DOCUMENT RESUME

ED 289 310 EC 201 271

AUTHOR	Vanderheiden, Gregg C.
TITLE	Practical Application of Microcomputers To Aid the Handicapped.
INSTITUTION	Wisconsin Univ., Madison. Trace Center.
PUB DATE	Jan 81
NOTE	10p.; A product of the Trace Research and Development Center on Communication, Control, and Computer Access for Handicapped Individuals. For related documents, see ED 201 272-280.
AVAILABLE FROM	Trace Center, University of Wisconsin-Madison, Waisman Center, 1500 Highland Ave., Madison, WI 53705-2280 ($1.10).
PUB TYPE	Reports - Descriptive (141) -- Journal Articles (080)
JOURNAL CIT	Computer; Jan 1981
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Assistive Devices (for Disabled); *Disabilities; *Microcomputers; *Rehabilitation; Sensory Aids

ABSTRACT

The paper focuses on the development of relatively low-cost microcomputers, which provide a potentially powerful tool for the rehabilitation field. The paper discusses such areas of application as sensory enhancement/translation, manipulator controls, information amplification, special control interfaces to other devices, recreation and development aids, educational aids, communication aids, cognitive and language processing assistance, information resource/management, security/monitoring systems, and so on. Three approaches to providing aids to the handicapped are discussed: commercially available aids, custom-built aids, and modified standard systems. Barriers to more extensive use of microcomputers in rehabilitation are cited, and approaches to the problems of multilevel and multitasking processing are examined. (JDD)

PRACTICAL APPLICATION OF MICROCOMPUTERS TO AID THE HANDICAPPED

Vanderheiden, G. C.

1981

Trace Center

Trace Research and Development Center
on Communication, Control, and Computer
Access for Handicapped Individuals
University of Wisconsin-Madison

Waisman Center/1500 Highland Avenue Madison, Wisconsin 53705-2280 (608)262-6966 TDD: (608)263-5408

Microcomputers are providing rehabilitation engineers with powerful tools for designing cost-effective assistive devices. Potentials, approaches, and current shortcomings are discussed here.

Practical Application of Microcomputers to Aid the Handicapped

Gregg C. Vanderheiden
Trace Research and Development Center
University of Wisconsin—Madison

The advent of relatively low-cost microcomputers has provided a new and potentially powerful tool for the rehabilitation field. Although there are many situations in which microcomputers are not applicable, they can provide flexible, cost-effective solutions to a wide range of problems faced by handicapped individuals. Because of widespread availability and support, the more popular microcomputers offer certain advantages, such as ease of dissemination, over custom-designed aids. They can also reduce one of the biggest problems in the area of rehabilitation, maintenance and repair.

The potential of the microcomputer as a rehabilitation tool, however, is currently limited by a number of system and configurational constraints. These constraints tend to reduce applicability to simple one-task problems—the exception rather than the rule in the rehabilitation field. Removal of these constraints would permit application of microcomputers to a much broader range of rehabilitation problems, including those faced by the severely and multiply handicapped.

Areas of application

The use of microcomputers as processors or controllers could aid—to some degree—almost any aspect of human activity that has been impaired. Compiling an exhaustive list of application areas would be impossible, but common areas which have been or are being explored include

- sensory enhancement or translation,
- manipulator controls,
- information amplification for the motion impaired,
- special control interfaces to other devices,
- recreation and development aids,
- education—educational aids and computer education;
- communication—phone, writing, and conversation aids;
- cognitive and language processing assistance;
- information resource/management;
- security/monitoring systems;
- nonspecialized, general uses—computing, word processing, and control systems for work/home; and
- combinations of the above, one driving another.

Sensory enhancement/translation. In the area of sensory enhancement or translation, microcomputers can be used to provide clarification of audio or visual information so that it can be more easily understood, or translation from one medium to another. For example, microcomputers can be used to expand visual displays; provide visual displays of auditory information or auditory displays of visual information; translate printed text into speech, text into Braille, or—in the near future—speech into text; and provide tactile displays and feedback to deaf/blind individuals.

Manipulator/controller. Individuals with severe motor impairments could control powered prostheses or robots with remote actuators. One difficulty with this proposal—and a potential role for microcomputers—lies in the large number of signals required to control such devices. Microcomputers might help control remote manipulators by developing and remembering complex movement command chains for specific types of activities. The user could call upon these routines with only a few commands, thus making complex motions with reasonable speed and ease.

Information amplification. The problem of slow information transfer is not restricted to the manipulator/control field; in fact, its greatest impact is probably in communication and writing. Here, the speed with which one can transfer information is crucial, and the demand for reasonable speed is extremely high. A speed differential of even four or five (the average for a motor-impaired individual is 10-20) can mean two hours versus eight hours of work per day, or the ability to do two hours of homework (which would otherwise take 8-10 hours) in an evening.

The microcomputer can be used in a number of ways to increase or amplify the amount of information that can be relayed with a given number of keystrokes or signals. Most of these techniques take advantage of redundancy in the information transferred, but others are more involved. A simple example would be an abbreviation-expansion routine which would allow an individual to abbreviate all commonly used words, greatly reducing the number of keystrokes required to type out messages, programs, etc. The program would automatically expand the "abvs" as the user typed them. The abbreviations could represent commonly used words, mnemonics, phrases, sentences, or entire blocks of frequently used information.

In another technique, a program using a large word base anticipates the word being typed, truncating the process of spelling words out. This method could be based on word frequency as well as spelling. More elaborate schemes involve translating ideas or concepts into text or speech. A phrase/sentence recall system based on semantic features, where three to five keystrokes would define an entire sentence, is also being explored. It involves barely 60 keys, but their meaning varies as a consequence of the order in which they are pressed. Although complex to imagine and still very much in the formulation stage, approaches of this type may be necessary to offset the extreme information-transfer-speed problems of severely motor-impaired individuals.

Special control interfaces. Another method for increasing the information-transfer rate uses microcomputer-based interfaces to obtain the best possible match between the individual's residual capabilities and the characteristics of the systems he is trying to control. Depending upon the severity of the physical handicap, these special interfacing techniques take a variety of forms. Some extremely impaired individuals may need single-switch input systems where the microcomputer presents choices until the user responds by activating his switch. More common and more effective, however, are various direct-selection or encoding input techniques. For example, individuals with head control can use screen-based optical headpointing schemes similar to long-range light pens. Others can use expanded and/or recessed keyboards. For those able to point but unable to discriminate among sufficient elements to represent a full keyboard, smaller numeric arrays can be used in an encoding fashion to specify letters, words, etc. Efforts are also being directed toward cost-effective methods using eye movement for both encoding and direct selection of displayed items. In all these approaches, sizes and arrangements can be adapted to individual needs and capabilities.

Recreation and development aids. Handicapped persons could, of course, use microcomputers to play games in the same manner as anyone else. For children with severe physical or sensory handicaps, however, microcomputers can play a more extensive role. For these children, the manipulation and exploration important to development may be impossible. Special microprocessor interfaces may be able to partially offset this handicap by providing a reliable means to control, explore, and manipulate objects either in real space or on a display. With the aid of these devices, the handicapped child could also conceivably move himself about in space, thereby gaining new perspectives on his environment by reaching and acting on the objects within it.

Educational aids. Many specific educational problems are addressable in part by microcomputers. One area of difficulty involves the severely physically handicapped individual's slow rate of response, which lengthens remedial drill or practice session time and therefore increases personnel and other costs. With microcomputer-based aids, an individual can work on lessons independently, at his own speed. Another problem involves the manipulation found in chemistry, physics, and other sciences. Here, microcomputers and computer-aided instruction can allow severely physically handicapped individuals to handle "flasks" and "chemicals" on the TV screen, thus carrying out experiments and manipulations normally beyond their direct control.

Another area uses microcomputers not as educational aids but to provide certain capabilities necessary for meaningful, effective education. Examples for the "normal" individual include eyeglasses and a pencil and paper. Since the need to see, read and write, take notes, and do independent work are necessary capabilities for receiving an education within our current system, the severely physically handicapped individual who lacks them is at an extreme disadvantage. Microcomputer-based writing systems with the flexibility and correctability of a scratch pad and pencil could provide some of the basic capabilities necessary for appropriate, adequate participation in educational programs.

Finally, microcomputers can be used to teach basic microcomputing and programming skills. Because of the many ways in which microcomputers can aid individuals with handicaps, and because of the direction in which many aspects of the employment world are heading, it is quite clear that microcomputers hold great promise for facilitating employment potential. Computer literacy and the ability to reconfigure or oversee the reconfiguring of their systems to meet their changing needs may be extremely important skills for handicapped individuals to have.

Communication aids. The stationary nature of current microcomputers tends to limit them to work-station applications. These include computer-aided writing and filing systems, work-station phone control, and phone communication using speech output capabilities. The existing stationary systems cannot meaningfully address the conversational needs of individuals with severe speech impairments, but recently introduced portable and hand-held computers are opening up the potential for portable writing/notetaking and conversational communication aids. Because of the fine motor control required, these portable units will find their greatest initial use among individuals having mild to moderate physical handicaps. As components within systems having other input techniques, however, they could be used by more severely handicapped individuals. The limited memory, I/O, and control capabilities of these systems is currently hampering their application. Memory capabilities may greatly expand in the near future, but the I/O and control capabilities, generally not emphasized in portable units, may continue to cause problems for some time.

The major barrier to using microcomputers as communication aids, however, is the custom interfacing needed to achieve optimum speed. This usually involves the development of special interfaces which are not commercially available. Since using custom hardware with standard computers can negate many of the advantages of microcomputers, care must be taken in deciding between an adapted microcomputer and a specially designed—but commercially available—aid.

Information resource/management. Inability to quickly manipulate and scan materials may prevent handicapped individuals from making effective use of notebooks, filing systems, calendars, dictionaries of frequently misspelled words, phone lists, etc. With microcomputer-based interfaces designed specifically to work with their residual physical and sensory capabilities, they can parallel all of these functions. At present, most applications are in the area of user-generated information storage and retrieval, although in some cases, such as a dictionary of word spellings, materials or data bases are being developed for general use and dissemination.

Security/monitoring systems. The lack of effective, economical means to ensure safety and summon help prevents many handicapped or aging persons from living independently. Ways in which a microcomputer could aid independent-living endeavors include mechanisms for controlling locks and windows, emergency call systems, monitoring systems, and medication reminder systems. A monitoring system checks periodically and signals (first local, then remote persons) if the individual fails to answer its queries. Reminder systems can be developed both to provide reminders as to when medication should be taken and to check whether certain necessary actions (e.g., opening the refrigerator) have been done. Lack of response to these reminders can also be used as an alerting signal to the monitoring/call system, which can in turn call for help.

Cognitive and language-processing assistance. Congenital or acquired conditions often leave an individual with impaired cognitive processing. In some cases, it is a general processing deficit, as in mental retardation. In other cases, it is a specific dysfunction of a particular process, such as short-term memory, word-finding abilities, or the ability to program speech. The greatest difficulty in identifying effective applications of microcomputers in these areas is the limited knowledge about these processes and remediation methods in general. The prospect of microcomputer-based cognitive prostheses is far beyond the current state of the art, but not beyond imagination. The use of microcomputers in remediation, however, may be much closer and more realistic, expecially in areas where extensive drill and practice are associated with the remediation process.

Same uses as the nonhandicapped. Computing, word processing, computer games, computer-aided instruction, and control, including environmental control both at home and on the job, are all purposes for which the computer can be put to good use by individuals who may or may not have a specific handicap. When used by handicapped individuals, however, these functions are often combined with others, such as special input interfacing or information acceleration. As discussed later, there can be significant problems when the microcomputer is required to operate simultaneously in a traditional function and as an input controller.

Microcomputers vs other approaches

There are basically three approaches to providing aids to the handicapped: commercially available aids, custom-built aids, and modified standard systems. Commercially available aids have the advantage of being specifically designed and optimized to meet the needs of a certain class of individuals. But they have two disadvantages: (1) since these aids must be designed for a category of people, they may not meet specific needs; and (2) only aids needed by a large number of individuals can be produced economically. At the other end of the spectrum are custom-built aids designed and constructed for specific individuals. With this approach the aid can be tailored to an individual's specific capabilities and needs, but cost per function is extremely high and maintenance and repair are difficult. The third approach—modifying or adapting standard hardware (standard for either handicapped or nonhandicapped individuals) to meet the needs of an individual or a class of handicapped individuals—lies between the two extremes and has some of the advantages and disadvantages of both. The use of microcomputers as aids for the handicapped falls into this category.

As soon as hardware modifications or additions are needed, microcomputer-based aids quickly begin to resemble custom-built aids

Table 1 profiles the advantages and disadvantages of the three approaches. Since the middle approach can involve anything from minor to very extensive modifications, its characteristics vary as well. For this reason, the chart divides the second category into four subcategories, according to the amount of modification. Modifications to accomplish the specific function can include either changes to the basic microcomputer or the addition of custom hardware to the standard computer hardware.

The most-cited advantage in using standard microcomputers is low cost. Where microcomputers can provide all

Table 1.
Comparison of three types of aids for the handicapped.

TYPE		COST	AVAILABILITY	MAINTAINABILITY	REPLICABILITY	OVERALL
(1)	STANDARD AIDS (designed, manufactured for categories of handicapped individuals)	MEDIUM-HIGH	GOOD (once available)	MODERATE	VERY GOOD	GOOD
(2)	MICROCOMPUTER-BASED AIDS					
	(a) NO MODIFICATIONS (all standard parts, accessories)	LOW-MEDIUM	EXCELLENT	EXCELLENT	VERY GOOD	VERY GOOD
	(b) SIMPLE MODIFICATIONS (electrical modifications but none in electronics or moving mechanical parts)	MEDIUM	GOOD	GOOD	GOOD	GOOD
	(c) MODERATE MODIFICATIONS (moderate detachable modular adaptations)	MEDIUM-HIGH	FAIR-POOR	POOR	FAIR-POOR	FAIR
	(d) EXTENSIVE MODIFICATIONS (extensive or built-in modifications)	HIGH	POOR	POOR-VERY POOR	FAIR-POOR	POOR
(3)	CUSTOM-BUILT AIDS (designed and constructed for an individual)	EXTREMELY HIGH	POOR	VERY POOR	FAIR-POOR	POOR

of the hardware functions and capabilities needed, they are generally much less expensive, because of mass production, than either their specially designed or custom-built counterparts. Where specific hardware functions are missing, which cannot be compensated for in software, microcomputers may or may not be more cost-effective, depending on the extent of the modifications or additions to the standard microcomputer. Referring to Table 1, it can be seen that 2a and 2b are more cost-effective than 1 or 3, but 2c and 2d are only more cost-effective than 3. In addition, other factors—often more important than cost—must be considered.

Availability, maintainability, and replicability also vary tremendously, depending on the amount of custom work. For systems which have no hardware modifications or additions to the basic microcomputer, system availability is greatly enhanced since there is no production gear-up time. This eliminates the year's delay usually involved in developing and producing special hardware. On the same note, local maintenance is readily available for systems using all standard components. Replicability by other centers and for other individuals, as well as overall dissemination of the materials, is also greatly enhanced.

As soon as hardware modifications or additions are needed, however, microcomputer-based aids quickly begin to resemble custom-built aids. With custom-built aids, extremely high development and construction costs must be covered by the end user. Since design and construction are seldom initiated until the user's needs are identified, availability is delayed. Securing parts, assembling, and testing also affect delivery of most custom systems. Maintenance is doubly difficult, especially for complex systems. Good maintenance documentation is extremely expensive and rarely, if ever, done for custom hardware. Thus, maintenance depends on the recollection and minimal documentation of the researcher or developer, usually the only available maintenance source. A number of factors—from turnover of development personnel to the expense of shipping—can increase the difficulty and cost of maintaining custom systems. Their replicability is hampered by similar problems of documentation and parts availability.

The degree to which a standard microcomputer must be modified or supplemented, therefore, greatly affects each of the above areas. The effect on cost and availability is somewhat linear, in that development of a system which is 50 percent standard and 50 percent custom components could cost about half that of a custom one. The effect in other areas, however, is not linear; systems containing a significant portion of custom parts have essentially all the maintenance and replication problems associated with custom hardware. As a system using standard microcomputers is modified, therefore, many of its advantages over specially designed aids are quickly lost. At the same time, many of the problems inherent in custom devices begin to appear rapidly.

Thus microcomputer-based systems will not obviate the need for specially designed equipment, particularly in areas dealing with severe or multiple handicaps. There are, however, many applications where microcomputers can provide low-cost, easily available, easily maintainable, and easily replicated solutions to problems traditionally approachable only through specifically designed or custom-built aids. In addition, where custom aids are required, they can often be made much less expensive and more easily maintainable through the incorporation of standard microcomputer subsystems.

Barriers to more extensive use of microcomputers in rehabilitation

Although there are many good applications for microcomputers in their present form, there are many more potential applications for which they are not currently suitable. Improvements or developments in several specific areas could greatly increase both their application and effectiveness. Some current weaknesses of microcomputers are

- stationary design,
- limited durability,
- storage access speed with low-cost systems,
- limited operating systems,
- battery back-up,
- lack of multilevel program execution capability, and
- lack of multitasking capability.

Items one through five are important but fairly straightforward problems. The stationary nature of current microcomputers precludes their use in portable systems. Although they can be configured to run off batteries, they are not designed to handle the stress and abuse that a portable system must withstand. Hopefully, the portable computers just coming onto the market will develop rapidly enough to eliminate this problem soon.

Durability is best handled by custom inputs for individuals whose movements are too strong or erratic for standard keyboard interfaces. At the same time, these ruggedized input interfaces can be tailored to meet individual needs.

The storage access speed of current disks is unreasonable for many communication applications. The development of new low-cost, high-speed bulk memory technologies is progressing rapidly, however, and should soon provide new tools and capabilities to rehabilitation system designers.

Many aids, particularly ones used in emergency situations, do require battery back-up. This is not a serious problem, but cost-effective methods for providing battery back-up power to the major computer models should be developed and documented for the rehabilitation community. For several of the models, battery back-up capabilities are already available.

The final two problems, multilevel programming and multitasking, are more complicated and are major barriers to the effective application of microcomputers in many areas, particularly those dealing with severely and multiply handicapped individuals. Lack of multilevel capability refers to the inability of microcomputers to nest two programs so that one of them feeds the other (e.g., a special input routine feeding a standard text-editing program). Lack of multitasking refers to the inability of computers to jump back and forth between two programs without losing one's place in either.

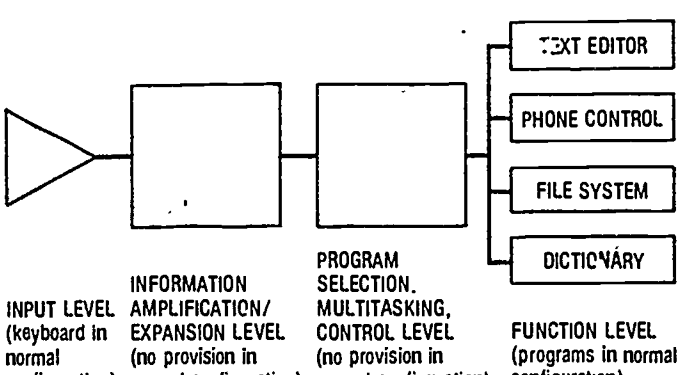

Figure 1. Four function levels in a rehabilitation microcomputer system.

Importance of multilevel (nested) and multitasking processing of standard programs

In order to explore the problems of multilevel processing and multitasking, it is helpful to examine the different functions that a microcomputer-based system may have to provide for a handicapped individual. These tasks can be broken down to four levels as shown in Figure 1.

The first level, the input and control level, includes programs or routines whose major purpose is to get information from the user. In standard microcomputer configurations, this is handled as a purely hardware function carried out by the keyboard.

The second level in the rehabilitation model is the information-amplification/expansion level. The purpose of these programs or routines is to expand the user's signals wherever possible, thereby reducing the overall time and effort required for input. In standard microcomputer configurations there is no parallel to this function, although machine-language routines sometimes use control characters to perform similar functions in conjunction with selected types of programs.

The third level, the program selection/multitasking control level, would parallel an advanced operating system in a normal microcomputer configuration—if it had one. Most microcomputers have very limited operating systems incapable of multitasking.

The final level is the function level—that is, the actual function programs. These would be the same programs that would be run in normal microcomputer configurations.

A multilevel programming capability would enable running input and information-amplification routines/programs in conjunction with standard software programs. Multitasking would allow the individual to move back and forth between programs at the function level without losing his place in any of them.

Need for multilevel programming. The need for multilevel programming is based on both economic and practical considerations. The problem essentially comes down to a trade-off between multilevel program execution capability and rewriting or modifying immense amounts of software for each user application (Figure 2).

To examine this problem, consider three approaches to providing complex software packages to handicapped individuals:

- write one very large program encompassing all of the functions an individual requires,
- write each function as a special module and combine them to comprise a system, or
- create a capability whereby independently written programs run in a nested fashion.

The first approach results in an almost infinite number of programs, due to the diversity of handicapping conditions and residual capabilities coupled with the diversity of needs and potential applications. Essentially, it approximates a custom-programming situation with its accompanying high costs and limited application.

The second approach provides a good mechanism for minimizing duplication of effort and for maximizing the compatibility of different programs. This approach, however, requires that all of the software be written either by one center or by a large number of centers working in perfect unison to ensure compatibility. No one center could or should write all of the software, but coordination between centers is possible, at least to some level. Part of the answer may lie in this approach. It does not, however, allow utilization of the tremendous amount of software already written for nonhandicapped individuals and would require rewriting that into compatible, modular form. Since much current software is written with the assumption that it is the only thing in the computer, and therefore has absolute control and access, the rewriting process could be very difficult. Further, many of the more powerful programs utilize the entire memory space, are written in machine or nonstandard languages, and/or are protected. All of these factors tend to put the modular approach beyond the economic resources of the field for all but the more simple or single-function applications.

Given the limited financial resources of the rehabilitation field, it would seem more productive and effective to concentrate on the input and information-amplification aspects and on those function programs specific to the handicapped. These programs could then be combined with and used with the vast and ever-expanding library of software which the private sector is already writing for other functions. In employment situations, it is especially critical that the handicapped individual's system work with standard software; employers are generally not interested in providing a different system, with different procedures, than that being used by other employees.

In employment situations, it is expecially critical that the handicapped individual's system work with standard software.

The second or modular approach does provide a mechanism for developing useful, adaptable program packages. It could be used very effectively in small systems and in situations requiring a limited number of input, processing, and output modules. Systems for educational environments, particularly at the elementary level, could function well with this approach. For advanced education and long-term productive/employment applications, however, a full multilevel capability using standard software will be needed, thus requiring a multilevel or nesting capability.

Need for multitasking. To understand the need for multitasking, imagine an individual sitting at a desk, working on a problem, when the phone rings. He turns and answers the phone. The caller is a colleague asking for information. While on the phone, the individual pulls out a file, runs off some calculations, and makes some notes based on feedback from his colleague. He then hangs up and goes back to his calculations.

INPUT CONTROL PROGRAMS

Selected to match the individual's physical and cognitive abilities

INFORMATION AMPLIFICATION/EXPANSION PROGRAMS

Selected to match the individual's cognitive/language level and communication needs

- Abbreviation expansion
- Word anticipation

PROGRAM/COMPUTER CONTROL PROGRAMS

Selected to reduce physical manipulation and allow multitasking

- Text editing
- Phone control
- Data base filing system

FUNCTION-LEVEL PROGRAMS

Standard and custom programs to be used by the individual

- Job-related programs
- Dictionary of commonly misspelled words
- Calculator functions

Figure 2. Areas requiring multilevel program execution and multitasking capabilities.

A severely physically handicapped individual who uses an assistive microcomputer-based system would need multitasking capability to accomplish the above. First, he would have to suspend what he was doing—without destroying it or waiting to update and store it—before answering the phone. While on the phone, he would need to access his information system, use his writing system to make notes, and use some computing capability, before hanging up the phone and reentering the program he had suspended. During this process he would need to enter and exit several programs or routines without losing his place in any of them, thus requiring multitasking.

As with the multilevel problem, this problem would disappear if it were possible to write an all-encompassing program for each individual; the program could be written to allow suspension of activity and jumps from one section to another. As a matter of fact, the entire discussion regarding multilevel programming could be replayed here for multitasking. The end result is that, if severely and multiply handicapped individuals are to take advantage of the bulk of the software and applications being written for microcomputers, some type of program-independent multitasking ability is needed.

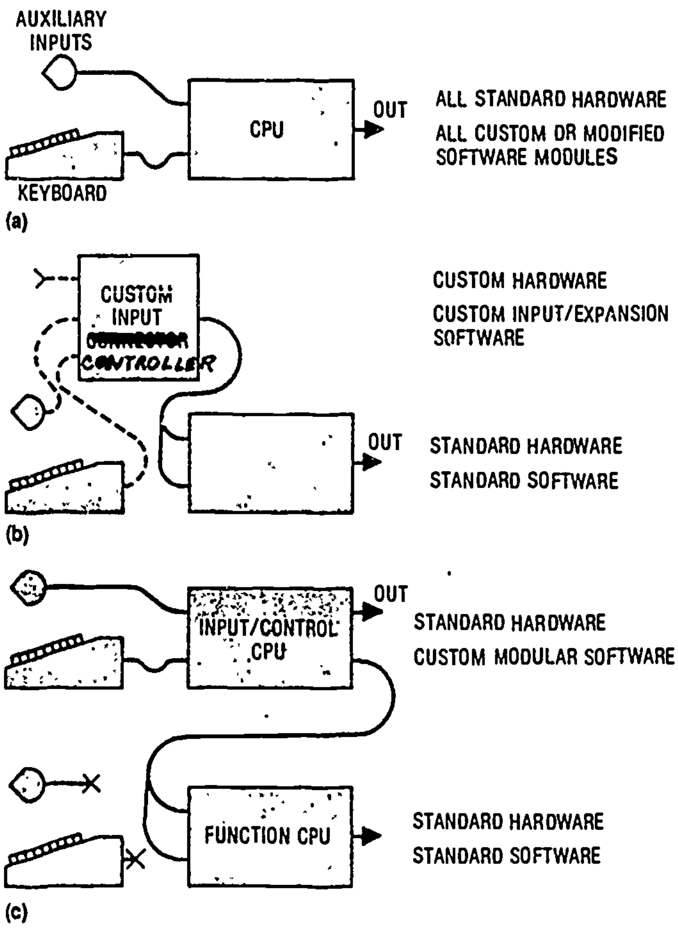

Figure 3. Three approaches to multilevel program execution: (a) software approach, (b) hardware approach, and (c) dual nested computer approach.

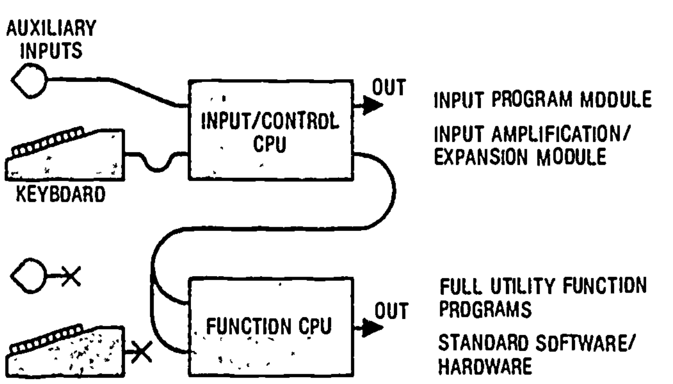

Figure 4. Quasi multitasking using the dual nested computer approach.

Approaches to the multilevel and multitasking problems

Multilevel approaches. In tackling the multilevel processing problem, there appear to be at least three basic approaches. The first is a purely software approach. Although the cheapest to implement and the easiest to disseminate, it might be the most expensive to develop. Most of the cost would come from required modifications to much of the software used at the function level (see Figure 3). In this essentially modular approach, all programs would have to be modified to act as modules within the overall structure. As such, it doesn't represent a true multilevel approach, but modifications could be very minor, closely approximating the multilevel goal. Protected programs, machine-language programs and ones in other programming languages, or very large programs would still cause severe problems.

A second approach attacks the problem from a purely hardware standpoint. With this approach, a plug-compatible alternate keyboard would replace the computer's own keyboard. Since the software could not distinguish between the alternate and original keyboards, the function-level software would need no modifications. The alternate keyboard module would contain all of the intelligence necessary for the input software as well as the input-expansion software. Through very elaborate means, enough memory might be hidden and the interrupt structure sufficiently linked to use CPU intelligence for both input processing and function-level program execution. With this approach, however, there is no guarantee against contention for the same areas of memory—and thus possible collision of the two programs. It also requires the development of custom hardware, which is not easily supported, repaired, etc.

The third approach uses dual nested computers: one for the input-level programs and another for the function-level programs. A cable connecting the first computer to the other's keyboard would cause the second computer to think that its own keyboard was being used. At first glance, using two computers appears to be a brute-force solution; it is, however, the most flexible and straightforward of the three approaches—and, in most cases, the least expensive. Since the function-level programs would run on a separate computer, they would not require modification and could be written in any way, in any language. It's not even necessary for the two computers to be the same make, brand, model, or size. Because of the additional capacity available, the first computer could use a high-level language to implement its input routines. Thus, modifications for specific users would be much easier, and complex input routines and data structures could be used. This approach would also be much easier to modify and adapt over time to match the individual's changing abilities and needs.

If two identical computers were used in the dual nested computer approach, the user would have built-in hardware back-up capability. If either computer went down, the other could be put into the input-level position. If the input program package included some basic function capabilities, the user would have at least a rudimentary system during repair of his CPU, disk drive, etc.

For some emergency call or monitoring systems, the two computer systems might operate in a parallel or self querying manner, thereby providing additional safety should the system go down without the user being aware of it. A configuration in which either system is capable of carrying out rudimentary emergency calls or monitoring during a computer failure might also be possible.

At first glance, using two computers appears to be a brute-force solution.

There are, however, several disadvantages to the third approach. It doesn't allow a truly flexible nesting capability beyond the first level, which might or might not be sufficient. Another major problem could come from funding agencies. While open to funding aids for the handicapped, agencies might balk at buying them a home computer-based aid and stop cold at buying them two home computers—even if the net cost to develop, configure, and implement the system is less with this approach. The problem, however, should abate with time and experience.

Comparing the three approaches, then, each has relative advantages and disadvantages. The first approach has the advantage of being purely software. The second is implementable within the confines of a single computer, without modifying the existing software. The third approach seems to be the best of the three, both in terms of function and flexibility. It would, however, add to hardware bulk and involve the development of some custom hardware (although it is conceivable that this might be limited to a cable).

Multitasking approaches. The multitasking problem concerns the handicapped individual's need to do several things concurrently, even if he must rely upon the same computer for each activity. As with the multilevel problem, it can be approached from both a hardware and software standpoint.

Recalling the four levels—(1) input level, (2) input amplification/expansion level, (3) core or control level, and (4) function level, we see that the multitasking problem is one of creating a core structure which allows concurrent execution—without interference—of multiple programs on level 4. The difficulty comes from the fact that many level-4 programs, written prior to and regardless of core structure, assume that they have complete access to the computer. All of the problems inherent in the multilevel approach are also present here, with the additional difficulties of (1) suspending a program in mid-execution, (2) using the same resources to execute a second program, (3) recovering or reentering the first program at its last point of execution. Unless the program is specifically written for it, true multitasking may not be possible because of settable—but not readable—bits, flags, or memory locations in the microcomputer. Without the ability to read locations, it is difficult to use and restore those locations without cooperation from the program being interrupted.

Some of the effects of multitasking, however, may be achievable by using the dual nested approach and dividing the function programs between the two computers. The input, input amplification, core, and specially written function-level program modules would be run on the first computer. The second computer would be used for high-power, independently written (standard) function-level programs. Only one high-power program could be used at one time, but any number of other function programs—written for the first computer, with multitasking in mind—could be run concurrently (see Figure 4). It would then be possible to enter and exit any of the programs as needed.

The dual nested approach—a reasonable one for many applications—does not, of course, provide a total solution to the multitasking problem. Further research and work is needed to solve both the multilevel and multitasking problems. Ideas, feedback, and inquiries are invited.

The use of microcomputers in rehabilitation engineering—very much in its infancy at this time—can provide rehabilitation personnel with a new set of powerful, cost-effective tools. Still, a number of very basic questions must be addressed to facilitate the development of economical aids. Of particular note is the need for better methods to take advantage of existing software, possibly through the development of multilevel and multitasking capabilities. Then, more attention and funding could be focused on the basic problem of providing better, more effective interfacing between handicapped individuals and the devices they must control for communication, education, and employment.

The overall potential for microcomputer-based aids is excellent, however, and it is quite clear that computer literacy will soon be a basic requirement of anyone involved in rehabilitation, particularly of individuals with severe or multiple disabilities. ■

Gregg Vanderheiden has been an active participant in the field of special communication and control aids for the handicapped for the past 10 years. He co-founded and is the director of the Trace Research and Development Center at the University of Wisconsin, an interdisciplinary research and resource group which specializes in communication and control aids for several physically handicapped individuals. Vanderheiden's efforts have been directed across a broad range of activities, including needs analysis, research and development, summary information collection and dissemination, and training. He has served as principal investigator on 17 grants from the National Science Foundation, the Bureau for the Education of the Handicapped, consumer groups, and the private sector, which have dealt with the exploration, development, and evaluation of communication and control aids.

Vanderhelden holds two degrees in engineering (electrical and biomedical) and is currently pursuing a PhD in language and cognitive development in the exceptional child.