

COMPUTER GRAPHICS IN ARCHITECTURE

AND ENGINEERING

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INTRODUCTION

Although the title which appears in the tentative program is "Computer Graphics in Architecture and Engineering", after hearing the first day presentations, it seems more appropriate to make some general comments. Thus, the content of this brief critique concerns three separate subject areas, related only by the fact that all are involved with interactive computer graphics.

COMPUTER GRAPHICS IN THE ARCHITECTURE PROFESSION

Unlike the aerospace industry, the architecture or building profession is, unfortunately, completely fragmented. Structural, mechanical, and site engineers are usually separately contracted by the architect who is directly responsible to the owner-developer. Generally, the builder or general contractor is not actively involved in the design process until the successful acceptance of a bid. Although a few of these builders might perform their own "quantity take-offs", they usually subcontract large portions of the shop drawing preparation to their mechanical, electrical, or concrete subcontractors. These subcontractors, in turn, might even further subcontract so that the steel fabrication drawings or concrete formwork drawings are prepared separately.

This segmented building process as it exists today prevents the economic utilization of computer graphics. Without the ability to rely on a common data base, the true potential of interactive computer graphics cannot be realized. As a result, much of the publicized work has been primarily involved with the implementation of an efficient drafting system, but is not "computer-aided design" in the real sense.

In order for the potential for interactive computer graphics to be realized, it will be necessary to de-emphasize the re-creation of drawings, and to concentrate on the effective use of a three-dimensional data base.

Only then can the structural, cost-estimating and energy analyses be efficiently automated, and as a by-product, the working drawings also produced. However, the implementation of this logical process depends, not on any technological breakthrough in interactive computing, but primarily on the ability to vertically integrate the construction process.

CORNELL'S PROGRAM OF COMPUTER GRAPHICS

Cornell University has recognized the far-reaching importance of the emerging computer graphics technology in many aspects of scientific research and design. The University has established a Program of Computer Graphics and has received substantial support from the National Science Foundation for:

- (1) the development of computer graphics techniques,
- (2) the utilization of these techniques to solve specialized and varied research problems, and
- (3) the improvement of interactive design methodology.

A substantial community of faculty, staff, and researchers have been assembled to generate a broad, interdisciplinary research thrust in this direction. The cross-fertilization of specialists involved in many diverse problem areas provides a unique opportunity for demonstrating the unexploited potential of computer graphics. Some of the examples of research presently underway at Cornell which, in one way or another, maximize or require the use of computer graphics techniques follow:

- (1) Through data received from ground-based radar, computer graphics techniques will allow for a graphic depiction of the topography of Mars and Venus.
- (2) The pollution analysis of lakes can be greatly advanced by two- and three-dimensional pictorial real-time displays of the spread and effect of pollutants. It is possible to predict and graphically generate the lake circulation patterns using finite element techniques.
- (3) The use of interactive graphics capability in geological sciences is assisting in the determination of the fault mechanisms in the zone where two plates collide based upon the spatial distribution of deep earthquakes. The data being used is already available through research being conducted near the Tonga Islands by Cornell University.

- (4) Cornell scientists involved in the space exploration of the planet Jupiter wish to see the complex, time-dependent geometry of the plasma and magnetic fields surrounding that planet. The graphic visualization of these magnetic phenomena, which are extremely difficult to envision, could influence the selection of future flight paths.
- (5) The advantages of interactive computer graphics in structural engineering, particularly finite element analysis of complex geometric shapes, are obvious and have been adequately discussed at this conference. We are using these techniques for complete graphic input, including algorithms for mesh generation, optimum nodal numbering schemes, and displaying the results.
- (6) Architecture, since the entire discipline is founded on spatial representation, can benefit substantially from interactive computer graphics technology. At the present time, we have implemented a graphics and analytic capability to perform certain functions of automated structural design, cost-estimating, and energy analysis for the building sector.

These are only a few of the many existing research applications using interactive computer graphics at Cornell. There are many more areas, including water resources and flood control, protein synthesis, archeology, demography, and animation where efforts using computer graphics are currently being formulated, and where similar benefits would occur. Fortunately, since the Program is a "technique in search of a problem", I have had a unique opportunity to find out how truly diversified Cornell University really is.

Our present laboratory system includes a Digital Equipment Corporation PDP 11/50 with disk and tape units, an Evans and Sutherland Picture System, a Tektronix 4014 with hard copy, a Versatek printer/plotter, several digitizers, and a link to the University's IBM 370-168.

The laboratory presently has the capability of generating dynamic, black and white, wire-line drawings or perspective images of two- or three-dimensional objects. Emphasis is clearly placed on the utilization of both graphic input and output devices. It has the capability of interactive graphical input as well as hard-copy plotted output. Photographic equipment for both film-making and single-image documentation is included.

We are presently operating 22 hours/day, 7 days/week, and thus we are changing to a multi-user system. Since we have a need for four- and five-dimensional displays, we expect to have color display capability by the end of the academic year. A frame buffer will permit the assembly, using software, of the ordered information required to generate a static, continuous color image. A large MOS storage capacity combined with random access writing will

allow the researcher the opportunity to test many of the existing or new algorithms for half-tone picture generation.

CORNELL IN PERSPECTIVE: A COMPUTER SIMULATION

A fifteen-minute movie was made four years ago by twelve dedicated architecture students and me working at the General Electric Visual Simulation Laboratory in Syracuse. Since General Electric was on an eight-to-five shift, we worked from five-to-eight, three nights a week, for a semester. The movie was filmed from a standard television raster-display using a hidden-line algorithm requiring substantial preprocessing on object space. The maximum number of colors was limited to sixty-four appearing on any single image, and thus neither edge smoothing nor smooth shading algorithms are included. The story depicts the chronological development of Arts and Science quadrangle of Cornell from 1865 to 1975.

GENERAL COMMENTS

More seriously, after listening to the presentations of the previous session, I have the following observations, or questions, relating to the current state of interactive computer graphics as it exists in the United States today:

- (1) What means can be found to improve communications between people working in graphics? Much of the significant research which is presently being conducted at laboratories and universities throughout the country is "discipline-specific." Gathered at this conference is a substantial segment of the aerospace industry, all of whom have recognized the commonality of their problems with respect to computer graphics. But the technology required in other disciplines is also quite similar. Some very sophisticated computer graphics software capability has been developed in chemistry, biology, pollution studies, artificial intelligence, and animation. Yet the medium for information dispersal is poor and the information transfer is minimal. In fact, at this very moment, many computer graphic experts are attending a computer graphics animation conference in New York City.
- (2) Why have computer science departments, in general, not recognized or accepted computer graphics or computer-aided design courses as part of their curriculum?

- (3) How can we have an industry which collectively represents more than a billion dollar investment in computer graphics and computer-aided design, and simultaneously have only a small number of universities producing less than a dozen trained graduate students in this area per year?

If we are ever going to improve our productivity and progress in this field, then the above questions must be answered first. I personally believe that computer graphics and computer-aided design have not yet reached their potential. Furthermore, the demand for trained graduate students in this particular field is inevitably going to increase. Thus, I strongly urge your support, both moral and financial, to encourage universities throughout the country to educate students in this discipline.