

# Enhancing Human-Machine Interaction

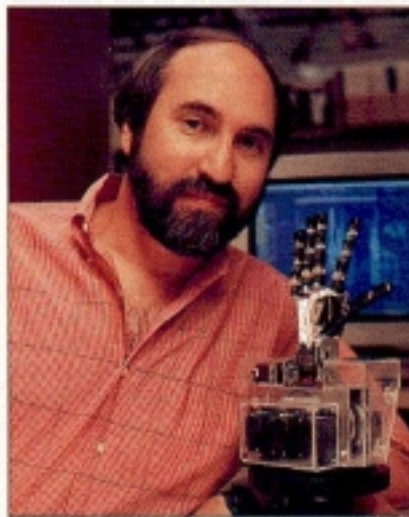
*Advances in interface technology continue to extend the ability of persons with disabilities to influence their environment.*

By David L. Jaffe

Life can be thought of as a sequence of experiences involving interactions between people and objects. The interaction of vision, for example, is realized by the reception and interpretation of energy packets (light) radiated by illuminated matter. Similar interactions produce the sensory communications of speech, hearing, and touch. These interactions can be two-way events. Humans and animals can generate signals and movements that affect objects and other life. However, humans alone build devices that extend in distance and in time our ability to communicate and influence people and nature. For example, telephones, libraries, and earth-moving equipment are a few of the machines and systems we have constructed to extend our will to others and mold the environment to suit our needs.

Interactions are facilitated by interfaces. Interfaces can be either biological, such as ears and vocal chords, or mechanical devices, such as loudspeakers and keyboards. Some - vehicles, telescopes, television, and public address systems - extend our natural abilities over great distances. Others - books, monuments, and recording mechanisms - enable us to project our presence through time. Our daily existence depends on the smooth operation of devices we take for granted. How many of us would be able to survive without cars, televisions, telephones, microwave ovens, computers, and information networks? These are just some of the devices that able-bodied people interact with and rely on to get through an average day.

Because people with disabilities may have a diminished ability to use these interfaces, they may experience difficulty in



participating fully in daily life. In many cases, however, the structure of our systems defines whether a person is able or disabled. For example, if stairs were never invented, the inability to climb stairs would not be a disability. Since society places the ability to communicate in high regard, non-vocal or hearing-impaired individuals can experience problems interacting with others.

Some people with disabilities cannot produce normal "output" functions in terms of mobility and production of communication for both person-to-person and person-to-machine interactions; others have difficulty with the "input" sensory functions of hearing and sight.

To cope with this problem, current devices (machines) for people with disabilities enhance the interaction between the user (human) and the environment (nature) and other people by providing either augmented or alternate communication pathways. To perform mobility, communication, and

daily living tasks independently, individuals with severe disabilities must find interface pathways to replace those that have been lost or amplify those that are functional. High-level quadriplegics especially must overcome the difficulty of replacing lost or diminished pathways to the outside world since many of them can only control the muscles in their neck and above. The power to promote user interface with a machine, translate sensor input into machine activation, and produce a result that reflects on the environment is available in many devices for people with disabilities.

Here are two examples of such interfaces, drawn from my work at the Rehabilitation Research and Development (RR&D) Center at the VA Medical Center in Palo Alto, CA.

## Ultrasonic Head Control Unit

The Ultrasonic Head Control Unit (UHCU) is an interface that allows quadriplegics to communicate their will to the environment by enhancing their control over equipment such as wheelchairs and specialized communication systems in a socially acceptable and aesthetically pleasing manner. The unit translates changing head positions into control signals that operate devices to which it is attached.

This design uses two ultrasonic transducers. These transducers emit inaudible sound waves that propagate through the air until reflected by an object. A portion of the echo signal returns to the transmitting sensor and is detected by an electronic circuit. The time from transmission of the ultrasound pulse to the reception of the echo is proportional to the round-trip distance from the sensor to the object. In the rehabilitation application, sensors are

directed at the user's head, from either the front or the rear, and on each side of the head. If the user is in a wheelchair, the sensors are generally mounted on the back of the wheel- chair. The sensors can also be mounted from the front. For example, if the user is operating a computer, the sensors can be mounted on the monitor.

The distance of each sensor to the head and the fixed separation of the sensors describe an imaginary triangle whose vertices are the two stationary sensors and the user's moving head. This geometric relationship allows the offset of the apex (the head) from the baseline and centerline of the two sensors to be calculated. The user's head position can then be mapped onto a two-dimensional control space.

UHCU users merely tilt their head off the vertical axis in the forward/backward or left/right directions. Their changing head positions produce signals identical to those from a proportional joystick. The UHCU can be thought of as a joystick substitute for controlling an electric wheelchair, a communication aid, or a video game.

Users of a modified electric wheelchair equipped with a UHCU can navigate the chair by tilting their head off the vertical axis. The changing head position is translated by the on-board computer into speed and direction signals for the electric motors on the chair, thus directing the motion of the chair. To travel forward, the user moves the head forward of its normal, relaxed vertical position. Similar movements perform the designed motion in the remaining three directions - left turn, right turn, and backwards. This system accepts combinations and degrees of these motions, so a smooth right turn can be accomplished by positioning the head slightly forward and to the right. In effect, the user's head becomes a substitute for the joystick control found on some electric wheelchairs.

Since the UHCU signals exactly mimic those produced by a joystick, in wheelchair applications the UHCU can be simply plugged into the motor controller. In this manner, no modifications to the motor controller are necessary; the UHCU becomes an electronic module providing head position control. Other devices that normally use a joystick or switch closure as the human input mechanism can instead use an adapted UHCU.

The main advantage of this type of hardware interface is that no physical contact between the sensors and the user's

head is required. This effectively separates the user from the device being controlled. Therefore, with this unit users should not feel "wired-up" or confined by an apparatus around the face or body, as frequently occurs with other interfaces. A UHCU implemented on an electric wheelchair also has aesthetic advantages over other man/machine interfaces used for this purpose. It seems to be more socially acceptable than alternative designs.

In actual operation, the UHCU wheelchair system performs satisfactorily. After about one hour of training and practice, this system can be mastered by any individual who retains good head position control. The head tilting required is so slight, only an inch or two, that observers frequently cannot deduce the method of control. Since the UHCU only responds to head tilts, the user can freely move the eyes or rotate the head without affecting the navigation path. In this manner, the user can watch for automobiles at intersections or converse with others while traveling.

The UHCU is, for all practical purposes, transparent to the operator, and the existence of any computer hardware or software is not apparent. One "test pilot" commented that the system was so high-tech that it appeared low-tech.

### **Dexter-II**

Dexter-II is a second-generation, computer-operated, electro-mechanical, fingerspelling hand. It offers an improved solution to the communication problems that deaf/blind people experience. This device translates incoming serial ASCII (a computer code representing the letters and numbers) text into movements of a mechanical hand. Dexter-II's finger movements are felt by the deaf/blind user and then interpreted as the finger-spelling equivalents of the letters that comprise a message. It enables a deaf/blind user to receive finger-spelled messages in response to keyboard input during person-to-person communication, as well as gain access to other sources of information.

This interface is designed to allow deaf/blind users to independently receive information from a variety of sources, including face-to-face conversation with people who do not know finger-spelling, telephone communication, and computer access. The enhanced communication capability will considerably improve the vocational and recreational opportunities available to the deaf/blind community.

In operation, a message is typed on a keyboard by an able-bodied person. Dexter-II's computer software matches each letter's ASCII value with a memory array of stored control values. These data program pulse-width modulation chips to operate its eight DC servo motors. Wire cables anchored at the mechanical hand's fingertips and wound around pulleys serve as the fingers' "tendons." As the motor shafts are energized, they turn the pulleys, pull on the cables, and flex the fingers. These resultant coordinated finger movements and hand positions are then felt by the deaf/blind communicator and interpreted as letters of a message. Although the mechanical hand cannot mimic the human hand in rotating the wrist to finger-spell a "J," the fact that it always produces the same motions for a given letter enhances its intelligibility.

Since it works with electronically transmitted information, Dexter-II can be connected to a computer, constituting an accessible "display." It can also be operated over the telephone either from a remote computer or by a caller using a telecommunication device for the deaf. When interfaced with a modified decoder for the deaf, Dexter-II gives deaf/blind individuals the ability to receive news, information, and entertainment from closed-caption television programs.

Reactions to Dexter-II have been enthusiastic, positive, and at times highly emotional. The increased communication capability and ability to "talk" directly with people other than interpreters are powerful motivations for using this interface. It has the potential to provide deaf/blind users with untiring personal, finger-spelling communication at rates approaching those of a human interpreter.

The Human-Machine Integration Section within RR&D is devoted to projects that help people with disabilities convey their desires to their environment and facilitate communication with others.

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