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The Maturation of Computer Graphics

by William G. Nisen and William Randolph Franklin

THE MATURATION OF COMPUTER GRAPHICS

In the past two decades, computer graphics has come from laboratory esoterica to a tool with uses as widespread as any in data processing

by William G. Nisen and William Randolph Franklin

Computer graphics as a field of endeavor has come of age. No longer is it a technology in search of a market. Graphs, maps and diagrams drawn by a computer are ubiquitous, and no longer attract the special attention that they once did. This was inevitable, as we who believed in the value and power of computer graphics watched with mixed emotions the migration of computer graphics from the laboratory to the marketplace.

This is not to say that the field has become blasé and stagnant; in fact, just the opposite is true. It seems that there are very few data processing activities that have as excellent a future as computer graphics. But before an examination of the current and future status of the field is undertaken, it will be useful to reflect on the beginnings of the discipline.

Where and when it all started is hard to answer. The 1950s witnessed both the use of oscilliscopes as graphics devices and line printers to depict data point dispersal or the graphs of mathematical functions. One of the first major achievements was Ivan Sutherland's "Sketchpad," which introduced the concept of interactive structured graphics. Also of importance was General Motors' DAC1 system and the work undertaken by Lockheed. The role of NASA and the space program should also be credited for demonstrating the utility of computer graphics.

Today, computer-generated graphics can be found in myriad applications. It would be pointless to try and review all the uses, but brief mention will be made of the more important and less mundane areas.

Computer graphics has probably not been used more often than in the field of Computer Aid Design (CAD). CAD is an interactive means to efficiently design complex surfaces such as ship hulls, aircraft fuselages, and automobile bodies. The speed and flexibility offered to the designer results in prototypes which can be quickly visualized and tested. Thus, more time can now be devoted not only to esthetic demands but also to structural and safety constraints.

Civil and electrical engineers have found computer graphics to be an aid in finite element analysis and the design of integrated circuitry. The overall engineering utilization of computer graphics is increasing at a phenomenal pace in such widely separated branches of the discipline as pollution control and highway construction.

Probably the fastest growing application area is in the field of business graphics. Millions of dollars are spent annually to produce sales charts, allocation diagrams, and revenue graphs using traditional manual methods of drafting and reproduction. Today, with the help of computer graphics, almost instantaneous graphical representations of sales, expenditures, etc. can be produced at a fraction of the cost of more traditional approaches. Now with color display technology becoming an affordable reality, computer graphics will have an ever enlarging role in the area of business graphics.

With an ever increasing amount of data being collected, it is imperative to reduce this data to a useful set of information that can be quickly and accurately assimilated

As our lives increasingly depend on the surveillance and analysis of supply networks, such as electricity, water, and natural gas, computer graphics assumes a new and important function. Large screen displays now alert public utility officials to possible trouble spots which serve to avert many inconveniences and tragedies. This is especially true in the monitoring of mass transit systems, as in Washington, D.C. and the San Francisco Bay area.

Along different lines, computer graphics is now entering the realms of art and animation. Just as the computer has served as a new medium for musical composition, interactive color display technology is offering the artist a new palette from which to create. Computer assisted animation has made new techniques available to the film maker, witness *Star Wars*, *Battleship Galactica*, and the logos for the three major television networks.

Another newly recognized application area is computer cartography or map-making. With an ever increasing amount of data being collected, it is imperative to reduce this data to a useful set of information that can be quickly and accurately assimilated. This is precisely where computer maps can be of value since they capitalize on the computer's unique ability to manipulate voluminous data sets while displaying the resulting output in map form which man is then able to interpret and give meaning to. Uses can currently be found in environmental analysis, market research, and epidemiology.

The field of computer graphics initially had many technical avenues along which to develop; however, within a relatively short time a few dominant streams emerged. Every cathode ray tube (CRT) computer graphics device is either a raster or vector display. Every CRT is also either a storage tube or refresh tube. Of these four possible combinations, all except storage tube raster devices are now in existence.

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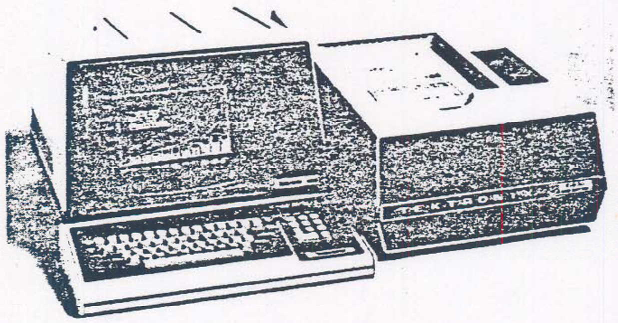
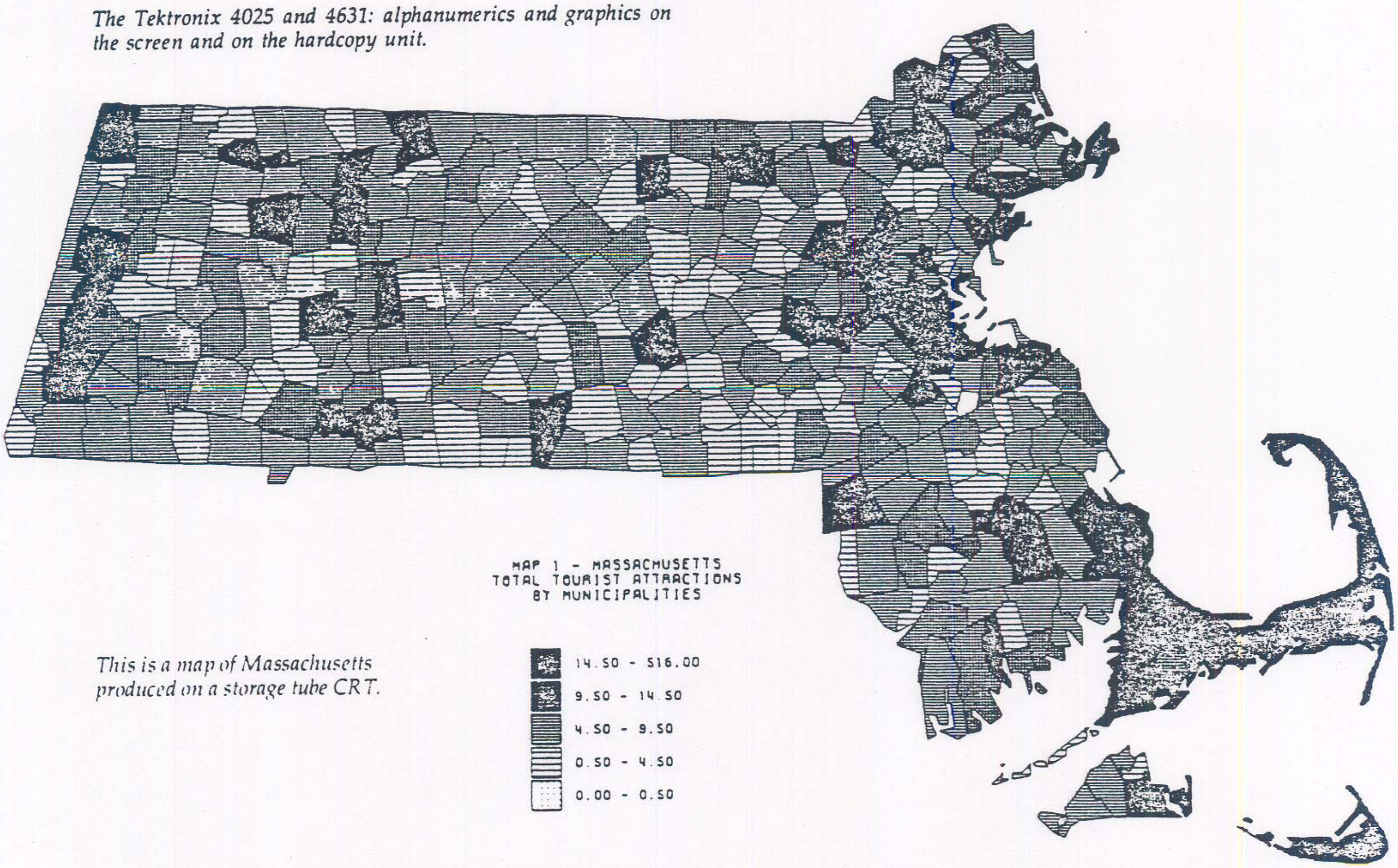
The first CRT graphics devices were vector refresh tubes. They allowed the user to rotate and edit the image in real time; however, to prevent perceptible image flicker the computer had to direct the CRT to redraw or refresh the image thirty to forty times a second. This requirement led to the development of an alternative display device, because refreshing was impossible in a timesharing environment which dominated predictions for the future at that time; and, as the image became more complex, more processing time was needed which often exceeded the one-thirtieth of a second constraint.

The storage tube CRT dispelled the onerous task of having to refresh the displayed image. With the good often comes the bad, and so it was with storage tube technology. By removing the need and hence the capacity to refresh the



The Tektronix 4025 and 4631: alphanumerics and graphics on the screen and on the hardcopy unit.



This is a map of Massachusetts produced on a storage tube CRT.

displayed image, the end user of the display system lost the ability to edit the graphic display in real time, since every deletion of a line or point could only be incorporated into the image by erasing the screen completely and redrawing the image. This proved to be a major obstacle especially at slow, *e.g.* 300 baud, data transmission rates.

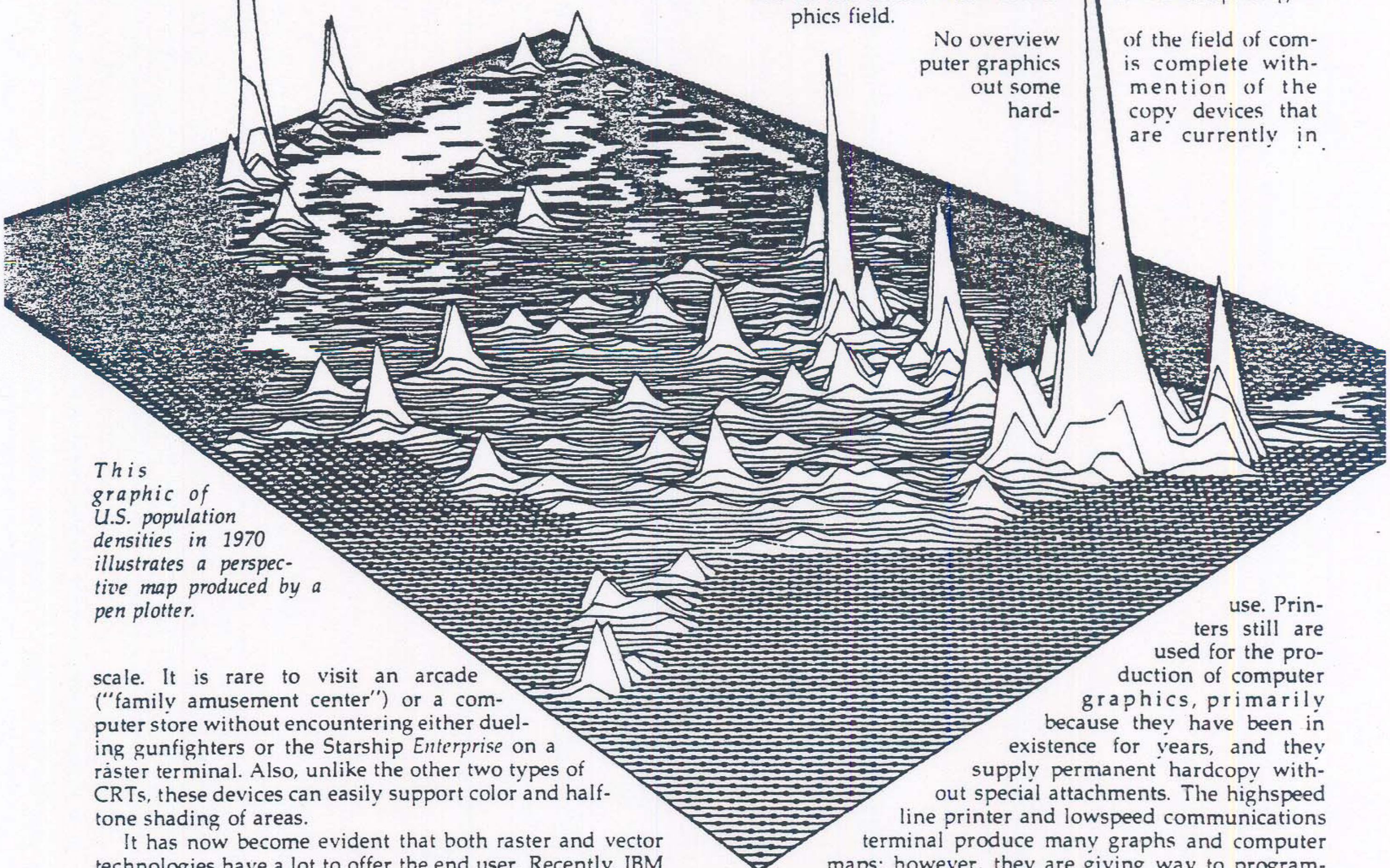
Clearly what was needed was a display device that could offer real time editing without being encumbered by refreshing increasingly complex images. The result was the refresh raster CRT which makes use of inexpensive memory and a local microprocessor to refresh the graphics display.

The raster refresh display is the most popular form of computer graphics display in the marketplace today. This is due in part to the wide price range of video display terminals with a preponderance of manufacturers offering numerous models at the low end of the price scale. It is rare to visit an arcade ("family amusement center") or a computer store without encountering either dueling gunfighters or the Starship *Enterprise* on a raster terminal. Also, unlike the other two types of CRTs, these devices can easily support color and halftone shading of areas.

It has now become evident that both raster and vector technologies have a lot to offer the end user. Recently, IBM has demonstrated its 3277 Graphics Station which is composed of a refresh as well as a storage tube in a master/slave configuration. High data transmission rates coupled with an abundance of local intelligence makes this system highly attractive to the graphics user. Tektronix is offering the 4025 raster tube which emulates a vector storage device. The uniqueness of this system is that one terminal appears to function in both capacities, and can scroll either alphanumerics or graphics.

Within the last few years a new, exciting development area has emerged. Color display technology, once limited to television engineering and some esoteric computer applications, is now extremely active. Computer-generated color graphics can be produced on a variety of output peripherals, e.g., multi-pen plotters, COM devices, jet ink plotters, and CRTs. Refresh raster displays dominate the color field due to advances first made in color television, and the ability with a refresh tube to change color almost instantaneously.

And finally, as with almost all areas of data processing, the microcomputer has done more to cause practitioners to reconsider their needs and budgets with respect to computer graphics. Microcomputers are making more people aware of the potential of graphics. This is being accomplished for most part by the orders-of-magnitude reduction of cost of the necessary hardware and software Micro- and mini-based graphics will be the future work-horses of the computer graphics field.



This graphic of U.S. population densities in 1970 illustrates a perspective map produced by a pen plotter.

No overview of the field of computer graphics is complete without some mention of the hardcopy devices that are currently in use. Printers still are used for the production of computer graphics, primarily because they have been in existence for years, and they supply permanent hardcopy without special attachments. The highspeed line printer and lowspeed communications terminal produce many graphs and computer maps; however, they are giving way to programmable dot impact printers and other new printing technologies, such as laser hardcopy devices. Nevertheless, impact printers will be with us for years to come.

Another traditional output device has been the plotter. Originally, the only available device was the pen plotter, but now the electrostatic models have a healthy share of the graphics marketplace. Plotters until recently offered the highest resolution of any graphics peripheral. And in many instances, they still represent the most economical means by which to obtain publication quality graphics. Not unlike its impact on programmable printers, microprocessing technology has made inroads into the plotter field, so now one is capable of programming pen changes, pauses and lettering fonts without relying on the host mainframe.

The development of high level graphics-oriented software programming languages has gained a momentum within the last few years...

Two of the newest and most exciting devices to be introduced to computer graphics output are computer output to microfilm (COM) and the jet ink plotter. The advantages of COM and other related micrographic products are primarily speed, reproducibility, and reduction in storage costs and space. The jet ink plotter has recently emerged from an experimental stage to fill a void with regard to the production of medium resolution color graphics in hardcopy format. The attraction of the jet ink plotter is its wide range of colors, and the speed by which the output is generated.

As is so often the case, software development seriously lagged behind the development and introduction of hardware technology. In fact, a lot of the blame for the overselling of computer graphics can be traced back to software and not hardware difficulties. Today, a lot of these types of problems have disappeared, but advances in software technology are still needed.

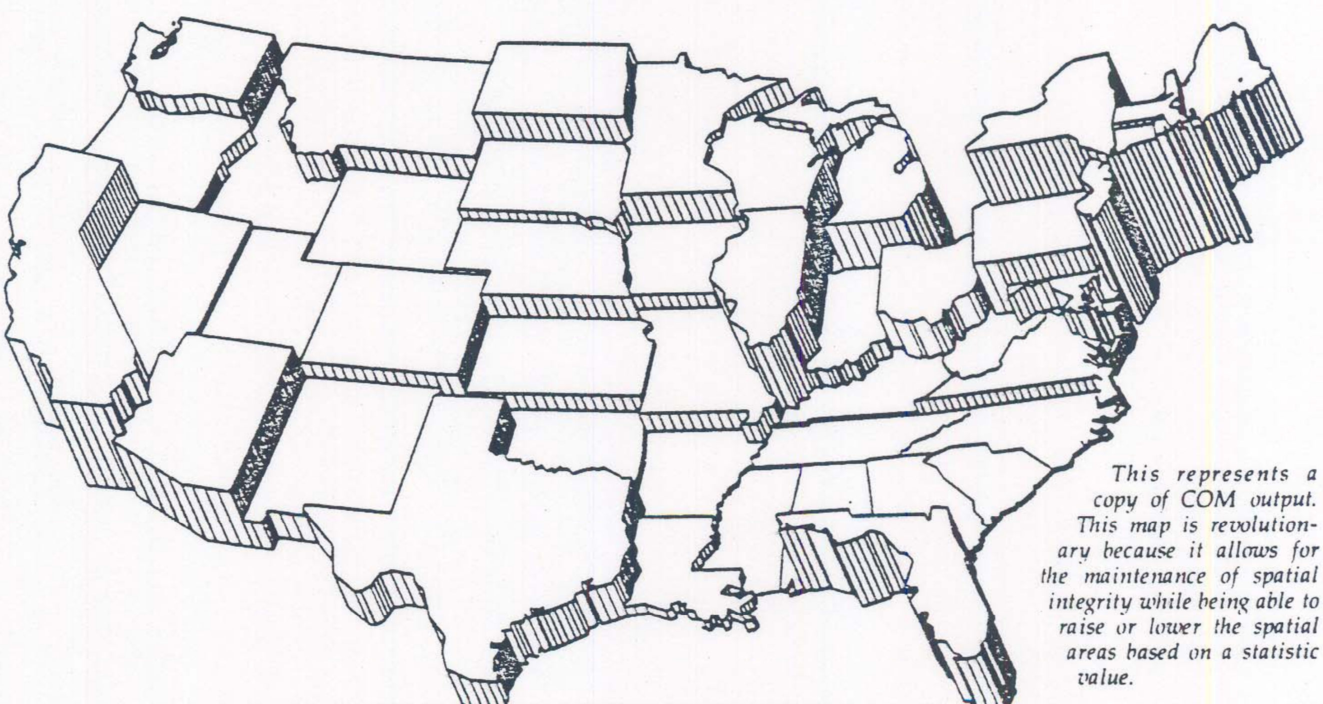
Necessary software for a minimal graphics package should be able to handle points and lines in two dimensions to accommodate the graphing of mathematical functions and the display of statistical graphics, e.g. histograms, trend lines. More elaborate software is needed to display surfaces and lines in three dimensions. The crucial obstacle to overcome in this context is the determination of hidden lines and the display (or nondisplay) of such. Initially, this task required the number crunching capability resident only on the larger mainframes. Once again, chip technology has helped to free us from this dependency.

It is also essential to have software to edit and transform graphical information. The transformations can be simply to rotate, translate, and scale the image, or as complicated as stretching, rubber sheeting, painting, and inverting individual components or subsets of the total image. Techniques such as these are absolutely essential in digital map production, especially when the source maps are distorted or at different scales.

Farther in the future, holographic displays will be made possible through computer control of the display process

The development of high level graphics-oriented software programming languages has gained a momentum within the last few years that will allow it to further enhance the field of computer graphics. One of the major factors that has facilitated this availability in beneficial software has been the decreasing price in hardware, most importantly memory. The availability of relatively cheap memory add-ons has removed the time-consuming process of developing overlaid code, and in additon has improved the computational efficiency of the various graphical algorithms.

What the future holds for computer graphics has always been a hotly debated issue, often fraught with disappointment and dashed expectations. Nevertheless, we can now prophesize with some degree of assurance that, first of all, computer graphics will become more commonplace as their

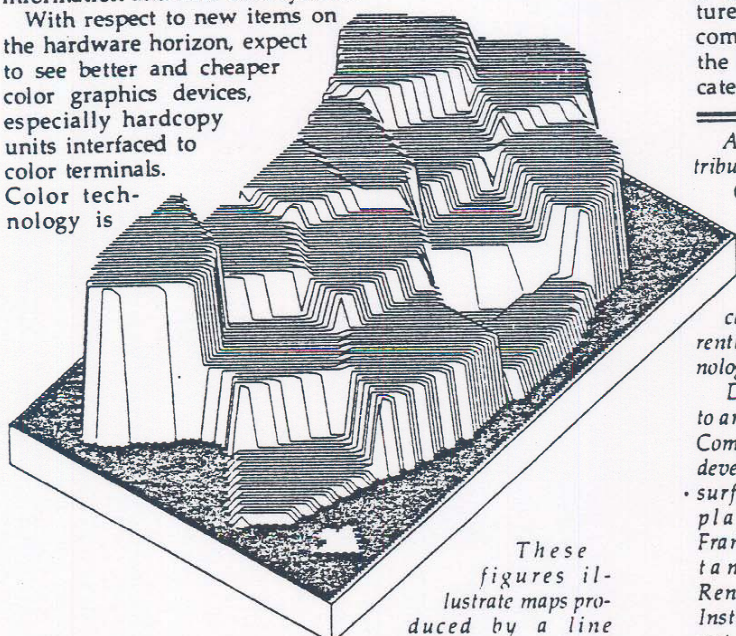


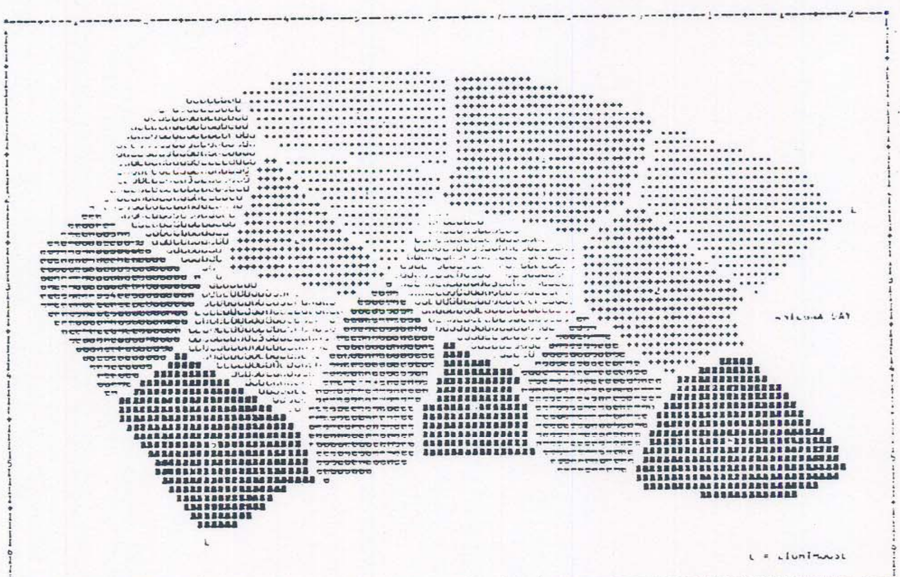
This represents a copy of COM output. This map is revolutionary because it allows for the maintenance of spatial integrity while being able to raise or lower the spatial areas based on a statistic value.

costs go down. No longer will they attract special attention or suspicion. More and more, the field of computer graphics will become end user-oriented, and the graphics will be used more frequently in a dynamic fashion during the analysis phase of a project, as opposed to "dressing-up" the summary statement. Along the same lines, graphics will find enhanced use in various physical and social simulation studies.

On a different front, more work will be going into the construction of graphic data bases, in particular cartographic data bases, and in the interfacing of graphics software with management information systems. Graphics modules will become as common as report generators in information and data base systems.

With respect to new items on the hardware horizon, expect to see better and cheaper color graphics devices, especially hardcopy units interfaced to color terminals. Color technology is on the verge of exploding much like the chip revolution of the early 1970s. Also worthy of note will be technological advances with regard to flat screens and plasma display tubes. Farther in the future, holographic displays will be made possible through computer control of the display process. Three dimensional display will be the logical extension of traditional computer graphics.





These figures illustrate maps produced by a line printer and a pen plotter.

In summary, the field of computer graphics can be proud of its accomplishments to date. Large, complex data bases are now more easily understood, with the analysts being able to call upon graphics in the form of charts, diagrams, and maps to help them in reducing redundant information, thus facilitating the reaching of conclusions. Computer graphics are also allowing engineers to design better structures and more efficient devices. And finally, the use of computer graphics will allow all of us to better cope with the information explosion, and to make better, more educated decisions.

About the authors — William G. Nisen is the director of distribution services for the Harvard Laboratory for Computer Graphics and Spatial Analysis. His chief responsibility at the Laboratory is the dissemination of information relating to the application and research in the field of computer cartography. Before coming to the Laboratory, Mr. Nisen had worked in the field of computer cartography applied to environmental analysis. He is currently involved with the application of computer graphic technology to the fields of epidemiology and public health.

Dr. William Randolph Franklin obtained his B.S.C. at Toronto and his Ph.D. at Harvard. He has been working for the Lab for Computer Graphics at Harvard as a senior research analyst developing algorithms for the implementing Three-D hidden surface geographic display programs. Dr. Franklin is now an assistant professor at Rensselaer Polytechnical Institute working on computer graphics and software engineering. **END**

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