of Cartoonist's architecture. The results of this study can be used as guidelines to multimedia presentations, specifically in the context of on-line help.

Project Members: Noi Sukaviriya, Krishna Bharat, Ray Johnson, Jim Foley
Sponsor: Sun Microsystems, Inc.

Systems Technology for Building a National Collaboratory

This project, conducted jointly with researchers at the University of Arizona, involves exploration and development of the computer systems technology necessary to build a nationwide information infrastructure for scientific communities (e.g. the development of "collaboratories"). As a testbed system, a mini-collaboratory is currently being developed.

This system will consist of an abstract information space through which scientists can interact with a variety of resources, including scientific data, information, computers, instruments, and colleagues. The information space will be a persistent and distributed object system that provides uniform and transparent access to resources, hiding their physical representation and location in the network. The user interface to this information space will enable scientists to browse through the available resources, analyze information they find, group related information, and update the information space with new resources.

Project Members: Scott Hudson
Sponsor: NSF

Multimedia Electronic Mail

Montage is an extensible multimedia electronic mail system. Unlike text-based electronic mail systems, Montage allows users to exchange ideas by communicating in the media types which are most meaningful. Montage runs on any Unix workstation which supports the X Window System, and supports interchange of complex multimedia compound documents consisting of text, audio, video, spreadsheet data, and so on. Further, the system allows annotations to be attached to messages, and these annotations may themselves be of any media type. A key element of Montage is its extensibility. Montage supports documents created by virtually any word processor, spreadsheet, database, editor,

or other application, including popular software such as Lotus, WordPerfect, Interleaf, and Framemaker. Montage also allows users to mail executable programs and their data. Users may also easily incorporate their own custom media types into the system. Many important research issues remain. We plan on exploring more fully the integration of live video into complex documents, and the storage and requirements of such high-bandwidth media.

Project Members: Bill Putnam, Keith Edwards, Tom Rodriguez
Sponsor: BellSouth, Advanced Technology Development Center

A Shared Window System with Voice-Over-LAN for Collaborative Work

A truly useful general-purpose collaborative environment demands that existing single-user applications be made accessible to collaborative efforts without modification. In addition, such a collaborative environment should be accessible on many types of platforms, and groups working within the environment should be able to interact in a manner which is suitable to the task and to the group. The Virtual X environment provides a mechanism for the collaborative use of unmodified X applications in a heterogeneous network of workstations. With such a system many users would be able to use any of their existing tools and applications to work together at the same time to produce a single result. With applications which were originally written to be single-user applications it is necessary to provide a system of floor control to determine which user has control of the application at any given time. The methods of floor control vary widely depending on group dynamics, and the determination of what constitutes good floor control protocols is currently an open research issue. Virtual X is supplemented by the EtherTalk system, which we have developed to support real-time voice conferencing over IP-based local area networks. EtherTalk provides both two-way point-to-point and one-way multi-point conferencing. The integration of application sharing with voice teleconferencing should facilitate remote collaboration, and should also provide opportunities for experimentation on human interaction through a computer-supported collaboration.

Project Members: Bill Putnam, Beth Mynatt, Ian Smith
Sponsor: BellSouth

Workstation-Based Video Processing

As workstation compute-power and storage capacity increase it becomes possible to work with high-bandwidth media in ways that were previously impossible. We have been working to build a purely digital software-based video processing system. This system digitizes incoming video streams and then stores the captured video on-line for processing and displaying by the workstation's CPU. Our current experimental prototype allows us to display multiple full-motion video windows concurrently on a workstation's screen with no special hardware. Using such a system it becomes possible to cheaply distribute video data to inexpensive client machines without the requirement for additional specialized video hardware. We are also investigating network transmission of video data. Our current prototype can deliver a full-motion video stream across a standard ethernet without significant loss of information or delays. Using this software base we plan on building video applications such as video editors and video conferencing systems. As a future project we would like to incorporate our workstation-based video systems into our

collaborative work environment efforts so that coworkers would be able to see (as well as hear) each other.

Project Members: Bill Putnam, Tom Rodriguez
Sponsor: BellSouth

A Non-Visual Network Computing Interface

While multimedia computing can be used to enhance the interaction between users, it can also be used to make computing technology accessible to users with special needs and to give those users capabilities not now available. Ideally, those users should have the same systems, software, and functionality as other users in their work group and on their network. The Multimedia Computing Group is working with the Center for Rehabilitation Technology to develop a workstation environment for use by visually impaired persons. As computer interfaces grow more graphical in nature they become even harder for visually impaired persons to use. We are developing a completely new interface, called Mercator, that maps the graphical user interface to an auditory and tactile one. Mercator will provide a synthetic 3-D audio space in which the user can manipulate objects using a combination of voice input, speech recognition and synthesis, keyboard input, and pointer devices. The interface is being built on top of the X Window System, and will provide users with access to the same applications, resources, and networking capabilities that are available to sighted users. Our current research is focusing on three broad areas: analyzing the characteristics of what an audio-based user interface should be, exploring the semantic issues of audio-based applications, and developing toolkits for audio applications.

Project Members: Bill Putnam, Beth Mynatt, John Goldthwaite, Keith Edwards,
Tom Rodriguez, Dave Burgess, Scott Sheppard
Sponsor: NASA

Education and Hypermedia Systems

Hypermedia is generally defined as the nonlinear viewing and presentation of information, where the information can be text, images, video, sound, drawings, gestures. In a hypermedia system, a user can select information in an order he chooses. "Writing" or authoring in hypermedia involves significant new ideas in terms of knowledge representation and cognitive models of human understanding. We are exploring the incorporation of AI and image processing techniques into hypermedia systems.

Project Members: Daryl Lawton

A Toolkit for the Development of Multi-user Collaborative Applications

Traditionally, collaborative multi-user applications have been very difficult to construct. This project is concerned with identifying a set of abstractions which are common across many collaborative multiuser applications, and then embodying these abstractions in some form of toolkit or other programming system. These abstractions may include distribution of application data objects, multiple views on application objects, access control and security primitives, support for synchronization and sequencing among multiple input streams, and session management. One of the end goals of this research is the development of a cohesive programming model for constructing collaborative multi-user

applications. This work should have implications for the direction of both Distributed Objects Everywhere (DOE) and generic conferencing-related software.

Project Members: Keith Edwards, Dave Gedy (Sun), John Stasko
Sponsor: Sun Microsystems

B.7. Human-computer interaction

Interactive Skill Acquisition in Human-Computer Interaction

A goal of the user interface designer is to build an interface that is appropriate to the user's skill level in using the system. User skill fluctuates over time, and by taking this variation into account, the system can facilitate the learning process for the longitudinal user. There are two general strategies that the system may allow the user: recognition for novices and recall for experts. Either strategy may be appropriate for a user at any time as they recall and forget while using the system. An interface is referred to as "adaptive" if it is flexible enough to automatically support the varying user. Designing an adaptive interface requires an understanding of how a user learns interactive skills. An understanding of how to support users as they repeatedly make the transition back and forth between recall and forgetfulness is also necessary. There are many factors that may affect a user's acquisition of the necessary cognitive skills, such as: knowledge context, prompt types, modes of interaction, command naming, word selection, and task complexity. How the longitudinal user behaves under such conditions when making transitions from recognition to recall forms the focus of our research.

Project Members: Albert Badre, Jeanette Allen, Andrea Lawrence

Selecting and Representing Information Chunks for Visual Presentation

The objective of this research is to identify and apply experimental techniques for locating and evaluating data patterns and chunks which are meaningful to the user of interactive displays. The identification of meaningful chunks of information is useful in specifying criteria for the development of decision-aiding algorithms that search for, classify, and display information. A related objective of this work is to determine the significance of chunking in the design of sequentially presented information. Experiments have been conducted to investigate: (a) the effect on recall accuracy of the sequential displaying of information chunks, and (b) the effects on recall accuracy and chunking characteristics of information presented on a display which itself is viewed as a member of a sequence of displays. This work is currently being extended to investigate the chunking of action sequences in human-computer interaction.

Project members: Albert Badre, Jeanette Allen, Mariano Garcia

A Knowledge-based Monitor for Human Computer Interaction

Most interface builders available today provide support for a faster and easier development of an interface, compared to the effort required to produce an interface based exclusively on more traditional programming. One of the components that is missing from most user interface management systems is a semantic level monitor that permits the automatic collection and analysis of human computer interaction events at a semantic level of processing. The goal of this project is to build a monitoring system that has the following characteristics: (a) Allow for UIMS integration as well as data collection and analysis of interfaces that were not generated by the UIMS, and are not executed under the supervision of a UIMS; (b) Allow for the specification of the relevant part of the semantics of the

application outside of a UIMS; (c) Allow for remote monitoring of interface usage; (d) Allow for an open and user-selectable set of metrics; and (e) have the objective of collecting data on the behavior of the transitional user in adaptable system environments.

Project members: Albert Badre, Paulo Santos

A Cognitive Architecture for Human-Centered Automation on the Flight Deck

We have been developing models of the flight crew when they interact with modern "glass cockpit" airplanes (e.g., Boeing 757). Working closely with NASA Ames Research Center and Delta Air Lines, with additional help from United Airlines, we have been investigating piloting functions in realistic tasks associated with flying. Models of operator function are being used to design and implement intelligent, context-sensitive displays and decision aids. A major goal is the development of computer-based operator aids for mode and situational awareness under highly automated flight conditions. This research complements our previous work sponsored by ONR.

Project members: T. Govindaraj, Christine Mitchell, T. Callantine, E. Crowther, M. Palmer, J. Williams
Sponsor: NASA Ames Research Center

Supervisory Control in Automated Manufacturing Processes: The Design of Human-Computer Interaction for "Lights-Out Factories"

This research is focused on modeling modern, computer-integrated manufacturing systems, and using these models to develop object-oriented simulations. This research benefits from close cooperation with several manufacturing plants of companies who are members of the Computer Integrated Manufacturing Systems Program and the Material Handling Research Center. Combining the strengths of faculty from different specialties, we plan to develop modeling methodologies for manufacturing systems, implement simulations, and study human supervisory control issues and interactive optimization. This research also complements other research on building operator aids.

Project members: T. Govindaraj, L. McGinnis, Christine Mitchell, D. Bodner, S. Dilley, S. Narayanan, U. Sreekanth, G. Vidyamurthy
Sponsor: National Science Foundation and Material Handling Research Center

Modeling the Evolution of Expertise in the Operation of Complex Dynamic Systems

The major objective of the proposed research is the investigation and modeling of expertise and its evolution as an operator interacts with a complex dynamic system. Understanding the nature of expertise is crucial for the development of effective training programs and the design of computer-based intelligent operator associates. The function of the operator associate is to aid human operators during diagnostic problem solving, compensate for routine system failures, and help humans develop expertise necessary for novel problem solving during system operation. This research will build on our previous work sponsored by the Office of Naval Research during which we built an intelligent tutoring system (ITS) for a simulated marine power plant (Turbinia-Vyasa). In a series of experiments using

Naval ROTC cadets, we found that the tutor promoted an improvement in problem solving performance and a better understanding of the steam power plant.

Project Members: T. Govindaraj, Christine Mitchell

Simulated Exploratory Environments with Interactive Interfaces for Instruction

We are developing an architecture for the design and implementation of a simulated exploratory environment for instruction in science and engineering. Dynamic systems implemented on relatively inexpensive computers can make learning in many areas very exciting and fun. Instructional effectiveness in a variety of fields within science and engineering can be enhanced by the use of simulation-based exploratory environments in which knowledge and fundamental principles are represented in multiple, redundant forms that support various cognitive styles. A typical exploratory environment will be comprised of a variety of interdependent subsystems from behavioral, biological, and physical sciences and engineering. The simulated systems will be capable of providing stand-alone, participatory learning as well as enabling interactions that emphasize the interdependence between various systems. This research will exploit our experience and expertise in developing real time simulations of continuous (e.g., steam power plant) and discrete event dynamic systems (e.g., manufacturing systems) that incorporate graphical, direct manipulation interfaces and real time interaction and tutoring and training systems and on-line decision aids.

Project members: T. Govindaraj, Christine Mitchell

B.8. Image Compression

Fast Parallel Wavelet Transform

This project involves a new parallel iterated function system (IFS) algorithm for computing the discrete wavelet transform (DWT). Compactly supported wavelets are used in digital signal and picture processing as a new orthonormal basis for representing multi-scale phenomena. Applications include Galerkin methods for partial differential equations, and signal/image compression. Current research is focused on the implementation of the IFS algorithm for multi-dimensional wavelets, and the analysis of their regularity properties.

Project members: Marc Berger, Kevin Leeds, Richard Coleman
Sponsors: AFOSR

Image Compression

This project involves IFS surface interpolation as a means of image compression. IFS interpolation is a technique for constructing fractal surfaces passing through given data points. The target image is decimated and an IFS is built to interpolate these decimated points. The free scaling parameters in the IFS are determined by least-squares fits with the full (non-decimated) image data. This scheme is currently producing compression ratios from 10-200.

Project members: Marc Berger, Kevin Leeds, Juakin Anderson
Sponsors: AFOSR and NSF

Real-Time Generation and Live Transmission of High-Definition Digital Pictures

This project involves using compressed images to rapidly transmit images to a recording device. The PI has an optical recording system for laying down computer animations onto laser disk, and is working on fast algorithms to generate high-definition digital fractal pictures.

Project members: Marc Berger

Lossless Image Compression for Computer Animation Image Sequences

Current lossless image compression algorithms have very poor compression ratios. For scenes of high visual complexity a compression ratio of two is about all that can be expected. We are developing several new algorithms which will take advantage of temporal coherence, even for scenes of high visual complexity. The new algorithms take advantage of the perfect knowledge of object motion which is available in computer animation to perform very high quality motion prediction followed by entropy coding of image residuals. We expect compression ratios to be significantly higher than a factor of two.

Project Members: Brian Guenter

B.9 Image synthesis

Incorporating Psychophysical Models in Image Synthesis Algorithms

My research in computer image synthesis is centered on finding practical ways of applying the results of visual psychophysics research to image synthesis algorithms. Psychophysical characteristics of the human visual system have been used for several years in the image processing and image compression fields, but the application to graphics is new and fundamentally different. In a typical image compression application the starting point is an uncompressed image. The goal is to eliminate information which the human visual system is not especially sensitive to so that image storage can be reduced without seriously affecting image quality.

In image synthesis the goal is to reduce computation. This means that the image synthesis algorithm must somehow determine which information not to compute. Obviously this determination of what not to compute must be less time consuming than simply computing the entire image or nothing is gained. I have several graduate students working on image synthesis algorithms now which take advantage of various psychophysical properties of the human visual system. Here is a sample of the projects:

1. Efficient motion blur computation which takes advantage of the spatio-temporal response of the human visual system
2. Fast postprocessing antialiasing which takes advantage of visual hyperacuity
3. Temporal filtering for radiosity images to reduce temporal artifacts in animation sequences
4. Using the reduced diagonal resolution of the human visual system to reduce computation by approximately a factor of two

Project Members: Brian Guenter, Charlie Patterson, Jack Tumblin

Characterization and Generation of Camouflage Patterns

We are investigating the application of computer graphics modeling and image synthesis techniques to the development of spatial patterns on camouflage materials. This research involves the production of algorithms that will analyze and reproduce patterns resembling selected background scenes. The prime consideration here is to find shapes that are characteristic of the scene being analyzed and that can be generalized to all scenes of that basic type. These algorithms are then applied to camouflage generation. Generated patterns are evaluated as to their potential to blend into a wide range of selected backgrounds.

Project Members: Larry Hodges, Ergun Akleman, Albert Sheffer, Ted Doll
Sponsor: Teledyne Brown Engineering

C. GVV CENTER MEMBERS

FACULTY/RESEARCH FACULTY

Albert Badre
Marc Berger
Greg Corso
Elizabeth Davis
Norberto Ezquerro
James D. Foley
T. Govindaraj
Brian Guenter
Larry F. Hodges
Laurie B. Hodges
Scott Hudson
Daryl T. Lawton
Christine Mitchell
Elizabeth Mynatt
Bill Putnam
William Ribarsky
Walter Rodriguez
Ron Shonkwiler
Michael Sinclair
John Stasko
Piyawadee Sukaviriya
Mary Trauner
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POST-DOCTORAL RESEARCHERS

Victor Maojo, M.D. and Ph.D. in Computer Science
Fernando Martin, Ph.D. in Computer Science
Piyawadee Sukaviriya, Ph.D. in Computer Science

STUDENTS

Stephen Adelson -- Advisor: Larry Hodges
Research Area: Stereoscopic Computer Graphics Algorithms

Ergun Akleman -- Advisor: Larry Hodges
Research Area: A Unified Approach for Object Modeling

Jeanette Allen -- Advisor: Albert Badre
Research Area: Pictorial vs. Textual Representation for Programming Contracts

Juaquin Anderson -- Advisor: Marc Berger
Research Area: Fractals

D. Bodner -- Advisor: T. Govindaraj, L. F. McGinnis or Christine Mitchell
Research Area: Simulation, HCI, Optimization

Dave Burgess -- Advisor:
Research Area:

T. Callantine -- Advisor: T. Govindaraj or Christine Mitchell
Research Area: Simulation, Aviation, HCI, Human-Centered Automation

Richard Coleman -- Advisor: Marc Berger
Research Area: Fractals

E. Crowther -- Advisor: T. Govindaraj or Christine Mitchell
Research Area: Simulation, Aviation, HCI, Human-Centered Automation

Hans de Graaff -- Advisor: James D. Foley
Research Area: Dynamic Control of User Interface Widgets Using Pre- and Postconditions

S. Dilley -- Advisor: T. Govindaraj, L. F. McGinnis or Christine Mitchell
Research Area: Simulation, HCI, Optimization

Keith Edwards -- Advisor: John Stasko
Research Area: Adding Sound to User Interfaces

Martin Frank -- Advisor: James D. Foley
Research Area: Dynamic Control of User Interface Widgets Using Pre- and Postconditions

Mariano Garcia -- Advisor: Albert Badre
Research Area: Iconic Representations and Levels of Abstractness

Warren Gardner -- Advisor: Daryl Lawton
Research Area: Image Understanding

Geoff George -- Advisor: Brian Guenter
Research Area: Computer Animation

Mark Gray -- Advisor: James D. Foley
Research Area: Automatic Selection and Layout of Widgets using Open Look Styleguide Rules

J. David Hobbs -- Advisor: Daryl Lawton
Research Area: Multimedia

Eric Hyche -- Advisor: Daryl Lawton, Norberto Ezquerra
Research Area: Image Understanding

Yves Jean -- Advisor: Larry Hodges
Research Area: Interactive Real-time Manipulation and Visualization of Dynamic Three-Dimensional Magnetic Resonance Images

Ray Johnson -- Advisor: James D. Foley
Research Area: User-Computer Interface Software

Lina Karam -- Advisor: Bill Ribarsky
Research Area: Interactive Stereo Visualization

Srdjan Kovacevic -- Advisor: James D. Foley
Research Area: Compositional Model of Human-Computer Dialogues

Eileen Kraemer -- Advisor: John Stasko
Research Area: Visualization of Parallel Programs

Andrea Lawrence -- Advisor: Albert Badre
Research Area: Modular Problem Solving

Kevin Leeds -- Advisor: Marc Berger
Research Area: Fractals

Shane McWhorter -- Advisor: Larry Hodges
Research Area: Representation and Display Issues in Virtual Spaces

Donald Mead -- Advisor: Daryl Lawton
Research Area: Hypermedia

Robert Minsk (Undergraduate) -- Advisor: Bill Ribarsky
Research Area: Visualization of Complex, Multiparametric Data

Rakesh Mullick -- Advisor: Norberto Ezquerro
Research Area: 3D Medical Imaging

S. Narayanan -- Advisor: T. Govindaraj, L. F. McGinnis or Christine Mitchell
Research Area: Simulation, HCI, Optimization

M. Palmer -- Advisor: T. Govindaraj or Christine Mitchell
Research Area: Simulation, Aviation, HCI, Human-Centered Automation

Charles Patterson -- Advisor: Brian Guenter
Research Area: Radiosity

Tom Rodriguez (Undergraduate) -- Advisor:
Research Area:

Juan Carlos Santamaria -- Advisor: Daryl Lawton
Research Area: Learning and Vision

Paulo Santos -- Advisor: Albert Badre
Research Area: Knowledge Base Monitoring

Scott Sheppard (Undergraduate) -- Advisor:
Research Area:

Ian Smith -- Advisor:
Research Area: Shared and Migratory User Interfaces

U. Sreekanth -- Advisor: T. Govindaraj, L. F. McGinnis or Christine Mitchell
Research Area: Simulation, HCI, Optimization

Jack Tumblin -- Advisor: Brian Guenter
Research Area: Computer Animation, Psychophysics Image Synthesis

G. Vidyamurthy -- Advisor: T. Govindaraj or Christine Mitchell
Research Area: Simulation, Aviation, HCI, Human-Centered Automation

Ben Watson -- Advisor: Larry Hodges
Research Area: Stereoscopic Animation

Joe Wehrli -- Advisor: John Stasko
Research Area: Three-dimensional Software Visualization

J. Williams -- Advisor: T. Govindaraj or Christine Mitchell
Research Area: Simulation, Aviation, HCI, Human-Centered Automation

Wayne Wooten -- Advisor: Brian Guenter
Research Area: Computer Animation

Chang Zeng -- Advisor: Daryl Lawton
Research Area: Image Understanding

D. FACULTY PROFILES

ALBERT BADRE is an Associate Professor in the College of Computing and the School of Psychology at Georgia Tech. He received his Ph.D. from the University of Michigan in 1973. His teaching, research and professional experience in the fields of Computer Software Usability and Human Interface Design and Technology extend over a period of seventeen years. Dr. Badre's background combines expertise in the empirical methodologies of the behavioral sciences and the design approaches of the information and computer sciences. He is a frequent consultant and lecturer to the data processing and computer industry in the U.S., Europe, and South America in the area of Human Computer Interaction. Dr. Badre has been the principal investigator on numerous research projects and contracts in the areas of software usability and user interface design. Dr. Badre is the author of over thirty technical papers in the areas of human computer interaction, user interface design, and cognitive science. He is a co-editor of the book *Directions in Human/Computer Interaction*. He is presently at work on a second book, *Human-Computer Environments: Strategies For Effective Interaction*. (badre@cc.gatech.edu)

MARC BERGER is a Professor of Mathematics and a consultant for Westinghouse Electric and Pittsburgh Supercomputing Center. He earned his Ph.D. from Carnegie Mellon University. His interests include stochastic processes, image processing, wavelets and computer-aided geometric design. He is author of *Introduction to Probability and Stochastic Processes* (Springer-Verlag, 1991) and managing editor of the journal *Random and Computational Dynamics* (Marcel Dekker). He runs the Pittsburgh Supercomputing Center Summer Institute for training students in vectorization and use of the CRAY Y-MP. He has authored some 55 publications and is a member of the Society for Applied and Industrial Mathematics and the Institute for Mathematical Statistics. He has held visiting positions at the Hebrew University, the Weizmann Institute and Bar-Ilan University in Israel, and at Carnegie Mellon University. He is an active scientific reviewer. (berger@math.gatech.edu)

JAY D. BOLTER is a Professor in Georgia Tech's School of Literature, Communications and Culture. He is the author of a successful program for hypertext, which he is now extending to multimedia and hypermedia applications. His work with computers led to the publication, in 1984, of *Turing's Man: Western Culture in the Computer Age*, a book that was widely reviewed and translated into several foreign languages. Bolter has lectured at dozens of universities and colleges on hypertext and hypermedia as well as on the cultural impact of computers. Bolter's second book, *Writing Space: The Computer, Hypertext, and the History of Writing*, examines the computer as a new medium for symbolic communication. (jb121@prism.gatech.edu)

GREGORY M. CORSO received his Ph.D. in Engineering Psychology from New Mexico State University in 1978. He has been at Georgia Tech since 1978, except for the 1986 academic year when he was a visiting professor at the United States Military Academy. Currently, he is an Associate Professor of Psychology and the Associate Director of the School of Psychology at Georgia Tech. He also serves as Associate Director for Education in the GVU Center. He teaches graduate classes in human performance, displays & controls, and environmental stressors. His research has been supported by General Dynamics, the Air Force Office of Scientific Research, and the Office of Naval Research. He has been a consultant to The Institute of Simulation and Training, BellSouth, NCR, and Lockheed Corporation. Dr. Corso's primary research interests are in visual display coding, theories of human performance, the effects of auditory noise on human

performance, and adaptive automation. Dr. Corso is a member of the Human Factors Society, and Sigma Xi. (gc4@prism)

ELIZABETH THORPE DAVIS received her Ph.D. in Experimental Psychology from Columbia University in 1979, was awarded a Fannie and John Hertz Foundation Fellowship, and received her M.S. in Computer Science from Columbia in 1987. Beth was an Associate Professor at S.U.N.Y. State College of Optometry before coming to Georgia Tech, where she is an Associate Professor in the School of Psychology. Her research interests include processing of spatio-temporal visual patterns by humans, assessing visual function in patients, application of visual psychophysical models and techniques to research in computer graphics, virtual reality, and computer vision. She is a member of AAAS, APA, ARVO, OSA, Pi Mu Epsilon, Psychonomic Society, Sigma Xi, and WAS. (ed15@prism.gatech.edu)

NORBERTO EZQUERRA obtained his undergraduate degrees from the University of South Florida, and the doctorate degree from Florida State University. In 1978 he joined the research faculty at Georgia Tech, where he served as a Senior Research Scientist in the Office of Interdisciplinary Programs. He is now an Associate Professor in the College of Computing, an adjunct faculty member in the School of Electrical Engineering, and an adjunct professor in the Radiology Department at Emory University. His research interests include medical informatics, computer graphics and visualization, computer vision in medicine, artificial intelligence in medicine, and models of visual reasoning. Dr. Ezquerra has served as principal investigator in numerous research programs in medical informatics, particularly in the interpretation and visualization of multidimensional medical imagery. He received a FIRST award from the NIH for his work in interpreting cardiac images, participated in the 1990 NATO Advanced Research Workshop in Biomedical Computing, and chaired the 1990 Conference on Visualization in Biomedical Computing. He is a member of Assoc. Computing Machinery, Am. Assoc. for the Advancement of Science, Am. Medical Informatics Assoc, IEEE Comp. Soc., Sigma Xi, IEEE Eng. in Medicine Biology Soc, and Am. Physical Society. (nezquerr@cc.gatech.edu)

JAMES FOLEY is Professor of Computer Science and Director of the Graphics, Visualization, and Usability Center. He was previously Professor and Chairman of the Department of Electrical Engineering and Computer Science at The George Washington University. He earned his Ph.D. from the University of Michigan. His interests include user interfaces and interactive computer graphics; his current research focuses on building UIDE, the User Interface Design Environment. Recent research funding has been from NSF, NASA, Sun, and Siemens. He is co-author, with A. van Dam, of *Fundamentals of Interactive Computer Graphics*, and is also co-author, with van Dam, S. Feiner, and J. Hughes, of the recently-published *Computer Graphics: Principles and Practice*. Foley is a Fellow of the IEEE, holds memberships in ACM, IEEE, Human Factors Society, and Sigma Xi, and serves on the editorial boards of *Computers and Graphics* and *International Journal of Man-Machine Systems*. He is Editor-in-Chief for *ACM Transactions on Graphics*. (foley@cc.gatech.edu)

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University of Illinois at Urbana-Champaign in 1979. He has been at Georgia Tech since 1982, after spending three years on the faculty of the school of industrial engineering at Purdue. Govindaraj has been studying human-machine/computer interaction in engineered, complex, dynamic systems, with the goal of developing computer-based systems to assist the human operator. His current fields of interest include: computerized automation and manufacturing systems, human-machine/computer interaction, science and engineering education, intelligent computer assisted instruction, and artificial intelligence and cognitive science applications. (tg@chmsr.gatech.edu)

BRIAN GUENTER is an Assistant Professor of computer science at Georgia Institute of Technology. He received his Ph.D. in computer science from Ohio State University. His current research interests are in the development of very high level computer animation systems and incorporating psychophysical models in image synthesis algorithms. (guenter@cc.gatech.edu)

LARRY F. HODGES is an Assistant Professor in the College of Computing at Georgia Institute of Technology. He received his Ph.D. in computer engineering at North Carolina State University in 1988. He also holds a MS in computer science/engineering from NCSU and a BA with a double major in mathematics and physics from Elon College. His research and consulting interests are in computer graphics, stereoscopic display, virtual environments, and scientific visualization. He is a member of the ACM, IEEE-CS, SID, and SPIE. (larry@cc.gatech.edu)

LAURIE B. HODGES is a Research Scientist in the Electro-Optics Laboratory of the Georgia Tech Research Institute. She received her Ph.D. in Information and Computer Science from the Georgia Institute of Technology in 1987. Before joining GTRI, she was an Assistant Professor of computer science at George Washington University and a Member of Technical Staff in the Computer Graphics and Interactive Media Research Group at Bellcore in Morristown, NJ. Her research interests include data and information visualization, natural phenomena modeling, fractal modeling, and computer animation. (laurie@bismarck.gatech.edu)

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KENNETH KNOESPEL

DARYL T. LAWTON is an Associate Professor in the College of Computing at the Georgia Institute of Technology and a Senior Research Scientist in the Image Processing Branch of the Electro-Optics Division of GTRI. His recent work is concerned with model-based vision systems, mobile robotics, dynamic image analysis, and software environments for image understanding research, hypermedia, and biomedical imaging. He

received the Ph.D. in Information and Computer Science from the University of Massachusetts at Amherst in 1984. He was a post doctoral fellow at the Computer and Information Science Department at the University of Massachusetts, working in motion processing and the realization of image processing on content addressable, parallel processors. He was a Principal Research Scientist and Program Manager in Robot Vision Technology at Advanced Decision Systems in Mountain View, California. He has been a principal investigator on research and development projects for agencies such as DARPA, ETL, HEL, and NASA. (lawton@cc.gatech.edu)

PETER McGUIRE, Ph.D., is an Associate Professor in Georgia Tech's School of Literature, Communication and Culture. A specialist in communication technology, he is co-author and co-editor of three communication texts, and numerous papers on communications and multimedia. At Georgia Tech, he teaches courses in basic and advanced multimedia design and the use of multimedia in documentation. (pm2@prism.gatech.edu)

STUART MOULTHROP is an Assistant Professor in Georgia Tech's School of Literature, Communication and Culture. He has done award-winning research on hypermedia in education, authored numerous articles on electronic text design, and developed various multimedia arts projects. He has lectured and presented both to the information industry and to academic groups. In 1989, his multimedia interactive

ELIZABETH MYNATT is a Research Scientist I employed by the College of Computing. Her areas of interest include human-computer interfaces, programming environments, object-oriented design, and computer supported education. She is currently serving as a principal investigator in the development of a non-visual X Windows interface for visually-disabled users of UNIX workstations. Beth is also overseeing the work of graduate and undergraduate students in the Multimedia Computing Lab of the Gvu Center. (beth@cc.gatech.edu)

BILL PUTNAM is a Research Scientist II in the College of Computing at the Georgia Institute of Technology. He received his MS in Computer Science at Georgia Tech in 1984. Mr. Putnam's research interests include multimedia computing, workstation teleconferencing, shared window systems, and human-computer interfaces. His recent projects include the development of an OSI/GOSIP compliant heterogeneous network testbed for use by the US Army Information Systems Command in evaluating open systems technologies, the development of a non-visual computer interface for X workstations, a multimedia electronic mail and conferencing system, and a computer system to support the teaching of ethics to undergraduate students. (putnam@cc.gatech.edu)

WILLIAM RIBARSKY is Senior Research Scientist and Manager of the Scientific Visualization Lab (a lab supported by the Office of Information Technology and located in the Gvu Center). Dr. Ribarsky is an expert in both interactive graphics and molecular dynamics (MD) and is an extensive user of supercomputers for large scale MD simulations. (He has received grants totaling over 3500 hours from the NSF-sponsored Pittsburgh Supercomputing Center.) He is also principal investigator on an NSF grant establishing an NSFnet backbone node at Georgia Tech. Among his research interests are the control and visualization of computations in large-scale (including wide-area) networked environments.

He also is developing new interactive visualization methods for representing and analyzing large scale, multiparametric datasets. (ccsupwr@hydra.gatech.edu)

MICHAEL SINCLAIR is a Senior Research Engineer and Technical Director of the Georgia Tech Multimedia Technology Laboratory, where he provided management and hardware design for the Olympic multimedia presentations. He has designed real-time flight and gunnery simulators and integrated circuits for video processing. He also holds a patent in 3-D graphics displays. (msinclair@gtri01.gatech.edu)

JOHN STASKO is an Assistant Professor of Computer Science in the College of Computing at the Georgia Institute of Technology. He earned his Ph.D. degree at Brown University in Providence, Rhode Island, where he developed the TANGO algorithm animation system. His research interests are program visualization, user interfaces, and programming environments. Specifically, he is interested in examining how visualization and animation can be added to software environments in order to make systems more informative and easier-to-use. Stasko is a member of the IEEE Computer Society, ACM, and SIGCHI. (stasko@cc.gatech.edu)

PIYAWADEE SUKAVIRIYA, often called "Noi", joined the Gvu Center in July 1991 as a post-doctoral research fellow in the College of Computing at Georgia Tech. She earned her doctoral degree from The George Washington University. Her dissertation work was on designing an architecture which supports the automatic generation of context-sensitive animated help from a user interface representation. Her interests are in user interface software tools, automated design and run-time user interface support tools, help system architecture, multimedia help, use of animation in user interfaces and visualization, application of AI techniques to user interface tools, and international user interfaces. She is a member of IEEE, ACM, and SIGCHI. (noi@cc.gatech.edu)

MARY TRAUNER is the Associate Director of Client Services, Information Technology, at Georgia Institute of Technology. She received a BA Degree from Indiana University in 1972 with a double major in Mathematics and Computer Science, and a Masters of Science in Information and Computer Sciences from Georgia Tech in 1979. She started working at Georgia Tech in 1975 and assists faculty and students in the academic and research use of high performance computing facilities. As a Senior Research Scientist, she assists in preparing proposals for improving campus computing facilities. In addition, Mary is working toward an advanced degree in Earth and Atmospheric Sciences. (mt7@hydra.gatech.edu)

NEFF WALKER earned his Ph.D. degree in Cognitive Psychology from Columbia University in 1983. Since then, he has been an assistant professor at the American University of Beirut and a visiting assistant professor at the University of Michigan. He is currently an Assistant Professor in the School of Psychology at Georgia Institute of Technology. His research interests include movement control, computer-based tutorial systems to promote the acquisition of basic skills, and interpreting graphical representations. (pswkrnw@prism.gatech.edu)

E. COMPUTING FACILITIES

The Graphics, Visualization and Usability Center utilizes the Scientific Visualization Lab, which contains the following hardware and software:

- Silicon Graphics
 - 4D/120GTX (two)
 - 4D/35GTX
 - 4D/25
 - 4D/50GTX
 - 4D/220GTX
 - 4D/240 (four processors)
- Macintosh II
- DECstation
- Tektronix Stereoscopic Shutter
- StereoGraphics CEI-1 CrystalEyes Stereoscopic Viewing System
- 3-D TV Stereoscopic Viewing System
- Head-mounted display
- Scanmaster III by Howtek
- DUNN Camera
- Video Equipment
 - Sony 25" Color Monitor
 - Sony LVR-5000 Video Disk Recorder
 - Sony LVS-5000 Processor
 - Sony LVM Optical Disk
 - JVC BR-7000US VHS VCR
 - Sony CCD-F50 8MM Camcorder

Software Package	Computer	Function
GEMM	SGI	Molecular modeling
Renderman	SGI	Rendering
Plot3D	SGI	Fluid dynamics and flow
Personal Visualizer	SGI	Modeling and rendering
Advanced Visualizer	SGI	Modeling, rendering, animation
Explore	SGI	Modeling, rendering, animation
NeoVisuals	SGI	Geom. modelling, animation
apE Software	SGI, Sun	Data visualization
BrlCad	SGI	Solid modeling system
RIP	SGI	Postprocessor for Plot3D
Utah Raster kit	SGI	Raster image manipulation
IM Raster Toolkit	SGI	Image manipulation
DI-3000	SGI	Graphics subroutine library
SunVision	Sun	Data visualization
ART	Sun	Expert system shell
AVS	DECstation	Data visualization
Iris Explorer	SGI	Object-oriented data analysis and visualization
AVS	DEC	Object-oriented data analysis and visualization
TDI Explore	SGI	Modeling, rendering, animation

The User Interface Laboratory includes the following equipment:

- Sun Monochrome SPARCstation 2
- Sun Monochrome SPARCstation 2, 48 MByte RAM
- Sun Monochrome SPARCstation 2, 32 MByte RAM, 2.6 GByte Disk
- Sun Color SPARCstation 2 (three)
- Sun Monochrome 4/280 SPARCsystem, 64MByte RAM, 1.6 GByte Disk

The Image Understanding Laboratory has the following equipment:

- Sun SparcStation 370
- NeXT Machine

and plans to purchase in the near future:

- Several CCD Cameras
- Two Sun Sparc IIs
- Another NeXT or a Silicon Graphics workstation

The Animation Laboratory uses video and audio equipment for the production of computer animation and computer animation research. Equipment consists of:

- Sun Sparcserver 4/370 24 bit color workstation, 32 MByte RAM, 1.6 GByte disk
- Sun Sparcstation SLC with 12 MByte RAM
- DAT tape backup unit, 1.2 GByte storage per tape
- Parallax video card (Digitizes video in real time and displays it on a window on the Sun workstation)
- Sound Tools digital audio system (CD quality audio with SMPTE synchronization MacII to control the digital sound system.
- SampleCell MIDI sampler (CD quality sound output)
- 16 channel mixer, power amplifier, monitor speakers and a few other pieces of audio equipment.
- 2 Panasonic MII component video recorders and associated video controller for doing single frame animation.

The Medical Informatics Laboratory is an interdisciplinary resource devoted to supporting research in the areas of computer graphics in medicine, biomedical visualization, medical imaging, computer vision in medicine, and artificial intelligence in medicine. It consists of:

- Sun 3/260 Workstation, 16MByte RAM, 700 MByte disk
- PIXAR Image Computer
- Tektronix 4017
- 3/4" video recorder
- 1/2" video recorder

The Multimedia Laboratory equipment consists of:

- 1 Sun SPARCstation 1
- 1 Sun SPARCstation 2 with VideoPix board and CD-ROM (arriving Fall 1991)
- 1 NeXT machine
- 1 MicroVAX with Parallax video board
- Audio equipment including microphones, speakers, equalizer, and amplifier

F. ACADEMIC COURSES

The following courses which are relevant to Graphics, Visualization and Usability, are offered at Georgia Tech. Faculty who frequently teach the course are indicated in parentheses.

CS 4390 Introduction to Computer Graphics

This course is an undergraduate introduction to computer graphics hardware and software algorithms. Topics covered include: raster graphics hardware, generation of lines and curves, polygon definition and representation, 2-D and 3-D transformations, specification of windows and viewports, and clipping polygons (Guenter, Hodges, Stasko).

CS 4391 Advanced Techniques in Computer Graphics

A continuation of the topics covered in 4390, with an emphasis on three-dimensional computer graphics. Topics covered include: 3-D display mathematics, projections, hidden surface elimination, illumination models, and ray tracing (Hodges).

CS 4753 Human Factors in Software Development

Examines human factors in the software design and application process from initial requirements to testing and implementation, with emphasis on designing the user interface (Badre).

CS 6363 Pattern Recognition

Basic principles and methods of statistical pattern recognition in machine vision; decision functions; pattern classifications by distance and likelihood functions; trainable pattern classifiers; feature extraction

CS 6490 Computer Graphics

An introductory course in computer graphics for graduate students. This course provides a thorough overview of hardware and software issues for design and implementation of computer graphics algorithms. Topics covered include 2-D and 3-D transformations, computer graphics hardware, line and polygon algorithms, transformations, clipping, hidden surface removal, illumination models, and ray tracing (Foley, Guenter, Hodges).

CS 6491 Advanced Computer Graphics

This course will provide a detailed introduction to image synthesis algorithms. Students will learn basic and advanced image synthesis techniques and program complete image synthesis algorithms. Topics to be covered: hidden surface algorithms, scan conversion, texture mapping, bump mapping, shading models, antialiasing, motion blur, image processing techniques as they apply to computer graphics (Guenter).

CS 6751 Human-Computer Interface

Human-computer interface is considered in terms of user-system compatibility. Concepts in human factors and interface design are covered in relation to capabilities and limitations of both humans and computers (Badre).

CS 8113 Low Level Computer Vision, CS 8113 High Level Computer Vision

This is a two part sequence on computer vision and machine perception in general. The first course deals with techniques and representations for the extraction of symbolic and environmental information from images. The second course, High Level Computer Vision, deals with the recognition and matching of models and how to build autonomous vision systems. Topics in the first course will include a discussion of several different paradigms in computer vision; image formation and sensors; contour and region

segmentation; depth recovery from stereo, motion, texture, and perspective; symbolic representation of shape; machine architectures for low level machine vision; and processes for perceptual organization (Lawton).

CS 8113 Hypermedia

Hypermedia is generally defined as the nonlinear viewing and presentation of information, where the information can be text, images, video, sound, drawings, gestures. In a hypermedia system, a user can select information in an order he chooses. "Writing" or authoring in hypermedia involves significant new ideas in terms of knowledge representation and cognitive models of human understanding. In this course we will begin with the history and impact of hypermedia and the current and future hardware which will support it. We will then examine existing hypermedia authoring systems, advanced user interfaces and explore topics related to representation of information for knowledge navigation, developing hypermedia based tutoring systems, and the incorporation of AI and image processing techniques into hypermedia. There will be an associated laboratory and students will be required to work on a new or existing project, individually or in teams (Lawton).

CS 8113 Visualization in Programming

Program visualization is the use of graphics to illustrate computer algorithm programs and their methodologies. This course introduces students to current research in program visualization and other closely related research areas. Selected topics include program and algorithm animation, data structure display, graphical debugging, visualization in software development, visualizing parallel programs, graphical user interfaces, languages for graphics, visual programming, and innovative visual environments. In class, we discuss recent research projects and publications. Students also get hands-on experience developing these types of systems (Stasko).

CS 8113 User Interface System Design

This course examines user interfaces from the system design and implementation point of view. We study current window systems and user interface development tools and their methodologies, analyzing each's strengths and weaknesses. Selected topics include window systems, user interface toolkits, user interface management systems, graphical user interface development tools, X11 and NeWS, and look-and-feel arguments. Students will read selected recent research publications and develop programs under a variety of user interface design paradigms (Stasko).

CS 8113H Visualization Techniques in Science and Engineering

This course is an introduction to computer graphics rendering and display techniques that may be used for visualization of data in science and engineering applications. The course will be divided into three basic sections. The first section consists of a broad overview of basic surface and volumetric rendering techniques (4 wks). This is followed by more detailed discussion of visualization tools such as animation, use of color, 3-D displays, and filtering techniques (4 wks). Case studies that present application problems which use these techniques in representative fields such as bioengineering, medical imaging, mathematics, and molecular modeling will constitute the last section of the course (2 wks) (Hodges).

ARCH 4521 Multimedia Studio I, II

Studio instruction in the visual arts with a concentration on experimental graphics utilizing numerous techniques, ranging from air brush and lithography to video.

EE834X Medical Imaging Systems

The objective of this course is to study the principles of medical imaging systems in terms familiar to the electrical engineer, such as the impulse response, the transfer function, and the signal-to-noise ratio. X-ray, ultrasound, nuclear medicine, and nuclear magnetic resonance imaging systems will be examined in detail. Sufficient underlying physics is presented in each imaging modality so that the system model can be developed logically.

EE6418 Digital Image Processing

An introduction to image processing fundamentals. Major topics include image compression, picture enhancement, image restoration and segmentation

ISYE 6205 Cognitive Engineering

The application of existing cognitive science concepts in system design, and the development of concepts appropriate for understanding and aiding cognition in naturally or technologically complex environments.

ISYE 6214 Models of Interactive Computer Interfaces

Models that predict and describe human behavior on interactive computer interfaces are covered. A common theme among course topics is modeling users with mechanisms. These mechanisms include optimum seeking, formal grammars, internal device models, task analyses, and human information processing

ISYE 6215 Models of Human-Machine Interaction

The development and use of mathematical models of human behavior are considered. Approaches to modeling that are discussed include estimation theory, control theory, queueing theory, fuzzy set theory, rule-based models, pattern recognition, and Markov processes. Applications considered include flight management, air traffic control, process monitoring and control, failure detection and diagnosis, and human-computer interaction

ISYE 6219 Human Factors Engineering

Application of cognitive engineering principles and knowledge of human capabilities and limitations in the design of human-machine interfaces.

ISYE 6400 Design of Experiments I

Analysis and application of standard experimental designs, including factorials, randomized block, latin squares, confounding and fractional replication multiple comparisons, and an introduction to response surfaces

ISYE 6845 Effective Use of Interactive Computer Graphics

Proper use of color, shapes, and text to develop good graphical interfaces are taught. Human performance considerations, including appropriate perceptual and cognitive aspects, are considered

MATH 6300 Fractal Geometry

Introduction to fractal geometry and applications to science and engineering. Notions developed include metric spaces, iterated function systems and fractal dimensions

NURBS, the definition of surfaces using lofting, sweeping and tensor product patches, and the definition of solids using boundary representations and constructive solid geometry. Assignments expose the student to many levels of geometric representation -- beginning with theoretical derivations and proceeding to the development of programs to generate and display geometries. (Rushmeier)

PSY 4407 Experimental Psychology I

An introduction to psychological measurements and laboratory techniques used in the experimental study of topics such as sensory processes, perception, psychomotor performance, and learning.

PSY 4409 Introduction to Engineering Psychology

Engineering psychology is presented as an integral component in the design and evaluation of human/machine systems. applied problems and general methodological questions are examined.

PSY 4411 Experimental Psychology II

Consideration of principles and research methods in the areas of learning and motivation, with special emphasis on classical and operant conditioning of nonhuman animals

PSY 6012 Cognitive Psychology

A survey of the core areas of human cognition: attention, memory, language, representation of knowledge, thinking, reasoning, problem solving, decision making. History, theoretical issues and methods are also addressed

PSY 6014 Sensation and Perception

An examination of human experience which results from stimulation of the senses. Topics treated include: psychophysics, sensory processes, and how we perceive "that out there"

PSY 6602 Applied Experimental Psychology

Consideration of the application of the methods and data of experimental psychology to the problems of man and the environment, emphasizing the engineering psychology approach.

PSY 6611 Quantitative Methods in Psychology I

A survey of quantitative methods in psychology used in the design of psychological experiments and studies and used in the analysis of psychological data

PSY 6612 Quantitative Methods in Psychology II

A coverage of the theoretical and applied aspects of regression/correlation procedures in the analysis of psychological data

PSY 6613 Quantitative Methods in Psychology III

Coverage of experimental design and the use of analysis of variance procedures in the analysis of experimental data in psychology

PSY 6627 Human Learning

A comprehensive consideration of principles, problems, methods and experimental data in the study of human learning, including discussion of applications of theory and experimental findings

PSY 7012 Seminar in Engineering Psychology

Critical examination of current problems in a selected area of engineering psychology. The area to be discussed may vary each time the course is offered

PSY 7020 Advanced Learning

An advanced and systematic examination of selected topics dealing with the experimental psychology of learning and memory. Theoretical approaches to learning, transfer and retention will be discussed

PSY 7021 Sensation and Perception

An examination of human interpretation of physical stimulation. The student studies in some detail the nature of perceptual processes, including human sensory processes

PSY 7022 Vision

An advanced examination of the visual processes and the fundamental role they play in human behavior. Emphasis is placed upon objectively obtained data

TEX 4503 Science of Color

The physical, chemical and biological principles involved in perception, measurement and specifications of color

G. SHORT COURSES

These short courses are offered by GVV Center faculty via the Division of Continuing Education. They offer CEU credits.

Computer Vision

This course is organized into two parts. The first part deals with image processing and techniques and representations for extracting symbolic and environmental information from images. Topics will include an overview of different paradigms in computer vision; image formation and sensors; contour and region segmentation; depth recovery from stereo, motion, texture, and perspective; symbolic representation of shape; machine architectures for low level machine vision; and processes for perceptual organization. The second part deals with the recognition and matching of models and architectures for autonomous vision systems. Topics include matching, 3D object representations, hypothesis management, and control.

Design Approaches, Prototyping and Testing User Interfaces

The design process, and application of design principles to the design process. User interface prototyping and development tools. Top-down and bottom-up design strategies. Levels of design: conceptual, functional, sequencing, hardware binding. User interface evaluation methodologies, and the role of rapid prototyping. User interface development software: interactive design tools, user interface management systems, help tools. Students will visit the fully-equipped user interface testing lab of the Graphics, Visualization, and Usability Center. They will participate in a testing session, both as subjects and as testers.

Designing User Interfaces

This is a two-day intensive course in the guidelines and concepts of designing the user/computer interface and interaction strategies. Participants will learn how to design usable display screens and user interfaces. Emphasis is placed on techniques and guidelines to design and critique different types of screens, transaction codes, types of interaction, and help strategies. The course will include lectures, team projects, usability critique of selected material, and examples of interface components that are designed for usability. Participants are encouraged (but not required) to bring material from current or past development projects for critique during the course.

Hypermedia

Hypermedia is generally defined as the nonlinear viewing and presentation of information, where the information can be text, images, video, sound, drawings, gestures. In a hypermedia system, a user can select information in an order he chooses. "Writing" or authoring in hypermedia involves significant new ideas in terms of knowledge representation and cognitive models of human understanding. In this course we will begin with the history and impact of hypermedia and the current and future hardware which will support it. We will then examine existing hypermedia authoring systems, advanced user interfaces and explore topics related to representation of information for knowledge navigation, support for collaborative work, developing hypermedia based tutoring systems, and the incorporation of Artificial Intelligence techniques into hypermedia.

Introduction to Computer Graphics

The course will begin with a broad overview of the state-of-the-art in graphics technology and techniques. First we will introduce the major techniques of computer graphics with each technique illustrated with a series of color slides. Concepts which will be presented will include basic two-dimensional techniques and advanced three-dimensional imaging concepts such as hidden surface removal, illumination models, fractals, transparency and

translucency. After this introduction of graphics concepts we will discuss computer graphics hardware architecture as seen from the viewpoint of a programmer or user. After this extended introduction we cover, in detail, the primary algorithms and operations which are needed to implement two and three-dimensional raster graphics systems. In particular algorithms will be developed and discussed for transformations, windowing and 3D projections. The final part will be devoted to discussing advanced topics in three-dimensional graphics including hidden surface removal, illumination models, use of color and ray tracing. The course will be conducted in an informal atmosphere which encourages discussion and questions. Advanced topics covered during the final day of the course will depend, in part, on the interests of the attendees.

Practical and Theoretical Issues in Scientific and Engineering Visualization

This first part of the course consists of an introduction to computer graphics rendering and display techniques that may be used for visualization of data in science and engineering applications. This will include detailed discussion and demonstrations of visualization tools such as animation, effective use of color, stereoscopic display, and filtering techniques.

The second half of the course will deal with practical issues such as:

- Why is visualization so important and why will its importance increase
- What can we expect during the next 5 years in high performance computing, in networking, in graphics and image processing capability?
- What will be rapidly growing areas during the next 5 years needing visualization and image processing capabilities?
- How can a scientific and engineering visualization lab (hardware and software) be set up without breaking the budget?
- Can we get someone to run and/or use the lab after it's set up? (user-friendly software and training)
- What visualization techniques and applications are currently available? (a survey)
- What techniques will it pay off to develop? (a discussion of a few key areas)

Case studies that present application problems which illustrate these techniques in engineering, medical imaging, and the physical sciences will be presented in each part of the course.

X11 Window System Programming

The course will provide an in-depth examination of X11 Window System Programming. We will begin by examining the X11 programming paradigm and system model. Important topics here are X's network transparency and the client-server model. Next, we will focus on Xlib programming, in particular, the use of windows, graphics contexts, text, color, input and events. Following Xlib, we will discuss the X Toolkit, a higher-level interaction model. Important topics within the X Toolkit are the use of resources, the XT Intrinsics, callbacks, and using widgets. We will focus on the Motif widget set, in particular, and describe the available widgets and how to interact with them. Finally, we will survey other widget sets and toolkits, such as OpenLook, and discuss the merits of each. We will examine how graphical user interface builders utilize these and other X11-based tools. The course will include many X11 code excerpts, to help foster learning by example.

H. RECENT GROUP PUBLICATIONS (affiliated members in bold type)

Books

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J. Foley, A. van Dam, *Fundamentals of Interactive Computer Graphics*, Addison-Wesley (IBM Systems Programming Series), Reading, MA, 664 pp., 1982.

J. Foley, A. van Dam, S. Feiner, J. Hughes, *Computer Graphics: Principles and Practice*, Addison-Wesley, Reading, MA, 1174 pp., 1990.

Book Chapters

A. Badre, Designing Chunks for Sequentially Displayed Information in *Directions in Human/Computer Interaction*, A. Badre and B. Shneiderman, eds., Ablex Publishing Corp., pp. 179-193, 1982.

J. Foley, Software Tools for Designing and Implementing User-Computer Interfaces, in *State of the Art in Computer Graphics: Visualization and Modeling*, R. Earnshaw and D. Rogers, eds., Springer-Verlag, Berlin, 1991, pages 273-310.

J. Foley, GUIDE - An Intelligent User Interface Design Environment (with W. Kim, S. Kovacevic, and K. Murray), in *Architectures for Intelligent Interfaces: Elements and Prototypes*, J. Sullivan and S. Tyler, eds., Addison-Wesley, 1991, pages 339-384.

J. Foley, Models and Tools for Designers of User Computer Interfaces, in *Theoretical Foundations of Computer Graphics and CAD*, R. Earnshaw, Ed., Springer-Verlag, Berlin, NATO ASI Series, pp. 1121-1152, 1988.

T. Govindaraj, Intelligent Computer Aids for Fault Diagnosis of Operators of Large Dynamic Systems, in *Intelligent Tutoring Systems: Lessons Learned*, J. Psotka, L. D. Massey, Jr., and S. A. Mutter, eds., Lawrence Erlbaum Associates, 1988.

T. Govindaraj, Y. Su, A Model of Fault Diagnosis Performance of Expert Marine Engineers, in *The Foundations of Knowledge Acquisition*, J. Boose and B. Gaines, eds., Academic Press, 1989.

L. Hodges, "Stereoscopic Display," Invited chapter to appear in *Electro-Optical Displays*, Mohammad A. Karim, ed., Marcel Dekker, 1991.

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D. Lawton, J. Rieger, M. Steenstrup, "Computational Techniques in Motion Processing", in *Vision, Brain and Cooperative Computation*, M. Arbib, A. Hanson, eds., MIT Press, Cambridge, Massachusetts, pp. 419-488, 1987.

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V. Siamecka, H. Camp, W. Hall, **A. Badre**, MARI: The Medical Aggregate Record Inquiry System, in *Clinical Methods: The History, Physical and Laboratory Examinations*, 2nd Edition, Boston, Butterworth, 1980.

Papers

S. Adelson, **A. Badre**, **L. Hodges**, "Comparison of 3-D Display and Depth Enhancement Techniques", *Proceedings of the Society for Information Display*, vol 32, no.1, 1991.

S. Adelson, **A. Badre**, **L. Hodges**, "Comparison of Different Techniques for Determination of Shape and Relative Position of Objects," *Proceedings of SID*, May 1990, pp. 351-354.

S. Adelson, **A. Badre**, **L. Hodges**, A. Lunde, "Comparison of Different Techniques for Determination of Shape and Relative Position of Objects", *International Symposium of the Society for Information Display Digest of Technical Papers*, vol. 21, 1990, pp. 351-354.

S. Adelson, J. Bentley, I. Chong, **L. Hodges**, J. Winograd, "Simultaneous Generation of Stereographic Views", *Computer Graphics Forum: Journal of the European Association for Computer Graphics*, vol. 10, no. 2, 1991, pp. 3-10.

S. Adelson, **L. Hodges**, "Computational Speedup for Ray-Traced Stereoscopic Images", Georgia Institute of Technology Technical Report GIT-ICS-90/24.

E. Akleman, **L. Hodges**, "Parametric Fractal Interpolation", *Proc. of 27th Annual SE ACM Conference*, 1989, pp. 348-353.

E. Akleman, **L. Hodges**, "Iterated Parametric Transformations", *Proc. of The Fourth International Symposium on Computer and Information Sciences*, 1990.

M. Arbib, K. Overton, **D. Lawton**, "Perceptual Systems for Robots", *Interdisciplinary Science Reviews*, Vol. 9, No. 1, 1984.

R. Arkin, **D. Lawton**, "Reactive Behavioral Support for Qualitative Visual Navigation", *IEEE International Workshop on Intelligent Motion Control*, Istanbul, Turkey, August, 1990.

A. Badre, "Designing Transitionality into the User-Computer Interface," *Proceedings of the HCI International*, G. Salvandy, ed., Elsevier Science Publications, 1984, pp. 27-34.

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A. Badre, "Designing Chunks for Sequentially Displayed Information", *Directions in Human Computer Interaction*, Badre and Shneiderman eds., Ablex, 1982, pp. 179-193.

A. Badre, "Human Cognitive Factors in Front-End Interaction", *COMPCON '80 PROCEEDINGS* (Twenty-first IEEE Computer Society International Conference), Washington DC, Sept. 1980, pp. 119-122.

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A. Badre, R. Russel, "The Effects of Withholding Information about Implementation Details on the Design of a Human-Computer Interface," *International Journal of Human-Computer Interaction*, 1989, pp. 53-67.

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A. Badre, P. Zunde, T. Tine and D. Hughes, "Science Information Transfer for Learning", *Information Utilities*, 1974, pp. 120-124.

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M. Barnsley, **M. Berger**, "Pictures Worth a Million Words", *Projects in Scientific Computing: 1988-1989*, Pittsburgh Supercomputing Center, pp. 34-35.

M. Barnsley, A. Jacquin, F. Malassenet, **L. B. Reuter (Hodges)**, A. Sloan, "Harnessing Chaos for Image Synthesis," *Computer Graphics (SIGGRAPH 88 Proceedings)*, Vol. 22, No. 4, August 1988, pp. 131-140.

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M. Berger, "A Trotter Product Formula for Random Matrices", *Stochastics* 23, 1988, pp. 79-84.

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M. Berger, "Computational Methods for Two-Phase Flow in Networks", in *Progress in Astronautics and Aeronautics*, Vol. 111 - *Liquid Metal Flows: Magnetohydrodynamics and Applications*, H. Branover et al., eds., AIAA, Washington DC, 1988, pp. 539-572.

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