HUMAN FACTORS IN INTERACTIVE COMPUTER GRAPHICS

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ABSTRACT

Human factors criteria that are applicable to the design of interactive computer graphics software are: (1) iconic vs. semantic cues; (2) short-term memory; (3) man vs. machine allocation of tasks; (4) bandwidth of human information channels; (5) spatial layout and borders; (6) response time; (7) feedback; (8) forgiveness and understanding; and (9) security.

Pierce is a graphics package for data display and curve fitting.

The human factors are briefly described, using examples from Pierce to show how they were applied to its design.

FACTEURS HUMAINS DANS LES GRAPHIQUES PAR ORDINATEUR À ACTION RÉCIPROQUE

ABRÉGÉ

Les facteurs humains applicables à la conception du logiciel pour systèmes graphiques informatisés à action réciproque sont les suivants: 1) l'iconique au regard de la sémantique, 2) la mémoire à court terme, 3) la répartition des tâches humaines et mécaniques, 4) la largeur de bande pour la communication avec l'homme, 5) la distribution spatiale et les limites, 6) le temps de réponse, 7) la réaction, 8) l'oubli et la compréhension, et 9) la sécurité.

Le Pierce est un programme-produit par graphique employé dans l'affichage des données et l'ajustement des courbes.

Les facteurs humains sont décrits brièvement à l'aide d'exemples tirés du système Pierce pour démontrer comment ils ont été appliqués lors de la conception du système.

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The interactive computer graphics package, Pierce, used for data display and analysis was designed with human factors criteria being applied to the functional aspects of the man-computer interface. The human factors are described, and examples from Pierce are used to show how they were applied.

THE HARDWARE SYSTEM

The hardware on which Pierce was implemented is shown in Figure 1. The PDP-9 computer handled all computer functions except for curve-fitting calculations, which were done using existing software on a Xerox Sigma-7 via a communications link. The equipment is located at the Communications Research Centre in Ottawa.

HUMAN FACTORS

The human factors that apply to the functional aspects of the man-computer interface are not all amenable to precise definition, nor are they readily verifiable by experiment. Some of them are of an intuitive nature, and their application is more of an art than a science. Nevertheless, their use should be encouraged, if only in an attempt to discover whether or not the interface is improved by their application.

The factors that were applied to Pierce are:

(1) Iconic control cues. If semantic material (i.e., text) is used as light buttons for controlling system action then it is necessary for the user to perceive the word and encode it aurally before its meaning can be understood. However, if icons (i.e. pictures) are used, the intermediate aural encoding process is unnecessary and the meanings of light buttons are perceived more quickly, especially in the initial learning stage of system use. Figure 2 shows a part of the data entry sequence, where iconic cues are used to identify the input devices-magnetic tape, disk, keyboard, and paper tape.

(2) Short-term memory. Where a number of information entry or control actions are necessary, it is easy to forget the earlier actions as the sequence progresses. It should therefore be easy to check the complete state of the system to confirm the progress that has been made. Figure 3 shows how pertinent data is displayed after it has been entered. This tableau is always available for review.

(3) Man/computer allocation of tasks. In an interactive system, those tasks to which judgment or intuition can be applied should be assigned to the operator, whereas those which are essentially clerical in nature are best performed by the computer. In this case, sorting of data points into numerical order and calculation of the polynomial coefficients of a fitted curve are examples of the latter, while selection of the appropriate degree of curve to fit is an example of the former.

(4) Bandwidth of human information channels. Whereas the visual channel is capable of receiving information at a high rate, there is a problem in enabling the operator to communicate at a high rate to the computer. Perhaps the fastest practical method is the keyboard, but this requires the learning of a concise command language with which to give instructions to the computer. However, if the range of possible meaningful commands at any stage of the man-computer dialogue is limited, then it is possible to display light buttons for each command. In this way, not only is the necessity of learning a command language avoided, but the possibility of giving illegal commands is avoided as well. Care must be taken however, not to display too many buttons at one time (which may be done by organizing them into a tree structure if necessary), so as not to overload the operator's input channel. (There may be interactive situations where system response requirements outweigh the desirability of limiting the bandwidth. In such cases all commands may be made available and the operator will have to familiarize himself with the command menu and learn to ignore what is not pertinent.) Figure 4 shows how the legal commands are all available around the periphery of the display.

(5) Spatial layout of commands. The light button for a particular display function should be integrated into the display in such a manner that it can be readily related to the function it controls. An example is shown in Figure 4 where the controls for the limits of the axes are placed in a label of the axis, rather than being in a list of limit commands

in some unrelated part of the display. Selecting one of the limits numbers allows entry of a new number to replace it.

Each of the four sides of the screen can be associated with commands of a particular type. For example, commands on the left are used for going back to a previous state and those on the right for moving ahead to a new state. The locations of commands can be separated around the periphery of the screen, so that a particular light button can be remembered not only by its iconic or semantic content, but by its position as well.

(6) Borders. Borders can be placed around light-button items to draw attention to them, and around large areas having special significance. In Figure 2 a border is used to identify the area in which a selection must be made. (DATA SOURCE).

(7) Response time. Response time is the interval between an event and the system's response to the event. In an interactive system, response times must be fast. A response time greater than 15 seconds rules out interaction (although an operator may be content to wait some minutes if he knows that the processing he has requested involves a great deal of calculation -- an example is shown in Figure 7). A response greater than 4 seconds is too large for activities requiring retention of information in short-term memory; greater than 2 seconds is too long where a high level of concentration is required. Response must be less than 2 seconds where the operator has to remember information throughout several responses, and almost instantaneous to such actions as pressing a key or drawing a curve with a light pen. On the other hand, a too short response time may be harassing to a slow-thinking operator; some systems use a built in delay to make the minimum response time 1.5 seconds.

(8) Feedback. The system should always respond in some fashion, if only to acknowledge receipt of a command, to every operator action. The message in Figure 7, "WAITING FOR ...", is provided chiefly for that reason.

(9) Errors and Help. There should be a means for the operator to easily correct errors, and to obtain help in understanding a bewildering display. The system should be forgiving and understanding. Pierce allows any data item that has been entered to be changed, and, if necessary, changes the state of the system accordingly and asks for data that is no longer valid to be entered again. The help function, as can be seen

from Figure 6, had not been implemented very elaborately at the time the project terminated.

(10) Security. The data base and system state created during a session should be secure from session to session. The state of Pierce may be saved on disk or magnetic tape through use of the cues at the top of the display (Figure 5). A default file name for the saved information is provided which may be changed by the operator if he so desires. In that fashion a number of sequential states may be stored for rapid recall and comparison. System state is restored by use of the cues at the bottom of the display shown in Figure 2.

CONCLUSION

The factors described above do not constitute an exhaustive list. Nor are they universally applicable. Catering to them puts extra demands on the hardware resources of the system and on the time required for design and programming. Nevertheless, these features do enhance the ease of use of a system and may be essential if a system is to find acceptance in a broad market. An iconic language will undoubtedly develop over the next few decades as the cost and complexity of equipment necessary to "write" in the language is reduced. The interactive devices that are being developed for television receivers are a step in this direction. The application of human factors to the design of these systems can be expected to speed development and user acceptance in this area.

REFERENCES

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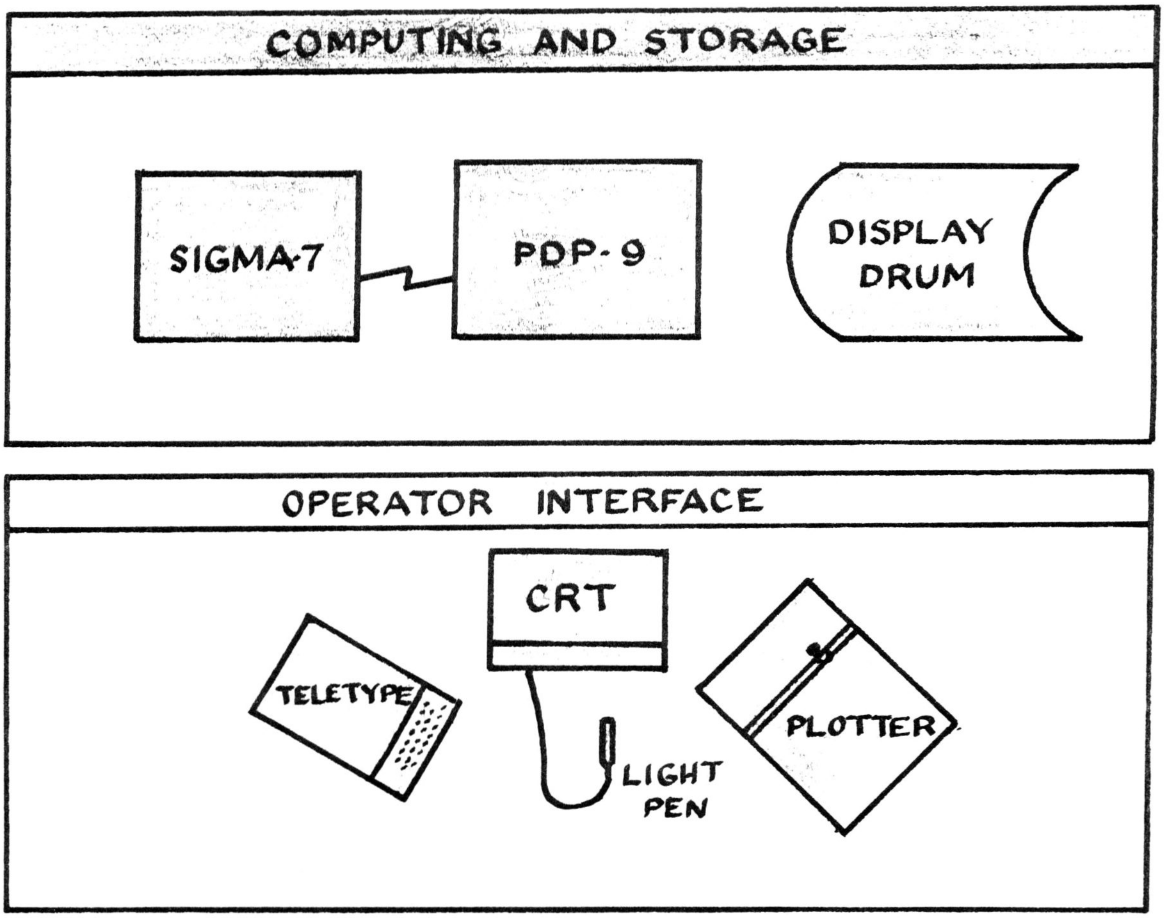
W.M. Newman and R.F. Sproull, Principles of Interactive Computer Graphics, McGraw-Hill, 1973.

E.J. McCormick, Human Factors Engineering, third edition, McGraw-Hill, 1970.



PIERCE HARDWARE SYSTEM

Figure 1

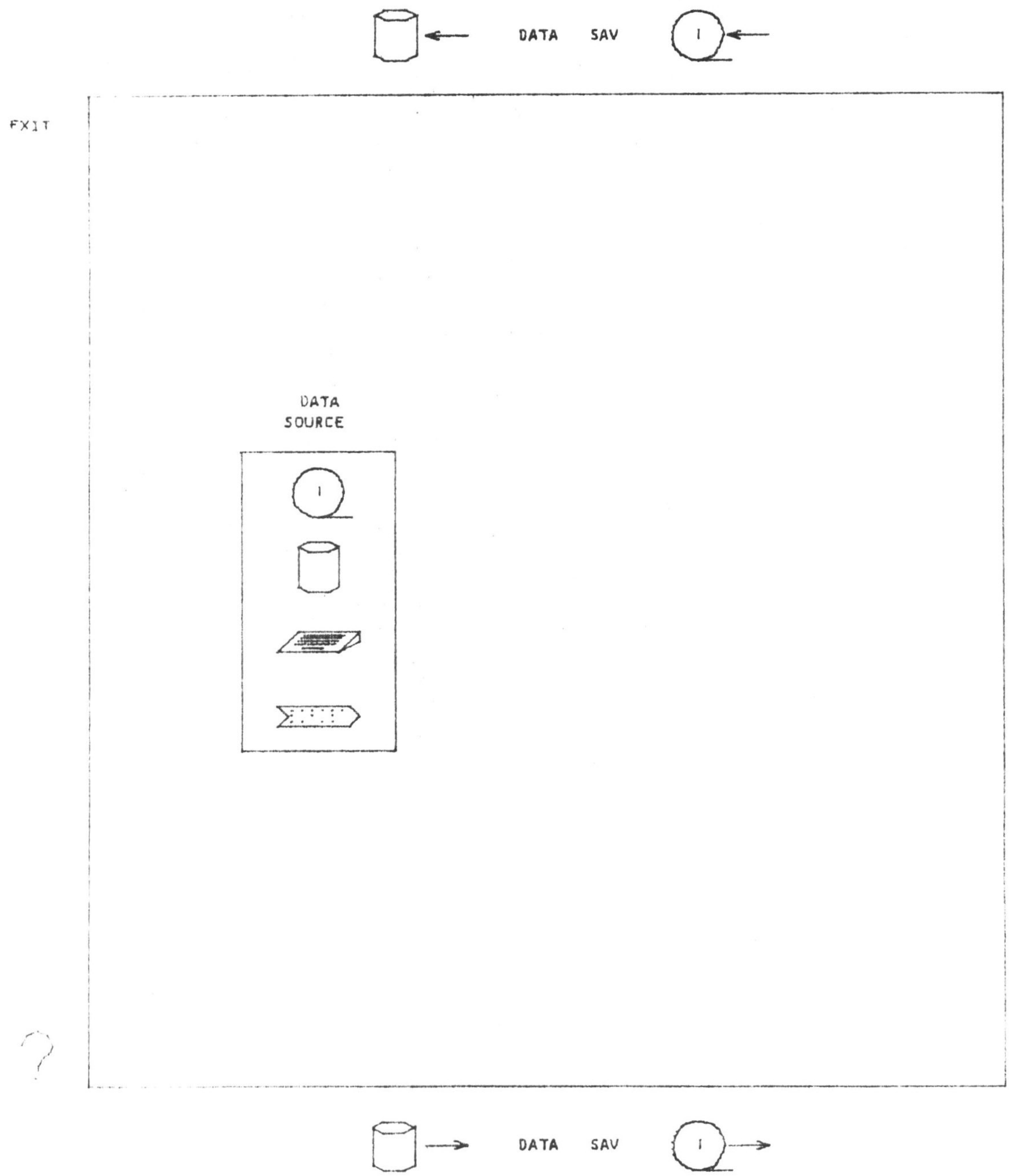


Figure 2

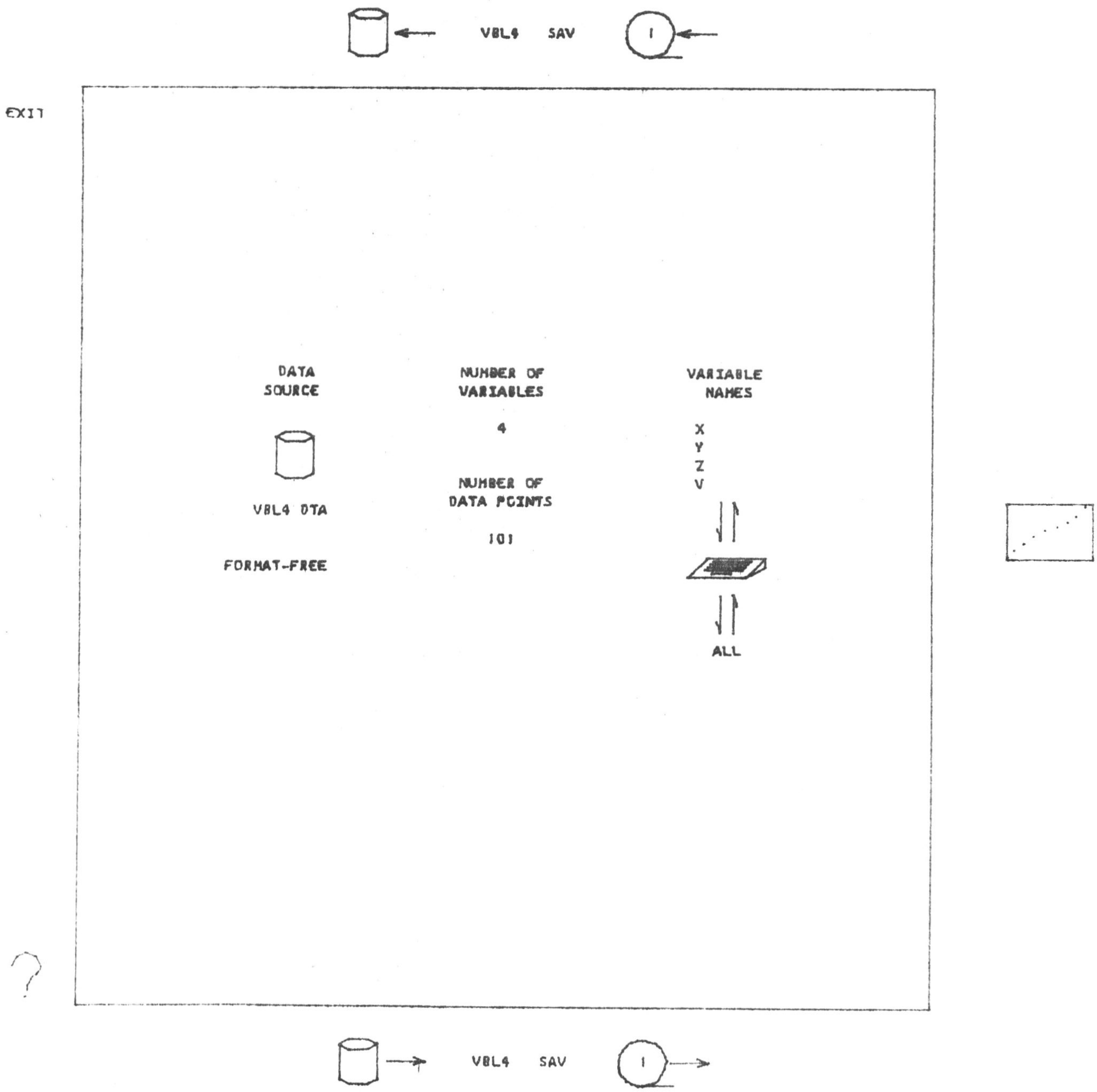

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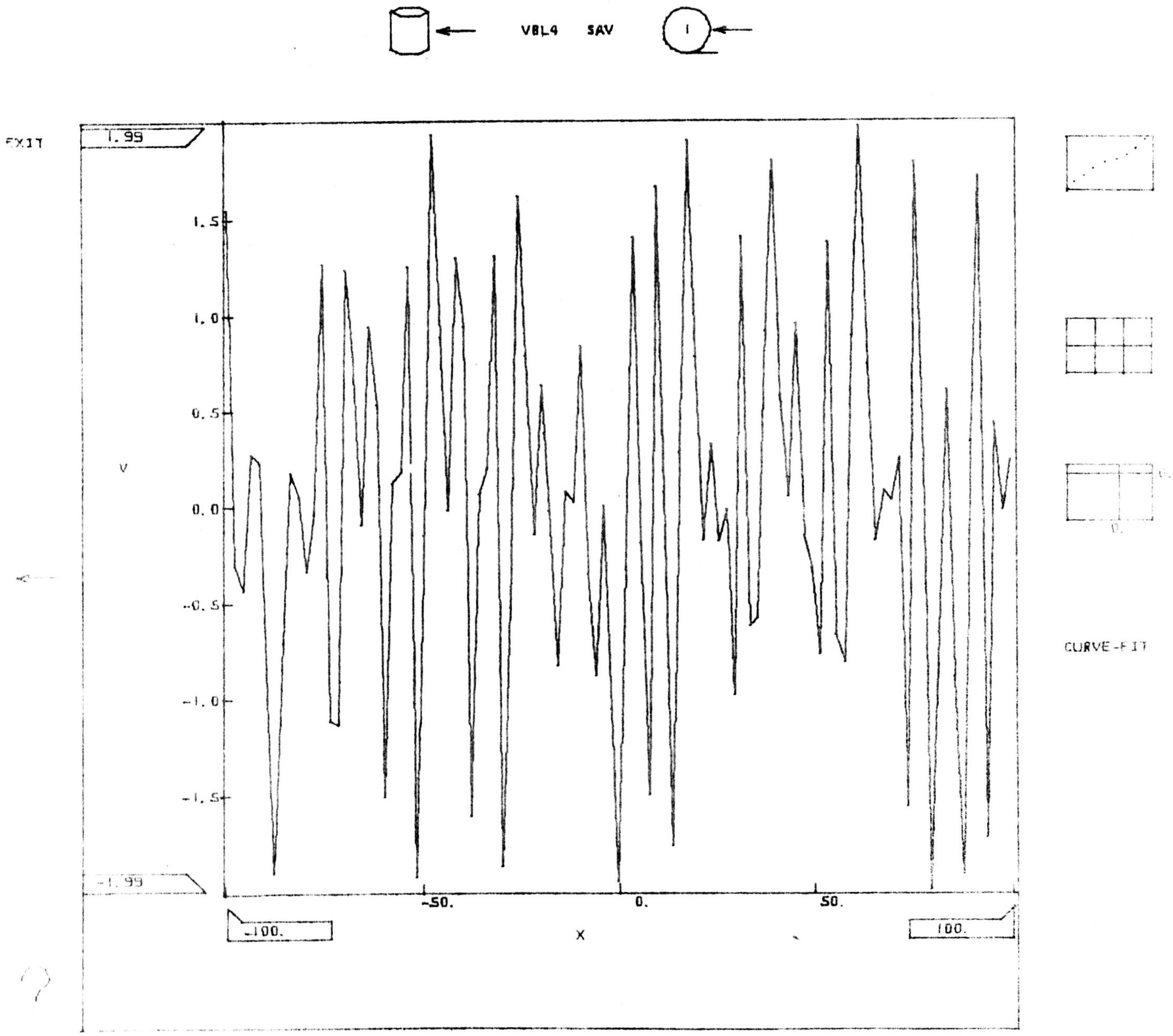
Figure 3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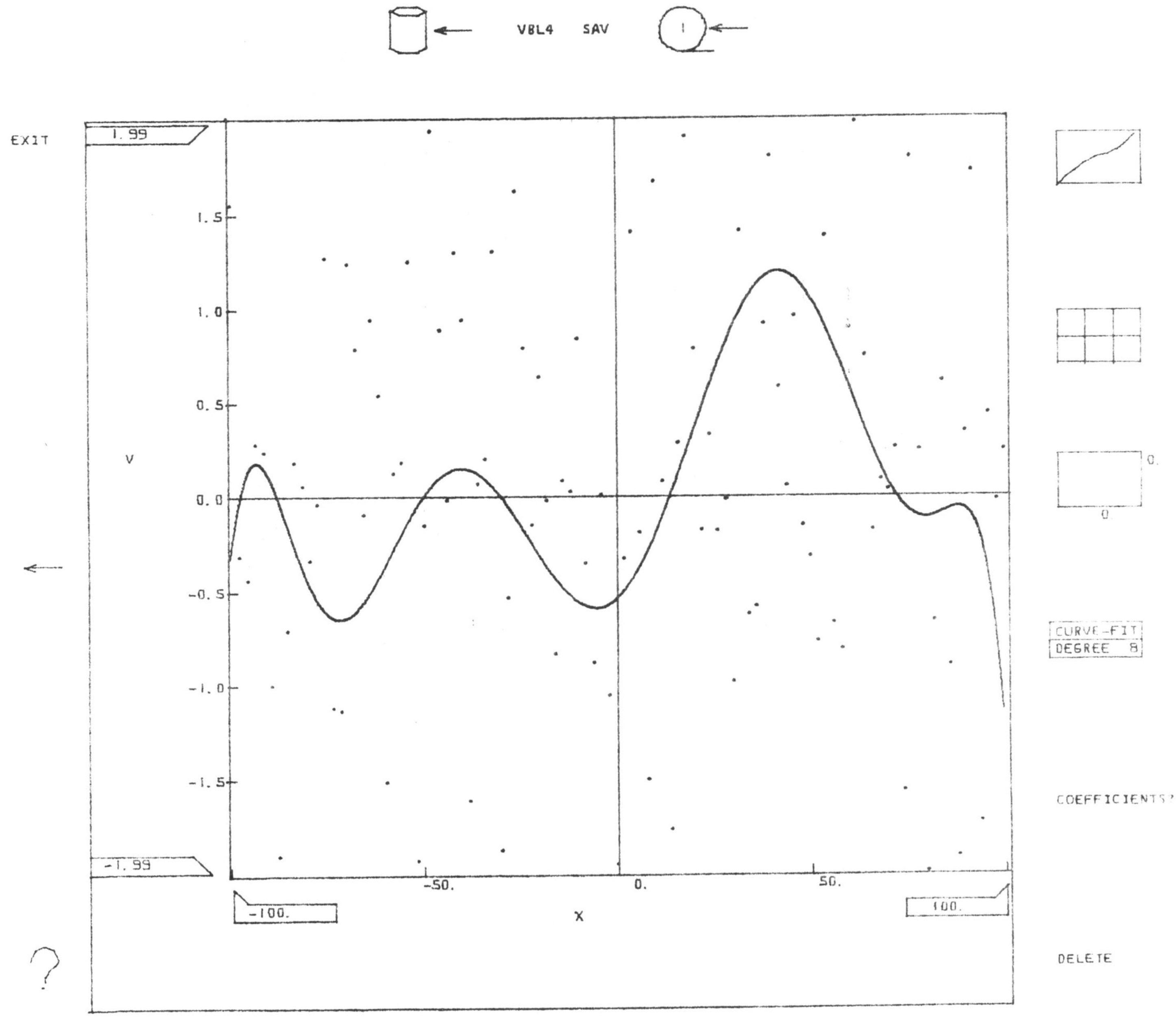
CURVE-FIT

Figure 4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CURVE-FIT
DEGREE 8
COEFFICIENTS?
DELETE

Figure 5

PLEASE CONSULT STAFF FOR ASSISTANCE

Figure 6

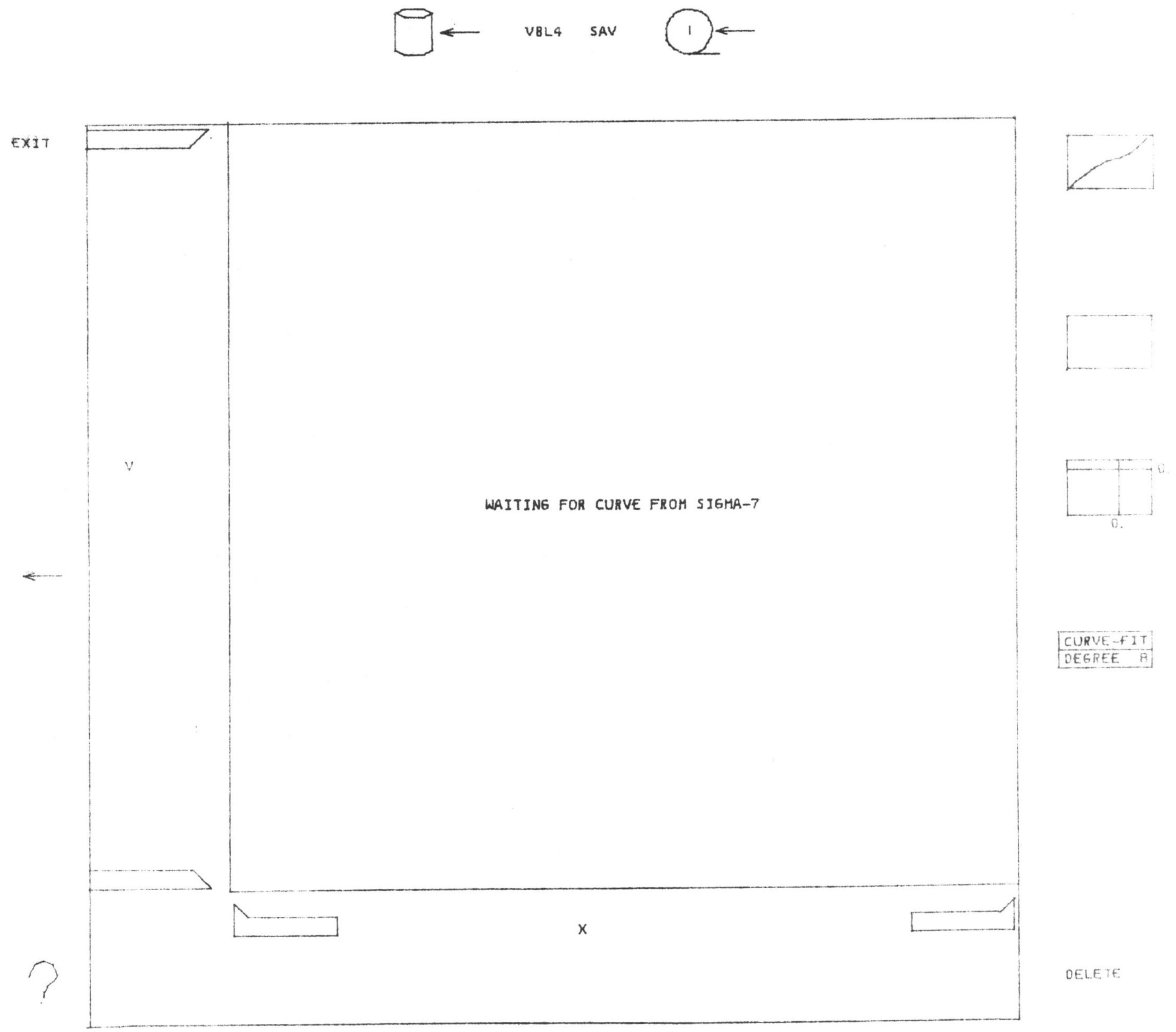

Figure 7