An overview of rehabilitation engineering research at the Applied Science and Engineering Laboratories.

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ABSTRACT

The Applied Science and Engineering Laboratories of the University of Delaware and the Alfred I. duPont Institute have an ongoing research program on human machine interactions with a special emphasis on applications for people with disabilities. The Laboratories house two Rehabilitation Engineering Research Centers, the first on Augmentative and Alternative Communication Systems and the second on Applications of Robotics to Enhance the Functioning of Individuals with Disabilities. This paper reviews several projects within these two Centers as well as a project within a programme on Science, Engineering and Math Education for Individuals with Disabilities.

Consumer involvement has always been central to the research philosophy of the Laboratories and is achieved at a variety of levels and this paper includes a discussion of how effective user involvement is achieved.

Keywords: Consumer involvement, Haptic display, Virtual laboratory, Assistive technology, Rehabilitation robotics, Augmentative and alternative communication

1. INTRODUCTION

1.1 The Research Environment

The Applied Science and Engineering Laboratories are situated in the grounds of the Alfred I duPont Institute, a children's hospital in Wilmington, Delaware. This hospital provides a full range of clinical services to children under the age of 18, and along with rehabilitation research also conducts an extensive programme of clinical and medical research, and the Laboratories have benefited from the ready availability of medical expertise.

The Laboratories are jointly operated by the Nemours foundation, who also fund the main hospital, and the University of Delaware. The Applied Science and Engineering Laboratories maintain a satellite laboratory and office space at the University's main campus sited about 15 miles away. The Laboratories have also established and maintained links with the University of Pennsylvania, and Drexel University both situated in Philadelphia, as well as local rehabilitation organisations.

Funding for research comes primarily from grants, and a major portion of these comes from the Federal Government. Two of the 17 Rehabilitation Engineering Research Centers (RERC's) funded by the National Institute for Disabilities and Rehabilitation Research (NIDRR - part of the US Department of Education), are managed by the Applied Science and Engineering Laboratories. These are the RERC on Augmentative and Alternative Communication Systems and the RERC is on Applications of Robotics to Enhance the Functioning of Individuals with Disabilities. The Laboratories also manages a NIDRR grant on the provision of assistive technology, a National Science Foundation project on Science, Engineering and Math Education for Individuals with Disabilities, as well as individually funded research projects

In addition to work outlined in this paper there is ongoing research on access to large data-base, speech processing, natural language processing, telerobots for individuals with disabilities, power assisted orthotics, applications of robots in the school and workplace, design and manufacture of rehabilitation products and enhancing provision of assistive technology services.

The Applied Science and Engineering Laboratories focus on improving the access of individuals with disabilities to enabling technologies. This philosophy has resulted in the Human Machine interface being a primary focus of research, but the Laboratories has also sought to ensure that research is appropriate and in context so an important part of the work is the provision of novel technology related services to individuals with disabilities and related support organisations.

2. RESEARCH UTILISING VIRTUAL REALITY TECHNIQUES

2.1 Computer Recognition of Gestures in American Sign Language

Research on recognising American Sign Language (ASL) grew out of work done in the Applied Science and Engineering Laboratories on transmitting gestures across a telephone channel. Although text based telephone equipment such as TDD and the associated relay service exists, written English is not necessarily a fluent language for an individual who has ASL as their first language. Thus, there is interest in transmitting native ASL from one signer to another via telecommunication services. The problem of this approach is that the bandwidth of a telephone does not allow transmission of images, although Galuska and Foulds (1990) demonstrated that it is adequate for the transmission of sign.

As a consequence of linguistic and virtual reality research, tools and techniques are now sufficiently established to allow a very compact representation of ASL that could be transmitted across a telecommunications network. Since this requires acquisition and representation of ASL by a computer there is also the potential to do language translation to and from ASL. Success in language translation, or at least a subset of this, would not only improve access to telecommunication services, but would also substantially improve a deaf individual's access to other services in the speaking world, in particular the possibility of direct communications with non ASL speaking individuals.

Figure 1: *Animation output from ASL translator*

The gesture research group at ASEL have collated and demonstrated components of a machine to recognise and interpret ASL. A pair of "CyberGloves", from Virtual Technology along with a "flock of Birds" with 3 sensors from Ascension Technology are the primary input mechanism. Simple record and playback has shown that a majority of ASL information is still available by recording hand shapes, and hand and head positions via these transducers.

A neural network recogniser has been demonstrated to recognise the hand shapes of the manual alphabet and work is in progress on translating English via an intermediate form of notation derived from Stokoe's linguistic analysis of ASL, to an animated model of a signer (figure 1).

2.2 Enhanced Sensory Feedback

This is described in an accompanying paper (Harwin and Rahman, 1996), however work in this area was the catalyst for many of the associated projects in investigating haptic systems in telemanipulation and virtual reality.

2.3 A Virtual Interaction Interface

Many individuals need to either do routine movements for the purpose of physiotherapy, or would benefit with a greater understanding of the physical world if they could have meaningful interaction with it. Thus an individual with cerebral palsy may not understand the flight of a ball because he or she may never have had the opportunity to throw one. For such individuals there may be benefit in exploring virtual environments that are tailored to the persons abilities and learning needs.

The virtual interaction interface has been designed primarily using off the shelf components, so that such a device would be affordable by schools, and hospital therapy facilities. It allows "low-immersion" virtual reality that provides many of the benefits of more expensive systems, but without costly and encumbering equipment.

A blue background is provided behind the user and a video camera is positioned to capture any movements. Using a chromatic threshold the background can be removed from the image and replaced with suitable graphics. This combined video and animation image is then displayed to the user who gets immediate feedback on his or her movements and how

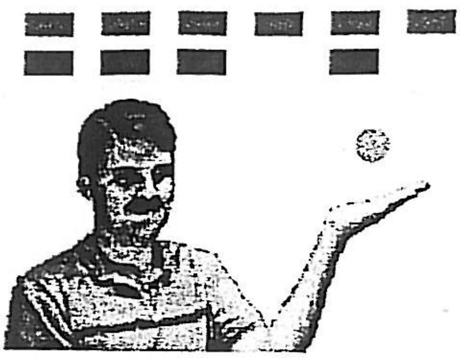

Figure 2: *Composite image from virtual interaction project*

these affect the virtual world.

Algorithms to monitor movements of the silhouette boundary and record when this intercepts the trajectory of any virtual objects are in place and these can be used to program a variety of physical laws such as objects bouncing, rolling or sticking to the 'virtual' individual. A break-out type game has been implemented to demonstrate the potential of this approach and explore the needs of the interface.

2.4 Supporting Large Language Spaces in Augmentative and Alternative Communication

People who use augmentative and alternative communication (AAC) devices need to access a large database of linguistic units as efficiently as possible. The problem is compounded by the fact that most AAC users typically have poor physical skills and that their language is often organised to "fit" into the display or keyboard of the AAC device. The alternative is for the individual to use and remember short forms of the vocabulary, such as words without vowels, or a sequence of pictograms. This approach requires the user to have a good memory for the location of language data and does not give intermediate feedback so often a language element will be chosen incorrectly.

Technology in common use for virtual reality research could support an expanded language space and thus provide a more natural communication for individuals with severe speech and motor impairments. The key to this research is to establish efficient mechanisms for this to happen.

Human Computer interface research is currently moving away from symbolic representations and towards spatial metaphors, the Apple desktop being a typical example. The implications of this trend may have important consequences for AAC research. A central tenet is that spatial metaphors of information can be more efficiently searched than hypertextual representations. Further people with speech and motor impairments can access this information efficiently and the input device can range in complexity from a single switch to a trackballs or a pointing devices.

This laboratory is using a high performance graphics computer to simulate and explore the consequences of spatially based AAC devices. This allows novel approaches to be explored that do not become limited by the computational abilities of the platform. This is also reasonable since it is likely that the speed and storage capacities of computers will continue to increase to allow low cost implementation of facilities such as realistic animation or high speed scrolling. Once promising techniques are established they can be transferred to more practical AAC systems and work is ongoing on a transferring one conceptual AAC device to a practical system based on a low cost head mounted display - the private eye from Reflection Technologies (Demasco et al, 1994).

2.5 Multimodal User Supervised Interface and Intelligent Control (Musiic)

Rehabilitation robots designed to assist an individual with a motor impairment to manipulate their environment have typically depended on one of two interface strategies. The first, command oriented interfaces, are simple for the individual to access but require a high level of structure to the environment and can only perform a small number of tasks (Harwin, 1995). In contrast directly controlled robots have a higher level of flexibility but require a high level of manual dexterity on the part of the operator.

The Applied Science and Engineering Laboratories are developing an interface that attempts to utilise a command level of interface but maintains the flexibility of a direct interface. Central to the interface philosophy is that information that is acquired by the robot should be fed back to the user so that instructions can be given based on a knowledge of what the robot can achieve.

Figure 3. *Real and virtual environments in the Musiic project.*

This project utilises a force sensing robot and optical sensors able to measure surface detail to the millimetre level. The interface uses a speech recogniser and a head mounted pointing device to allow the individual to locate objects to the robot. The system maintains a database and if a match is possible will manipulate the object as commanded. If a match is not possible a dialogue ensues to allow the object to be correlated with information in the database or a new instance of an object to be recorded (figure 3).

This system has been demonstrated in a preliminary form that allows a user to point to an arbitrary object, and move it to an arbitrary location with the command "put that there" (Kazi et al, 1995).

2.6 Haptic Display Systems For Individuals with a Visual Impairment

Teaching methods, especially in science, engineering and maths, tend to discriminate against individuals with disabilities, especially if the individual is blind or visually impaired. This is because of the vast amount of information that must be assimilated visually, including graphs of data, pictures of a physical phenomena, formulae, instrument displays etc. As a result very few individuals with disabilities acquire the scientific skills that allow them to enter employment in a technically skilled work force.

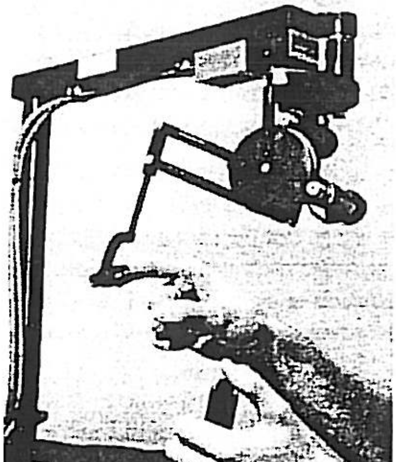

Figure 4. *Haptic representation of scientific data.*

Technology based solutions may have much to offer in making scientific information more accessible to visually impaired individuals. Central to this research is the study of haptic systems that appeal to the sense of feel and touch. This, in combination with auxiliary outputs based on braille displays or synthesised speech, are hypothesised to form a cogent interface for scientific data visualisation. The haptic display system is based on a PHANToM 3 axis interface from SensAble Devices (figure 4). Using this interface Fritz and Barner (1996) have demonstrated a haptic representation of simple xy graphs and work is also ongoing on tactile representation of pictures.

3. CONSUMER INPUT IN RESEARCH AND DESIGN

Because of the low incidence of technical skills in individuals with disabilities, a greater effort is necessary to ensure that research and development is achieving the goal of enhancing the abilities of individuals with disabilities. The Applied Science and Engineering Laboratories has a multi-levelled approach to ensure that research goals are in keeping with the needs of the individual.

The first of these is to ensure that there is a high representation of individuals with disabilities on the staff, and the Laboratories have been pro-active in recruiting professional and motivated individuals with disabilities to its staff. The Laboratories also seek to ensure that the needs of the individual are met with appropriate work-site modifications and with an employment practice that accommodates the needs of the individual.

The Laboratories also run a variety of focus groups related to particular projects where individuals with disabilities relating to the research meet with the researchers and discuss the progress of the work. The frequency of these meetings depends on the research goals, but several projects aim to meet with the consumer advisory group on a fortnightly basis.

The laboratories have also made significant effort to drawn local disability support groups into the research agenda and to liaise with organisations and individuals within the disability community. This approach has been successful in establishing projects that are targeted primarily at enhancing the lives of individuals with disabilities in the local community.

Several research projects need to make measurements on human subject and after review by the hospital ethics committee, this is conducted at the convenience of the individual. Thus, where possible, measuring equipment is designed to be portable so that it can be taken to the individuals home or to a more convenient location.

Formal evaluations of the research goals are made by an advisory committee that includes people with disabilities and part of this process is both open, and closed discussion about the laboratories research goals. Finally the laboratory encourages visits from individuals with an interest in disabilities and technology. Visitors include individuals with disabilities, their family and careworks, clinical professionals and academics. The laboratory tour is customised so that projects relating to the visitors disability are discussed and informal comments allow the research staff to gain a deeper insight to the nature of the disability.

All these methods of consumer interaction have value for the research projects, however it is difficult to quantify the nature and value of these interactions. There is considerable value in engaging a motivated workforce with direct experience of the disability under study however there are very few individuals who meet this criteria. Frequent meetings of a paid review group are also highly effective in gathering data, especially if there is a clear product design in view. Such a group is likely to need to meet less often where the project has more research oriented goals and it is correspondingly harder to keep the group dynamics active and to gather the necessary information on disability concerns. There may also be problems in recruiting and keeping a suitable group of individuals as motivated individuals usually have a large number of other commitments.

4. CONCLUSION

The Applied Science and Engineering Laboratories has an ongoing commitment to supporting appropriate research in enabling technologies for individuals with disabilities. The research environment is highly diverse but with a central focus on the technology needs of individuals with disabilities. Many of the research projects use virtual reality technologies or have developed tools and techniques that are applicable to virtual reality research. The Laboratories involves individuals with disabilities in a wide spectrum of areas to ensure that research maintains focus and the researcher staff gains a thorough understanding of the nature of an individuals disabilities and how that relate to the research.

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Most of the projects discussed in this paper are ongoing and further information may be available via the applied science and engineering laboratories web site http://www.asel.udel.edu/

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