Title

"Modular Low-Cost Computer-Interface Systems for the Severely Disabled"

Budget (TBA)

In keeping with SGER restrictions, support will be requested for one year at a level approaching $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 18 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 disabled individuals. A major area of focus will be education, specifically science education. This proposal relates to a concurrent 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, *viz.* knowledge networking.

While, we expect to devote more of our own time and effort to the project with the Syracuse teenager, Eyal, the Kuwait project will offer special opportunities to establish and maintain along distance 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 stable 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 (home, school, 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 such severely disabled individuals. Moreover, we are employing our own software that is still 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 outside the mainstream of the field, although we intend to start making our presence better known this year by attendance at disabilities conferences, not to mention our 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

This proposal relates to a large-scale proposal being submitted concurrently to the KDI program, specifically in the focus area of knowledge networking. The tentative title is "Universal

Access to Education: Human-Computer Interface Technologies for the Severely Disabled".

In that project, we have formed alliances with the Trace Research and Development Center at the University of Wisconsin (Prof. Gregg Vanderheiden, director), the bioengineering 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.).

Background and Pilot Studies

Core Technologies

Software. NeatTools is a powerful visual-programming environment developed by our team at Syracuse has a general purpose tool for human computer interactions and other applications, including those in the health-care 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, each 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 TangoInteractive 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 disabled individuals 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, 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 COM port of the computer via a cable that is included. 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 for $5), custom joysticks (extracted from $20 off-brand game controllers), and Hall-Effect magnetic sensors (Honeywell or Allegro).

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 18. 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 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 a success story, is Brooke Kendrick (see below), a 7-year-old spastic quadriplegic with cerebral palsy.

Thanks to recent developments, Eyal is now able, after a brief setup by others (e.g. his mother), 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 also participated in chat sessions while at home and connected to the NPAC server. Using a commercial program

(TextO'le™, which comes 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 (below), and extension to other users, which will often present a lesser challenge than what we have been facing. This is now truly becoming an academic research project, in which each disabled person will remain an active and critical member of the team.

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

With Eyal, we have 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. Using the joy mouse, 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.

Further information and background on our work with Eyal and Brooke is available in the pictorial "webumentaries" linked to the Pulsar home page (www.pulsar.org).

Kuwait Connection: Bader Al-Khamees

We have recently reached 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 seemed 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 recently mutually 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.

Research Plan

In order to improve Eyal's typing efficiency, we will employ InstantText™ software, a companion to the Fitaly™ on screen keyboard. InstantText™ allows abbreviation expansion and phrase completion in a very flexible automatic way. Using these 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 Nottingham High School and the Syracuse University physics department.

We have established collaboration with Eyal's physics teacher, Dr. James Stacey. In the wings is the chemistry teacher Eyal will have next year when he is a senior. Currently, the high school team is developing robotic experiments (using LEGO Dacta™ systems) that Eyal will actively participate in along with his partners. Dr. Stacey 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 will receive academic credit, along with Eyal.

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, directly and implicitly, how best to design and evaluate systems for a disabled person in his extreme circumstances.

Hypotheses

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

- A severely physically disabled individual, such as a brainstem quadriplegic, can progressively gain substantial ability to control, compose, and communicate with affordable computer interface hardware and software, including NeatTools software, serial modules, sensors, and mounting hardware.
- Such an individual can conduct 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 in some cases lead to a successful career in science or technology fields.
- A disabled individual 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, an individual can become an active member of a knowledge network specifically researching and

developing technologies and implementation strategies for severely disabled individuals

- Technologies developed for the disabled user can provide new human computer interaction modalities that can also benefit able-bodied users, and thereby generally 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 headmounts, wheelchair mounts, and eyeglass-frame mounts
- laboratory kits and software, as well as robotic systems, to provide ample participation by and creative input from the disabled student
- interactive sessions between home, school, university, and other locations such as collaborators in other states or even countries
- multimedia and new media including audio and video streaming

Extensions

With our new collaborations (on KDI proposal), as mentioned above, we will gradually introduce other disabled 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 the disabled, 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 software and interface hardware, while working closely with disabled individuals and their families and professionals. Accordingly, for success of this project, we consider it essential to focus our efforts mainly on Eyal and Bader, while beginning to extend the work to others when appropriate.

Conclusion

This project endeavors, in a very low-cost way, to "push the envelope" on information, communication, and interface technologies for the disabled, exploiting GUIs and the Web in particular. Insofar as this project succeeds, it will provide ample opportunity to help individuals communicate compose and control their environment, adding new dimensions to their lives, notwithstanding major disabilities. The time is ripe to exploit the rapid advances in computer and communication technologies to enable those with severe physical limitations to enjoy a creative, fulfilling, active, and productive life.