

control. And games are only a starting point. Many hobbies such as computer art, music composition, ham radio, and even investment management can be pursued with the microcomputer.

Occupational Capabilities. The occupational capabilities of the MHSS offer the greatest potential benefit to a handicapped individual. There are many blue- and white-collar jobs that can be adapted for MHSS-based performance. However, this area also poses the greatest software challenges because efficient software subroutines will be needed to interface the MHSS with the occupational equipment.

The most obvious blue-collar job opportunities center around the operation of electrical or electronic machinery that is monitored by visual means. Such jobs exist in many places as a result of increasing automation. Automation reduces manual labor but still requires some operators for their visual abilities. In many of these jobs, a motor-handicapped person is no longer at a disadvantage.

For instance, printed circuit companies have a set-up machine for automatic drills. The operator of this machine enters drill hole positions. With simple controls, he manually moves a cursor around on a projected image of a printed circuit. He centers optical crosshairs on a hole, punches a button, and the data are automatically entered into a computer. Once set up, the job is 90% visual and 10% manual. By replacing the manual cursor with a motor drive, using voice control through the MHSS, and building some simple software, that task could easily be performed by a motor-handicapped person.

There are even more opportunities for white-collar jobs. Most white-collar occupations are designed to be performed at a desk arranged with various tools, information, and, of course, the telephone. During the last few years, technology has begun to simplify

the desk clutter by replacing both the information and tools with a computer or computer terminal. This is taking place most rapidly in occupations such as buying, sales (particularly phone sales), data research, and computer programming. Also, many of these jobs can be performed at home, with completed work sent to the company via computer communications.

Dave Ward described himself as an excellent candidate for such an occupation. Before his injury, Dave worked as a sales representative for several construction equipment companies. His job was to find the type, price, and configuration of equipment that would generate a sale to his customer. To do this, he used a series of catalogs provided by his clients. After his injury, flipping through a number of catalogs was no longer possible. Dave had been wondering if some computer application would let him continue his earlier work. Using an MHSS to put an automated microfiche reader and a telephone under voice control would be an excellent solution to Dave's problem.

Adaptability of the MHSS. The MHSS can be adapted to provide all of the above capabilities merely by adding new software. This guarantees the long life of the system and ensures that it can be beneficial in a wide range of situations.

Additional Notes

The prototype MHSS described above is now operational. What is needed is a test program with handicapped individuals and optimization of the final software.

The circuit board described above and much of the control software are available for either the Heath/Zenith H-89/Z-89 or the Digital Group microcomputer. The board will also be available soon for S-100 systems and Radio Shack computers.

VISION

ADAPTING PERSONAL COMPUTERS FOR BLIND AND SPEECH-HANDICAPPED USERS

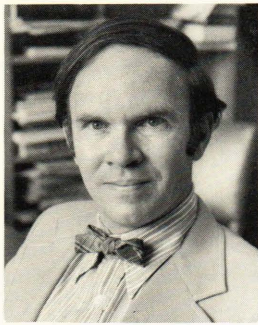
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The types of personal computers in most widespread use have been adapted by the author for the use of blind and speech-handicapped users by the addition of unlimited vocabulary speech output, Grade II braille output, and Morse code input for the physically handicapped. Experiments are under way with multifont optical character recognition input and are planned with portable electronic typewriter input. Field tests have shown that personal computers can

provide low-cost aids to blind users in study, employment, and recreation.

Introduction

Software has been developed by the author to adapt the majority of personal computers for blind and speech-handicapped users. Software modules include unlimited vocabulary text-to-phonetics programs for English (developed by the author), for



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French (developed by the author and Pierre Trescases), and for Spanish (developed by Bruce Sherwood); a talking terminal program (developed by the author); a Grade II braille translation program (developed by the author); a Morse code input program for users with physical disabilities (adapted by the author from a public domain program); an experimental multifont optical character recognition system (developed by the author); talking computer and terminal programs for use with the CP/M and Radio Shack operating systems (developed by the author); and a talking computer program for the Apple operating system (developed by Dianna Visek and the author).

Output Systems

Personal computer systems usually have a video screen as the primary output medium, with a printer available as an extra-cost option. Video output is useful to blind persons working with sighted associates, and printer output is important for preparing letters and reports; however, the blind user needs output in a form that can be perceived by the senses of hearing or touch, while the mute user needs an artificial voice. Therefore, the author has developed speech and braille output systems.

Speech Output

Voice output is supplied through commercially available speech synthesizers. The process of going from phrases in English (French, Spanish, etc.) to synthetic speech involves three steps: translation from text to a phonetic representation, translation from the phonetic representation to the electrical impulses needed by a particular synthesizer, and translation of these impulses by the synthesizer to synthetic speech audio output.

Text-to-speech rules for English were developed by a number of researchers in the 1960's and 1970's. In 1978, the author implemented one of these algorithms^{1,2} in a real-time version for the 8080 and Z-80 microprocessors, along with software to interface to the Votrax VS-6 speech synthesizer. He adapted this software for marketing with the now obsolete Computalker Synthesizer in 1979. In 1980, he adapted the algorithm to the Votrax VS-B synthesizer (which has a high-speed speech capability particularly helpful for blind users) and added an intonation scheme de-

veloped by Bruce Sherwood.³ In 1981, he worked with Dianna Visek in translating this algorithm for the Apple II computer.⁴ This version is being marketed by Street Electronics Corp., along with its low-cost speech synthesizer for the Apple II. The phonemes generated by the algorithm are translated by software developed by Milo Street into codes to drive the Texas Instruments 5200 linear predictive code speech synthesis chip.

The Votrax SC-01 single-chip synthesizer released in 1980 is software compatible with the VS-6, and the author is adapting his software for use with that chip on 8080/Z-80 systems (e.g., Radio Shack and CP/M) and 6502 (e.g., Apple, Commodore, Atari) microprocessor-based personal computer systems. In 1980, Votrax introduced the VS-A speech synthesis board and in 1981 it introduced its serial interface Type-'n-Talk synthesizer, both having built-in text-to-phonetics conversion software.

In 1980, the author and Pierre Trescases developed a French text-to-speech algorithm and implemented it for the 8080 and Z-80 microprocessors and in a PASCAL version.^{5,6} In 1981, Bruce Sherwood made an 8080/Z-80 version of his Spanish text-to-speech algorithm available.³ These algorithms have been interfaced with the Votrax VS-B synthesizers with French and Spanish phoneme sets. Others have developed Swedish and German text-to-speech systems.⁷ Thus, with the appropriate hardware and software, blind persons can obtain output in a variety of languages, and speech-handicapped persons can communicate by voice in these languages using personal computers.

Braille Output

Computer output braille devices have been commercially available from Triformation Systems and other sources for a number of years. Such devices are useful for the minority of blind persons who read braille⁸ and desire hard-copy output; they are essential for deaf-blind individuals. Both public domain and proprietary programs have been available for some time that translate ordinary English into Grade II braille (the very complex system of braille abbreviations normally used in English-speaking countries). However, the public domain programs have tended to be complex and difficult to adapt for efficient operation on microcomputers. Therefore, the author developed a program written in standard PASCAL driven by a table of braille rules in a simple format. This program is compatible with PASCAL compilers available for most microcomputers and can be used to provide braille output on either commercial or homemade braille devices merely by changing the output codes to correspond to those used in a particular device.

Input Systems

Personal computer systems use a standard typewriter keyboard as an input system. This keyboard works well for most blind users.⁹ However, the

author has experimented with two other input systems: Morse code (for the physically handicapped) and optical character recognition. Computer input systems for physically handicapped sighted users often rely on selection from a menu on the computer video screen. Since blind users do not have this option, Morse code input seems more appropriate. Morse code input software available in the public domain was used for this purpose. The experimental work on optical character input is designed to offer an alternative approach to that used by the Kurzweil Reading Machine. Published algorithms have been combined and modified to allow real-time processing on a Z-80 microprocessor of input data from a Reticon optical scanning chip. The philosophy behind this experimental work is that one or more pages of text would be read into the personal computer automatically, and that the user would interact with the text through the computer rather than trying to control the motion of the optical scanner itself.

A new product, the Sony Typecorder, a compact portable recording electronic typewriter with a computer interface, promises to help solve a serious problem of blind students and professionals, that of note taking.¹⁰ At present, for those not knowing braille the only option is tape recording, which offers only sequential access to notes. Persons knowing braille can take notes on paper but soon accumulate unwieldy masses of notes. Paperless braille devices are available that could be used to provide machine-readable notes, but they are extremely expensive and hard to get repaired. In addition, notes taken in Grade II braille require translation into English before computer processing, and translation programs are unavailable. By taking notes on a Sony Typecorder and feeding them into the talking personal computer developed by the author, a student will have full random access and text-editing capability for dealing with the notes.

Operating System Interfaces

A speech output capability is only useful for a blind user if it is integrated into a microcomputer operating system so as to give the user access to the normal computer functions and to commercially available software. With this goal, the author has developed interfaces for the three most popular personal computer operating systems: CP/M, Radio Shack, and (with Dianna Visek) Apple. The software captures output and speaks it as it is sent to the screen, including optional echoing of keys as letters appear on the screen. Input is also captured, with normal input going to the computer operating system, but with user commands to the speech system being intercepted and executed. User commands include full speech or spelled speech, instant replay of any line or position on the screen, and cursor position readout.

This system gives the user access to commercially available software, including both programming languages (BASIC, PASCAL, etc.) and application pro-

grams (accounting, statistics, recreation), with two exceptions. First, output written directly by programs to memory-mapped screens rather than through operating systems will not be captured but can be replayed, though graphic output will not be correctly interpreted. Such output is fairly common in programs for the Apple and Radio Shack TRS-80, particularly in game programs. It does not occur in CP/M-compatible programs since, to be compatible, such programs must use only CP/M operating system routines for input and output. In extended experiments with the author's program for the TRS-80 Model I at the Tennessee School for the Blind, it was found to be relatively easy to remove the direct screen output and graphics from commercially available programs to adapt them for blind users. The second exception is the unavailability of memory space in user programs used by the text-to-speech and control software. A survey of advertisements in personal computer magazines indicates that this problem affects less than 25% of advertised software. The problem is eliminated almost entirely when using the author's interface for the Type-'n-Talk to the CP/M operating system, since that interface requires only about 4 kilobytes of memory (almost all CP/M-compatible software allows that much memory for system programs).

Talking Terminal

The first full-speech talking terminal was developed at the University of Illinois in 1976 by James Kutsch, a blind graduate student.¹¹ While not giving full working details of the terminal structure, his thesis indicated that such a terminal is possible. The present author independently developed a talking terminal in 1978, using the text-to-phonetics software discussed above and his 8080-based personal computer. Copies of this terminal have been in use continuously at the U.S. Department of Justice and various universities since 1978. A copy of the software for the terminal was made available to Maryland Computer Systems when it was designing the first commercially available computer terminal in 1980. The talking terminal has been adapted for Radio Shack and CP/M software, and work is under way to produce Apple talking terminal software.

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A BRAILLE WORD-PROCESSING SYSTEM

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More than secretaries and journalists, braille transcribers need word processing to help them be more productive. An inexpensive but full-powered braille word-processing system is described that can be used to transcribe both textual and nontextual (e.g., music or scientific) materials. Using a slightly modified Apple II personal computer, braille is keyed into the system. It is then displayed in the standard braille format on the screen, revised using a powerful text editor, and embossed by a computer-adapted Perkins brailler. High-quality braille is produced by the system without the frustration and delay of rebrailleing an entire page when a mistake is made.

Introduction

The visually handicapped individual who has learned braille depends on ready access to braille materials. In the United States, braille is produced by both large braille printing houses (e.g., the American Printing House for the Blind) and individual volunteers working in their homes. The large printing houses handle the high-volume braille materials such as magazines and popular literary works. Low-volume and nonliterary work (music and technical texts)

are handled almost exclusively by volunteer brailleists. These 2000 or so individual brailleists are collectively responsible for producing all braille music and most college textbooks, plus other scientific, mathematics, and foreign language braille texts.

Volunteer brailleists produce braille in their homes on a mechanical braille embosser such as the Perkins brailler. This machine embosses raised dots directly onto heavy paper. Each braille page consists of 25 lines of braille with up to 40 braille characters per line. When a mistake of a single dot is detected, the entire sheet must be rebrailleed. (If another mistake is made while copying the correct portion onto the new sheet, it too is ruined.) This extraordinary concern for perfection is necessary. Blind readers are very sensitive to even small "blips" (partially raised dots) on the page. Perfect braille pages are also required when using a thermoform duplication process, which copies entire pages of braille onto thin plastic. Much of a brailleist's time is wasted rebrailleing pages to correct errors.

Recently, progress has been made in developing computer systems that can automatically translate computer-readable text into what is called Grade II braille. A straightforward literary work can be typed into such a system by a secretary, and usable braille copy will be produced. Unfortunately, there is much printed material that cannot be processed by automatic translation. Many materials, including music scores, mathematical formulas, engineering equations, and foreign languages, can, however, be converted to braille and typed in braille form into a braille machine.

A Braille Word Processor

A word processor is a computer system that absorbs text into its memory as it is typed on the keyboard, displays the text on a screen for proof-reading, allows effortless correction of errors, and finally types out a perfect copy on paper. A braille word processor performs the same functions but with the input, display, and output in braille format. Since the braille format is unnatural to regular keyboards,