NEXT GENERATION KEYBOARDS: THE IMPORTANCE OF COGNITIVE COMPATIBILITY

John R. Amell
Computer Sciences Corp.
Cincinnati, Ohio 45201

Michael E. Ewry
Systems Research Laboratories, Inc.
Dayton, Ohio 45324

Herbert A. Colle
Wright State University
Dayton, Ohio 45435

ABSTRACT

The computer keyboard of today is essentially the same as it has been for many years. Few advances have been made in keyboard design even though computer systems in general have made remarkable progress in improvements. This paper discusses the future of keyboards, their competition and compatibility with voice input systems, and possible special-application intelligent keyboards for controlling complex systems.

INTRODUCTION

The keyboards in use today do not differ substantially from those used early in this century. The standard QWERTY keyboard, designed for a wholly mechanical typewriter, has remained unchanged, despite the now totally electronic environment. Substantial amounts of research have been devoted to computer systems, including the man-machine interface, with little improvement over the way data is transferred from human to machine.

Keyboard design research has focused mainly on physical parameters such as height, angle, key resistance, and key shape (Alden, Daniels, & Kanarick, 1972). Key arrangement has also been studied, but very little research has been devoted to innovative keyboard design. Even a supposedly innovative keyboard, the Dvorak keyboard, only focuses on balancing the typing load between fingers and hands. Dvorak rearranged the alphabetic keys based on frequency of use for letters in English text (Dvorak, Merrick, Dealey, & Ford, 1936). Keyboard design has not been directed at capitalizing on the cognitive processes of human operators. Although a considerable amount of research has been directed at the study of cognitive processing during typing, the focus has been to describe the processing underlying the use of QWERTY keyboards rather than being directed at the development of new keyboards (Salthouse, 1986).

When evaluating keyboards to be used for a particular task, several general measures can be used. Accuracy of input, rate of input, and time to learn combine with physical parameters to provide a measure of keyboard's suitability for a given task. Accuracy and rate of input are straightforward measures. Time to learn a keyboard is dependent upon several variables: the number of possible entries, the type of task, the expected operational input rate and accuracy, and the keyboard's cognitive compatibility. Cognitive compatibility is an important concept, but one that is easy to overlook. A keyboard is more compatible if its functions map regularly into natural human cognitive processes. Keyboards with cognitive compatibility should be easy to learn as well as rapid to operate.

There have been attempts at improving the cognitive compatibility of keyboard designs. These keyboards can be classified as either alphanumeric or icon based. Icon based keyboards include the multi-function keyboards used in fighter aircraft and item selection keyboards used in some fast food restaurants. Chord keyboards, stenotype machines, telegraphs, alphabetic, Dvorak, and QWERTY keyboards are examples of alphanumeric keyboards.

ICON KEYBOARDS

With icon keyboards words, phrases or concepts are processed rather than single letters. Multi-function keyboards, used in fighter aircraft, allow a pilot to select an action, based on the current configuration of the keyboard. Key labels appear on the CRT adjacent to the keys and change to reflect current operability. Other multifunction keyboards have several labels on the key and require the use of shift keys to access all functions. Menu-based computer interfaces are a derivation of an icon keyboard.

Item selection keyboards have dedicated keys, each one corresponds to a particular item. An important characteristic of icon keyboards is that items are organized by class. For example, on a fast food item selection keyboard, sandwiches would be grouped separately from drinks. Within these general classifications, sub-classes also can be grouped. Specialty sandwiches might be separated from hamburgers within the sandwiches group. This semantic organization is very compatible with operator's cognitive processing when an order is placed. Operators do not have to look up or remember the price of each item. Nor do they have to make several keystrokes to enter the price on the register. (There are other advantages such as communication to team members and inventory which will not be discussed.)

There are, of course, limitations on what can be done with an icon keyboard. The most obvious limitation is that it cannot produce free form text. Also, it is a visual search device which limits the speed at which it can be operated and, typically, it takes considerable space to accommodate all icons.

ALPHANUMERIC KEYBOARDS

Text processing refers to any keyboard used to output letters and words. In alphabetic and QWERTY keyboards each letter has a key that is dedicated to it. A telegraph keyboard is at the opposite extreme. It may have only one key; a pattern of dots and dashes are used to represent individual letters. Chord keyboards are intermediate. With chord keyboards, combinations of several keys are pressed simultaneously to produce letters, syllables, or words.

Alphabetic Keyboards. These keyboards have the keys arranged in alphabetical order, usually in three rows. Basically, the alphabetic keyboard was an attempt to increase cognitive compatibility by taking advantage of a human operator's knowledge of alphabetic order. This attempt has not been successful. Norman (1986) has suggested that the artificial breaks in the alphabet, due to the three rows, reduces the effectiveness of the alphabetic keyboard.

Qwerty Keyboards. Today's microcomputer keyboards, while remaining basically QWERTY text processors, have added function keys, a control (Ctrl) key, and an Alternative (Alt) key. This is a first attempt at integrating both text and concept processing into one keyboard. Typically, Ctrl and Alt key are used to execute a higher level command which would require a string of letters if typed. Often, there has been some attempts to use a mnemonic code to select the command associated with a particular key. Usually this has been to use the first letter of one of the names for the command. If the operator remembers the command name, the result can be higher cognitive compatibility. Seldomly does it achieve the level of compatibility inherent in the use of the shift key. While it is expected that when we strike a "c" on the keyboard, a lower case "c" is produced, and when we strike a "<shift> c", an upper case "C" is the result, it is not so obvious what will result when a "<Ctrl> c" or a "<Alt> c" is pressed. The problem is a lack of cognitive compatibility. The same is true of function keys labeled F1 to F10. There is no inherent meaning in the label.

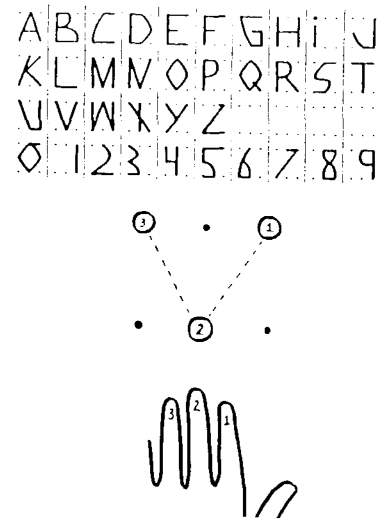

Figure 1 The Alpha-Dot code.

Chord Keyboards. These keyboards typically have fewer keys than standard keyboards since characters are produced by pressing multiple keys on a stroke. Two examples of chord keyboards are the Alpha-Dot keyboard, a one-handed typing device, and the two-handed Stenotype machine. A variety of other chord keyboards have been proposed. See Ewry (1987) for a review.

The Alpha-Dot keyboard has just three character keys and it requires a two strokes for each character entered (Sidorsky, 1974). The specially designed character set (Figure 1) visually maps the shape of the printed letter onto a matrix of two rows of three dots, corresponding to the three character keys. Each row of dots represents one keystroke. Tests have shown that people can learn to use this keyboard, by touch, in one hour or less (Amell, 1986; Ewry, 1987). In comparison, when letters are randomly assigned to keystrokes, learning takes considerably longer (Ewry, 1987). Trying to arrange keys based on frequency of use will usually make them appear to be randomly organized. The Alpha-Dot keyboard is learned rapidly because it is cognitively compatible. Compatibility in this case is different than the cognitive compatibility of icon keyboards. The spatial coding scheme of the Alpha-Dot keyboard relates letter shape to key patterns. By using visual imagery, operators can remember many keystroke patterns. A problem with Alpha-Dot coding is that not all letter-keystroke patterns can be represented without resorting to distorted letter shapes.

Stenotypewriters are chord keyboards that have been developed for use in courtroom transcription. These stenotype keyboards use a very different cognitive coding principle. An operator enters a syllable or word with each two-handed keystroke. The machine shorthand code is basically phonetic. Operators enter a consonant-vowel-consonant sequence (CVC) on each stroke, representing a syllable. More complicated CVC patterns also can be entered. Front consonants and back consonants are represented separately on the keyboards. Chord responses are used in two ways. First, to define the CVC. Second, to define consonants and vowels because there are only 22 keys and not all consonant and vowels have a single key definition.

Stenotyping can lead to very rapid text transcription. Expert stenotypists can achieve entry rates of 225-300 words per minute. In contrast, comparable QWERTY typists achieve entry rates of only 60-80 words per minute. Modern online computer transcription can convert stenotype codes into normal alphanumeric text. High entry rates can only be achieved because the system is designed for fast human throughout. On the negative side, however, are the long training times necessary to learn the complete stenotyping code and the high drop out rate of students in training programs. Clearly, stenotyping causes problems for human operators.

Voice Recognition. One solution to the cognitive compatibility problem would seem to be the development of automatic speech recognition. Unfortunately, speech recognition research requires major conceptual breakthroughs before automatic speech recognition can be used routinely. Current systems have trouble segmenting words in continuous speech, and have trouble differentiating homophones. They are also speaker dependent. Currently, most automatic speech recognizers use only a small speaker-dependent vocabulary. Actually, even optimal speech recognition devices would not eliminate the need for keyboards because privacy is required for many keyboard uses. Thus they are similar to icon keyboards.

THE FUTURE OF KEYBOARDS

A small next step would be to integrate what we know about keyboards and speech recognition into a single system. Functions currently accessed by function keys or Alt Ctrl combinations could be called by voice command. This would relieve some of the cognitive incompatibilities present in current systems. Since we generally know what we want to do, we just don't know which key combination does it. This would necessitate the recognition system be part of the front end, even part of the keyboard itself. This would result in personalized keyboards which would be transportable between systems since the output of the keyboard would still be ASCII characters. In addition, since personalized keyboards would have memory for speech recognition, we could also customize the key combinations to produce often used words or phrases instead of functions.

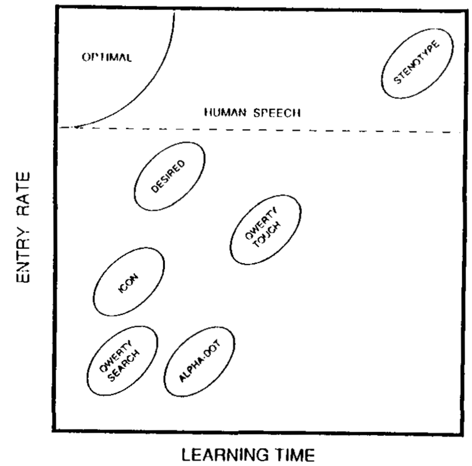

Figure 2 The keyboard design space.

Major changes in keyboard design also may be possible. Figure 2 represents the current state of keyboard design. The axes show the two major parameters of keyboard operation, rate of entry and time to learn. Several keyboards are easy to learn, but their entry rates are low. The stenotype keyboard in the upper right quadrant of the figure represents a keyboard which requires a long learning time, but entry rates are extremely fast. The "desired" elipse in Figure 2 represents an area of the space where new development work should focus. What is needed is a keyboard in which high entry rates can be achieved with minimal training. By stressing human cognitive processes, this goal may be attainable.

Chord keyboards provide a level of flexibility that lends itself to the development of innovative keyboard designs with high cognitive compatibility. In order to achieve the goal of an easily learned keyboard with entry rates in the range of a QWERTY touch typist or human speech, attention must be paid to the relationship between the operator and the keyboard. One design strategy could be to design down from the stenotypewriter. Simple phonetic coding is easy to learn. Instead of a system for very high entry rates, it may be possible to design a code which is more systematic and regular but at the cost entry rates that are lower than the 225-300 attainable with stenotyping.

Chord keyboards have another advantage. They can be made with very few keys and can be used with one hand. The one-handed chord keyboards may be used as data entry devices where space is a design constraint and speed of entry is noncritical. They could also be used as hand-held remote terminals that communicate with a main computer. The ability to interface with a computer while engaging in activities in the field offers many possibilities. They could be used anywhere a notepad could without the restrictions of even a laptop computer. A keyboard such as the Alpha-Dot could revolutionize laptop computer design.

Keyboards are not going to disappear in the foreseeable future. With current technology, we have the ability to improve their functionality and take greatly improved keyboards into the 21st century.

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