Computer-Aided Industrial Design

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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.