THE UNIVERSITY OF CALGARY

Report on the U of C Multimedia Adaptive Workstation for the Disabled (MAWD) project.

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Man-Machine Systems Laboratory Report

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Summary

This document reports the status of the MAWD project. The project is concerned with research on improved computer access for disabled university students. The history of the project is briefly reviewed, and the progress and achievements to date are noted. Practical and commercial possibilities arise from what has been accomplished so far. Major financial support from: Esso Resources: the Natural Sciences and Engineering Research Council of Canada under grant A5261: and of the University of Calgary Innovative Projects Fund is gratefully acknowledged. Some additional funding has been provided by Murphy Oil Company Limited and by PanCanadian Petroleum Limited. This support is also gratefully acknowledged.

Introduction

In 1982. a three faculty and a disabled graduate student at the university of Calgary (Witten, Cleary, Hill and Darragh) were involved in the design of a keystroke accelerator to facilitate keyboard entry of text for people with motor disablities. An account of the work is published in Witten *et al*. (1982). In order to continue and expand the work, the MAWD project was initiated and a sponsor sought. The project was targetted specifically at the needs of disabled university students. Two main questions were involved. First, how could we make the computer facilities normal students use in their courses (particularly computer science courses) more accessible to disabled students. Secondly, what useful facilities could be built into a personal computer workstation to help disabled students in general to function more normally and effectively in the context of university studies. Clearly, these questions are closely related, and entail a host of more detailed questions and problems. However, for the first question , the emphasis is on access to standard computing facilities, whilst in the second the emphasis is on innovation for any helpful purpose. The first question is of especial interest in that computer science careers offer particular attractions for disabled students capable of working at a university level. Vanderheiden (1982) aired similar views:

> In considering the use of computers by disabled individuals, it is very important to remember that disabled people also need to use the same programs and accomplish the same tasks as anyone else. Thus the blind individual who may make good use of a text-to-braille program also needs to be able to use standard text editors, spreadsheet programs (e.g. *Visicalc*), and database managers, to name only a few. Similarly, the physically disabled individuals who could use a game or a writing program that requires only the operation of a single switch also need to be able to use the standard educational software as well as the accounting programs and computers at the companies considering them for jobs.

The project considered three classes of disability: sensory impairment (blindness. partial sight, dyslexia. hearing loss, and the like): motor impairment (reduced control or speed in upper body functions); and mobility impairment (difficulty in getting around and reaching things). It is important to realise that, by restricting our attention to the needs of university students, some of the more difficult problems are avoided altogether, because such an individual has the mental ability, motivation. and physical performance needed to meet certain minimum standards. This limitation was partly a response to a perceived need on campus, and partly a necessary restriction to limit the range of problems considered, as the project is on a very modest scale.

Major funding has been provided for the MAWD project by Esso Resources, the Natural Sciences and Engineering Research Council under grant number A5261. and the University of Calgary Innovative Projects Fund. This support is acknowledged with gratitude as is additional support from Murphy Oil Company Ltd. and Pancanadian Petroleum Ltd. It should be emphasised that the MAWD project has been a research project, not intended to duplicate service functions provided through other agencies. Nevertheless, a basic assumption has been that the results from the MAWD project would be public domain, and that such agencies, or manufacturing companies. would be encouraged to use the results in products and services designed to help disabled university students. Reasonable effort has been expended in this direction and, despite some early setbacks, we are currently working towards two practical goals: one the set-up of several workstations based on our research under the auspices of Academic Computer Services; the other the commercial production of an integrated personal workstation for those wishing to have excellent access to computers despite visual impairment. The latter equipment represents a specialised abstraction of the research embodied in the former. The expectation is that such a specialised workstation could be cheaper, more accessible to the public at large. and more effective for Its purpose. It is this second device which may be of immediate interest to commercial sponsors. Future work is likely to spawn different devices of a similar character. An important component of future interactive systems will be the amount of specialist knowledge built into the devices for a variety of purposes.

Investment, personnel and progress to date

Investment and personnel

The approximate total cash support over the last three years, from all sources, is $57K. divided roughly into $22K for equipment and $35K for operating costs (mainly salaries). In addition, we have obtained valuable co-operation from Dr. Dewar and his students in the psychology department (especially Edie Adams), and Dr. Wardell and his students in Environmental Design (especially Bill Mak) absolutely free. This assistance, mainly in 1984-85, resulted in the design of an integrated physical support system for the workstation, and probably amounted to 75 man-hours of faculty time and 400 man-hours of student time. In addition, there has been an indirect benefit of association with the *Jade* distributed programming environment project, in terms of access to expertise and software. Some of the personnel had *Jade* responsibilities as well as those connected with MAWD. Some of the work other graduate students of mine have done in this connection has been of direct interest to MAWD (e.g. Hill and Irving 1984), and benefits also pass in the other direction, in connection with innovative interfaces. These are not counted. Drs. Cleary and Witten became occupied with other duties before the funded project really got under way, but my own time has been provided at no cost, and totals at least 400 man hours since the project started. In addition to time put in by some of my graduate students and research assistants (Esau, Döhrn, Jansonius. & Polischuk), included in the salary totals above, two experimental evaluations of project components have been carried out by graduate students in Computer Science 681 (Human Computer Interaction) under my direction. One of these was the subject of a thesis (Döhrn 1984). One of Dr. Witten's students (Darragh) continued work on the keyboard accelerator, but medical problems diminished his contribution and have finally taken him out of the program temporarily. His scholarship is not included in the salaries above. A number of disabled students at the university have been involved in experiments and discussions. One (Steve Dawes, who is blind) was hired as a research assistant this summer (85) in connection with Corine Jansonius' work on an Intelligent Tutoring System for Braille. Other names appear in various places, mainly because of the connection with the *Jade* project, but were really not involved in the MAWD project. Finally, the project builds on my extensive background in human computer interaction, especially my ongoing research interests in speech interaction and the use of expert system techniques for the human computer interface. If the time donated or otherwise provided free is added into the total, at hourly rates rather than consulting rates, investment in the MAWD project as of September 1985 is roughly $76K.

The work is continuing and current personnel comprise: myself (D.R. Hill): a faculty member. Richard Esau and Corine Jansonlus (graduate students. Ph.D. and M.Sc. respectively): and Steve Dawes (a visually disabled undergraduate student). We expect further co-operation from Drs. Dewar and Wardell. In addition. Dr. B.R. Gaines has recently joined the department as a Killam Research Professor. Dr. Gaines has considerable experience in human computer interaction, and Is involved in the plans for the Knowledge Sciences Institute. Both these activities will enhance the environment within which the MAWD work is carried out. providing ideas and students. Dr. Gaines is expected to make a direct contribution. Dr. Witten has completed a term as Head of Department and should rejoin the project, whilst Dr. Shaw has recently accepted a post in the department and is expected to contribute. based on her work in expert systems and CAI, which is of direct relevance to the work on intelligent Tutoring Systems (ITSs). Operating and minor capital expenses are currently borne by my NSERC operating grant, except that Jansonius holds an NSERC scholarship, and Esau is supporting his graduate studies by working as a part-time teaching assistant.

Progress

The main achievements of the project. to date, have been:

- the design and evaluation of the Speech Pad (currently tentatively renamed *Touch 'n Talk*);
- the redesign and re-implementation of the *Touch 'n Talk*, now almost complete:
- the evaluation of a prototype keyboard accelerator;
- the development of a new approach to operating system design (which overlaps *Jade* and the Interactive Dialogue Driver [IDD] work, but provides for the necessary control and reconflgurabillty of an adaptive workstation);
- the production of a large amount of new software, including experimental software for speech input and output, for large font display, and for workstation control and reconfiguration;
- experiments with electromyographic control of system functions;
- the detailed design of the physical support needed for the workstation; and
- the accumulation of relevant knowledge and references, including identification of major problems and possibilities.

Touch 'n Talk is a self-contained personal computer equipped with a speech synthesiser. specially modified digitising tablet, and the possibility of connection to other devices using RS232, Centronix or IEEE488 connections. As such, it can also be programmed to act as a terminal to some remote host. Programs for this purpose have also been written. All material that would normally appear on the screen of a normal PC or terminal is also directed to a virtual screen. In fact the viewable screen is a visible copy of the virtual screen and, in addition, the virtual screen is mapped onto the two dimensional area represented by the digitising tablet. The tablet has a special overlay, with patterns that can be felt. A visually impaired user, guided by the patterns (lines, areas, columns), can access the virtual screen by touch whilst holding the tablet stylus. Thus the structure of the material, menus to control facilities, and the like, can be "seen" and used, based on touch and proprioceptive/ kinaesthetic feedback. Part of the control facility is concerned with the manipulation of cursors which record where in the text the user is looking. and where the working location (for text entry, deletion, etc.) is situated. Control mechanisms exist that allow text to be read in various units (word, phrase. sentence, paragraph); that allow text to be spelled out; that allow the cursors to be manipulated, found again, brought into coincidence, and the like, using audio feedback, and that interpret normal gestures in a knowledgeable way. Thus, a distinction is made between the natural actions of going back slowly to repeat some text, and going back to the beginning of the next line, since the machine response should be different in the two cases. Experiments have shown that this approach to cursor control and text access is easier to use, improves performance, and Is preferred by the target population, compared to alternatives such as the key operated *Information Through Speech* made by Maryland Computer Systems. Furthermore, a greater degree of control is possible (for example, speech rate can be dynamically varied to correspond to the rate of stylus movement). Much research remains to be done to improve our working prototype. The more knowledge that we can build in and use, the better the system will be. This includes intelligent tutoring for auxiliary equipment (such as a *Versabraille* machine) or basic skills (such as reading Braille); user and task modelling to allow the machine to provide assistance that is more directly relevant and less obtrusive; and utilising better knowledge concerning the cognitive structures and techniques Involved in text access using computers. This latter topic has very general implications that go well beyond the MAWD project. It is well known, from informal experience, that many people prefer reading hard copy over reading a computer screen. Part of the reason for this is the higher quality image, and absence of refresh artifacts. However. part of the reason is undoubtedly the nature of the structural cues and strategies that people use, when browsing, skimming and searching text, that are inhibited when the text is accessed In computer form. Discovering and formalising this kind of knowledge, so that it can be used to improve access to text stored in computers, is of fundamental importance in human computer interaction. An early paper by Benest and Jones (1982) covers some of the problems and ideas that are also treated in Döhrn’s thesis (1984). Nagy & Seth (1984) and Witten & Bramwell (1985) represent other views. More research is also needed on the editing task, especially in the context of Touch ‘n Talk, and algorithms to exploit the advantages of this new kind of access. The experiments we have carried out (using both normal and visually impaired subjects) confirm that our device offers some of the advantages of direct manipulation to the visually impaired. Direct manipulation is exemplified, for normals, by the use of a mouse to pick and manipulate items on a visible screen. The Touch ‘n Talk may also be valuable for the form of visual impairment known as dyslexia or "word blindness” (Truin 1983).

The keyboard accelerator work is based on the need to help to raise the typing speed of individuals who suffer some form of motor disability that slows or inhibits their manual dexterity. The scheme we tested involved modelling the characteristics of the material being typed by a user, on a statistical basis, and using this information to predict future input on the basis of current input. Up to a line o text could be predicted, and keys were provided to allow successive single characters, words, or even a whole line of prediction to be accepted. The single character acceptance may seem redundant, but (if correct) would allow the user to tap the same key repeatedly for different desired characters. This would offer advantages to people with certain kinds of motor impairment. Experiments with an initial version of this predictive software showed conclusively that text entry was faster, and the total keystroke count was lower, for individuals who typed at 2 characters per second or less. The extent of the advantage varied, as might be expected. with the character of the material being typed. There was much more advantage if the text was highly redundant (as in typing COBOL programs). The experiments also highlighted problems areas, and suggested modifications to the scheme in terms of the presentation of, and access to the predictions. Regrettably, due to John Darragh’s medical problems. this work is temporarily suspended, although a revised scheme based on adaptive menus in place of single predictions was completed as a working prototype.

One major problem that has been much more difficult to solve than expected has been the operating system software needed to manage the adaptive workstation. A rather different approach has been needed to provide the kind of hooks and auxiliary data in the operating system kernel that are required to deal with reconfiguration and control. For experimental purposes. and for some control purposes (e.g. managing the rate of speech), time stamping of events has been necessary. Some effort has been devoted to questions of dialogue management, device abstraction, and dialogue specification. This work is a major source of overlap with the *Jade* project. Solutions to these problems have not yet been found, and they remain a source of difficulty for workers around the globe, as well as for us. The incorporation of expertise at the operating system level seems to hold part of the answer, but there are tricky questions of: dynamic management of feedback; division and description of i/o devices in terms of overall system function; and adequate handling of arbitrary applications interfaces on arbitrary hosts to be overcome; to mention only a few topics. Our current thinking is along the lines of a radical restructuring of the whole system so that applications are wrapped up in "applications subroutine packages" just as the interface is wrapped up in an "interface subroutine package", or just as graphical output might be wrapped up in a "graphical subroutine package". Then In place of a dialog prototyping and management system we would have a task prototyping and management system that would be integrated into the operating system. This would still not solve the problems of access to arbitrary host-resident software using arbitrary interaction channels. Some preliminary work on the latter problem was reported in Esau (1984). Our current operating system incorporates some of these ideas. but lacks a specification language and control component. Also, the notion of "subroutine package" is limiting. Just as graphics languages offer more than graphics subroutine packages (since they provide graphical data structures and graphical operations that comprise an integrated system), so a task control language is needed that integrates system, applications, and interface operators with appropriate data structures that embody the right kinds of entities, consistencies, and expertise. The whole concept of "applications operators" and the associated data structures, formalised as merely part of a higher level language, is relatively unexplored. With the exception of graphical i/o, device abstraction on the basis of function has never really been considered in these terms either.

We have written a lot of code, and thrown a lot away as we have learned. A voice operated modeless text editor exists, as does all the software for the most recent incarnation of *Touch 'n Talk*. A variety of utilities have been constructed to encapsulate devices in a form appropriate to a flexible. reconfigurable system, and to provide various functions in a task independent form. Thus there is an "editor subroutine" that can be called with one set of arguments to look like an editor. Called with a different set of arguments, it provides an editable command line input for an arbitrary input and output device configuration. The modeless editor will be recast in terms of this new software very shortly and will provide a good test of the savings gained. Work that forms part of the *Jade* project is highly relevant to this part of MAWD (e.g. that on the IDD, Hill & Irving 1984).

An experimental form of cursor control was implemented, based on detecting action potentials around the orbit and temporalis muscles. An experiment showed that subjects were able to learn to control a cursor, but more work remains to be done. Most of the difficulty lies in the software needed to interpret the signals. Better models and constraining principles will improve this form of input.

Finally, a flexible physical support system for the equipment needed to form a workstation has been designed. The results of this part of the project, carried out in co-operation with the Faculty of Environmental Design are recorded in the documents authored by Bill Mak (1984. 1985a & 1985b). Bill Mak was the person responsible for the detailed design of the workstation support, under the supervision of Ron Wardell, with the MAWD team acting as "clients" in a specification and monitoring role. A standalone framework, based on inexpensive scaffolding materials, supports adjustable work surfaces specifically tailored to the equipment and functional needs of a variety of disabled students.

The future

Apart from continuing the work, as outlined above, a number of significant steps must be taken, and plans are already being formed to take them. First, we hope to take the work we have done so far and, without further development, make a number of workstations available for use. This should not only fulfill our goal of putting our work to practical use, but will gather information to allow us to improve existing facilities and add new ones, based on the experiences of our disabled users. Within the MAWD project. we do not have the resources of space or budget to manage such an enterprise. However, both Academic Computer Services (ACS) and Student Counselling Services (SCS) have shown enthusiasm for a proposal to provide a service under their aegis. As it happens, the existing microprocessor laboratory, run by ACS, is being reviewed. We have suggested that, in replacing the existing facilities, some of the resources be devoted to four workstations that incorporate our work over the past three years. We should continue to make our research results available, and update the software and functionality on that basis. The budget. space and day-to-day running would be the responsibility of ACS and SCS. The basic workstations could be set up for roughly $9000 apiece. The highly desirable addition of a *Versabraille* machine at each station would just about double the cost. Such provision, though not legally required yet (as it is at universities in the States) is certainly necessary. We believe that what we can provide is at least as good as alternatives, though we would expect this belief to be checked out by others.

A second step that must be taken is to develop the *Touch 'n Talk* as a standalone system. In its present form, it is not well enough packaged for general distribution. Production engineering into a suitable form would allow commercial exploitation of the system. Plans were laid for this step, but fell apart due to difficulties with the SRTC regulations and differing interpretations placed on these by different parties. The cost of getting into production, excluding production tooling costs and overheads, was estimated as $105K operating and $78K capital. with a time period of 7 months to complete the work.

A third step to be taken is the development of the functionality of the *Touch 'n Talk*. This will improve its marketability and value. In particular. further development of text access and control algorithms will be carried out, and components added to provide the usual PC functions in appropriate form. Furthermore, the problem of connection to an arbitrary host must be tackled and our current solution greatly improved. This certainly requires a host-resident expert system, possibly one that can learn, for optimum performance, and is a long term project. If carried out as an industrial enterprise, rather than as university research (which would speed up the process considerably and give reasonable expectation of staying ahead of any competition), the cost would be of the order of $400K operating and $150K capital. based on loaded rates for an estimated 4 man-years. and the equipment needed.

A refinement, for commercial purposes, would be the development of a subsystem that could be plugged into one of the popular microcomputers (such as the IBM PC) to provide it with at least the major functions of *Touch 'n Talk*. Such a system would reduce the cost of this kind of access for the disabled considerably. A complete system, as it now exists, might sell for $8000. and the main customers would be institutional. A PC subsystem. whilst less powerful. at least compared to what could be developed standalone, might sell for less than $2000.

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