Has computer graphics come of age? Yes—several times, with more companies, better technology, and lower costs each time.

A Brief, Personal History of Computer Graphics

Carl Machover
Machover Associates Corporation

A formal history of computer graphics needs to be written—one that recognizes the people, the companies, and the events that have led to today's $1.5 billion industry. The history should be researched, footnoted, complete, and accurate.

This article is not that history. This is a personal history of computer graphics—one observer's perception of the field in which he has been involved for the last two decades. In this "memory dump," aided by notes, conversations, and old files, I may confuse or mistime events, inadvertently omit important work and important people, and reach "gut" conclusions that perhaps could not be substantiated by rigorous analysis; but with these cautions in mind, let's proceed.

The beginnings

One way to look at the history of computer graphics is to look at eras, giving each era a name. For example, the middle 50's to the early 60's was the "beginnings" era. The early 60's to the late 60's was the "gee whiz, look what aerospace and automotive is doing" era. The late 60's to the early 70's was the "let's form a new graphics company" era. And now, the middle to end of the 70's is the "everybody into the pool" era.

It could be argued* that the first computer graphics systems appeared with the first digital computers. MIT's Whirlwind computer had CRT graphic displays in the control room (Figure 1).

*Thanks to Peter Cook of Tektronix and J. O'Brien of Mitre.

Another early use of computer graphics as a man-machine interface was the SAGE air-defense command and control system of the middle 50's. SAGE converted radar information into computer-generated pictures. SAGE also introduced the light pen, which allowed the operator to select information by simply pointing at the appropriate target displayed on the CRT (Figure 2). I have never read anything that tells who invented the light pen, but the lore I am familiar with ascribes the invention to Bert Sutherland, recently of Bolt Beranek and Newman. (Bert Sutherland is the brother of Dr. Ivan Sutherland, about whom more in a moment.)

In a non-military environment during the 50's and early 60's, the TX1 computer at MIT featured a similar type of interactive graphics console. One of the early Digital Equipment Corporation interactive computer graphic displays, the Type 30, was modeled after the MIT TX1 system (Figure 3). Another early DEC development evolved from the Type 30 experience—the DEC338, introduced in 1968 and probably the first intelligent graphics terminal commercially available.

The middle 60's

A milestone in the development of computer graphics was the pioneering work of Dr. Ivan Sutherland, whose 1963 MIT doctoral thesis describing Sketchpad[1] contained some of the seminal data-structure work laying the software-theoretical basis for computer graphics. (Later, in 1969, Dr. Sutherland and Dr. David Evans formed the Evans & Sutherland computer company to produce computer graphics equipment.)

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Figure 1. Portion of Whirlwind computer control room (1953). (Photo courtesy of Mitre Corp.)

Figure 2. Experimental Sage operator consoles. This may be the first use of the light pen in computer graphics. (Photo courtesy of Mitre Corp.)

Also around 1963, MIT's Steve Coons* began developing surface-patch techniques, ideally suited for computer-graphics modeling. Another historically significant graphics program began independently at General Motors. DAC/1 (Design Augmented by Computer) evolved into a major computer-aided design effort, which has become a key element in the design of GM cars and trucks (Figure 4). (Ed Jacks and Don Hart had key roles in the GM effort.) The DAC/1's IBM Alpine Display evolved into the IBM 2250 graphics console, which was introduced with the IBM System/360 computer series in 1964.

At about the same time, S. H. "Chase" Chasen put together a team at Lockheed-Georgia to investigate the use of computer graphics for NC part programming, Lockheed's first effort in computer graphics.

Itek's Digigraphic Program was also proceeding at the same time as Sketchpad and DAC/1. Under the influence of Thurber Moffett and Norm Taylor, the Digigraphic product became the basis for Control Data Corporation's interactive computer graphics line, which subsequently evolved into a variety of systems.

The early-to-middle 60's was a fertile period for computer graphics. By October 1966, even the *Wall Street Journal* recognized the activity, and wrote about computer graphics and computer-aided design. Major US aerospace corporations like Lockheed, McDonnell-Douglas, and Boeing began to explore the use of computer graphics for aircraft and missile design. IBM organized a program called Demand, and worked with Lockheed, McDonnell-Douglas, North American Rockwell, Rolls Royce, and TRW in an effort to evolve computer-aided design and, ultimately, computer-aided manufacturing techniques. Demand may have influenced the design of McDonnell's CADD and Lockheed's CADAM computer-aided design and manufacture programs.

Figure 5 shows David Prince's[2] perception of the technological milestones that led to the development of computer graphics during this period.

*Now at the University of Colorado.

Figure 3. Digital Equipment Corporation Type 30 display (early 1960's). (Photo courtesy of Digital Equipment Corp.)

Display and computer graphics professional societies were also being formed during this time. The Society for Information Display was founded in 1963. The ACM Special Interest Committee for Computer Graphics was formed in late 1966, and

Figure 4. General Motors DAC/1—Design Augmented by Computer—installation. (Photo courtesy of GM Research Laboratories)

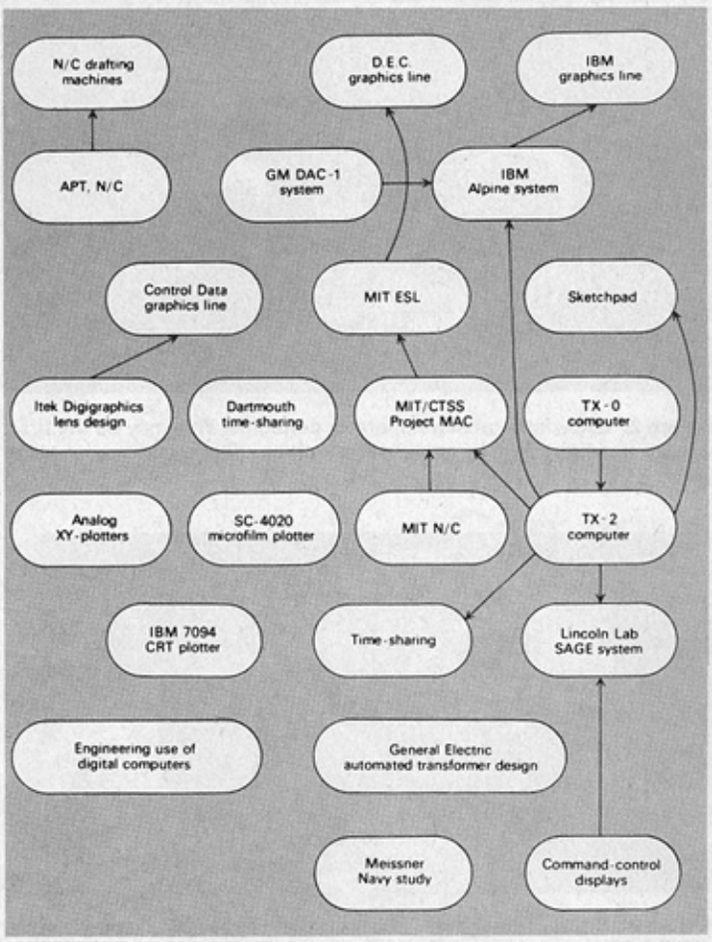


Figure 5. Technological milestones leading to computer graphics. (Figure courtesy of Addison-Wesley Publishing Co.)

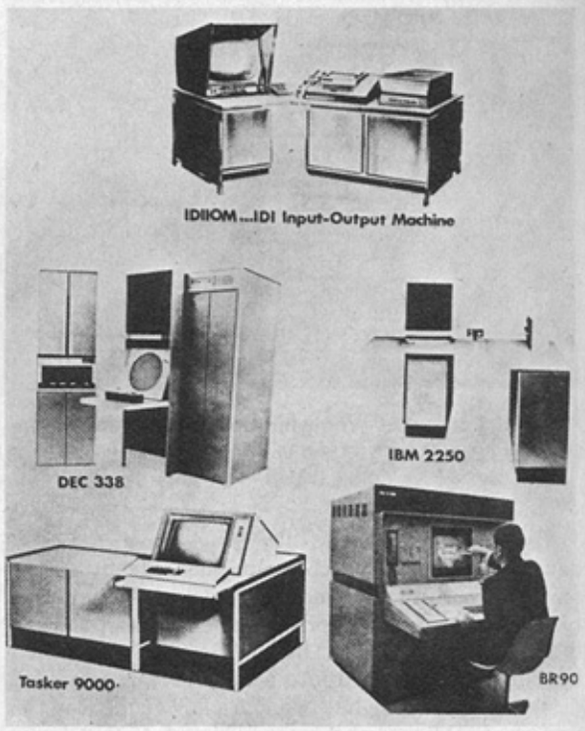


Figure 6. Typical computer graphics terminals of the mid-1960's. (Photo courtesy AFIPS)

became a Special Interest Group—SIGGRAPH— in 1969.

In the middle 60's, manufacturers of commercial CRT graphics terminals included

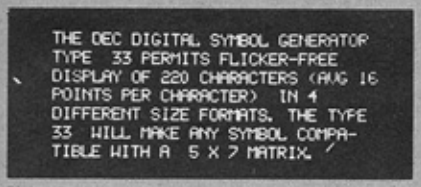
Bolt Beranek and Newman
Bunker Ramo
Control Data
Digital Equipment
Ferranti
Information Displays, Inc.
Information International, Inc.
IBM
ITT
Philco Ford
Sanders
Scientific Data Systems
Stromberg Carlson
Systems Engineering Laboratory
Tasker Instruments
Univac

Some typical consoles of this era are shown in Figure 6. It is of some interest to note that of this group, CDC, DEC, IDI, III, IBM, and Sanders still offer such products. That list is now supplemented by another 30 or 40 manufacturers of graphic terminals, plus an additional 70 or more companies that offer a variety of input and output devices, complete turnkey systems, and services.

In the early 60's, "computer graphics" was by no means the universal term for the technology. Devices were called electronic displays, computer controlled displays, information displays, and evaluated data displays. The British called their displays "VUBU"—visual unit back-up!

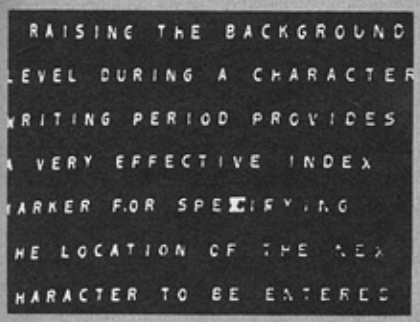
About 1961, Data Displays, Inc., offered a graphics terminal whose performance was not unlike those available today. In order to get high speed and high data content, the system used transmitter vacuum tubes as the deflection drivers. The founder of the company, Malcolm McCauley, used to point out that there was already a vacuum tube in the terminal (the CRT), so why worry about another tube or two! Data Displays was ultimately acquired by CDC, and Malcolm McCauley ultimately went to Australia.

One of the prime hardware issues in the early 60's was how to generate characters and lines on a tube. In 1964 I wrote, "At last count there was some 25-30 different manufacturers of character generators or other character generating systems."[3] These included beam-forming techniques involving tubes manufactured by General Dynamics and Hughes, dot raster systems offered by DEC, Ford, Hazeltine, IPC, ITT, LFE, Philco, and Teleregister, and line raster systems offered by CBS and Raytheon. A special and rather popular kind of line raster using a monoscope was available from A. B. Dick, Electrada, and Avco.

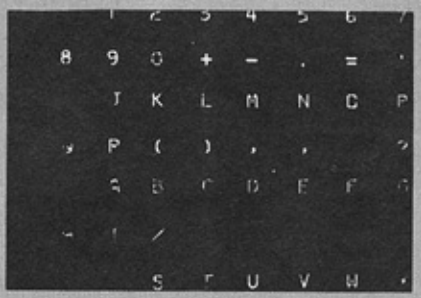


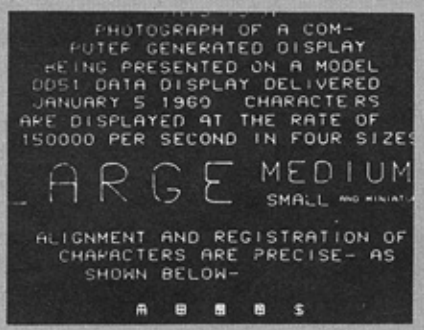
Digital Equipment Corp.'s dot raster generator.

CBS Vidiac line raster character generator, analytic type.



Analog line raster character generators, A. B. Dick (above), and Electrada (below).





Marconi (top) uses generalized Fourier techniques. Straza (middle) uses programmed dots as does DDI (bottom). Difference is that Straza intensifies beam as it reaches the dot, and DDI leaves beam on.

Stroke type generators.

Figure 7. Typical early 1960's character generators. ("Actual, unretouched photos," as the expression goes.) The upper righthand characters came from the IDI Curviline stroke-type generator. The middle righthand characters came from the Contronics-Sand stroke-type generator.

Various kinds of analog character generators were also available. Some, which used line-following techniques (using masks of a CRT), were available from Skiatron and Philco. More common were the stroke and dot signal generators, which were available from companies like DDI, Contronics, IDI, Marconi, Marquardt, Raytheon, Skiatron, Strand, Straza, Wang Laboratories, and Wyle Laboratories. You know you're an "old-timer" in computer graphics if you recognize more than about half those names!

Figure 7 shows some of the typical character-generator outputs. These character generators cost in the range of $2000 to $10,000. The point of recalling this 15-year-old technology is to emphasize the comparison with today's raster-character chip, which sells for under $50. Computer graphics has benefitted from the shift in technology.

Storage-tube displays

Although Tektronix is now synonymous with (and is practically the sole supplier of) storage-tube display terminals, it is worth remembering that "way back" in 1965, Bolt Beranek and Newman offered the Teleputer terminal using an early 5-inch Tektronix storage tube (Figure 8). Further, Tektronix was not the first company in the marketplace with the larger storage-tube terminal. That honor is shared by Computer Displays, with their ARDS terminal (Figure 9), and Computek, with their 400 Series terminal (Figure 10). These first systems, which came out in about 1968, used the Tektronix 611 6 x 8-inch storage tube and offered terminals in the $12,000-$15,000 range. Tektronix then entered the marketplace with the T4002A at about $9000,

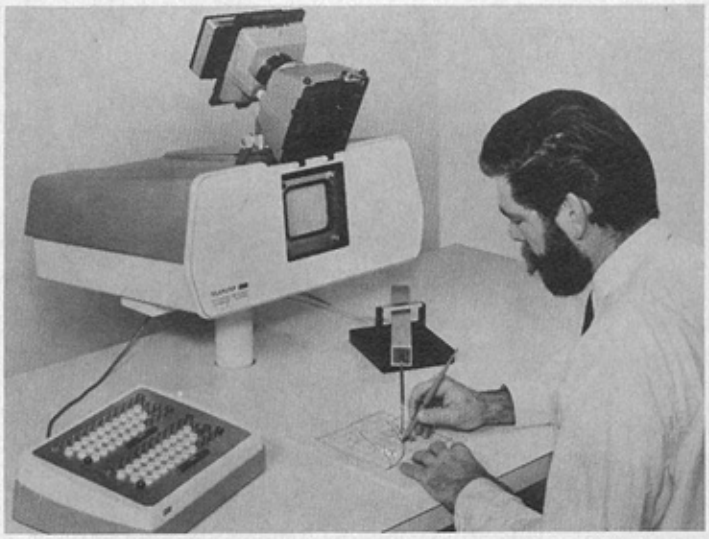


Figure 8. BBN Teleputer, an early system using a 5-inch storage tube. (Photo courtesy Roland Bryan, Associated Computer Consultants)

Figure 10. Computek, Inc., Model 400 storage tube terminal. (Photo courtesy of Computek)

followed by the 4010 at about $4000 (Figure 11). With the introduction of the 4010, Tektronix was able to dominate the storage-tube display market and, to a large extent, the computer graphics market.

These storage-tube products succeeded in opening computer graphics to literally tens of thousands of new users. Prior to the introduction of the storage-tube terminal, users were faced with initial investments of $50,000 to $250,000 for hardware alone; the cost of software was extra (and usually indeterminate!). These early systems had cost-per-console-hour figures in the range of $50 to $250. The storage-tube systems had much lower initial costs and could be configured into systems that were costing in the range of $10 to $30 per console hour. Responding to this low-cost marketplace, manufacturers using other technologies (such as stroke-writing refresh tubes, scan converters, plasma displays, and digital TVs) began to offer terminals in the same low price range.

Figure 9. ARDS terminal manufactured by Computer Displays, Inc. First "low cost" storage-tube-based graphics terminal. (Photo courtesy of Adage, Inc.)

Figure 11. Early Tektronix computer graphics products. T4002A, lower righthand corner; T4010, upper lefthand corner; 4610 hardcopy unit, upper righthand corner. (Photo courtesy Tektronix)

Hardcopy devices

Hardcopy devices are an important element of computer graphics systems. An early workhorse was the CalComp 565 drum plotter (Figure 12), introduced in 1958. The Tektronix dry silver copier, Model 4610, offering a fast, dry hardcopy capability for under $5000, was a major contribution to the growth of computer graphics (Figure 11). Now, electromechanical plotters and electrostatic plotters in the same price range are available.

I've always been sorry that Larry Kamm's Typagraph* (Figure 13) never caught on. Although matrix printers and plotters are common now, this modified Teletype could plot 500 dots across the line and work well in the usual TTY environment—and in the late 60's no less! But the product's major contribution, I think, was covering the TTY beige with a lovely *teak* cabinet!

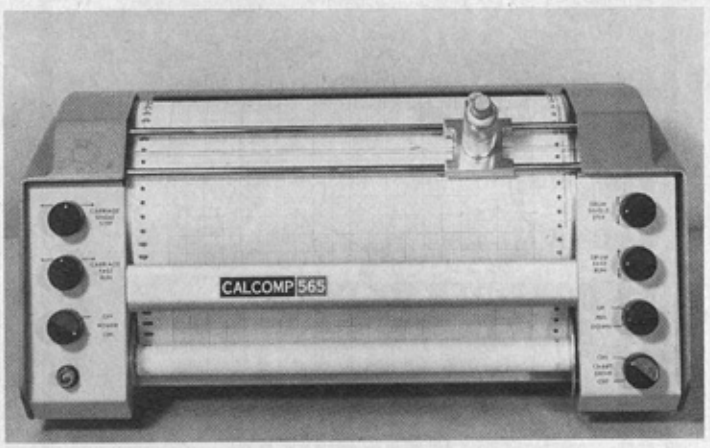


Figure 12. CalComp 565, an early digital incremental drum plotter. (Photo courtesy of CalComp)

Coming into the 70's

User input devices. In the early systems, these were limited primarily to keyboards and light pens, but they have been expanded to include low-cost graphic tablets, digitizers, and touch-sensitive devices. Incidentally, the early graphic tablet, called the Rand tablet or the Grafacon by most people, is sometimes called the Teager tablet by a small group who knew Herb Teager when he was at MIT.

Software. The growth we see now has also been made possible by rapid expansion of a wide variety of software packages. It was characteristic of early systems that once the user received the hardware, the burden of making the hardware work with a computer was pretty much the user's problem. That situation has gradually changed over the last decade, so that a wide variety of proprietary packages are available that simplify the generation of images, plots, and interaction. Since the early 70's, complete turnkey systems have become available that almost entirely isolate the user from software issues. The system is delivered to the user as a problem-solving device, capable of immediate application in the user's facility.

Growing pains. Through the 60's and early 70's, computer graphics devices were considered by many to be expensive toys that could be justified only by government agencies, the Fortune 500, and university research environments. Computer graphics was affectionately known as a "solution for no known disease," and seminars proliferated that asked the question, "Why is computer graphics always a year away?"[4-5]

Although computer graphics has apparently reached puberty several times, I think it's now well along in a very exciting continuing growth curve. However, apparently some people still ask that question. It's interesting to note that a recent article[6] entitled "Interactive Computer Graphics: Poised for Take-Off?" rankled at least one well-known worker in the field, Jon Meads,* former manager of IDS Computer Support for Tektronix, who wrote a very perceptive letter that was published in a recent issue of *Computer Graphics*.[7] Meads said in part: ". . .computer graphics *has* come of age—a few years back as a matter of fact. Computer graphics is a multi-million dollar industry. I estimate that there are over 100 corporations that receive a major portion of their yearly revenue from the sale of computer graphic hardware and software. There must be over 5000 people who earn their living supporting computer graphics through manufacture, sales, and applications thereof. SIGGRAPH alone has approximately 3000 members. To support this, there must be several tens of thousands of users."

Figure 13. Ad photo showing the teak-enclosed Typagraph plotting teletype. (Photo courtesy of Typagraph Corp.)

*Typagraph Corporation, San Diego, California.

*Now with Electroscientific Industries, Beaverton, Oregon.

In the late 60's and early 70's, a number of new computer graphics companies were organized. Listed below are just a few of these companies and the dates on which they were founded or on which they became active in computer graphics:

Adage (1965)
Applicon (1969)
Calma (1968)
Computek (1968)
Computervision (1969)
Evans & Sutherland (1968)
Houston Instrument (1968)
Imlac (1968)
Lundy (1970)
Megatek (1972)
Princeton Electronics Products (1969)
Ramtek (1971)
Science Accessories (1969)
Talos Systems (1974)
Summagraphics (1972)
Vector General (1969)
Zeta Research (1969)

The situation today

In an earlier article,[8] I estimated that there were probably no more than 100 graphics terminals installed in 1964. That number has grown to about 50,000 by 1977. The applications that I could describe in the 60's included computer-aided design in the aircraft and textile industries, management information systems, simulation, process control, computer-aided education, pattern recognition, graphic arts, and computer-generated movies. Graphics are certainly still being used in these areas, and market penetrations are considerably higher than they were in the middle 60's.

Computer-aided design now dominates the integrated circuit field. One recent market study[9] reported that almost 75 percent of all IC design activities are carried on with computer graphics systems. Management information systems are on the brink of explosive growth, I believe. With the recent introduction of an MIS product by IBM, Trend Analysis/370, plus the availability of low-cost color raster graphics, the conditions are right for a major expansion of graphics in that area. The process control field, including the SCADA—Supervisory Control and Data Acquisition—systems, are a major factor now for most utility companies.

Graphics applications in computer-aided instruction are developing somewhat more slowly than one would have expected. However, this application is very cost sensitive, and the appropriate hardware and software products are just now becoming available. One can expect a major expansion when the cost per console hour falls below $1.00. Pattern recognition and image processing are now beginning to experience the growth that was expected for them.

Afterword

Several bibliographies are available for further reading.[10-12] For a good flavor of the 60's technology, check the bibliography in *Computer Graphics for Architecture and Design.*[13] Professor Bert Herzog, director of the Computer Center at the University of Colorado, Boulder, has a group of early-60's computer graphics films that were given to him by Thurber Moffet. Herzog is willing to lend them to interested groups.

A final note. S. H. "Chase" Chasen, Peter Cook, Bert Herzog, Thurber Moffett, J. O'Brien, and Fred Aronsen were especially kind in sharing their recollections with me. There is a need for a detailed computer graphics history, and there is a need for recording the oral history as recalled by the computer graphics pioneers. Perhaps this is a project NSF, ACM, or IEEE might undertake. ■

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Carl Machover is president of Machover Associates Corp., a White Plains, New York, computer graphics consulting firm. He has been involved with computer graphics and display systems for more than 25 years. Before starting MAC in 1976, he was executive vice president of Information Displays, a company he helped found in 1960. During 1959-60, he was director of sales for Skiatron Electronics and TV, and from 1951-1959, he held several engineering and marketing positions with the Norden Division of United Technologies.

A member of IEEE, SID, and ACM SIGGRAPH, Machover was national president of SID and is a fellow of that society. Machover holds a BEE from Rensselaer Polytechnic Institute and has done graduate work at NYU.