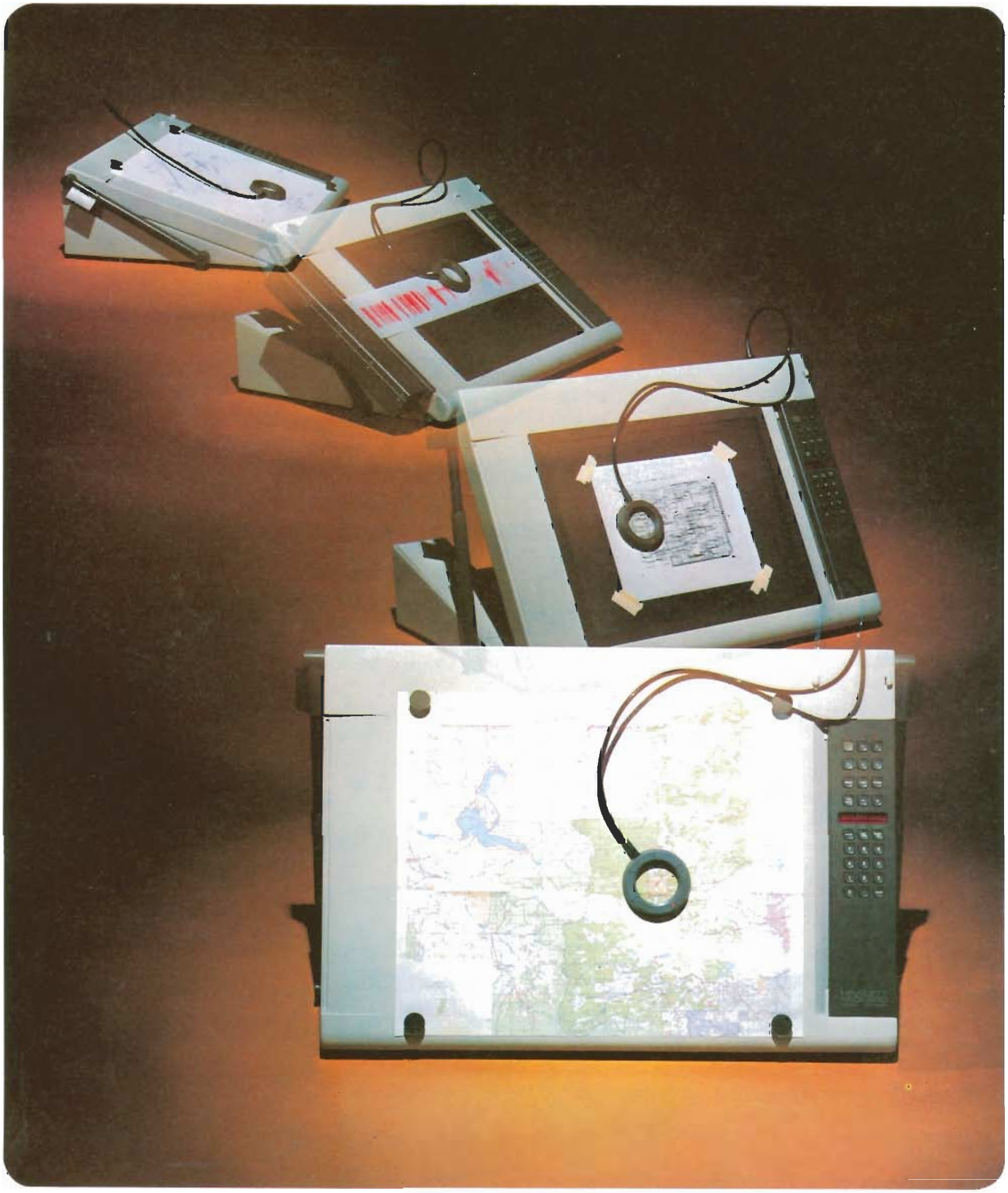
Keyboard

1978/3 A Publication of Hewlett-Packard Desktop Computer Division



Keyboard

Overview

In April, Hewlett-Packard's Calculator Products Division moved to a new, two-building, 310,000 square foot complex in Fort Collins, Colorado, 12 miles north of the Loveland facility. To commemorate the move and to formalize its commitment to desktop computers, peripherals and systems, the division changed its name to the Desktop Computer Division (DCD).

Now sharing the first building in the new complex with the Fort Collins Division, DCD will occupy one of these buildings when the second is completed; the Fort Collins Division, which manufactures small business computers, will occupy the other. The move will allow us to increase production and give our desktop computer customers better service than ever before.

A new digitizer, the HP 9874A, enables digitizing of documents with larger dimensions than allowed by any previous model, plus a large cursor, vacuum hold-down, digitizing of rear-projected images, and many other conveniences. For details, please see the article on page 6. We hope you will find the general article on digitizing interesting, as well.

Due to some unforeseeable assignment changes, Crossroads will not appear for the present time. We hope to be able to resume it in a later issue.

Other items of interest include two articles on mathematics; complex arithmetic with the 9830, and teaching calculus with the aid of the 9810A; also an article on demographic studies with the System 45 involving statistics and text processing. We appreciate the authors' time and willingness to share their findings.

Features

Departments

Please remember that your comments and suggestions on how we can improve *Keyboard*, which is your publication, will be appreciated — as well as your contributions of proposed articles and programming tips.

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Digitizing and Computer Graphics

*by Paul E. Maybaum,
Hewlett-Packard Company, Desktop Computer Division*

Computer graphics system with digitizer in typical application, determining length of pipe in network.

In recent years, increasing numbers of people have discovered the value of low-cost computer graphics systems, resulting in considerable interest in graphic data entry devices such as digitizers. These products help make the data entry process more efficient, flexible and interactive. The use of microprocessors in digitizers increases their convenience and introduces a human-engineered work-station concept.

A short discussion of the benefits of computer graphics in general is a prerequisite to discussing digitizing and digitizers. An explosion in sales of computer graphics systems has occurred because of the need to streamline the interface between man and machine. Humans think in pictures and images, and the speed and accuracy with which a human can recognize patterns is unmatched as yet by any computer. Therefore, the initial demand on computer graphics was to facilitate decision making by converting computer-generated data into a more human-usable form. This was done via graphic output devices such as plotters and graphic CRTs. Tables of numbers were plotted as graphs and charts to help humans observe trends in data. Data bases were constructed so that engineering designs could be displayed in pictorial form to facilitate modifications and shorten the design process. Visual simulation and animation on graphic CRTs produced tremendous savings in time and equipment.

The function of a digitizer is a logical extension of computer graphics' translative benefits to the data input process. Many existing sources of data in human-usable form are unusable to the computer. Documents such as photographs, X rays, maps and engineering drawings are but a few examples of information that normally comes in pictorial form but needs to be converted to a computer-understandable form for further analysis. The digitizing process allows the human to exercise his superior pattern-recognition capability to pinpoint the meaningful data, then convert it into computer-usable form.

History and Development of Digitizers

The first digitizers came into existence during the late 1960s. Before that users in mapping applications were computing distances and areas with planimeters, mechanical devices with fixed cursors mounted on movable beams or arms. The position of the mechanical linkage in a planimeter determines the point position with respect to the "origin" of the linkage. The Gerber Scientific Equipment Corporation developed an encoder to interface this device with a minicomputer and various output devices, creating the first digitizing system. The system was large and expensive, and could only be justified in high-volume or specialized applications.

In 1968-69, the concept of a free cursor was introduced to the marketplace. This device was connected to an electronic sensor that enabled position to be determined. The benefits were easier operation for the user, because he could move the sensing device in a more natural manner, and improved resolution and accuracy because position was sensed electronically instead of mechanically.

At about the same time, the digitizer manufacturers' philosophies diverged. One group of companies concentrated on assembling, interfacing, and writing software for the whole digitizing system on a custom order basis. Another group concentrated on building digitizers having higher resolution that were lower in cost and more easily interfaced with computers. The result was either extremely high-priced, tailored systems, or low-priced components from which a user could put together his own system.

During the last few years, the trend has been for the systems manufacturers to develop lower cost, but still application-specific, digitizing systems. Concurrently, the "digitizer" manufacturers have added more capabilities to their low-cost, general-purpose machines. These

Data tablet speeds entering of data selected from several alternatives.

trends have been accelerated by two factors: first, the appearance of truly low-cost computer graphics systems with inexpensive plotters and other graphic peripherals; and second, the advent of the microprocessor, which greatly improves the capabilities of low-cost digitizers. Together, these factors have given impetus to one more improvement in digitizer systems — the concept of the human-engineered work station. Built-in microprocessors enable the user to control the digitizer or other peripheral entirely at the peripheral location, without having to spend part of the time at the computer to complete the operation. This means simpler programming, simpler user instructions, and less susceptibility to user errors.

Current Hardware and Techniques

The user can choose from several types of digitizing hardware and techniques, depending on his particular application. Flatbed digitizers are common; these use a cursor or stylus to define coordinates, and allow the operator to work on a horizontal digitizing surface. A new Hewlett-Packard digitizer of this type is described in another article in this issue. Image scan digitizers are the automatic type, usually with a drum-shaped platen, using servo systems instead of an operator to follow lines on the source document. Generally these automatic systems are much higher priced than user-operated systems. Also available are CRTs equipped with a light pen, which are used in the same manner as data tablets.

The coordinate-sensing technique may be a sonic or a mechanical or electrical wave type. Sonic sensors detect the sound of an electric spark generated by the stylus, and are subject to interference by objects such as the operator's hand inadvertently placed in the path of the sound wave. Mechanical wave sensors rely on the vibration of a wire and the velocity of the physical wave. Electrical wave sensors measure the time taken for an electrical wave with known velocity to travel from the source to the cursor location. Each technique has its own advantages and drawbacks. Generally, more satisfactory results are obtained consistently from digitizers having a self-calibrating capability, so that adjustments or recalibrations because of changes in temperature or humidity are not needed.

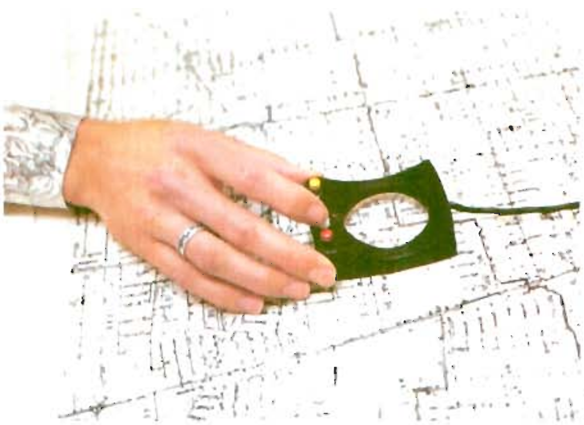
Resolution and accuracy are two vital directly comparable specifications among digitizers. Speed is often specified; however, the realizable speed of a digitizer is the speed of the slowest element in the system. In many cases, the digitizer speed can far exceed that of the computer interfaced with it; therefore, the user/specifier should look at the speed of the overall system in reviewing available systems to do his or her particular job. The overall speed for a manually operated system is limited by the operator and the type of job.

Digitizer Applications

There are three general areas of digitizer applications: data entry and system interaction, measurement and test analysis, and mapping and computer-aided analysis.

Data entry and system interaction concerns itself primarily with making data entry more efficient. The digitizers used here are more properly known as data tablets or graphic tablets. Their objective is to relieve operators from having to use the computer keyboard to enter information quickly while selecting from a well-defined set of alternatives. The active area of the data tablet is defined to be a pattern of squares or other areas known as a menu. An ordinary sheet of paper can be formatted and placed on the digitizer to help the operator with appropriate descriptions of the meaning of each square. Placing the cursor or stylus of the digitizer over the desired square causes the X and Y position to be sent to the computer. The computer program can determine from the received coordinates which square or area the operator selected and take the proper action. In this way the operator can control the data entry process by pointing at the predefined areas on the digitizer rather than typing in the information. Considerable time is saved in applications such as job cost and material estimation, inventory control, scientific or business modeling, or process control simulations.

The second application area, measurement and test analysis, uses the digitizer as a high-accuracy measurement tool. Much of the data generated from tests, experiments and simulations is in the form of photographic slides, movies and strip charts. These media are qualitatively very meaningful to the human, but the information must be quantified to be usable by a computer. One good example of this is in the area of destructive testing. Mounting sensitive instruments on or near items undergoing this type of testing is costly and subject to many problems, including the possibility of destroying the instruments themselves. Often the only tangible output of such a test is a high-speed movie, which must be analyzed frame by frame. The U.S. Navy uses this technique with exploding shells to determine their performance, including such characteristics as acceleration, velocity and mass of the various fragments. A digitizer with rear projection capability can aid significantly in quantifying the data contained in this type of movie.



A large transparent cursor increases visibility and aids accuracy of the manual digitizing process.

Another example of digitizing in the measurement area is a research project being conducted for an eastern U.S. university to study the feasibility of using the Fourier series to describe the wing shape of North American mosquitoes. A scientist digitizes the shapes of mosquito wings as an aid in classification and in determining the effect of wing shape on flight characteristics and the chances for survival. Digitizing is done quite accurately from microscope slides in work of this sort.

Strip charts are commonly the output of scientific experiments and simulations, as well as that of energy consumption monitoring or manufacturing process monitoring. Often the errors encountered and the time consumed by manually pinpointing and entering data from these charts completely discourage attempts to perform critically-needed data analysis. A digitizer can transform the data translation task into a much faster, more accurate and comparatively enjoyable function.

The third digitizer application area, mapping and computer-aided analysis, generally involves as a source document a large map, a blueprint or drawing, or an aerial photograph. Rear projection capability is a distinct advantage when the source document is a photographic transparency. The objectives in digitizing these documents include creation of a data base using the pictorial information, or performing length and/or area computations. The U.S. Department of Agriculture supplies an example of area computations with their weekly analysis of satellite photographs of crop land. The photos are analyzed to accurately determine the amount of land under cultivation for various crops, allowing predictions for the size of the harvest. Maps and photographs are also used by mining, lumber and petroleum companies to help estimate and manage mineral reserves, an increasingly important function in the U.S.A.

A fairly specialized area of computer graphics is printed-circuit board layout, with the option of using a computer-interfaced CRT or a digitizer for oversized drawings that are subsequently reduced photographically to produce the actual board masks. Although the CRT and the digitizer each have their own advantages and drawbacks, the digitizer offers a more comfortable horizontal or variable-angle working surface compared to the CRT's usually vertical screen. The digitizer also has the advantage of working at full scale, compared to the reduced-scale limitations of even a 19 or 21 inch CRT screen. The digitizer's cursor allows precise positioning to define a point; the CRT's curved surface and screen thickness cause imprecision and require more complex software than does a digitizer to allow approaching the same degree of accuracy. The choice of equipment is dictated by the user's exact requirements for precision, drawing complexity and budget limitations.

Medical digitizer applications include volumetric measurements used in cardiac analysis, lung capacities, growth comparisons, strip chart analysis, standard waveform comparisons, radiation therapy isodose contour computations, and statistical counting in pathology and microbiology. Source documents can range from strip charts, X rays and photographs to microscope slides.

Future Developments

Increased accuracy and speed are the two most significant benefits to be derived from automation in digitizer systems. While automatic digitizing systems are available today, they are expensive compared to manual systems, costing from $250,000 to $1 million. In the next decade it is likely that technological advances will bring about automatic digitizing systems at considerably less cost. One possibility in this direction would be digitizers interfaced to desktop or other computers programmed for more automatic operation to reduce errors caused by the weakest component in the system — the human operator.

Another development already underway is the concept of the human-engineered work station, made possible by including increasingly powerful microprocessors in the digitizers themselves. This means the operator can execute all the commands for digitizing from the source document and enter the data into the computer while sitting at the digitizer location.

Although published articles commonly indicate that there is a preference for CRTs with light pens over digitizers, the actual practice is fairly evenly split.

Summary

In a relatively short time, digitizing has come into being and evolved into an essential tool for converting qualitative visual information into quantified data that can be analyzed accurately as an aid to scientists, medical professionals and engineers. The current state of the art appears as an interim phase that can become an automated realm having minimum requirements for operator decisions and action, with consequent reduction in human errors. Refinements will certainly occur both in CRT/light pen and digitizer technology, with reduction in cost for a given level of performance. Automation and the human-engineered work station are seen as two signigicant steps toward the digitizing system of the future.

END

Demography and the System 45

by William H. Durham

Professor William Durham editing a System 45 program used in demographic statistical analysis.

At Stanford University, on the San Francisco peninsula, we are using a small desktop computer to help students learn the principles of demography and population studies, as well as to teach them the principles of computer programming and generally aid in the study of anthropology.

Anthropology, once a qualitative study, has in recent years found increasing need for data processing, particularly in specialized branches requiring statistical analysis, such as demography. These population-related studies often entail acquiring and processing huge quantities of data normally associated with the capacity of a large computer. One example of a Stanford study that gives an idea of the magnitude of this type of work is an ongoing demographic study of Taiwanese families. This study, covering 50 years and tens of thousands of subjects, analyzes trends in Taiwanese marriage patterns, fertility and mortality rates, family size, land holdings and many others. Obviously, this kind of work is nearly impossible to do by hand. A computer becomes more than just a novelty; it is an essential everyday tool.

Stanford's Anthropology Department has long used the University's computer facilities, particularly for large-scale problems. However, the faculty began to realize a real need for a small system resident in our department that could be dedicated solely to department tasks — in particular, for the analysis of subsections of the large studies, for student education in computer analysis, programming, and demographic theory, and for general text processing use.

We investigated a number of different desktop devices, and foundthe Hewlett-Packard System 45 desktop computer to be the best suited to our needs. Instead of a minicomputer, which would have required purchasing a number of expensive peripherals, perhaps each from a different manufacturer, the HP System 45 combines all of the necessary features — CRT display, printer, mass memory and keyboard — into a single, portable package. We decided to include an HP 9871A Impact Printer and an HP 9872A Plotter with the system to use in producing camera-ready manuscripts and charts for publication.

Applications

One of the immediate benefits we derived from the System 45 has been its assistance in teaching students the principles of demography. Many of our students do not have a strong mathematical or computer background, but they find it necessary to deal with quantitative principles in their demogaphic studies. We use the computer to assist with many of the laborious and tedious computations involved in these studies. Using numerical integration techniques, for example, the machine computes changes in population size (or other variables) through time, and then presents the student with a graphic display of the results, saving hours of manual calculation or waiting time at the large computer to achieve the same goal.

Other benefits result from the System 45's approachability and its ease of programming. Students are not afraid to try it, as a novice might be in a first attempt to use a large computer — they find it is probably the easiest machine on this campus to learn how to program for the first time. This past summer, I ran a programming seminar for the students. Meanwhile, they are not only saving time and getting better accuracy in results through using the System 45;

Stanford University quadrangle.

they are also using it to edit their papers and to print out clean, error-free copy. A couple of students have begun writing and editing their doctoral dissertations using the System 45. The demand for machine time is so great we have to schedule its time in advance. It is often free only during vacations, and as a result, most of the programming I want to do must be accomplished on weekends.

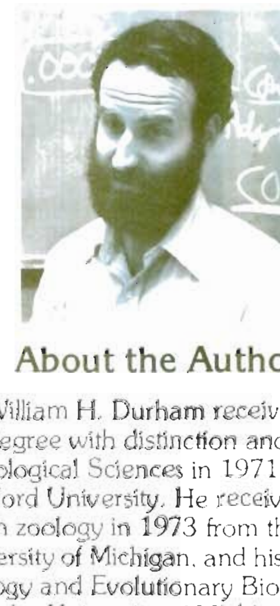
Processing subsets of large data banks is easily done with the System 45. My colleague, Arthur Wolf, who is doing the Taiwanese family studies, uses a program on the System 45 to calculate the ages of people in his sample at particular "vital events," e.g., age at marriage, age at first childbirth and age at second childbirth. This allows him to perform many data reduction tasks and preliminary tabulations without the waiting and complexities of going to the large computer.

Central American Study

My own research focuses on the causes and consequences of land scarcity among Central American peasant families. On one level, I analyze trends in access to land and in land tenure. The goal here is to determine what proportion of the growing land scarcity is due to population growth on the one hand, and to distributional dynamics on the other. On a second level, I investigate the relationship between access to land and rates of fertility, mortality, and migration among peasant families. The purpose of this part of the research is to see whether demographic trends represent an adaptation to rural ecological conditions in Central America. For both phases of this work, the System 45 statistical packages and graphics capability are tremendous assets.

Among other findings, this research has revealed a close, inverse correlation between family land holdings and rates of child mortality. As farmland decreases from two hectares (about 5 acres) to zero, for example, child mortality rises from 10% to 38% among the families included in the study. Fertility rates increase in a parallel fashion, suggesting that high rates of fertility in rural areas may in part be a response to the land-related mortality.

A complete description of this research and its results will be published as a book by Stanford Press, *Scarcity and Survival in Central America*, to be available in the fall. Portions of the final manuscript and a number of the illustrations are being prepared with the help of the System 45 and its peripherals.



About the Author

William H. Durham received his AB degree with distinction and honors in Biological Sciences in 1971 from Stanford University. He received his MS in zoology in 1973 from the University of Michigan, and his PhD in Ecology and Evolutionary Biology from the University of Michigan in 1977. Professor Durham has received several grants, fellowships and awards from the National Science Foundation and other organizations. He has held university teaching positions since 1971, and is now Assistant Professor at Stanford University, Department of Anthropology and Program in Human Biology. He and his wife live in Menlo Park, California.

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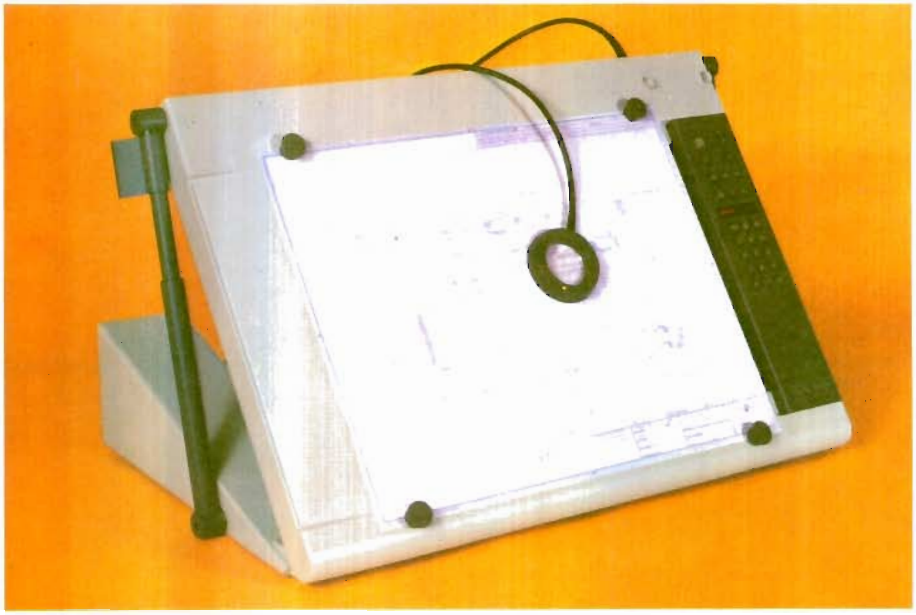
New Products



9874A Digitizer

by Karen Wardlaw, Hewlett-Packard Company, Desktop Computer Division

A powerful new microprocessor-controlled digitizer offers significant increases in performance and reliability. The HP 9874A simplifies operation through a human-engineered work-station concept.

The HP 9874 is designed to provide flexibility, high resolution and simplicity of operation in a broad range of applications using strip charts, drawings, photographic slides, microscope slides and other source documents. It can be interfaced easily with any HP Series 9800 Desktop Computer or other HP-IB compatible computer such as the HP 1000 to provide a complete, powerful digitizing system made entirely by Hewlett-Packard.

The 9874's built-in microprocessor allows the operator to perform all digitizing operations directly from the digitizer location. As a result, the system is easier to use and reduces the possibility of human error because the operator does not have to shift between the digitizer and the computer.

Advanced Features and Capabilities

Some of the 9874's new time-saving and convenience features include:

- An adjustable glass platen to suit various applications and maximize user comfort.
- Rear projection capability to allow using photographic slides or movie frames as source documents.
- Audio tone to guide user operations.
- Illuminated cursor with vacuum holddown to prevent slippage.
- Built-in self-test to assure proper operation.
- HP-IB (IEEE Standard 488-1975) interfacing for easy connection to various computers.
- Multiple-function user keyboard.

Adjustable Platen

The glass platen easily tilts to a convenient angle between vertical and about 20° from horizontal for a comfortable operator position. For rear projections of movie frames or other transparencies, it is adjusted to the vertical position. The image is projected through the transparent platen onto the treated front surface, giving a parallax-free image for maximum accuracy.

Audio Tone

Conventional digitizers use two of the operator's five senses: sight and touch. The 9874 adds a third sense, hearing, with an audio tone that can be used in several ways. The programmable tone can verify correct procedures, signal data entry into the computer, increase cursor positioning accuracy and assure the operator he or she is working in the proper sequence.

The HP 9874A Digitizer assists in printed-circuit layout.

Cursor and Stylus

The cursor is lighted for clear viewing, and has an open-circle target 0.250 mm (0.010 in.) in diameter for accurate positioning over points being digitized. The cursor has a switch to start and stop digitizing in the continuous mode or digitize points in the single mode. A cursor vacuum switch allows leaving the cursor unattended regardless of the platen angle.

An interchangeable stylus is also supplied with the 9874 for users who prefer it over the cursor for particular applications. A digitize switch is activated or deactivated by pressing down on the stylus, and an ink cartridge in the stylus can be used to mark the digitized portion of the source document.

Computer system with 9874A Digitizer enhances mapping and area measurements.

Keyboard

The 9874's keyboard allows the operator to set the operating mode, set size limits, align and extend the axes, digitize and enter data into the computer, and initiate up to ten special routines involving the computer and other peripherals in the digitizing system.

A single-mode key allows the user to digitize specific points by pressing the cursor digitize switch for each point to be recorded. A continuous mode key allows digitizing points sequentially, either at user-specified regular time intervals or at equally spaced points based on cursor movement.

An axis align key allows automatic alignment of the x and y digitizer axes with those of the source document to reduce setup time and give the operator a more comfortable working position. An axis extend key permits digitizing documents much larger than the platen's working surface in either the x or y direction without complicating the software. Documents up to 53 km (33.3 miles) long can be digitized and the points transferred to the computer, still referencing the initial origin.

The P_1 and P_2 keys can set limits anywhere on the 9874's platen surface. This is useful in scaling data into user units, and limiting the active area to be used on the platen. It also simplifies interaction between the 9874 and other HP graphic devices using HP's graphic language (HPGL).

The numeric pad facilitates entering digitized data into the computer, including the x and y coordinates, a pen position indicator and a numerical annotation related to a specific point. An LED display allows verifying the annotation and coordinate information before entering it into the computer.

Five Special Function keys with shift allow initiating up to ten routines in the computer program, such as signaling the digitizer when to start taking points and when to stop. This enhances the human-engineered work-station principle that lets the user control the entire operation from the digitizer.

Specifications

Resolution of the 9874 is 0.025 mm (0.000984 in.), or ten times that of the preceding HP 9864 Digitizer. Nominal accuracy between 10°C and 40°C is ±0.125 mm (0.00492 in.) for the cursor, or ±0.500 mm (0.01969 in.) for the stylus. Although the active digitizing area is 435 mm x 315 mm (17.13 in. x 12.40 in.), axis extension permits digitizing strip charts or other documents up to ±53 687 km (33.36 miles) on either axis.

Applications

The 9874's capabilities are matched to a number of important industrial applications, such as determining the total length of pipe required for a complex gas-distribution network, or computing from aerial photographs the total acreage planted in particular crops. Other applications include clinical medicine and electronic design. Present digitizer users who will find the HP 9874 of particular interest include hospitals and clinics, agricultural and forestry services, research and development operations, military installations, surveying and mapping firms, electronic equipment manufacturers and universities.

If you would like more information, please contact your nearest Hewlett-Packard sales and service office or write to *Keyboard*, 3400 E. Harmony Road, Fort Collins, Colorado 80525, U.S.A.

END

Complex Arithmetic Using The 9830 Matrix Option

by Read Predmore and Jesse Davis

Many scientific and engineering calculations require the use of complex quantities and complex arithmetic. By representing complex quantities by real 2 × 2 matrices, complex arithmetic can be done using the matrix arithmetic in the 9830A/B matrix option or ROM.

Complex numbers $C_K = A_K + jB_K$, $k=1,2$ where $j = \sqrt{-1}$, are represented in real matrices as

$$\underline{C}_K = \begin{pmatrix} A_K & B_K \\ -B_K & A_K \end{pmatrix}$$

In this form matrix addition, subtraction, multiplication, and division are equivalent to the same complex arithmetic operations. To illustrate the equivalence, define the real 2 × 2 matrices $\underline{I}$ and $\underline{J}$ which correspond to 1 and $\sqrt{-1}$.

$$\underline{I} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} ; \underline{J} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$$

Then matrix multiplication gives

$$\begin{aligned} \underline{I} \bullet \underline{J} &= \underline{J}, \\ \underline{J} \bullet \underline{J} &= -\underline{I}, \\ \underline{J}^3 &= -\underline{J}, \\ \underline{J}^4 &= +\underline{I}, \text{ etc.} \end{aligned}$$

and matrix division gives

$$\underline{I}/\underline{J} = \underline{J}^{-1} = -\underline{J},$$

as for the complex number $j = \sqrt{-1}$.

The full equivalence is shown below for addition and subtraction, multiplication and division. In each case, the real and imaginary parts of the resultant complex number are the first and second numbers in the first row of the resultant matrix.

Addition and subtraction:

$$\underline{C}_3 = \underline{C}_1 \pm \underline{C}_2 = \begin{pmatrix} A_1 \pm A_2 & B_1 \pm B_2 \\ -(B_1 \pm B_2) & A_1 \pm A_2 \end{pmatrix},$$

corresponding to

$$C_3 = (A_1 \pm A_2) + (B_1 \pm B_2)\,j.$$

Multiplication:

$$\underline{C}_4 = \underline{C}_1 \bullet \underline{C}_2 = \begin{pmatrix} A_1A_2 - B_1B_2 & A_1B_2 + A_2B_1 \\ -(A_1B_2 + A_2B_1) & A_1A_2 - B_1B_2 \end{pmatrix},$$

corresponding to

$$C_4 = (A_1A_2 - B_1B_2) + (A_1B_2 + A_2B_1)\,j.$$

To accomplish complex division, the matrix represented by the divisor is first inverted and then multiplied by the matrix representing the complex numerator.

$$\underline{C}_5 = \underline{C}_1 \bullet (\underline{C}_2)^{-1} = (\underline{C}_2)^{-1} \bullet \underline{C}_1 =$$

$$\frac{1}{(A_2^2 + B_2^2)} \begin{pmatrix} (A_1A_2 + B_1B_2) & (A_2B_1 - A_1B_2) \\ -(A_2B_1 - A_1B_2) & (A_1A_2 + B_1B_2) \end{pmatrix}$$

corresponding to

$$C_5 = C_1/C_2 = \frac{(A_1A_2 + B_1B_2) + j(A_2B_1 - A_1B_2)}{(A_2^2 + B_2^2)}$$

Because of the form of the matrices, the result is independent of the matrix order for all four of these operations. During a sequence of operations the numbers are represented as matrices and the real and imaginary part only extracted at the end of the calculation.

An example of this technique is the transformation of a complex impedance Z_1 down a transmission line. The resultant complex impedance Z_2 is given by

$$Z_2 = \frac{Z_1 + jZ_0 \tan B\ell}{Z_0 + jZ_1 \tan B\ell}$$

The real impedance of the transmission line is Z_0, and the propagation constant is $\beta = 2\pi/\lambda$, where λ is the wave length and the transmission line length is ℓ.

The HP 9830A/B BASIC program for this calculation is given on the next page.

About the Authors

C. Read Predmore received the BS degree in Physics from the Virginia Polytechnic Institute and State University, Blacksburg, Virginia, in 1967, and the PhD degree in Physics from Rice University, Houston, Texas, in 1971.

From 1971 to 1972 he was an Assistant Professor in the Department of Space Physics and Astronomy at Rice University where he continued his work in radio astronomy and initiated a submillimeter laser project. In 1972 he joined the National Radio Astronomy Observatory where he worked on the development and design of the TE_{01} circular waveguide transmission system for the Very-Large-Array radio telescope. Since 1975 he has been at the University of Massachusetts, Amherst, where he is doing research and development on low-noise receivers, quasi-optical techniques and molecular astronomy for the millimeter-wave telescope of the Five College Radio Astronomy Observatory.

Jesse E. Davis received the BS degree in Physics from Virginia Polytechnic Institute in 1970 and the MS degree in Electrical Engineering from the University of Virginia in 1975. He is currently employed by the National Radio Astronomy Observatory, Tucson, Arizona, in the area of millimeter wave research and development. Mr. Davis is a member of the IEEE, Microwave Theory and Techniques Group.

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END

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10 DIM I[2,2],J[2,2],Z[2,2],T[2,2],N[2,2],D[2,2],E[2,2]
20 REM INITIALIZE I AND J MATRICES
30 MAT I=IDN
40 J[1,1]=J[2,2]=0
50 J[1,2]=1
60 J[2,1]=-1
70 FIXED 3
80 REM ENTER REAL AND IMAGINARY PARTS OF Z1 AND LINE PARAMETERS
90 DISP "REAL, IMAG, BETA, LENGTH, Z0 =";
100 INPUT R1,I1,B,L,Z0
110 PRINT "INPUT DATA IS"R1;I1;B;L;Z0
120 PRINT
130 REM CALCULATE REAL AND IMAGINARY PARTS AND SUM
140 MAT Z=(R1)*I
150 MAT T=(I1)*J
160 MAT Z=Z+T
170 REM INPUT IMPEDANCE IS IN MATRIX FORM
180 REM CALCULATE NUMERATOR
190 RAD
200 MAT N=(Z0*TAN(B*L))*J
210 MAT N=N+Z
220 PRINT "NUMERATOR IS"N[1,1];
230 IF N[1,2]<0 THEN 260
240 PRINT "+J"N[1,2]
250 GOTO 280
260 PRINT "-J"-N[1,2]
270 REM CALCULATE DENOMINATOR
280 MAT D=(TAN(B*L))*J
290 MAT E=D*Z
300 MAT T=(Z0)*I
310 MAT D=E+T
320 PRINT "DENOMINATOR IS"D[1,1];
330 IF D[1,2]<0 THEN 360
340 PRINT "+J"D[1,2]
350 GOTO 370
360 PRINT "-J"-D[1,2]
370 PRINT
380 MAT E=INV(D)
390 MAT Z=N*E
400 REM EXTRACT RESULTANT COMPLEX IMPEDANCE
410 R2=Z[1,1]*Z0
420 I2=Z[1,2]*Z0
430 PRINT "RESULTANT IMPEDANCE IS"R2;
440 IF I2<0 THEN 470
450 PRINT "+J"I2
460 GOTO 480
470 PRINT "-J"-I2
480 PRINT
490 PRINT
500 GOTO 90
510 END
```

Using the 9810A In Calculus Instruction

by Thomas M. O'Loughlin, Chairman of the Department of Mathematics, State University of New York, College at Cortland, Cortland, New York 13045

In recent years a number of studies and projects have been undertaken to explore ways in which new methodologies and techniques may be used to improve student achievement in the first year of calculus. The justifications for these studies are numerous, but three that are of particular importance are:

- There is an influx of a new category of students into the calculus classroom. That is, no longer is calculus the domain of just the mathematics, physical science, or engineering student; we now have biology, social science, and behavioral science students enrolled. This new type of student often does not have an innate interest or as extensive a background in mathematics and therefore does not have the same level of mathematical abilities as the more traditional student.
- The post-Sputnik revolution in mathematics education has stressed the formality and structure of mathematics while, unfortunately, sometimes ignoring the development of an intuitive understanding of mathematical concepts and facility with the mechanics of mathematics.
- Many types of computing devices are now available, which could provide the student with quick access to more numerous and more detailed illustrations of mathematical concepts and therefore improve achievement.

In 1973, I conducted a study at SUCC (State University, College at Cortland) to investigate the effect on student achievement of the incorporation of an electronic programmable calculator (mini-computer) in a first course in calculus. Prior to conducting the study, I had explored the possibility of using a computer-assisted technique, but I discovered a serious problem. Before the computer can be used as an aid to instruction, students must learn how to program, and this would have required course time, resulting in either an actual decrease in the calculus content or an extension of the time requirements of the course. I was particularly concerned with avoiding the latter.

Additional rationale for using a minicomputer was that the computational requirements for such a course are far below the capabilities of a computer (but well within the range of a minicomputer), and it is not reasonable to engage the computer to perform in a manner far beneath its potential (nor to have undergraduates compete for computer time with a faculty member or researcher whose studies require the capability of the computer); the 9810A is mobile and can be used in both the classroom and the mathematics laboratory; and over a period of a few years the cost of a minicomputer is less than the rental of a terminal.

After discovering some of the difficulties associated with the use of a computer, I decided, at the suggestion of Professor Robert Exner of Syracuse University, to explore the possibility of using a minicomputer. It was immediately obvious that the time required to train students in the operation of a minicomputer, including the writing of simple programs, was minimal, and I decided to pursue the study in detail. The decision to use a 9810A was made after examining a number of brands of minicomputers, keeping in mind the financial limitations of this institution. The deciding factor in favor of the 9810A was that since the operating characteristics and programming requirements were simpler than the other brands, it would be a relatively easy task to train students to operate it quickly and effectively. Although our system has been expanded since the time of the study, it then consisted of the 9810A, a mathematics ROM block, a printer, and mark-sense card reader.

The study consisted of a one-semester experimental first course in calculus that employed the 9810A as an instructional aid and as a student laboratory device. The course is flexible, it is not dependent on a specific text, and it can be adapted to the traditional lecture method of teaching. The experimental course was specifically designed to be an improvement on the lecture method but to remain within the general format of the lecture method, particularly with respect to the semester hours required of the course. The distinguishing characteristics of the experimental course and the incorporation of the minicomputer are:

- It provides the instructor with the opportunity to discuss numerous exemplars and non-exemplars of a concept in more detail.
- It includes topics normally omitted or reserved for a subsequent course.
- It includes more realistic applications of calculus.

Two sections of a first course in calculus were selected to serve as the control and experimental groups. The control group was taught in the traditional lecture method, and the course content consisted of the typical topics covered in beginning calculus. The treatment group was taught in the experimental course with the content consisting of the topics covered in the control group plus additional topics in limits of functions, applications of the derivative and numerical integration.

Thomas O'Loughlin instructing a student in numerical integration using the HP 9810A.

The method of instruction used with the treatment group was the lecture method augmented by the use of the 9810A as a teaching aid. A series of tests was constructed to measure student achievement with respect to the following:

- Limits of functions
- Continuity
- Interrelationships between a function and its first two derivatives
- Local extrema of a function
- Solving verbal problems involving maxima-minima and related rates
- The definite integral

As it was impossible to exert any control over student registration in the two groups, it was decided to use a three-by-two analysis of variance with unequal cell frequencies to analyze the data. The entire sample was partitioned into three blocks on the basis of previously demonstrated achievement in mathematics in order to maintain some balance between the two groups with respect to mathematical ability.

Eight tests were administered throughout the semester to measure student achievement of the six items listed. (Additional tests were given to measure achievement of other course objectives, such as application of the techniques of differentiation, that would not be influenced by the use of a minicomputer.)

The data obtained from the analysis of variance implied there was no significant difference in student achievement with respect to the four tests in the area of limits and continuity. These tests were primarily objective in nature and measured the student's ability to determine whether specific limits existed and their values if they did exist, to interpret and apply the definition of a limit of a function at a point, to determine if a given function was continuous at a specified point, to determine intervals where a given function is continuous, and to predict the behavior of a function that is continuous on a closed interval.

The failure to obtain evidence of any significant differences between the two groups in these areas was actually a positive result. As the tests could only include content common to both groups and since the experimental group discussed additional cases of limits (i.e., infinite limits), the lack of difference in achievement verified that additional content could be discussed in the experimental group without reducing their achievement on the concepts tested. Further, it was anticipated prior to the study that a more computational approach to concepts might reduce the student's knowledge of the theoretical aspects of a concept. However, the test data failed to support this conjecture.

The data did imply that the method used in the treatment group produced significantly higher student achievement in observing the interralationships between a function and its first two derivatives ($F = 7.00$, $df = 1, 30$; $p < .05$), in solving verbal problems involving maxima-minima and related rates ($F = 3.87$, $df = 1, 29$; $p < .05$), and in interpreting the definition of the definite integral ($F = 3.40$, $df = 1, 29$; $p < .05$).

The first of these significant results was primarily a result of the students in the treatment group being able to use the 9810A to evaluate functions at points in their domain and by having written a number of general programs for evaluating most of the commonly encountered functions in beginning calculus. With this capability, the students in the experimental group were able to graph in detail many more illustrations of these relationships than those in the control group and hence gain a much better understanding of these relationships. An added side effect of the students writing their own programs for evaluating the commonly encountered functions was that they began to recognize common characteristics of functions from the same family. For example, not only did they immediately recognize that any function of the form $(f)x = ax^2 + bx + c$, with $a \neq 0$, was a parabola, but also that the function $g(x) = |ax^2 + bx + c|$ with $a \neq 0$, was a parabola with the negative values of $f(x)$ reflected into their additive inverses.

The second significant result was a direct result of the students being exposed to and familiar with the operating techniques of the 9810A. In order to operate and program the minicomputer efficiently, the student had to organize his or her thoughts and work to determine exactly what operations should be performed, in what sequence they are to be performed, in what registers is data to be stored, and so on. After approximately 12 weeks of work with the 9810A, this mandated analysis and organization of material was incorporated into the student's approach to problem solving.

The final significant result verified what I believe to have been the most effective use of the minicomputer as the means of clarifying a particular concept. The typical procedure used to introduce the concept of the definite integral usually entails the computation of upper and lower sums for a few simply defined functions. These sums usually are based on a closed interval with no more than six or eight partition points. By using the 9810A it was possible not only to consider more examples within the same period of time, but to allow the number of partitioning points used to increase from the usual range of six or eight up to 200 or 300. At the conclusion of the classroom discussion, it was obvious that the students in the experimental group had a strong intuitive understanding of the concept of the definite integral instead of the somewhat vague "I think I know what's happening" attitude of the students in the control group. The computation of the upper and lower sums was easily extended from usual area problems to problems involving distance, volume, and arc length, with the result that the students did not fall into the common misunderstanding that the definite integral was synonymous with the computation of area. Further, after having developed the basis for the definite integral using numerical computation of upper and lower sums, it was only reasonable to extend the numerical methods to include the Trapezoidal rule and Simpson's rule, which are topics normally reserved for a subsequent course.

In addition to measuring the effect of the use of the 9810A on student achievement, I was also concerned whether there would be an effect on the students' overall attitude toward mathematics and the reaction of the students toward the use of a desktop computer as an aid to learning. On the first and last day of class a Thurstone-type attitude scale was administered to the control group and the experimental group. The scale consisted of 21 statements, each of which expressed an attitude toward mathematics, and the students were to indicate whether they agreed with each statement. Each statement had a weighted value (unknown to the students), computed prior to the study and based on the opinions of some 40 mathematics teachers. As is usually the case in beginning calculus, there was a shift in attitude on both sections toward a less positive attitude, but there was no significant change either within the groups or between the groups.

A careful examination of the changes of sentiment in the experimental group, with respect to two statements, underlined one pedagogical effect of the use of the 9810A. There was a marked increase in the number of students who agreed with the statements "I dislike having to learn definitions and theorems in mathematics" and "I enjoy solving problems in mathematics but I dislike doing proofs." This change is directly attributable to the computational approach to mathematics incorporated within the experimental course. The availability and capabilities of the 9810A provide the student with the means to develop a strong intuitive understanding of the concept(s) without a rigorous theoretical development. Further, the student often can obtain the answer to a problem by using the minicomputer instead of more laborious techniques. This type of reaction was expected and need not be considered detrimental to the course, as it should be noted that the scale was based on the opinions of mathematics teachers, who have a tendency to favor a definition and theorem oriented approach to mathematics.

At the last class meeting I asked the students in the experimental group to complete an anonymous questionnaire in which they expressed their reaction to the use of the 9810A. Their response was almost unanimously favorable. (One extremely bright student did not feel it at all necessary to use the minicomputer and her excellent grades indicated that in her case it was not.) Some typical reactions were:

"Plenty of illustrations and examples can be covered in class and in detail."

"It helped me understand concepts and lessened the time for unnecessary calculations."

"Made figuring out applications more practical."

"Allowed us to understand more clearly since we were more directly involved."

The statistical data and their significance obtained in the study and the students' reactions confirmed my belief that the minicomputer can be effectively employed to improve instruction in introductory mathematics courses and that its capability is comparable to that of a computer when used as a teaching aid in beginning calculus.

The 9810A minicomputer system used has since been extended to include an X-Y plotter. Initial investigations indicate that the addition of graphics representations of various problems and concepts further increases the 9810A's effect on student achievement.

About the Author

Thomas O'Loughlin received his BS in Mathematics from the State University of New York, College at Albany in 1956; his MA from the University of Illinois in 1960; and his PhD in Mathematics Education form Syracuse University in 1974. He taught high school mathematics from 1956 until 1963, when he accepted a position with the State University of New York, College at Cortland. He taught mathematics there in several capacities, and is now chairman of the Mathematics Department.

Dr. O'Loughlin has received grants from the National Scholarship Federation and the U.S. Office of Education, and has authored papers related to the subject of this article.

Programming Tips

FORMATting the Display (9830A)

Submitted by Andrew Vettel, Jr., Science Dept. Chairman of Steel Valley School District, Homestead, Pennsylvania, U.S.A.

The formatting capability available with the WRITE statement cannot be used in the lighted display of the 9830A since no select code is provided for the display. However, if both the Strings and Extended I/O ROMs are installed, a formatted display may be accomplished as follows:

```
1Ø DIM A$ (4Ø)
2Ø X = 5.4
3Ø OUTPUT (A$, 4Ø) X, X ↑ 2, X,
     SQRX
4Ø FORMAT F4.1, "↑ 2 =", F6.2,
     "&SQR (",F4.1,")=",F6.3
5Ø Disp A$
6Ø END
```

9845 Label Centering

Submitted by Brad Miller, Hewlett-Packard, Desktop Computer Division.

The LORG statement in the System 45 is a very powerful tool for lettering graphic output. However, several questions have come up when using LORG 5 (label centering). Labels do not appear to be centered! This is not because of problems with LORG 5 but rather because of the characteristics of the LABEL statement. The LABEL works like PRINT in that it puts literals (text) into 20-character fields. Therefore, LABEL "123456789Ø12345" will be sent with 5 leading blanks and consequently not appear centered. The solution (as with PRINT) is LABEL "123456789Ø12345"; the ; causes the literal to be sent "as is" and it will then appear centered! Happy labeling!

Salvaging a Program with ERROR 59 (9830A)

Submitted by Andrew Vettel, Jr., Science Dept. Chairman of Steel Valley School District, Homestead, Pennsylvania, U.S.A.

When loading a program from a tape file and an ERROR 59 (check sum) occurs, more often than not it is impossible to list or display any lines at or beyond the line where the bit error occurred. Further, ERROR 1 occurs if an attempt is made to store those lines that were loaded without error. For example, STORE 2, 10, 240 will produce ERROR 1 even though there are no errors in lines 10 - 240.

The following procedure makes use of the RECALL buffer to transfer the undamaged line one by one from mainline memory to a special function key, say f9:

STEP	KEY	COMMENTS
(1)	FETCH	Places lowest numbered line in display
(2)	EXECUTE	
→(3)	BACK	Removes ⊢
(4)	END OF LINE	Store line in the RECALL buffer
(5)	FETCH	Access SFK where lines are being stored
(6)	f9	
(7)	RECALL	Retrieve line from RECALL buffer
(8)	END OF LINE	Store line on the SFK
(9)	END	Exit the SFK
(10)	[↓]	Place next line in display Repeat procedure beginning with Step 3

Care must be taken not to attempt to place in the display any "damaged" lines. Once all salvagable lines have been placed on the Special Function Key, mainline memory should be SCRATCHed before the lines of the key are then stored in a nondefective tape file.

Detecting Missing Data in Formatted Input With the General I/O ROM (9825A)

Submitted by Dr. R.K. Littlewood, Biophysics Laboratory, University of Wisconsin, 1525 Linden Drive, Madison, Wisconsin 53706, U.S.A.

An undocumented feature of the General I/O ROM for the 9825A allows one to differentiate between zeroes and blank fields when doing formatted input. This capability is very helpful when writing statistical programs that must accommodate missing data. When a "red" statement is executed and any field designated by an "fw" specification is completely blank, the value of the corresponding item in the data list is left unchanged, rather than set to the value zero. The following test program illustrates the point. (Select code 2 is a 9883A Paper Tape Reader in this example.)

Code:
```
0: -999→A→B→C
1: fmt 3f5
2: red 2,A,B,C
3: fmt 3f5.0;
   wrt 16,A,B,C
4: sto 0
*5474
```

Input:
```
00000          00001
     0000100000
```

Output:
```
     0  -999      1
-999      .1      0
```

Note also that this General I/O ROM feature requires you to preset values to zero before doing a "red," if blanks are to be interpreted as zero.

Update

9815S Desktop Computer

by Dave Breville, Hewlett-Packard, Desktop Computer Division

The new 9815S Desktop Computer provides increased programming and/or data storage for the popular HP 9815.

Like the 9815A, the 9815S has 23 built-in scientific function keys, the same RPN logic system used by HP pocket calculators, a buffered keyboard, large display, and a hard copy alphanumeric printer. The built-in, high-speed, bidirectional data cartridge allows the operator to record new programs or to use prerecorded programs available from HP. Data may be entered into the 9815 either through the keyboard or through the 9800 Series input peripherals.

The key distinctions between the 9815S and the 9815A are memory and I/O channels. The 9815S has 3800 program steps (as compared to 2008 with 9815A Opt. 001), making it ideally suited for complex computations and data acquisition applications. It also offers as standard two I/O channels (Opt. 002 of the 9815A).

Problem solving with the 9815S is simplified through the ability to divide available memory space between program steps and data registers. The RPN programming language includes such sophisticated features as FOR-NEXT loops; symbolic, absolute or calculated addresses; automatic address updating during editing; descriptive error messages; and subroutines up to seven levels deep.

Interfacing to Hewlett-Packard plotters, printers, voltmeters, paper tape punches and paper tape readers is easy with an optional interface card. Flexible interfacing is also available for a variety of instruments by other manufacturers, using BCD, bidirectional 8-Bit Parallel, RS-232-C, and HP-IB (IEEE 488-1975) interfaces.

Existing 9815As may be upgraded to 3800 program steps with the 98125A field upgrade kit.

9845 Nonlinear Regression Software, 09845-15040

This software pack contains programs using Marquardt's Method to fit nonlinear models using up to ten parameters. It includes Basic Statistics and Data Manipulation. Required hardware is the 9845S; the 9869A Card Reader and 9885M Flexible Disk or 7906A or 7920A Disc Drive are optional.

98137A Tape Duplication Interface

by David Breville

This interface provides duplication of 9815 tape cartridges easily and quickly.

The 98137A consists of two special I/O cards, each with 1024 bytes of PROM, connected by an interface cable. One I/O card is the "master" and is plugged into the "master" 9815; the other is the "slave" and is plugged into the "slave" 9815.

A special function key on each 9815 is pressed and the tape cartridge is automatically duplicated. All programs and data may be duplicated, including binary programs.

9845 General Statistics Software, 09845-15030

This software pack contains parametric and nonparametric tests for single sample, paired sample, two independent samples and multiple sample data. It includes statistical distributions that eliminate the need for tables, and Basic Statistics and Data Manipulation programs. Required hardware is the 9845S.

Keyboard
Hewlett-Packard, 3400 E. Harmony Road
Fort Collins, Colorado U.S.A. 80521

Keyboard

Publications Manager - Ed Bride
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For further information on HP products or applications, please contact your local Hewlett-Packard Sales and Service Office or write to Keyboard.

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