Title

"Enhanced Access to Science Education for Students with Severe Disabilities Using Modular, Customizable Human-Computer Interface Systems"

Budget (TBA)

In keeping with SGER restrictions, support will be requested for one year at a level not exceeding $100,000.

Senior Personnel

- Edward Lipson, PI (Professor of Physics; Faculty Associate NPAC)
- Geoffrey Fox, co-PI (Professor of Physics and Computer Science, and Director of Northeast Parallel Architectures Center = NPAC)
- David Warner, MD (Nason Fellow, NPAC; Director, Institute for Interventional Informatics)

Introduction

In the proposed work on this SGER project concerning human-computer interaction for persons with severe disabilities, we will focus initially on two quadriplegic individuals, both approximately 17 years old. One (Eyal) lives in Syracuse New York and the other (Bader) in Kuwait City. The project will have great applicability for a large number of individuals who are disabled. A major area of focus will be education, specifically science education. This proposal relates to a concurrent Knowledge and Distributed Intelligence (KDI) proposal of much broader scope. However, it is urgent to secure funding in the short-term to make the progress necessary for the large-scale project which will include more individuals, collaborators, and areas of concentration.

While, we expect to devote more of our own time and effort to the project with the Syracuse teenager, the Kuwait project will offer special opportunities to establish and maintain a very long-distance (and intercultural) collaboration taking advantage of Internet and World Wide Web technologies, including those developed recently at NPAC (e.g. Tango Interactive collaboratory software). This activity will also reinforce our emerging domestic collaborations in the KDI context of knowledge networking.

The project is in urgent need of funding in order for us to be able to accelerate our efforts and achieve the success required to make quadriplegic users functioning members of their communities (school, home, workplace, etc.). SGER funding would provide a bridge until KDI and/or other major funding can be secured for this and related work.

SGER Considerations

This project carries high-risk inherently, because we are working with individuals who are severely disabled. Moreover, we are employing our own software that is still under development and refinement in advanced beta version. The hardware, similarly, is custom built and adapted to match the capabilities of the individual. Our approach is highly innovative and so far outside the mainstream of the field. We do intend to start making our presence better known this year by attendance at disabilities conferences, as well as our forthcoming prominent participation at a large sigKIDS exhibit at SIGGRAPH in July 1998 in Orlando. Our recent association with the Trace Center and other collaborators (see below) will open channels for dissemination of our unique, and revolutionary, approach.

KDI Proposal Collaboration

Our proposal being submitted to the interdisciplinary KDI program, specifically in the focus area of Knowledge Networking (KN), has the tentative title: "Universal Access to Education: Human-Computer Interface Technologies for People with Severely Disabilities". In that project, we have formed alliances with the Trace Research and Development Center at the University of Wisconsin (Prof. Gregg Vanderheiden, director), the Biomedical Engineering Department at Catholic University of America (Prof. Corinna Lathan), and the Human Interface Technology Laboratory (HITLab) at the University of Washington (Erik Viirre, M.D., Ph.D.).

Objectives

Hypotheses

The following hypotheses will be formally developed and tested on this SGER project:

- An individual with a severe physically disability can progressively gain substantial ability to control, compose, and communicate by using affordable computer interface hardware and software, including our NeatTools software, serial interface modules, sensors, and mounting hardware (see below).
- Such an individual can conduct effective research and exploration using Web technologies in conjunction with our systems.
- Such capabilities can greatly enhance independent, creative, life-long learning in the classroom, at home, and in the workplace.
- An individual with severe disabilities can participate actively in laboratory science experiments and data analysis and interpretation, for optimal learning and appreciation of science, that could lead to a successful career in science or technology fields.
- A individual with a disability can serve as a key member of a research team providing continual feedback and constructive criticism as well as creative ideas for project improvement not only for himself or herself, but for others with disabilities. Accordingly, the individual can become an active member of a knowledge network, specifically researching and developing technologies and implementation strategies for individuals who are severely disabled.
- The student with such a disability can actively build NeatTools application networks, and in turn train others (whether disabled or not) to do so. In doing so together, they will all learn and appreciate digital logic, mathematics, and science, as well as practical interface design.
- Technologies developed for the user with a disability can provide new human-computer interaction modalities that can also benefit general users, and thereby advance the field of human-computer interaction in novel ways.

Framework

The experimental framework for testing these hypotheses and for advancing the project will include the following:

- establishment of qualitative and quantitative performance criteria, with particular attention to time required to execute events (e.g. successive “keystrokes”) and accomplish tasks; we already have event-tracking (database & dynamic graphical display) systems on related projects that can be readily adapted for use here
- team effort to construct alternative versions of NeatTools networks to test which features and options, as well as calibration settings, provide the best performance and human-factors aspects
- development and refinement of sensor and transducer modalities for performance comparisons and continual optimization
- alternative mounting systems, for example wheelchair mounts, headmounts, and eyeglass-frame mounts
- laboratory kits and software, as well as robotic systems, to provide ample participation by and creative input from a student with a disability
- multimedia and new media including audio and video streaming (edutainment)
- interactive sessions between home, school, university, and other locations (such as with collaborators in other states or countries)

Background, Pilot Studies, and Research Program

Core Technologies

Software. NeatTools is a powerful visual-programming environment developed by our team at Syracuse as a general purpose tool for human computer interactions and other applications, including in the

healthcare and telemedicine arenas. To develop an application in NeatTools, one drags and drops modules from toolboxes onto the desktop and then links them extensively to one another. Typically, a module contains inputs on the left, outputs on the right, and control inputs on top—although there are number of departures from this. NeatTools includes multimedia functions, Internet sockets, and a host of logical, arithmetic, and input-output functions (for custom or standard computer peripherals).

In addition, we have ready access to the powerful Tango Interactive collaboratory software system developed at NPAC. This will be used both for our communications with colleagues elsewhere, including Kuwait, and as an integral part of the research program to investigate ways to connect individuals with disabilities to networked communities in various fields (educational, healthcare, disabilities, professional, recreational, and artistic).

Hardware. In early 1998, the PI developed a general-purpose serial interface box, called TNG-3 (quantity of 100 made to date at net cost of $50 each), that works in conjunction with NeatTools software, allowing up two eight analog inputs (via standard stereo plugs) and eight digital inputs (via ribbon cable or individual miniature mono plugs) to be fed to a computer's serial port via a built-in cable. TNG-3 is based on a powerful microcontroller chip (Microchip PIC16C74A, costing $10 in singles) programmed in PIC assembler language. Among the low-cost sensors we use are a) lever switches, b) linear and rotary potentiometers, c) pressure sensors (custom-made in our labs from 3M Velostat™ conductive plastic, and copper sheet), d) bend sensors (from Abrams Gentile Entertainment; $5), e) photocells (CdS; 50 cents) , custom joysticks (extracted from $20 off-brand game controllers), and Hall-Effect magnetic sensors (Honeywell or Allegro; $1–20).

Syracuse Projects: Eyal Sherman (and Brooke Kendrick)

Support for this work has become especially appropriate in view of its recent successes. Since the beginning of 1996, we have been working with Eyal Sherman, who is now 17. Given that he is a brain-stem quadriplegic, unable to move his head or to vocalize, his case is particularly challenging. Our work with him as a member of our team has proceeded concurrently with our development of hardware and software technologies. Indeed, much of this work has been driven by what we have learned from him and his special needs. The generality of our applications software and devices testifies to the value of focusing on one or a few particularly challenging cases. Another such individual, also an ongoing success story of ours, is Brooke Kendrick, a 7-year-old spastic quadriplegic with cerebral palsy; we have significantly enhanced her in-school and other activities. Further information and background on our work with Eyal and Brooke is available in the pictorial "webumentaries" linked to our Pulsar home page (www.pulsar.org) on the NPAC server.

Thanks to our recent developments, Eyal is now able, after a brief setup (usually by his mother alone) to control a graphical user interface (GUI; here, Windows 95), communicate, surf the Web, type text, etc. Eyal has sent e-mails to the PI and to others, and has also participated in chat sessions while at home and connected to the NPAC server. Using a commercial program (TextO'le™, bundled on SoundBlaster CD-ROM from Creative Labs), Eyal has been able to generate speech by typing text using our hardware and software systems, and then pressing a play button; he is also able to save his own sound files, as with other types of files.

However, while we have established proof-of-concept, these operations are still rather slow; typically, it takes Eyal several seconds at best to type each letter. In general, all aspects of our technical systems remain subject to refinement and ample testing in the context of scientific hypotheses (above), and extension to other users, who will often present a lesser challenge than what we have been facing.

The breakthroughs this year have been facilitated by the development of the JoyMouse network (at www.pulsar.org, click on NeatTools link, and then on link pertaining to JoyMouse), an advanced NeatTools application created by the PI for precise nonlinear-analog mouse control (cubic and other profiles). This in turn was made possible by the maturation and power of the NeatTools visual-programming environment. Now that these tools are available, more formal research is needed to test and optimize ways for Eyal and others to communicate and control efficiently.

Recent academic successes have been achieved thanks to the active participation of Eyal's physics teacher, Dr. James Stacey, who has formed a dedicated team of high school students, selected for their proficiency in programming and/or experience as hobbyists, to assist in development of the special laboratory projects. For this effort, they are receiving academic credit, along with Eyal. In the wings is the chemistry teacher Eyal will have next year when he is a senior. Eyal has recently begun participating actively in science experiments (including data acquisition, graphing, and interpretation) by use of our interface software and hardware. This accomplishment has been a source of excitement not only to Eyal but also to the others involved. Currently, the high school team is developing robotic experiments (using LEGO Dacta™ systems) that Eyal will actively participate in along with his partners. Continuation of this particular application area (experimental science) will be a major focus of this SGER project.

We have also begun to explore artistic expression, including music and art. For example, the PI has constructed a drum machine in NeatTools for Eyal to learn and play rhythms with, as well as record and play back the files himself. In this case, there are two instances of NeatTools: JoyMouse and Drum, with the former used to control the latter. Using the JoyMouse, Eyal has begun doing some artwork in paint programs. These pilot studies constitute a proof-of-concept that Eyal can express himself creatively, using our software and systems in conjunction with commercial software.

In order to improve Eyal's typing efficiency, we will employ InstantText™ software, a companion to the Fitaly™ on-screen keyboard we have provided to him for typing . Note that neither of these low-cost utility products were intended for the disabilities field. We discovered that they work very well in that realm and have shared this information with the inventor, Jean Ichbiah, president of TextWare Solutions, who designed the optimized Fitaly One-Finger Keyboard layout for pen computing; and InstantText for professional typing (see www.twsolutions.com). InstantText™ allows abbreviation expansion and phrase completion in a very flexible automatic way.

Using these and other commercial products in conjunction with our own systems and other resources, we will establish hypotheses and goals for typing speed and GUI control and then design and evaluate performance in actual science education applications, including answering homework questions, researching and preparing term papers, and participating actively in high school and college science laboratory activities as part of a team. The latter would include laboratory data analysis and interpretation as we have already begun to do using Vernier™ software, which is used at both Nottingham High School and the Syracuse University Physics Department.

Science education will the main application focus of the research work involving Eyal and others. To achieve increasingly active participation in science experiments and other interactive class activities will require an ever more efficient interface system. The present prototype constitutes an excellent start and the present approach is scalable and extensible given the modular nature of our hardware and software. The fact that, once JoyMouse is active, Eyal can already control a GUI and type text (e.g. dialing from home and logging in to NPAC, opening a browser, typing URLs, surfing, saving images, text, and bookmarks, …). This capability provides considerable power for a wide range of classroom, research, and composition activities essential to the active learning of science.

A longer-term goal of this effort is universal access to computer and information technologies for people with more varied disabilities. Eyal is teaching us, both directly and implicitly, how best to design and evaluate systems for a person in his extreme circumstances.

Kuwait Connection: Bader Al-Khamees

We have recently established an agreement with the Kuwait Institute for Scientific Research (KISR) and the Kuwait Special Schools (KSS) to embark on a collaborative project. The initial focus will be on a 17 year old quadriplegic (Bader), who has rare progressive neuromotor disorder, such that his limb and head motions are extremely slow and limited; his hands are curled in towards the wrist so that he is unable to use a keyboard or mouse. Sadly, his two younger brothers are similarly affected, but at earlier stages. During a trip to Kuwait in November 1997, for unrelated professional service, the PI arranged to meet with officials including the Director General and department managers at KISR, and the superintendent of KSS (as well as and her staff members and some resident students). Following on-site demonstrations, it

was tentatively agreed that our NeatTools software and associated devices appeared very well suited to help Bader (and eventually his siblings), as well as other students there. The PI also met with in private with Bader's father, who is an engineer, and he too was left very hopeful.

After additional communications with Kuwaiti officials and professionals, we have agreed to proceed. In order to get the project off to a rapid start, we are presently (early May) sending interface devices to KISR at no cost. We are recommending to our colleagues at KISR and KSS that they start with a custom joystick and the JoyMouse network (freely downloadable along with NeatTools), which we hope will work well for Bader, along with other interface modalities (switches, sensors, etc.). The KISR department manager who will be our primary contact, Hani Qasem, previously developed a bilingual Braille printing system in cooperation with KSS; they have commercialized and disseminated this to other countries in the region with Arab populations, including Israel. Further details on this project will be provided in our KDI proposal (which will also include assistive technology for the blind). We will also prepare a Web page on the Kuwait collaboration that will be linked to the Pulsar home page.

Kuwait will serve as a valuable test bed for long-distance collaboration using the Internet and the World Wide Web, using both NeatTools and Tango in both synchronous and asynchronous modes. While it may be possible in the long run to obtain support from the government of Kuwait, we consider it far better to obtain binational support (as the PI has done on various scientific projects in the past), such that Kuwait supports the efforts there, and NSF supports our efforts here.

Extensions to Other Students with Disabilities

With our new collaborations, notably on the proposed KDI project as mentioned above, we will gradually introduce other participants to the project. At Syracuse, we will continue working with Brooke and her family and therapists to enhance her functionality and learning experiences. At Syracuse University, we have made contact with the Disabled Students Union, currently headed by a student with cerebral palsy. We have also made contact with local organizations for people with disabilities, such as Arise and Enable. On the other hand, though, we do not want to spread ourselves too thin, given that we must continue developing our innovative software and interface hardware, while working closely with individuals, and their families and professionals. Accordingly, for success of this project, we consider it essential to focus our efforts mainly on Eyal, Brooke, Bader, while beginning to extend the work to others when appropriate.

Conclusion

This project endeavors—in a way that will provide highly affordable systems to end users—to "push the envelope" on information, communication, and interface technologies, exploiting GUIs and the Web in particular. This will provide ample opportunity to help individuals communicate compose and control their environment, adding new dimensions to their lives, notwithstanding major disabilities. We hope this will enable bright, talented individuals to become interested in active careers in scientific research who might not otherwise be encouraged to do so without the innovative HCI technologies as described above. The time is ripe to exploit the rapid advances in computer and communication technologies—in conjunction with low-cost sensors and microcontroller electronics—to enable those with severe physical disabilities to enjoy a creative, fulfilling, active, and productive life.