

**CISE Research Infrastructure Grant CDA-9303152
Interactive Accessibility**

**Department of Computer Science
Virginia Tech**

Year - 4 Progress Report

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The Research Program:

Our major goal for this year was to complete the physical implementation of our infrastructure (e.g., lighting, windows, networking connections), in particular in the Usability Methods Research Lab and its Teleconferencing facility. Both these labs are now fully refurbished and in active use for research and for instruction. A number of research projects, both on-going and newly initiated, are underway in these two labs and the other infrastructure facilities. A research goal was to begin using the Usability Methods Research Lab to develop new usability evaluation methods, and to begin using the facilities to support usability evaluation activities. For this reason the laboratories have been designed with tripled observation rooms for meta-observation. The Teleconferencing Lab has increased interest in collaborative work research issues and was used in the new CS CSCW course. The major upgrades to our networking infrastructure to support these facilities is proceeding in collaboration with the University and is targeted for this spring. We began to achieve our goal of actively leveraging our infrastructure for outreach across campus for other timely, emerging research topics such as virtual environments. To this end, the University's Center for Human-Computer interaction directed by Dr. Jack Carroll is now in its second year of operation.

In outreach, we have had extensive involvement with several organizations in the United States government. We have presented, for the past two years, at a National Institute of Standards and Technology (NIST) Symposium on Usability Engineering, and have collaborated with the Social Security Administration (SSA) to improve their interactive system development process. The SSA group received a government award as a result of their work with us. We are also being funded to perform an independent user-based evaluation of a major project for the Marine Corps, called Sea Dragon, that will be deployed to the fleet in the next biennium.

Work supported by this infrastructure grant has extended to many researchers in the Computer Science and Information Systems and Engineering departments, and it is difficult to present the full scope of these activities. However, we present below some of the activities in four major thrust areas of virtual environments, usability research, K-12 educational technologies, and digital libraries.

Virtual Environments

Our work has strongly moved, during the past year, into virtual environments (VEs). VEs are being developed by a broad variety of organizations -- military, government, commercial, and industrial. But most of the focus of VE development continues to be on innovative technology, with little or no attention paid to VE usability. Even as VEs have been gaining broad attention, usability of the user interface has become a major focus of interactive system development. But the exciting new technology of VEs has not yet been closely coupled with the important characteristic of usability, a necessary coupling if VEs are to reach their full potential.

An underlying assumption among both researchers and developers seems to be that VEs, because they are a new technology, are inherently good and usable. Progress is needed to move beyond this flawed assumption, to have a focus on usability become a routine activity in VE development. Methods are needed to produce VEs that are effective and efficient for their users, not merely new and different. An in-depth literature review by a Virginia Tech PhD candidate [Snow, 1996] confirms a lack of foundational work for VE development and especially for usability evaluation.

Thus, our VE research is not just about developing innovative VE technologies. In addition, we are focusing on developing methodologies that ensure usability of VEs. Research was conducted on the use of sequential experimentation to development of empirical models of perceived presence based on free-module magnitude estimations in virtual environments. We also developed metrics based on laboratory experimentation and ethnographic evaluations of the efficacy of using computer conferencing in distance learning.

Through separate NSF funding, Virginia Tech is building a six-wall CAVE™. The CAVE™ will be fully functional by August 1997. Our CAVE™ will include, we believe for the first CAVE™ ever, dual eye trackers, funded by the Office of Naval Research. Numerous projects from across campus are already planned for the CAVE™.

We have also acquired, from additional Office of Naval Research funding, spatialized sound and haptic feedback equipment. This equipment will be used in several projects comparing VE user interfaces with and without feedback and/or spatialized sound, as we continue to explore what characteristics of VE are most important for ensuring usability, improving user performance, and increasing user satisfaction.

Other VE work focused on a user-based comparative evaluation of a new interaction technique, called pre-screen projection, in which the screen display moves in response to a user's head movements. In a comparison of panning and zooming using pre-screen projection, a SpaceBall,

and a mouse, we found that pre-screen projection, interestingly, positively influenced learning of good strategies for panning and zooming, even though it did not show overall superior user performance.

We are also completing a taxonomy of usability characteristics in VEs (funded by the Office of Naval Research). This taxonomy will form the foundation of user-centered development and evaluation methods for VE. It has several major components, including user tasks in VEs, interaction techniques (input mechanisms) in VE, and presentation techniques (output mechanisms) in VE. It is some of the first basic research upon which structured, scientific development and evaluation of VEs can be based.

In another project we are evaluating the Marine Corps' Sea Dragon user interface (also funded by the Office of Naval Research). This VE application runs on a Responsive Workbench (essentially a one-wall CAVE™), and will be used for situational assessment and planning for battlefield management. In addition to this evaluation project, we are pursuing other projects outside Virginia Tech, with a goal of establishing Virginia Tech as a site for independent evaluations of VE applications for all types of applications.

In addition to the CAVE™ and the Sea Dragon project, other new projects are being inspired and leveraged by our new infrastructure. For example, there are now two major research projects in educational technologies, one dealing with collaborative technologies in the domain of the physical sciences, and the other a long term assessment of achievement in a 5th-grade classroom in which the students have immersive exposure to a networking technologies-supported curriculum. The project equipment has directly supported these efforts, and later this spring we expect to begin using the Teleconferencing Laboratory to do non-invasive remote observation of our 5th-grade classroom in a school some 15 miles away.

Usability Research

Numerous aspects of usability research are being carried out, mostly in the UMRL. For example, one major area is that of remote evaluation for situations where the remote and distributed location of users (often on a network) precludes the opportunity for direct observation in a controlled laboratory environment. Often the network itself and the remote work setting have become intrinsic parts of usage patterns. The over-arching objective of this work is to develop a cost effective remote usability evaluation method for real-world applications to real users doing real tasks in real work environments. This global goal divides into the following steps or sub-goals, each a substantial project on its own:

1. Initial case study to explore relevant issues, develop working hypotheses, and find intuitive indications of the validity of the working hypotheses;
2. Extensive qualitative study of the method to gain understanding and insight about the method;
3. Controlled laboratory-based experiments validating research hypotheses; and
4. Field studies conducted in real work environments, accounting for work context factors (e.g., noise, interruptions, multi-thread task performance).

Another area of strong activity is that of usability problem classification. Last year Susan Keenan developed an initial version of the Usability Problem Classifier (UPC) and evaluated it. Results showed that it was a good start and a good concept, but reliability (a measure of how consistently classifications are made across different evaluators) needed improvement. This year Linda van Rens has taken entirely new approach to the structure for classifying usability problems, to boost reliability.

The initial version was built on the assumption that usability problems could be classified separately in both the object and the task dimensions. This caused difficulty in classification when a usability problem didn't have a strong object aspect, and vice versa. A major difference in the new approach is that the task and object dimensions are assumed to be more interrelated and, in the taxonomy, are now integrated together. This allows object aspects of a usability problem to play a classification role only when appropriate. The evaluation component of her project is built-in, in that the whole process is an iteration of design, formative evaluation, analysis, and redesign.

As a complement to the work on usability problem classification, we are also developing a usability problem database. Cara Cocking is working on a Web-based database tool to connect as an integral part of the UPC. Each node in the UPC will have access to a database record form for describing a usability problem in terms of UPC classification category, type of user interface object involved, location (e.g., screen) within the interface. The database record will document the entire life cycle of the usability problem, including detection during usability evaluation, analysis, classification, cost-benefit tradeoffs, management decisions re. Fixing or not, estimated and actual cost to fix, downstream testing results on the effects of fixes.

Finally, to test the UPC and to populate the usability problem database with examples, we are compiling a collection of usability problem examples. Mridu Darshani is working on compiling a comprehensive collection of usability problem scenarios and examples. Eventually these will be used to populate the Usability Problem Data Base, where developers and evaluators can retrieve, for example, examples of usability problems and solutions of a given type (to match, for example, a type of problem they are experiencing in their own project).

The goal of the project is to compile a comprehensive collection of illustrated and annotated examples of usability problems, mostly taken from Windows 95 and Windows 95 applications. We expect this database to serve eventually as a valuable resource for usability management, as a teaching aid, and as a reference for the HCI community as a whole.

K-12 Educational Technology

The Research Infrastructure is also providing a research environment for two major educational technology research projects, the Linc project, and the PCs for Families program.

The LiNC project proposes to create and evaluate a K-12 infrastructure for constructing and conducting experiments in a virtual laboratory. It will develop software and other tools to support real-time collaboration between remote locations, and examine the online interactions between students of differing grade levels and in differing locations. Funding for the project comes from a

grant awarded under the National Science Foundation's Networking Infrastructure for Education program, with support from the Department of Computer Science at Virginia Tech, Montgomery County Public Schools, and Apple Computers.

The project involves four schools in Montgomery County which have high-speed Internet connections: Auburn High School, Auburn Middle School, Blacksburg High School, and Blacksburg Middle School. At each school, a physics (high school) or physical sciences (middle school) classroom will receive additional computers, and a teacher will work with investigators to develop and foster incorporation of computer-supported collaboration into classroom learning activities.

Part of the Linc project involves the design of Java-based support for collaborative networking. We are approaching the problem of supporting collaboration on the WWW in two ways: "transparent" collaboration environments to support existing Java applets, and collaboration-aware applets.

JAMM is a prototype Java runtime environment that supports the shared use of existing Java applets, thus leveraging the existing base of software for synchronous collaboration. Our approach is based on a replicated architecture, where each user maintains their own copy of the Java applet, and the users' input events are broadcast to each applet copy. We discuss solutions to certain key problems, such as unanticipated sharing, supporting late-joiners, and replicating input sources other than user inputs (e.g., files and sockets).

SLUICE is a framework for constructing collaborative, interactive modular visualization environments (CIMVEs) for use on the World Wide Web. SLUICE provides support of using Java to build modules that create, manipulate, and generate visualizations of tables of data. SLUICE provides necessary infrastructure for a CIMVE, including interface specifications for methods that modules of the MVE must implement.

The US Department of Education is supporting a 3-year program in the Computer Science Department at Virginia Tech in cooperation with the Montgomery County Public Schools. Nicknamed the PCs for Families program, the project seeks to determine whether, under the best of circumstances, access to networked computing by both students and their families has measurable effect upon long-term student achievement. Initiated September 1, 1996, the program leverages the resources of the community network known as the Blacksburg Electronic Village.

A 5th-grade classroom has been designed at Riner Elementary School, a national Blue Ribbon School, with a networked computer for every two students. Virginia Tech is lending a computer for an extended period of time to the family of each student in the program. That will enable the students to work at home with their families in the same way that they do at school. A constructivist curriculum is being designed to encourage reading, writing, exploration, collaboration, and critical analysis. Parents are being trained in networked computing along with their children, and their participation will be required.

Besides assessing outcomes when students are immersed in network-based computing at an early age, the project seeks to determine the human costs associated with full technology utilization. Also to be studied is the applicability of different technologies across a wide range of lesson types.

In yet another education project, Faculty from the Social Sciences and Computer Science will produce computerized course materials that promote understanding and appreciation of statistics and mathematical models among undergraduate students in the social sciences. Our goal is to integrate statistical methods throughout the curricula, rather than isolate student contact with statistics to one or two courses as is common today. This will help students understand the role of statistics in the evaluation of hypotheses, and help students apply analytical thinking skills to claims of fact presented to them in their everyday lives.

Digital Libraries

In the area of digital libraries, the Networked Digital Library of Theses and Dissertations has become an internationally known project, and within a short period of time we expect to have operational an extremely large library of theses and dissertations. Most of the digital library activities are discussed in the later section on the Information Access Laboratory.

The Project Envision digital library has progressed further this year, and its unique user interface is being used as the basis for ground-breaking research in psychophysical issues in user interaction design. An empirical investigation of icon size, shape, and color is underway to determine effects of each of these encoding mechanisms on user task performance.

UMRL - Usability Methods Research Laboratory:

This project has achieved its goals this year and, in fact, has surpassed its objectives thus far in the life of the project. In the Usability Methods Research Laboratory, we set up a stable version of IDEAL in a permanent installation, along with two-way windows and user observation rooms. We installed peripheral video-cameras, microphones, audio mixers, tape decks, and video editing equipment to support several projects related to usability evaluation and development of new methods. A new version of a usability problem classification method is also being developed in the Usability Methods Research Lab. Further, our work in remote usability evaluation is progressing with observation of subjects in isolated rooms, reviewing and editing tapes, analyzing data, and evolving the remote evaluation method - exactly the types of activities this lab is designed to support! This laboratory has exceeded our expectations over what we envisioned when we wrote our proposal. The equipment, set-up, and space provide a very exciting environment for the many projects underway.

Instrumentation for the electronic teleconferencing lab in the UMRL was a major focus of equipment acquisition this year. Ten workstations and a moderator's console were instrumented with Pentium PCs into a LAN. Lighting and sound controls, video recording facilities, speaker

telephones, a Liveboard facility, and Internet connections to a compatible electronic workstation in the Human-Computer Interactions Laboratory in Whittemore Hall were installed this year.

This facility is now operational and has been used in two demonstration studies. The first study was conducted in connection with a class project in the CS 6724 CSCW course and dealt with multiple views and telepresence in a desktop videoconferencing system. The second study was a thesis investigating the effectiveness of feedback and electronic augmentations (i.e., chatroom, e-mail, and computer conferencing) for tutoring black minority students in engineering.

IAL - Information Access Laboratory:

The Information Access Laboratory has become a focus for undergraduate and graduate research and education in this area, with 7 undergraduates and 10 graduate students based there, and over 50 undergraduates using the various facilities for project work. Students in CS5604, Information Storage and Retrieval, and CS4624, Multimedia, Hypertext and Information Access use Laboratory equipment for a large part of their course efforts, some of which include over 15 group projects that usually provide service assistance to the university or local community.

An IBM donation of approximately \$400K worth of equipment has rounded out the \$250K award of the previous year, extending equipment in McBryde and the Computing Center. These support experimental work with a campus courseware server, departmental and campus proxy servers, expansion of the main digital library server to 6 processors and 4 Tbytes storage, 4 systems for monitoring / proxy work, and a large workstation to replace the one loaned by IBM during the previous year.

One key area of attention has been the Networked Digital Library of Theses and Dissertations. A Sun ULTRA 1 system was purchased to serve as the naming server for NDLTD, for PURLs (using software from OCLC) and handles (using software from CNRI). OCLC is donating its Site Search software, worth over \$50K, to support searching and Z39.50-based distributed access to the NDLTD collection. IBM digital library software, worth over \$50K, was purchased by Virginia Tech to run on the donated equipment and help with this project. Universities around the Southeast, the nation, and the world have or are interested in joining; there is already collaboration with South Africa, Canada, UK, Singapore, and Korea. Publicity about the project has reached the Chronicle of Higher Education and NPR. Over 350 electronic works have been contributed by students at Virginia Tech, and the total NDLTD count should reach thousands in the next year, with a target of 100K by the end of 1999.

An IBM RS/6000 system was acquired, loaded with digital library software and content, and delivered to ACM Headquarters. The Virginia Tech CS courseware server has been upgraded to a faster Alpha, and regularly gets 100-150K accesses each week from around the world to over 10K pages of content. A workshop to disseminate what has been learned in this area will run June 15-21 at Virginia Tech, making extensive use of the Laboratory and other parts of Interactive Accessibility facilities. Further extensions in 1997 will add content about digital libraries, as well as pages for all NSF CISE Education Innovation projects.

The MARIAN system continues to expand. A Pentium based server for NeXTstep was purchased, and the original NeXTstation-oriented software has been generalized to run on both types of platforms. The new version should make experiments and widespread use on campus much easier.

A Korean researcher, Jong-Min Bae, will join the Laboratory August 1 for his sabbatical year. An ABD Fellow, Denise Haskings (minority) from George Washington University has joined the Laboratory for Summer 1997. Work on network modeling and analysis is assisting with the evaluation of the various systems being devised, and should help with planning and deployment of future information systems.

Collaborating with the digital libraries group is another research group dedicated to data visualization and the improvement of WWW technologies. A group of nine Ph.D. and M.S. students worked in the Network Research Group with Profs. Marc Abrams and Ed Fox to analyze uses of the World Wide Web and apply that analysis to improve Web performance. The analysis work considers two problems. First, how do users search for information on the Web? Second, what are good workload models of traffic that a network experiences in carrying Web traffic. The work on improving Web performance has focused on better algorithms to decide which document to replace when the disk space in a caching proxy server is full. We presented at WWW6 a new algorithm that attempts to balance the time that users wait to download pages with the size and popularity of Web pages. We distributed modifications for the popular Harvest cache that incorporate our new algorithm. We also developed two tools: a simulation of a Web proxy server; and WebJamma, an artificial HTTP traffic generator, intended to test servers. These are available from www.cs.vt.edu/nrg/. In addition we applied these research results by setting up hierarchical Web caching on the Virginia Tech campus and a single cache for the Montgomery County Public School System for use by 5th grade students. Work in progress includes developing improvements to the Inter Cache Protocol used between proxy servers in the Web today, and developing a real time Web traffic measurement tool.

Prof. Abrams also developed novel visualization methods for multidimensional, categorical time series data with former Ph.D. student Randy Ribler. Visualization algorithms resulting from the work are now being considered by Virginia Tech Intellectual Properties for a patent.

Curriculum and Education:

We added two new graduate-level courses in human-computer interaction to our curriculum this year. A course in fundamental theory and models of HCI was offered for the first time in Fall 1996, and a project course in CSCW is being offered in the current semester. Last year's new undergraduate course in HCI was again well-subscribed this year. Next year Virginia Tech's original CS course in HCI, on usability methods, will again be offered for the first time in three years. All these courses make use of the various laboratories, especially the Usability Methods Research Lab and the Teleconferencing Lab.

New Personnel:

Deborah Hix was appointed to a new permanent faculty position in the Computer Science Department and will dedicate her efforts to work in Human-Computer interaction and the new CAVE™ environment to be installed at Virginia Tech this summer. Woodrow Barfield has been appointed as professor in Industrial and Systems Engineering; he, too, will focus on the usability of virtual environments. Jim Eales was appointed to a postdoctoral research position, with primary responsibilities to assist with the NIE/NSF collaborative networking program.

Equipment:

Major equipment purchases during this year included substantial support for the research thrust in the area of virtual environments and included a Sense 8 site license with 2 workstations, shutter glasses, and monitors (\$85,000), two portable usability labs for remote evaluation (\$35,000), and roughly \$50,000 of instrumentation for the Usability Methods Research Laboratory that includes Pentium PCs for each station and a video switcher for controlling the presentations on the participants' screens. Also being bid at this time is a Liveworks Liveboard for CSCW work in the electronic teleconferencing lab and for remote conferencing. The Liveboard will be designed to provide for the digital projection needs of the teleconferencing lab. Virginia Tech's Learning Resources department is also purchasing a Liveboard so that collaboration experiments can be carried out within the university community with these facilities.

The long awaited ATM networking installation is expected momentarily, and we expect to support a substantial portion of that aspect of our departmental infrastructure. Finally, other computers and workstations were purchased to provide a base of support for new research projects coming into the Department, such as a proxy server for monitoring WWW traffic for some of our growing education projects.

Plans for Next Year:

Next year we hope to complete our network expansion activities and finish tuning the performance and capabilities of the interactive teleconferencing lab. Much effort will be put into the development of our virtual environment research program, and we expect to invest additional infrastructure funds in support of specialized VE equipment.

Other visualization projects planned across campus include visualization of business information, visualization of molecular structures to determine weaknesses in various kinds of materials (e.g., ceramics), effects of learning in VEs (in initial application domains of abstract design, statics, and dissection), VE for portrayal of confocal microscopy images, and use of VEs for design of wireless communication systems.

Our VE work has expanded rapidly and broadly, covering a broad spectrum of disciplines and a large number of diverse faculty across campus and the region. We have already had several articles published in local newspapers and newsletter. Further, immersive technologies have recently been strongly endorsed by the University administration as a major research focus area for the University in the twenty-first century.

The virtual reality equipment in the UMRL will be used to evaluate age differences in using virtual environments, disorientation in virtual environments, and applications of augmented reality to multi-tasking in computer-augmented manufacturing. He will conduct laboratory research in the UMRL to evaluate visualization techniques to facilitate user navigation and location within complex, hyperlinked computer files. He will also use the conferencing facilities in the UMRL to develop visual, auditory, and textual communication metrics to evaluate team and collaborative work in computer conferencing activities.

Regarding digital libraries for computer science, we will add in content about digital libraries for two courses in Fall 1997 on digital libraries: one an undergraduate honors class and the other an advanced graduate course. The resulting content will be made available to help others teaching or learning in this field. Also, as we develop WWW pages for the NSF CISE Education Innovation Program, we hope to make it easier for innovations to be disseminated to aid CS programs around the nation. Finally, we will continue to study where and how our courseware is used in connection with our WWW traffic analysis efforts.

The main focus of effort for digital libraries research, however, will be on building the Networked Digital Library of Theses and Dissertations. Now that interest is building, we will continue to work with publishers so that there is a more harmonious development of the genre of electronic theses and dissertations with traditional journal and book publishers. This will be made possible by developing and applying advanced rights management methods of digital libraries, and effective distributed digital library mechanisms.

In the area of usability methods research, work will continue on remote evaluation and the development of the UPC and UP Database, since we are currently leading the HCI world in these particular areas.

Finally, in the area of K-12 educational technologies, we hope to increase the scope of our work by expanding into learning theory and by expanding the scope of our educational assessment work on immersive technology classrooms.

Budget:

Expenditures are very close to our target, although we wish to request a carryover into the fifth year of **60,570** as detailed below:

1. Programmer salary: As we explained in the Year 1 progress report, our research associate was not available until February of Year 1, and as result we wish to slide his employment ahead to the end of the grant period, which represents a 4-month salary carry-over. This, together with Year 5 funds and the University cost sharing amount provide exactly for his salary in the final year.
2. Laboratory equipment: We hope to be able to carry over roughly \$30,000 in funds from Year 4 to Year 5 for replacement of some of the equipment purchased in Year 1. This includes the SGI Indigo system and will provide for upgrades to servers and other equipment that have become obsolete or saturated during the intervening years.

Expenditure	Carryover
John Kelso, Res. Assoc.	17,000
Fringe	4,080
Equipment	30,000
Indirect Costs	9,490
TOTAL	60,570

APPENDIX

Infrastructure-Related Publications:

Begole, J.A., Struble, C.A., and Isenhour, P. (March-April 1997). Toward Collaboration Transparency in Java. *IEEE Internet Computing* 1 (2) pp. 57-64.

Carroll, J.M. (1997). Human-computer Interaction: Psychology As a Science of Design. *Annual Review of Psychology* 48, pp. 61-83. Also reprinted in *International Journal of Human-Computer Studies* 46, pp. 501-522.

Carroll, J.M. (1997). Review of Douglas Schuler's "New Community networks: Wired for Change." *The Information Society* 13 (2).

Carroll, J.M. and Rosson, M.B. (1996). Getting Around the Task-Artifact Framework: How to Make Claims and Design by Scenario. In M. Rudisill, C. Lewis, P.B. Polson, and T.D. McKay (Eds.), *Human-Computer Interface Design: Success stories, emerging Methods, and Real-World Context*. San Francisco, CA: Morgan-Kaufmann, pp. 229-268.

Carroll, J.M. and Rosson, M.B. (December 1996). Developing the Blacksburg Electronic Village. *Communications of the ACM* 39 (12), pp. 69-74.

Carroll, J.M., Rosson, M.B., Chin, G., and Koenemann, J. (August 1997). Requirements Development: Stages of Opportunity for Collaborative Needs Discovery. *Second ACM Symposium on Designing Interactive Systems*, Amsterdam.

Chin, G. (March 1997). Participatory Analysis: Shared Development of Requirements from Scenarios. *CHI Conference on Human Factors in Computing Systems*, Atlanta, GA, pp. 162-169.

Crouch, C., McGill, M., Lesk, M., Jones, K.S., Fox, E., Harman, D., and Kraft, D. (March 1997). In Memorium - Gerard Salton. *Journal of the American Society for Information Science* 47 (2), pp. 108-115.

Ehrich, R.W., (1996). Technology-Induced Disparity in K-12 Education, *Virginia Libraries* 42 (3), pp. 11-14.

Ehrich, R.W. and Kavanaugh A.L. (1997). Managing the Evolution of a Virtual School. In Cohill, A.M. and Kavanaugh, A.L., Eds., *Community Networks: Lessons from Blacksburg, Virginia*. Reading MA: Artech House.

Fox, E.A., Eaton, J., McMillan, G., Kipp, N., Wiess, L., Arce, E., and Guyer, S. (September 1996). National Digital Library of Theses and Dissertations: A Scalable and Sustainable Approach to Unlock University Resources. *The Magazine of Digital Library Research*.

Fox, E. (November 1996). Interactive Learning with a Digital Library in Computer Science. *Proc. FIE '96*, Salt Lake City, UT.

Han, S.H., Williges, B.H., and Williges, R.C. (in press). A Paradigm for Sequential Experimentation. *Ergonomics*.

Kies, J.K., R.C. Williges, and B.H. Williges (in press). Desktop Video Conferencing: A Systems Approach. In M. Helander, Landauer, T.K. and Prabhu, P. Eds., *Handbook of Human-Computer Interaction* (2nd Edition). Amsterdam: Elsevier Science.

Kies, J.K., R.C. Williges, M.B. Rosson (in press). Evaluating Desktop Video Conferencing for Distance Learning. *Computers and Education*.

Kies, J.K., Williges, R.C., and Rosson M.B. (in press). Studying Computer-Supported Cooperative Work: A Review of Research Issues and Strategies. *Journal of the American Society for Information Science*.

Kirschenbaum, M. and Fox, E.A (June 1997). Electronic Theses and Dissertations in the Humanities. Proc. Joint International Conference ACH-ALLC'97, Queens University, Kingston, Ontario, Canada.

Liu, X. and R.W. Ehrich (December 1996). Analysis of Moire Patterns in Non-Uniformly Sampled Halftones. Proc. 3rd IEEE Workshop on Applications of Computer Vision, Sarasota FL, pp. 208-213.

Nowell, L.T., France, R.K., Hix, D., Heath, L.S., and Fox, E.A. (August 1996). Visualizing Search Results: Some Alternatives to Query-Document Similarity. Proc. SIGIR 1996 Conference, Zurich, Switzerland.

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Pesante, J.A., Williges, R.C., and Woldstad, J.C. (May 1997). The Effects of Multitasking on Quality Inspection in Advanced Manufacturing. Proceedings of The 6th Annual Industrial Engineering Research Conference, Miami, FL, pp. 113-118.

Ribler, R., Mathur, A., and Abrams, M. (January 1996). Visualizing and Modeling Categorical Time Series Data. Proc. Symposium on Visualizing Time-varying Data, Williamsburg, VA, pp. 3-19.

Rosson, M.B. and Carroll, J.M. (1996). Expertise and Instruction in Software Development. In M. Helander and T.K. Landauer (Eds.) *Handbook of Human-Computer Interaction*, Second Edition. Amsterdam: North Holland.

Shaffer, C.A. (1997). *A Practical Introduction to Data Structures and Algorithm Analysis*. Upper Saddle River, NJ: Prentice Hall.

Shaffer, C.A. (1997). *Instructor's Manual for A Practical Introduction to Data Structures and Algorithm Analysis*. Upper Saddle River, NJ: Prentice Hall.

Snow, M.P., J.K. Kies, D.C. Neale, and R.C. Williges (1996). A Case Study in Participatory Design. *Ergonomics in Design* 4(2), pp. 18-24.

Tinoco, L.C., Fox, E.A., Ehrich, R.W., and Fuks, H. (November 1996). QUIZIT: An Interactive Quiz System for WWW-based Instruction. Proc. VII Brazilian Symposium on Educational Technology, Belo Horizonte, Brazil.

Tinoco, L., Fox, E., and Barnette, N.D. (February 1997). Online Evaluation in WWW-based Courseware. Proc. SIGCSE Technical Symposium on Computer Science Education, San Jose, CA, pp. 194-198.

Williams, S., Abrams, M., Standridge, C.R., Abdulla, G., and Fox, E.A. (August 1996). Removal Policies in Network Caches for World-Wide Web Documents, Proc. SIGCOMM '96, Palo Alto, CA.

Rooster, R.P. and Abrams, M. (May 1997). Proxy Caching that Estimates Page Load Delays. WWW6, Santa Clara, CA.

Talks:

Carroll, J.M. and Sears, C. (1996). Community Networks. Tutorial, CSCW Conference on Computer-Supported Cooperative Work, Cambridge MA, November 16-21.

Carroll, J.M. and Rosson, M.B. (1997). Network Communities; Community Networks. Lecture series, University of Tampere, Tampere, Finland, May 13-14.

Carroll, J.M. (April 1997). Colloquium at Georgia Tech.

Ehrich, R.W., Matusevich, M., and Rowland, K. (April 1997). PCs for Families - Evaluating Long Term Achievement in a Technology Rich Home-School Environment.

Fox, E.A. (March 1997). Digital Libraries: Their Educational Applications and Uses, keynote session for Web Week, Rice University.

Fox, E.A. (December 1996). National Digital Library of Theses and Dissertations, invited presentation at AT&T Laboratories, Murray Hill, NJ.

Fox, E.A. (December 1996). National Digital Library of Theses and Dissertations, Invited presentation and chairing of working group on this topic, NSF/DARPA/NASA DLI (Digital Library Initiative).

Fox, E.A. (December 1996). Electronic Theses and Dissertations, project briefing at Coalition for Networked Information Fall meeting, San Francisco, CA.

Fox, E.A. (November 1996). The Future Role of Publishers in the New Education Dynamic, chaired plenary luncheon for Proc. Frontiers in Education, FIE'96, Salt Lake City, UT.

Fox, E.A. (November 1996). Interactive Learning With a Digital Library in Computer Science, invited long presentation for NSF CISE EI PI's workshop at FIE'96, Salt Lake City, UT.

Fox, E., Abdulla, G., and Heagy, W. (July 1997). Quantitative Analysis and Visualization Regarding interactive Learning with a Digital Library in Computer Science, poster at ACM Digital Libraries '97, Philadelphia, PA.

Fox, E.A., Eaton, J., and McMillan, G. (May 1997). National Digital Library of Theses and Dissertations, invited session for CAUSE/CNI regional conference, University of Delaware.

Fox, E.A. (April 1997). Publishers and Electronic Theses, project briefing at Coalition for Networked Information Spring meeting, Crystal City, VA.

Fox, E.A. (February 1997). Multimedia, Hypertext, and Information Access. Panel presentation at ACM SIGCSE '97, San Jose.

Fox, E.A., talks at universities: MIT (June 1996 and November 1996), Georgia Tech (October 1996), Illinois (October 1996), Utah (November 1996), Stanford (December 1996), Ohio State (February 1997), San Jose State (February 1997), Rutgers (March 1997), Rice (March 1997).

Fox, E.A. (March 1997). Digital Libraries for Computer Science Education, half-day tutorial presentation for ACM SIGCSE '97, San Jose CA.

Fox, E.A. and Akscyn, R. (November 1996). Applying Digital Libraries: Part 1, introduction and Part 2, research, ACM Multimedia '96, Boston, MA.

Fox, E.A. (1996). Building and Applying Digital Libraries, half-day tutorial for SIGIR '96, Zurich, Switzerland.

Hix, D. (August 1996). Human-Computer Interaction at Virginia Tech, Mitretek.

Hix, D. (October 1996). A Taxonomy of Usability Characteristics for Virtual Environments, Office of Naval Research.

Hix, D. (March 1997). Improving the Cost-Effectiveness of Your usability Engineering Process, NIST Usability Engineering Symposium.

Hix, D. (June 1997). Keynote Speaker at American Management Systems Associate's Day.

Kies, J.K. and Williges, R.C. (March 1997). Video-Mediated Communication for Classroom Collaboration. Poster presented at the Fourth Annual SUCCEED Conference, Clemson, SC.

Rosson, M.B. (March 1997). Designing Object-Oriented user Interfaces from Usage Scenarios, Workshop on Object Models and user Interfaces, CHI'97, Atlanta, GA.

Rosson, M.B. (September 1996). A Web Storybase: Dimensions of Sharing Over the Internet, Colloquium Series, Center for human-Computer Interaction, Virginia Tech, Blacksburg, VA.

Rosson, M.B. (November 1996). Grassroots Technology: Developing the Blacksburg Electronic Village, Research Triangle Park Chapter of the ACM, Durham, NC.

Rosson, M.B. (February 1997). Reaching Out Over the Web: Sharing and Annotating Stories of Web Use, Human-Computer Interaction Consortium Winter Workshop, Frazer, CO.

Williges, R.C. (October 1996). Electronic Seminar at North Carolina State University, Department of Psychology, Usability of Emerging Human-Computer Interfaces.

Williges, R.C. (November 1996). Electronic Lecture at University of Illinois, Urbana-Champaign, Institute of Aviation, "Lessons in Excellence: ARL 1970-76".

Williges, R.C. (August 1996). Electronic Lecture for the Engineering Summer Conference, The University of Michigan, Introduction to Experimental Design.

Williges, R.C. (March 1997). Adaptive Interfaces Using Models of Human-Computer Interaction. Position paper presented at Panel on Human-Computer Interaction Models and Application Development at the ACM Symposium on Applied Computing 1997, San Jose, CA.

Infrastructure-Related Workshops and Conference Activities:

Fox, E.A., Member, Steering Committee, 39th Allerton Institute, Fall 1997

Fox, E.A., Member, Program Committee, First European Conference in Research and Advanced Technology for Digital Libraries, Pisa, Italy, September 1997

Fox, E.A., Member, Program Committee, 20th International Conference on R&D in Information Retrieval, July 1997, Philadelphia, PA

Fox, E.A., Chair, Education and Curriculum Development for Multimedia, Hypertext, and Information Access: Focus on DL and IR Workshop, July 1997, Philadelphia

Fox, E.A., Member, Program Committee, IEEE International Conference on Multimedia Computing and Systems, June 1997, Ottawa, Canada

Fox, E.A., Chair, Courseware, Education, and Curriculum in Multimedia Workshop, June 1997, Ottawa, Canada

Fox, E.A., Chair, Joining the National Digital Library of Theses and Dissertations, University of Delaware, May 1997

Fox, E.A., Member, Program Committee, 1997 International Conference on Software Engineering, Boston, MA

Fox, E.A., Organizing Committee member, Workshop on R&D Opportunities in Federal Information Services, May 1997, Arlington, VA

Fox, E.A., Chair, Technical Committee meeting for National Digital Library of Theses and Dissertations, April 1997, Crystal City, VA

Fox, E.A., Chair, Steering Committee meeting for National Digital Library of Theses and Dissertations, March 1997, Washington, DC

Fox, E.A., Member, Program Committee, Multimedia Computing and Networking, February 1997, San Jose, CA

Fox, E.A., Chair, Technical Committee meeting for National Digital Library of Theses and Dissertations, December 1996, San Francisco, CA

Fox, E.A., Member, Program Review Committee ACM '96 Multimedia Conference, November 1996, Boston MA

Fox, E.A., Chair, Courseware, Education, and Curriculum in Multimedia Workshop, November 1996, Boston, MA

Fox, E.A., Member, Steering Committee, 38th Allerton Institute, October 1996

Fox, E.A., Member, Program Committee, 19th International Conference on R&D in Information Retrieval, July 1997, Zurich, Switzerland

Fox, E.A., Chair, Courseware, Training, and Curriculum in Information Retrieval workshop, August 1996, Zurich, Switzerland

Fox, E.A., Member, Technical Program Committee, HPDC Focus Workshop on Multimedia and Collaborative Environments, August 1996, Syracuse, NY

Fox, E.A., Chair, Workshop on Electronic Theses and Dissertations in the Southeast, August 1996, Charlotte, NC

Rosson, M.B., Technical Program Co-Chair, SIGCHI 1997.

Rosson, M.B., Member, International Program Committee, INTERACT 1997.

Rosson, M.B., Panels Chair, OOPSLA 1997.

Rosson, M.B., Member, Program Committee, ACM Symposium on Designing Interactive Systems 1997.

Honors and Awards:

Edward Fox received an ACM Recognition of Service award for his activities as program chair of the 1996 digital libraries conference.

Robert C. Williges was appointed the Ralph H. Begole Professor of Industrial and Systems Engineering in December 1996.

Lucy Nowell invited to participate in highly competitive SIGCHI'97 Doctoral Consortium, "Graphical Encoding in Information Visualization." This is a highly competitive selection from international candidates.

New Grants and Proposals Related to Infrastructure:

Abrams, M., Fox, E.A., and Pollard, J., **World-Wide Web Traffic Characterization with Application to In-Network Caching and Prefetching**, NSF, \$320,559 (funded).

Barfield, W., Beaton, R.J., Kleiner, B.M., and Williges, R.C., **Augmented Reality Displays for Training, Research, Scientific Visualization, and Human Performance Studies**, Office of Naval Research, Defense University Research Instrumentation, \$202,700 (funded).

Barfield, W. and Williges, R.C., **Augmented Reality, Spatialized Sound, and Haptic Interfaces in Manufacturing Processes**, ASPIRES/Virginia Tech. \$46,500 (funded).

Blythe, E., Fox, E.A., and Crowder, J., **A High Performance Connection for Research and Education Institutions and Facilities in Virginia**, NSF, \$350,000 (funded).

Ehrich, R.W., **Testing a Network-based Approach to Home-School Coupling in K-12 Elementary Education (PCs for Families)**, US Department of Education, \$559,254 (funded).

Ehrich, R.W., Crawford, H., Hauenstein, N., and Shaffer, C., **K12 Learning Tools for Data Exploration and Critical Analysis**, NSF, \$49,927 (declined).

Fox, E.A., Eaton, J., and McMillan, G., **Improving Education with a National Digital Library of Theses and Dissertations**, FIPSE, \$208,040 (funded).

Fox, E.A., **Supplement to the Education Infrastructure Grant in Progress**, NSF, \$66,846 (funded).

Fox, E.A., **Support by Virginia Tech for Integration Testbed Proposal for SAIC for DARPA CVIM 97-09 BAA**, \$240,000 (funded).

Fox, E.A., **A Digital Library Based Computer Science Teaching Center (CSTC)**, Subaward for proposal to NSF for the DUE CCD program 97-29 being submitted by D. Knox of The College of New Jersey, \$72,820 (pending).

Fox, E.A., **Curriculum Resources in Interactive Multimedia (CRIM)**, NSF, \$238,418 (pending).

Hix, D., **Enhancing a CAVE with Eye Tracking Systems for Human-Computer Interaction Research in 3D Visualization**, ONR, \$57,800 (pending).

Hix, D., Templeman, J.N., and Darken, R., **Systematic Development of Testbeds, Principles, and Methodologies for Ensuring usability of Virtual Environment User Interfaces**, ONR, \$448,500 (pending).

Hix, D., **Improving User Interface Development Tools and Processes**, NSWC, \$125,000 (pending).

Hix, D., **Acquiring an Immersive Workbench for Human-Computer interaction Research in 3D Visualization**, ONR, \$89,700 (declined).

Kafura, D., Shaffer, C.A., Abrams, M. and Kriz, R.D., **Adaptive Multi-Dimensional Collaboration**, DARPA, \$4,384,386 (declined).

Kamke, F.A., Watson, L.T., Ribbens, C.J., Allison, D.C.S., Abrams, M., Kafura, D., Rosson, M.B., and Shaffer, C.A., **Towards Leadership in Problem Solving Environments for Science**, ASPIRES/Virginia Tech, \$25,000 (funded).

Klemperer, D. and Ehrich, R.W., **Worldwide Web Accessible interactive Learning Software for Forest Economics Courses**, USDA, \$79,309 (pending).

Kriz, R. and Hix, D., **Acquisition of a CAVE: Breaking Research and Educational Barriers by Developing and Evaluating 3D Visualization Tools with CAVE Technology**, NSF, \$800,000 (funded).

Puckett, A., Kavanaugh, A., and Ehrich, R.W., **The Impact of Culture on the Differential Use of Community Networking**, NSF, \$451,061 (declined).

Shaffer, C.A., Carroll, J.A., Campbell, J.B., and Hauenstein, N., **Integrating Statistics and Models Across the Social Sciences**, FIPSE, \$277,801 (funded).

Shaffer, C.A., Barfield, W., Carroll, J.M., Hix, D., McLain-Kark, J., Kriz, R.D., Shires, P.K., Wiedegreen, E.A., and Wildman T.M., **Breaking Conceptual Barriers: Learning in Collaborative Virtual Environments**, NSF, \$1,474,289 (pending).

Wilder, P.G., Arrington, L.W., Ehrich, R.W., and Kavanaugh, A.L., **Implementing System-Wide K-12 Reform In a Networked Community**, US Department of Education, \$5,460,611 (declined).

Williges, R.C. and Rosson, M.B., **Usability Evaluation of Electronic Connectivity in the SUCCEED Coalition**. National Science Foundation \$40,000 (funded).

Service:

Fox, E.A., Chair, SIGIR Nominations Committee, 1997

Fox, E.A., Member, SIGIR Education Committee, 1993-

Fox, E.A., Member, SIGIR Electronic Publishing Committee, 1995-

Fox, E.A., Co-chair, SIGMM Education Committee, 1995-

Fox, E.A., Member, Digital Library Advisory Committee, Columbia University

Fox, E.A., Member, Working Group, Networking Computer Science Technical Report Library technical committee

Fox, E.A., Member, OCLC's Research Advisory Committee

Fox, E.A., Member, Steering Committee, Monticello Electronic Library

Fox, E.A., Editorial Boards: The British Computer Society Journal of Digital Information, Electronic Publishing - Origination, Dissemination, and Design Journal (Wiley), Information Processing and Management, Journal of Educational Multimedia and Hypermedia, Journal of Multimedia Tools and Applications, Morgan Kaufmann Series on Multimedia, Multimedia Systems (Springer), The Journal for Universal Computer Science (Springer)

Hix, D., Member, Interactions editorial board

Hix, D., Member, Advisory board, Federal Intelligence Document Understanding Laboratory, Vienna, VA

Rosson, M.B., SIGPLAN Executive Committee, 1995-1997

Infrastructure-Related Degrees Awarded:

Joey Gabbard, MS, *A Taxonomy of Usability Characteristics for Synthetic Environments*

Andrew Gellatly, PhD, *Guideline Development for the Implementation of Speech Recognition Technology in Automotive Control Systems*

Marla Hacker, PhD, *Optimization of Small Group Decision Making During Implementation Planning*

Susan Keenan, PhD, *Product Usability and Process Improvement Based on Usability Problem Classification*

Jonathan Kies, PhD, *Empirical Methods for Evaluating Video-Mediated Collaborative Work*

Michael Mitchell, PhD, *Effects of Locus of Control and Embedded Questions on Behavioral-Attitudinal Change and Knowledge Gain in a Computer-Based Interactive Video Environment.*

John Raley, MS, *Issues in Undergraduate Programming Performance*

Randy Ribler, PhD, *Visualizing Categorical Time Series Data with Applications to Computer and Communications Network Traces*

Cheryl Seals, MS, *Documenting and Supporting the Reuse of Object Oriented Application Frameworks*

Mike Snow, PhD, *Charting Presence in Virtual Environments and Its Effects on Performance*

Lucio Tinoco, MS, *Online Evaluation in WWW-based Courseware: The QUIZIT System*

Infrastructure-Related Degrees in Progress:

Gahleb Abdulla, PhD, *Digital Library and Web Scalability Through Characterization and Modelling*

Brian Amento, PhD, *Developing and Evaluating New Interaction Techniques for Virtual Environments*

James (Bo) Begole, PhD, *Bringing Collaboration Awareness to Collaboration Transparent Applications*

Jose Castillo, MS, *User-Assisted Critical Incident Identification for Remote Usability Evaluation*

George Chin, PhD, *Integrating Ethnography, Scenarios, and Participatory Design*

Laura Clark, MS, *Design and Testing of a Quick-Connect Wheelchair Power Add-on Unit*

Cara Cocking, MS, *A Relational Database for Usability Problem Classification*

Joey Gabbard, PhD, *Developing Methodologies for Virtual Environments*

Craig Ganoë, PhD, *Dissertation area to be determined*

Hope Harley, PhD, *An Environment for Guided Exploration of Object-Oriented Programming and Design*

Win Heagy, MS, *A Web Server Log Visualization Program and Its Evaluation*

Philip Isenhour, MS, *Java Support for Collaborative Applications*

Tommy Johnson, PhD, *Improving Caching in the World Wide Web*

Neill Kipp, PhD, *Document Structuring Style for a Digital Library of Theses and Dissertations*

Suzanne Lee, PhD, *An Investigation of the FHWA Hearing Requirements for Commercial Vehicle Operators*

Binzhang Liu, MS, *Analyzing the Spread of CS Education Innovation*

Paul Mather, PhD, *Digital Libraries for Theses and Dissertations*

Faith McCreary, MS, *Adult-Child Differences in Spatial Learning in an Immersive Virtual Environment as a Function of Field of View*

Michael McGee, MS, *Assessing Negative Side Effects in a Virtual Reality Maze Environment*

Lucy Nowell, PhD, *Psychophysical Foundations for User Interface Design*

Jose Pesante, PhD, *Applications of the Theory of Signal Detectability to Multitasking and Industrial Quality Inspection in Manufacturing*

Ray Reaux, PhD, *Including Cognitive, Task, and Systems considerations in an Object-Oriented Software Engineering Process*

Joe Reiss, PhD, *Information Management on the World Wide Web*

Brandon Satanek, MS, *Navigational and Visualization Aids for Searching Complex Hyperlinked Computer Files*

Cheryl Seals, PhD, *Documenting and Supporting the Reuse of Object-Oriented Application Frameworks*

Joseph Shaw, MS, *Combination of Multiple Queries and Retrieval Methods for Improved Full Text Information Retrieval*

Paige Smith, MS, *Human-Centered Communication Technologies to Enhance the Tutoring of Minorities*

Stephen Van Aken, PhD, *Team Effectiveness: An Investigation of Semi-Autonomous Teams in Manufacturing*

Linda Van Rens, MS, *Usability Problem Classification Methodology*

William Wake, PhD, *A Model and Interface for Documents with Multiple Views*

Roland Wooster, MS, *Optimizing Response Time, Rather than Hit Rates, of WWW Proxy Caches*

Visitors:

Alistair Sutcliffe, City University of London, Fall 1996

Wolfgang Dzida, GMD Darmstadt (German National Center for Information Technology), Fall 1996

Benjamin Bederson, University of New Mexico, March 1997

Allison Druin, University of New Mexico, March 1997

Douglas Gordin, Northwestern University, March 1997

Ronald Hübscher, University of Georgia, March 1997

Lee Hollar, University of Utah, November 1996

Elliot Soloway, University of Michigan, April 1997