Joystick Versus Mouse

Pointing Device Communication

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For more than 20 years designers have puzzled over the problem of how best to enter information into the computer. They have concluded that a device using the controlled motion of forearm, wrist, thumb and index finger to point to graphic patterns on the display screen could substantially facilitate the control and instruction of the computer. Many believe that pointing devices provide the most powerful non-keyboard way to communicate with a computer, and even the computing public has recently shown an emerging willingness to accept pointing devices as an improved mode of computer interaction. Although the current popular belief is that the "mouse" is the only appropriate pointing device for all applications, nothing could be further from the truth.

In 1967, a classic study established that the digitizing tablet was the best overall pointing device. But this much-quoted study—by English, Engelbart and Berman—understandably did not concern itself with the prohibitively high cost of the tablet, since mainframe computers were the order of the day. Even today, the digitizing tablet remains the best general pointing device in situations where money is no object.

But, with the advent of inexpensive microcomputers, studies have shifted their attention to low-cost pointing devices. In a 1978 study by Card, English and Burr, the joystick, mouse, arrow keys and text keys were compared for text selection and editing performance. The Card study (also known as the Xerox study) concluded that the mouse was "found to be fastest on all counts and also to have the lowest error rates." Although proponents of the mouse have relied heavily on this conclusion, the crucial point is what *kind* of joystick is compared with the mouse.

Until recently, there have been two kinds of joysticks available: the *absolute* and the *rate*. With an absolute, the travel of the joystick corresponds directly to the scope of the display. Moving the absolute joystick to its topmost position places the cursor at the top of the display. Moving it to its lower left position places the cursor at the lower left corner of the display, and so on.

With the rate joystick, the travel of the joystick imparts a direction of motion to the cursor. Push the rate joystick to the left, and the cursor will move from wherever its present position is. Push it to the lower left, and the cursor will move diagonally in that direction. Let the stick return to center, and the cursor comes to a halt. Furthermore, in typical designs, by varying how *far* in any direction the rate joystick is moved, one controls the speed with which the cursor will move. When the rate joystick is moved up slightly, the cursor rises slowly. Push it to the top of its travel, and the cursor moves upward at maximum speed.

While the Card study did find marginal advantage in positioning speed for the mouse *(Figure 1)*, this was only in comparison to the *rate* joystick. An absolute joystick was not included in this study. In the earlier English study, the absolute joystick was found to meet or exceed the positioning speed of the mouse. It should be noted that, in applications where it is desirable to integrate a pointing device into a keyboard, the mouse is ruled out. In such cases, an arrow or text key design could be used, but a joystick solution would be far superior.

A New Kind of Joystick

Recently preliminary tests were

conducted using a NorthStar Advantage computer and an absolute/rate joystick, a hybrid that combines the advantages of both traditional designs. A switch on the side of the joystick handle under the thumb (adjustable for left- or right-hand operation) is depressed to select absolute mode. In this position, a motion to the upper left corner of the joystick corresponds to the immediate movement of the graphics cursor to the upper left corner of the computer display. Once the target area is reached, the thumb-index finger pressure is relaxed. The switch is thus released, and the joystick reverts to rate operation. This hybrid combines the large-motion positioning speed of the absolute joystick with the rate joystick's small movements and fine control. As a result, in applications where coarse positioning speed predominates, it is expected that the absolute joystick mode (which is lockable on software request or by double-clicking the thumb-actuated state switch) will easily meet or exceed the positioning speed of the mouse.

For small cursor movements, even the Card study found the rate joystick and mouse essentially identical (only a 1% to 3% difference) for movements of less than an inch *(Figure 1).* Furthermore, in the rate mode, a 15-degree motion from the center of the joystick produces an incremental change in the output of the joystick of one part in 4,096—

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ten times the precision of the best mouse available.

The Need for More Research

A pointing device must be compatible with the requirements of both man and machine. Yet far too little attention has been paid to the joints and muscles that will have to operate the device—often for hours at a time. A thorough examination should not only focus on the required positioning precision for the specific task, but also on the duration of the task for any muscle group and its particular fatigue factor. Such a study would be an important guide to both the engineer and the system integrator. In addition, studying muscle groups would establish evaluation criteria for future pointing device development.

The two main muscle groups involved in pointing devices are forearm/wrist and thumb/finger/wrist. The general relationships between these two groups and the various pointing devices are, of course, inherent in the basic designs. Movement of the forearm/wrist group generally requires more energy, and is more fatiguing, than movement of the thumb/finger/wrist.

The digitizing tablet, in making use of forearm and wrist motions, closely approximates the activity of writing and drawing. And, because of the very high lineal resolution of the tablet, thumb/index finger motions can be captured as well. The tablet is the only device discussed here that can represent both the

Effect of Target Distance on Positioning Time

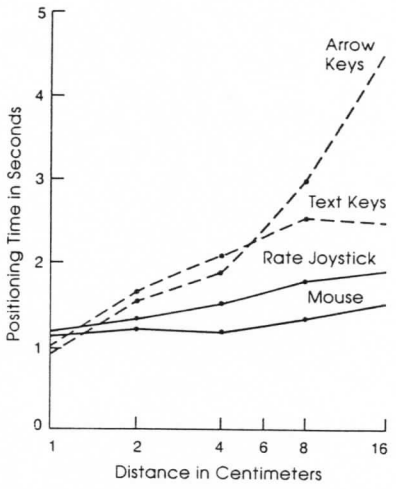

Figure 1

Decision Factors in Pointing Device Selection

Pointing Device	Resolution Capability	Positioning Speed	Cost	Fatigue Factor	Portable?	Compact?
Digitizing Tablet	High	High	High	Medium	No	No
Absolute Joystick	High	High	Low	Low	Yes	Yes
Rate Joystick	High	Medium	Low	Low	Yes	Yes
Mouse	High	High	Med/High	Medium	Yes	No
Absolute/Rate Joystick	High	High	Med/Low	Low	Yes	Yes
Arrow or Step Keys	N/A	Low	Low	Medium	Yes	Yes
Light Pen	Low	High	Medium	High	Yes	No

Figure 2

thumb/finger/wrist motion and forearm/wrist motion.

The optical or mechanical mouse uses forearm/wrist motion exclusively (except for switch activation), while the joystick uses the motion of thumb/finger/wrist motion exclusively.

Operation of arrow or text keys requires only the repeated "on/off" striking motion of the finger and wrist. Since the key is either up or down, this device does not take advantage of the natural human ability to control and modulate movements.

Text Editing Recommendations

Although none of these devices is appropriate for every situation, tentative guidelines can be suggested even without the benefit of detailed studies. The most common use of pointing devices today is for text or text-related editing in which a keyboard is a necessity. A keyboard-mounted pointing device is therefore advantageous, because it always leaves the wrist and forearm in a known relationship to the keyboard. Thus, a return hand motion is minimal, direct, and repeatable. By contrast, the return hand motion with either the tablet or mouse is indeterminate and not automatically repeatable. Hence, the editing process is interrupted and delayed.

There is also reason to believe that, for text editing, the absolute/rate joystick may actually position faster and with fewer errors than the mouse. Once the joystick in absolute mode has placed the cursor in the region of a text line or character column, the rate mode can be used to move it easily in a horizontal or vertical direction. This allows the rapid selection of a character within a line, or a line within a paragraph. And, when moving the cursor along a line of text in the rate mode, an inadvertent upward deviation that does not exceed 15 degrees will not push the cursor off the text line of interest. Thus, the cursor movements tend to adhere to the line-and-column grid of written text. With a mouse or tablet, however, an inadvertent motion such as this would actually displace the cursor one or more text lines, resulting in a positioning error.

General Application Recommendations

The following guidelines are suggested for other applications, and are based primarily on the resolution and positioning speed required, as well as on cost sensitivity. However, factors such as space requirements, fatigue, compactness, and portability are also taken into account *(Figure 2)*.

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The cost of a pointing device will depend, in large measure, on the degree of resolution required. However, for comparable applications, a joystick is typically 60 to 80 percent less expensive than a mouse.

A portable device can be incorporated into a portable computer's carrying package, while a "compact" device can be integrated into the computer keyboard. "High" resolution means the operator's ability to resolve over one part in two thousand (2048 x 2048 picture elements). "Medium" resolution corresponds to a 512 x 512 display, and "low" resolution to 256 x 256 pixels.

High Resolution: For high-resolution applications where cost is not a primary consideration, the digitizing tablet is outstanding. The tablet offers natural, absolute mapping of the user's motions onto the display space, with resolution as high as 500 to 1,000 points per inch. Desk area must be provided for the tablet, and the fatigue factor is moderate. This device is neither portable nor compact.

For applications that are cost-sensitive, however, either a mouse or absolute/rate joystick is recommended. The mouse offers high speed and high resolution (100-300 points per inch), but does not offer natural, absolute mapping. Some desk area must be provided, and the fatigue factor is moderate. This device is portable, but not compact.

The absolute/rate joystick offers high speed and high resolution (100-400 points per inch in absolute mode; 1,000-10,000 points per inch in rate mode. The joystick provides natural, absolute mapping in the absolute mode, and no extra desk area is required. The fatigue factor is low, and the device is both portable and compact. For high-resolution applications that are extremely cost-sensitive, the absolute/rate joystick is recommended.

Medium Resolution: Either a mouse or an absolute/rate joystick is recommended for medium-resolution, cost-sensitive applications. For this degree of resolution, the joystick's rate mode would be adjusted to operate more coarsely.

Low Resolution: For low-resolution, cost-insensitive applications, either a mouse or an absolute/rate joystick would be appropriate. For applications that are cost-sensitive, the absolute joystick is recommended, since at this resolution the rate mode is dispensable. The absolute joystick offers high speed, provides natural, absolute mapping, and no extra desk area is required. The fatigue factor is low, and the device is both portable and compact.

For extremely cost-sensitive applications, step keys are recommended. Step keys, which function much like a simple rate joystick, provide an ultra low-cost pointing device. No extra desk space is required, the fatigue factor is moderate, and the device is both portable and compact. ■

References

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Vic Kley is president of KA Design Group, and has been involved in computer graphics and input device design since 1977. He holds six patents in input device technology and has two more pending.