Display-Selection Techniques for Text Manipulation

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***Abstract*—Tests and analysis to determine the best display-selection techniques for a computer-aided text-manipulation system reveal that the choice does not hinge on the inherent differences in target-selection speed and accuracy between the different selection devices. Of more importance are such factors as the mix of other operations required of the select-operation hand, the ease of getting the hand to and gaining control of a given selection device, or the fatique effects of its associated operating posture.**

Besides a light pen, several cursor-controlling devices were tested, including a joystick and an SRI-developed device known as a "mouse." The study was aimed directly at finding the best display-selection means for our own text-manipulation system but generalizations applicable to other types of on-line systems were derived.

1. Introduction

1a This paper describes an experimental study into the relative merits of different CRT display-selection devices as used within a real-time, computer-display, text-manipulation system in use at Stanford Research Institute.

1a1 Briefly, we have developed a comprehensive on-line text-manipulation system. We wanted to determine the best means by which a user can designate textual entities to be used as "operands" in the different text-manipulation operations.

1a2 Techniques and devices for display-entity operand selection represent a major component in any display-control scheme, and are readily isolated for purposes of comparative testing, once the procedural environment in which selection is done has been established.

1a3 An important conclusion of our experimentation is that this environment has considerable effect upon the choice of display-selection means for a given display-control system.

1b Our text-manipulation system is designed for daily usage, and our experiments and conclusions stem from extensive personal experience as users as well as designers.

1b1 To emphasize this, we point out that for two years we have been using the system for producing most of the internal memos—and all of the proposals and reports—associated with our research program.

1b2 This paper itself was extracted from one of these reports—reorganized and modified by use of the system. See 1 (ENGLISH 1).

1b3 The format and writing style which represent an important experimental component of our research, are left in the form with which we work.

1b3a Statements—be they subheads, phrases, sentences, or paragraphs—are numbered and presented in hierarchical order. These statement numbers are one "handle" by which a statement may be grasped for any of the operations performed on- or off-line.

1b3b References, which appear in the Bibliography at the end of the paper, are shown in the text by a mention of their statement numbers "see 1 (ENGLISH 1)", rather than by the more familiar superscript notation.

1c The tests of the display-selection devices simulated the general situation faced by a user of our on-line system when he must interpose a screen-selection operation into his on-going working operations. See Fig. 1 for a layout of the on-line work station.

Fig. 1. The on-line system work station showing the CRT display, keyboard, pushbuttons, and mouse.

1c1 The user has generally been entering information on the typewriter-like keyboard.

1c2 To begin making the screen selection, his right hand leaves the keyboard and takes hold of ("accesses," in our terminology) the selection device.

1c3 By moving this device he controls the position on the screen of an associated tracking mark (or "bug"), placing it over the "target" text entity.

1c4 He then actuates a pushbutton associated with the particular selection device, to tell the computer that he is now "pointing at" the target entity.

1c5 The computer puts a special mark under the entity which it determines as having been selected.

Manuscript received December 2, 1966.
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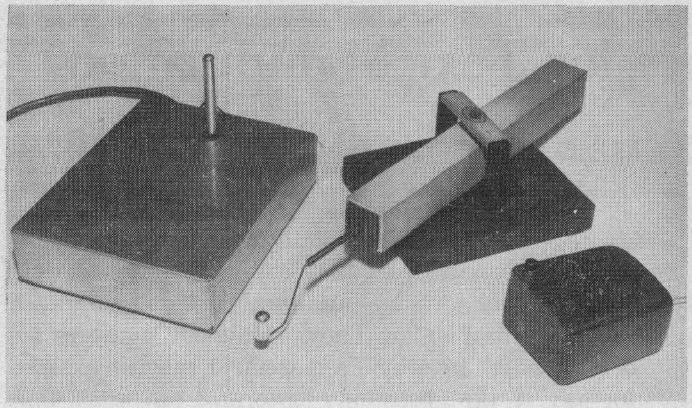


Fig. 2. Bug-positioning devices from left to right: joystick, Grafacon, and mouse.

to give the user an opportunity to see if a correct selection has been made.

1d We designed and conducted our experiments in order to learn more about the following characteristics of the operand-selecting devices currently available in our on-line system:

1d1 The comparative speed with which they could be used to select material on the display screen. Two kinds of time period were measured:

1d1a "Access time": the time it takes for the user to move his hand from the keyboard to the operand-selecting device.

1d1b "Motion time": the time period beginning with the first movement of the bug and ending with the "select" action fixing the bug at some particular character position.

1d2 The comparative ease with which an untrained user could become reasonably proficient in using the various devices.

1d3 The comparative error rates of the various devices.

2. Description of the Devices Tested

2a The tests included both a light pen and various devices to position a cursor (or "bug" as we call it) on the CRT screen.

2a1 Operand entities displayed on the screen are chosen by selecting a character within the operand entity (word, line, or statement).

2a2 The light pen or bug is first located near the desired character, then the SELECT switch on the device is depressed (or in the case of the knee control a special "CA" key on the keyboard is struck).

2b Grafacon (see Fig. 2):

2b1 The Grafacon was manufactured by Data Equipment Company as a graphical input device for curve tracing. See 2 (FLETCHER 1). The particular device that we tested is no longer marketed under this name.

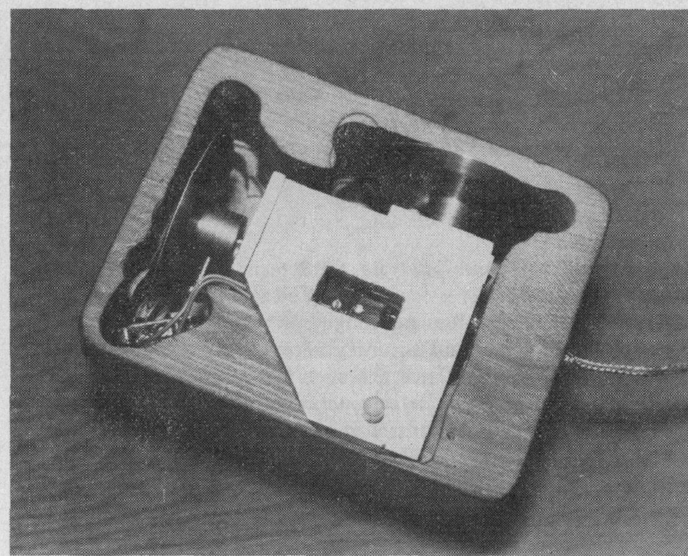


Fig. 3. Bottom side of mouse, showing mechanical details.

Data Equipment Company now markets the Rand Tablet under the name "Grafacon." See 3 (DAVIS 1).

2b2 It consists of an extensible arm connected to a linear potentiometer, with the housing for the linear potentiometer pivoted on an angular potentiometer.

2b2a The voltage outputs from the Grafacon represent polar coordinates about the pivot point, but are interpreted by the system exactly as the outputs from the "mouse" or joystick, which represent rectangular coordinates.

2b2b This means that to trace a straight line across the screen with the bug, the user must actually move his hand in a slight arc.

2b2c We planned to program polar-to-rectangular conversion into our bug-tracking process, but we initially coupled the Grafacon "directly" (i.e., with this geometric "tracking distortion") to get a general feel for its performance. We found no evidence that the user was aware of this distortion and never did write the conversion routine to eliminate it.

2b3 A knob on the Grafacon arm is moved about by the user, and is depressed to activate the select switch (added by SRI) associated with the Grafacon.

2b3a The Grafacon as originally obtained was equipped with a pen mounted on the potentiometer arm. This was replaced with a knob to better suit our purposes.

2c Joystick (see Fig. 2):

2c1 The joystick that we used was manufactured by Bowmar Associates (Model X-2438).

2c2 It is constructed from two potentiometers, mounted perpendicularly and coupled to a vertical stick in such a way that they resolve the motion of the stick into two components.

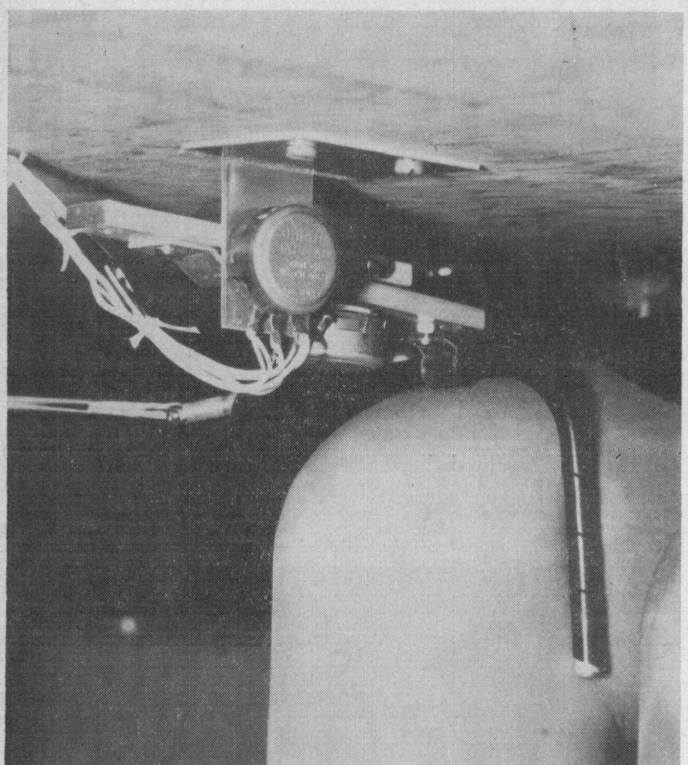


Fig. 4. Knee control bug-positioning device.

2c2a The original stick was $1\frac{1}{2}$ inches long; a 3 inch extension to the shaft, housing a switch actuated by pressing down on the stick itself, was added by SRI.

2c3 Two modes of operation with the joystick were implemented:

2c3a An "absolute" mode, in which the bug's position on the screen corresponds to the position of the joystick handle; and

2c3b A "rate" mode, in which the bug's direction of motion is determined by the direction of joystick handle deflection, and the bug's rate of motion is determined by the amount of joystick deflection.

2d Mouse (see Fig. 2):

2d1 The "mouse" was developed by SRI in connection with this research.

2d2 It is constructed from two potentiometers, mounted orthogonally, each of which has a wheel attached to its shaft (see Fig. 3).

2d2a The mounting frame for the potentiometers is enclosed in a 2 inch × 3 inch × 4 inch wooden case.

2d3 As the case is moved over a surface (e.g., the table surface in front of a display)

2d3a the wheels ride on the surface and turn the potentiometer shafts, with a combined sliding and turning action depending upon the relative orientation of the motion and the wheel axes,

2d3b to resolve the motion into two orthogonal components in much the same manner as do the

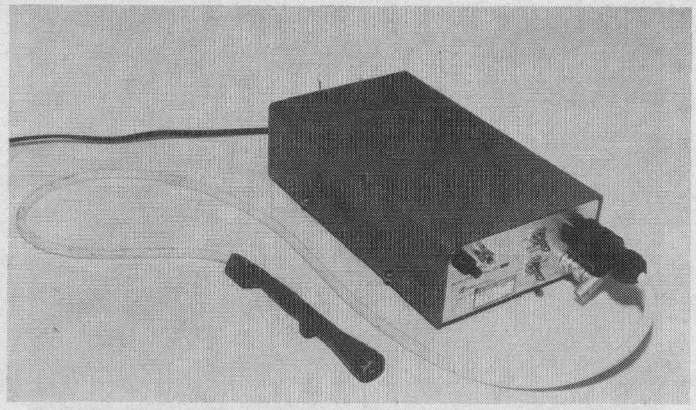


Fig. 5. Light pen.

disks in planimeters or in the old-fashioned mechanical differential analyzers.

2d4 A travel of about five inches is required for full edge-to-edge or top-to-bottom coverage of the CRT screen.

2d5 A switch mounted on the case is used for the select function.

2e Knee Control (see Fig. 4):

2e1 A preliminary model of a knee control was made for this research.

2e2 It consists of two potentiometers and associated linkage plus a knee lever. The linkage is spring-loaded to the right and gravity-loaded downward.

2e3 The user pushes the lever with his knee; a side-to-side motion of the knee moves the bug edge-to-edge, while the top-to-bottom bug movement is controlled by an up-and-down motion of the knee (i.e., a rocking motion on the ball of the foot).

2f Light Pen (see Fig. 5):

2f1 The light pen used was manufactured by Sanders Associates of Nashua, New Hampshire (Model EO-CH).

2f2 It consists of a hand-held pen coupled to a photomultiplier tube by a fiber optic bundle.

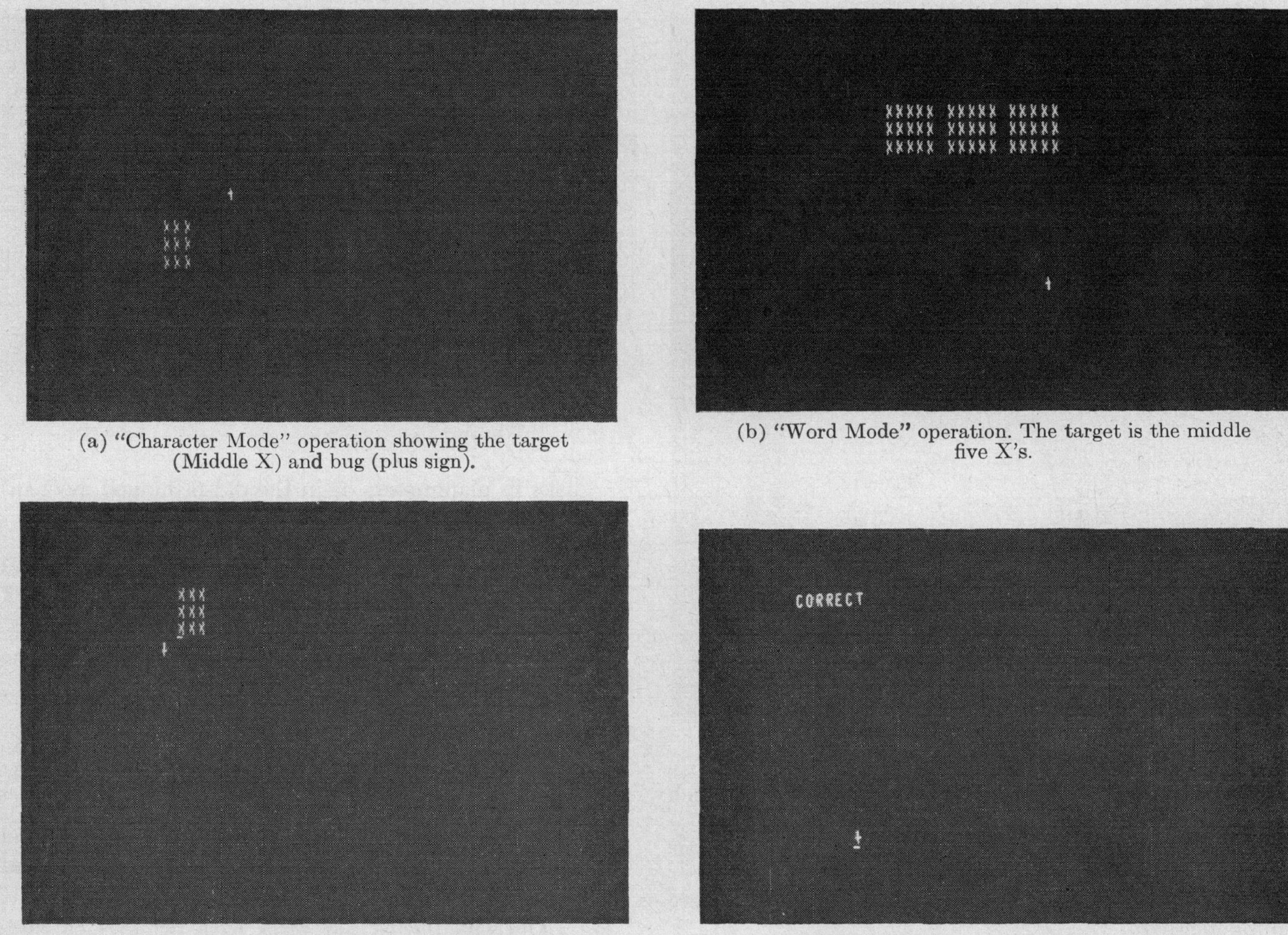
2f3 The pen is pointed at the desired character on the CRT screen with the aid of a projected circle of orange light indicating the approximate field of view of the lens system.

2f3a A switch on the pen unit is used for making the selection.

3. Description of the Experiments

3a The experiments were designed to test the various operand-selecting devices under conditions similar to those that the user would encounter when actually working on-line.

3a1 However, certain features of the live working conditions were not closely related to the actual efficiency of the operand-selecting devices, such as



(a) "Character Mode" operation showing the target (Middle X) and bug (plus sign).

(b) "Word Mode" operation. The target is the middle five X's.

(c) An incorrect selection is underlined. The configuration of X's and the bug remain on the display.

(d) A correct selection. The position of the target is indicated by the bug mark and underline.

Fig. 6. Targets used to experimentally evaluate the operand-locating devices and results of an incorrect and correct selection.

3a1a The need to enter literal input from the keyboard,

3a1b The need to designate commands, and

3a1c The user's indecision in choosing which display-entity to select.

3a2 We tried either to eliminate these features from the experimental environment, or to fix them in some standard way throughout the experiment.

3b Two different kinds of display-entity "targets" were presented in the experiments: "word" targets and "character" targets. The target patterns presented to the subject were configurations of x's rather than actual text.

3b1 A configuration simulating the "character mode" operation of the system consisted of nine x's, in a three by three array, with the array as a whole randomly placed on the display. The specific target entity was the middle x [see Fig. 6(a)].

3b2 A configuration simulating the "word mode" operation of the system consisted of nine groups of five x's each, in a three by three "word" array, with the array as a whole randomly placed on the display. The target entity was any one of the five middle x's [i.e., any character in the middle "word"; see Fig. 6(b)].

3c The subject was given a series of tests with each of these two types of target, and was to perform the following task sequence:

3c1 When the target appeared on the display screen, the subject was to strike the keyboard space-bar with his right hand, causing the bug to appear on the display. (Requiring that he use his right hand for both the space bar and the operand-selecting device made the experimental task closer to the actual on-line environment, where the user would often have both hands at the keyboard before moving to the operand-selecting device. It also gave us a way of measuring the access times for the various devices.)

3c2 The subject was then to move his hand to the bug-positioning device being tested, and use it to guide the bug to the target entity on the display.
3c3 When the bug and the target coincided the subject was to "fix" the bug at that location, using the select switch of the bug-positioning device.

3c3a An incorrect selection was signalled by a bell, and the incorrectly selected entity was underlined in the displayed target pattern [see Fig. 6(c)]; the subject was then to relocate the bug and reselect the target entity.
3c3b A correct selection caused the target to disappear, and the word "CORRECT" to appear on the display screen [see Fig. 6(d)]. About three seconds later, the next target pattern was displayed (in some new randomly-determined position), and the process was repeated.

3c4 When the light pen rather than a bug-positioning device was used, the task sequence was much the same: after the target appeared, the subject was to strike the keyboard space bar with his right hand, then grasp the light pen and point it at the target entity (with the aid of the finder beam). The subject "fixed" his choice by depressing the select switch on the light pen. Correct and incorrect selections were signaled in the same way as with the bug-positioning devices.

3d There were two groups of subjects: eight "experienced" subjects who were already somewhat familiar with the on-line system, and three "inexperienced" subjects who had never before used either the system or the particular devices being tested. The experienced group were given experiments to test the devices after a reasonable amount of practice. The inexperienced group were tested to see how quickly and how well they learned to use the devices without previous practice.

3d1 For the experienced subjects, the entire testing procedure, which was broken into two time periods, proceeded as follows:

3d1a The subject was given a brief explanation of the experiment and the target patterns.
3d1b He was then given his first device and allowed to practice with it for about two minutes.
3d1c Next he was tested using this first device, in both the "word" mode and the "character" mode of selection. Thirty-two targets of each type were presented.
3d1d After a two-minute rest period, the subject was given his second device and allowed to practice with it for about two minutes. He was then tested with this device—again, with 32 targets of each type.
3d1e This same sequence of rest, practice, and testing was carried out for each of the devices being tested. This constituted the first time period of the experiment.

3d1f During the second time period, the subject proceeded backward through the list of devices, begining with the last device he had used in the previous time period, then using the next-to-last device, and so on.
3d1g Each subject began with a different device and was presented with devices in a different order.

3d2 For inexperienced subjects, the experimental procedure was somewhat different:

3d2a The subject was given an explanation of the experiment, the target patterns, and the way the particular operand-selecting device worked. He was allowed to get the feel of the device, but was not given a practice period. He was then presented with ten sequences of eight target-patterns each, in the "character" mode.
3d2b This procedure was followed for each of the devices being tested.
3d2c Each subject began with a different device, and was given a different order of devices to work with.

3e The computer was used extensively in conducting these experiments: for presenting target patterns, signalling of correct and incorrect selections, determining the (random) position of the next target pattern, determining the short time-delays between a correct selection and the presentation of the next target, etc. In addition, for each presentation-selection event, the computer recorded the following information on magnetic tape for later analysis:

3e1 The position of the bug (in relation to the target entity) was recorded each 10 milliseconds.
3e2 The times the subject hit the space bar, and the times he made either a correct or an incorrect entity selection, were recorded and appropriately tagged to aid in identifying these significant points in the late data analysis.

3f The length of the experimental runs; the rest periods allowed between runs; the order in which the various devices were tested; and the modes of operation ("character" or "word" targets) were controlled by the person conducting the experiments.

4. Description of the Data Analysis

4a The analysis software was designed to allow flexibility in studying individual performance curves and results. This software provided operator commands for scanning the recorded data on the magnetic tape, selectively printing out results, producing CRT-displayed curves of each subject's performance, and calculating certain averages over a block of tests.

4a1 Tape-handling operations, controlled by commands from the on-line keyboard, facilitate searching through the data recorded on the magnetic tape.

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