PSYCHOPHYSIOLOGICAL DATA ANALYSIS USING A LOW COST COMPUTER GRAPHICS SYSTEM

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This paper is the result of a joint project in the fields of Electrical Engineering and Communication Arts to study and analyze the biometric data obtained from human responses to 2D stimuli. The programs and equipment needed to operate the system, convert the data, and to display the resulting information will be covered. Human factors such as the ease of operation and manipulation of the program by the researcher, and the processing and verification of the results into a final useable form are some of the innovations that were considered in the design of the system and programs. A final summary of the work up to date, with documentation, and possible future applications will illustrate the power of that man-computer interface.

ANALYSE DE DONNEES PSYCHOPHYSIOLOGIQUES SE BASANT SUR UN SYSTEME GRAPHIQUE D'ORDINATRICE A PRIX MODIQUE

Ce mémoire est le résultat d'un projet conjoint dans le domaine du génie électrique et de la Communication afin d'étudier et d'analyser les données biométriques obtenues par la réaction humaine au stimuli 2D. Le programme et l'outillage requis pour fair fonctionner ce système, en interpréter les données et exposer l'information reçue seront inclus. Les facteurs humains tels que la facilité de fonctionnement et la manipulation du programme par les chercheurs de même que la conversion et la vérification des résultats en une formule utilisable sont quelques unes des innovations prises en considération dans les projets du système et de ses programmes. Un résumé sommaire du travail à date, avec documentation, et son utilisation future possible, illustre la puissance de cet "interface" entre l'ordinatrice et l'homme.

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1.0 Introduction

Physiological data extracted as electrical signals from a human body can serve as indicators of the corresponding psychical processes, especially if related to sensoric information input, occuring at the same time. Manual extraction of such data, as described in the works of J.E. Purkinje (1838), J. Helmholz (1884) and G. Malcolm (1964), is a very laborious task demanding enormous time from the researcher, and at the end giving little chance for correlating the test results between different members of the test group. When the measurements are done using complex information stimuli where targeting, feedback control and decision processes are involved, changes of the physiological signals occur within short time intervals (< 1 sec.), and simultaneously on all measuring channels. Furthermore, when analyzing the results of the tests it is necessary to keep correlating the pretest and test patterns with the recorded biometric responses to the stimuli.

In a conventional physiographic measuring arrangement, the responses, obtained by eye-track, EEG, EKG, GSR instrumentation, are recorded on paper using standard multichannel strip-chart recorders. Since high speed registration is required, it means that approx 200 feet of paper must be analyzed using overlay masks, in order to obtain any meaningful information. At the same time this information must be condensed into an easily understandable form. Consequently, this task would mean about 2-4 hours of work for a skilled researcher.

It will be shown here how a rather simple interactive computer graphics system can be used to aid the analysis process described above. Since it must be assumed that the researcher knows little about the internal structure of the system, the supporting software must be written in such a way that the commands are kept simple, easily understandable, and at the same time the programs must be such that any new operations can be included without too much difficulty. The graphics system is centered around a PDP-11/20 computer, and the graphics oriented hardware/software was developed by electrical engineering undergraduate students in the form of projects in their computer oriented courses. The use of the system as a tool in the forementioned research as undertaken in the Department of Communication Arts is its first practical application. As such, it represents a rather successful effort in bringing two different departments (Engineering and Comm. Arts) together with the aim of solving a particular problem.

2.0 Hardware Description

The graphics system is built around a PDP-11/20 computer, as shown in Fig.1,4. Only the devices required for this particular application are shown in the block diagram of Fig. 1. The Tektronix 613 storage display serves as the graphics output device. The joystick as interfaced to the system via the upper 4 A/D channels is used as a graphics input device. However, the positioning of the cursor is achieved by a software program which samples the A/D converter on the corresponding channels and then sends the data, properly scaled, to the display. The supporting graphics routines, as well as all the necessary hardware changes, were developed by undergraduate students as their projects.

The instrumentation (Fig. 3) for the biotelemetric application consists of an eye-tracking device (retinograph) which generates two signals corresponding to the X and Y eye coordinates of the subject under test. These signals are recorded on a low speed stripchart recorder (for verification purposes) and sampled at about 40 samples/sec. on channels 0 and 1 of the A/D converter. The other two channels of the ADC (3 and 4) are used to sample the signals coming from an Electroencephallograph (EEG) and an Electrocardiograph (EKG), respectively. These instruments are used to monitor the activity of the visual neurocortex and of the heart system.

3.0 Software Description

The application software (Fig. 2) consists of two programs, both running under the RT-11 operating system. The first one, written in MACRO-11 Assembler, performs the data acquisition from the instruments (channels 0-3 of ADC), and then it dumps all the values obtained without modification onto a DECtape file previously opened. This operation uses two swapping buffers for fast data rate. At the same time, though, the eye movements as sampled on channels 0 and 1 are displayed in Cartesian co-ordinate system on the screen for monitoring purposes.

The second program was written in BASIC language, and runs under the BASIC/RT-11 interpreter, augmented by our own graphics routines for controlling the Tektronix 613 display, as mentioned in Section 2. (These subroutines allow for plotting points, vectors, circles, characters, and for an interactive control via the joystick/cursor setup and the console keyboard. - See Appendix B for detailed description.) The program reads the data from DECtape (as created by Program 1) and under interactive control of the researcher, it selectively displays the information on the screen. Basically, two main modes of display are provided - the normal, stripchart form, as shown in Figures 5,6 and 7. In either mode, the data can be manipulated so as to eliminate noise, blinks, provide the time of certain events, etc. The operation of the program can be best understood by analyzing the commands which are summarized in Appendix A.

4.0 Results and Conclusion

Some 20 experimental data sets have been generated so far. The data-integrating effect and flexibility of the display has been most impressive for researchers who have worked with a manual system alone. Of particular interest has been the vector form of the eyetrack X-Y display which provides a dynamic replica of eye motion.

The validation and analysis of the data sets obtained thus far has shown the usefulness of the system in an unexpected way. It became evident from the computer presentations that an inconsistency in the eyetrack behavior was present. Such an inconsistency would have been extremely difficult to identify without the use of the graphics system. Thus its usefulness for validation was amply demonstrated.

The instrumentation is undergoing repair at the present time. Expected valid eyetrack illustrations, which would display anticipated correlation between the actual stimulus image and the sampled eyetrack, are not available at this time. However, Figures 5,6 and 7 are of the correct format. They illustrate the integrated presentation of the experimental data and indicate the potential power of the system.

Currently refinements are being made in both the hardware and software portions of the system.

The display controller has been redesigned to provide for faster operation and up to 8 levels of display intensity. Corresponding changes in the software are also underway.

It could be argued that both software programs could be brought under the control of the BASIC interpreter. Unfortunately, at the time this application program was started, no BASIC data acquisition routines were available for our hardware options. This, however, is being corrected, such routines are just about completed as student projects. Consequently, it is hoped that eventually both of the programs will be combined into a single one, possibly with overlays, so as to run under BASIC/RT-11.

APPENDIX A

Interactive Commands in Program 2:

Commands in which cursor position is unimportant:

- C - Change time interval displayed.
- C - Change scale factors.
- M - Move viewing window in time forward or backward. Time increment (+ or -) is input via the keyboard.
- N - "Normal" display requested, i.e. all four channels in strip-chart form. (Fig.5)
- A - same as N, except absolute values are displayed.
- F - same as above; however, digital filtering applied.
- E - close the data file and exit to BASIC interpreter.
- V - display eyetrack X-Y in point form (Fig. 7).
- P - display eyetrack X-Y in vector form (Fig. 6).
- W - change X, Y scale factors in V or P display (see command X).

Cursor position is important in the following commands:

- T - display the time of the event pointed to by the cursor. Valid in N mode only (Fig. 5).
- D - delete a section of the eyetrack display. Upon typing the D character, a label D1 appears on the screen at the position of the cursor. That determines the initial point of the section to be deleted. By positioning the cursor to the end point of the section (to the right of D1), and typing any key will cause the label D2 to appear on the screen at that point. The section delimited by D1 and D2 (the X-coordinate of the points is used only) is marked in the data file as deleted (not destroyed, though), and this segment will not show on the X-Y display of the eyetrack. On the N type display the deleted part is marked by having the 0 channel (eye-X) recording missing. (The deletion is achieved by adding a constant $+20000_{10}$ to every eye-X point).
- R - restore a deleted section. Performs the opposite of the D command. The area delimited by points R1 and R2 (operated as in D) is made visible again.
- X - display eye X-Y in Cartesian coordinate system. The cursor is positioned to the starting point (time) of the section to be viewed, and the character X is typed. The label X1 flags that point on the screen. The end point is delimited by X2 (same as in D command). The program then asks for the X,Y scale factors to be used. These have to be input via the keyboard. Then the area delimited in time by (X1, X2) is displayed on the screen (Fig. 6,7). V or P can be then used to alter the format. Sections deleted by D command will not be shown. The command W can be used to change the X, Y scale factors, while the command O can be used to offset the display on the screen. The command M can be used freely between the X1 and X2 commands.
- O - offset the eyetrack X-Y display. The image is moved on the screen by the distance of the cursor from the center of the screen.
- I - enter text string. The program then asks for the height of the characters to be displayed and for the text string itself to be input via the keyboard. The text is written on the screen starting at the point at which the cursor was positioned at the time when the I command was issued.

APPENDIX B

RT-11 BASIC Graphics Routines for Tektronics 613 Display

The routines written in PDP-11 Macro Assembler language are linked with the BASIC interpreter as external routines callable by a CALL 'NAME' (parameter list) statements.

1) CALL 'MODE'(M) - mode control routine

M = Ø storage mode and erase
  = 1 set storage mode only

= 2 set non-storage mode
= 3 set cursor mode

2) CALL 'PLOT' (X,Y) - display point (X,Y) in either mode

To have the point plotted on the screen the following relation must hold

$$-1280 \leq Y \leq +1280$$

$$-1600 \leq X \leq +1600$$

Coordinate (0,0) is at the center of the screen.
Scaling factor is approximately 400/in. in both X and Y direction

3) CALL 'VECT' (X1,Y1,X2,Y2,I) - vector generator

Display a straight line from point (X1,Y1) to point (X2,Y2) in either mode. Intensity is controlled by I > 0, in the sense that the points of the line are plotted with increment of 1 in both X,Y directions, but only every I-th point is intensified.

4) CALL 'CIRC' (XØ,YØ,R,I) - circle generator

Display a circle with radius R with the center at (XØ,YØ). Intensification control I > 0 is the same as for the 'VEC' vector generator.

5) CALL 'CHAR' (XØ,YØ,S,D,C$) - character generator

Display the text string C$, which could be either a string variable or a test string "XXXX" delimited by "or', starting at(XØ, YØ) in the direction given by D:

D = 0 +X
= 1 +Y direction
= 2 -X
= 3 -Y

The size of the characters is given by S > 0, so that the actual size in inches (height) is determined approximately as

$$\text{size in inches} = \frac{7 * S}{400} \quad \text{(inch)}$$

6) CALL 'JOYS' (X,Y,C) - cursor control by joystick

When the routine is entered, scope is turned into cursor mode and its position on the screen then can be controlled by the joystick. Upon typing any key on the teletype keyboard, the display is switched to storage mode and the last coordinates of the cursor on the screen are returned in X and Y. The binary value of the character typed is returned in C.

The CHR$ BASIC function can then be used to convert C into a one character ASCII string.

e.g. The key 1 is typed, then $C = 61_8$
and
LET S$ = CHR$ (C) would return a one character string "1" in S$.

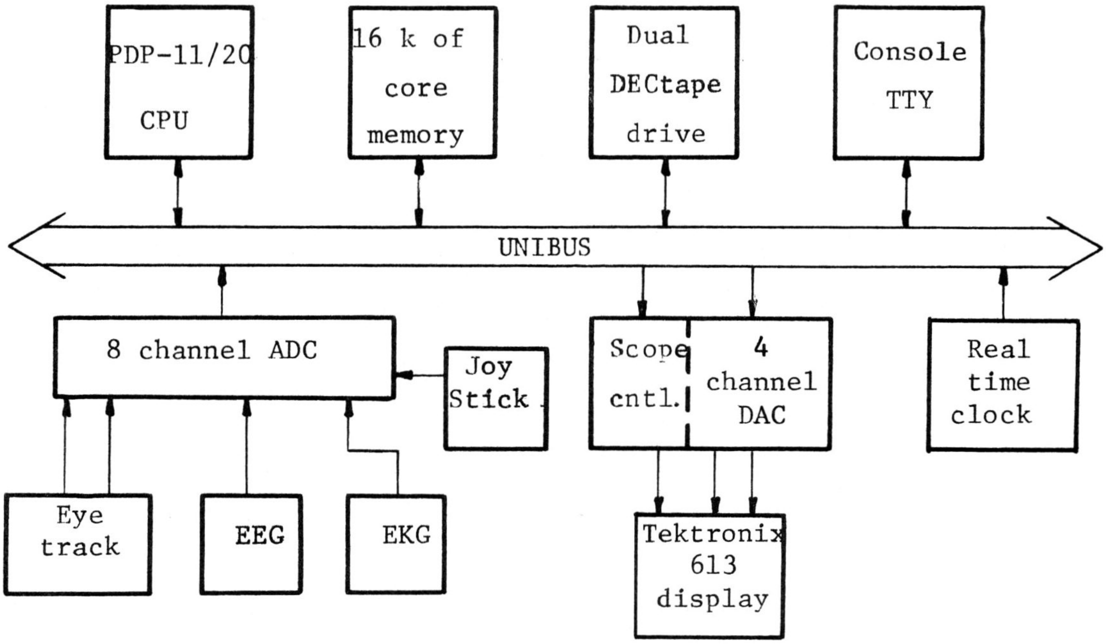

Fig. 1: System Lay-out

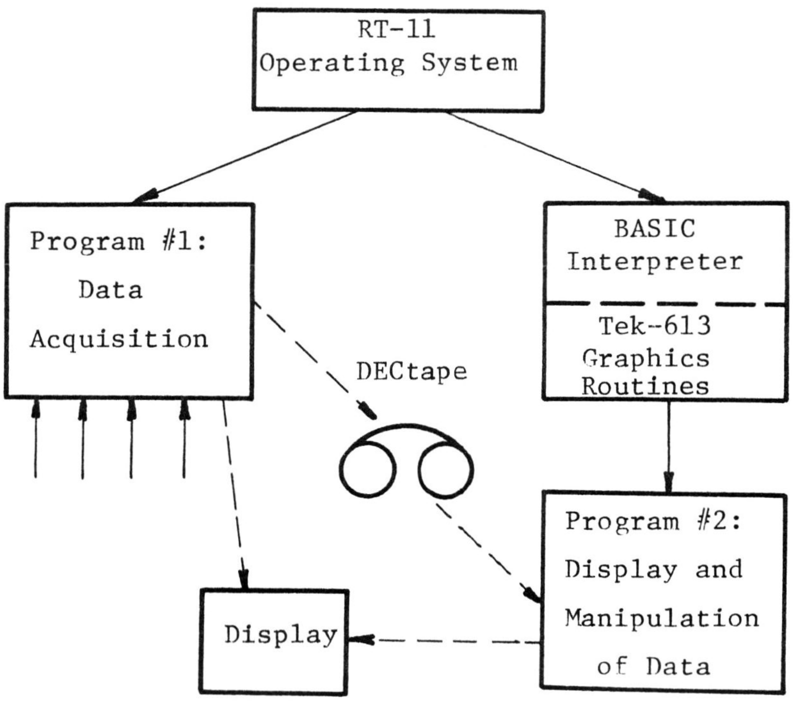

Fig. 2: Application Software

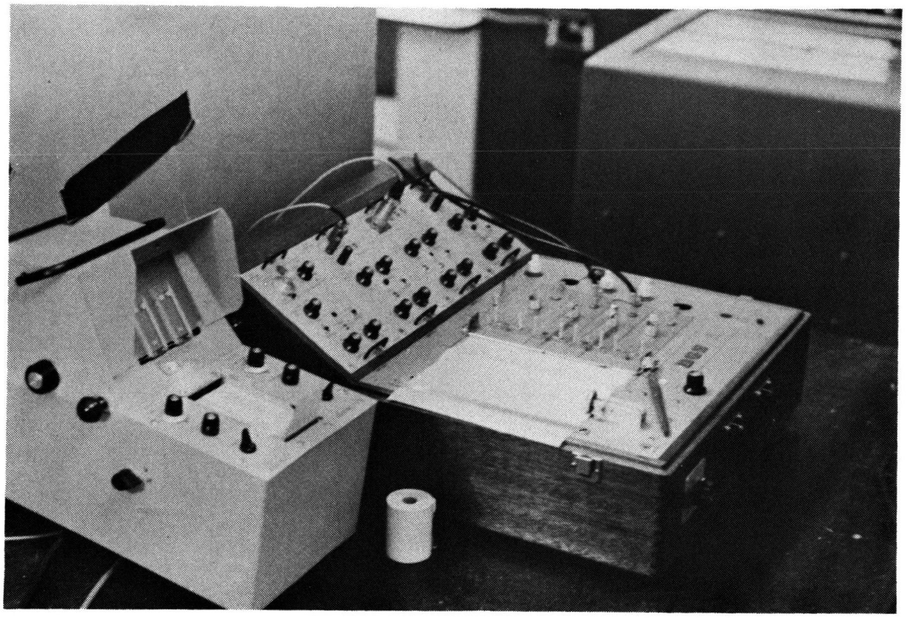

Fig. 3: Eyetrack,EEG and EKG Instrumention

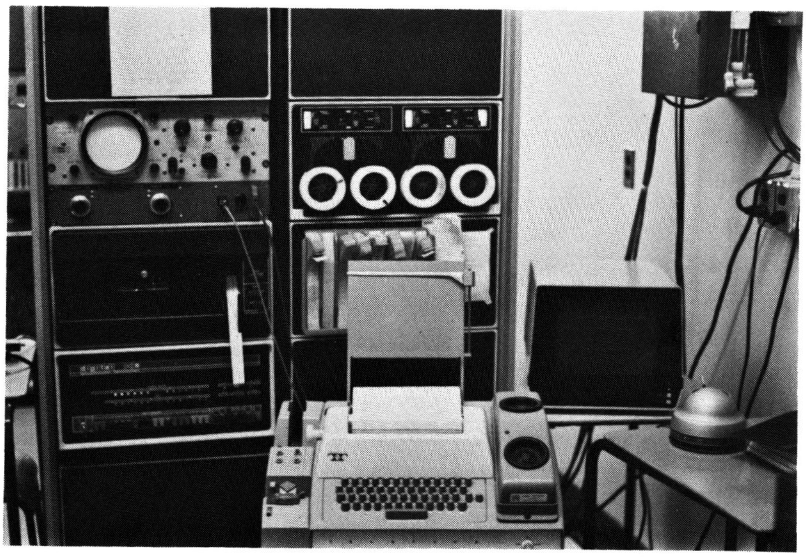

Fig. 4: PDP-11/20 System with
Tektronix 613 Display

Fig. 5: Strip-Chart Form of Display

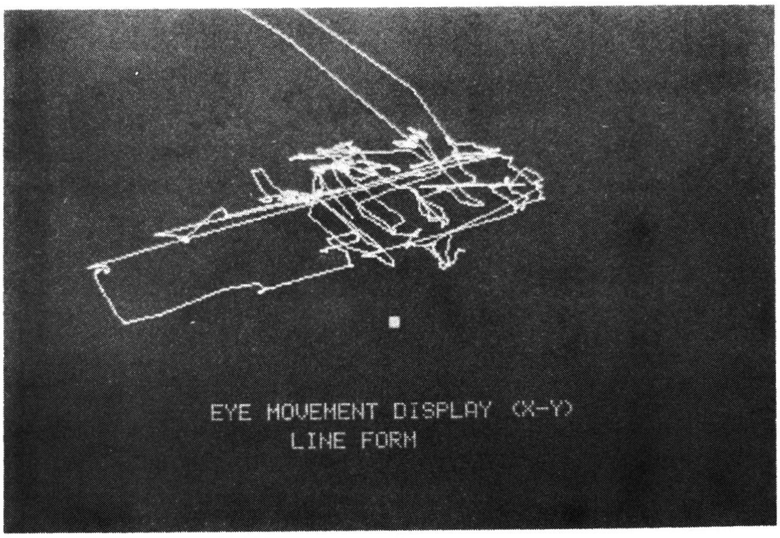

Fig. 6: Eye track X-Y Display (Vector)

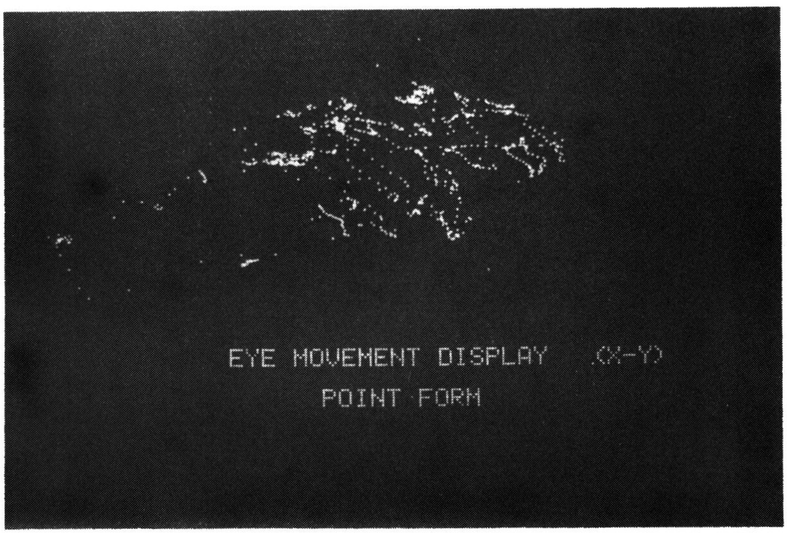

Fig. 7: Eye track X-Y Display (Point)