

THE MOTOR-HANDICAPPED SUPPORT SYSTEM

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This paper describes a hardware/software prototype system designed to be plug-in compatible with standard microcomputers. The system is intended primarily to assist the quadriplegically handicapped but could benefit many motor-handicapped or bed-ridden people. The basic system concept is threefold: first, to provide the handicapped person with voice-recognition access to the powerful communications and control capabilities of a microcomputer; second, to provide a number of useful but low-cost peripherals applicable to the needs of the motor handicapped; and third, to develop interfaces to special-purpose equipment offering meaningful blue-collar and white-collar job opportunities.

Introduction

Until lately, the quadriplegically handicapped person has had few tools to aid him with the problems of daily living and virtually none capable of providing the means for a steady occupation. The mouthstick is the most common tool; with it a quadriplegic can perform manual tasks such as turning the pages of a book or typing a letter. Another, more complex tool is a row of straw-like tubes that the individual can activate by blowing or sucking. The tubes connect to pneumatic switches that can control devices such as a motorized wheelchair. In a newer version of this concept, the tubes are replaced with joystick-type controls that can be operated by moving the lips or chin. These examples require fairly awkward movements of the head and are generally useful only for simple tasks.

Recent electronic advances are now giving us the means to develop a new generation of tools for the severely physically handicapped. Since the quadriplegic's problem is the loss of a general ability to manipulate objects and information, the ideal tool should be a general-purpose support system that provides a variety of manipulative abilities. The system should be modular so that it can be tailored to a user's needs and be quickly upgraded with technological advances. This paper describes an operational version of this general-purpose tool. The system is called the Motor-Handicapped Support System (MHSS).

The MHSS is built around a standard microcomputer and performs three basic functions — communication, translation, and control.

Communication refers to the link between the individual and the system. In the MHSS, this link is voice recognition. Other means are possible, but voice recognition requires no head movements, minimizes hardware cost, and offers efficient and simple communications.

The translation function of the MHSS is performed by the microcomputer. The computer translates the vocal command of the user into the electronic control language required by a manipulating device. If necessary, complex calculations can be carried out during translation.

The control function of the MHSS is the transmission of the translated commands to the "manipulators" connected to the MHSS. As many special- or general-purpose manipulators can be added as desired because the control capabilities of the microcomputer are so versatile.

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The experimental MHSS now in use is a hardware/software combination designed to plug into the Heath/Zenith H-89/Z-89 microcomputer. Another version has been designed for the Digital Group microcomputer. Detailed descriptions of both the hardware and software are given below.

Hardware for the Motor-Handicapped Support System

The MHSS hardware consists of a 30-square-inch, double-sided, printed circuit card. The card adds to the microcomputer a voice-recognition communications capability and several "manipulator" devices useful to a motor-handicapped person. On the card are electronics for voice recognition, sound synthesis,

voice synthesis, a BSR home control interface, two RS-232 communications ports, and a real-time clock/calendar. Installation requires only that the board be plugged into the host microcomputer and connected to a microphone (for voice recognition), an ultrasonic transducer (for BSR communications), and an audio amplifier (for sound and voice synthesis).

The unique aspect of the MHSS design is that so many electronic capabilities are available on a single printed circuit card. This design keeps costs low, simplifies software development, and provides a basic MHSS capable of demonstrating a wide variety of motor-handicapped support capabilities.

Sound Synthesis. The efficient use of circuit board space was made possible with the use of two General Instruments AY-3-8910 integrated circuits. These integrated circuits not only serve as versatile sound synthesizers but also provide two input/output ports that provide links to the other devices on the board.

Voice Recognition. The voice recognition module is a combination of two bandpass filters and threshold detectors. An audio signal from a microphone is separated into high- and low-frequency components. Operating independently, each of the two threshold detectors controls a single input bit to the computer. The computer continually reads these bits to build a time-based signature of the spoken phrase.

Clock/Calendar. The clock/calendar module is provided by a single integrated circuit that is designed for microcomputer interfacing. A battery backup circuit was added, and the chip was interfaced to two ports on the sound chips.

Home Control. The interface to the BSR home control unit uses minimal electronics. The home control signals are generated entirely by software and transmitted to an ultrasonic transducer through one output bit of the sound chip.

Voice Synthesis. Because current voice synthesis chips vary greatly in voice quality and ease of programming, the voice synthesis was designed as a separate plug-in module that piggybacks onto the circuit board. A Votrax SC-01 module is now operational and a Texas Instruments 5220 synthesizer will soon be operational. The Votrax module has the advantage of an unlimited vocabulary but is much less intelligible than high-quality voice synthesizers such as the Texas Instruments 5220.

Dual RS-232 Interface. The dual RS-232 interface on the MHSS board makes it possible to link the MHSS system to any RS-232 compatible device. Two good examples are a printer and a modulator/demodulator. With the proper device driver, this would give the handicapped individual voice access to data banks and the ability to send and receive electronic mail. He could also operate electronic machinery that can be controlled by an RS-232 link.

Software for the Motor-Handicapped Support System

The addition of appropriate software converts the microcomputer into the Motor-Handicapped Support System. The three main parts of the software reflect the three basic capabilities of the MHSS that were discussed above — communication, translation, and control. A voice recognition algorithm handles the communication function, the MHSS control program performs the translation function, and control is performed by tailored driver routines that actuate either the manipulators on the MHSS circuit card or external devices connected to the two RS-232 interfaces. The resulting package is a general-purpose system that can be tailored with the external devices and voice commands to meet the individual's needs.

The Voice Recognition Algorithm. The MHSS voice recognition algorithm was designed to keep the cost low while achieving reliable recognition of a library of 20 to 30 phrases. Using only zero-crossing circuitry with a total parts cost of less than \$15, a software algorithm has been developed that will recognize 24 separate phrases with about 95% reliability. Some commercial systems can improve these results and handle larger vocabularies but cost thousands of dollars — out of the question for most handicapped persons. There are six basic steps to the algorithm:

1. Collect the voice signature,
2. Normalize the signature length,
3. Normalize the total zero-cross count,
4. Compare the signature to the library,
5. Select the best fit,
6. Reject out-of-range signatures.

In step 1, when a sound trigger (which activates the algorithm only when sound is detected) is triggered, zero crosses are counted and stored in "boxes" at intervals of about 15 milliseconds. The counting is continued for 2.5 seconds. In step 2, ending silences are clipped off each box, and the counts are reorganized into a new set of 16 boxes containing equal time fractions of the entire phrase. This corrects for varying phrase lengths. Further corrections for time and amplitude variations are done in step 3 by normalizing the total number of counts in all the boxes to a constant number. In step 4, a linear fit routine scores the new signature against the entire library of previously recorded signatures, and in step 5, the library signature with the best fit is selected. And finally, it is verified in step 6 that the fit is good enough for a valid recognition. If so, the program continues on the basis of the selected fit. Otherwise, an error message is printed, and the loop is restarted.

The entire algorithm is written in Z-80 assembly language; it takes about 300 milliseconds to identify one out of 24 signatures.

The MHSS Control Program. The MHSS control program is a complex program written entirely in Z-

80 assembly language for efficiency and speed of operation. The 18 kilobyte machine code program is assembled from a source code over 128 kilobytes long. The program allows the user to build a complete voice or time/date control system for calling single or multiple driver subroutines.

The MHSS program is organized in a menu with these options:

1. Load voice signatures and actions,
2. Load time control actions,
3. Execute home control,
4. Exit.

Option 1 lets the user load a voice signature and easily link it to one or more callable subroutines. Signatures are loaded by speaking them into a microphone. After processing as described above, each voice signature is stored in 64 bytes of memory. Option 2 lets the user edit a time-control queue to execute subroutines at a certain time and date. Option 3 gives a status display of devices under computer control and allows the user to activate voice and/or time control. Once voice control is enabled, 24 separate voice commands are available to perform as set up under option 1.

The operation of the program is very simple and at present requires only a few key strokes for loading voice signatures or editing the time queue. Once the user enters the voice-control mode, no keyboard entries are necessary. The next version of this program will replace the keyboard setup commands with voice control.

Two other features of the MHSS control program are important. Although the current design limits the number of active voice commands to 24, new libraries of 24 different commands can be loaded by a voice command as well. This makes an unlimited number of voice commands available and allows the organization of command libraries into a tree structure for different types of operations. The other useful feature is a variable recognition tolerance. A variable tolerance allows the definition of critical voice commands with tighter tolerances to minimize erroneous recognitions. Also, a "sleep" mode can be entered wherein only one command will return the program to the normal control mode.

Manipulator Driver Routines. With the device drivers now included in the MHSS control program, the user can manipulate 16 lights and appliances, a sound synthesizer, and a voice synthesizer. By adding other peripherals and associated driver subroutines, control can be extended to any equipment that can be interfaced to the computer.

An experimental driver routine lets the user actually type a letter using only his voice. A fixed library of 40 key words is used to provide access to the 26 letters, punctuation, and control functions such as capitalization, tabs, and backspace. The demonstration routine can also call up new library banks that use the same 40 key words but connect them instead to make complete words. This means that in limited vocabu-

lary applications, such as computer programming or form letter production, high typing rates become possible.

A project will be under way soon to provide a driver for an automated microfiche reader. This application could provide a handicapped individual with voice access to hundreds of thousands of pages of data, with access to any page in 10 seconds.

Capabilities of the Motor-Handicapped Support System

The MHSS has all the hardware functions available on the host microcomputer and the MHSS circuit board. Essentially, anything the microcomputer can operate can theoretically be voice controlled. In its basic configuration, the MHSS has control of the computer's display and printer as well as lights and appliances, a clock/calendar, a sound synthesizer, and a voice synthesizer. With devices like these under its control, the MHSS can provide many capabilities to a motor-handicapped person. These capabilities fall into three areas: utility, recreational, and occupational. Each of these areas is discussed below in terms of the basic functions of the MHSS and some extended functions that are possible with software and hardware additions. Credit for many of the ideas is due to Mr. David Ward, who is quadriplegically handicapped. Mr. Ward kindly provided some valuable advice on MHSS applications.

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Utility Capabilities. The present MHSS offers control of lights, television, a stereo, and other electrical devices. This environment-control capability can be extended easily to moving drapes, doors, and similar objects by adding simple motor-driven devices that can be switched on and off with the BSR control system. A variety of sensors that could also be added to the MHSS could range from simple thermometers to complete burglar alarm systems. The telephone is probably the most important interface because it opens the door to many other options such as links to other computers. In the future, still other capabilities will be possible when the cost of experimental robot arms now being designed goes down.

Recreational Capabilities. The area of recreation for the severely motor handicapped has been seriously overlooked. Rehabilitation centers normally have a number of activities such as pool tables and board games available for paraplegics. However, for quadriplegics the only form of recreation normally available is television. The current MHSS, because it is built around a standard personal computer, is ideally suited for designing video games based on voice control. In fact, in many cases only a small software effort is required to convert an existing game to voice

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 multifold 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