Forth Application in Devices Serving Persons with Disabilities

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Abstract

Those devoted to Forth are well aware of its advantages over other programming languages. In this paper, I discuss how Forth's features are being used in devices that serve disabled individuals with four specific examples drawn from my research and that of my colleagues.

Ultrasonic Head Control Unit

The Ultrasonic Head Control Unit (UHCU) is a unique man/machine interface that has been developed at the Rehabilitation Research and Development Center (RR&D). It is designed to provide severely disabled individuals (quadriplegics) with a means of communicating their will to their environment by controlling equipment such as wheelchairs and specialized communication systems in a socially acceptable and aesthetically pleasing manner. The unit translates head position information into control signals which operate devices to which it is attached.

In this design, two Polaroid ultrasonic transducers are employed. They emit inaudible sound waves which 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 commercial camera application, camera focussing is accomplished by ranging to the subject being photographed. In this rehabilitation application, two separated sensors are directed at the user's head (from the front or the rear). The two distance ranges, one from 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. A geometric relationship allows the offset from the base line and center line of the two sensors to be calculated. This information maps the user's head position into a two-dimensional control space.

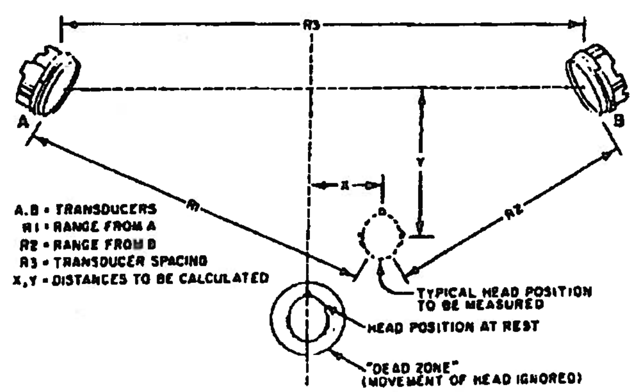

Figure 1 - Ultrasonic Head Control Unit Geometry

In operation, users of the UHCU merely tilt their head off the vertical axis in the forward/backward or left/right directions. Their changing head position produces output signals identical to those from a proportional joystick. Both these interfaces, the UHCU and the joystick can be used to control devices to which they are attached such as an electric wheelchair, a communication aid, or a video game.

Users of a modified electric wheelchair equipped with the UHCU can navigate the chair by tilting their head off the vertical axis. Head position is translated by the on-board Forth software into speed and direction signals for the electric motors on the chair. Users thus direct the motion of the chair with their head. To travel forward, for example, one moves the head forward of it normal relaxed vertical position. Similar movements perform motion in the remaining three directions; left pivot, right pivot, and backwards. Since this system accepts combinations and degrees of these motions, a smooth right turn can be accomplished by positioning the head slightly forward and to the right. In effect, the user's head has become a substitute for the joystick control found on some electric wheelchairs.

In addition, a generalized interface for a robotics application has also been developed. As with the UHCU, head position is used by the robot user to select tasks and control the operation of a mobile robotic arm. Specifically, the vehicle's navigation path is under the control of the user - its trajectory being "drawn" on a CRT with head movements.

A Robotic Fingerspelling Hand Communication Aid for the Deaf-Blind

A second example of a Forth application using an embedded computer is a communication aid for deaf-blind individuals. These people experience extreme social and informational isolation and a total dependence on others for communication.

Deaf people use "fingerspelling", which refers to the manual communication system in which there is a specific hand and finger configuration for each letter of the alphabet (Figure 2), as well as sign language, which incorporates more global movements and configurations of the hands and arms, as well as facial expressions.

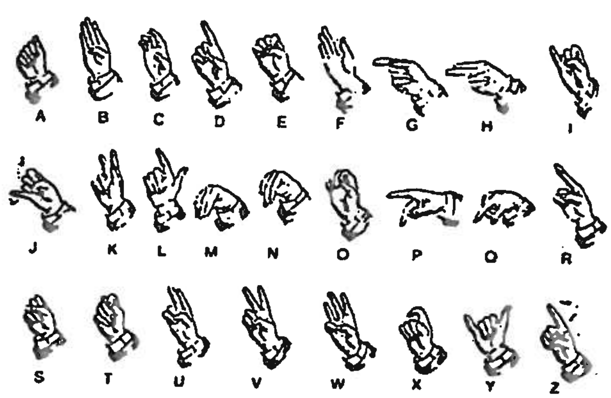

Figure 2 - One-Hand Manual Alphabet

A common communication technique used with and among deaf-blind people is simply a combined, hands-on version of fingerspelling and/or sign language. Instead of receiving communication visually as deaf people do, the deaf-blind person's hand (or hands) remain in contact with the hand (or hands) of the person who is fingerspelling or signing. Many of the motions present in sign language, where both hands and arms are employed to convey whole words and phases can not be employed in the tactile communication mode required by a deaf-blind individual. Instead, each word to be sent is typically spelled out, one letter at a time with the fingerspelling technique. Although many deaf-blind users can speak intelligibly or use sign language, others require a "hands-on" system for expressive communication.

The Rehabilitation Engineering Center of The Smith-Kettlewell Eye Research Foundation sponsored a class project conducted by four graduate students in the Department of Mechanical Engineering at Stanford University to design and fabricate an improved state-of-the-art fingerspelling hand. A major goal was to develop a communication device which could accurately mimic the finger positions of the fingerspelling alphabet produced by a human interpreter. These qualities were realized in "Dexter", the first computer driven robotic fingerspelling hand.

The current device is a computer-based, servo motor powered, electro-mechanical fingerspelling hand. It enables a deaf-blind user to receive tactile messages from the mechanical hand in response to keyboard input during person-to-person communication, as well as gain access to local and remote computers and the information they contain.

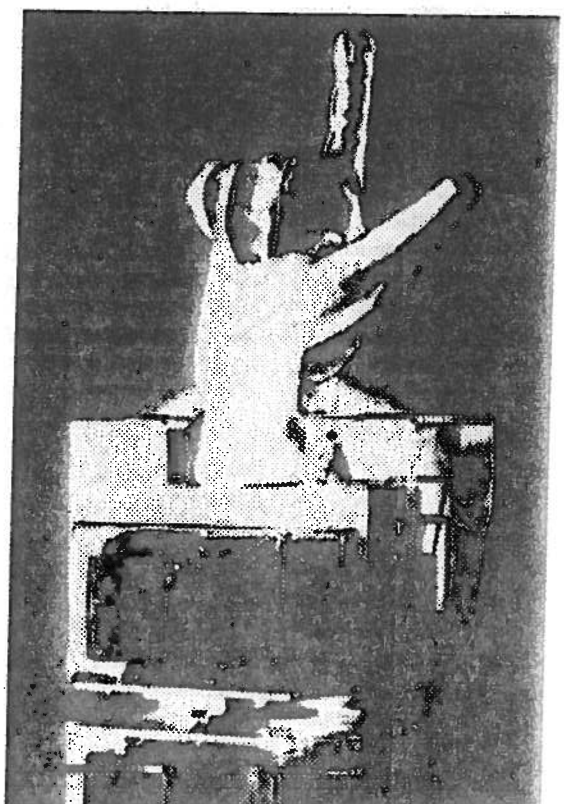

Figure 3 - Robotic Fingerspelling Hand

An individual wishing to communicate with a deaf-blind person using the hand type a message on an Epson HX-20 computer. Each keystroke is sent over a serial interface to the hand's computer, and displayed on the HX-20. The computer translates the letters of the message into a timed sequence of commands that operate 8 DC servo motors. These motors pull on cables that are the tendons of the fingers, causing them to flex. The cable and the return springs bring the finger back to an unflexed state. The deaf-blind user feels the motions and positions of the mechanical fingers and interprets them according to the Manual Finger Spelling Alphabet as letters of the message.

The device's processor, a Zilog Z80, is complemented by memory which contains the application program written in Forth, a serial interface to the HX-20 microcomputer, pulse-width modulators operating the servo motors, and a counter-timer used to control the delays necessary in the coordination of the servo motors.

The device looks like a mechanical version of a human hand projecting vertically out of a box. The four fingers and a thumb are joined together at a palm, operate independently of each other, and have a range of motion comparable to human fingers. The thumb is jointed so as to allow it to both sweep across the palm as well as move in a plane perpendicular to it.

This project is intended to serve deaf-blind users as a complete receptive communication system, not just a means of receiving information in face-to- face situations. Its ability to respond to computer input means it can be interfaced to a TDD to provide deaf-blind people with telephone communication. It can also be connected to computers to provide improved vocational and avocational potential to the deaf-blind community.

Tongue Touch Keypad

The Tongue Touch Keypad is an element of Zofcom, Inc.'s Control System, a commercial device intended to provide severely physically disabled individuals with the ability to operate an array of equipment such as an electric bed, nurse call, electric wheelchair, electrical appliances, remote control consumer electronics, telephone, and computer by means of an in-the-mouth keypad.

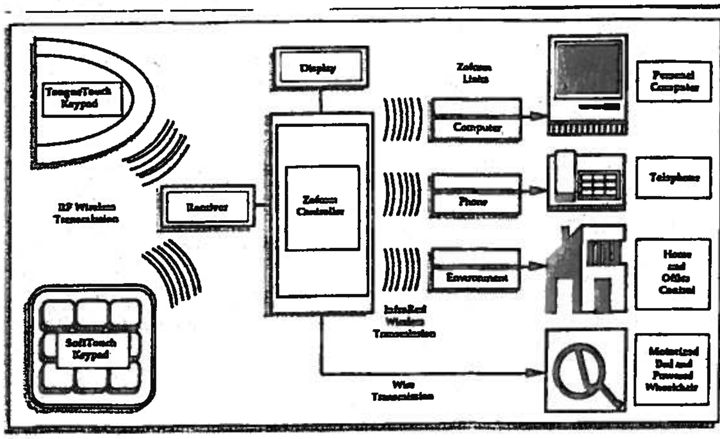

Figure 4 - Zofcom Control System

User input is accomplished through the Tongue Touch Keypad, a battery-powered radio-frequency transmitting device which is similar in appearance to an ordinary orthodontic retainer and incorporates a keypad with tongue operated keys. The keypad is custom made for each user and fits against the roof of the mouth. Small, pressure sensitive switches are pressed by the tongue in order to control external equipment.

In operation, the user presses the switch (one of a 3 by 3 array of switches) on the Keypad with the tongue which represents his/her control choice. The Keypad transmits a unique radio frequency signal for each switch. The companion receiver is placed near the user, either at the bedside or on an electric wheelchair. It detects and demodulates this signal and sends it to the System Controller which contains the microcomputer. It is here that the signal is decoded and the peripherals are controlled, some through an infrared link.

For controlling lights, the nurse call, and other electrical appliances, the X-10 PowerHouse system is employed. The System Controller generates signals that drive the Infrared Remote Control Unit and the X-10 Converter. Traditional remote controlled consumer equipment such as televisions, VCRs, and music systems are also controlled via this infrared link. A specialized telephone that responds to the same infrared signals can also be operated. A four line by twenty character LCD display provides the user with a series of menus showing the current control choices. The display is organized in a 3 by 3 matrix with each item representing one of the nine Keypad switches. The display elements change with each keypress to direct the user to the menu which includes the name of the desired device to be operated.

Computer mouse and keyboard input can be achieved through the Zofcom ComputerLink Module. Windows and Macintosh computers can be accessed through mouse emulation. The middle Keypad switch corresponds to the mouse button, while the remaining switches produce cursor movement in the up/down, right/left, and diagonal directions. Using these emulated mouse movements and mouse clicks, the user can access files, open and close applications, and through commercial on-screen keyboard emulator software, easily perform all operations associated with unmodified personal computer software.

The Tongue Touch Keypad and Zofcom Control System are advertised as providing people with limited mobility a new way to access the environment, utilize their intellectual resources, and live more productive lives.

Lingraphicia

Lingraphicia is an Apple Powerbook-based communication device and commercial product of Tolfa Corp. It is based upon research performed at RR&D and designed to assist in the rehabilitation of persons with language deficits resulting from brain damage during adulthood (aphasia). It helps these individuals reacquire linguistic competencies through the access and manipulation of graphically meaningful pictorial icons within a system which provides animation, synthesized speech output, text output, and a highly interactive, responsive, and intuitive interface.

Approximately 2000 concept-images in the device represent objects, people, verbs, occupations, places, foods, time, and other parts of speech for a population of users who can not speak, understand spoken speech, or read and write. In operation, selections are made from the image gallery with the trackball and dragged to the storyboard, a part of the screen where a request, response, or other communication is constructed. Individual image galleries are organized as a hierarchy for easy access. For example, a particular food object may be found in a scene of a kitchen which is accessed by clicking on the appropriate room in home floor plan. The refrigerator, drawers, and cabinets can be opened to reveal foods and utensils commonly found there. Clicking on a verb or preposition icon results in its animation. The meaning of the drinking icon, for example, is clearly illustrated in this manner. After the storyboard is completed, a text translation or synthesized speech output can be generated, facilitating interaction with family members or other communication partners.

Tolfa promotes Lingraphicia as a device designed to maximize both the residual skills and relearned capabilities of people with severe brain injury, stroke, and aphasia.

Lingraphica

The Language Prosthesis for Aphasia

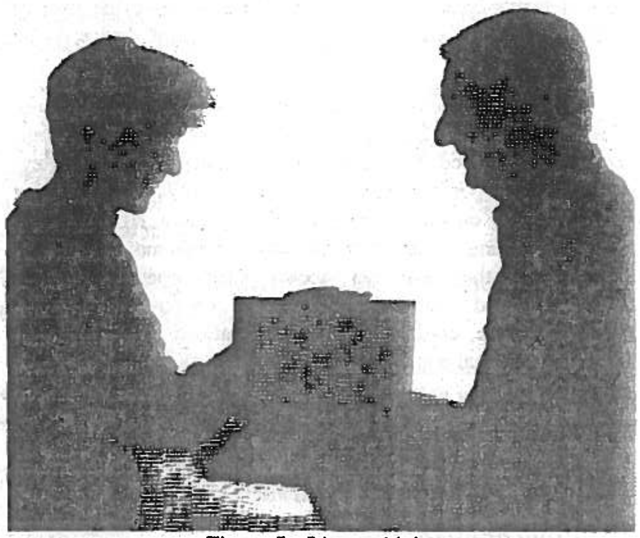

Figure 5 - Lingraphicia

Conclusion

In summary, the flexibility, short development cycle, and ability to use Forth for embedded projects make it an ideal programming language choice for use in rehabilitation applications.

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