EDP ANALYZER

Editor and Publisher: RICHARD G. CANNING

EDP ANALYZER

FEBRUARY, 1982
VOL. 20, NO. 2

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COMPUTER GRAPHICS FOR BUSINESS

For almost two decades, supporters of computer graphics systems have been urging their use for business management purposes. The military has pioneered in the use of computer graphics, for command and control. And computer graphics systems have been put to effective use in such areas as computer-aided design and manufacturing, real-time simulation, animation, and video games. At long last, computer graphics for business management has become a 'very hot area.' We checked to see what management is doing with these systems.

Citizens and Southern National Bank is the largest bank in Georgia, a state that does not have branch banking. The bank is located in Atlanta, and has assets of $5 billion. We contacted the bank's trust department, which manages $3 billion in funds, to learn about their growing use of computer graphics generated on a micro-computer.

Early last year, a new senior vice president joined the trust department to become director of research and to perform investment counseling. At his previous employer, he had used a time-sharing service and an in-house Hewlett-Packard color plotter to generate computer graphics. The graphics were created and reviewed using a CRT terminal and then output on the plotter. One of the first things this vice president did after arriving at Citizens and Southern was to recommend acquiring a computer graphics system for the department.

After some study, the department chose to acquire an Apple II Plus computer, with 48K bytes of memory, two 5-1/4 inch floppy disk units (which provide a total of 256K bytes of storage), a 16-inch color television monitor, and a Qume Sprint 45 printer. The large television screen and the correspondence-quality printer not only serve current graphics needs but also will be useful for word processing.

The entire system, including six popular software packages for the Apple II, was purchased from the Compushop of Georgia, an Atlanta computer store, at a total cost of $6,500.

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The bank obtained three packages for performing business graphics—VisiPlot, VisiTrend/VisiPlot, and Apple Plot. The other three packages included VisiCalc, VisiTerm, and the Dow Jones Portfolio Evaluator.

The primary reason for buying the system was to create graphs for presentations. Investment counselors within the trust department often make presentations to the bank's investment committee, to current trust clients, and to prospective clients. Graphics play an important role in these meetings. Typically, graphs are created to show various trends in: the economy, the stock market, industry groups, some of the bank's trust accounts, and the stocks they are recommending for purchase. For these uses, a picture is worth "at least 1000 words," we were told.

Both hardcopy and softcopy (CRT display) graphics are used for these presentations. To prepare for a presentation, an investment counselor either types the necessary data into the Apple II by hand or uses data already stored on a floppy disk. Then, by using one of the graphics packages, he/she creates the desired graph(s). If hardcopy prints are desired, the information is passed to the Qume printer. Multiple copies are made of these prints to hand out at the meeting. Overhead projection foils are also made to project onto a large screen.

In some cases the Apple II is hooked up to a 19-inch color television set to give 'live' color graphics presentations to small groups. Black and white paper copies of the graphics created on the Qume printer may also be given to attendees.

The department purchased both VisiPlot and Apple Plot because neither performs all of the functions they need. For example, with Apple Plot, users can create hardcopy graphs, but they cannot create pie charts or put multiple charts on one page. On the other hand, using VisiPlot, users can create pie charts, as well as hi-low, scatter, area, and time series charts. And they can create several charts on one 'page,' which is often very useful for making visual comparisons. But they cannot create hardcopy graphs. Both products handle color and can take rows and columns of data from VisiCalc for generating graphs.

The trust department would very much like to be able to generate color hardcopy prints of the graphs, but they have not yet found an economical product—one that does not cost almost as much as the rest of the system combined. They expect that a color flat bed plotter designed for micros will come onto the market soon.

The department also looks forward to using the system to perform other work. They plan to add a word processing package soon. And they would like to avoid some of the hand entry of data; for example, they would like to be able to use the data from the Dow Jones Portfolio Evaluator directly with a graphics package. And finally, they would like to access trust account information stored on the bank's central computer. So they see their use of a micro-computer for business graphics and trend analysis as just beginning.

General Mills

General Mills, Inc. is a diversified producer of packaged consumer goods, with headquarters in Minneapolis, Minnesota; 1980 sales were over $4.8 billion. The consumer foods group, the largest division of the company, produces such well-known brand name products as Betty Crocker cake mixes, Bisquick baking mix, Wheaties cereal, and many others.

In competitive fields such as these, management must stay on top of rapidly changing conditions. For the past ten years, the marketing department of the consumer foods group has relied upon computer graphics to plot market share data. At first, they used a commercal time-sharing service and a black and white plotter. They used a program written for them at Dartmouth, called INF*ACT, to perform marketing analysis and generate the graphs.

In 1977 General Mills decided to establish an in-house time-sharing service and offer graphics capabilities. They installed a Hewlett-Packard 3000 computer dedicated to time-sharing, an H-P 2748 high resolution black and white graphics terminal, and an H-P 7221 four-color plotter in the time-sharing department. The terminal resolution is 2000 by 2000 points on its 11 by 5 1/2 inch screen. For software, they acquired ISSCO's DISSPLA, a Fortran-based business graphics package for use by programmers; it runs on numerous mainframe and large mini-computer systems.

In 1979 the time-sharing department added a DEC 2020 computer from Digital Equipment Corporation, another H-P plotter, and two more graphics packages—the Nicolet Zeta Z-Plot and Z-Chart. They also had the marketing analysis package interfaced to this system. In 1981 they purchased yet another graphics package, the Hewlett-Packard DSG 3000. This is a very user-friendly package and allows users to create graphs by filling out options on a menu. Users who have taken the training course that General Mills offers are enthusiastic about creating their own graphs; the volume of graphics output has doubled in a recent five month period.

The main users of business graphics at General Mills have been first level supervisors and staff members—analysts, engineers, and market researchers. Their primary use is creating graphs for in-house presentations. Many of the graphs are plotted not on paper but on transparency foils for overhead projectors—and colors come through vividly with these foils, we were told. Another use has been to replace some computer printouts previously given to top management for tracking personnel and transportation information; in such cases, the graphs have almost totally replaced the computer listings. And a third, growing use is making projection slides. The photographic department recently acquired a Dicomed D38 computer-based 35mm slide-maker. General Mills sees slide-making as a very high payoff area for business graphics, because they can create slides for one-half the cost of their previous methods.

The time-sharing department has fifteen staff members, including two who work mainly on graphics projects, and one manager. One of the staff members works with a user team on its current graphics evaluation effort. She also teaches the day-long graphics class to end users and orders graphics hardware. She enhances purchased packages when desired, and writes production programs when needed for graphics output.

Another staff member handles users' requests. A user generally visits the time-sharing department with sketches of five to ten graphs he or she wants produced. Often these are to be re-created periodically for a series of meetings. The time-sharing staff member studies the desired graphs and quotes the user a price for setting up the graphing programs. The cost usually is about $25 per graph. Then he creates the graphs; a few iterations may be needed before the user is satisfied. Thereafter, the user need only supply the appropriate data one day before the meeting and the graphs will be generated overnight.

The time-sharing department currently serves about 30 users, and produces some 200 graphs a month. About 90% of the data needed for these graphs is entered manually; since this is a major part of the cost of producing the graphs, continual efforts are being made to use data already on the computer.

The department is also looking at more hardware and software that will allow end users to create their own graphs. To this end, a team of users was formed for studying the options. But General Mills has moved cautiously in this direction, for two main reasons. For one thing, they felt that the end-user software packages on the market were not flexible enough. Secondly, the users at General Mills have always wanted high resolution graphics, and high resolution terminals are still expensive.

As an example of their flexibility needs, users often want to plot both product cost (or price) and number of units produced (or sold) on vertical axes, versus time on the horizontal axis. Few packages today allow two vertical scales (double scaling—say, one in dollars and one in units), so the company has not yet decided how to offer this feature on an end-user basis.

As far as high resolution is concerned, however, they are considering one approach—which is to provide end users with inexpensive low resolution terminals for previewing graphics. Once the graphs are satisfactory, they can then be produced on a good-quality color plotter.

The time-sharing department within General Mills consumer foods group has established a good foundation for the increased use of business graphics.

Computer graphics in business

Why use graphics for business information? The simple answer is: to improve comprehension of the information. As is generally the case, however, there are lots of 'pros and cons, ifs, ands and buts' relating to the use of graphics. Graphical display is not always the superior solution for management's information needs—but it does have its advantages.

To get an idea of where graphics can play a useful role, let us first consider some of the various uses of graphics.

Uses of graphics

Here are some of the ways that people in business have been making use of graphics in the past—generally, manually-prepared graphics.

Reports. Graphics are widely used in reports, such as reports to management. Because these reports normally are printed in black ink on white paper, black-and-white graphics suffice. Perhaps the most common uses are bar charts and time series charts.

Presentations. Graphics are used in 35mm slides and overhead projection foils, for presenting information at briefings, meetings, and conferences. Color graphics generally are preferred. Presentations are normally a one-way form of communications, and the graphics help to get the points across in the absence of a two-way dialog.

Management tracking of performance. 'Management chart rooms' are not uncommon in business and industry, where the charts give reasonably up-to-date information on actual versus planned performance. The charts allow everyone in the room to see the same information, and are particularly useful for showing trends.

Analysis, planning, and scheduling. Certain types of graphics have proved to be very helpful for supporting management decisions. Two-dimensional maps are useful for relating (say) the locations of customers and the locations of your company's customer service facilities. For instance, Takeuchi and Schmidt (Reference 1) give interesting views on management uses of graphics, based in part on their experience at Harvard University's Laboratory for Computer Graphics and Spatial Analysis. Of the seven graphical illustrations given in the article, six are maps and the seventh is a layout of a retail shopping center and shows sales per square foot of sales area for the different stores in the shopping center. A tremendous amount of information is conveyed by maps and map-like graphics.

'Three-dimensional' maps show surface contours with a three-dimensional effect. With black-and-white rendition, they can show the relationship among three variables; with color, four or even more variables can be related. These 'maps' are not limited to geographical information, but can be used to show relationships among any three variables—such as the number of employees by age and by years of service with the company.

Critical-path charts (such as PERT and CPM) have been effective in vividly showing the critical activity path of (smaller) projects. However, with large projects, charts became too big and expensive to maintain and have been replaced by computer listings (probably with some loss in comprehension).

Command and control. While not often found in business and industry, command and control centers are widely used in the military. Also, some local governments are using them for controlling the disposition of police, fire, and other vital public services. Maps and other graphical techniques play a key role in these centers.

Training. The value of training films, which may include the use of animation, is widely recognized. We will have more to say later in this report about some exciting research on the role that computer graphics can play in training.

Documentation. Graphics are often needed for documentation, such as exploded assembly drawings used in parts re-ordering catalogs. And while programmers do not make as much use of flow charts are they formerly did, graphics still have a role to play in program documentation.

Other uses. One of the main use of graphics, which we will not discuss in any length, is for providing design, engineering, and production drawings, for the manufacture of products. Computer-aided design (CAD) and computer-aided manufacturing (CAM) systems are receiving a lot of attention these days. Another area, medicine, is also making increasing use of computer graphics, in connection with scanners that show the internal workings of the human body. Graphics are being used in tele-conferencing and in the new videotex systems. Recreational computer games use graphics. Computer-generated art uses graphics.

So, all in all, there are many uses for graphics—and a good number of those just listed can be found in business and industry.

Types of graphics

There are a wide variety of graphics forms in use today. Here are some of the more popular ones.

Text. Text plays a critical role in graphics—for listing points that the speaker is discussing, for showing subject titles, for identifying components and values of a chart, and so on. Text must be easily readable.

Time series charts. These are perhaps the most widely used form of graphics, showing the value of one or more variables versus time. The value scale can be linear or logarithmic.

Bar and pie charts. Both can be used to show total values (by the size of the bar or pie), as well as component values, such as breakdowns of (say) 'sources of money received' and 'where the money was spent.'

Scatter diagrams. These show the (imperfect) relationship between two variables, such as the number of air travelers that fly on Mondays, on Tuesdays, etc.

Maps—both two-dimensional and three-dimensional—have been discussed above.

Layouts of rooms, buildings, shopping centers, etc. convey much information in relatively simple diagrams.

Hierarchy charts, such as organization charts and module charts, are widely used.

Sequence charts, such as flow charts, may not be quite as popular as they once were, but they still have a role to play.

Motion graphics, such as motion pictures and television, clearly will continue to perform vital functions. Their future becomes even more exciting when, through the use of computers, they are tied in with some of the other graphic techniques listed above.

Yes, there are many forms of graphics now being used. But the subject of this issue is 'computer graphics in business.' So we return to the question: why use *computer* graphics in business?

Why computer graphics?

When an organization first considers using computer graphics, from what we gather in our discussions, their initial interest is in continuing to produce the same types of graphics that they have been producing—but faster and at less cost. There is just no comparison in the speed with which drawings, slides, foils, etc. can be produced by computer in contrast to manual methods. And, depending upon volume, the cost of computer graphics can be substantially less than manual graphics.

From a management standpoint, this means that the charts displayed in a management chart room can be much more up-to-the-minute.

It also means that different formats, scales, colors, etc. can be tested out economically, to see which format gives the best comprehension of the information, for a particular chart.

There is still another big benefit in computer graphics for management. Their speed and relatively low cost make the answering of many 'what if' questions feasible, such as, "What would our expense picture have looked like over the past year if we had ...?" Management can ask questions like that and the new charts can be displayed very rapidly.

But there is another side to the coin. Here are some of the objections that we have heard raised about computer graphics.

Some objections

Before a computer graphics system is installed, or in the early days of its use, a new user organization is likely to encounter one or more of the following objections to it.

Management resistance. A good many managers, we are told, see computer graphics as too costly. Also, they say they prefer to see the actual reports, because they feel more comfortable with numbers than with graphs. This is not really a valid objection, we suspect, but is simply due to the fact that these managers have not been exposed to *effective* graphics systems.

Rising expectations. Some organizations may start with an inexpensive computer graphics system, but may soon become dissatisfied with it. For one thing, the quality may not be adequate; diagonal lines show up as 'staircases' rather than straight lines, or curves are distorted. Or they may want to make what they feel are simple changes to the system—such as showing two time series with two scales on the same chart, or showing two charts on the same page or screen—only to find that it is impractical to make those changes with their inexpensive system. So they get frustrated with the new system.

Need programmer help. Creating new graphics formats may require the use of a graphics programmer. This means that managers and other users are back in the familiar scene of waiting for the programmer to become available, waiting for the program to be written, finding that the new format is not quite what was wanted, and ending up with a non-trivial cost.

Not familiar with graphics. A computer graphics system will not automatically produce 'good' graphics; the users have to know what to ask for. And many new users are not familiar with good quality graphics.

The problem may be as simple as a poor choice of scales. If the scale is too small, viewers may miss significant variations in values. If the scale is too big, mountains will be made out of molehills. If someone uses a logarithmic scale, a quite-different interpretation of the data may be drawn as compared with the use of a linear scale.

The resolution of the graphics system may be relatively low, which means that care must be taken to obtain usable graphics. We recently observed color slides made from the outputs of several computer graphics systems. In some cases, the lettering on the slides was not readable, and diagonal lines were quite 'staircased.'

Another problem area is the choice of colors for a particular graph. A poor choice of colors can adversely affect the viewers' reaction to the graph, regardless of how important its message is. If used well, color can add to the message, not detract from it. Colors can be used to highlight deviations from plan or from standard.

Also, some users may not be too familiar with common graphical techniques. For instance, one such method is the 'overlay' technique. A chart is shown, giving some information. Then an overlay is added, which adds more information. A second overlay adds still more information, and so on, so that the observer receives information gradually and can thus comprehend it more easily.

Further, blinking can be used on a CRT display, to draw attention to some value. And numbers can be displayed next to critical high or low points on a graph, so that viewers see not only trends and relationships but also actual values.

Thus, while users may be unhappy with their early use of computer graphics, as they get more 'professional' graphics, satisfaction should increase.

The graphics marketplace

The necessary elements of a graphics system are: a processor and its memory (generally lots of memory), disk storage plus a file management or database management system for handling the stored data, a display (usually a CRT), graphics software, probably some provision for hardcopy output, and possibly a data communications facility for obtaining data from another computing system.

There are several alternatives for acquiring computer graphics capabilities. The graphics system can be a self-contained, stand-alone system with all the elements required, often designed especially for graphics use. Or it can consist of a device connected to a general-purpose host computer. The host can be either a minicomputer or mainframe, and can be in-house or at a time-sharing service bureau.

Stand-alone graphics systems. One type of stand-alone system uses a general-purpose microcomputer. For example, the Apple II microcomputer with graphics software, such as Apple Plot or VisiPlot, and perhaps a hardcopy device, is currently the least expensive way to obtain business graphics in-house. Such systems generally are not designed specifically for graphics, and they provide lower resolution output and have more limited capabilities than those that are so designed. These systems cost $7,000 to $10,000 or more with a hardcopy device attached.

When most vendors use the term 'stand-alone graphics system,' they generally mean one that is designed specifically for graphics. These are self-contained systems, not communicating to a separate host computer. They are typically microprocessor based and sell for $12,000 to $100,000. They are offered by Chromatics, Intelligent Systems Corporation, Ramtek, and others.

High end options are often dedicated slide-making systems, such as the Genigraphics system. They sell for $250,000 to $500,000.

Time-sharing services. Time-sharing service bureaus provide a less-expensive way of getting started with business graphics, unless the needed capacity is already available on an in-house mini-computer or mainframe. As volume of use increases, however, the cost of the time-sharing approach becomes greater than an in-house system.

Computer graphics services are provided in various U.S. cities by National CSS, Boeing Computer Services, Informatics, Tymshare, American Management Systems, and others. The small initial investment is one appeal, as is the assistance from support personnel and the availability of software and databases. Also, an interface between a DBMS and the graphics software is often available.

A second type of service is the slide-making service. Xerox, Dicomed, Genigraphics (General Electric), and others have computerized services for making slides from *graphics* data that is sent to them via tele-communications or on a magnetic tape. Also available is the total graphics service where users send raw data, not graphics data, and the bureau uses its own graphics programs to create the graphs and print them out in the requested hardcopy form.

Mini-computer systems. Historically the host computer for graphics has been mainframes, but general purpose graphics software packages are now available for the larger 32-bit mini-computers. For instance, Integrated Software Systems Corporation (ISSCO) has two graphics packages, TELL-A-GRAPH and DISSPLA, which run on DEC and Prime computers.

Mainframe computers. The largest source of business graphics is mainframe computers, with terminals at user locations. Software is available from the computer manufacturers, commercial graphics software vendors, and others.

Display devices

In graphics applications, the display and hardcopy devices take on added importance, and they contribute measurably to the cost of the graphics system.

When people discuss display devices, one of the first questions asked is: What is the resolution? We will briefly discuss both resolution and color, because they are often inter-related.

The question of resolution. Resolution refers to the number of points per unit of area that are used to convey the pictorial information. Most vendors refer to resolution by giving the number of discrete horizontal points and vertical points that are displayed in their screen areas. Thus, a display with 512 points per horizontal lines times 512 horizontal lines on the screen has a total of over 262,000 individual points. This total figure is useful in understanding how much memory will be needed to support that display in an interactive mode. The prime limiting factor for resolution is *memory.*

In black and white CRT displays, each point is stored as one bit—either black or white. Therefore, a screen with 512 by 512 points requires at least 262K bits (or 33K bytes) of memory to store the contents of the screen.

Color, on the other hand, usually requires much more memory, because each point generally requires more than a one-bit representation; however, there are varying schemes for representing color. To illustrate, Cromemco recently announced a color graphics system with two modes of operation for their popular micro-computers. In the high resolution mode, the system permits a choice of two colors per screen, out of a total 'palette' of 4096 colors. In this mode each point is represented by one bit, so the system is able to provide resolution of 754 by 482 points, or some 370,000 total points. In the second mode, they allow 16 colors on one screen.

Here, each point requires four bits of information, and resolution drops to 377 by 240 points, or about 90,000 points.

So memory can restrict how much information can be stored for each point as well as how many points can be represented on a screen. To double a screen's resolution requires four times as much memory. And to add color requires storing anywhere from 3 to 24 bits per point.

Memory can also restrict resolution by affecting how fast the screen can be refreshed. Displays that are refreshed less often than about every 1/30 to 1/60 of a second appear to flicker; therefore, many vendors add a refresh memory to their systems to handle this function. The Cromemco system just described has added 48K bytes of refresh memory to its 64K byte system for this purpose. Systems without refresh memories—for example, host-based systems using dumb terminals—must use some of their main memory for refreshing, which may lead to lower resolution.

Color has more components than are at first apparent. In the more flexible (and more expensive) color systems, color is represented in three 'dimensions.' The first is the hue—what most people call color—green, cyan (blue), magenta (red), yellow, etc. The second dimension is intensity, which mixes the hue with varying degrees of white or black. And the third dimension is saturation, from pale red to 'fire engine' red. Some systems allow a very large palette of possible colors from which the user chooses a few for use in any one display. Other systems have a fixed number of hues with a few intensities and varying saturation for each.

So the limiting factor in graphics systems, all other components being equal, is memory.

Back to the question of resolution. Although the number of discrete points that can be displayed on a screen seems clear-cut, users' interpretations vary considerably on what is low resolution, what is medium resolution, and what is high resolution. A person's view generally depends on what he is used to seeing. Vendors of high-resolution systems are quick to point out that executives are used to seeing charts of 'graphic art quality,' created by graphic artists. So these vendors say executives will expect the same quality in computer graphics. We have not found this to be absolutely true, but it is the case that people become used to, and then expect, high resolution once they become accustomed to it.

As best we can generalize, displays with less than 140K (about 375x375) total points, have very marked 'staircasing' on diagonal and curved lines; these are generally called low resolution devices. Displays with over 250K points (500x500) have less evident staircasing, and are known as normal or medium resolution. High resolution starts at about 750K points (about 860x860), we believe.

The best recommendation we can give on the question of resolution is to find out exactly what minimum resolution your users will accept, by showing them samples of various resolutions. In most cases, systems with medium resolution appear to be adequate for business graphics purposes, from what we can tell from the users we have talked with.

Now back to the types of display (softcopy) devices. There are three basic technologies used in display devices: raster scan, vector refresh, and storage tube. Many of the technical points made below are from Ogdin (Reference 2) and Wright (Reference 4a).

Raster scan devices use an electron beam that moves in a regular pattern horizontally across the screen one line at a time. This technology is used in both television and CRT devices, but in slightly different ways. In television, the beam is modulated to give a range of luminescence for the points on the screen; in CRTs, the beam is either turned on or off at each point. Another difference is 'allowable' resolution. In the U.S., each commercial television channel has a five megahertz bandwidth, dictated by the Federal Communications Commission's allocation of bandwidth to broadcasters. Because of the need to refresh the screen often enough to avoid perceivable flickering, this regulation has resulted in U.S. television displays of 640 points per line, with 512 lines per screen. Graphic CRTs, on the other hand, do not have this limitation and can have 12 to 15 MHz bandwidths; therefore, they can have higher resolution and still use many standard television components, which keeps their cost down. Still higher resolution devices use 30 to 50 MHz; they are more expensive because they cannot use television components, explains Ogdin.

Raster scan devices allow selectively erasing parts of the screen, because the whole screen is recreated (refreshed) 30 to 60 times a second. The screens are bright, they allow color, and they permit display of realistic images. Their major drawbacks are that unless they have high resolution, many lines have a staircased effect, and the images need to be continually refreshed.

Wright notes that most graphics software communicates with graphics terminals in the form of vectors (the lines to be drawn, not the points that form the lines). So a vector-to-raster conversion must be performed for a raster scan device. This generally is done in the terminal, but in some cases (such as some IBM terminals), it must be done in the host—with a significant use of the host's resources.

Companies offering raster scan graphics systems include Chromatics, DEC, Hewlett-Packard, IBM, Intelligent Systems Corporation, Ramtek, Tektronics and others.

Alpha-numeric terminals are generally not appropriate for graphics use because only blocks of points, not individual points, can be addressed. However, some companies are now selling enhanced alpha-numeric terminals which permit medium resolution, monochrome displays and emulate a popular (often Tektronix) graphic protocol.

Vector refresh devices use an electron beam that, rather than moving in a regular pattern of horizontal rows, directly draws the lines on the screen. Thus the drawings can be more precise and have better resolution—say, the equivalent of 4096 by 4096 points (16 million total points) per screen. These systems are most often used for CAD/CAM and other engineering applications. The components are more expensive than those used in television sets, and, like raster scan, their images need to be continually refreshed.

Generally these devices have only been monochrome, although at least one company now has a color system on the market. Some companies are combining vector refresh with raster scan technologies to take advantage of both. Companies that manufacture vector refresh systems include Adage, Evans and Sutherland, Megatek and Vector General.

Storage tube technology is quite different from the other two technologies in that once an image is created on the screen, it is stored there and it does not need to be refreshed. But, at the same time, when a change needs to be made to the image, the entire screen must be redrawn, which might take several seconds. The displays are monochrome and allow high resolution. One major supplier is Tektronix.

Hardcopy devices

Permanent copy graphics output devices include various types of plotters, copiers, printers and camera systems. Good discussions of some of these options can be found in Whieldon (Reference 3) and Wright (Reference 4a).

Plotters. There are two types of plotters: electro-static plotters (often called printer-plotters) and pen plotters. Electro-static plotters operate like copiers, generating a full page at a time. They can combine text and graphics and produce high quality color graphs. Pen plotters produce charts by drawing the lines and 'lettering' the characters; for business graphics purposes they produce nice looking charts. And by using different colored pens, some produce multi-colored graphs. The plots can be made on paper or on overhead transparency foils. The maximum plot size can range from 24 inches to 12 feet square, depending upon the plotter. A new development in the field is pen plotters for microcomputer systems; they cost about $2000 and up.

Copiers. Copiers use the image presented on a CRT screen to produce a copy of the image on paper, generally in black and white. However, the new color photocopiers, such as the Xerox 6500, are being used increasingly to produce hardcopy color graphics, as well as serve other company copying needs.

Printers. Whieldon points out that an important new option is dual-mode dot matrix printers that can serve both word processing and data processing needs, a few of which have graphics capabilities. These printers cost from $2,000 on up. Some are color ink jet printers, while others are impact printers that use three-color ribbons to produce up to eight colors.

Camera systems produce color photographs of a color CRT screen, so resolution depends on the CRT's resolution. These systems are growing in popularity because they provide a convenient way of producing 35mm slides in-house, when used with a high resolution color terminal. Major suppliers of camera systems are Dunn Instruments, Matrix Corporation, and Image Resources. The systems cost from $6,000 to $18,000.

At the 1981 National Computer Conference Professional Development Seminar on business graphics that we attended, the leader, Alan Paller, of AUI Data Graphics in Washington, D.C., noted that a 'homemade slide-making machine' can be made using a 35mm camera with a zoom lens attached. Very presentable slides can be made by placing the terminal in a darkened room and by photographing the display screen from about eight feet away, he said.

Graphics software

Graphics software basically performs three functions: provide an interface between the host computer and the output devices, generate the graphics, and link to other application software and data files.

Output device interface. Software is required to provide the interface between the host computer and the output device—display or hardcopy. A user should be able to request that the same chart be created both on a CRT and a color plotter without having to worry about the differences in the two output devices; the software should take care of the translation. Further, this software may be located in the intelligent input/output device rather than in the host computer. Computer manufacturers provide such software only for their own devices. Independent software suppliers generally provide this software for many different brands and types of devices; they use this device-independent aspect of their products as a major selling point.

Graphics generation. This portion of the software translates data into graphics form. The language that accompanies this portion of the software is what end users and programmers see. Up until just a few years ago, virtually all graphics languages were procedural programming languages. Many still are, but the number of 'end user languages' is growing. The most sophisticated and most versatile products still require procedural programming, but some companies find the end user languages to be sufficient for most of their common business graphics needs.

Currently, computer graphics products for general purpose micro-computers are quite limited in their capabilities. But many proponents say these products will increase both in the functions they perform and in the quality of their output—an example being the Cromemco system mentioned earlier.

Links to other applications and data files. We found business graphics used mainly to prepare presentation materials, rather than for management tracking of performance, analysis, scheduling, etc. But some graphics software is being coupled with other application software, providing an alternative to numerical output—such as graphical output for financial management packages and statistical analysis packages. Even the popular VisiCalc electronic spreadsheet package can now be linked to several graphics packages.

Equally important is linking graphics to existing computerized data files. Hand entry of data to graphics systems is very common, but not very desirable. In his seminar, Paller noted that links to a number of popular database management systems are now available; for example, Intel's System 2000 has a link to TELL-A-GRAF.

Supporting business graphics

Paller, Szoka and Nelson (Reference 4b) say that users' views of their graphics needs can, and often do, change quite dramatically once they begin to receive graphic output. They will ask to have more elaborate charts, such as 'exploded' pie charts, stacked bar charts, charts with double scaling, and so on. Many companies that start with a limited package soon find that they must purchase another, more flexible one, because the users really did not know their needs until they started using the system. Thus starting out with a time-sharing service may be wise, just to get needs better defined.

Paller, in his seminar, said that a company planning to start offering business graphics, *using their existing mainframe or mini-computer,* should be prepared to spend about $30,000 for a flexible graphics package. In addition, they will need to spend about $40,000 for medium to high resolution output devices, plus an additional $40,000 for support for the first year. This comes to a total of about $110,000. A more modest start can be made for about one-half this amount, but the software will probably not provide enough flexibility for longer-term use, he believes.

If an organization chooses to 'start small,' a micro-computer system can cost less than $10,000 for the graphics hardware and software. Such a system can be suitable for use within a single department, for instance, and generally no special support people are needed. This option provides a limited number of charting options, and the quality may be satisfactory for presentation graphics.

Supporting business graphics is a lot like supporting end user programming, which we discussed in detail in the May and June 1981 issues. But business graphics has a few differences which we should point out.

As far as graph quality is concerned, what seems obvious when you look at someone else's graph is not always so obvious when creating your own charts from scratch. So companies that are going to let end users create their own charts need to first teach them some rules for generating good graphs. A 39-page pamphlet, entitled, *Choosing the Right Chart* (Reference 4b), gives some useful ideas on this subject.

For more information on providing support for business graphics, see the Commentary section in this issue, where Robert Widener and Howard Morgan give their views.

A look to the future

The use of computer graphics is sure to increase, and rapidly. We recently saw projections which indicated that by 1990, 95% of the CRTs for use in business (for terminals, personal computers, etc.) will use color, which implies graphics. Hardware prices are falling, and intense competition is occurring in the software markets. So users will find graphics becoming more and more economical.

At first, users will apply computer graphics to making the same types of graphs that they have been making manually. But soon, new types of uses will emerge, as user ingenuity is applied. To illustrate what such new uses might be like, consider research that is underway at (1) the University of Southern California's Information Sciences Institute on graphics briefings and (2) at MIT's Department of Architecture for using graphics for (say) training repair technicians for complex systems.

Graphics presentations and briefings. At the Information Sciences Institute, a research institute of the University of Southern California, in Los Angeles, they are experimenting with 'remote' graphics for presentations and briefings. They are extending the color graphic system we described in the August 1979 issue to allow remote graphics briefings over the ARPANET network. Their system consists of a graphics editor with which the presenter prepares the set of screen images ('slides') plus the 'script' he will use during the 'meeting.' These elements are stored in named files for later recall and distribution. The system also contains data files and graphics generation software in one or more host computers. The device drivers are located in host computers or in the intelligent output devices.

The components of this system are available today, but the system itself is in the research and development stage. When completed, it will allow remote participants to 'meet' by viewing the presentation on local output devices. They also might participate in an audio conference call, which would be used so that the leader can comment while the information is being shown on the various remote devices. The system will accommodate one or many presenters and one or many viewers, all geographically dispersed.

Interactive graphics for training. We obtained several papers from the architecture machine group in MIT's Department of Architecture (Reference 5) that describe some of the ideas that have emerged from their mating of computer graphics, television, new computer input methods, and optical video disk technologies. Optical (laser) video disks have been used rather than ones that use mechanical (capacitance) pick-up of signals. One reason for this choice is that the researchers make extensive use of 'freeze frames' and no mechanical wear results from the same frame being shown for relatively long periods of time (seconds or even minutes). But in addition to freeze-frames, motion picture frames are also used, as well as verbal and other audible messages.

The concepts being investigated by the researchers might best be explained by an example—a 'personalized repair manual' for repairing a bicycle. (The same concepts would apply for repairing jet engines, computers, or other complex devices, but the bicycle example explains the principles.) The 'repair manual' is a combination of hardware and software; in size, it might range from that of a tool kit to the size of a television set. Preferably, it would be small and light, so that the repair person could carry his/her unit to the job.

When the unit is activated, the bicycle repair is requested by (say) touching the CRT screen where the menu listing for bicycle repair is shown. A picture of the bicycle appears. The screen is touched to the part of the bicycle in which the repair person is interested (say, the brake) and then the word 'zoom' can be touched. Now a close-up of the brake appears. By touching the screen to show the part to be displayed, and then touching a command 'button,' the device is directed to provide more and more detailed information.

But that is only the beginning. Motion pictures of the brake disassembly and re-assembly can be shown. An audio description of what is being done can be provided. If the brake makes a peculiar sound that is related to the problem at hand, that sound can be stored on the video disk and played back when desired. Further, the repair person can make personalized 'notes' at any time, just like written notes in the margins of a printed repair manual. Computer graphics and animation can be used to supplement the pictures. A tremendous amount of information of such types can be stored on one optical video disk.

Yes, all of this is working now—at MIT's Department of Architecture. It gives a good idea, we think, of what innovative uses of computer graphics may be like. At the outset, users will apply their new computer graphics systems to 'conventional' uses, such as making charts, slides, and foils. But it is hard to imagine what some pioneering companies will be doing with their graphics systems, say, five to seven years hence.

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   b) Paller, A., K. Szoka, and N. Nelson, "Choosing the right chart," Spring 1981; price $8.50.
5. For information on their interactive graphics research, being performed by Professors Nicholas Negroponte, David Backer, Andrew Lippman, and others, write Architecture Machine Group, School of Architecture and Planning, Massachusetts Institute of Technology, Cambridge, Mass. 02139.

Study after study has shown that very few managers use computers directly, to aid them in their decision making. But that situation may be changing, due to the arrival of 'user-friendly' decision support software, data management systems, and personal computers for managers. Next month, we will discuss progress in this area.

COMMENTARY

GRAPHICS STANDARDS NEEDED—FOR DECISION-MAKING

by W. Robert Widener, Intelligence Interlink Corporation, New York, N.Y.

The two major application areas that are emerging in the new world of computer graphics as applied to business are (1) *presentation graphics* and (2) *graphics for management decision making.*

Presentation graphics covers the wide range of visual aids and printed or 'hard-copy' graphics that are used in a business—for marketing presentations, for visually enhancing both internal and external publications, for adding color and drama to management speeches and presentations, etc. The graphics created for these applications are artistic in nature, can employ dozens of different colors, can be modern, free-form, pop-art, funny, etc. There are literally no restrictions on presentation graphics—the artist or designer creates what he or she thinks is most appropriate and will enhance the message most effectively.

Decision support graphics. In the development of graphics for decision support, however, the rules change dramatically. You must limit the colors, for example. In 15 years of developing and implementing graphic reporting systems, I have found that only seven colors can be utilized in the top-level decision environment. These are: red, green, yellow, light blue, dark blue, white and black. Any other colors—such as purple, or orange, or any other gradations of the red or blue hues—may not be clearly distinguishable; also, too many colors become distracting.

Equally important is the need to develop *standards* for scales, for key graphic elements of the business chart, for legends, for reference limits and, in fact, for every component and text element. Once these standards are developed, they must be reviewed with management. The highest level of management should participate in the final decisions on what the charts mean, how they are generated, their context, what each component means, what variance limits have been set, and what comparisons are being made.

In the development of graphic reporting standards, all relationships between chart components, text, and reference or variance panels must be agreed on, and then frozen. From that point forward, the computer programs can be written that produce all of the key management reports precisely within these approved guidelines. Only if this is done, and only if these standards are adhered to, will the computer graphics system be actually used to support decision-making.

Will computer graphics succeed for decision support? They will if someone in management recognizes the need to be totally involved in both the format development and the final test and approval process. Then a computer graphics system can be developed and installed that will find wide user acceptance and support at the highest management levels.

LET THE SYSTEM DO MORE FOR THE USER

Prof. Howard Lee Morgan, Wharton School, University of Pennsylvania

It has become *de riguer* to call 'user friendly' those software packages that are to be used by managers. But what if one has trouble using a supposedly 'friendly' system. Is it because he or she is not intelligent enough?

More often than not, it is the arrogance of the programmer/designer of the package that is the cause of the trouble. These designers assume a far greater knowledge of computer terminology than is fair. A manager should not be expected to unravel mysterious computer input or output.

The friendliness of a management graphics system rests on the question, "Just how much of the load can the system take from the manager's shoulders?" Some of today's systems—which provide 'English-like' languages for specifying bar charts, pie charts, and trend graphs—can help a manager display data in a presentation form that is more meaningful than a table of figures.

Recently Sakunthala Gnanamgari and I set out to design a system that is even more friendly than these English-like languages. Rather than requiring a beleaguered manager to figure out what type of chart to display, our system incorporates the knowledge of expert graphics designers to *automatically select an appropriate graphical form.*

For her Ph.D., Ms. Gnanamgari interviewed the art directors for several leading publications, including *TIME, Fortune,* and *Scientific American,* as well as the director of visual communications for McKinsey and Company. Their decision rules are incorporated into the program, which determines the graphical presentation based on inherent characteristics of the data and the manager's objectives.

In our system, a command to generate a graph showing (say) amount of sales by salesperson by customer would elicit two questions from the system for the user: (1) "Are you interested in absolute or relative comparison of the amounts?" and (2) "Are you interested in trend analysis?"

Armed with the table of data and the manager's *objectives* in viewing the data, the *system* chooses the style of graph, the scaling and the labeling; it generates a title and instantly displays a picture—on any of the variety of color or black and white devices. Of course, the user can change scales, titles, colors, etc. through standard 'friendly' techniques which include menu selections, spelling correction commands, and prompts.

We hope that our system will succeed in keeping managers from trying to become graphic artists. Those systems which make the manager deal in computer terms—such as "draw a pie chart with these data at this scale"—might be considered friendly. But those interfaces which deal with the manager's *purposes* in interacting with the data are truly 'friendlier' still. (This system, trade-named RAINBOW, is currently offered by International Database Systems, Inc. Philadelphia, Penn.)

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