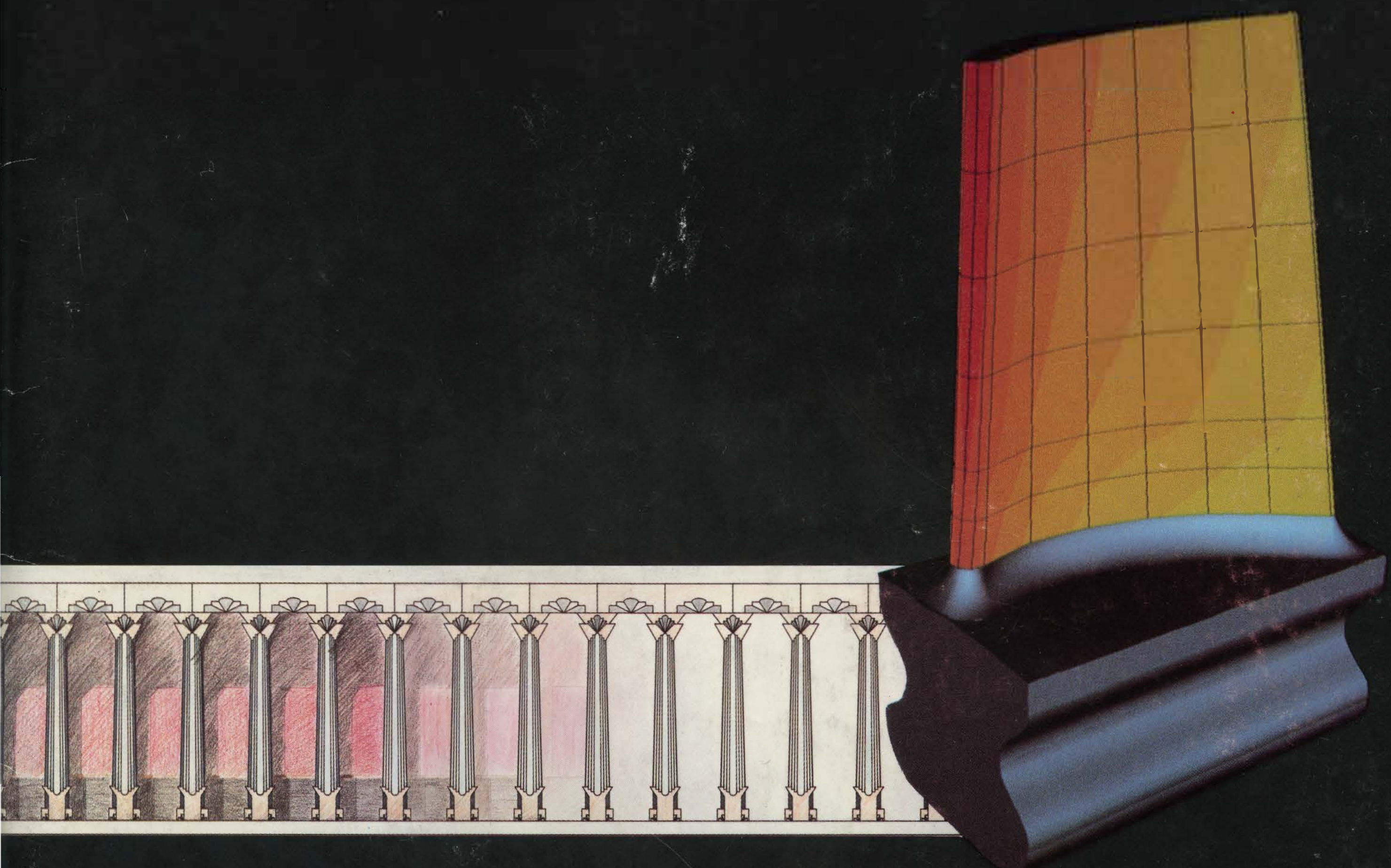
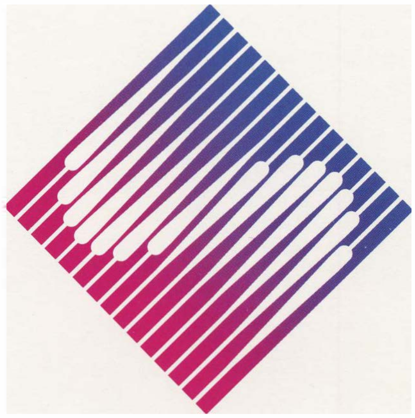
Computer Supported Design Exhibition

1984 SIGGRAPH Conference





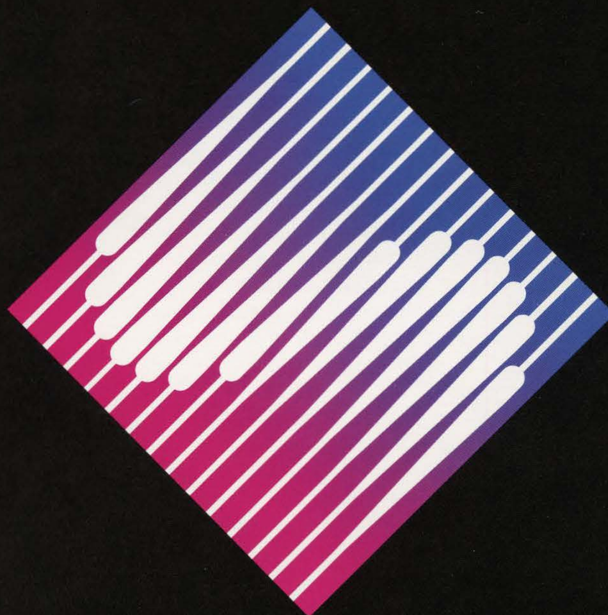
Computer Supported Design Exhibition

1984 SIGGRAPH Conference

As is clear to those who habitually attend the SIGGRAPH conference, the exhibition is different this year. In it are, among other things, a ski boot, a remote control device, hand-colored images of an arched doorway, and a computer game that explains machine logic. The common element uniting these seemingly disparate projects is that they demonstrate current applications of computers to design problems. In each of them the computer played a significant role in the design and, often, in production.

The point of view illustrated in the exhibition is that the computer will, as is so often said, serve as a tool in helping with various aspects of our work. More important, however, the computer is viewed here as having the potential for becoming a medium capable of altering our ways of thinking about our work. The exciting objective for computer-supported design at this time is to go beyond mimicking past media (as all new media do at their inception) and continue to develop processes and formal structures that are inherent to the computer's distinct characteristics.

Patrick Whitney, Chairman
Design Arts Exhibition Committee



Contents

Information, Computers and Design

Patrick Whitney

The Dilemma of the Specific and the General

In the Yucatan peninsula, corn is planted by Indian farmers in the same way it was done hundreds of years ago. The farmer wears a sack filled with seed slung over one shoulder. As he walks the field's rows, he uses a long stick to make holes in the ground into which he drops seeds. Although the stick is a simple tool, it is not naive. It has features that make it well-suited for its task: it is long enough so the farmer can make the hole without bending to the ground; and, the end of the stick is sharpened to a point to make the hole for the seed.

In some developing countries, one can still see people, like the farmer in the Yucatan, who are both the users and designers of their tools. In the industrialized world, the roles of designer and user have become separated. Though separate, the user-designer and the modern designer should share certain obvious concerns. It has always been the business of design to affect human experience and behavior by shaping elements of the physical world. Human artifacts such as buildings, cities, agricultural implements, industrial tools, books, and signs, are but a few examples of the items we make to support human survival, safety, comfort, communication, pleasure and rituals.

Craftsmen were, in a sense, precursors to today's designers. Craftsmen specialized in making needed goods for members of their immediate community. Unlike contemporary designers however; craftsmen physically made products; they developed expertise in manipulating tools and materials; and the things they produced both followed and reinforced the traditions and values of the communities in which they lived.

It was not until the Industrial Revolution that a complete separation between the tool-maker and the tool-user occurred. Rather than hand-producing everything for a particular person who requested it, the designer was paid by a manufacturer, developer or publisher, to specify the characteristics of artifacts made on equipment meant to make large quantities of identical products. The things he designed were for people he would never see. Not only was he separated from the users, he found himself writing and drawing specifications that would allow someone else to actually produce the item.

With economy of scale, the number of items produced were increased and individual consumers were transformed to become "the market" which grew continually larger. Producers found it economically advantageous to design for the average characteristics of a large number of users. This led to relatively low costs, and a trend for products to be *just good enough* to meet a wide number of needs. This meant in turn, that no mass-produced product could exactly match the needs or wants of a single person or group. Designing for a mass audience required a large number of compromises to be made in order to reach the level of average acceptability.

This has been one of the major dilemmas of design in the industrial age: how can one meet the needs of individuals when the central characteristics of mass production lead to messages, artifacts and buildings that are made for the average?

There is some differentiation in manufactured products. Of necessity, products come in different sizes; and, in any one general product type, there is variation in price. These variations match roughly the needs and wants of different segments of the population. But clearly, they are no more than crude gestures when contrasted to the "custom-made" work done by craftsmen for individual customers. The designer is left in the ironic position of professing concern for the user, while being restrained by mass production tools that allow him to design only for the average.

Of course, it is the economy of large production runs and other characteristics of industrialized society that has helped the Western middle class achieve its materially abundant life. The computer's capability to deal with specific details within a large amount of information allows one to consider producing more specialized artifacts.

Computers, communication systems, a highly educated population, and other contemporary developments are bringing about major structural and social changes. We are now at the beginning of an information revolution which is characterized by two major changes: the availability of a new **design tool** and a population living in a new **information environment.**

New Design Tool

The first change - one that speaks directly to the design dilemma - is the use of the computer as a design tool. Interactive design stations allow designers to explore far more alternatives than have been possible with traditional tools. Robotics and cyber-automated production processes are allowing both the economy of scale and a wide degree of variation in individual artifacts. Numerically-controlled printing presses and production equipment (see figure 19) are far more flexible than offset printing plates and metal production dies. The new flexibility permits alterations to be made in a product or publication according to the needs of an individual or a group. Changes are made by manipulating the information encoded in a computer database, which in turn, instructs and guides the machinery making the product.

In less technologically advanced production processes, information cannot be manipulated so simply; the information is not stored in a database, it is frozen on an offset printing plate, or in a metal production tool. As a result of the new technology, components for houses, products and printed pages can be altered to meet specific needs rather than average needs, while still being cost effective.

It is paradoxical that computer-supported design and a highly automated production process can restore the specialized design quality that was taken away by the Industrial Revolution. These are, after all, qualities we associate with phrases like "hand-made", and images of solitary craftsmen working carefully, laboriously, to perfectly execute every detail of their product.

To the designer, this design/production process offers the chance to design for the user in a way that has not been possible with mass production. But, for the time being, this remains only a potential use of the computer. For this much acclaimed new tool to achieve this potential requires the design process to take into account the needs of specific users. What is needed then, is an effective way to gather and organize information in a manner that helps lead to more intelligent solutions to problems.

Of course computers are ideally suited to helping designers analyze, organize and evaluate information. The analytical aspects of the design process, however, seem to be forgotten in all of the discussions about computer-supported design. It is here that the computer has a critical role to play. If one looks at the general divisions of the design process (defining the problem, research, idea development, forming the solution, production and evaluation), computer applications can be found to support each one.

Defining the Problem (analysis)

In complex problems such as the development of new lines of products, buildings, signage systems for complex facilities, or corporate identity programs, it is difficult to keep the factors of the problem in an order that allows one to see all of the relationships. There are computer programs that allow one to list the attributes of the various parts of a problem and restructure them into new relationships that lead to new insights about the basic problem.

Some of the most advanced work in developing computer-supported methods for structuring problems is being done by Professor Charles Owen at the Institute of Design, Illinois Institute of Technology. His computer programs are designed to break complicated problems into elements which can be reorganized into various structures. The designer evaluates the structures for appropriate and insightful relationships.

Research (analysis)

If doing research for a design problem includes gathering information and reorganizing it into useful components, then there are two main ways the computer can be used in this phase.

Gathering information can be helped by computer-assisted searches through banks of information. At its simplest level, this takes place through bibliographic searches directed by key words. As information about design accumulates and the cost of using these systems comes down it is likely that a computer information network dedicated to information about design will develop. The computer can also be used in a more basic information gathering mode called data capture. As its name implies, this technique does not gather information, but data, which through analysis, becomes information. Data capturing is used to monitor environments to develop information related to human factors such as temperature, humidity, sunlight, and noise levels. The same procedures can be used to monitor physiological characteristics such as muscle fatigue, heart and breathing rates, and eye motion. The quickness, patience, and objectivity of the computer make it a very desirable monitoring system.

Its usefulness is enhanced if the computer can also organize data into a meaningful hierarchy. By taking information from networks and data from the environment the computer can organize it into structures that relate to a problem.

Developing Alternative Ideas (synthesis)

This part of the design process is often characterized by drawing, building models, or trying alternate text/image relationships for printed materials. In this phase, the computer is used to quickly develop two-dimensional images of these alternatives. As with the computer industry in general, the cost of systems is coming down as the capabilities are increasing. As this leads to affordable systems that display relatively high quality images, it allows the designer to rapidly make, view, modify and review images. **It alters the process to one that combines the versatility of drawing and the speed of collaging.** The London Column (figure 2) is a good example of this. The sketching done on the machine produces images which can then be evaluated. Because the drawing can be done more rapidly, more ideas can be tried, presumably resulting in better, more appropriate solutions. This process is being extended into the design and production of products by connecting the database used for design to numerically-controlled milling machines which produce models and molds more efficiently than those done by hand.

A more current aid to the development of three-dimensional objects is solid modeling. This is a process in which an image can be displayed in three-dimensional perspective. Although these images do not look significantly different from perspective surface drawings, they are significantly different in that they can contain information about the material proposed for the product. The product can be tested for impact, wear, and user requirements by computer processes before it is physically made. The aluminum wheel design (see figure 18) is an example of this. In another example, architects can, using a computer, "walk through" environments they have designed before they are actually built, to see the structure from different positions and perspectives.

Forming the Solution (synthesis)
The same functions that allow one to view alternate images can be used to produce final working drawings, floor plans, elevations, typeset text, layouts, and enhanced photographs. The complex plans (figure 4) are a good example of this.

Production (synthesis)
Robots, laser printing and numerically-controlled manufacturing equipment can be guided in production by the use of the same database as that used in design development. This potential could eliminate a good deal of what lies in the middle area between design conception and design production. (This includes the people producing printing mechanicals, technical drawings and plans, and assembly line workers. Conversely, it also offers the potential of new design activities, particularly in the analytical areas.)

Evaluation (analysis)
The process of evaluating a completed message, product or space can be done by using systems similar to those used in the research phase. These would gather data, and organize it into a hierarchy relevant to, not only the design solution at hand, but to the entire field of design. The information gathered in such analysis can be used in building a body of knowledge about design issues that can be used in the future.

Information Environment
The second major change is that members of our society are living in an information environment. Evidence of the change is plentiful; for example, there has been an increase in the percentage of workers in knowledge industries and a decrease in manufacturing, mining and agriculture.

The shift in occupation is evidence of other broad changes occurring in society that have consequences for design. The type of work that people do has changed, their level of education has changed; and, not surprisingly, their tastes, and buying habits have changed as well. There is evidence, for example, that some consumers are willing to buy expensive items of very high quality while skrimping elsewhere. A consumer like this might have an $800.00 Italian espresso machine and serve the espresso in cracked mugs. Our hypothetical consumer may be isolated in his extreme devotion to espresso but he is not alone in having a highly sophisticated taste for a particular product. What is becoming increasingly clear about the information environment society is that its members have very discrete tastes and are segmented into small groups. Predicting the tastes, and desires of these consumers is difficult, if not impossible. To design for today's society one needs to have an understanding of the new patterns, and an understanding of the means of designing for it.

While today's society is radically different and more complex than yesterday's, we now have the quintessential tool for helping us respond to complexity.

With few exceptions, the use of computers in design has been limited to supporting the synthesizing phases of the design process. This is somewhat ironic because the computer gives us the ability to rapidly gather and analyze information; and the information environment is presenting us with a situation as complex and rapidly changing as mankind has ever faced.

The inherent advantage in using the computer as a tool is in increasing speed, not quality. The assumption that quality will follow is based on the assumption that the people producing the larger number of images will have the ability to evaluate them and make a choice about which is best to use. The use of this new equipment will certainly not be limited to designers and others with critical faculties. What is likely to happen is that in the hands of a good designer, computer graphics systems will allow him or her to do more good work. In the hands of others it will mean more visual garbage can be produced than the world has ever seen.

The central question facing the design field is not simply how to use these computer tools to produce solutions more rapidly; but to use computers and to gain a clearer understanding of what should be designed to fit the new context of the information environment.

What Good is a Computer to an Architect?

William Mitchell

What good is a computer to an architect? Palladio found pen and paper perfectly adequate, after all. And it is hard to imagine Frank Lloyd Wright at a keyboard. (It just doesn't go with a cape and cane.) The most sophisticated piece of technology on most architects' desks, even today, is an electric pencil sharpener.

The salesman for CAD systems will tell you that you can increase professional productivity by replacing drawing boards with graphics workstations, and they will probably quote impressive productivity ratios. They may be right. But it is notoriously difficult to measure productivity, in any meaningful way, in a service profession; and it is certainly absurd to apply the industrial notion of productivity to artistic activity (and I take it that architecture should be at least partly that) In any case, we have an oversupply of architects in most developed Western countries, and every year there are more people trying to get into the profession than there are places. It could be argued, as a matter of social policy, that it would be better to create employment opportunities by decreasing individual professional productivity.

You might take the view that achieving higher architectural quality, rather than doing projects more quickly and cheaply, is the proper end of computer use. That is an attractive ideal. But there is no extensive body of distinguished computer-aided architectural design work to point to - at least not yet. At best you can find a few isolated tours-de-force to offset the leaden banalities that many firms are proudly popping out of their shiny new CAD systems.

We will not, in fact, find the answer by looking for ways in which computers can perform traditional design functions more quickly, or cheaply, or thoroughly, or accurately, than a human architect. There are some ways, but that is largely beside the point. The real importance of computer graphics for architecture is that it provides new ways of representing buildings, of manipulating those representations, and of interpreting them in various useful ways. A design process supported by a computer graphics system is qualitatively different from one carried out with pencil and paper; it has an altered pace and sequence, brings information to bear on decisions in new patterns, renders the visual effects of geometric, color and lighting decisions with unprecedented speed and precision, and so allows architectural ideas and effects to be explored in ways that were unimaginable before now. Computer graphics promises architects an aesthetic adventure ..one that is just beginning.

Composition of Lines

What are these new ways of representing buildings? We can best begin to understand them by considering some canonical definitions of architecture.

One traditional way to represent a building design, for example, is by means of lines - usually drawn on paper. When we use this method of representation, architectural design becomes (at one level of consideration) a matter of manipulating lines. In his ***Ten Books of Architecture,*** the great Italian Renaissance architect L.B. Alberti defined architecture, in these terms, as follows:

We shall first lay down, that the whole art of building consists in the design, and in the structure. The whole force and rule of the design, consists in a right and exact adapting and joining together the lines and angles which compose and form the face of the building.

By "lines" Alberti meant straight segments (vectors) and circular arcs. Operations of "adapting and joining together" lines to produce compositions were performed by executing Euclidean constructive procedures (for parallels, perpendiculars, bisectors, tangents, and so on) with straight-edges and compasses. Lines could be projected from three-dimensional space onto a two-dimensional surface by the newly invented (or rather, reinvented) method of perspective.

But the architect's traditional tools for constructing line drawings are now being replaced by computer drafting systems, which provide greater speed and convenience. (See figures 1 - 4.)

Composition of Surfaces in Light

Another way to think of a building is as a collection of surfaces, bounded and divided by lines, and made visible by light. This focuses attention on surface qualities of color, reflectivity and texture, and the creation of relationships between these. In his polemic ***Vers une Architecture,*** the young Le Corbusier set forth a stirring definition of architecture in these terms:

Mass and surface are the elements by which architecture manifests itself...Architecture is the masterly, correct and magnificent play of masses brought together in light.

This is not merely an esoteric matter of aesthetic theory; it has direct technical implications for computer graphics. If we conceive of an architectural composition as a collection of surfaces, a "wire-frame" vector representation of a building will not serve us adequately; we will need to work with some kind of surface model. The simplest way to do this is to take closed planar polygons as data types. The shape of each polygon (normally specified by giving vertex coordinates in anticlockwise order), then, becomes a low-level design variable. To define a composition, polygons must be located in space, and assigned surface qualities, such as color.

Not all surfaces found in buildings are planar, of course. Cylindrical curvature is found on vaults and moldings, and spherical curvature is found on domes. Much more rarely, warped and spline surfaces of various kinds are found as well. So the surface modeling techniques that have been given so much attention in computer graphics have some role to play in architecture, though not so central a one as they play in automobile and aircraft body design.

Le Corbusier emphasized that the elements of a compostion are "brought together in light." An architect is vitally interested in the lighting conditions, both natural and artificial, that will exist in and around a building, and how light will paint surfaces to create a visual experience. So a necessary adjunct of a surface model is a lighting model, which allows the characteristics of light sources to be specified, and effects of light on surface to be displayed.

The simplest useful lighting model is based upon the cosine law for diffuse light incident upon an opaque matte surface. The light source is modeled either as a point in space, or as a direction, together with an intensity value. The reflected light from a surface, then, is a function of the reflectivity of the surface and of the cosine of the angle that the incident light makes with the surface. This elementary lighting model, together with hidden-surface perspective software and a raster display device, provides an architect with a very useful way to study building massing.

Architects are interested in sunlight; the ways that the sun casts shadows on and around buildings at different times of the year, the patterns of sunlight penetration (insolation) through openings, and the thermal effects of sunlight incident upon the exposed surfaces of buildings, are all vital architectural issues from both technical and aesthetic viewpoints. Two basic kinds of calculations are required to determine sunlighting effects: calculation of sun position as a function of latitude, longitude, date, and time of day; and calculation of the pattern of cast shadows as a function of sun position and building geometry. Calculation of sun position requires evaluation of some complicated trigonometric functions, while calculation of cast shadows is isomorphic to the problem of generating a hidden-surface perspective of the building from the viewpoint of the sun. Both these calculations can be carried out by hand (indeed there is a traditional architectural subject, sciagraphy, that is concerned with them), but they are extremely tedious and time-consuming. Use of a computer saves a great deal of time and effort, and allows more thorough explorations of sunlight and shadow effects to be carried out.

Much monumental architecture of the past (from the pyramids onwards) was essentially a matter of opaque volumes, and the shading and shadowing effects of natural light. But Gothic cathedrals and Baroque churches also made important compositional use of natural light transmitted through translucent and transparent planes of glass. Then the Industrial Revolution of the Nineteenth Century made possible spectacularly transparent steel-and-glass structures like the Crystal Palace, and the intense artificial illumination of interiors. Since then, the revelation of form through layers of glass, and the night-time effects of internally illuminated transparent buildings, have been major concerns in architectural composition. It is fairly straightforward to extend a lighting model to deal with transparent as well as opaque surfaces, so that an architect can use computer simulation to explore transparency effects. Essentially, the illumination at any surface point is calculated by considering both reflection and transmission effects.

Not all surfaces used in buildings are smooth and matte. Some are shiny, so that highlights become part of the visual experience. Some have a metallic luster. Some act as mirrors, so that reflections appear. Many have texture. Visual simulation techniques can now be extended to encompass many such effects.

Furthermore, a building, or a space within a building, may be illuminated by multiple light sources, and the effects of interreflection within a scene may be visually important. Where accurate rendering of complex lighting effects is required, the technique of ray-tracing may be employed. This is computationally expensive, but it can produce extraordinarily realistic results.

It is sometimes suggested that use of computer graphics forces an architect to deal in barren computational abstractions, and places the emphasis in a design process upon technology rather than upon the subtleties and complexities of visual experience that enrich and enliven architecture, and give it the capacity to touch our hearts. But the techniques for simulating light on surface, and effects of color and texture, actually bring architects closer to the qualities of visual experience by rendering these quickly and accurately. These techniques have the same potential for liberating the architectural imagination that the technique of perspective construction had for the architects of the Renaissance, and the technique of graduated watercolor wash had for the architects of the Beaux-Arts. (See figures 5 - 7.)

Composition of Volumes in Space

You can see, now, that we are building up a geometric hierarchy. A vector is bounded by its end-points, and you can construct a plan, elevation or wire-frame three-dimensional model from vectors. A plane polygon is bounded by three or more vectors, and you can usefully represent a building as an assemblage of colored and shaded polygons. The next step is to recognize that a polyhedron is bounded by four or more polygons, and that you can represent a building as an assemblage of polyhedra. If we want, we can also admit curved as well as straight lines, curved as well as planar surfaces, and solids bounded by curved as well as planar faces.

Just as a polygon may be opaque or transparent, a polyhedron may be a solid construction element such as a column, or an enclosed void such as a room. Architectural theorists traditionally have emphasized that an architect composes both the solids and the voids. The Beaux Arts theorist Julien Guadet, for example, wrote:

...just as you will realize your conceptions with walls, openings, vaults, roofs - all elements of architecture - you will establish your composition with rooms, vestibules, exits and staircases. These are the Elements of Composition.

When a building is represented as an organization of polyhedral solids and voids, the designer needs operators for generating polyhedra. An extrusion operator, for example, can be used to generate a prism from a plane polygon. By rotating a plane profile about an axis, instead of translating it along an axis, a solid of revolution can be generated. By connecting the vertices of a plane polygon to a point, a pyramid form can be generated. There are others, but these are the most useful to architects.

Extrusion generates the basic architectural form of the cube and its variants. Extrusion or rotation (depending upon how you want to look at it) generates the cylinder. Rotation generates the sphere. And connection to a point (or rotation, if you like) generates the cone. In a famous passage, Le Corbusier pointed out the central role of these basic forms in architecture:

The light plays on pure forms, and repays them with interest. Simple masses develop immense surfaces which display themselves with a characteristic variety according as it is a question of cupolas, vaulting, cylinders, rectangular prisms or pyramids.

(See figures 8 - 9.)

Composition of Buildings in Urban Settings

Just as surfaces are built by composing edge lines, volumes are built by composing enclosing surfaces, and complete building masses are built by composing interior volumes and construction elements, urban form is eventually put together by composing building masses. The great French neoclassical architectural theorist J-N-L Durand expressed the point this way:

Just as the walls, the columns, etc., are the elements which compose buildings, so buildings are elements which compose cities.

Of course it is rare for an architect to design a complete city. More commonly, the task is to insert a building mass appropriately into an existing urban fabric. Thus urban form evolves in step-by-step fashion, as individual buildings are constructed, demolished, and replaced.

In order to see the effect of a proposed building in its urban context, an architect needs some kind of three-dimensional model of that context. Elaborate city models of wood and plaster have often been made to serve this purpose. (Mussolini made a famous one of Rome to guide the reconstructions that he had in mind, and the University of California at Berkeley has a beautiful model of downtown San Francisco for use in producing filmed simulations of proposed developments.) But such physical models are bulky, cumbersome, collect a lot of dust, and are difficult and expensive to keep up to date. An increasingly attractive alternative, now, is to maintain constantly updated form databases, which can be used to produce perspectives and animations showing proposed new buildings in context. (See figures 10 - 12.)

Conclusions

The Italian Renaissance drove a wedge between the computational and graphic aspects of design that has remained until the present day. Renaissance architectural theorists, such as Alberti, assimilated architectural design (along with painting and sculpture) to ***disegno,*** carried out through drawing. But Renaissance scientists (particularly Galileo in his investigations of structural member sizing) began a tradition of design by manipulation of mathematical models. Computer graphics, finally, is beginning to bring the two sides together again.

Computer-Aided Industrial Design

Del Coates

Computer-Aided Design (CAD) is destined to become the standard industrial design medium, for the same reasons it is revolutionizing other design and engineering fields. And many industrial designers are eager now to adopt it. Yet, only a fraction of CAD technology's potential has found its way into the industrial design studio. High costs are partly to blame, but even as costs decline, a more fundamental reason accounts for the slow adoption: the industrial designers' needs are so disparate that no single CAD system available today, has scope enough to fulfill them all.

Industrial designers' requirements for three-dimensional design capabilities do not differ greatly from the requirements of mechanical designers and engineers; the relatively ordinary mechanical CAD system suffices much of the time. But, industrial designers are graphic designers too, especially the substantial number of them engaged in package design. So, like artists, illustrators, and graphic designers, industrial designers need a "painting" system that can be used to create full-color two-dimensional art work.

That which does set the needs of industrial designers apart from other product designers the concern for a product's aesthetic character - gives rise to the most demanding requirement. The system must produce renderings of product concepts that look as real as photographs. This means that it must be able to reproduce, not only the effects of different colors, but of different finishes. The relative gloss of a surface, for example, whether it is shiny or dull, affects its aesthetic character as surely as its color.

In effect, a system for industrial designers would have to embody three different subsystems representing three relatively distinct technologies:
a three-dimensional, mechanical design and drafting subsystem;
a two-dimensional, graphic design subsystem;
a rendering subsystem.

The advantages of such a system become obvious with a few examples demonstrating the capabilities of each subsystem.

The Three-Dimensional Subsystem

Mechanical CAD systems represent objects in one or more ways: as "wireframe" models composed of lines; as surface models; or as solid models. Solid-modeling techniques, although more complex and expensive, are the preferred method because they can model an object more completely and realistically than the others. Any imaginable quality can be associated with a solid model.

Industrial designers are accustomed to thinking and creating in three-dimensional terms. Formal industrial design education stresses visual communication skills based on perspective drawings. Solid-modelers produce less confusing perspective drawings than wireframe-modelers because hidden lines normally are not visible.

The design for a cast aluminum automobile wheel, prepared by PDA Engineering, illustrates the process of designing with a solid-modeling system. (See figure 18.) The designer created the wheel's rim and hub by sweeping two-dimensional cross-sections of them about the wheel's centerline. "Negative solids" were created to be used as "tools" for "cutting" openings in the wheel. The computer can quickly calculate the wheel's volume, center of gravity, and other mass properties. The designer can assign any attribute to the wheel he wishes, including mass, material characteristics, even associated costs. This allows it to be "weighed", and its deformation under load to be modeled to determine whether it would fail under extreme operating conditions. Aesthetic factors, like form, color and finish can be varied too. By manipulating any or all attributes during design exploration, the designer can create many variations of a concept.

Smoothly shaded renderings of the solid-modeled Black and Decker sabre saw make it easy to perceive various internal components. (See figure 16.) By "cutting away" one side of the saw, the designer could examine interior mechanisms and verify whether external and internal parts were properly aligned. When rendered images of the internal mechanism and the housing were first combined, a misalignment between them was noticed. Without benefit of the computer-generated renderings, many hours and dollars might have been wasted building a prototype before this error was discovered.

The three-dimensional subsystem would also have two-dimensional capabilities for producing dimensioned orthographic drawings. Indeed, in most cases, today's CAD systems merely replace drafting machines. They are superior to conventional drafting means for several reasons. A three-dimensional system saves even more drafting time than a two-dimensional system because the various views of the object are associated with a single model of the object in the computer's memory. Thus, when the designer changes something in one view that would affect other views, those other views change automatically, too. Design details can be quickly revised, textual information changed, and new drawings created with far less effort.

Dimensioning can be relatively automatic. The drafter can readily move drawings about on the page, and change their scale. Only half of a symmetrical component need be drawn; the other half can be created simply as a mirror image of the first. Similarly, the computer can simply reproduce elements, like ventilation slots, that must be repeated in a design.

Adaptation and Variation

Many designs amount merely to adaptations of previous designs, often incorporating identical or nearly identical components. Nike, for instance, based the design of a ski boot on an outsole designed earlier for another product and stored on magnetic tape. The designer simply commanded the computer to make a copy of the design from the tape. He then modified certain details to suit the new boot, and combined it with newly designed elements to quickly create the new design. The various sizes of outsoles were created by making multiple copies of the basic design and varying their sizes. The computer then guided numerically-controlled (N/C) machinery that created the cavities for molding each size of sole.

In much the same fashion, a Kodak designer was able to quickly create many different designs by combining basic components, each stored on disk, in many different ways. Similarly, for a package design project at Cranston/Csuri Production a series of mustard jars were created as a variation of one design. (See figure 14.) The computer could be programmed to create thousands of slightly different designs by progressively varying several design characteristics, like height, diameter, etc., by small, incremental amounts. At the same time volume and other fixed aspects of the design could be kept constant.

This ability to produce permutations, quickly and easily, represents an important aspect of the computer's potential for increasing design creativity.

Unlimited Detail

Unlike conventional design media, such as paper and pencil, a computer's representation of an object can incorporate every conceivable detail. The amount of detail that a database can contain is virtually infinite, limited only by the available data storage medium (usually magnetic tape or disk)

Several methods are used to avoid confusion when depicting complex databases. When the object is extremely small or complex, as in the case of a computer microchip, the designer can magnify the detail by "zooming in" for a closer, clearer look. (See figure 13.) Theoretically, there is no limit to how detailed the design can be, nor to how close the designer can zoom in. If necessary, the object could be designed at the molecular, even the atomic level. Components also can be color-coded to further alleviate confusion.

Individual components or subsystems usually are defined on different "layers". The designer can view any number of them at once by selectively turning various layers on or off. Drawings of an AMT high-speed computer printer were done in colors to represent different layers. Because the lid was defined on a separate layer, the designer was able to move it through its range of motion to ensure that no components interfered with its movement. (See figure 15.) For clarity, the lid was drawn in a different color for each position in the sequence shown.

The designer can select for examination only those layers containing components and subsystems of immediate interest, while temporarily blanking the rest. Virtually all components of something as complex as an automobile, for example, including interior body panels, the engine and transmission, and suspension, can be modeled and stored in the computer's memory. But only the "character lines", defining the outermost appearance need be shown.

The Two-Dimensional Subsystem

A two-dimensional subsystem would be comparable to the most advanced "painting" systems available. It could simulate all conventional media (pencil, felt-tip pen, pastels, watercolor, acrylics, oils, and airbrush). Using it the designer could create original art and illustrations, or, he could retouch photographs scanned in with a camera.

Data in the ideal system could be exchanged between two-dimensional and three-dimensional subsystems. For example, a graphic rendering of a video cassette package was designed in a two-dimensional mode. "Painted" with color, the design was then "mapped" onto a model of the box that had been designed in a three-dimensional mode. In the process, the planes of the graphics became part of the three-dimensional world, along with the box, and conformed to all the laws of perspective as the image was moved about from one view to another in the sequence.

The Rendering Subsystem

A rendering subsystem would have to simulate both specular and diffuse reflection, and shadows, in order to create images of concepts with photographic realism (surpassing the capabilities of the best computer animation systems now available). Most systems that perform smooth shading model diffuse reflection quite well. But specular reflection, which accounts for mirror-like reflections of surroundings on a glossy object, has not been incorporated because the computations required for even a simple object are very time-consuming and costly to implement. A rendering of an automobile with true specular reflection might require days of a powerful computer's time. At best, commercially available systems only approximate specular effects.

Yet, the effects of specular reflection are crucial. The reflection on an automobile, for example, is a key design element. Where it occurs, and how it moves about the surface as we view a car from different angles, is as important, aesthetically, in a designer's considerations as the car's profile. The car's proportions, even its apparent scale, change when specular reflection is missing. Without it, the industrial designer cannot make proper judgements of his work, and will not see an image consistent with reality.

At Ford Motor Company, specular reflections have been simulated by "mapping" them onto the car's surface. This method is effective in making the car look very glossy without the computational expense of true specular reflection.

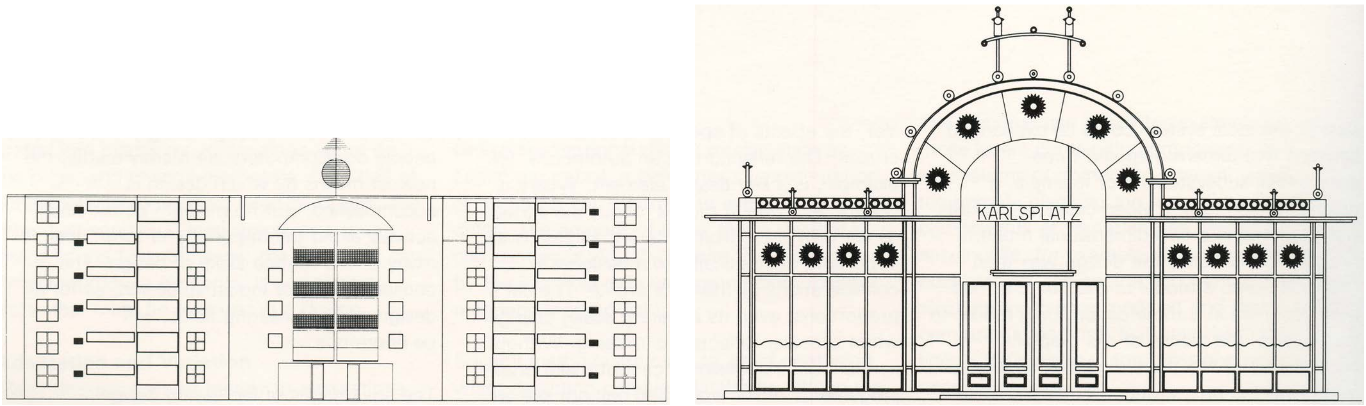
Related to the specular reflection issue, because it also depends on a so-called "ray-tracing" algorithm, is the ability to simulate refractive effects of transparent materials like glass and plastic. As with specular reflections, the distortions of things seen through transparent objects are, in effect, design elements that the package designer, for one, must take into account when addressing aesthetic issues.

Computers do not design things, of course; people do. Computers are merely media, the newest means by which design is accomplished. But no medium before has actively aided the designer and taken over many of the routine tasks of design. The consequences for industrial design, as for all design and engineering fields, will be enormous.

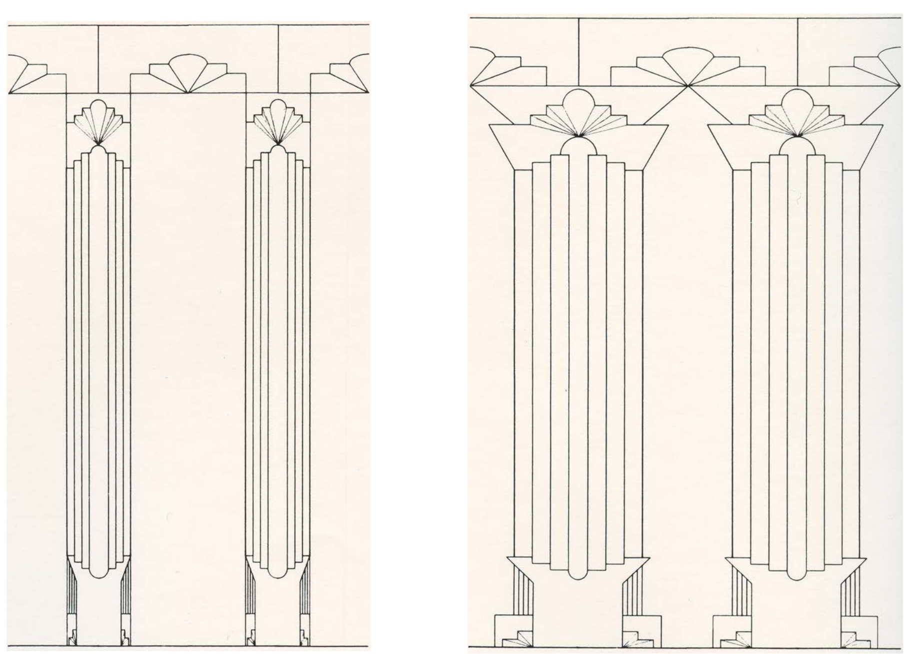
The advantages of increasing design productivity and quality are well known. But computers will also democratize industrial design, opening it to those with good design instincts who nevertheless are barred from the field now because they lack traditional media skills like perspective drawing, rendering, and even drafting. Freed of the drudgery of design, designers will be able to concentrate on more fundamental and important design issues. The computer has the potential of making every designer a good designer.

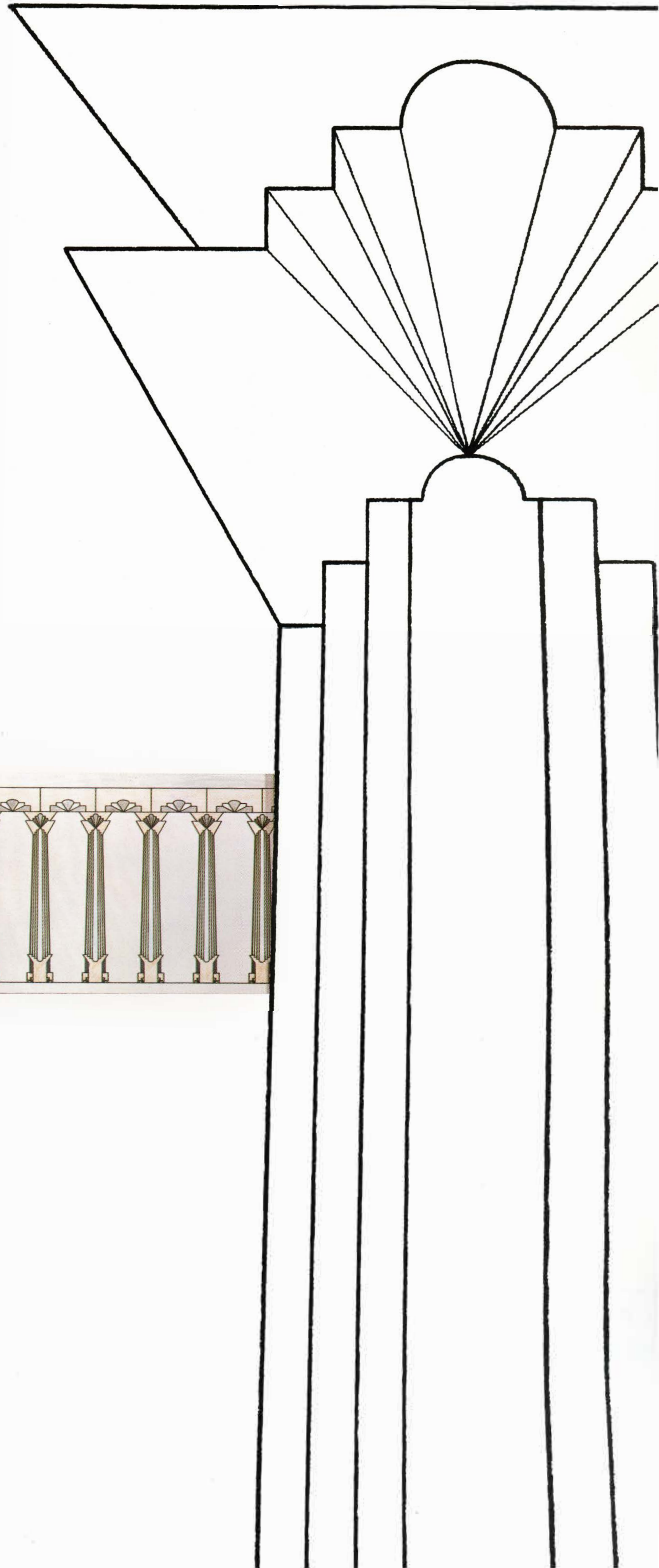
Composition of Lines

Architects have traditionally used T-squares or parallel rules, triangles and compasses to construct line drawings that define building geometry. But these traditional tools are now being replaced by computer drafting systems (just as the writer's traditional pencil and typewriter are being replaced by word processing systems).

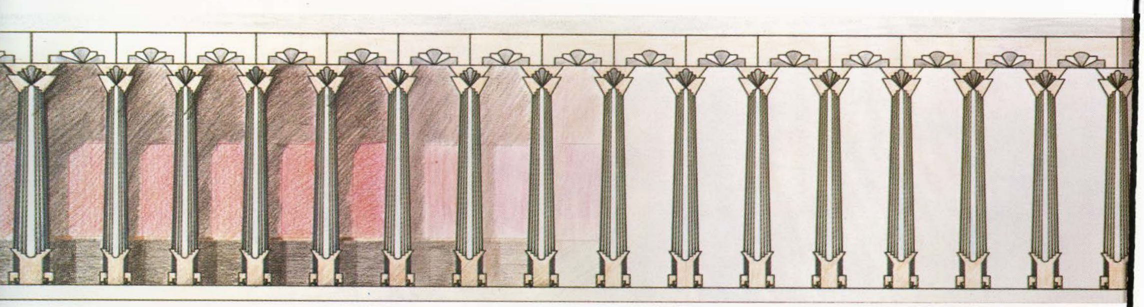


Student Elevations of Existing Buildings
(Figure 1)



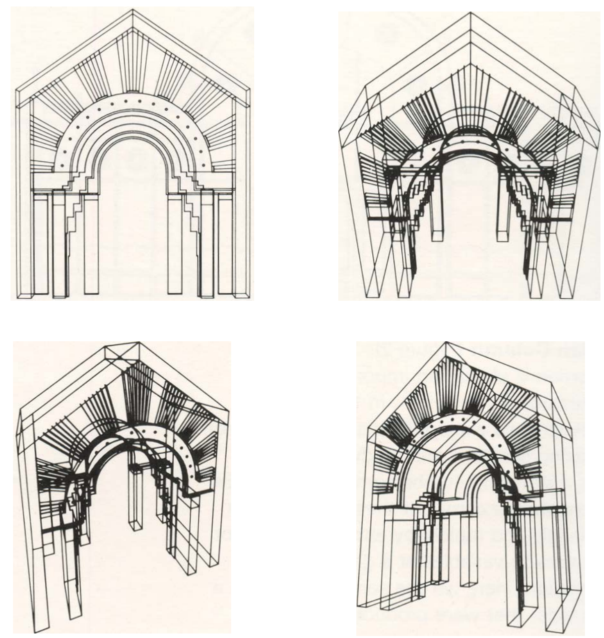


London Column (Figure 2)
Proportion is always an important issue in architectural composition. In the past, architects have explored variants in proportion by making sketches and study models, but this is a slow and cumbersome process. Now it is possible to carry out these explorations very fluidly and rapidly by entering values for dimensioning variables at a graphics workstation. Here we see some variants on a colonnade, that were produced in this way.



Arched Doorway (Figure 3)

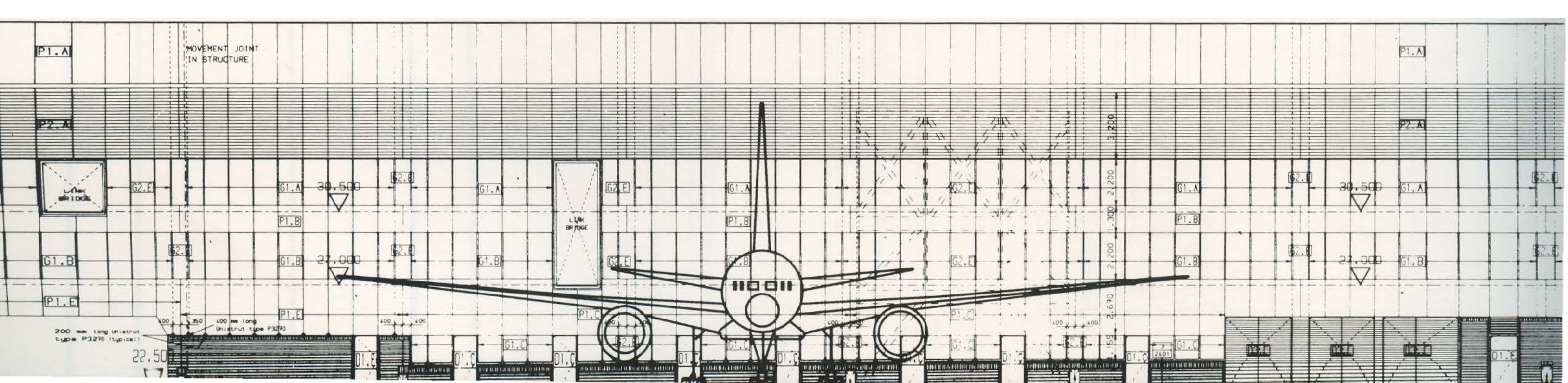
In this project, the proportions are not only of aesthetic importance, but also of technical significance, since the doorway is intended to function as a sun-control device. The software used to generate the variants allowed manipulation of about fifty dimensioning variables.

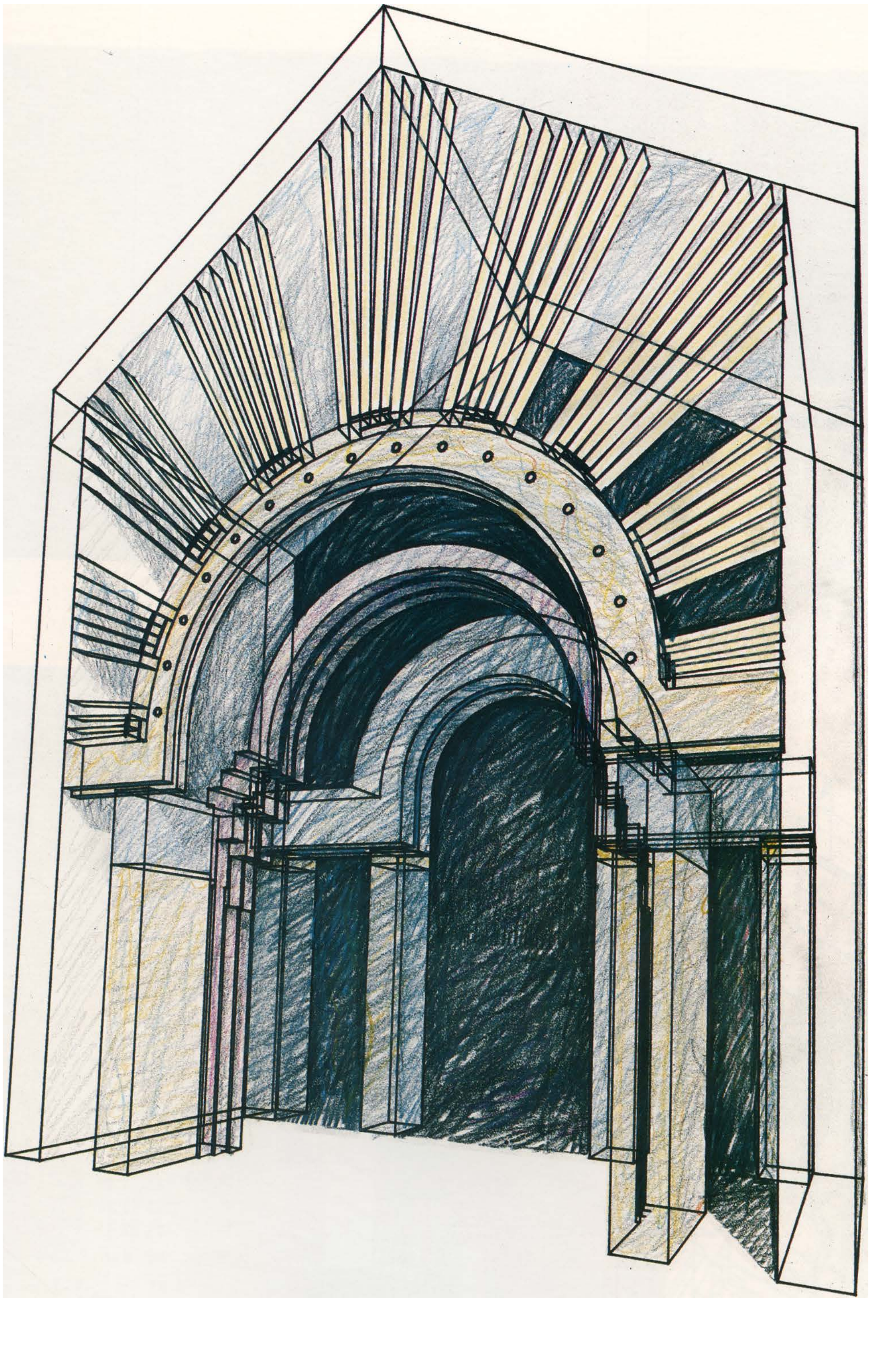


Terminal Four (Figure 4)

The major use of computer drafting systems in architecture, so far, has been in the production of working drawings. The objective here is to reduce the cost and shorten the time required for this phase of the design process by increasing the productivity of drafting workers.

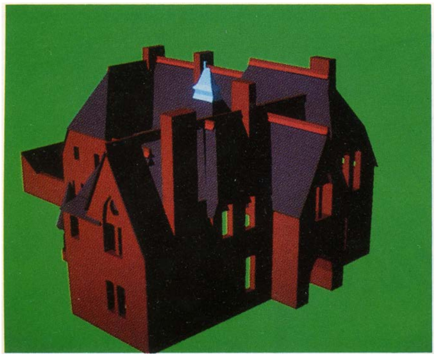
Computer drafting systems are particularly cost-effective on large projects with high levels of repetition, such as this airport terminal building.



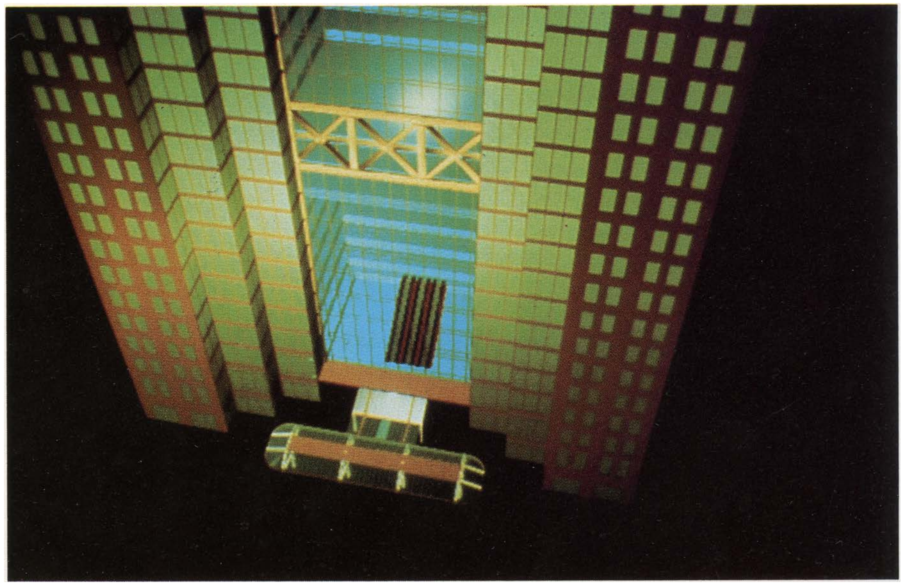


Composition of Surfaces in Light

Working models of wood, cardboard or clay, and graphic media such as watercolor and charcoal have traditionally been used to study the modulation of light by building surfaces. Now that high-resolution color raster display devices are available at a reasonable cost, computer graphics provides an increasingly attractive alternative. Software can be written to allow convenient variation of building form, color, light-source characteristics and of viewing parameters.



Computer-Generated Image of William Morris' Red House (Figure 5)

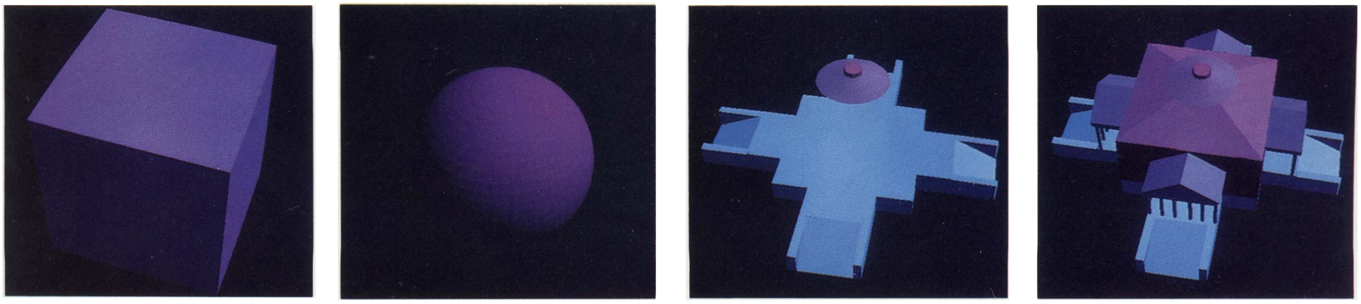


Highrise Office Building (Figure 6)

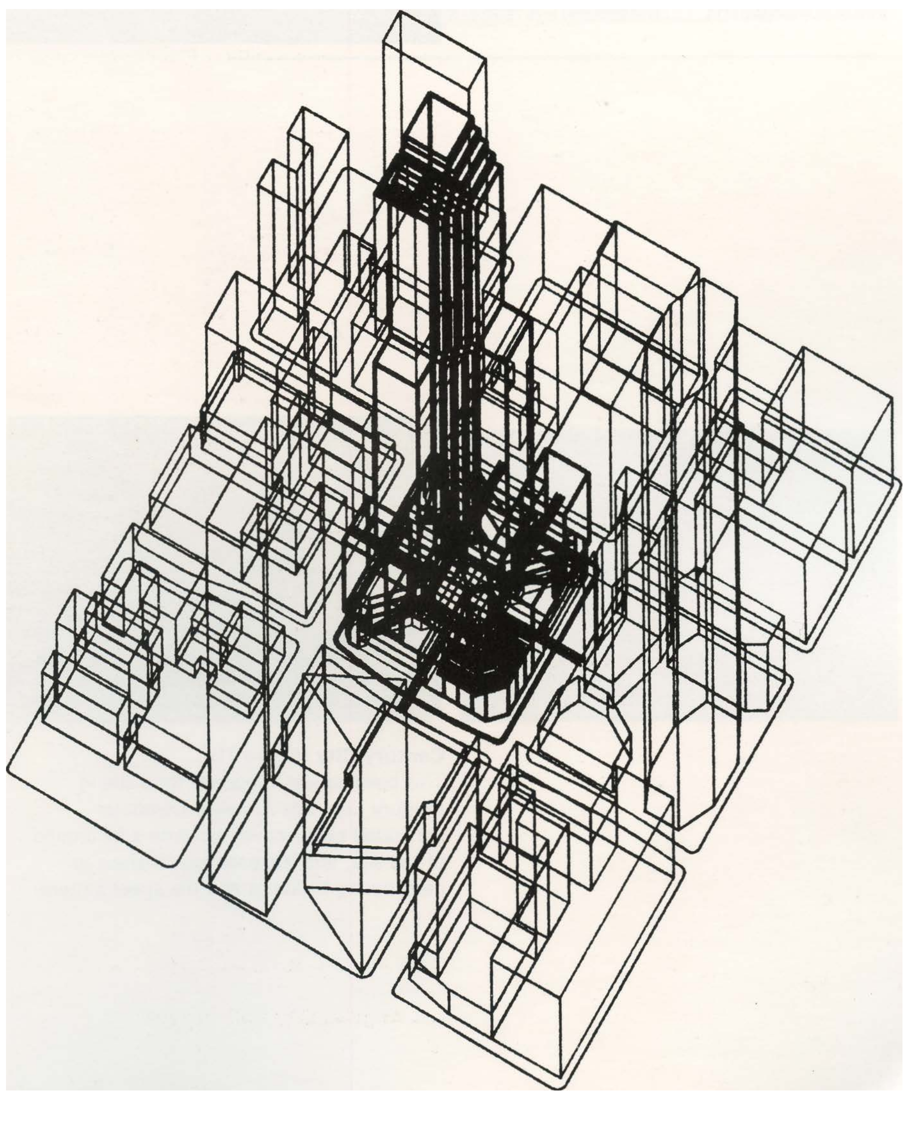
Los Angeles City Hall (Figure 7)

Composition of Volumes in Space

The section drawing and the interior perspective are the traditional ways of depicting the relationships of interior masses and volumes in a building. But, when a building is modeled in a three-dimensional computer graphics system, we need not restrict ourselves to these.



Volumetric Relationships
Palladio's Villa Rotonda
(Figure 8)
As this series of computer-generated images of the Villa Rotonda shows, we can take a building apart in many different ways to demonstrate important volumetric relationships

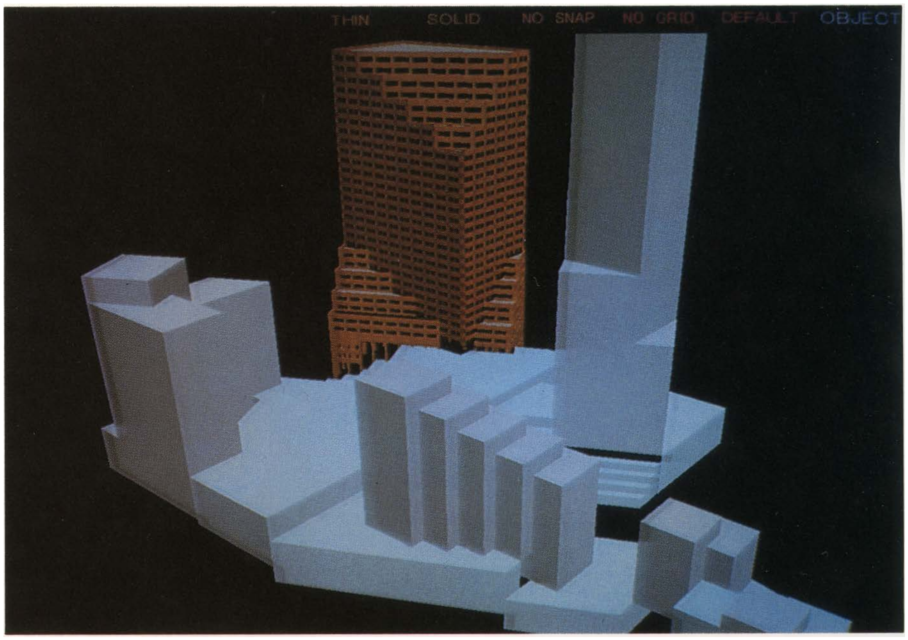


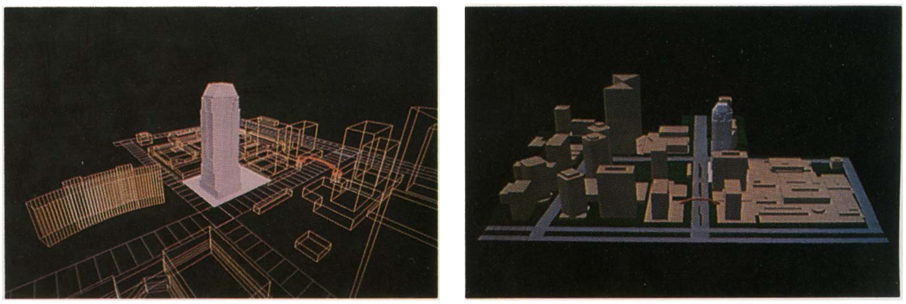
Composition Perspectives (Figure 9)
Architects have traditionally represented and manipulated the three-dimensional geometry of buildings either in flattened projections (plans, elevations and sections) or in small-scale physical models. Three-dimensional interactive computer graphics systems open up the exciting possibility of directly composing masses and volumes in three-dimensional space, projected into perspective from any desired viewpoint, and free from the limitations of material, gravity and smallness of scale that are encountered with the use of physical models.

Composition of Buildings in Urban Settings

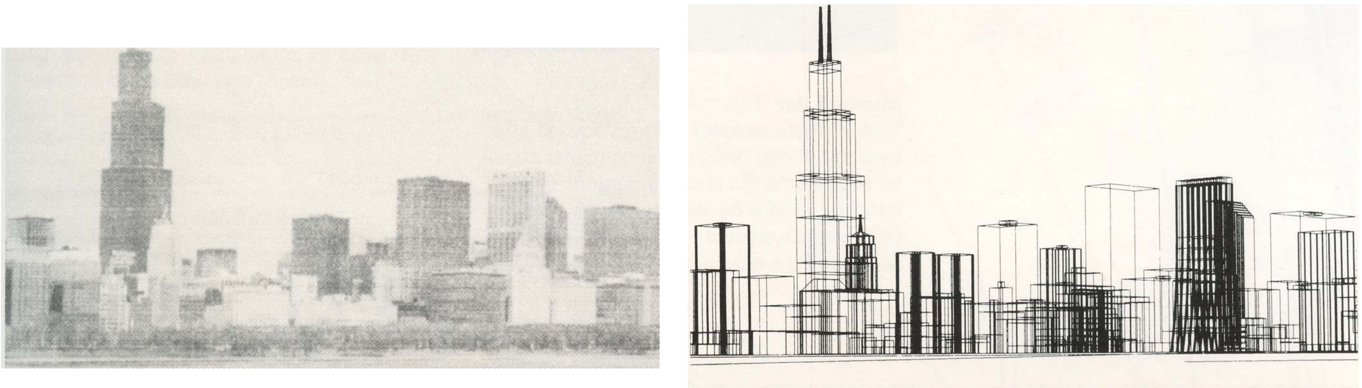
Complete building masses themselves become components of larger-scale urban compositions. These compositions change over time, as old buildings are demolished and new buildings are erected. Urban form databases now enable architects to place proposed buildings in context, and simulate their appearances from important vantage points within the city.

Site Massing Study (Figure 10)
This highrise office building proposed for a site in Bunker Hill, an area of downtown Los Angeles that is being developed intensively. The computer-generated site massing study shows its relationships to significant neighboring buildings, both existing and proposed.

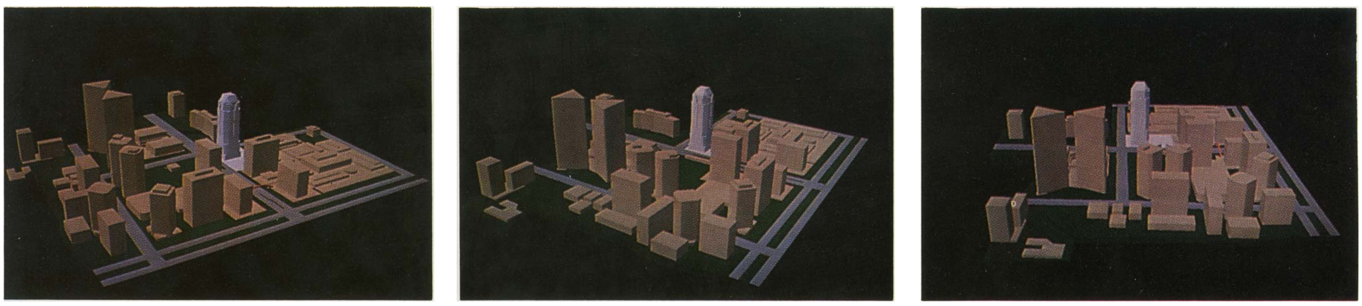




Century City (Figure 11)
This building was proposed for a site in Century City, Los Angeles. Computer-generated perspectives simulate a fly-around of the site, and illustrate relationships to neighboring buildings and the street pattern.

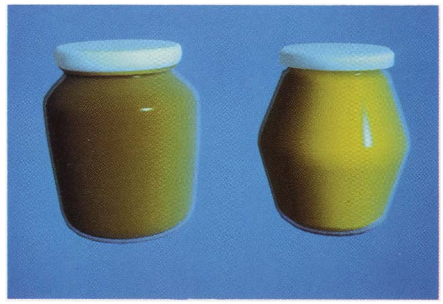


Chicago Skyline (Figure 12)
View from the Adler Planetarium, plotted from an architectural database.



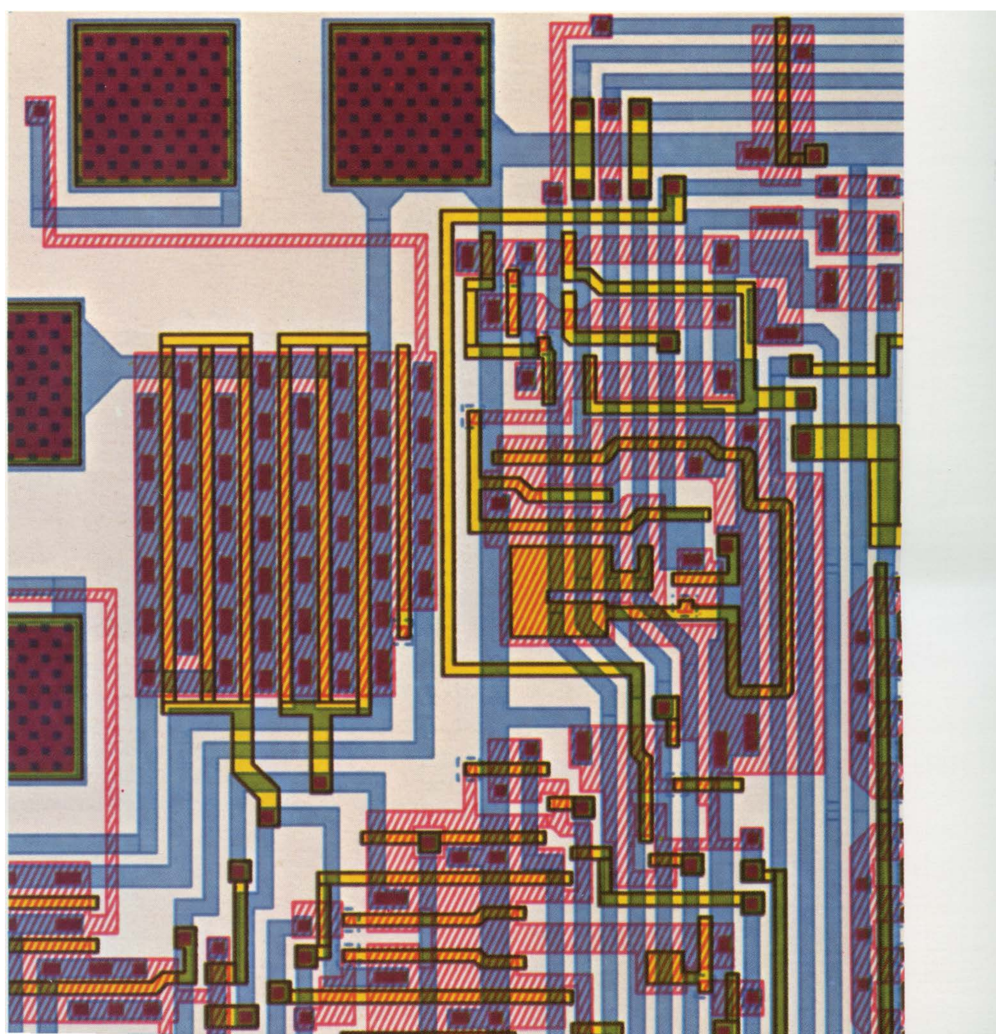
Unlimited Detail and Variation

Unlike conventional design media, such as paper and pencil, a computer's representation of an object can incorporate every conceivable detail. The amount of detail that a database can contain is virtually infinite, limited only by the available data storage medium (usually magnetic tape or disk). Being able to easily manipulate the database allows designers to rotate, twist, bend, and make other modifications very quickly.

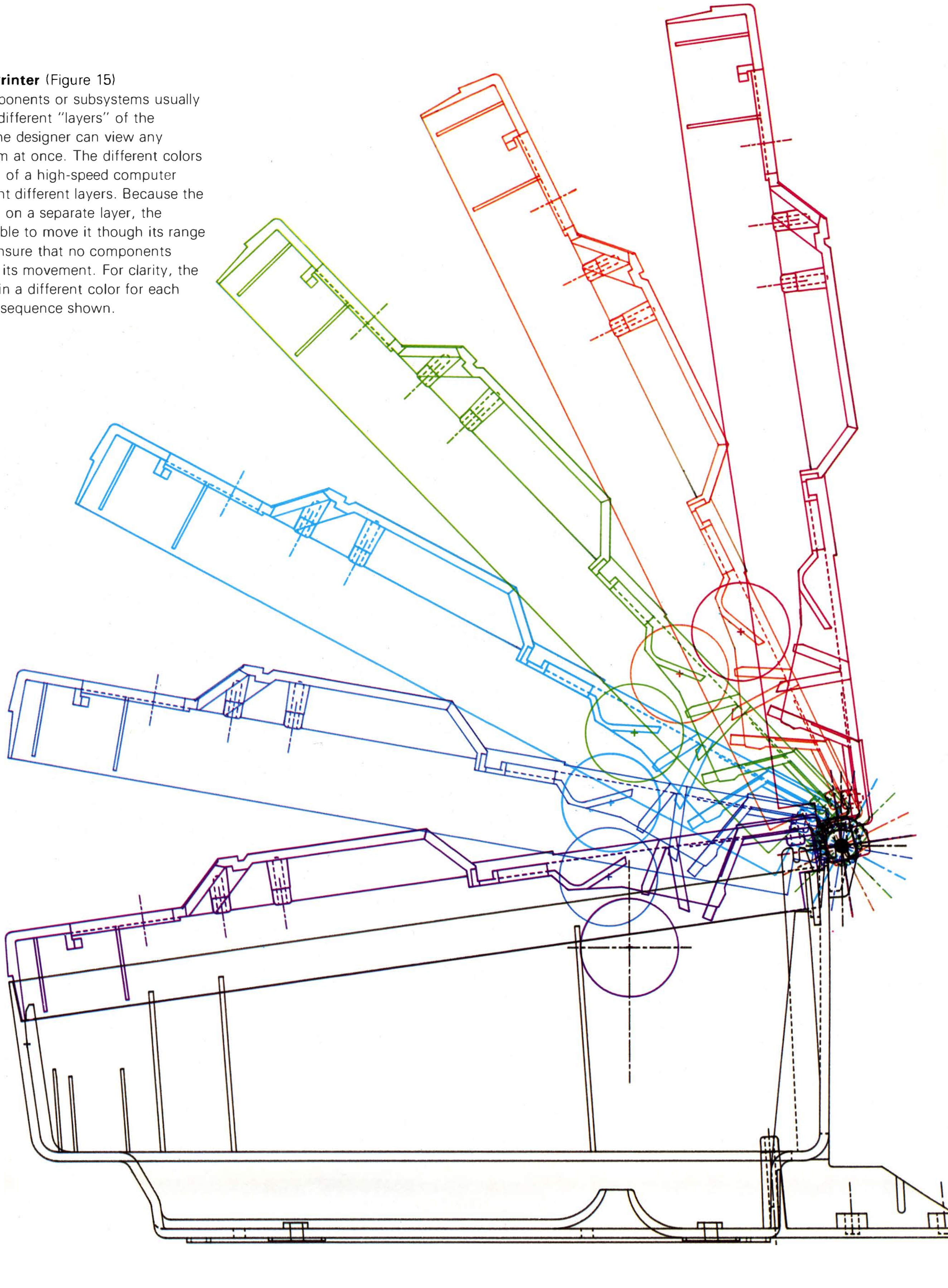


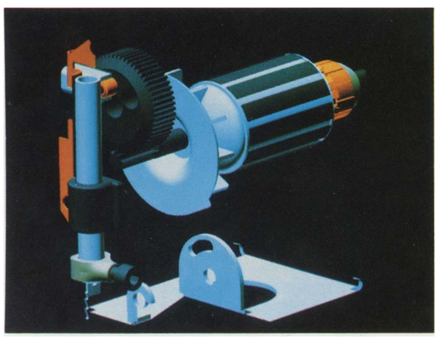
Mustard Jar (Figure 14)
Each of these mustard jars was created as a variation of one design. The computer could be programmed to create thousands of different designs by slightly varying several design characteristics. Volume and other aspects of the design could be kept constant.

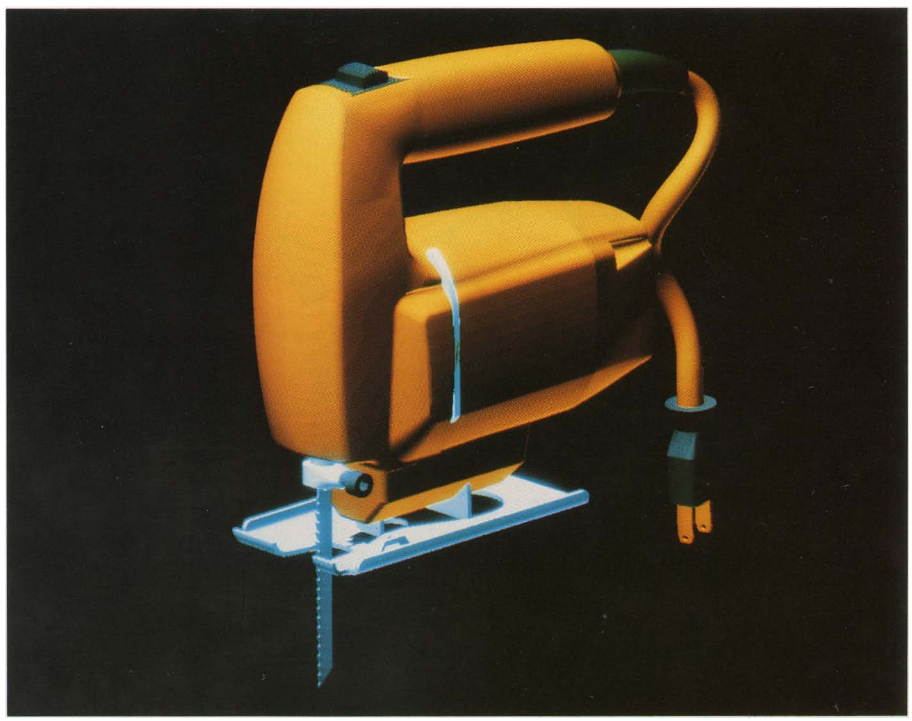
Microchip (Figure 13)
When the object is extremely small or complex, as in the case of this design of a computer microchip, the designer can magnify the detail by "zooming in" for a closer, clearer look. Theoretically, there is no limit to how detailed the design can be, nor to how close the designer can zoom in. (This image shows approximately 5% of the surface of a microchip.) If necessary, the object could be designed at the molecular, even the atomic, level. Components are also color-coded to avoid confusion.



High-Speed Printer (Figure 15)
Individual components or subsystems usually are defined at different "layers" of the database, so the designer can view any number of them at once. The different colors of this drawing of a high-speed computer printer represent different layers. Because the lid was defined on a separate layer, the designer was able to move it though its range of motion to ensure that no components interfered with its movement. For clarity, the lid was drawn in a different color for each position in the sequence shown.



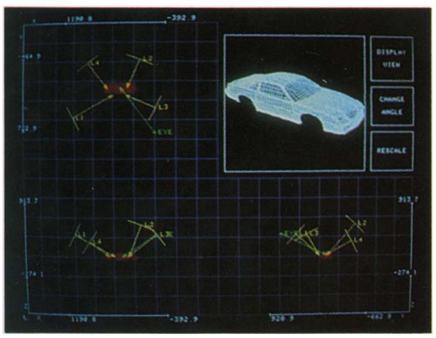




Sabre Saw (Figure 16)
Smooth shaded renderings of this sabre saw make it easy to perceive various components.

Subassemblies can be separated from the whole and viewed from any direction.

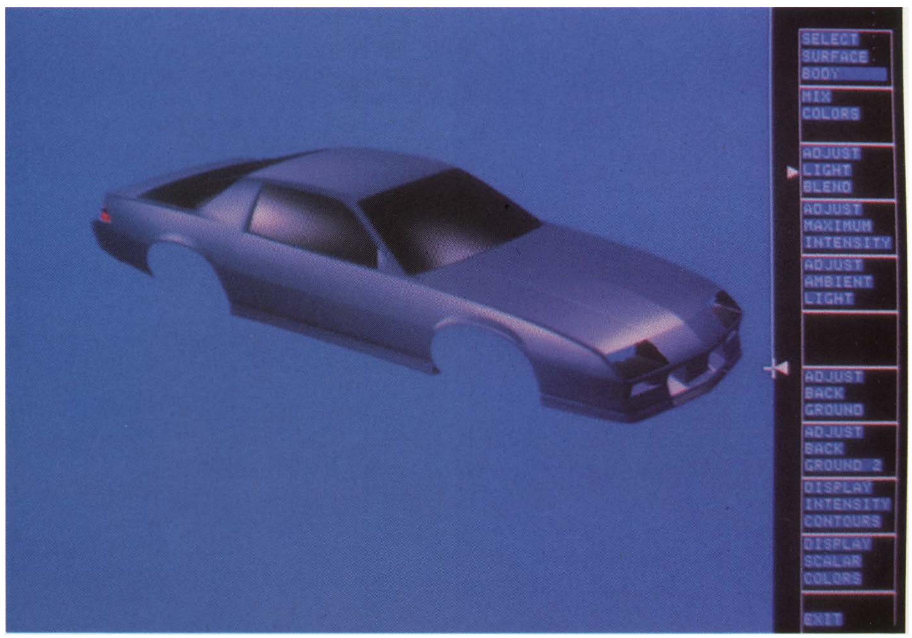
Filleting and blending capabilities allow the designer to interactively combine and smooth several major surfaces into the desired design envelope. Since the rendering software simulates the effects of light on an actual surface, even subtle imperfections show up as they would on an actual object. Note, for example, the unintended "wrinkle" in the vertical portion of the housing.



Car Rendering Software (Figure 17)
A CAD system can create a rendering of an automobile design in a fraction of the time required to build the customary realistic full-size model used for aesthetic evaluations.

The computer began the rendering of this car by approximating its surface with a mosaic of more than 10,000 planar polygons.

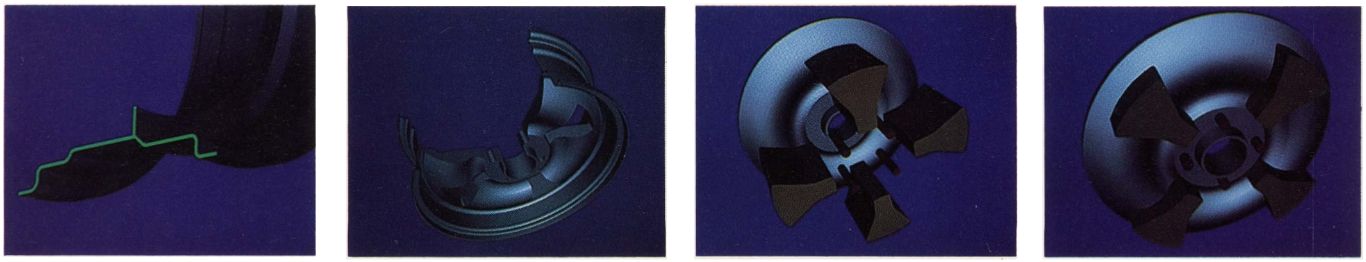
Using the "Light and View Selection" display the designer "set up the shot" with hypothetical camera and lighting fixtures just as a photographer would.



The result is this nearly photographic image. The apparent colors of the car and the lights could be altered by choosing different values from the "Color Mixing" display.

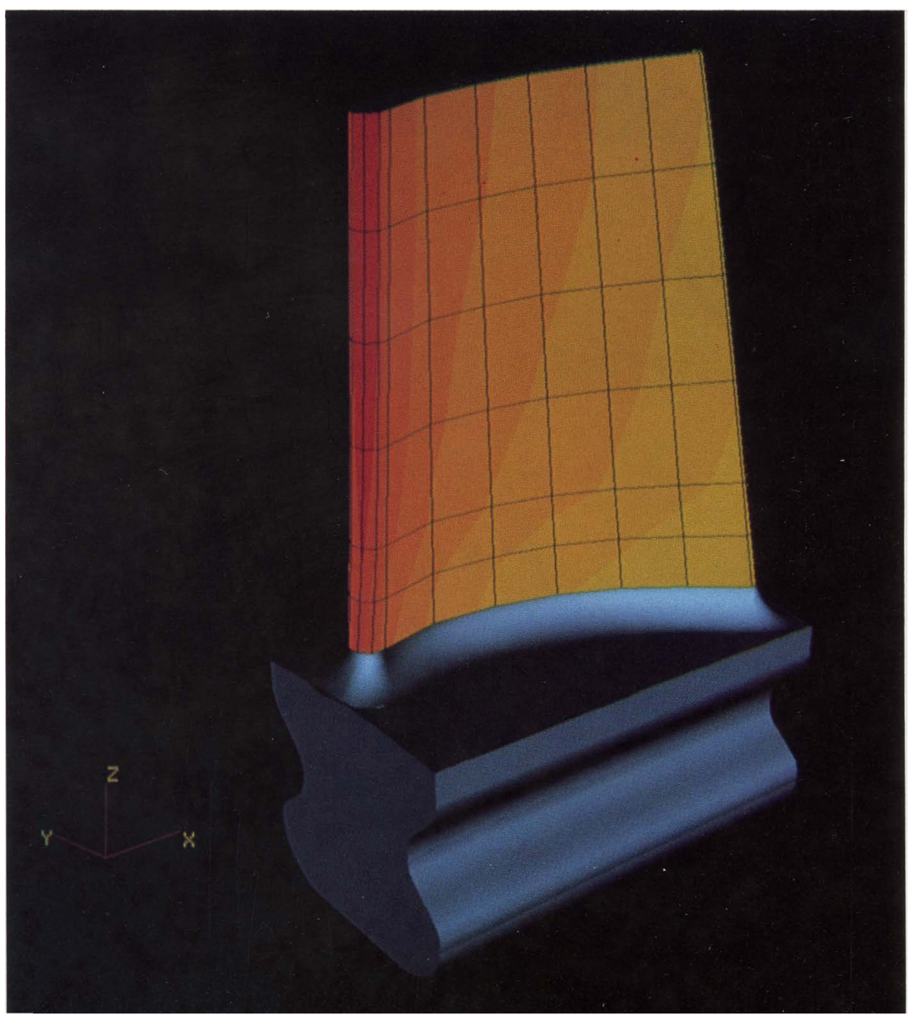
Solid Modeling

Solid models are complete representations of objects. An object's volume, center of gravity, and other material properties can be calculated.



Aluminum Wheel Modeling (Figure 18)
In the process of designing the automobile wheel shown in this sequence of illustrations, the designer used lines and areas as primitive forms to construct solid elements. These elements were combined to create more complex solids. Negative solids were created as "tools" for fashioning holes. Note also, that lines that would be hidden from view in a solid object are removed, a relatively easy thing for solid modeling software to do. These hidden lines can be visible if the user wishes.

Modeling Performance
Weight, strength, and other material properties can be associated with a geometric model of an object so that performance characteristics can be predicted. Finite-element modeling and analysis are used to simulate the performance of mechanical components under load, and to indicate how they would deform or fail. Designs can be optimized much more efficiently in this manner, before prototypes are built.

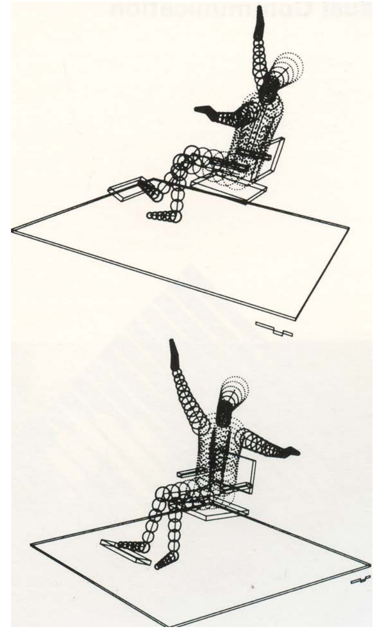


Human Factors Simulation

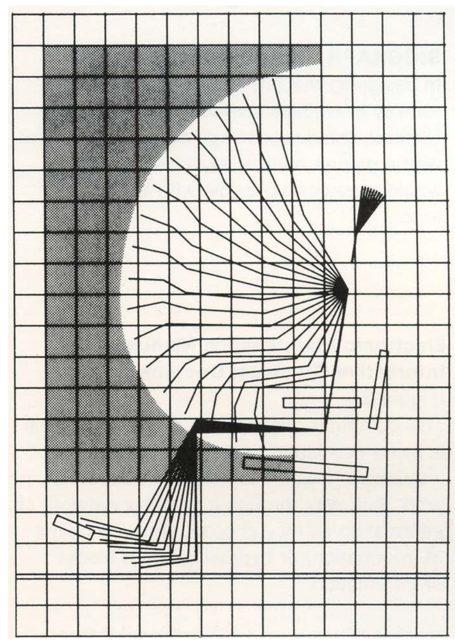
Remote Control Device (Figure 19)
The model of an object in the computer's memory can be used to shape a real and tangible model from wood, plastic, or metal through numerically-controlled (N/C) machining techniques. Prototype molds for this remote control device were made just as readily. They were realized in a fraction of the time that would have been required to make them by conventional means. It was thus practical to make many prototypes for more thorough testing in the time normally required to make only one. Overall development time for the product was thus shortened dramatically.

Simulating Human Physical Differences (Figure 20)
Human performance is usually dictated by the environment and our ability to adapt to its conditions. Understanding the multiple aspects of disability is a hard task for designers. Unfortunately, most of the design efforts for the disabled or handicapped to date have resulted in little more than wheelchair-accessible buildings.

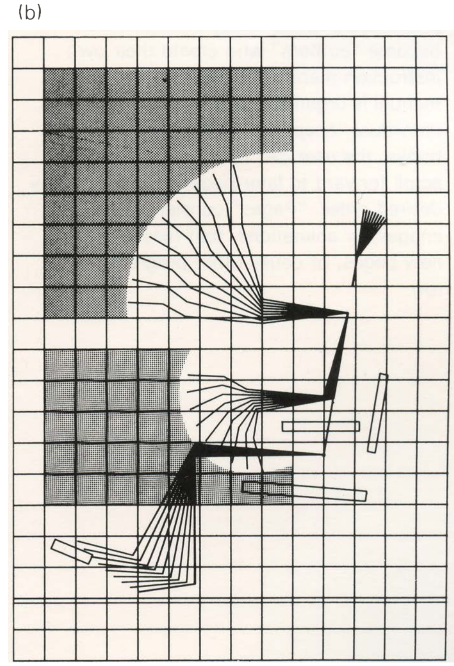
The objective of this research is to help designers to create products that can serve an extended range of people, especially those with disabilities. A computer graphics model designed to control, constrain and simulate special motions in a three-dimensional system is described. With the help of a model like this, professionals could ease the problems of dealing with the special client. Handicapping and disabling factors relevant to the design process can be explored through the comparison of normal and abnormal simulated motion conditions.



(a)



(b)



(c)

(a) Three-dimensional model for gross motion study.

(b) Arm motion (normal range) in stick-line format.

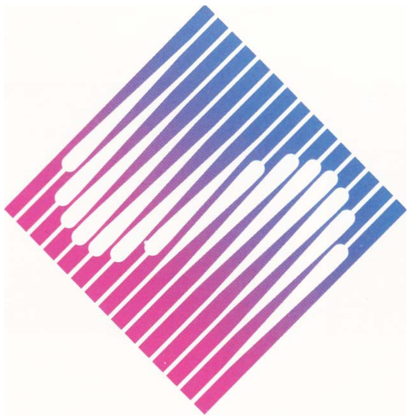
(c) Arm motion forced to an abnormal pass that is characteristic of a particular handicap.

Visual Communication

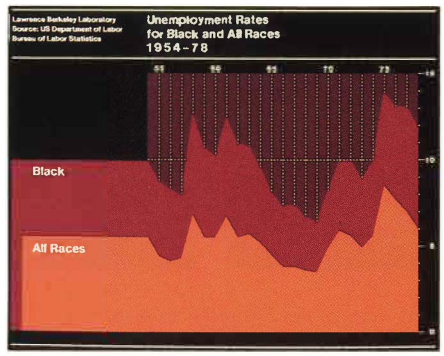
Publishing and Print

Publishing and print have been synonymous since the invention of moveable type. Computers and graphics first entered publishing as production tools. As digital communication media replaces print, traditional graphic design principles are being modified and applied to the design and presentation of such things as computer interfaces and programs.

High-density image storage devices such as video disk, provide the capability to archive, access and traverse massive amounts of graphic and textual information. With these and other tools in place, the design of information for dynamic, two-way communication between a user and computer can result.



SIGGRAPH Symbol (Figure 21!
In designing the SIGGRAPH symbol on a turnkey interactive computer graphics terminal, the designer was able to experiment with a greater number of variations than would have been possible with traditional tools.

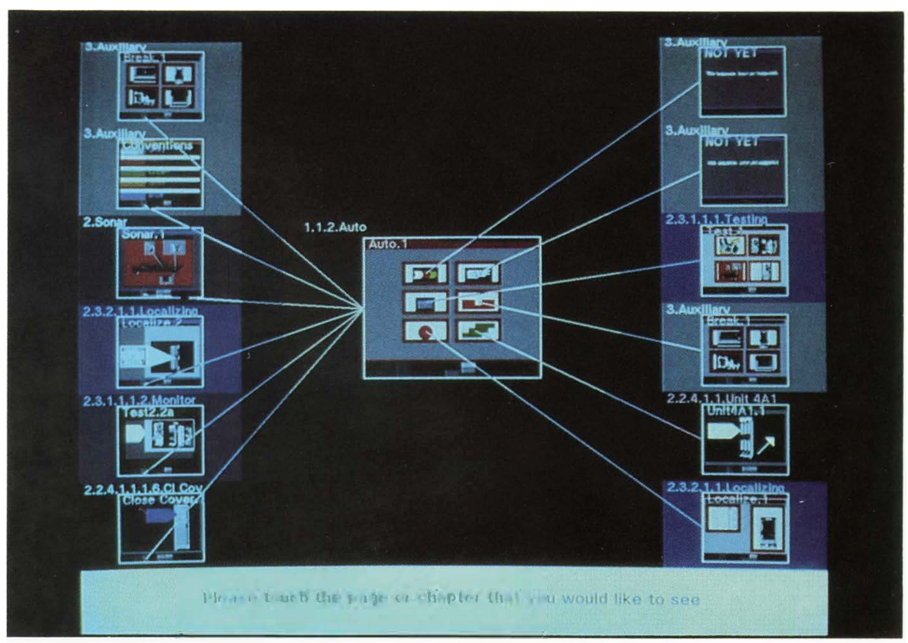


SEEDIS (Figure 22)
SEEDIS has an enormous database containing population and geographical statistics that are combined in answer to specific queries. This output, or outerface, is often most logically expressed by graphs, maps, charts or other diagrams.

Designers worked in collaboration with computer programmers to create prototypical solutions to the problem of presenting these graphic outerfaces. The problem required designers to find ways to control the semi-automatic generation of information. The problem also required that the solutions be aesthetically pleasing, that the system's capabilities be fully used, and that the designs meet the communication needs of the typical user.

Electronic Maintenance Manual: Interactive Graphical Documents
(Figure 23)
This computer-operated maintenance manual is being developed as an instructive, interactive "book" that allows its users to work their way through a complex network of information as they choose, pursuing points of information, or bypassing entire blocks of information.

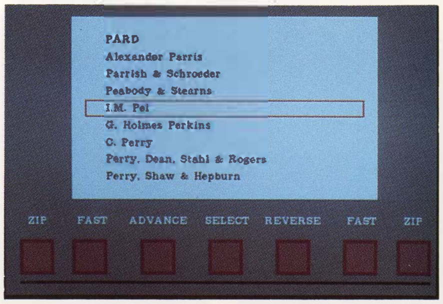
Using a "Document Layout System" that prescribes page formats, users can also become "authors" who create their own instruction manuals on the system. The manual is organized into "documents" with individual "chapters" and "pages". As with books, the user can return to earlier pages, scroll forward to later pages, and follow any desired order. "Pages" consist of text, images, or animations, that may branch to new pages, or cause other programs to be run.

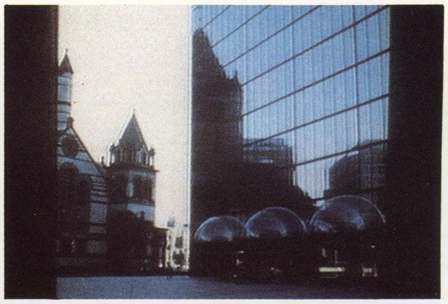


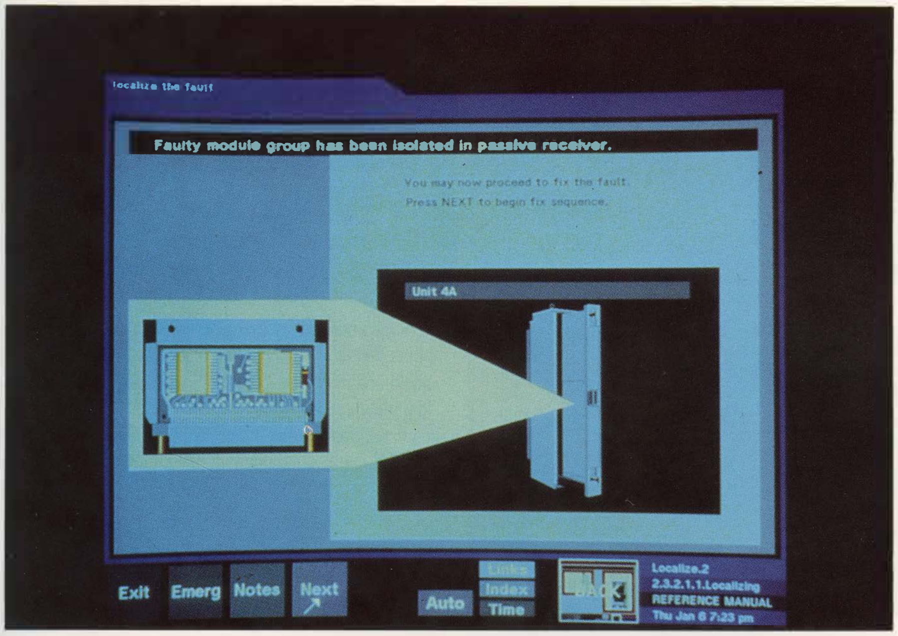
The Neighbors Page
The center page is surrounded by miniatures of its predecessors (on the left) and successors (on the right), each of which is nested in a box representing its chapter. Arrows emanate from the center page and from its predecessors and terminate on the pages they can access. Touching a page makes it the current page. Arrows at the bottom will scroll either column to show neighboring pages that would not fit on the display.

Electronic Archive (Figure 24)
Normally, one does two things when using a traditional archive: select specific information categories from a large, general card catalog, and; walk to slide files or book shelves to obtain detailed information.

The Electronic Archive combines these steps, allowing one to spend less time searching for and retrieving information. The optical disk in this system contains 5,500 images of buildings divided into categories such as: location, type, date of construction, and view (interior or exterior). By touching specific words or images on a screen, the user selects specific buildings from general categories and can then immediately see that building.







Fault Localization
This is a typical page from the maintenance and repair manual. The reader may select any of the buttons visible on the bottom of the page to turn to a new page or access any of a variety of facilities offered by the document.

Educational materials have traditionally been limited to linear media like film, video, and print. These materials were designed for limited question and answer interaction, and usually taught a specific body of information. The early design of computer-aided instruction (CAI) emulated this "textbook" instruction. But, recent advances in video games and computer learning programs afford far more interaction and individual pacing that enhance and complement natural learning processes. The responsiveness of the computer, the immediate and individualized testing and feedback capabilities it can provide, demands a new understanding of interaction on the part of the designer.

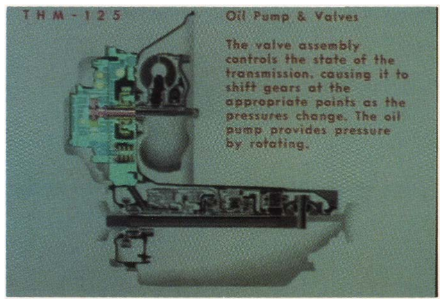
Movie Manual (Figure 25)
This transmission manual is not an ordinary manual, but a prototypical teaching device that uses the power of computer graphics and computer-controlled video disks for the display of images, movies, text and sound.

The system combines the best qualities of books, movies and computers while overcoming their individual limitations. It is an interactive, branching system that allows the user to pursue any avenue of questioning he likes. More conventional systems are linear, offering only multiple choice alternatives. In this system, the branching is consistent throughout, permitting the user to move anywhere he likes, from a general level of instruction, to one of the finest detail.

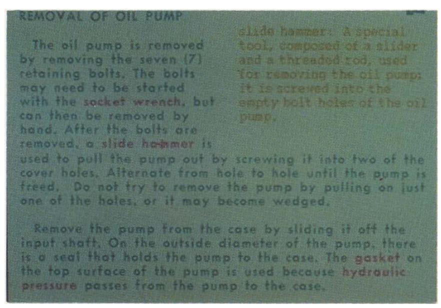
Answers from the system may come in the form of projected video pages with images and text; or as more sophisticated moving pictures with sound, animation, and three-dimensional modeling.

Data is stored on an optical video disk as picture, text and sound. Interaction occurs through a touch-sensitive display screen that allows the user to simply touch a part of a picture or text in order to ask for more information and get it instantly.

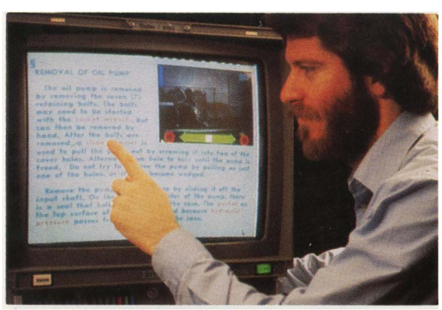
The reader begins at the touch-sensitive table of contents, which shows the automatic transmission of a car in cross-section. The reader "browses" through the contents of the manual by touching the picture.



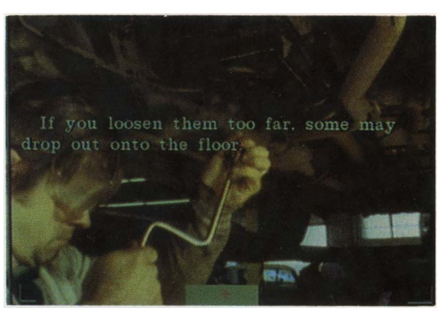
A touch in a particular region causes the appropriate subassembly of the transmission to be highlighted in color, and a short paragraph appears at the upper right describing it. Each region represents a chapter in the book, which has pictures, sound and text.



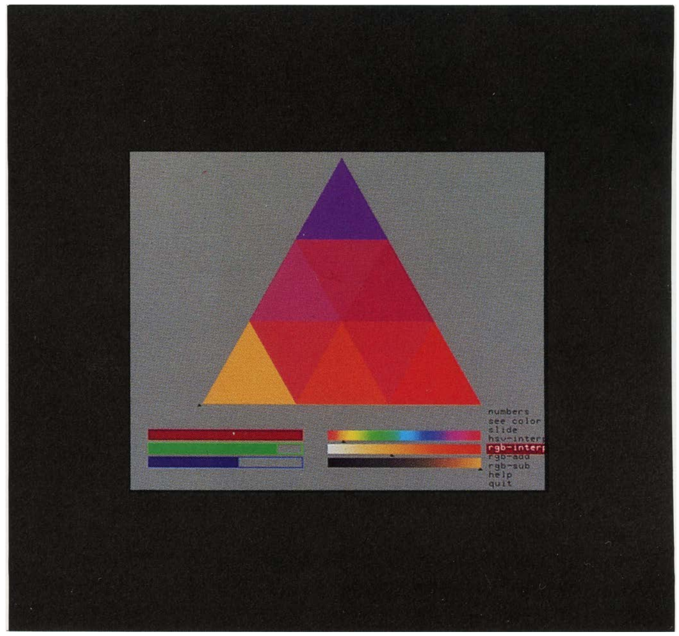
The words highlighted in color are glossary words, which the reader can "look up" with a touch. The word or phrase is retrieved and used as an entry into the glossary. The definition appears on the page, superimposed over the illustration. Other words in it may be investigated.



The illustration in the page is really a movie; color video graphics are used as touch sensitive controls for the video disk images. The reader can play the movie in forward or reverse, at various speeds. The mechanic shown here is removing the oil pump.



Another kind of page shows what happens when a repair is performed the wrong way. All of the live footage was recorded with synchronous sound, to provide the auditory cues of tool noises, parts moving, etc. that involve the reader in the process. Narration mixed with the ambient sounds reinforces the explanation in the text.



BUCOLIC is a series of exercises in color theory used by art students. Among the chief advantages in teaching color theory with this system is the student's ability to experiment. Typically, students of color theory can complete only a few exercises before the course is over because of the time taken for painting. Using BUCOLIC, design and implementation are not separated; students can explore design ideas freely without committing many hours to the painting.

Electronic Classroom (Figure 26)
Under normal circumstances, it is not possible for 60 students in one class to receive individual attention. Yet individual attention is provided to 60 students in a computer-based experimental classroom at Brown University.

Brown is experimenting with the concept of a "wired university", and has created as a first step, a "wired classroom". Students in the classroom each have a workstation with interactive capabilities that permit: students to see **animated demonstrations** showing precisely what is being done on the instructor's screen; **monitored instruction,** with the instructor and assistants observing student work as the student works; and **interactive graphics** using moving, dynamic graphics to communicate abstract concepts, or to generalize and explore problems.

Rather than using a blackboard to explain a concept, instructors are able to use dynamic graphic presentations. Concepts are typically introduced with each student's computer mimicking the instructor's. Then, students are given an opportunity to execute, at their own pace, what was observed, or work on a related problem.

The Electronic Classroom is currently being used to teach computer science, mathematics, neural science, and as shown in the series of images here, color theory.

Exhibition

Exhibitions require the design and presentation of information in time and three-dimensional space. The viewer's movement and experience is shaped and structured by the design of the exhibition. Exhibitions can be categorized as both entertainment and education.

While exhibitions have often included real-time demonstrations and viewer participation, to put effective static or dynamic information into a three-dimensional exhibition is awkward and expensive. Computers coupled with video, touch-sensitive displays, and video disks provide a wide range of more individualized access and choice of information to a larger number of people.

Knoxville World's Fair Exhibition (Figure 27)
Interactive video disk and personal computers were used at the 1982 Knoxville World's Fair in Tennessee to create a powerful and attractive system that was both instructive and engaging.

This system was designed to be a highly personal, elastic, non-linear presentation of information. It was interactive, responding to and allowing its users to pursue areas of specific interest while bypassing familiar or boring information. At the same time, the system made full use of its powers, employing images - both still and moving - text, and sound.

The subject of the system was energy, and it was covered from every conceivable angle: the sources and uses of energy; definitions of energy terms; and different expert views on energy issues.

Thirty-three thousand visitors passed through the exhibit each day, using a total of 42 different interactive video screens that offered immediate access to the visitor's specific area of interest.

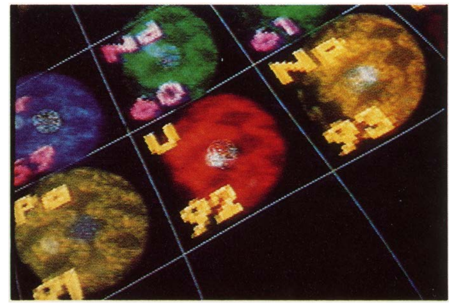
A user had only to touch a word or symbol on the screen to indicate an interest in more detailed information. The corresponding information would immediately appear, called up for display from its storage place on one of the system's video disks.

Touch-Sensitive Display Screen
Touch can be registered on the television screen because a grid of invisible infra-red light is cast across the screen by lights bordering the screen. When the screen is touched, the grid is broken, signaling precisely where the area of interest lies.

Video Disks
A video disk holds 54,000 images on one side. The interactive disk players use laser to play the disk instead of the more conventional stylus. A computer acts as an intermediary between the disk player and the interactive video screen. The computer registers the area of the screen touched by the user, and instructs the disk player to go to the place on the disk where the appropriate information is stored, and to "play" it.

Entertainment

Film and video are the media of modern entertainment. Animation is the bridge between static print graphics and dynamic film and video graphics. Traditionally, labor-intensive frame-by-frame drawings were coupled with time and motion to create animation.



Nova Opening (Figure 28)
This still comes from an animation sequence made for the PBS "Nova" series. Without the use of computers, it would have been very difficult to create.

The animation began in a conventional manner with a designer drawing the sequence out on a storyboard. It then went to a technical director who decided how to design and model each element and coordinate them with one another for the animation.

Two-dimensional techniques were used to make "flat" images and to perform zooms and pans. In those instances where three-dimensional images were required, the objects were described mathematically in the computer. To give an illusion of continuous motion, the computer rendered the objects from a fractionally different perspective for each frame of animation.

The Nova opening is only 15 seconds long, but through it, the viewer takes a voyage from the atomic to the cosmic scale. This is a voyage that clearly, no traveler could ever take, but which is represented here for the viewer by graphics.

New Graphic Directions

As information technology becomes more sophisticated and becomes more deeply embedded in our society, it is clear that a new graphics which include sensory input and output will serve as the primary means of communication with computers. The implications of the shift away from a print communication is difficult to assess; however, one can postulate that the professional understanding and practice of design will be expanded and synthesized with computer capabilities.

Some of the advanced issues of the new graphics are being explored now in research environments. Graphic languages that would help computer programmers in their programming work are being explored; as are dynamic graphics, capable of describing movement, and behavior, and which can be modified by the user.

Program Visualization (Figure 29)
Program Visualization will allow computer programmers to create, experiment with, debug, and document their programs by graphic programming means. The researchers say Program Visualization will "open the side of the machine", allowing both the user and the programmer to form an accurate model of a running program.

In Program Visualization, symbols will be invested with data that, once triggered, can prompt things to happen. To explain it, consider the difference between flipping a light switch and getting light, and flipping a light switch and getting a menu of computer options. Programming Visualization would be the one, in our hypothetical construct, that would give light, not menus. In other words, the effect of an action would be literal, not encoded in another layer of symbols. It is this visual directness that would allow users to "open the side of the machine" to see and understand a running program.

Programming Visualization would enable programmers to form clear, accurate mental images of the structure and construction of programs, and to select the most appropriate mode for a programming task.

To designers this means that graphics will be used not only to represent information statically, as is typical: instead, graphics will be used to control information and to manipulate information processes dynamically.

Architecture Credits

Student Elevations of Existing Buildings (Figure 1)
Graduate School of Architecture and Urban Planning - UCLA

Instructors:
Robin Liggett
William Mitchell

Equipment
32-inch pen plotter

London Column (Figure 2)
Contributor and Architect:
Charles Jencks

Programmer:
John Heile
Graduate School of Architecture and Urban Planning - UCLA

Arched Doorway (Figure 3)
Contributor and Architect:
Charles W. Moore

Solar Consultant:
Ralph Knowles

Programmer:
John Heile
Graduate School of Architecture and Urban Planning - UCLA

Client:
San Antonio Art Institute

Architects:
Moore/Ruble/Yudell
Santa Monica, CA

Terminal Four (Figure 4)
Contributors and Architects:
Scott Brownrigg and Turner consultant Architects

Client
Heathrow Airport, London

Equipment:
GDS turnkey drafting system (Developed by Applied Research of Cambridge, in Cambridge, England; and marketed in the U.S. by McAuto).

Computer-Generated Image of William Morris' Red House (Figure 5)
Contributor:
Applied Research of Cambridge, Cambridge, England

Geometric Modeling:
Applied Research of Cambridge staff

Equipment:
GDS drafting system color workstation

Highrise Office Building (Figure 6)
Contributor:
Cranston/Csuri Production

Los Angeles City Hall (Figure 7)
Contributor
Albert C. Martin Associates

Architect
Albert C. Martin

Software:
Developed by the computer group at Albert C. Martin Associates

Volumetric Relationships: Palladio's Villa Rotonda (Figure 8)
Software Development Directed by:
William Jepson
Graduate School of Architecture and Urban Planning - UCLA

Geometric Database developed by:
John Heile
Graduate School of Architecture and Urban Planning - UCLA

Composition Perspectives (Figure 9)
Contributor and Architects:
Skidmore, Owings and Merrill
Chicago, IL

Software:
Computer group of Skidmore, Owings and Merrill

Site Massing Study (Figure 10)
Contributor and Architects:
Welton Becket Associates
Los Angeles, CA

Equipment:
Tricad CAD system
Color raster display screen
Versatec color electrostatic plotter

Century City (Figure 11)
Contributor and Architects:
Welton Becket Associates
Los Angeles, CA

Equipment:
Tricad CAD system

Chicago Skyline (Figure 12)
Contributor and Architects:
Skidmore, Owings and Merrill

Software:
Computer group of Skidmore, Owings and Merrill

Computer-Generated Image of Le Corbusier's Villa Savoye
Software Development Directed by:
William Jepson
Graduate School of Architecture and Urban Planning - UCLA

Geometric Modeling:
Brian Ten
Graduate School of Architecture and Urban Planning - UCLA

Equipment:
Raster Technologies System

Sunlight and Shadow Studies
Contributor and Architects:
Skidmore, Owings and Merrill
Chicago, IL

Software:
Computer group of Skidmore, Owings and Merrill

Exploded Perspective
Contributor and Architects:
Skidmore, Owings and Merrill
Chicago, IL

Software:
Computer group of Skidmore, Owings and Merrill

Complex Floor Plans
Contributor:
Continental Graphics
Pasadena, CA

Equipment:
GDS turnkey drafting system (Developed by Applied Research of Cambridge, in Cambridge, England; and marketed in the U.S. by McAuto.)

Product Design Credits

Microchip (Figure 13)
Contributor:
Calma

Equipment:
Versatec plotter

Mustard Jar (Figure 14)
Contributor:
Cranston/Csuri Productions, Inc.
Columbus, OH

Designers:
Kornick Lindsay
Chicago, IL
Joe Kornick
Dean Lindsay

Animator:
Michael T. Collery
(Cranston/Csuri)

Client:
R.T. French Co.
Rochester, NY

Equipment:
Digital Equipment Corp. VAX 11/780
Custom-Built 32-bit Frame Buffer
Ampex Model ESS-2
Electronic Still-Store

Software:
Dr Frank Crow (rendering software)

High-Speed Printer (Figure 15)
Contributor:
Advanced Matrix Technologies
Newbury Park, CA

Designers:
I.D. Two, Inc.
Palo Alto, CA
Stephen Hobson
William Moggridge
Eric May

Service Bureau:
Ronningen Research
Vicksburg, MI

Equipment:
McAuto Unigraphics
CAD/CAM System

Sabre Saw (Figure 16)
Contributor:
Computervision Corporation
Bedford, MA

Part Data:
Black and Decker Corporation

Creators:
Allen Alley (Product Manager)
Robert McGill
Carl Soiberg

Equipment:
Computervision CDS 4000
CAE/CAD/CAM System
Computervision Instaview (R)
High Resolution Display

Software:
Advanced Surface Design (TM)
Imagedesign (TM)

Car Rendering Software (Figure 17)
Contributor:
General Motors
Research Laboratories
Computer Science Department
Warren, MI

Software Author and Creator:
David R. Warn

Equipment:
Digital Equipment Corp. VAX 11/780
Raster Technologies Model One/25
Display Processor
Ramtek 9300 Color Display

Aluminum Wheel Modeling (Figure 18)
Contributor:
PDA Engineering
Santa Ana, CA

Designer:
C. Hayden Hamilton

Equipment:
Digital Equipment Corp.
VAX 11/780 Computer
Raster Technologies Model
One/25 Display Processor

Remote Control Device (Figure 19)
Contributor:
RCA Corporation
Consumer Electronics Division
Indianapolis, IN

Industrial Designers:
Richard Bourgerie
Steve Schultz

Engineer:
Ted Smith

Design/Drafter
Mike Squillace

CAD/CAM Coordinator:
Paul Gunn

Model Makers:
Jim Carins
Gary Stevens
Jim Lynn
Kevin Larr

Equipment:
Computervision
CADDS 4 CAD System
Hillyer 4-Axis N/C Milling Machine

Simulating Human Physical Differences
(Figure 20)
Contributor:
Alonzo Miranda
Institute of Design
Illinois Institute of Technology
Chicago, IL

Disk Camera
Contributor:
Eastman Kodak Company
Rochester, NY

Designer:
Staff

Equipment:
Intergraph LSI Monochrome and
Color Raster
Design Stations

Digital Equipment Corp.
PDP 11/70 Computers

Flight Simulator
Contributor:
The Boeing Company
Seattle, WA

Software Authors:
R. Linder
(Boeing Commercial Aircraft Company)
J. Jaech
(Boeing Computer Services Company)

Equipment:
IBM 4341 Computer Raster Technologies
Model One/25 Display Processor
Matirix Color Graphic Film Recorder

"Starfighter"
Contributor
Digital Productions, Inc.
Los Angeles, CA

Equipment
Cray XMP Super Computer
Ramtek 9460 Color Display

Experimental Car
Contributor:
Ford Motor Company
Dearborn, MI

Designer:
Guiseppe Delena

Software Author and
Creator of Images:
Stephen H. Westin

Equipment:
Prime Computer
Zeta 52" Drum Plotter
Renderings done on Cray 1/S
Computer by Cray Research, Inc.
Mendota Heights, MN

Images created on
Dicomed D48S Film Recorder by
Dicomed Corp.
Minneapolis, MN

Software:
Product Design Graphics System
(PDGS) (surface development)
Modified MOVIE.BYU (rendering)

Car Interior Rendering
Contributor:
Chrysler Corporation
Detroit, MI

Designer:
Raymond Cannara

Equipment:
Control Data Corp.
Cyber Computers
Tektronix Display Terminals
Gerber Flatbed Pen Plotters
Calcomp photo-plotter

CAD Specialists:
Clinton T. Washburn
David A. Fick

Ski Shoe
Contributor:
Nike, Inc.
Exeter, NH

Designer:
Ken Geer

Equipment:
McAuto Unigraphics CAD System
Data General MV 8000 Computer
Bostomatic N/C Milling Machine

Visual Communication Credits

SIGGRAPH Symbol (Figure 21)
Contributor:
Seitz Yamamoto Moss Inc.
Minneapolis, MN

Designer:
Peter Seitz

Client:
SIGGRAPH

Equipment
Dicomed D38, Imaginator and slide system

SEEDIS
(Figure 22)
Contributor:
Aaron Marcus and Associates
Berkeley, CA

Designers/Technologists:
Aaron Marcus, Principal
Michael Arent, Design Director

Client:
Computer Science and Research Dept.,
Lawrence Berkeley Laboratory,
University of CA at Berkeley

Equipment:
DEC VAX 11/780
terminals - Ramtek 9400,
Tektronix 4027,
ADM-3, Dec VT100,
Tektronix 4104,
Autologic APS micro 5;
hardcopy - Xerox 9700,
Versatec V-80,
Tektronix 5218 printers

Software:
Primarily in Fortran and C,
DEC VMS operating system

Electronic Maintenance Manual: Interactive Graphical Documents
(Figure 23)
Contributor:
Department of Computer Sciences
Brown University
Providence, RI
Professor Andries van Dam, Chairman

Designers/Technologists:
Steven Feiner with Randy Pausch,
Jerry Weil, David Salesin

Client:
Office of Naval Research
National Science Foundation

Equipment:
DEC VAX 11/780
Ramtek 9400 graphics system
Matrix Instruments OCR D-4/2 film recorder

Electronic Archive (Figure 24)
Contributor:
Architecture Machine Group
Department of Architecture
Massachusetts Institute of Technology
Cambridge, MA
Professor Andrew Lippman, Director

Designer/Technologist:
Patrick Purcell,
Visiting Associate Professor of Computer Graphics, MIT

Client:
Sponsored in part by the Council for the Arts at MIT

Equipment:
Perkin-Elmer 3230 computer
Discovision optical videodisk
Elographics touch-sensitive display
Panasonic monitors

Software:
P1/1, on Magic 6 operating system

Movie Manual (Figure 25)
Contributor:
Architecture Machine Group
Department of Architecture
MIT, Cambridge, MA
Professor Andrew Lippman, Director

Designer/Technologist:
David Backer, Research Associate

Client:
Office of Naval Research

Equipment:
Perkin-Elmer 3230
Ramtek 9400 frame buffer
Discovision optical videodisk
Elographics touch-sensitive screen
Color graphics monitors

Software:
P1/1 on Magic 6 operating system

Electronic Classrooms (Figure 26)
Contributor:
Department of Computer Science
Brown University
Providence, RI
Professor Andries van Dam, Chairman

Designers/Technologists:
Mark Brown, Robert Sedgewick, with Joe Pato, Steven Reiss, Michael Strickman,
Edward Grove, Richard Hawkes,
Thomas Banchoff (BALSA);
Steven Drucker (neural display);
Barbara Meier, Roger Mayer (BUCOLIC)

Client:
Supported by NSF CAUSE program
Apollo Computer Inc.
DARPA
Office of Naval Research
Exxon Educational Foundation
National Science Foundation

Equipment:
60 Apollo DN300 workstations with 1024x800

b&w displays connected by
Apollo's Domain Network
Apollo DN600 for color versions of programs

BUCOLIC runs on a DEC VAX 11/780 and a Lexidata 3400 color graphics system

Matrix Instruments QCR D-4/2 film recorders

Knoxville World's Fair Exhibition
(Figure 27)
Contributor:
Ramirez and Woods, Inc.
New York, NY

Designers/Technologists:
Albert H. Woods, Principal-in-charge
Thomas Nicholson, Production Director
Daniel Pelavin, Susan Nicholson, Computer Graphics Staff, Videodisk Production with Steven Gregory and staff of New England Technology Group, Woburn, MA consultants for Systems Programming,
Design and Installation

Client:
US Department of Commerce

Equipment:
30 Apple II Computers
50 Sony LDP1000 videodisk players
50 Sony PVM1900 color monitors
25 Elographics Touch Sensors

NOVA Opening (Figure 28)
Contributor:
WGBH-TV Design Department
Boston, MA
Christopher Pullman, Director

Designer/Technologist:
Paul Souza with
David Geshwind
Computer Graphics Laboratory
New York Institute of Technology

Equipment:
DEC PDP 11/70 and 11/34 series, VAX 1170
Genisco frame buffer
Evans and Sutherland picture system
IVC 9000 video recorder

Software:
Proprietary software by NYIT written in C

Program Visualization
(Figure 29)
Contributor:
Computer Corporation of America
Cambridge, MA

Designer/Technologists:
Christopher Herot, Jane Barnett, Gretchen Brown, Richard Carling, David Dowd, Mark Friedell, David Kramlich, with consultants,
Ronald Baecker
(Human Computing Resources, Toronto)
Aaron Marcus (AM&A, Berkeley),
Rebecca Allen, Paul Souza (WGBH, Boston)

Client:
DARPA

Equipment:
DEC VAX 11/780
3 Adage 512 screens converted to
one high res, 1280x1024x8 bits

Caricature Generator
Contributor:
Atari Research Laboratory
Sunnyvale, CA
Kristina Hooper, Director

Designer/Technologist:
Susan Brennan with
Gary Phipps, Eric Hulteen,
Phil Agre, Jim Davis

Equipment:
Symbolics LM2 computer

Software:
Lisp

TV Fishtank
Contributor:
Atari Research Laboratory
Sunnyvale, CA

Designer/Technologists:
Ann Marion, Valerie Atkinson

Equipment:
Atari 800 microcomputer

Seeing C
Designer/Technologists:
Aaron Marcus, Principal
Michael Arent, Design Director
Andrea Pettigrew, Assistant

With programming consultants
Ronald Baecker, President
Paul Breslin, John Jackson, Allen McIntosh,
Christopher Sturgess, Programmers of
Human Computer Resources Corporation
Toronto, CAN

Client
US Defense Advanced Research
Projects Agency,
Systems Science Division

Equipment:
Autologic APS micro 5
Low resolution and high resolution terminals
Laser printer/plotters

Software:
C, Unix

Metaform
Designer/Technologists:
Aaron Marcus, Principal
Michael Arent, Design Director
Richard Mehl, Assistant

Client:
Intran Corporation
Edina, MN

Equipment:
Three Rivers Perq-1 computer, 16-bit
68000 - based b&w high resolution display
Xerox 9700 laser printer

Software:
Proprietary software in PASCAL,
on Three Rivers operating system

Rocky's Boots
Contributor:
The Learning Company
Menlo Park, CA

Designer/Technologist:
Warren Robinett

Client:
The Learning Co.

Equipment:
Apple II+ or IIe with color monitor and
joystick

View System
Contributor
Computer Corporation of America
Cambridge, MA

Designers/Technologists:
Christopher Herot, Jane Barnett, Gretchen
Brown, Richard Carling, David Dowd, Mark
Friedell, David Kramlich with consultants
Ronald Baecker, Aaron Marcus,
Rebecca Allen, Paul Souza

Client
Naval Electronics System Command
(NAVELEX)

Equipment:
DEC VAX 11/780
3 Adage 512 screens converted to
one high-res 1280x1024x8 bits

Electronic Newspaper
NewsPeek
Contributor:
Architecture Machine Group
Department of Architecture
MIT, Cambridge, MA
Professor Andrew Lippman, Director

Designer/Technologist:
Walter Bender, Research Associate

Clients:
Office of Naval Research
Mead Data Central,
R.R. Donnelly,
Associated Press

Equipment:
Perkin-Elmer 3230
Ramtek frame buffer
Discovision optical videodisk
Color monitors
Elographics touch-sensitive display
Voice recognition and synthesis

Software:
P1/1 on Magic 6 operating system

Programming by Rehearsal
Contributor:
Xerox Corp, Palo Alto Research Center
Palo Alto, CA 94304

Designers/Technologists:
Laura Gould, William Finzer

Equipment:
Xerox 1132 Dorado computer with high-res
display screen and mouse

Conference Co-chairs
Richard M. Mueller
Control Data Corporation

Richard A. Weinberg
Fifth Generation Graphics Inc.

Advisory Board
Dale Fahnstrom
Institute of Design
Illinois Institute of Technology

D'Arcy Gerbarg
New York University

Copper Giloth
Real Time Design, Inc.

Kristina Hooper
Atari Sunnyvale Research Laboratory

Tadashi Ikeda
Osaka University of Art

Aaron Marcus
Aaron Marcus and Associates

Charles Owen
Institute of Design
Illinois Institute of Technology

Curatorial Committee
Patrick Whitney, Chairman
Institute of Design
Illinois Institute of Technology

Del Coates, Product Design
San Jose State University

Muriel Cooper, Visual Communications
Visual Language Workshop
Massachusetts Institute of Technology

William Mitchell, Architecture
Graduate School of Architecture and Urban Planning
University of California - Los Angeles

Editor
Cheryl Kent
Whitney and Kent, Limited

Communication Development and Evaluation
C.G. Screven
University of Wisconsin - Milwaukee

Exhibition Development
Patrick Whitney, Director
Institute of Design

Jon Elliot,
Production
Institute of Design

Carlos Latorre,
Design and Production
Institute of Design

Jaime Douthit Louyeh,
Typesetting
Institute of Design

Suzanne Richards,
Production
Institute of Design

Peter Spreenberg,
Design and Production
Institute of Design

Darlene Swierczek,
Production
Institute of Design

Supporting Organizations
Cray Research

Graduate School of Architecture and Urban Planning
University of California - Los Angeles

International Neon Products Incorporated

Institute of Design
College of Architecture and Design
Illinois Institute of Technology

Visible Language Workshop
Massachusetts Institute of Technology

ACM SIGGRAPH '84

The Eleventh Annual Conference on Computer Graphics and Interactive Techniques

Sponsored by the Association for Computing Machinery's Special Interest Group on Computer Graphics in cooperation with the IEEE Technical Committee on Computer Graphics, Eurographics, the Minneapolis College of Art and Design, the University of Minnesota, the Science Museum of Minnesota and the Institute for Media Arts.

Printed in USA

SIGGRAPH '84