INTERACTIVE COMPUTER GRAPHICS SYSTEMS

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INTRODUCTION

CRITICAL ISSUES IN THE UTILIZATION OF BUSINESS COMPUTER GRAPHICS

The user of computer graphics for business applications is confronted with a bewildering variety of devices to consider. For example, the user must choose from among storage tube, raster scan, and vector refresh display units, between black and white and color displays, and, in some cases, between conventional CRT and flat panel displays. A choice must be made from among service centers, time-sharing systems, and in-house systems. If the decision is made to utilize an in-house system, system designers must choose between stand-alone (minicomputer) systems and mainframe graphics systems (with central site or remote terminals) and also between packages. Finally, decisions are required as to the degree to which human factors effectiveness will be emphasized at the expense of hardware/software efficiency and operating economy. A considerable degree of experimentation will likely be necessary to find the best combination of devices, tools, and techniques needed to meet the requirements of specific organizations and widely varying application mixes.

In selecting the best type of display device for an organizational unit or application set, consideration should be given to resolution and brightness, the complexity and amount of information displayed, a need for dynamic vs. static applications, the requirement for selective erasing and color, memory capacities and processing capabilities available, and cost. Storage tube display devices have good resolution but low brightness and contrast while raster scan devices and vector refresh devices are characterized by high resolution, brightness, and good contrast. Storage tube displays normally allow no dynamic motion, no color, and no selective erasure. Vector refresh units allow excellent dynamics with limited color, while raster scan displays provide excellent color with limited dynamic motion. The memory and processing requirements for both raster scan and vector refresh units are high but remain low

for storage tube displays. Stroke-written vector refresh systems tend to flicker if large amounts of data or complex drawings and reports are involved.

Stroke-written refresh systems are very useful for applications requiring rapid updating of displays and fast feedback to users in an interactive mode. Not only are vector refresh units well suited for manipulating displays but can prove invaluable for constructing complex geometric structures, animations and simulations, although costs are relatively high. The less costly storage tube displays require less memory than other devices for pattern storage, i.e., storing a picture as a list of drawing tasks. As a result, such displays are very effective with light pens since every point drawn is in memory. While effective for static, black and white charts or drawings, they are not appropriate for applications which require frequent moving or changing of parts of an image. Raster scan displays can display hundreds of colors at once and resolution can be improved by increasing the number of pixels, the size of the memory, and the total cost of the system. Raster scan devices are very simple geometric figures. However, they have only limited capabilities for dynamic representations and generally require extensive memory and processing capabilities, although acquisition/operating costs may be less than for other types of displays.

Flat panel displays provide a combination of the storage tube retention capability with the selective erase feature of refresh units. Brighter, higher resolution displays are possible with better linearity and accuracy plus lower power requirements than provided by conventional CRT displays. Maps, drawings, forms, and text material can be superimposed on the display screen. Flat panel displays also provide needed compactness in work areas having limited space, but wider usage is restricted by limited display resolution, slow picture update, and higher cost than conventional CRT displays. Small flat panel plasma display devices are most useful for applications requiring low power consumption, high daylight visibility, and shock resistance, but are not likely to replace conventional display devices on a widespread basis during the next decade. Although high performance, high resolution, and fast response systems are costly now, further declines in logic/memory costs should increase the utilization of these devices, particularly the raster scan type.

Color is becoming more widely used in both soft- and hard-copy form. Many organizations are discovering that operators can perform tasks more readily in color than with black and white images. Color images attract the viewer's attention more quickly and distinguish among different types of information more clearly than black and white shapes. Several studies indicate that both productivity and accuracy improve when color is substituted for black and white images in performing common work tasks. One system now available, Color Calc, organizes data into rows, using color-coded data categories to highlight vital information and simple CRT commands to change or update information as needed.[1] A companion system, Colorgraph, utilizes colored graphs and charts to show relationships otherwise difficult to visualize.

[1] See Fred Colev, "Enhancing Comprehension with Color," *Mini-Micro Systems*, August 1981, pp. 139–144, for a more complete discussion of these systems.

The choice between mainframe graphics connected to intelligent or dumb terminals and standalone minicomputer systems cannot be made on the basis of cost alone. Mainframe graphics systems normally utilize a large computer with excess capacity. By operating in a distributed processing mode with one CPU driving several graphics terminals, the cost per station can be reduced considerably but performance may be degraded. Standalone systems provide independent operations, good response times, direct control, and more flexible location than mainframe systems. Standalone systems are appropriate when communications links from outlying locations to the central computer are difficult or impossible to maintain or when such systems will never be called on to produce outputs other than those for which they were designed.

Selecting an operating mode from among lease/purchase plans for in-house graphics system, using an outside service center, or utilizing a time-sharing service is not as easy as it might appear. Careful consideration should be given to such factors as the extent of computing and financial resources available, adaptability of software provided, amount of flexibility available, degree of commitment involved and extent and complexity of applications processed. An effective, efficient approach is to begin with a limited commitment of resources and expand gradually as experience is gained in graphics use.

Two kinds of intelligent terminals are now emerging: sophisticated, complex manipulation devices and standalone work stations. Voice recognition and touch-sensitive screens can now be incorporated into lower cost units. Intelligent terminals will require additional memory and processing capability to provide the clarity and precision required to produce bar graphs and pie charts for presentations. As costs decline, intelligent terminals will increasingly be expanded into management work stations with local file management, data entry, and production of status reports in color graphic form. Graphics software will also become easier for nontechnical people to use.

The appearance of user-friendly terminals should make operators happier, safer, and more productive. A well-designed, human-engineered graphic system can save both time and money in drafting, product design, information display, or system control. A good system consists of proper hardware, effective software, and a carefully designed human interface—all of which will increase system development costs. Other factors may take precedence over ergonomic considerations in many cases. A recent survey of 3000 users ranked price, maintainability, and availability higher than human factors, sales support, and styling, providing evidence that hardware/software efficiency, and economy are still regarded as important.[2]

Three major uses of business graphics are for management analysis, reporting, and presentation. In the analysis phase, graphics representations of numeric data are frequently developed. A picture or drawing can be modified or redrawn many times until the desired form is obtained. The user must select from a variety of formats and graphic types to meet individual application requirements. Graphs can be used to

[2]See David Whieldon, "The Newest CRT's: Graphics Aid More," *Computer Decisions*, August 1981, pp. 90–122, 148–152, for a detailed discussion of current developments in display devices and usage patterns.

compare multiple elements on a single graph, to highlight trends over time, and to pinpoint opportunity or problem areas. Increased user productivity, more effective problem solving, and reduced task accomplishment often result from utilization of computer graphics for business analyses.

In reporting information using computer graphics, it is desirable for users to be able to store and update data without having to re-input the same data. They must also determine how report outputs are to be handled and if data is to be tabulated alongside pictures. If hard copy is needed, it should be made available at a reasonable cost, with good quality results, and in adequate quantities. Graphic outputs can be used to report progress up the organization and down the hierarchy as a communicating and reinforcing tool for highlighting performance.

One of the most popular uses of computer graphics is for management presentations. Graphic images can be reproduced with speed and accuracy in the form of paper, acetate, or slides. Users must decide how outputs from analysis and added material should be incorporated into presentations. Text, numerics, and graphics can be merged into one output if desired. Quality, color, clarity, and flexibility should be carefully considered in the selection of output devices and formats. Above all, graphic presentations often prove invaluable in monitoring, reviewing, and correcting performance.

CONTENTS

1

COMPUTER GRAPHICS: Getting More From a Management Information System

by Charles E. McEwan

ABOUT THE AUTHOR: Charles E. McEwan is president and chairman of the board of Ramtek Corp. Ramtek is a pioneer in the field of computer graphics. It designs, develops, manufactures, markets, and services raster scan computer graphic displays, a high percentage in color, which convert computer-generated data into visual images on a video display, printer/plotter, or large screen projector.

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Overview

William C. House

In his article, McEwan emphasizes that computer graphics systems are superior to tabular printouts in tapping the human brain's capacity for nonverbal perception and in more fully utilizing visual channels. Faster perception, more vivid display of data relationships, and simplicifaction of complex data via contrast is possible with the addition of color to graphics systems. Some studies indicate color images may provide five times as much information as black and white displays, will allow detailed examination of solid three-dimensional images, improve pattern recognition, and stress important over unimportant information.

Trends and concepts are more easily presented in graphical than tabular form, highlighting successes, failures, and problems summarized from tabular printouts. Often revealed are patterns not so easily seen in columns of numerical figures. Supporting details can then be gleaned from tabular reports to provide more data about exceptional items rather than vice versa. Graphic outputs permit more effective, concise management presentations, and, in areas such as financial planning, permit combining historical and forecast data to produce projections as a basis for future action.

Storage tube displays, one of the earliest of the major technologies to be introduced on a widespread basis, require only a small memory, have high resolution, and are relatively low cost to acquire and operate. They are limited by short tube life and operators may experience visual problems in low-level room lighting, making such displays unsuitable to interactive applications requiring extensive equipment use, sizeable data storage capacity, and good lighting for prolonged individual viewing. Stroke-writer displays, on the other hand, are brighter, having higher resolution, and permit easy image modification and rotation. With the addition of a beam, limited color is possible, but there may be some problems with image flicker. The stroke-writer display equipment is more suitable than storage tube units for interactive applications requiring frequent, fast image modification for information reporting and design purposes.

Raster scan technologies are expected to increase from one-third to two-thirds of the total market for display devices by 1982. Although more costly than other types of units, these are the only types offering virtually unlimited colors. Further impetus to the expanded use of raster scan devices is likely to come from the results

of studies which indicate that color images provide considerably more information to viewers than black and white images. Raster scan units utilize either pixel-addressable or character graphics. Color images with a multitude of colors are possible using either eight standard colors or a user-selectable palette. Pixel-addressable graphics employs every point on the screen, permitting flexible object positioning with a variety of color schemes. Character graphics addresses only a block of pixels or character matrix. While not as costly and complex, character graphics has less flexibility than pixel graphics and is best suited for such simple images as bar charts and block diagrams. The number of pixels used in graphics systems largely determines the quality and amount of information presented.

A number of system options are available to meet various user needs and budgets in terms of color, resolution, independent vs. dependent systems, input/output devices, and software. Colors may be limited or unlimited and resolution low or high, depending on the cost and complexity of systems selected. Users often begin with low-cost, simple, and inflexible graphic terminals connected to centralized systems. As the number and complexity of graphic applications increase, standalone systems with greater capabilities become more feasible. Input devices available include keyboards, graphic tablets, joysticks, trackballs, and light pens, while output devices can take the form of display screens, photographs, films, and paper copies. One of the most important user decisions is whether to develop in-house graphics software or purchase software packages from outside vendors.

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WHY GRAPHICS? THE HUMAN BRAIN'S VISUAL CHANNEL HAS THE POTENTIAL TO UNDERSTAND 30-40 MILLION BITS OF INFORMATION PER SECOND.

Any organization that has developed a Management Information System (MIS) will agree that the ever-growing diet of computer-printed statistics has given rise to the new malady of "information indigestion."

For the manager who must make decisions from a mountain of data, the value of the information is directly proportional to its understandability.

Companies have become very efficient at gathering data and storing it in the computer. But getting the information out again in a usable form and disseminating it to the appropriate decision-makers has become an immense problem. Historically, computer output has come in the form of paper printout—by the yard and the mile. The sheer volume of data contained on paper is the biggest problem for MIS managers.

COMMUNICATING THROUGH GRAPHICS

Computer graphics is an effective solution to the problem.

By tapping the human brain's vast capacity for non-verbal perception, computer graphics can communicate as much as 100,000 times more effectively than statistical printouts alone. Recent studies of visual perception indicate that "a picture is worth a thousand words" seriously undervalues graphic communication.

Information conveyed only via printed messages dramatically underutilizes the visual channel (the eyes, optic nerves and visual centers of the brain). Physiologists estimate the total capacity of the visual channel at 30-40 million bits of information per second. Assuming an average of seven bits per character and five characters per word, the capacity of the visual channel is, therefore, equivalent to 48-72 million words per minute. But most humans read at only 600 to 1,200 words per minute.

It's easy to see, then, why graphics is much more effective than alpha-numeric printouts.

Going one step further, the addition of color makes communication even faster. Color provides clarity and impact; it highlights, separates, defines and associates information on the screen. Relationships are vividly displayed and complex data are simplified through color contrast.

SELECTING THE RIGHT SYSTEM

As in any management decision, a computer graphics system should be chosen only after all the options are considered. Three display technologies are applicable to business graphics: Storage tube, stroke writer and raster scan.

In the storage tube, the first technology used for computer display, an electron beam slowly pencils in a light green picture against a dark green background. Because the face of the tube is used to store the image, very little memory is required. Unfortunately, a change in any part of the image requires that the entire image be redrawn. Therefore, while it permits very high resolution on the screen, the storage tube is unsuited to interactive situations and requires subdued room lighting. Tube life is relatively short and replacement is expensive.

The stroke writer can be described as a storage tube made brighter and given interactive capabilities. Instead of storing the image data on the CRT screen, the stroke writer uses a memory non-intensive computer listing to generate the image. This permits easy modification of selected portions of the image and facilitates image rotation and other dynamic functions. For considerable added cost, a beam penetration tube can be used to provide a limited palette of three colors. Very high resolution is possible, but as the presentation becomes more complex an annoying image flicker appears on the screen.

Raster scan technology is the familiar color TV image, refined for the more sophisticated demands of business, industry and research. An electron beam scans across and down the screen, turning on and off at selected points. Because the raster display screen uses three colors of phosphor, like a TV screen, it can provide the user with an effectively unlimited palette of colors and gray-scale values. Because every point of the screen is scanned, solid objects are also possible. Furthermore, image intensity can be varied easily for a broad range of brightness levels.

Within raster scan technology, two distinct types of system are available—pixel-addressable and character graphics.

PIXEL-ADDRESSABLE GRAPHICS

A pixel-addressable color graphics system can display each point on the screen (called a picture element or pixel) in a different color. Characters, graphs and pie charts can be positioned anywhere and in any orientation on the screen and colored at random.

With a character graphics system, color can be addressed only to a block of pixels or character matrix. This is suitable for bar charts or block diagrams, but offers less flexibility in comparing overlaying graphs and trend lines in different colors on one display. Thus the system's usefulness in day-to-day situations is severely limited.

RASTER SCAN TECHNOLOGY

The most significant recent trend in computer graphics is the move to raster scan technology. Currently accounting for about 30 percent of the graphics terminal market, raster scan is expected to have a 66 percent share by 1985–dominating a total terminal market of approximately $1 billion.

The most important reason for this move to raster scan is color. Raster is the only technology which offers an effectively unlimited palette of colors and gray-scale values. Studies have shown that bright, easy-to-read color images provide five times more information than black-and-white images. Color provides a coding mechanism for separating information, emphasizes important information by drawing attention to it, enhances human pattern recognition and adds appeal and naturalness to the data presented.

Raster scan technology also lets the user put complete, solid pictorial images on the display screen in three-dimensional form. These images can be modified easily without erasing and starting from scratch. The user can scan a complete picture, or zoom in on a small detail for minute examination.

SELECTING OPTIONS

After selecting the right graphics technology for a given application, the user still has an array of system options from which to choose: Color, resolution, terminals v. standalone systems, input and output devices and software.

- There are two approaches to color: A system with eight standard displayable colors or the "palette" approach, which allows the user to select the displayable colors from a larger number (usually 64).
- Resolution–the number of picture elements (pixels) on the screen–has a direct bearing on picture quality and the amount of information displayed.
- Color graphics can be implemented by the addition of interactive terminals or by standalone systems.
- The most common input device is a keyboard. Information can also be entered using a graphic tablet, joystick, trackball or light pen.
- Output takes many forms: The display screen (or a larger screen), photographs, film, transparencies, slides or plain paper.
- A basic software package is part of the equipment from the manufacturer. Specific applications software is either developed by the user company, or purchased from an independent vendor.

COMPUTER GRAPHICS AS A MANAGEMENT TOOL

Computer graphics serves the function of taking columns of numbers from a computer and translating them into pictorial form—easily understood graphs and charts from which trends and concepts can quickly be deduced. A highly flexible alternative to long lists of often-confusing tabular information, graphics lets management view data on a display screen or as hardcopy available in a variety of formats: Photographs, 35mm slides, overhead transparencies, 16mm film and printed paper. This is not to say that computer graphics will make tabular information obsolete. On the contrary, traditional printouts will continue to be useful in supplying supporting detail while computer graphics takes over as management's primary source of decision-making, financial planning and presentations.

Computer graphics facilitates decision-making by summarizing tabular printout into a visual form. The manager then can analyze the data, without having to sift through stacks of paper. For example, a manager can receive a monthly packet of computer-generated charts that, for each division, compare sales and earnings, show past performance and make corporate projections. Problems and successes are highly visible.

Using computer graphics in financial planning allows management to combine historical and forecast data, and to manipulate that data to determine future action. As a result of predicting sales trends, for instance, management can revise production schedules to insure that output is sufficient to meet the estimated demand for products.

Presentations also are an effective use of computer graphics. They can be straightforward (tables, charts, graphs) or complex (using animation). Going back to the premise that a picture is worth a thousand words, it becomes evident that management can reach and educate its audience most effectively through computer graphics.

WHAT NEXT?

According to a study done by Strategic Business Systems, Inc., the market for computer graphics is expected to grow from $1.4 billion in 1981 to more than $4 billion by 1985. Of this market, 46 percent will be dominated by computer-aided design (CAD) applications, compared to only 15 percent for business applications. The study states that although the long-range potential for business applications is greater than that for CAD, the growth of the business market will be held back by a lack of available software.

Graphics software falls into two categories. Software that provides the basic graphics capabilities (i.e., routines for drawing circles, polygons, graphs and text) is a part of the equipment as it comes from the manufacturer.