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December 1980

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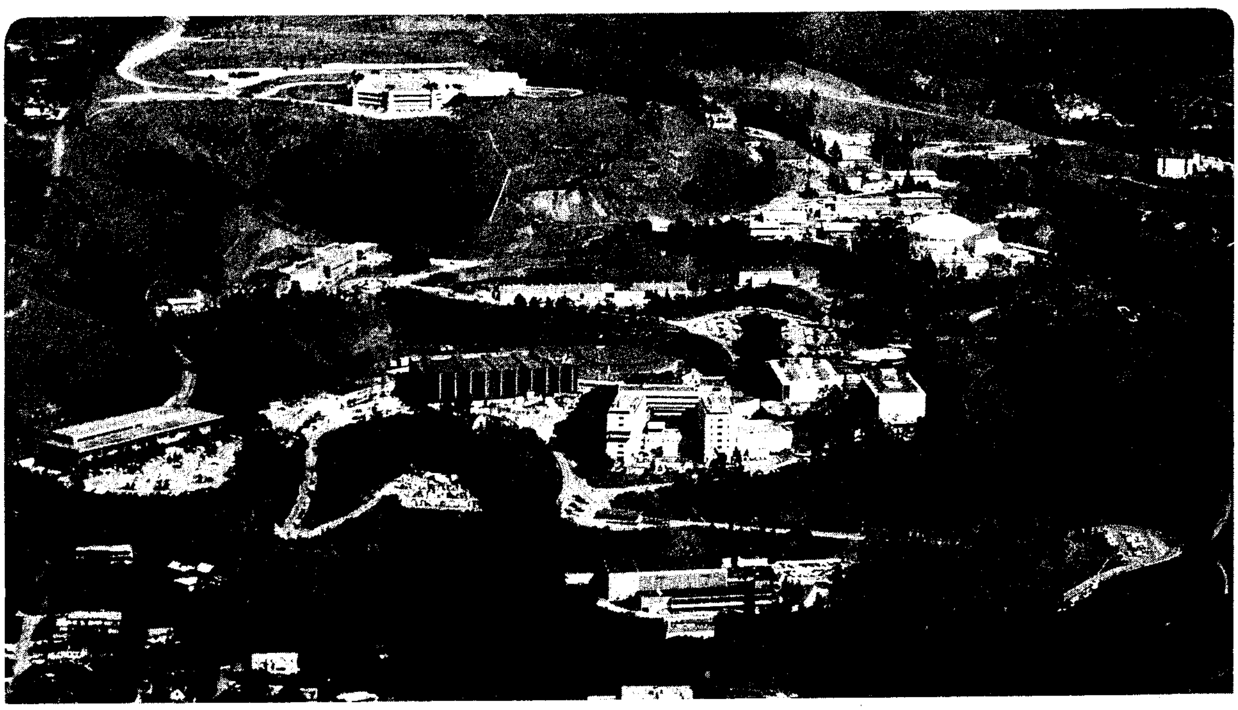

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TACTILE AND KINESTHETIC CONTROLS FOR USE IN INTERACTIVE MINI AND MICROCOMPUTER ENVIRONMENTS

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ABSTRACT

The traditional visual bias for computer-to-user communications seems to have reached the point of excluding other, non-traditional solutions to computer-user linkage problems. Users, generally humans, are much more than simple video communicators and expanding the number of methods by which the computer converses with the user can be used to significantly enhance the intimacy of the relationship. Human communication channels include, in addition to video; sounds, tactile sensations (vibrations, temperature, direct electrical stimulation) and kinesthetic sensations (resistance to movement). This paper describes simple vibrating, kinesthetic and temperature-variable switches with respect to their implementation, their limitations and their potential applications. We conclude that such devices are generally simple to implement and control and offer substantial benefits to interactive environment users as mechanical 'pointers' to appropriate response classes and as binary (yes/no) responders to specific user queries.

INTRODUCTION

Communication with computers and related hardware is benefitting immensely from the ongoing rapid development of affordable graphic displays and upcoming bidirectional speech capabilities. In the rush to make every computer-user communication occur through the display terminal, other and often more appropriate communication routes should not be neglected. Speech communication is developing rapidly in concert with display developments. We are proposing developments in tactile and kinesthetic devices to complete the ongoing expansion of communicative breadth which is occurring.

Computer sciences spring from a batch-processing tradition, characterized by dedication to the rate (volume per unit of time) of information passing through the interface. Usefulness of the information is secondary since queuing up to make a second pass through the batch processor has traditionally been very tedious. The batch processing syndrome appears in contemporary literature on graphics display systems.

> "The basic reason for using graphics....is that it conveys more information to the user. The brain.... must apprehend text or numerals in a more laborious, one-at-a-time fashion. During this serial operation the processor of the brain must 'pay attention'; he must 'concentrate'--a somewhat unpleasant sensation. In contrast, looking at pictures seems to be effortless and even pleasant" [1, p. 49].

Undisguised in this quotation is the dedication to information volume and the allusion to some equality between useful and "effortless and even pleasant". As mini and microcomputers are used to generate a more intimate interaction between the user and the computer, usefulness becomes more important than volume. It has been our experience that intervals of concentration and 'paying attention' coincide with useful results, 'effortless and even pleasant' sensations typically emerging from dramatic efforts on television. Divorcing some of our ideas from the volume tradition opens the way to serious considerations of low-volume information transfer routes--tactile and kinesthetic devices.

In another article covering the same conference, Myers reports on an informal talk by Jack Grimes of Tektronix:

> "How people use information ... is related to how it gets into their memories and how they retrieve it. One way is holistically, an all-at-once input like looking at a map, painting, picture, or block diagram. The other way is serially, a sequential input like reading a book or a program. The educational system has been largely based on the serial approach, and that is some kind of indictment of the educational system ..." [2, p. 46].

Without denying the importance of holistic information presentations via display terminals, a recognition of the frequent appropriateness of a serial presentation must be made. One prominent example used throughout one of Myer's articles [2] is that of a word processor. Consider the following:

THERE IS AT LEAST ONE
ONE MISTAKE IN THIS SENTENCE.

The one mistake is likely to be overlooked in a system which would imbed it in an entire page of text presented to the user in a holistic flash. To find such an error is easier if the "processor of the brain" is forced to view it "in a more laborious, one-at-a-time fashion". Unpleasant as concentration may seem to the viewer, it is often an invaluable aid to problem solving.

Since the Roger Sperry studies in the early 1970's [3], the picture of the human brain (and perhaps of other creature brains as well) has become one of a left hemisphere mostly dedicated to serial processing, as occurs naturally from verbal inputs; and a right hemisphere mostly dedicated to parallel processing. "The system consists of hundreds of successive two-dimensional arrays of millions of interconnected parallel computers."[1, p. 50], a situation undoubtedly necessary to the effective use of holistic visual presentations. A computer system which caters too exclusively to holistic presentations is ignoring half the computing power available from the intelligent part of the system--the user.

Recent developments in voice communication with computers [4] and [5] have begun to appear regularly in the literature. Being sequences of words, such communication potentially makes use of the left brain. We propose further expanding of communication by way of the user's tactile and kinesthetic information channels. Such an expansion may legitimately be questioned on the basis of its value relative to its cost and the ease with which it can be used. The inexpensive, dedicated microcomputer controller has helped reduce the expense and ease of using such devices. Software peculiar to the unit is stored within the dedicated microcontroller, not burdening the host minicomputer system.

The 'batch processing 'syndrome' which we mentioned earlier tends to place the user and the computer on opposite sides of a table, across which are passed commands and raw data in one direction and back across which is passed processed and predigested data in the other direction. The width of this table has of necessity begun to shrink. As problems increase in complexity, we are arriving at a juncture where not only are solutions to problems unclear, but even the direction to take to progress towards a solution is muddled. For example, in an increasing number of experiments in the nuclear sciences the volume of data accumulated per experiment has increased dramatically, and the potential number of intercorrelations among data events has similarly exploded. Data analysis is often a trial-and-error interplay between computer and user. The analysis depends on sequences of educated guesses and hunches pushed to their logical conclusions via an intimate association with data massaged by an understanding processor and presented to the user in the most effective and uncluttered way available. To operate effectively, the natural barrier between computer and user must be, as much as is practical, dissolved. The computer and user together become one integrated problem solving unit.

The idea of user and machine operating within an intimate symbiosis is not new. Licklider [6] described his idea of such a union 20 years ago, and Jeffels' [7] description continues the tradition:

> "... the machine is a bold and noble extension of the flesh: same pulse, same respiration, same beat of the blood, same spirit and elan. The vital processes are one; they are inextricably linked by bonds of mutual respect and affection. In a wondrous symbiosis of man and metal, the two move in preordained rhythms".

TACTILE AND KINESTHETIC DEVICES

We have proposed a number of devices which would appear to be simple and inexpensive to implement as well as being operationally effective.

THE VOCO SWITCH

Figure 1 consists of a standard toggle (or pushbutton) switch mounted on a thin plate driven through a sealed air tunnel by a small loudspeaker. Off-the-shelf 2-inch loudspeakers do not normally have the depth required to enclose the switch body so we have proposed placing a short section of 2-inch diameter plastic pipe between the speaker frame and the switch mounting plate. This configuration can easily enclose a conventional mechanical switch. Proximity switches or other special types may be thin enough to make the pipe unnecessary.

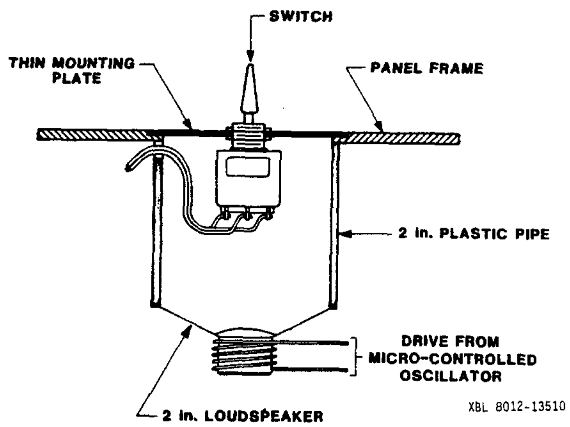

Fig. 1 The voco switch uses a small commercially available loudspeaker to force the switch platform to vibrate noticeably. If audible vibration is the objective, the rise time and frequency of drive signals must be carefully controlled.

The voice coil on the speaker is driven to produce vibration of the switch body. The vibration provides a tactile signal to the user as the switch is touched. This scheme is simple and inexpensive although it prevents mounting adjacent switches closer than 2 inches. The speaker (or array of speakers in a multiple-switch system) can double as an audible-stimulus producer if driven at a sufficiently high frequency. Our experience is that driving the speaker with sharp-edged signals produces an audible result even for very low repetition rates. A low frequency signal with a slow rise and fall time (such as a sine function, 10-100 Hz) can be made noticeable tactilely while remaining inaudible. Some resolution of different frequencies is possible and may be useable. Although individuals may be able to discriminate between different drive amplitudes, variations from person to person preclude the assumption that amplitude variations could be sensed by any particular user.

THE SHAKER SWITCH ARRAY

Figure 2 uses a stepper motor mounted on the switch mounting platform to produce a vibration noticeable when the switch or platform is touched. The net effect is similar to that of the voco-switch. However, the voco-switch is better when the unit is intended to double as an audio device.

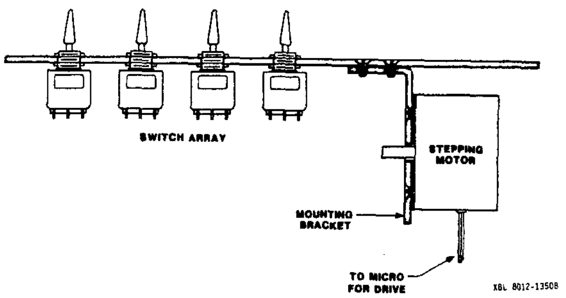

Fig. 2 The array of switches in the shaker switch configuration vibrates noticeably when the stepper motor is driven so as to rotate.

Drive to the shaker switch array is inherently digital whereas that to the voco-switch is inherently analog. The shaker switch is well adapted to driving large arrays of switches by selecting a stepper motor of sufficient size to shake relatively large areas of mounting platform.

KINESTHETIC SWITCHES

Kinesthetic switches (Figure 3) are designed to variably resist being actuated. The resistance in each instance is electronically variable. Both a rotational switch and a lever switch are sketched in Fig. 3. The lever (or knob) is attached directly to a motor shaft. Application of current to the motor windings varies the resistance to motion in each.

Two fundamental types of mechanical resistance may be applied by the use of the appropriate motor. If a DC motor were used, the shaft would rotate when released. Thus, the lever switch would be the equivalent of a spring-return switch with a variable-constant spring. The rotational switch would be required to incorporate a stop of some sort to prevent return rotation beyond home position. The stepper-motor driven switches could be utilized in like manner to the DC motor driven switches simply by supplying an appropriate sequential pulse train to the windings. Incidentally, used this way either of these switches has the capability of being actuated from the controller, possibly useful in diagnostic situations.

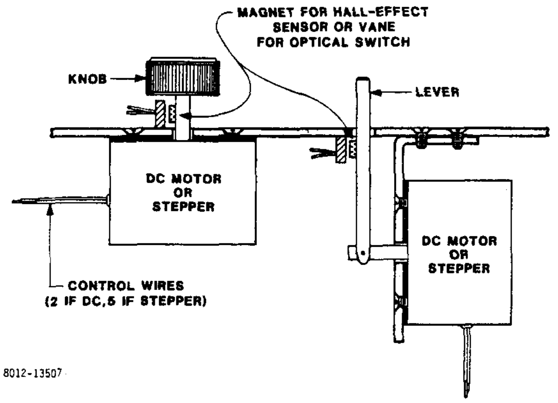

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Fig. 3 Kinesthetic switches are configured to be controllably resistive to movement of the switch knob or lever by the user. If the stepper motor is DC-driven, it will not return to home position when released.

The stepping-motor switches have a potential advantage over the DC motor switches. By applying a variable-level DC current to the stepper's windings, it will become variably resistant to being rotated in either direction. When released, it will not automatically return as will the DC motor driven switch.

THE HOT SWITCH

Figure 4 has heating elements mounted in a specially constructed switch actuating pad. By applying current, the controller can heat the switch handle enough to be easily noticed by the user.

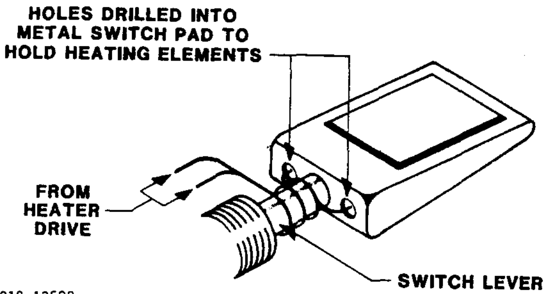

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Fig. 4 The hot switch is driven by a small heating element mounted inside the metal finger-pad which is specially built to replace the one which comes with the purchased switch. To make assembly easier, the pad can be built as two pieces of a sandwich into which grooves are cut to accept the heater. The sandwich is then bolted together to form the finger pad.

DRIVERS

These special devices require special drivers. Some possibilities are sketched in Figure 5. The voco-switch can be driven from an audio amplifier. Signals supplied to the audio amplifier come from a gated low frequency sine wave source when it is desired to produce only a tactile effect. The sine wave must be switched on at the zero crossing to prevent an audible click. If it is desirable to produce audible signals simultaneously, an oscillator producing waves with fast rise and/or fall times may be gated into the audio amplifier. An alternative is simply to raise the frequency of the sine wave oscillator. Tactile effects may disappear at higher frequencies, however.

The shaker switch requires a stepping motor drive. Similarly, one kinesthetic switch variation contains a stepping motor. The drivers for both steppers can be identical. A gated low-frequency oscillator drives a translator which produces changing DC levels to the appropriate stepper windings. Whereas in the shaker switch the direction of motor rotation is irrelevant, in the kinesthetic switch direction must be controlled. DC drive to the stepper translator need not be variable for the shaker switch. However, the kinesthetic effects will be proportional to this level, which must therefore be variable for the kinesthetic switch. In fact, if rotating the kinesthetic switch from the controller is not important, all that is required is a source of variable DC to drive the windings, and the hot switch controller may then double as the kinesthetic switch drive.

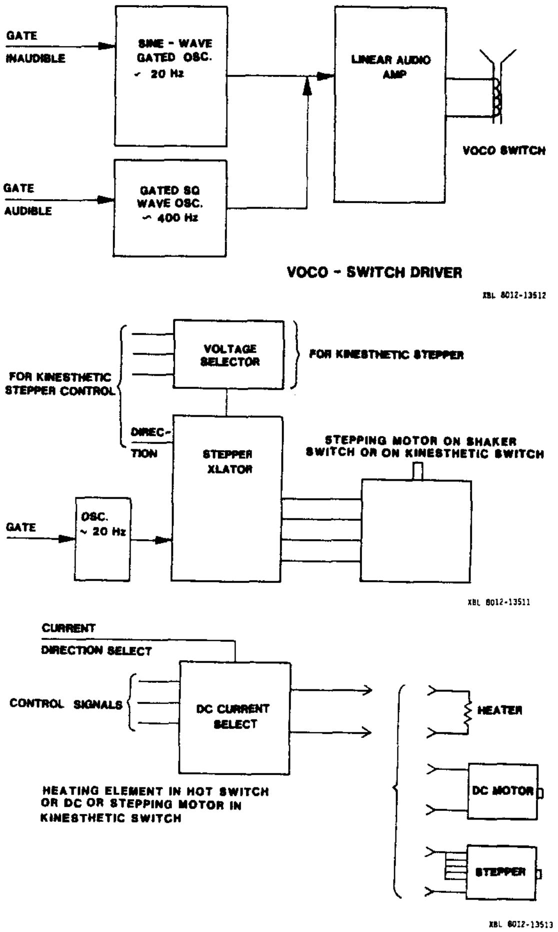

Fig. 5 Special hardware translates from microcomputer--generated control signals into drive signals for the various devices. Some drivers can handle more than one device.

The hot switch controller is a controlled direct current (DC) source. If it is used to control the DC motor drive to a kinesthetic switch, the current direction must be controllable as well as its amplitude. It may be practical to add tactile (shaking) effects to kinesthetic switches by reversing the current direction at an appropriate frequency.

The control requirements for special tactile and kinesthetic effects added to switches are modest per switch--five control signals for the most elaborate kinesthetic stepper; one control signal for the simplest voco-switch.

However, in large arrays the total number of control lines requiring individual attention can become large enough to require a microcomputer controller dedicated to just this function. In particular, having the option of changing a switch's tactile or kinesthetic drive as a function of the closure state of its contacts requires rapid tight-loop control best done in a dedicated microcomputer controller.

APPLICATIONS

Our avowed objective is to add dimensions, tactile and kinesthetic, to those already available for user-computer communications, mainly visual but perhaps soon to be audible. The devices we are describing are binary communicators. In order to produce completely unambiguous information transfers, they are best used either "switched on" or "switched off", the user being able to unambiguously detect these two states.

Since we are adding to, rather than replacing existing dimensions, our special switches must harmoniously augment audible and visual communications. They are uniquely able to do this because they communicate without distracting. While watching activity on a computer display, the user may detect by touching switches whether or not they are active. For example, if the computer is in the midst of a lengthy operation which must be followed by a switch closure, the group of switches may be signalled active when they are to be read. If a sequence of switch operations is required, guidance may be offered by the computer system at each step simply by vibrating or heating the proper group at each sequential step.

The kinesthetic switch offers unique possibilities for inhibiting what may be destructive or dangerous switch closures without absolutely prohibiting such operations. A master reset operation, for example, may be contraindicated in the midst of a lengthy data processing operation. The computer can make this switch difficult to actuate without absolutely disabling it.

Working with displays, our active switches can signal data conditions which do not appear on the display or which appear on the display so inconspicuously as not to be noticed. For example, two large numbers displayed as bars on a bar graph may appear equal. A switch thrown may be programmed to vibrate when such an equality does exist. Or the hot switch can be programmed to get progressively hotter as the numerical difference increases.

The kinesthetic switches have a unique property in their ability to selectively produce a spring-return action. In one of our data analysis operations, switch closures are powerful functions. It is always desirable to begin the operation with all switches in a home position. Presently a message is flashed on the display: "zero sense switches." This is often proceeded by a fumbling through various switching actions in order to find the correct initial positions. Kinesthetic switches could be initialized by the computer. Not to be overlooked is the ability of kinesthetic switches to be closed and opened by the computer for diagnostic purposes.

CONCLUSIONS

Kinesthetic and tactile dimensions can be added to computer-user communications using conventional switches in conjunction with common devices such as stepper motors, loudspeakers and direct current motors. Conventional electronics, controlled from a dedicated microcomputer, can be used to drive the electromechanical devices. The voco-switches may, by being driven with sharp rise time or higher frequency signals, double as an audio channel. Shaker switch arrays signal the user by being vibrated by a stepper motor attached to the switch mounting plate. Kinesthetic switches may be programmed to resist user attempts to move them. These devices, along with the hot switch, are capable of signalling binary conditions to the user without being distracting to the attentions required by a visual display. As such they may be used to improve the intimacy of interaction between the user and the computer.

ACKNOWLEDGMENTS

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