THE ENGINEERING DESIGN GRAPHICS
Journal

Spring 1986 Volume 50 Number 2

ENGINEERING DESIGN GRAPHICS DIVISION
AMERICAN SOCIETY FOR ENGINEERING EDUCATION

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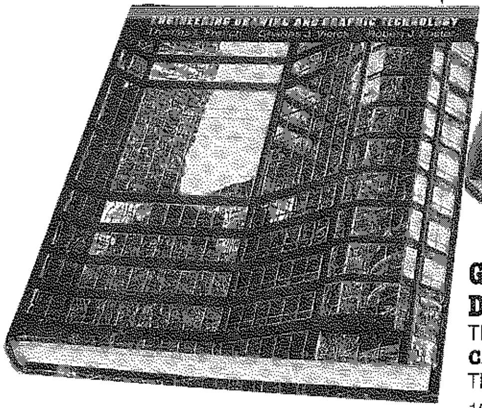

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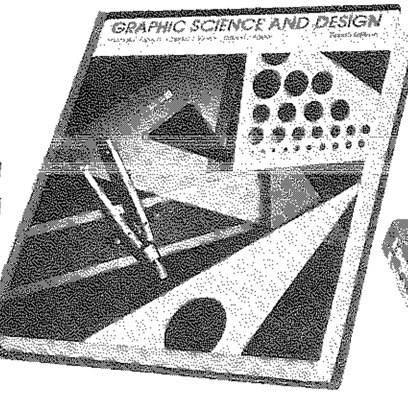

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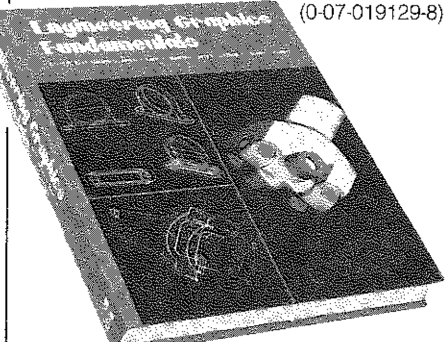

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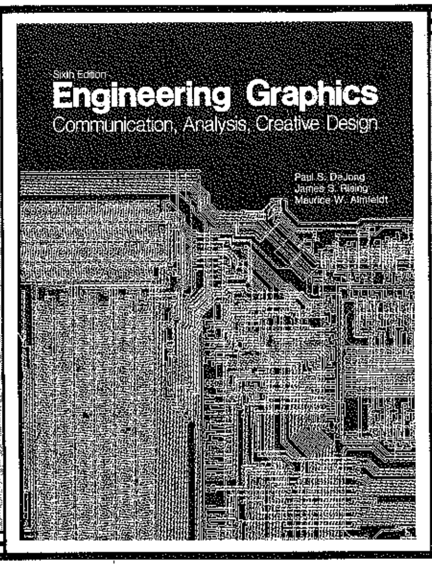
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OBJECTIVES OF THE JOURNAL

The objectives of The Journal are:

1. To publish articles of interest to teachers and practitioners of Engineering Graphics, Computer Graphics, and subjects allied to the fundamentals of engineering graphics education and graphic technology.
2. To stimulate the preparation of articles and papers on topics of interest to its membership.
3. To encourage teachers of graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses.
4. To encourage research, development, and refinement of theory and application of engineering graphics for understanding and practice.

DEADLINES

The following are deadlines for submission of articles, announcements, and advertising: FALL-September 15; WINTER-December 1; SPRING-February 1.

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3. Two copies of each manuscript are required.
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Continued inside back cover.

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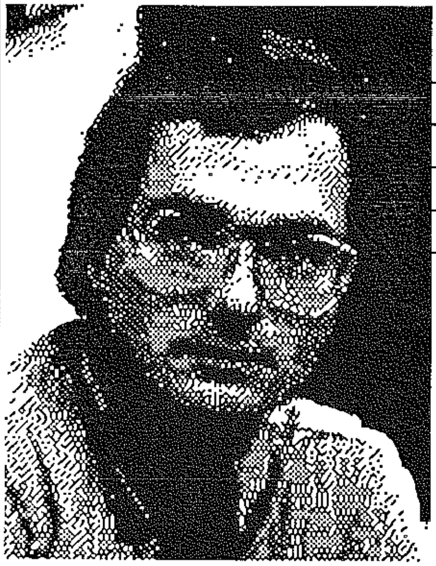
Features



Jon M. Duff
Editor

editor

FROM THE DESK OF THE EDITOR

On April 9, 1986, The State University of New York at Farmingdale, along with Grumman Aerospace and Brookhaven National Laboratories, sponsored a "CAD on Micros Conference." Attended by this editor and engineering and technical business and faculty from the east coast, it provided a forum for the latest trends in CAD, and especially CAD on microcomputers.

Several impressions were made, some expected and some unexpected. It is still evident that there are several industries that are by their very nature more likely to be engaged in the cutting edge of CAD technologies. These companies work with massive intelligent data bases and require large host computers to do their work. They do not consider the PC, even the IBM PC AT, as their engineering workstation. Rather they see the SUN or Apollo 32 bit desktop mini as the engineer's tool. But for the rest of the world the PC AT appears to be the platform that will be used in the near future. That was expected.

What was not expected was the total disregard among most for managing the day-to-day activities of the engineer, coordinate the mounds of information, and allow the engineer to be productive <u>outside</u> CAD. Yes Virginia, there is an engineering world outside CAD. Grumman has placed my favorite tool, the Macintosh, on their engineers' desks as both a productivity tool, and as a bit-map terminal for entry into the Sun and Apollo environment. The justification for this is to relieve the engineering workstation and the host computer of all 2-D functions such as text processing, diagrams, charts, reports, etc.

"learning time is cut by a factor of 10 by early micro CAD experience"

Another interesting outcome was the strong emphasis on 3-D data bases and their applications. Even in introductory teaching, the feeling from employers and faculty alike was that teaching 2-D representation of 3-D geometry was a disservice.

The keynote address by **Carl Machover** of S. Klein Newsletter fame spoke to the subject of CAD on Micros from a current needs perspective. He mentioned that only 5% of the total cost of a product is in its engineering and that fully 80% of the time spent on CAD systems is in drafting activities. This, as many companies have found out, is a horrendous overhead. Mr. Machover stressed the idea of creating the model first, and letting the drawings later represent that model. On the publishing scene, **WYSIWYG** is now the standard and the systems that work the best are the ones where the user isn't aware that the system is working at all! He felt that learning time on a major system is cut by a factor of 10 by early micro CAD experience. He discussed the subject of graphic standards, especially IGES, PDES, and STEP , as well as GM's MAP (Manufacturing Automation Protocol), and TOP (Technical Office Protocol). He closed by stressing that the cost of equipment is trivial, it is the cost of the data that is critical.

From the Grummann Corporation, Space Systems Engineer **Paul Levitt** related his experience in adapting business software to engineering needs, especially in the Macintosh environment. He strongly believes , as does this editor,in the decentralization of computing.

Continued on page 7

chairman

A MESSAGE FROM THE CHAIRMAN

Robert J. Foster
Chairman

We would all agree that a year is a very short span of time, especially in the life of an organization such as our Division with roots back to 1928. It seems only last month that my responsibilities as Chairman began at the June 1986 meeting in Atlanta. Being chairman isn't a lot different from other jobs with a group such as ours. The work done by persons in the background is just as vital, perhaps more so, than the rituals expected of the Chairman.

Still, it has been a position of both joys and frustrations. The former outnumber the latter! There is joy in seeing how the many component committees and segments of the Division fit together and function. The result is an entity whose sum exceeds its parts. The total thrust exceeds by far what the individual committees working separately could accomplish.

There is also joy in the fellowship and stimulation of interacting with one's peers in the workshops, seminars, and meetings occurring in the course of a year. Whether at a CAD workshop at the Midyear Meeting, or sharing a lunch between sessions at the Annual Conference, being with colleagues in engineering education gives a lift to one's professional spirit. The problems and successes back home can be aired with others. One knows that he or she is not operating in a vacuum, but that others may be having similar experiences. This is good for mental health and vitality!

Frustrations? Yes, there are always some as seen by any officer of any organization. One worry is that progress seems to move so slowly. The old saying, "Let's refer that to committee," is too often true. Sometimes courage is needed to promptly resolve an issue, pro or con, rather than prolong the agony with committee.

Planning for constructive future growth is another frustration. Oh, for a crystal ball! We are not granted such easy vision, however. We must extrapolate as best we can, based on knowledge and the collective wisdom of the membership. Then, adding in a bit of luck, we may just be moving in what may later prove to be the correct direction.

Looking to the future, these are some needs our Division should address. One is the need to increase communication back and forth among officers and members at large. The Journal and hoped-for newsletters can go "out", but what comes back "in" can be very scant. Let's see some real traffic within the Division and also with other Divisions of ASEE to which we relate (Computers in Education and Engineering Technology). The constituent Committee of Freshman Programs is another ally in education.

Another need is to wisely invest some of our accrued reserve funds in worthy projects. We need to move beyond sitting on our hands in terms of using our funds. Yes, special projects take work, but there can be considerable benefits: mutual transmission of data, research,and findings, and a renewed mental vigor among peers. If you have a project you believe has merit, please submit a proposal to the Executive Committee. Incoming Chairman Rollie Jenison will be glad to channel your thoughts to the proper group.

> "increased communication back and forth among officers and the membership. . . . . ."

Yes, Rollie Jenison is the connecting link between outgoing officers and the incoming. As Vice Chairman for 1985-1986, he has an overview of the total organization. This, coupled with good previous years of prior experience within EDGD, will ensure a smooth transition. Give him your support. Ask what you can do to serve the Division. Better yet, <u>tell</u> him what you want to do. You may be pleasantly surprised that the Division embraces your ideas with open arms!

division

NEWS OF THE DESIGN GRAPHICS DIVISION

EDGD MIDYEAR

Meeting

Imagine leaving the cold and ice for warmer climes and be able to attend a great graphics conference to boot! January 6-7, 1987, should prove to cure the winter blahs if you decide to attend the ASEE/EDGD Midyear Meeting hosted by The University of Texas at Austin. A side trip to the Gulf for shrimp and walks on the beach should punctuate anyone's winter. Paper abstracts are solicited on the topics listed below.

Ronald C. Pare'
Mechanical Engineering
Technology
University of Houston
4800 Calhoun
Houston, TX 77004
(713)749-4652

Send 500 word abstract
by July 15, 1986

Topics:
engineering and computer graphics, CAD,CADD, micros, 3-D graphics, solid modeling, geometry, degree programs, graphics programming.

International Conference

Update

Plans are continuing for an International Conference on Engineering and Computer Graphics to be held in August, 1988, in Vienna, Austria. Look for a **Call for Papers,** possibly in Volume 51, Number 3.

There is sufficient lead time to give everyone who has an interest and an interesting topic to prepare a paper abstract. Start thinking about it now, possibly going to the extent of cultivating a project that might be of interest in 1988, even though what we now do changes so rapidly.

How to get there, now that's a problem. I suggest a "two pronged approach." First, put away $25.00 into your credit union each month between now and then. Second, investigate the sources of support at your institution for foreign travel. The Research Foundation or Graduate School may have a **Foreign Travel Grant** program for just this purpose. In general, submit your application through your Dean's office for the first screening. Investigate this early! It is not uncommon for monies to be committed in December for the next fall semester.

review

A REVIEW OF NEW PRODUCTS AND MATERIALS

Applied Descriptive Geometry by Susan A. Stewart. Demar Publishers, 1986.

This text-workbook is a cut above the expected for disposable course materials. The writing is short and to the point, often not the case with descriptive geometry texts, with many pictorial illustrations which help explain spatial problems.

The text has what might be called "single problem exercises" which are more appropriate for engineering technology, where most graphics is taught anyway. Gone are the involved engineering design problems which may have never been appropriate for an introductory Descriptive Geometry offering.

The book is organized logically, beginning with a review

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Editor

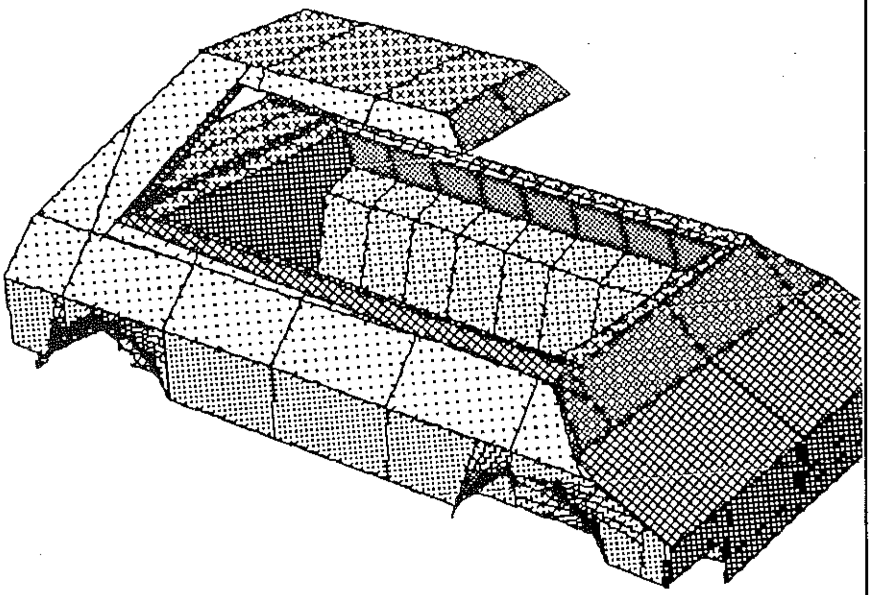
from page 4

At Grumman they are working on the theory that micros and mainframes can coexist, each doing what they do best. They use a "Tek-a-Like" emulator for the Mac to address host computer graphics applications over phone lines.

Networking was a hot topic with **Michael Poncher** of CAD Design Systems, Inc., discussing the capabilities of various Local Area Networks (LANs). The distributed bus design accounts for most of their installations, he said, and agreed with Mr. Machover that CAD penetration is a function, right now at least, of company size. Among companies with 100 or fewer workers, CAD shows only 17% penetration whereas among companies with greater that 1,000 employees, CAD had achieved a 48% penetration.

Seymour Fisch from the architectural firm of Haines Landberg Waehler took the audience through a project start to finish on an Intergraph system, not really much to do about micros but informative just the same. He was very positive about cost effective vendor training—not tying up his equipment or personnel with non-money making training. Recently factory trained designers continue to learn at HLW by adding to the company's cell library of standard architectural symbols. Making use of color as a design tool, he lamented the inability to send the same high quality graphics out to the contractors. CAD seems to be the coordinating catylist between the architect, interior designer, engineer, and manager.

Lastly, **Drew Davis** from Microscource CAD/CAM and **Thomas Wheeler** of GE-CALMA discussed managing data bases and the various hardware and software configurations. Both agreed that the future is a color engineering workstation with multiple processors having one fourth the power of a CRAY, able to merge text and graphics from any number of scources.



From the International
Conference on Engineering
and Computer Graphics

1984 北京

The Application of Descriptive Geometric Method in the Computer Information Processing System

Wang Bao-Hua
Shanghai Shupbuilding
Technology Research
Institute
China State Shipbuilding
Corporation

Introduction

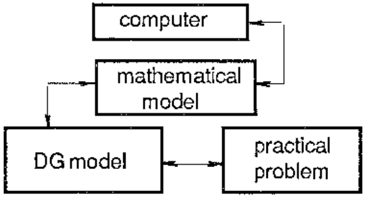
In the computer information processing systems for modern engineering, it is imperative to solve a series of problems in multidimensional space, such as the definition, fitting, fairing correlation and figuration of various surfaces, the determination of space position and shape of some surfaces which have special requirements the developability, discrimination, and approximate development of surfaces. On the basis of abstraction and summerization by the descriptive geometric method, the author of this paper has sorted out the above-mentioned problems into direct or indirect geometric models upon which computing modules were established. Practices both in computing and production have proved that the descriptive geometric model is an effective way in the solution of very complex surface problem.

This paper relates the different use and characteristics of the descriptive geometric model through the citation of five groups of examples.

The Analysis of the Different Ways for Applying Descriptive Geometric Models.

In general, there are three ways for applying descriptive geometric models in computer information processing systems.

The following is the flow chart of the **first way.**



(The mathematical models discussed in this paper refers to fitting, fairing of curves in two-dimensional planes and analytical models of geometric figure intersection.)

Take the fairing of ship's hull surface as an example. It is very difficult to fair different hull surfaces by a uniform computing mode due to the variation of ship's forms. As an approach to the solution, it is required to divide the different hull surfaces into various basic surfaces in accordance with shape analyses and establish corresponding descriptive geometric models after total analyses of formation principle, defining method, fairing procedure and matching capability of such basic surfaces. (See Fig. 1)

Then, the hull surfaces are to be pre-processed to simplify the boundaries. The desirable boundary line must have the following three characteristics:

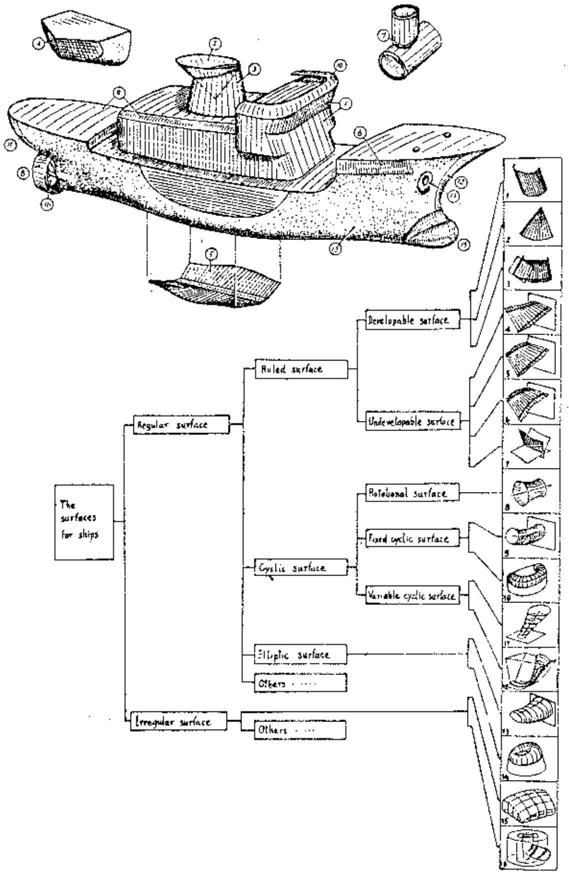


Figure 1

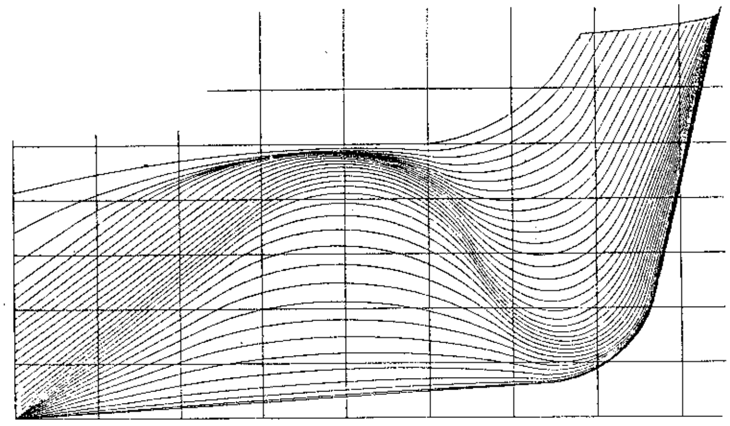


Figure 2

a. The boundary line must be smooth and harmonize with the surface where it locates.

b. The boundary line must be stable and fixed.

c. The boundary line must locate in a simple space position.

However, necessary treatments should be given to the actual boundary lines of ship's hull (including free boundaries, the boundary which is tangent to a ruled surface, the boundary which is tangent to the generator of a circle, and the boundary which intersects with other surfaces.)

Such a treatment proceeds on the following two principles in most cases.

a. addition--subtraction principle.

New virtual boundaries which meet the requirements of desirable boundary as far as possible could be established in different position by extending the hull surfaces upwardly, downwardly, forewardly and backwardly.Based on the surface fairing, various regular surfaces can be generated.

The extension part remained for irregular surfaces will be subtracted after the combination of the regular surfaces.

b. Subtraction--addition principle.

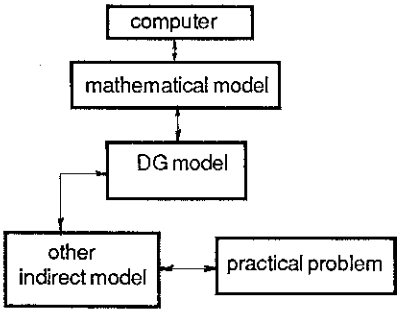
As a first step, the appendages of hull surfaces (propeller hub fairing for example) are neglected for the simplication of surfaces.

Those surfaces for appendages will be generated and assembled after the fairing process for the simplified hull surfaces. Thus, surface fitting and fairing program can be easily composed due to the standardization of input information. It must be pointed out that the differences of angles included between the hull surfaces and sectional plane at the various positions will result in variation of sectional line accuracy and the difference of ability in the representation of surface figure. Therefore the correct selection of surface fitting and fairing program in accordance with the degree of sectional line accuracy can not only insure the quality of surface fairing, but also increase the computational speed.

Figs. 2, 3, 4 show a ship's frame plan obtained with computer on the principle of descriptive geometry.

In the field of hull surface fairing, two-directional fairing program (for water lines, section lines and diagonal lines) and tri-directional fairing program (for water lines, buttock lines and section lines) have been developed. These programs can be utilized for various ship forms provided that the boundaries have been preprocessed.

The flow chart for the **second way** is as follows:



This way is featured by the fact that the second-stage indirect model formed by the descriptive geometric method is based on the first-stage indirect model form by the method other than descriptive geometry.

Here are two examples:

Example 1. Approximate calculation of Gauss curvature of irregular surface.

In order to develop irregular surfaces precisley and utilize plates economicaly, it is necessary to calculate Gauss curvature of each point on the surface quantitatively. For this purpose, the corresponding differential geometric model must be formed as the first-stage indirect model. In accordance with the differential geometric axiom, Gaussian curvature must be the products of two principal curvatures. It would be quite complicated to obtain a solution if the irregular surface is defined by dot matrix.

In the present example, a characteristic cylinder is used to intersect with a surface. When the axial line of the cylinder becomes the normal line of the surface section, the figure of each normal surface section can be obtained and the curvature radius of the normal curvature can be determined as well. Therefore, the product of the principal curvature values which are obtained by fitting each normal curvature into curves is Gauss curvature. See Fig 5.

It can be seen from this example that the numerical calculation of Gauss curvature of irregualr surfaces can be tranformed into curve fitting and intersection on two-dimensional plane through dimensional decrease of the descriptive geometric model which is based on the differential gemetric model. By this way, a high degree of accuracy in calculation can be assured without analytic expressions.

Example2. Computer-aided design of the shell flange for the hawser on ships.

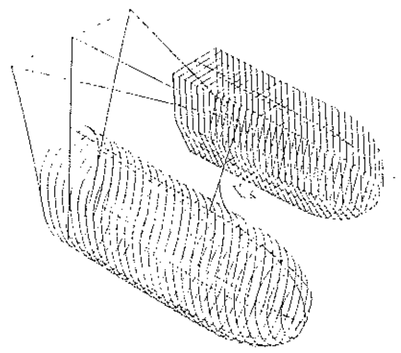


Figure 3

The shell flange for hawser has a very complex shape and locates in a general space position. It is not easy to get a correct geometric definition for it. Its final position had to be determined after full-scale model experiments. The development of computer-aided design program for the shell flange of hawser changes this situation.

Firstly, the position of theoretical plane of symmetry of the anchor must be determined in the principle of perspective correspondence according to the location of anchor in space. Then, a virtual simplified skeleton is required to act as a guide surface for the surface movement in normal direction. The guide surface controls the rules of thegeneratrix movement of the surface moving in normal direction. Finally, the varied ellipse can be used to generate the full section of the shell flange for hawser. (See Fig. 6)

In this example, the establishment of the first-stage affine geometric model is

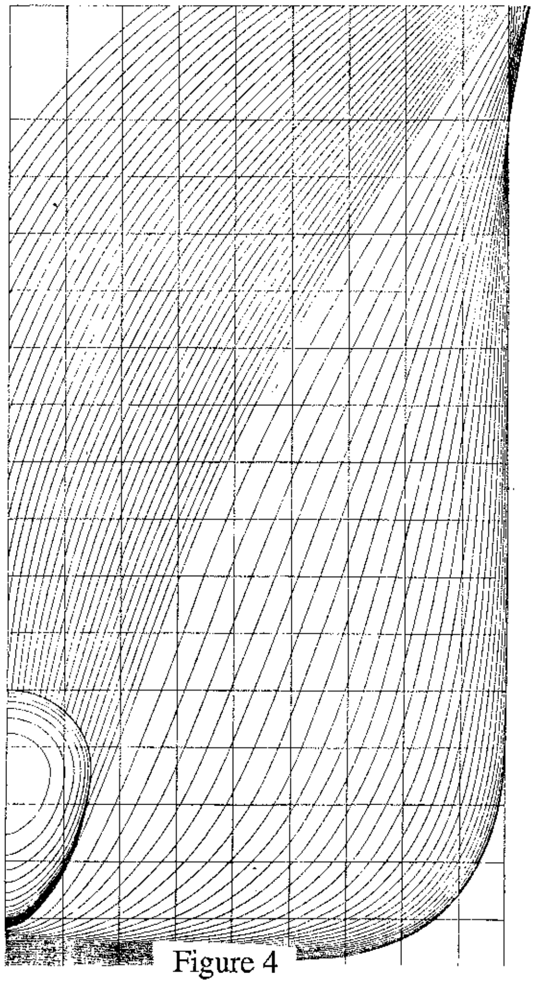


Figure 4

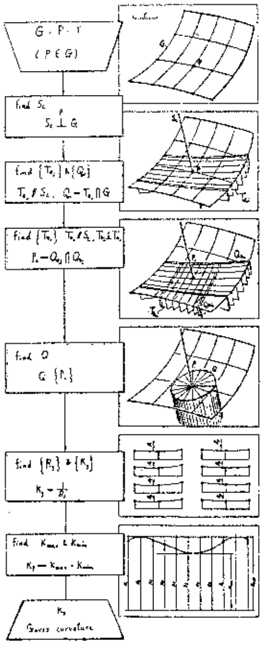
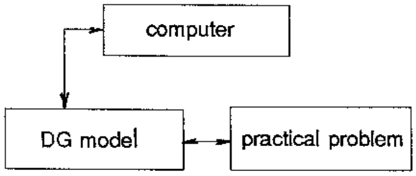


Figure 5

followed by the tranformation from the surface graphing into an ellipse, graphing in plane through descriptive geometric model. The geometric characteristics of the ellipse can be further used to construct surfaces without formulating analytic expressions. Fig. 6.e is the sectional drawing for the shell flange of hawser, which is drafted with computer. Shipyard practice proves that such shell flange of hawser is excellent both in performance and in appearance.

4. Following is the flow chart for the **third way**.



This was is suitable for such cases, as the computing module can be directly composed on the basis of descriptive geometric models. Here are two examples.

Example 1. A proposition raised by Mr. Casor, an American professor:

Determine: the center of the sphere which is tangent to all the given lines.

To solve this proposition, it is reasonable to prepare the descriptive gemetric model for peaks computation of two-dimension response surface. (see Fig. 7) With this descriptive geometric model which can facilitate the optimization process, the computation of the surface peak positions of three-dimensional space can be changed into that of limiting point of curves in two dimensional plane.

Thus, the above proposition can be solved by the following procedure.

The distance from the center of the sphere to the four given lines is determined in relation to the determined initial value of the center of the sphere. Then the adjustments are made to the position of the center until the distance difference from the center to each given line reaches zero. Therefore this proposition can be interpreted as the optimization problem of three (three variables refer to x,y,z coordinates of the center of the sphere; one target means that the distance from the center of the sphere to each given line must be zero). In order to determine the peak location of three-dimensional response surfaces, a family of planes can be set to cut three-dimensional response surfaces. Their intersection will be the family of

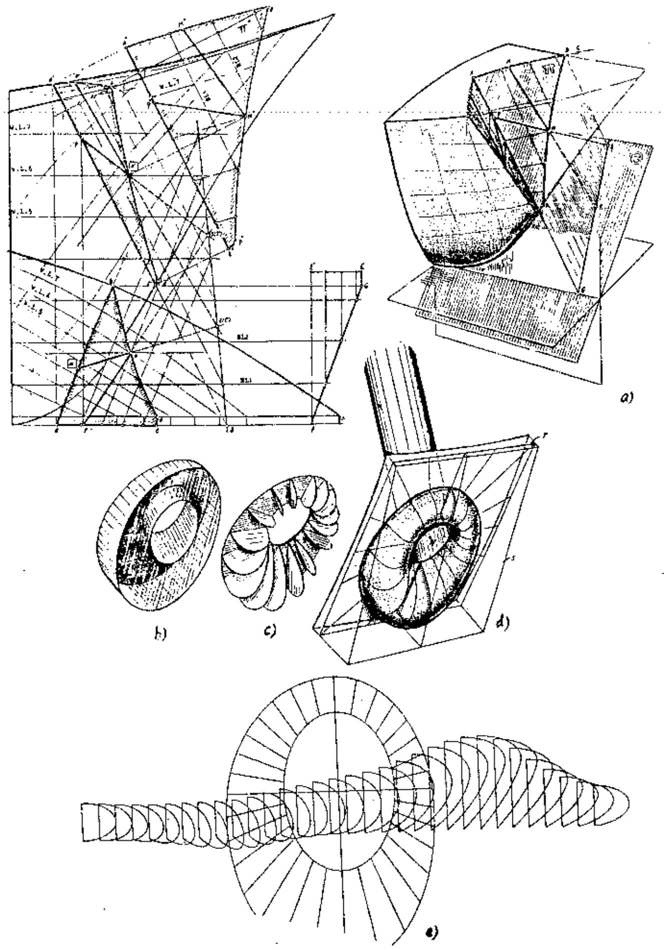


Figure 6

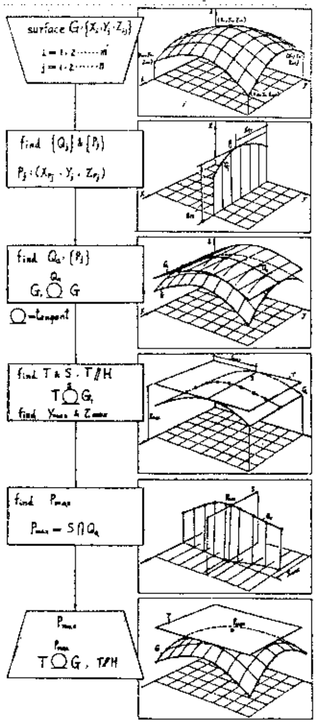


Figure 7

two-dimensional response surfaces in three-dimensional space (See Fig. 8). With the help of the descriptive geometric model, the optimization of a three-dimensional response surface in four-dimensional space can be changed into that of the family of two-dimensional response surface in three-dimensional space, which becomes eventually the graphical solution for limiting points of the family of curves in two-dimensional planes.

Assume that four given lines (S1, S2, S3, S4) are located by eight points. the calculation error 8<10 .

S1: (2, -5, 4, 5, -2, 4.2)
S2: (-6, 2, 4.5, 1, 4, 4)
S3: (7, 1.5, 3, 2.5, 6, 5)
S4: (-5, -2, -4, -2, -5.5 -5)

then, the center of the sphere(P_a):

(1.92417, 0.150373, -1.95692)

the distance from the center to each given line is:

7.148578, 7.148492, 7.148531 respectively.The error is just 0.000087.

Example 2. The surface figuration of transition zone in intersected cylinders. The surface of transition zone in intersected large diameter cylinders (for example, in water conservancy engineering) is a female surface of spherical surfaces which are tangent to each other. The trajectory of the sphere can be regarded as the insection line of two isometric cylindrical surfaces. The projection of the trajectory of the center of the sphere on the cylindrical surface will be the contour of the surface in transition zone.

A development drawing (an isoceles) can be made with the center of the sphere and its projection on the cylindical surface. Then, an arc which is made with the radius of sphere is required to be divided

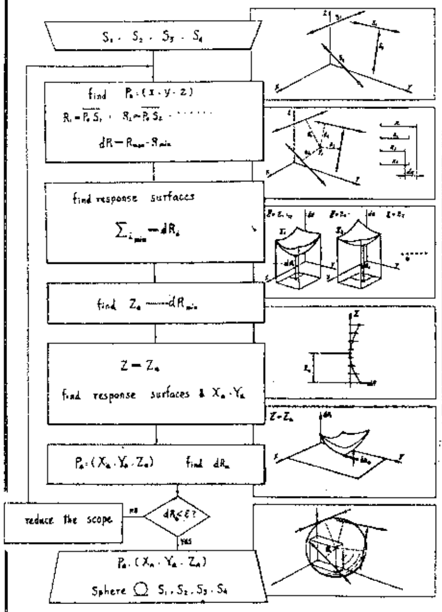


Figure 8

equivalently. The space postion of the generatrix of circle can now be determined through perspective restoration in the principle of affine correspondenc (See Fig. 9).

The above-mentioned female surface of the sphere with equal radius can produce the female surface of the sphere with varied radius after a little modification provided that the variation rule of the radius can be determined when the sphere locates in different positions. Fig. 10 shows the projective plan and perspective plan drawn with computer.

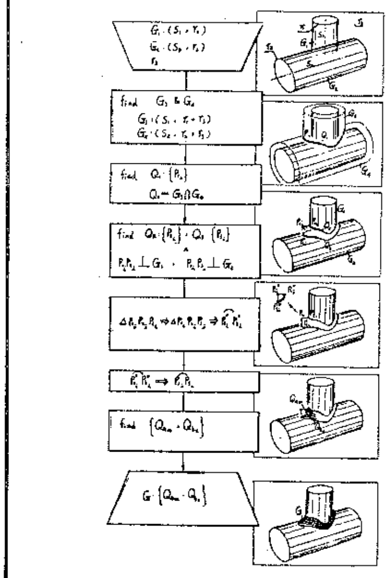


Figure 9

The following characteristics can be seen from the above examples.

a. Exact definition of input information can be further simplified and easily standardized through the reasonable abstraction of the studied objects.

b. Clearness in conception. The algorithmic program based on the descriptive geometric model can provide correct perceivable geometric significance.

c. Easiness in calculation. Descriptive geometric models will become a very important means in software structure design. With this models, program composition will, in turn, become a process of assembling basic subroutines. It must be pointed out that descriptive geometric models not only lead to mathematical models, but also to the basis for program composition. In this sense, descriptive geometric models bear many features of algorithmic geometry.

d. Reliability in result. The descriptive geometric model, the conception of which stems from practice, is a simple model capable of meeting diversified demand. Particularly, it is suited to be applied in interactive computer systems.

Conclusion

In principle, the dimension-decrease method in descriptive geometry is an approximate discrete method. With this method, a surface is described by a family of lines while a curve is described by point array. The impossibility of establishing integrated continuous models for described objects is a shortcoming, and at the same time a characteristic of this method. The discrete model of descriptive geometry is quite d,fferent from the continuous model of analytic geometry. However,

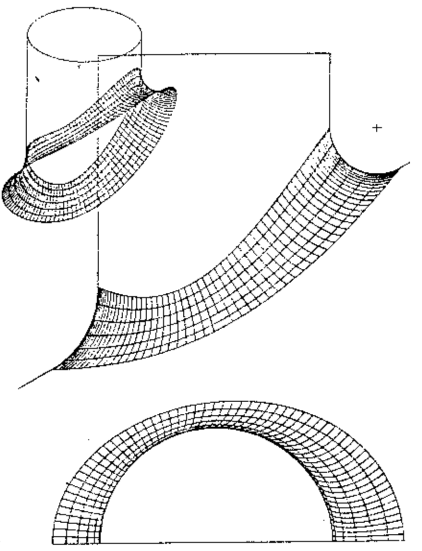


Figure 10

descriptive geometry is quite identical with the nature of computers whose hardware, software and basic information units are discrete.(8)

The combination of descriptive geometric method and computer technique is a very important project, which can find direct application in shipbuilding, aeroplane-building, chemical industry and other fields associating with spaces figures and give an impetus to the progress of CAGD and graphics theory.

Acknowledgement
The author of this paper has made direct use of the achievements made by his colleagues, Engineer Zhen Zi-chiu et al. in their research work. The author gratefully acknowledges the assistance given by them and the advice give by Pf. Xu Bo-kang and Xu Zi-yan who are the leading members of China Engineering Graphics Society.

Purdue 1985
Midyear Meeting

THREE DIMENSIONAL GRAPHICS MODELING

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Introduction to Geometric Modeling

A model is a representation of a physical object or an integrated system. Engineers create models to visually display their design ideas, to simulate and test the design, and to document the design for manufacture and construction. The model most frequently used in engineering practice is a geometric model, which describes size and shape of an object. A major consideration in using modern CAD/CAM systems for geometric modeling of 3D objects is whether to use a two-dimensional or three-dimensional modeling approach.

Geometric Modeling is a process of formally describing the graphical attributes of an object in a way which computers can interpret. A graphic model is a simplification of the object with sufficient details for the designer's purpose. A graphic model can be two-dimensional, like the model of an electronic schematic or an architectural layout, or three-dimensional like the model of a machine part. Note that an electronic schematic or an architectural layout are by themselves models of an electronic circuit and of a building, respectively, although not necessarily geometric models. Strictly speaking, the direct geometric modeling of a three-dimensional object can be only three-dimensional. When referring to the two-dimensional approach (i.e. using multiview projections) to model three-dimensional objects, we imply that a primary two-dimensional model of the three-dimensional object already exists in the designer's mind or on his sketches.

There are different ways to build a three-dimensional model. When we talk about wireframe, surface, and solid methods of modeling, distinction should be made between the method used to describe the model in the computer memory, and the rendering technique with which the model is shown for visualization on the display surface. An object described in the computer memory by using a solid modeling method, because the precision of the description is important for some later applications, may be shown on the screen with a wireframe technique to speed up the process of picture generation during the design modification stage. In another case the wireframe modeling method may be used as sufficient for a specific application, in which case internal representation of the model will be referring to only its edge lines. Its visualization on the screen may be edited by color area filling the surfaces, thus producing a surface representation of the model. The additional information needed to fill the surfaces during the editing process illustrates the imprecision with which the wireframe model describes an object.

Geometric Modeling and Solid Modeling

Before proceeding further it is necessary to clarify the difference between geometric modeling and solid modeling as these two terms are being frequently confused. While geometric modeling encompases all the methods of describing graphic models, solid modeling is only one specific method of geometric modeling. It is the most powerful method used in modeling three-dimensional objects, but at the same time it is the one with the most algorithms and procedures requiring large computer memory and high computer processing power. As opposed to the wireframe and the surface modeling methods, solid modeling describes precisely the space enclosed and occupied by the object rather than the boundary-surfaces or edge-lines which only imply object space. A solid sphere of radius r, centered at the origin, and described by the surface modeling method would have its mathematical model of the following form:

$$x^2 + y^2 + z^2 = r^2$$

This equation describes the surface of a sphere and we only imply that the space inside the spherical surface is our three-dimensional object. By using the solid modeling method, however, the following mathematical description would be generated:

$$x^2 + y^2 + z^2 \leq r^2$$

This equation describes a set of (x,y,z) triplets which fill the space occupied by the object. The precise description of the occupied space and the available algorithms for set manipulations make the method very powerful.

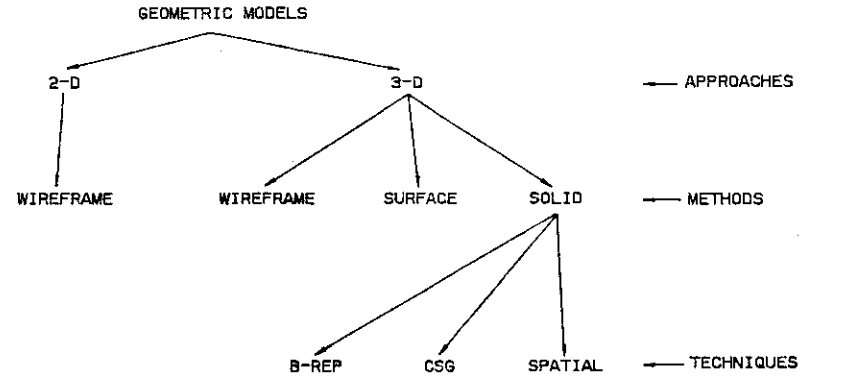


Figure 1

The solid modeling method can be applied with different techniques of internal representation of the model, but all techniques share the same precision related to the three-dimensional description of the object. The relation of different approaches, methods, and techniques used in geometric modeling is given in Figure 1. These will be sequentially elaborated in the following pages.

Two-Dimensional Wireframe Modeling

A two-dimensional wireframe model is built with a set of two-dimensional primitives such as points, lines, circular arcs, ellipses, and splines. The two-dimensional wireframe is used to model a multi-view drawing of an object. Each view in the model can be created by piecing together the basic primitives, as illustrated in Figure 2. The interactive addition of dimensions and annotations to this model can make a very complete drawing for reading on the manufacturing shop floor.

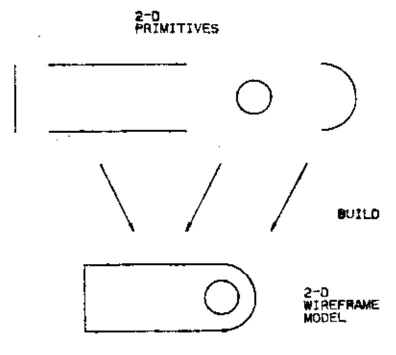


Figure 2

A 2-d wireframe approach has some distinctive limitations. The model relies on human interpretation for construction of the part. Complex features are hard to represent, as attested to by the many industrial drawings with multiple auxiliary views. Also, automatic checking for drawing errors by computer is very difficult to implement for the 2-d wireframe model.

Three-Dimensional Wireframe Modeling

A three-dimensional wireframe model is an extension of the 2-d case to include primitives that are defined in an (x,y,z)-coordinate

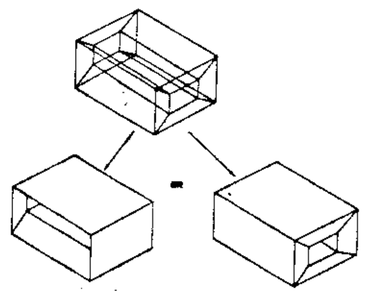


Figure 3

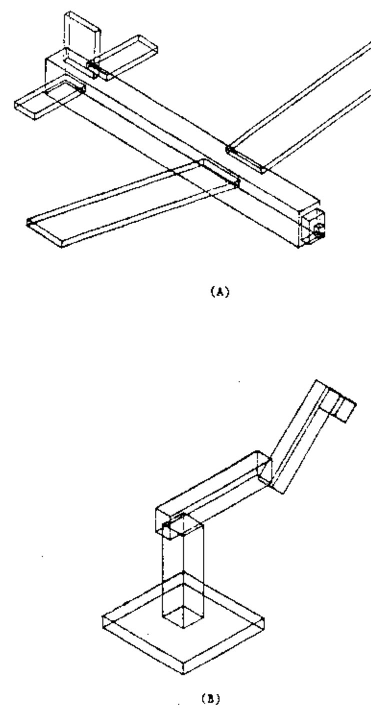


Figure 4

system. Wireframe models are relatively easy to create and the addition of spatial features aids in design conceptualization. However, in some cases the 3-d wireframe model without hidden line removal appears ambiguous, as illustrated in Figure 3. This is because the faces of the object must be inferred by the viewer, and are not defined by the model itself. Even with this drawback, 3-d wireframe models of simple designs are easily recognizable (Figure 4).

Computer interpretation of 3-d wireframe models presents many problems. For one, curved surfaces are not fully defined but only represented by their edges. Hence rounded ends, fillets, and troughs are not part of the 3-d model. It is not easy to check for interference of two parts in a wireframe model. For example, an edge or face may pass through a solid portion of the object. Wireframe models also lack associativity. The ends of two lines that overlap are typically represented by different data, rather than logically by a single line element.

Surface Modeling

A three-dimensional surface model generally begins with a wireframe outline, to which mathematically-defined surfaces are added. Each surface is then bounded by a 3-d line or curve. The surfaces may be regular shapes such as planes, cylinders, or spheres, or they may be more complex sculptured surfaces represented by small surface patches. Parametric equations are also often used to define complex surfaces in the model.

In constructing the surface model, the user can piece together various surface types to define a geometric envelope of the part, as shown in Figure 5. In many cases, these surface types can be selected from a menu of surfaces. Each individual surface can then be stretched, scaled, or repositioned in accordance with the designer's requirements. The simplest of these surface types is a ruled surface (Figure 6-a). A ruled surface consists of straight lines connecting boundary lines or arcs. Surfaces of revolution (Figure 6-b) are formed by revolving a 2-d curve around an axis. A tabulated cylinder (Figure 6-c) is formed by projecting a two-dimensional figure (circle or arc) into the third dimension.

For complicated objects, the designer may need to resort to more complex sculptured surfaces. Such surfaces commonly occur in the design of automobile bodies, airplanes, and ships. Such surfaces have no exact mathematical definition, but rely on patches that are bounded by B-spline or Bezier curves (for example, see Figure 6-d).

Surface models are especially well-suited for 3-d geometry where the application is primarily concerned with the exterior shell, such as sheet-metal or plastic moldings. Surface models are also convenient for generating finite element grid meshes and for NC programming. Perhaps the single biggest disadvantage to surface modeling is that the model does not define which side of the surface is solid and which side is air. In addition, a face could be left off the model or a face could be inside the solid region of the object. Hence, there are some deficiencies in surface modeling that can be overcome by a solid description.

Solid Modeling

The previous wireframe and surface models produce incomplete representations of an object, and consequently could lead to discrepancies in the manufacturing phase. A solid model is a mathematically precise, or unambiguous, representation of a fully-enclosed part. The solid model is constructed by joining lower-order solid primitives (box, cylinder, sphere, etc.) using Boolean operations. The standard Boolean operations used are:

1. Union,
2. Intersection, and
3. Difference.

These operations are illustrated in Figure 7.

The building of the model begins with the selection of a primitive from a convenience menu. Unary transformations (scaling, translating, mirroring, stretching, etc.) are applied by the operator to position the basic primitives in space. To this basic primitive, a new primitive (perhaps also after unary operations) is applied in accordance with one of the Boolean operations. The main advantage of such modeling is that it offers the designer a flexible tool from which many complex objects can be constructed.

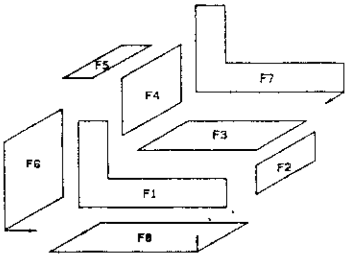


Figure 5

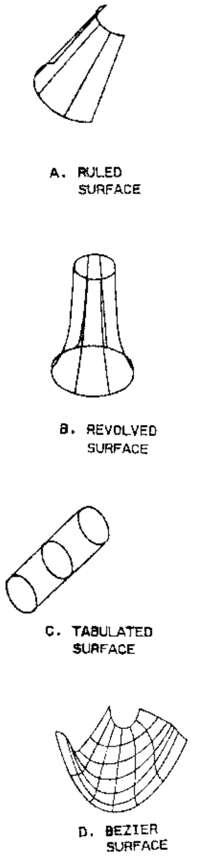
Once the solid model is constructed, the way it can be represented in computer memory can vary from one system to the next. However, most systems will employ one of three possible techniques:

1. Boundary Representation (B- Rep)
2. Constructive Solid Geomerty (CSG), or
3. Spatial Subdivision

The differences between these three representation methods will be delineated later.

Because of the unambiguity of solid models, they hold much promise for fully automated design and manufacturing. Only physically realizable parts can be constructed by using solid modeling. Because of this, design errors or impossibilities can be avoided. Using high-level Boolean operations, global part definition can be accomplished by combinations of smaller parts which all reside in a systematic data structure.

A solid modeling system (Figure 8) consists of four major components: an interactive graphics computer, a software modeler, the model data base, and applications software. The interactive graphics computer consists of a processing unit, high-resolution color display, and interactive devices (light pen, joystick, mouse) by which the user can input commands to create the model. This component is referred to as the workstation. The modeling software (or internal representation scheme) accepts the designer's commands and mathematically creates or modifies the solid model. The model itself consists of a systematically arranged set of data files residing in computer memory. The applications software consists of programs used to view the model (projection algorithms, hidden surface algorithms, and shading routines), as well as programs to compute mass properties, create finite element meshes, produce numerical control (NC) commands, and so forth.


A. RULED SURFACE

B. REVOLVED SURFACE

C. TABULATED SURFACE

D. BEZIER SURFACE

Figure 6

Boundary Representation (B-Rep) Solid Modeling

The boundary representation solid model is formed using a detailed topological data file that relates all faces, edges, and vertices of an enclosed space. The faces can be simple planes, hollow cylinders, or more complex patches. The B-Rep approach is convenient for positioning and moving objects in space, and offers considerable memory savings over some other solid modeling techniques.

The relationship between these faces is determined by a set of pointers in a data file. Each data file consists of a face list, an edge list, and a vertex list. Some general rules for linking faces, edges, and vertices would include:

1. Each face is related to the set of edges that bound it.
2. Each edge is related to the two surfaces it joins.
3. Each edge is related to the two vertices at its endpoints.

For example, in Figure 9, edge E1 joins faces F1 and F3 as indicated by the pointers. Likewise edge E3 joins faces F1 and F8. If continued in this fashion, for instance, face F1 would have all of its edges (E1 through E5) pointed to it. Furthermore, vertex V1 joins edges E1, E1 and E6. Vertex V2 joins edges E2, E3, and E8. Hence, since both V1 and V2 point to E2, and since E2 points to F1, it can be deduced that V1 and V2 are two of the six vertices of F1. It should be noted by the reader that the data lists of Figure 9 are incomplete, but could be completed in a straightforward fashion.

Constructive Solid Geometry (CSG) Solid Modeling

The process of building a CSG model can be readily implemented using a tree form diagram. For example, in Figure 10-a, a solid model is constructed using a solid base box (P1), a solid upright box (P2), and a solid upright cylinder (P3). It is to be assumed that the cylinder has a longitudinal axis that is extended entirely through the base primitive (P1). The building process is illustrated in Figure 10-b. The model starts by taking a set of primitive solid boxes and applying respective unary operations to get P1 and P2. Then P1 and P2 are joined in union to get an intermediate object. The cylinder P3 is formed, and is then subtracted (difference operation) to yield the target CSG model. These building steps are really the model description.

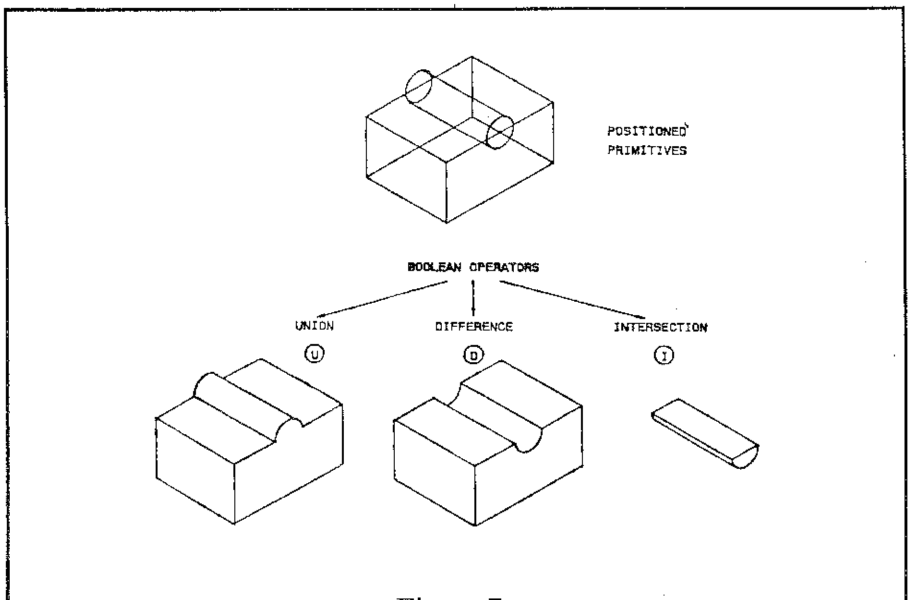


Figure 7

The CSG is a compact model using the tree data structure or an equivalent list structure, which results in efficient use of computer memory. The major limitation of CSG is that non-primitive geometry cannot be associated with the model.

Spatial Subdivision Solid Modeling

Spatial subdivision systematically divides an object space or universe into 3-D volume leaf cells called "voxels." A voxel then becomes the smallest solid piece of the larger solid object. The solid object is built into a large data structure which simply identifies which voxels in space are filled (F), and which are empty (E).

One way of implementing this is to use the octree data structure. The object space is first divided into eight cells of equal size. If any one of the cells is homogenous (either all filled or all empty), then the subdivision stops for that cell. If a cell is heterogenous or partially filled (P), then it is further subdivided in the octree manner, until all lower cells are homogenous within the limitations of the voxel unit. This octree process is illustrated for a simple solid in Figure 11.

The octree representation has several advantages. For one, any arbitrarily shaped object can be fully represented within the resolution of one voxel cell. Second, geometric properties such as volume and center of mass can be readily calculated because all single pieces of the model are simple cubes. The octree representation, however, has a

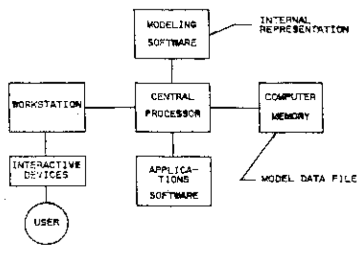


Figure 8

simple cubes. The octree representation, however, has a major limitation in that it requires a large amount of computer memory to store the status of each voxel. For instance, an object space that has a 1000 x 800 x 1000 cubical resolution (equivalent to a high resolution display) would require roughly 100 Mbytes of core memory for a straightforward universal representation of the model.

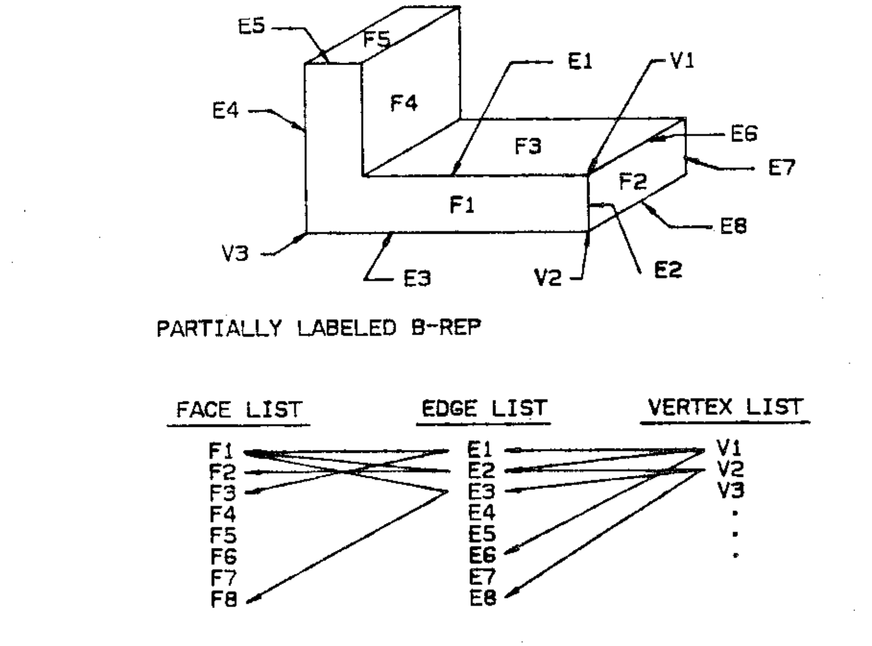


Figure 9

Different sophistications are now being used to save on memory when applying spatial decomposition. One such new approach is to use a polytree data structure. The polytree approach expands the number of leaf cells to: full, empty, vertex, edge, and surface. This increased leaf complexity gives the polytree a significant advantage over the octree since the object can be decomposed with a fewer number of steps leading to memory savings.

Engineering Applications of Solid Modeling

Although solid modeling is still on the forefront of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM), many potential engineering applications have already been identified. This is because solid modeling produces a complete and unambiguous data base which can be transferred from design to manufacturing.

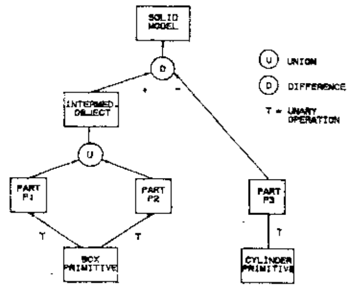


Figure 10-B

Probably the most easily recognizable application is mechanical design and layout. Standard parts can be created and stored for a wide range of applications. Assemblies can be pieced together, and then checked for interference and clearance. Application of a solid modeling system for the design of a universal joint is shown in Figure 12.

Solid modeling also facilitates many types of engineering analyses during the design process. Finite element meshes can be generated and structural analysis performed on the object. Weights and moments of inertia can be calculated. Manufacturing tools, jigs, and manipulators can be incorporated into the design analysis and planning stages.

Solid modeling can be used for automatic generation of engineering drawings. This can be accomplished by arranging the model parallel to the screen and then performing standard orthographic projections. Section views can be easily cut through the model to see internal features. Automatic dimensioning and annotations are additional features that can be added to the solid modeling package.

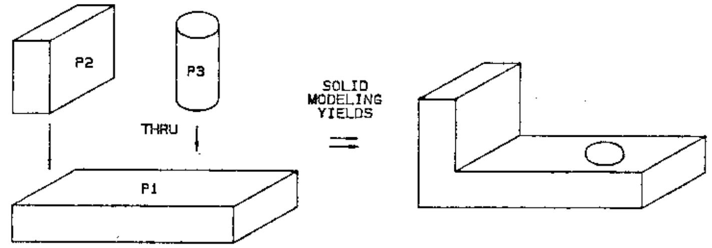


Figure 10-A

Finally, two by-products of geometric modeling that should not go unmentioned are the applications of technical illustration and computer art. Models can be used as illustrations in business reports, maintenance manuals, and advertisement brochures. These can be very effective with the application of color shading (rendering) algorithms. In the area of computer art, 3-d modeling is an effective tool for movie animation and scene generation. Indeed, solid modeling on sophisticated computer systems in the limit will reach a level of realism equivalent to a photographic picture.

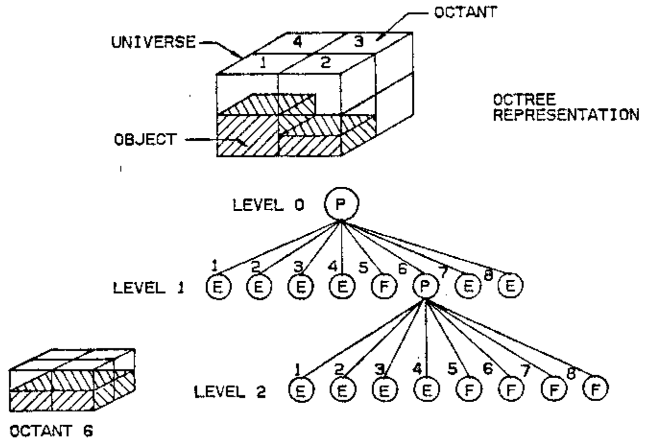


Figure 11

Further Reading

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Purdue 1985
Midyear Meeting

THE IMPACT OF MICRO-CADD IN ENGINEERING DESIGN GRAPHICS INSTRUCTION

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Introduction

In the second year of a major grant-supported project, the authors' department is progressing with the development of an innovative experimental instruction laboratory. It is intended for the conduct of pilot educational using the department's engineering design graphics (EDG) course GE 103 which serves College of Engineering and other students. The laboratory's key ingredients include 35 microcomputers in a local-area network (LAN) supporting graphics workstations and server machines, the latter for file storage, plotting etc. A professional Computer-aided Design Drafting (CADD) software package is used in what is referred to as a micro-CADD environment.

Previous papers [1-3] have given the rationale for and traced the developments and accomplishments of the project. This paper presents a digest of project highlights and assesses the impact of micro-CADD and EDG instruction within the framework of departmental experience.

Project Objectives and Rationale

The project's long-range goals include both technical and educational components. The former includes pioneering effective ways of networking IBM microcomputers in an EDG instructional setting. The latter includes developing and using innovative instructional techniques afforded by the interactive computer graphics (ICG) and networking environments. The project's ultimate aim is the delivery of a more effective, comprehensive and unconstrained introduction to and reinforcement of the relevant concepts and methodologies of EDG than can be achieved by the traditional instructional method.

In embarking upon this project, it was felt that two key results could be expected in the long term. These are the answers to two questions: what needs to be taught in a modern EDG course; and how can the course be best taught from intellectual and cognitive viewpoints? The authors have already concluded independently of others [4] that a central core of topics pertinent to both manual and CADD implementations are appropriate, though judgement must be reserved on the range and depth of those topics. In the context of modern EDG instruction, the authors have noted [3] that several key themes will prevail. These include the integration of computers and appropriate software in the instructional process, the emphasis of concepts and cognitive aspects, the elimination of graphical solutions to analytical problems, the emphasis on the use of sketching as an essential mode of technical communication, and the drastically reduced use of instrument drafting practice.

The philosophy of the use of micro-CADD activity is pragmatic. It is based on the authors' belief that the principles and methodologies underlying the study of EDG remain the same in both the traditional and micro-CADD instructional environments. Put another way, alternate sets of tools may be employed to achieve the same end. In this vein, the project's instructional activity does not exclude traditional facets. Students are expected to acquire basic "graphite" skills, while exploring the power of learning with a micro-CADD system.

"Students are expected to acquire basic "graphite" skills while exploring micro-CADD"

But why micro-CADD at all? Simply put, the authors have become thoroughly convinced that the ICG techniques available in professional-quality micro-CADD software open new and valuable vistas in EDG education whose benefits far outweigh the costs, especially if the implementation is well executed. An analogy to word processing is very appropriate: the graphical construction and editing maneuvers afforded in micro-CADD are the equivalent to creation, movement, modification and adaptation of text.

Educational Results

The educational impact of the project is being assessed by internal and external qualitative evaluations that to date have been highly favorable. More significant are quantitative project studies that have shown the use of micro-CADD to positively affect test scores and work efficiency.

The first large-scale quantitative comparison involved the use of test and control groups of about seventy students in each group. Although students chose the hour of instruction, they were assigned to the control or test group by random selection while maintaining balance of gender, academic level and academic major. Additionally, even instructor experience, rank, and reputation for teaching skill were balanced for the paired control and test sections at each attendance hour. The parallel sections were tested identically and simultaneously in graphite mode. The outcome was higher average scores by the micro-CADD test group on quiz and exam questions in all pertinent topic areas except one.

In a smaller subsequent study, records were kept of the times needed by the same students to complete similar assignments using the micro-CADD and graphite approaches. It was found that in almost all cases the average time was five to forty-five percent less for the micro-CADD approach, even if the first exposure to a topic assignment was with micro-CADD.

Testing aside, staff members observing student performance and attitudes have concluded that the students in the micro-CADD groups seem to be learning more, learning better and learning faster than their peers in the control sections. This is particularly evident in situations where anomalous results of micro-CADD algorithms were not only noticed by students, but dealt with effectively. In addition, student in the micro-CADD sections showed the willingness to put an extra effort into their work and take pride in the results, traits noticeably lacking by comparison in the control group and students of prior year.

> "vanishing point perspective is taught first ..."

Instructional Coverage

In the evaluations prior to the fall of 1985 the experimental EDG course content, structure and standards remained essentially identical to those prior to micro-CADD activity. Thus the "what" question of a modern EDG course was not really explored. In the current project EDG course offering that question is beginning to be addressed.

The "what" is emerging to be a device-independent core of EDG topics that may be addressed in different ranges and depths depending upon the particular needs of the learning audience. EDG remains the discipline most suited to fully prescribing the geometry of physical objects with maximum efficiency in terms of an engineer's or technician's time. Thus the "what" includes much of the traditional EDG subject matter, but with an emphasis on concepts rather than skills. Included and expected to prevail are orthographic (principal view), auxiliary (perpendicular to principal view) and pictorial representations; sectioning and dimensioning applied to these representations; and, for pedagogical rather than utilitarian reasons, fundamental descriptive geometry.

For the core of topics described, a reversal in the commonly prescribed presentation order for orthographic and pictorial representations is being used. This reversal, termed the "Inverted Approach", has been used successfully by the lead author for over ten years. Briefly, it involves introducing vanishing-point perspective first as the natural and general representation form, followed by axonometric (trimetric, dimetric and isometric) and oblique pictorials as special cases of object and sight line positions, and finally orthographic (and auxiliary) views as a special case of the axonometric form. With the introduction of CADD, the use of the Inverted Approach has become even more efficacious. Within the micro-CADD environment of the project this opportunity has been explored extensively to produce a synergistic effect.

Descriptive geometry is the embodiment of graphical solutions to analytical problems. If present real-world trends continue, descriptive geometry may lose its importance and no longer serve its original purpose for actual problem solving. Yet in an EDG instructional setting, it may retain and important role in providing the basis for the comprehension of important spatial relationships that cannot be conveyed by analytic geometry alone. Thus the emphasis of its use in the experimental course is more from problem formulations and insights into solutions expected than the solutions themselves.

Discovered quickly by the introduction of micro-CADD in EDG instruction was the important distinction between visual representations ("drawings") and their underlying coordinate data ("database"). The relationships inferred by appearance and dimensioning in "graphite" work must in CADD be integral to the "constructions" formulated by means of ICG manipulations or else the result is worthless for any application. Thus the integrity of the database becomes paramount for correct representation. This means that to effectively evaluate CADD work, the database -- and not a graphic portrayal of it -- must be examined. Thus the instructional practice of grading hardcopy plots of CADD work falls short of reality. In the project, special attention has been given to database evaluation of student assignments at workstations that is discussed further in the System Environment.

Instructional Environment

Since the birth of the project, the "how" of a modern EDG course has been continually developed and refined [1-3]. In the fall of 1985 there is again a test environment, this time involving over 350 students, less than half of the total course enrollment. To accommodate this larger test group and to maximize the use and benefits of micro-CADD, course meetings have been rescheduled and restructured.

The experimental EDG course using micro-CADD operates in modular form as listed, with hours per week indicated in parentheses:

- conducting lecture-demonstrations in a specially equipped auditorium featuring a workstation and a large-screen projection monitor (2)
- performing class assignments at computer workstations (2)
- conduction follow-up discussions (1/2)
- treating non-CADD topics, e.g., sketching, design methodology (1)
- testing in graphite mode (1/2)

In addition, graphite homework is assigned, complementing micro-CADD assignments where deemed appropriate. Additional "open" lab hours are maintained for "catch-up" time, averaging one hour per student per week. With this mode of scheduling and operations, sixteen sections can be taught each semester. The last three activities take place in a traditional classroom in small student groups. Except for a single introductory lesson, students are never required to share workstation and a 12:1 or less student-to-helper (instructors or assistants) ratio is maintained for all instructional periods.

Micro-CADD demonstrations and assignments include "from-scratch", modification and adaptation modes. The latter are particularly useful and effective in focusing attention to concepts in ways not otherwise possible or that are free from the tedium of "redrawing" characteristic of graphite work [1]. The strategies and maneuvers tried so far have been favorably received. They and others to be developed show great promise for cognitive enlightenment and reinforcement of fundamental EDG concepts.

Much of the discussion presented has been in the context of two-dimensional constructs or "drawings". Emerging micro-CADD software that, like high-powered CADD software, utilizes pseudo or actual three-dimensional coordinate data (subsequently presented as planar views by projective transformations within the software), shows great potential for effecting change in CAD/CAE/CAM work. Within the project, such programs are used for demonstrations to illustrate important underlying EDG concepts not easily done via 2D micro-CADD. However their use by students is forestalled at for the present by the relative slowness of all but the largest and fastest of current computers that results in ICG processing delays that are intolerable for assignments. This situation will change in the near future and certainly have a strong influence on both the "what" and "how" of modern EDG instruction.

System Environment

An integral component of the "how" of a modern EDG course includes system facilities and software -- the tools to perform the task. Most of the project microcomputers are housed in a specially designed room that accommodates twenty-four student workstations. Servers and a development workstation are also present. Grader workstations are located in an adjacent room andthe student network is in the lecture auditorium.

All of the personal computers are highly enhanced IBM PC-AT/99s. They presently have non-IBM graphics controllers that can produce either 720 x 700 pixel resolution in monochrome of 640 x 400 in eight colors. Amber monitors are being used temporarily at the student workstations. Color display capability will be introduced shortly.

The LAN is supported by IBM PC-Network hardware and software. Its effective use has been facilitated by the introduction of locally-written software to provide an interactive, menu-driven operating environment to replace the user interface with IBM's PC-DOS and PC-Network software. In addition to executing the micro-CADD software and performing diskette operations, the menu environment provides network options to get and store assignments, get graded work, produce plots, etc. File security and backup protection features are built into the system. As an added precaution, student store their work outside the network on diskettes -- which are kept in the lab -- in hidden directories accessible only through the lab's menu environment.

Workstation grading of assignments is made relatively effective and efficient by the use of locally written software to automatically fetch ungraded and store graded student work on the file servers. In addition this software "sets up" and "closes" the grading process and is augmented by specially written micro-CADD software grading menus and macro commands that permit markings, comments and scores to be easily added to work displayed on a separate viewing "layer".

Acknowledgements

The experimental micro-CADD instructional laboratory described in this paper was made possible in large part by an equipment and software grant under the auspices of Project EXCEL (for Excellence in Computer-aided Education and Learning), and Advanced Education Project sponsored by Academic Information Systems of International Business Machines Corp. Additional support from UIUC Campus, College of Engineering and Department of General Engineering provided laboratory facilities, equipment and software, support personnel and faculty release time for the project.

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Purdue 1985 Midyear Meeting

THE IMPACT OF COMPUTER GRAPHICS ON INSTRUCTION IN ENGINEERING GRAPHICS

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There can be little doubt that we live in an age of rapidly advancing technology. For an engineering college, keeping pace with advances in industry, and being responsive to the needs of students, is an important aspect of curriculum development. One such area in the 1980's is engineering graphics.

The advent of the computer has had a profound effect on all aspects of life, from business, industry and education to the home. For several years engineers have been able to do engineering design work with the use of the computer. However, it has only been in relatively recent years that engineers have been able to 'draw' with the use of computers. Significant developments since that time have enabled computer graphics to be commonplace in many industries (1).

Computer graphics systems have become computerized equivalents of conventional graphics tools - pencils, erasers, compasses and scales. Today even paper may face the prospect of becoming obsolete
curricula that have stressed the development of manual graphic technique alone, must now revise this practice to survive (3).

Many schools across the country are making an attempt to implement computer graphics within their curriculum. The literature suggests that a course in engineering graphics is the most common location for a first experience in computer graphics. However, several problems exist with this implementation:

1. There is no general agreement concerning what the needs of industry are.

2. There is no agreement as to curricular objectives to guide educators in implementing these programs (4,5).

3. There is no general source of information defining what configuration of hardware best fits curricular objectives (6).

4. No consensus exists as to what type of software should be implemented to best achieve curricular objectives(4,5).

In an attempt to cast light on the problem of implementing computer graphics into the engineering graphics curriculum, a study was undertaken at Marquette University. The following research questions were proposed:

1. What set of classroom curricular experiences are identified in the literature as experiences that are needed or are desired to prepare engineering graduates for computer graphics in industry?

2. What is the level of importance and the level of provision placed upon identified skills or curricular experiences as seen by industry relating to computer graphics preparation? What additional skills exist, if any?

3. What is the level of importance and the level of provision placed upon identified skills or curricular experiences by engineering schools, relating to computer graphics preparation? What additional skills exist, if any?

4. What differences exist, if any, between mean levels of importance and mean levels of provision of identified skills, both within the above groups and between groups?

> "emphasize the use of available software to do computer graphics, as opposed to relying on programming as a teaching technique..........."

There appears to be relative agreement about what constitutes valid objectives of a traditional engineering graphics course, but not when it concerns computer graphics. The results of this study could be a valuable resource to those who require information in order to make decisions about computer curricula. The decisions made on curricular objectives will have a direct effect on the decisions made for hardware and software purchases.

Method of Study

The objectives of the study were accomplished in three phases. Phase 1 of the study involved a systematic search and review of the literature related to the needs of industry in the area of computer graphics skills. The information obtained from this portion of the literature was used to compile a list of skills or curricular experiences that industry feels engineering graduates should possess. This list of skills and experiences were then used to construct a survey questionnaire relating to engineering graphics curriculum.

Phase 2 of the study incorporated the above questionnaire in a mail survey of both industry and engineering colleges. Information gained through this survey was used to make recommendations and conclusions in regard to the structure of the engineering graphics curriculum.

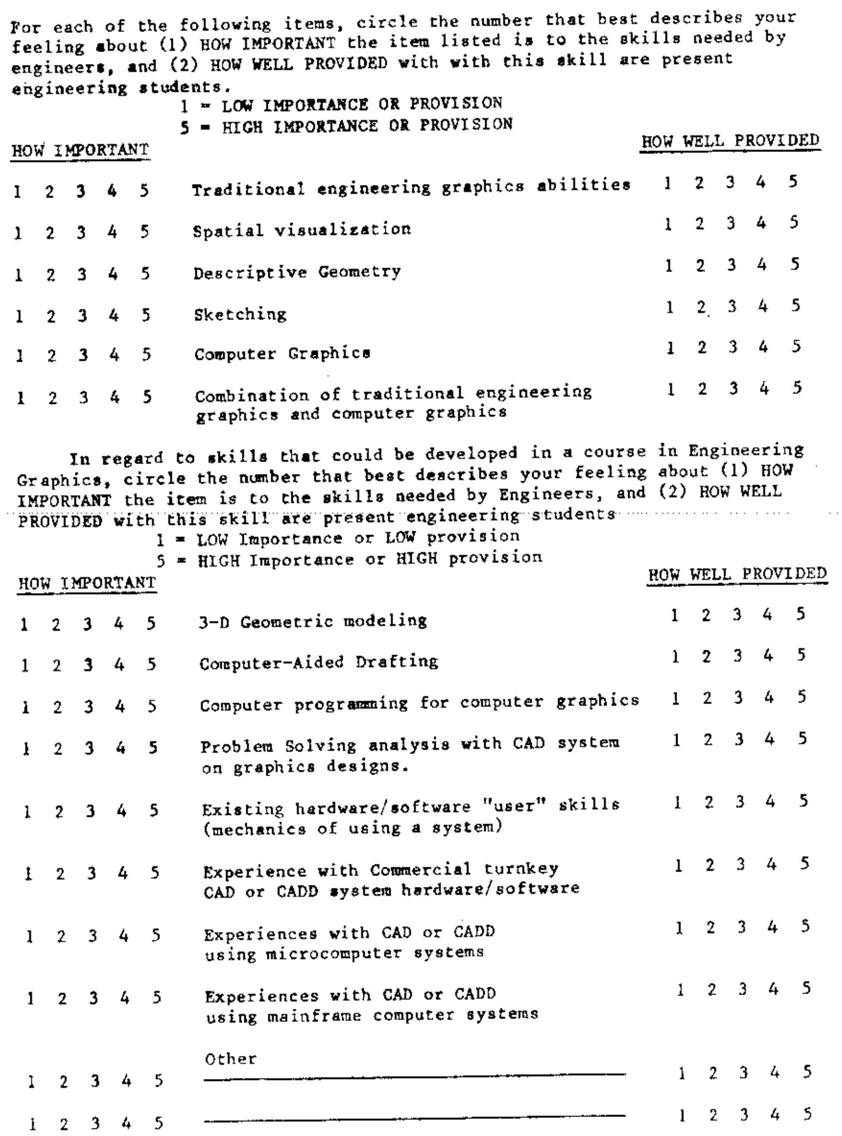
Phase 3 of the study incorporated a statistical analysis to compare and contrast any differences between needs as seen by industrial respondents and needs as seen by engineering college respondents.

Industrial Respondents

In order to evaluate the skills that were identified through the literature, the survey questionnaire described above was sent to industrial respondents. These industrial respondents were taken from a listing of the members of the National Computer Graphics Association. This list was culled to exclude academic, business, and artistic users. A random sample of this remaining list was taken and contained 142 prospective respondents from the Continental United States.

Academic Respondents

To access what skills or curricular experiences are important to, and provided by engineering schools, the above questionnaire was



For each of the following items, circle the number that best describes your feeling about (1) HOW IMPORTANT the item listed is to the skills needed by engineers, and (2) HOW WELL PROVIDED with with this skill are present engineering students.

1 = LOW IMPORTANCE OR PROVISION
5 = HIGH IMPORTANCE OR PROVISION

HOW IMPORTANT		HOW WELL PROVIDED
1 2 3 4 5	Traditional engineering graphics abilities	1 2 3 4 5
1 2 3 4 5	Spatial visualization	1 2 3 4 5
1 2 3 4 5	Descriptive Geometry	1 2 3 4 5
1 2 3 4 5	Sketching	1 2 3 4 5
1 2 3 4 5	Computer Graphics	1 2 3 4 5
1 2 3 4 5	Combination of traditional engineering graphics and computer graphics	1 2 3 4 5

In regard to skills that could be developed in a course in Engineering Graphics, circle the number that best describes your feeling about (1) HOW IMPORTANT the item is to the skills needed by Engineers, and (2) HOW WELL PROVIDED with this skill are present engineering students

1 = LOW Importance or LOW provision
5 = HIGH Importance or HIGH provision

HOW IMPORTANT		HOW WELL PROVIDED
1 2 3 4 5	3-D Geometric modeling	1 2 3 4 5
1 2 3 4 5	Computer-Aided Drafting	1 2 3 4 5
1 2 3 4 5	Computer programming for computer graphics	1 2 3 4 5
1 2 3 4 5	Problem Solving analysis with CAD system on graphics designs.	1 2 3 4 5
1 2 3 4 5	Existing hardware/software "user" skills (mechanics of using a system)	1 2 3 4 5
1 2 3 4 5	Experience with Commercial turnkey CAD or CADD system hardware/software	1 2 3 4 5
1 2 3 4 5	Experiences with CAD or CADD using microcomputer systems	1 2 3 4 5
1 2 3 4 5	Experiences with CAD or CADD using mainframe computer systems	1 2 3 4 5
1 2 3 4 5	Other ________________	1 2 3 4 5
1 2 3 4 5	________________	1 2 3 4 5

Figure 1

mailed to a sample of selected, academic respondents. These respondents were taken from a national membership listing of the Engineering Design Graphics Division of the American Society for Engineering Education. This list was culled to exclude industries, retired persons, and personnel from vocational technical and technology programs. A random sample of this list was taken and contained 118 prospective respondents from the Continental United States.

Method of Analysis

The survey instrument is divided into two main parts. The first 6 items relate to basic graphics skills and concepts as well as computer graphics. Responses to these items indicate the importance and provision of basic skills in the curriculum and the overall importance and provision of computer graphics as a topic of study. The final 8 items on the questionnaire relate to importance and provision of specific computer skills and general types of hardware and software.

In order to determine the levels of importance and provision of the various skills and curricular experiences, an item analysis was performed. This analysis indicates the frequency of response for item and item mean response for each group. In addition to these statistics a ratio of importance (r) was calculated for each skill. This ratio is of the following form:

$$r = \frac{HI}{HWP}$$

where:

HI = mean value for "How Important"

HWP = mean value for "How Well Provided"

This ratio provides a level of overall importance in the curriculum, as seen by each group. In the data analysis, the "How Important" factor is treated as an independent variable. It may then be suggested that a ratio value approaching 1.00 implies a balanced situation with regard to a particular skills importance and its provision in the curriculum. Values that depart from 1.00 (either higher or lower) imply an unbalanced situation and appropriate conclusions were made.

In order to determine if any differences exist between levels of Importance and levels of Provision within the two groups or between groups, a t-test for independent samples was performed on the item means. A two-sample calculation was used in which no assumptions are made about the population variances. A level of $p = .05$ was required as a minimum for statistical significance of differences. Four sets of t-tests were performed on the survey data.

Presentation and Analysis of the Data

A total of 260 survey instruments were mailed to prospective respondents from industry and engineering schools. The total number of responses received from both samples was 189 or approximately 73% of the original mailing. Of the 189 responses, a total of 84 were received from the academic sample (approximately 72%) and 105 were received from the industrial sample (approximately 74%). After the data collection was complete, a reliability estimate of each instrument was determined by calculation of coefficient alpha (∂). The reliability of the industrial survey instrument is reported as $r_{XX'} = .775$, and the reliability of the industrial survey instrument is reported as $r_{XX} = .981$.

The presentation of the data and findings includes an item analysis of the response by group. A ranking of the skills and experiences by group is also provided in accord with item mean responses for the Importance factor. The two halves of the questionnaire, Items 106 and Items 7-14, are ranked separately within each group.

Discussion of the Industrial Survey

One purpose of the study was to determine the level of importance placed on identified skills or curricular experiences by industry and the level of provision these skills and experiences have received in engineering graduates.

From an initial analysis of the survey responses, see Table 1, it can be concluded that all of the skills, as identified in the literature, are important elements of the skill base of engineers in industry. This is evidenced by the magnitude of the importance levels and the lack of response to the "other" category.

The first six items on the survey provide a picture of the relationship of basic graphics skills to computerized methods. Spatial visualization was ranked first by the industrial respondents. Four of the six items on this portion of the survey rank ahead of computer graphics by itself, even the "combination" item. Industry apparently feels that these skills are important before computer graphics. Descriptive geometry was ranked 6th out of six items, but with an importance level of 3.87 it is still an important

Item Analysis for the Industrial Survey
(Rank Ordered by Mean Importance)

	Rating Code HOW IMPORTANT (HI)						Rating Code HOW WELL PROVIDED (HWP)					
ITEM	1	2	3	4	5	$(\bar{X})$	1	2	3	4	5	$(\bar{X})$
Spatial Visualization	1	5	14	42	43	(4.15)	5	33	48	16	2	(2.77)
Sketching	1	5	16	48	35	(4.05)	22	48	28	5	2	(2.20)
Combination of Traditional Engineering Graphics and Computer Graphics	1	6	17	43	38	(4.05)	15	43	41	5	0	(2.34)
Traditional Engineering Graphics Abilities	2	5	19	45	34	(3.99)	3	26	40	32	3	(3.05)
Computer Graphics	3	5	29	31	37	(3.89)	26	43	29	6	0	(2.14)
Descriptive Geometry	1	5	22	55	22	(3.87)	4	31	43	23	3	(2.90)
3-D Geometric Modeling	0	3	19	46	37	(4.11)	29	48	19	7	1	(2.06)
Problem Solving Analysis with CAD System on Graphics Designs	2	3	14	49	37	(4.10)	21	49	23	11	1	(2.25)
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	6	10	23	29	37	(3.77)	18	47	29	10	1	(2.32)
Computer-Aided Drafting	2	6	36	36	25	(3.72)	18	47	35	4	0	(2.24)
Experiences with CAD or CADD Using Microcomputer Systems	7	22	21	28	26	(3.42)	28	46	21	6	1	(2.07)
Experiences with CAD or CADD Using Mainframe Computers	6	16	30	35	18	(3.40)	24	40	30	8	1	(2.24)
Experiences with Commercial Turnkey CAD or CADD Hardware/Software	12	19	29	30	14	(3.14)	30	45	23	4	1	(2.03)
Computer Programming for Computer Graphics	17	36	35	16	1	(2.50)	21	14	32	23	15	(2.97)

Table 1

item. The final 8 items on the survey represent specific computer skills and general types of hardware and software experiences. From the ranking of this list it can be concluded that computer skills and experiences in graphics are generally important. However, one skill ranks significantly lower than all the rest, that of computer programming for computer graphics. Existing hardware and software "user" skills ranks above computer-aided drafting, the three items regarding hardware systems, and far above computer programming for computer graphics. This appears to be an indication that learning to "use" computer graphics is more important than learning to program one. In regard to the general types of CAD equipment, the importance levels indicate that students should have experience with all three. But microcomputer systems appear to be receiving more attention in industry.

The "How Well Provided" responses to the survey, provide a picture of how well industry feels the skills and experiences are being provided for. These levels all represent significant differences from their respective importance levels. Ordinarily this result would indicate a conclusion that all of the skill and experience items require improvement of some sort. However, it would not seem fair to single out the educational system as a general problem area, rather, that the survey instrument produced some of these differences.

The importance ratios, see Table 2, provide a sense of direction for improvement in the curriculum. Almost all items have ratios greater than 1.00, indicating a need for more provision of this skill or experience. However, in the examination of these ratios, one stands out different from the rest. With an importance ratio of .84 (less than 1.00, or balance) it can be concluded that industry feels that this skill is being provided for more than necessary. It is important to note that this is not a concluson that computer programming is, in itself, unimportant.

Discussion of the Academic Survey

Another purpose of the study was to determine the level of Importance placed on identified skills or curricular experiences by engineering schools and the level of Provision for these skills that engineering students receive.

From an initial analysis of the responses, see Table 3, it can be concluded that the academic respondents considered all of the survey items as generally important. This is evidenced by

Results of t-test
Between Importance and Provision for the
Industrial Sample

ITEM	HI_I	HWP_I	r	t
Traditional Engineering Graphics Abilities	3.99	3.05	1.30	7.38**
Spatial Visualization	4.15	2.77	1.49	11.46**
Descriptive Geometry	3.87	2.90	1.33	8.18**
Sketching	4.05	2.20	1.83	15.12**
Computer Graphics	3.89	2.14	1.81	13.26**
Combination of Traditional Engineering Graphics and Computer Graphics	4.05	2.34	1.72	14.48**
3-D Geometric Modeling	4.11	2.06	1.99	17.30**
Computer-Aided Drafting	3.72	2.24	1.66	12.28**
Computer Programming for Computer Graphics	2.50	2.97	.84	-2.91**
Problem Solving Analysis with CAD System on Graphic Designs	4.10	2.25	1.81	14.81**
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	3.77	2.32	1.62	9.90**
Experience with Commercial Turnkey CAD or CADD System Hardware/Software	3.14	2.03	1.54	7.54**
Experience with CAD or CADD Using Microcomputer Systems	3.42	2.07	1.64	8.83**
Experiences with CAD or CADD Using Mainframe Computer Systems	3.40	2.24	1.52	8.18**

HI_I - How Important within the Industrial Sample

HWP_I - How Well Provided within the Industrial Sample

* - Significant at the .05 level

** - Significant at the .01 level

$r = \frac{HI_I}{HWP_I}$

Table 2

the magnitude of the importance levels and the lack of response to the "other" category.

The first 6 items on the survey provide a picture of the relationship of basic graphics skills to computerized methods. Only one skill (spatial visualization) is ranked ahead of computerized or partially computerized approaches to graphics. The fact that the "combination" item ranked 2nd and ahead of computer graphics, however, indicates that some manual or traditional skills are desired. But traditional engineering graphics is favored less than computer approaches. This ranking leads to a general conclusion that engineering schools are recognizing the importance of new computerized technology. Sketching as a manual skill ranks significantly lower than all other skills on this portion of the survey.

The final 8 items on the survey represent specific computer skills and general types of hardware and software experiences. Problem solving analysis is ranked 1st by engineering schools on this portion of the survey. Engineering programs in general focus on problem solving and analysis, and this ranking may be a reflection of that emphasis. Computer programming for computer graphics is ranked 4th, and appears to be relatively important to engineering schools. Nearly sharing this rank however, is existing hardware and software "user" skills. This may seem contradictory at first, but it may be an indication that more "user" oriented software is being integrated into engineering graphics programs. In regard to experiences with general types of CAD equipment, the importance levels indicate that microcomputer systems are most important. Commercial turnkey CAD system experience was the only item on the survey that indicated an importance level below 3.00.

The "How Well Provided" responses to the survey provide a picture of how well engineering schools feel they are providing for these skills and experiences. These levels all represent significant differences from their respective importance levels. The importance ratios, see Table 4, which are all greater than 1.00, would indicate that all of the skills and experiences need improvement in provision. However, it is suggested that the survey instrument produced some of these differences.

Comparison of the Two Surveys

A comparison of the item rankings of the two samples shows that the two groups actually rank the items quite similar. Strong differences occur in relatively few places.

Item Analysis for the Academic Survey
(Rank Ordered by Mean Importance)

	Rating Code HOW IMPORTANT (HI)						Rating Code HOW WELL PROVIDED (HWP)					
ITEM	1	2	3	4	5	($\bar{X}$)	1	2	3	4	5	($\bar{X}$)
Spatial Visualization	2	0	11	21	50	(4.39)	7	14	40	17	6	(3.01)
Combination of Traditional Engineering Graphics and Computer Graphics	1	2	11	34	36	(4.21)	11	30	30	12	1	(2.54)
Computer Graphics	1	2	14	41	26	(4.05)	16	27	32	7	2	(2.42)
Descriptive Geometry	1	6	15	41	21	(3.89)	13	26	27	10	8	(2.69)
Traditional Engineering Graphics Abilities	3	9	15	27	30	(3.85)	9	15	23	29	8	(3.14)
Sketching	8	19	22	29	6	(3.07)	10	24	35	9	6	(2.72)
Problem Solving Analysis with CAD System on Graphics Designs	3	7	18	32	24	(3.79)	26	22	27	7	2	(2.25)
Experiences with CAD or CADD Using Microcomputer Systems	4	10	19	33	18	(3.60)	23	24	22	10	4	(2.37)
Computer-Aided Drafting	2	9	26	33	14	(3.57)	17	28	30	5	4	(2.41)
Computer Programming for Computer Graphics	3	15	19	35	12	(3.45)	23	24	22	8	7	(2.42)
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	3	12	29	27	13	(3.41)	15	25	30	10	4	(2.55)
Experiences with CAD or CADD Using Mainframe Computers	3	15	25	34	7	(3.32)	28	22	21	10	3	(2.26)
3-D Geometric Modeling	7	20	18	27	12	(3.20)	26	25	25	6	2	(2.20)
Experiences with Commercial Turnkey CAD or CADD Hardware/Software	12	19	24	24	5	(2.89)	39	21	13	10	1	(1.96)

Table 3

To determine how responsible engineering schools are to the items that industry feels are important, a t-test for independent samples was performed, see Tables 5 and 6. Because the rankings on the survey items were generally similar, this test also performs the function of identifying those items that are ranked close enough to be considered the same ranking, and identifying those that clearly represent different rankings. Although some rankings are quite different between samples, industry and engineering schools are in agreement on the importance levels of 9 out of 14 items.

Significant differences occur for the following items:

- Sketching
- 3-D Geometric modeling
- Problem solving analysis with CAD systems
- Existing hardware and software "user" skills

Industry places significantly more importance on these items than engineering schools. A significant difference also exists in computer programming for computer graphics. Industry places less importance on this skill than do engineering schools.

In order to contrast the levels of provision (How Well Provided) between samples, a t-test for independent samples was performed. This test performs the function of identifying items that have provision levels close enough together so as to be considered the same, and to identify those that clearly represent different levels. Significant differences occur for the following items:

- Sketching
- Computer graphics
- Experience with CAD using micro-computer systems

Industry feels that these skills and experiences are being provided for significantly less than engineering schools do. A significant difference also exists in computer graphics. This indicates that industry feels that there is significantly more provision for this skill than engineering schools do.

> " there appears to be relative agreement about what constitutes vaild objectives in a traditional course........"

Results of t-test
Between Importance and Provision for the
Academic Sample

ITEM	HI_A	HWP_A	r	t
Traditional Engineering Graphics Abilities	3.85	3.14	1.22	4.05**
Spatial Visualization	4.39	3.01	1.45	9.44**
Descriptive Geometry	3.89	2.69	1.44	7.48**
Sketching	3.07	2.72	1.12	2.06*
Computer Graphics	4.05	2.42	1.67	11.70**
Combination of Traditional Engineering Graphics and Computer Graphics	4.21	2.54	1.65	12.06**
3-D Geometric Modeling	3.20	2.20	1.45	5.77**
Computer-Aided Drafting	3.57	2.41	1.47	7.46**
Computer Programming for Computer Graphics	3.45	2.42	1.42	5.79**
Problem Solving Analysis with CAD System on Graphic Designs	3.79	2.25	1.68	9.44**
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	3.41	2.55	1.33	5.28**
Experience with Commercial Turnkey CAD or CADD System Hardware/Software	2.89	1.96	1.47	5.33**
Experience with CAD or CADD Using Microcomputer Systems	3.60	2.37	1.51	7.07**
Experiences with CAD or CADD Using Mainframe Computer Systems	3.32	2.26	1.46	6.40**

HI_A - How Important within the Academic Sample

HWP_A - How Well Provided within the Academic Sample

* - Significant at the .05 level

** - Significant at the .01 level

$r = \frac{HI_A}{HWP_A}$

Table 4

Summary of Conclusions Based on Comparisons of the Two Surveys

Based on the comparison of the two surveys, several conclusions can be drawn. However, it can be concluded that, in general, engineering schools appear to be doing a commendable job in attempting to be responsive to the needs of industry. In addition, the following conclusions can also be drawn:

1. Industry and engineering schools <u>disagree</u> significantly on the importance of 3-D geometric modeling. However, the two groups agree on the levels of provision this item is receiving. Therefore this is not apparently an area that requires improvement in the engineering graphics curriculum.

2. Industry and engineering schools <u>disagree</u> significantly on the importance of problem solving analysis with CAD systems.. However, the two groups are in agreemet on the level of provision this item is receiving. Therefore, this is not apparently an area that requires improvement in the engineering graphics curriculum.

Results of t-test
Importance (HI_A) vs Importance (HI_I)
Between Samples

ITEM	HI_A	HI_I	t
Traditional Engineering Graphics Abilities	3.85	3.99	.86
Spatial Visualization	4.39	4.15	1.83
Descriptive Geometry	3.89	3.87	.13
Sketching	3.07	4.05	6.62**
Computer Graphics	4.05	3.89	1.12
Combination of Traditional Engineering Graphics and Computer Graphics	4.21	4.05	1.21
3-D Geometric Modeling	3.20	4.11	5.98**
Computer-Aided Drafting	3.57	3.72	1.07
Computer Programming for Computer Graphics	3.45	2.50	6.34**
Problem Solving Analysis with CAD System on Graphic Designs	3.79	4.10	2.13*
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	3.41	3.77	2.18*
Experience with Commercial Turnkey CAD or CADD System Hardware/Software	2.89	3.14	1.45
Experience with CAD or CADD Using Microcomputer Systems	3.60	3.42	1.07
Experiences with CAD or CADD Using Mainframe Computer Systems	3.32	3.40	.57

HI_I - How Important within the Industrial Sample

HI_A - How Important within the Academic Sample

* - Significant at the .05 level
** - Significant at the .01 level

Table 5

> "The engineering graphics curriculum should provide experiences with a variety of computing hardware."

3. Industry and engineering schools disagree significantly on the importance of existing hardware and software "user" skills. However, the two groups are in agreement on the level of provision this item is receiving. Therefore, this is apparently not an area that requires improvement in the engineering graphics curriculum.

4. Industry and engineering schools agree on the importance of computer graphics. However, the two groups disagree significantly as to the level of provision this item is receiving. Therefore, this is an area that requires improvement in the engineering graphics curriculum.

5. Industry and engineering schools agree on the importance of experience with CAD or CADD using microcomputer systems. However, the two groups disree significantly as to the level of provision this item is receiving. Therefore, this is an area that requires improvement in the engineering graphics curriculum.

6. Industry and engineering school disagree significantly on both the level of importance and the level of provision for sketching. Therefore, this is an area that requires modification in the engineering graphics curriculum.

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The participants
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- Professor Ro
University of
- Professor Joh
Virginia Poly
andState Uni
- Professor Joh
Ohio State U

Purdue 1985
Midyear Meeting

Interactive 3-D Geometric Modeling with Vectors and Viewpoints

K. R. Helmlinger
and
L. L. Northup
Freshman Engineering
Iowa State University
Ames, Iowa

Introduction

It is obvious to all that the application of computer graphics is changing the business of engineering graphics. Those responsible for design and manufacturing in industry are now talking of databases rather than design drawings in many instances. Students must be prepared to intelligently interact in the modern industrial world and it goes without saying that engineering faculty are responsible for preparing them to do so.

Those who have a traditional background in engineering graphics and descriptive geometry have not found it easy to modify their approach but nevertheless they are changing. The authors don't consider traditional graphics education as a detriment to working in the computer age, but rather believe that the marriage of traditional graphics and computer applications results in a powerful combination for engineering graphics faculty. The best of both worlds can be combined to effectively educate students to be successful engineers.

The first use of computer graphics in industry might be described as an electronic drafting machine. Traditional drawings were prepared with lines and text on a CRT rather than on a piece of paper. These drawings, when printed were of high quality but provided no more information about the design than had been previously supplied by a skilled drafter. To be sure, there are some significant advantages to computer-aided-drafting. Increases in productivity of the designer were seen particularly where drawings contained repetitive material or where standard symbols or objects could be prepared and used again and again. Design drawings can be quickly changed to reflect engineering changes and everyone who needs the latest version has immediate access to it.

Designers are rapidly moving toward 3-D databases from the 2-D computer-aided-drafting databases. A 3-D database continues to offer a complete geometric description of an object. In addition, however, the 3-D database can be used as input to many analysis packages. Thus the designer can conveniently determine properties such as total mass, moment of inertia, center of mass, and so forth. Also stress and temperature distributions can be found with minimal geometric data preparation.

If it can be agreed that 3-D databases will be generally used in the future, it follows that students must be able to create and manipulate them. Traditional descriptive geome
combined with sin
analysis offer a pro
understanding how
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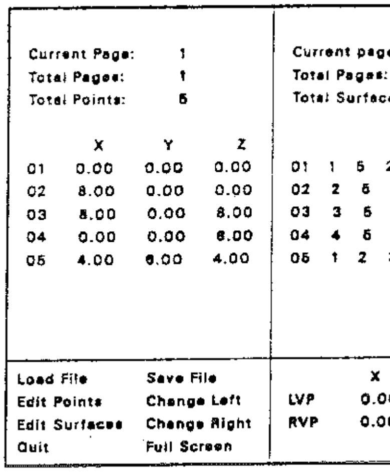

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Current Page:      1              Current page
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05     4.00    6.00    4.00       05   1   2

Load File        Save File                  X
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Edit Surfaces    Change Right      RVP     0.0
Quit             Full Screen
```

Figure 1

particular hardwar
systems, or graphi
will not be present
Discussions of the
the 3-D database,
the viewpoint conc
necessary rotation
several examples
program are inclu

The Menu and the Database

An interactive 3-D geometric modeling program (DISPLAY) has been developed in the Freshman Engineering Department at Iowa State University. This program allows students to enter and manipulate a 3-D database for simple geometries (convex polyhedra) with plane surfaces (no curved or warped surfaces) through a program menu. The program menu (Figure 1) allows the user to either load, edit, or save a data file containing the object geometry. Specifications for displaying the 3-D object as a wire-frame model on the 2-D monitor screen are also given through the menu. Different views of the object may be displayed on the left half and right half of the monitor simultaneously or the object may be displayed on the full screen. However, before using the program, the geometry of the object must be completely defined.

The database for the object is built around the concepts of points (nodes) and surfaces, where the number of nodes and number of surfaces are placed in the database. The x, y, and z coordinates of each node of the object are determined in an object coordinate system (a right-handed cartesian system fixed to the object) and stored in the database. Since surfaces can be described by a series of points or lines, the database actually includes the order in which the points are connected to form the surfaces of the object. This connectivity scheme enables the program to correctly construct the object on the monitor screen by describing the endpoints of each line to be drawn.

If the removal of hidden lines from any view of the object is to be considered at some future time, a convention must be established for defining the connectivity of the points on each surface. This convention will reflect future planning since no convention is specifically needed for a wire-frame model. The convention used here to define each surface is to list the nodes for the surface in a counterclockwise order as seen when viewing the surface from the outside of the object.

Vector Concepts

Since the points (nodes) and lines (edges) comprising a surface, various geometric properties of the object, and the viewpoint which defines the viewing direction for the image may be related to vectors, a review of appropriate vector concepts is included.

A free vector is defined as a quantity that requires a magnitude and a direction for its complete description. A vector can also be thought of as a directed line segment between two points. For example, the vector $\mathbf{P}_1\mathbf{P}_2$ has the initial point P_1 and the terminal point P_2. A vector with its initial point at the origin of the coordinate system and its terminal point at P can be represented as **P**. In other words a point can be thought of as the end of a vector which starts at the origin and ends at the point.

The vector representation of a point, P, in space is shown in a right-handed cartesian coordinate system in Figure 2. The position of the point is shown as the vector sum of the components of P in the **i**, **j**, and **k** directions where **i**, **j**, and **k** are the unit vectors along the x, y, and z axes respectively. The magnitude of the vector, **P**, can be determined from,

$$|\mathbf{P}| = \sqrt{x^2 + y^2 + z^2}$$

and a unit vector in the direction of **P** is,

$$\mathbf{p} = \frac{\mathbf{P}}{|\mathbf{P}|} \quad \frac{x\mathbf{i} + x\mathbf{j} + z\mathbf{k}}{\sqrt{x^2 + y^2 + z^2}}$$

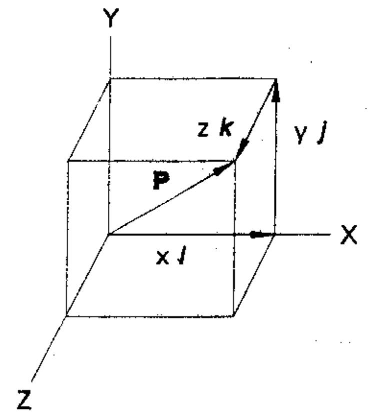

Figure 2

The sum of two vectors, $\mathbf{P}_1$ and $\mathbf{P}_2$, is obtained by placing the initial end of $\mathbf{P}_2$ at the terminal end of $\mathbf{P}_1$ and constructing a vector **R** which has its initial end at the initial end of $\mathbf{P}_1$ and its terminal end at the terminal end of $\mathbf{P}_2$. This corresponds to summing the components of the two vectors in the directions of the appropriate unit vectors and is shown in Figure 3.

$$\mathbf{P}_1 + \mathbf{P}_2 = (x_1 + x_2)\mathbf{i} + (y_1 + y_2)\mathbf{j} + (x_1 + x_2)\mathbf{k}$$

The difference of two vectors can also be seen in Figure 3 where,

$$\mathbf{P}_1 + \mathbf{P}_1\mathbf{P}_2 = \mathbf{P}_2$$

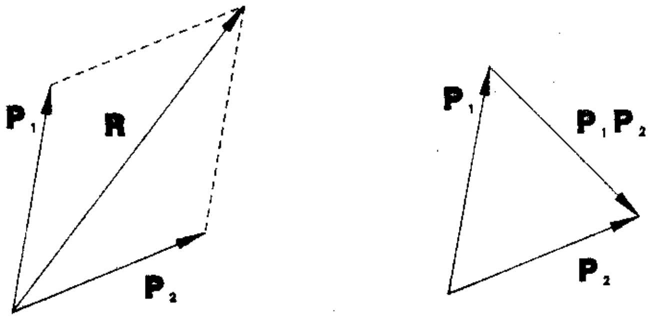

Figure 3

or,

$$\mathbf{P_1P_2} = \mathbf{P_2} - \mathbf{P_1} = (x_2 - x_1)\mathbf{i} + (y_2 - y_1)\mathbf{j} + (x_2 - x_1)\mathbf{k}$$

The family of parallel vectors shown in Figure 4 can be written as follows,

$$\mathbf{P_1} = 2\mathbf{i} + \mathbf{j}$$

$$\mathbf{P_2P_3} = \mathbf{P_3} - \mathbf{P_2} = 2\mathbf{i} + \mathbf{j}$$

$$\mathbf{P_4P_5} = \mathbf{P_5} - \mathbf{P_4} = 4\mathbf{i} + 2\mathbf{j}$$

$$\mathbf{P_7P_6} = \mathbf{P_6} - \mathbf{P_7} = -2\mathbf{i} - \mathbf{j}$$

or in general, any vector which is parallel to vector $\mathbf{P_1}$ can be written as $c\mathbf{P_1}$ where c is a scalar multiplier. Recall that P_1 is a vector which begins at the origin and ends at the point P_1. Conversely, any vector in space, defined by an initial point and a terminal point, can be multiplied by some scalar multiplier to obtain a parallel vector which goes through the origin.

Vector multiplication is also reviewed here. Two types of products which involve vectors will be discussed: the scalar or dot product, and the vector or cross product.

The scalar or dot product of two vectors, $\mathbf{P_1}$ and $\mathbf{P_2}$, is defined as,

$$\mathbf{P_1} \quad \mathbf{P_2} = |\mathbf{P_1}| \quad |\mathbf{P_2}| \cos\theta = x_1x_2 + y_1y_2 + z_1z_2$$

where θ is the angle between the two vectors when taken from a common initial point. As seen in Figure 5, the dot product can be used to obtain the component of any vector in the direction of any other vector. The component of any vector along any of the three axes can then be computed from the dot product of the vector and the appropriate unit vector **i**, **j**, or **k**. The dot product of two perpendicular vectors is also seen to be zero.

The vector or cross product of two vectors, $\mathbf{P_1}$ and $\mathbf{P_2}$, results in a vector, **N**, that is normal to both vectors, where the direction of **N** is such that $\mathbf{P_1}$, $\mathbf{P_2}$, and **N** form a right-handed sytem (Figure

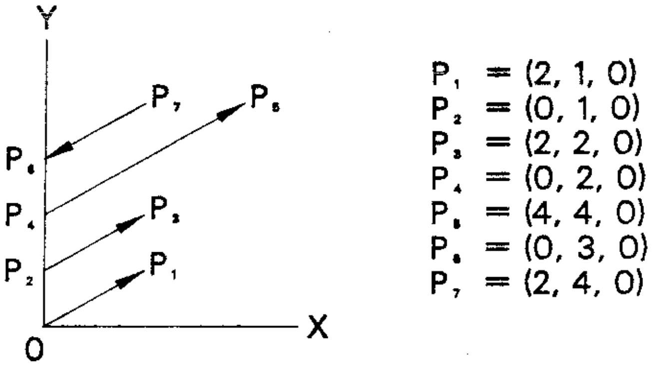

Figure 4

6). The vector, **N**, can also be thought of as a vector which is perpendicular to the plane defined by the two vectors, $\mathbf{P_1}$ and $\mathbf{P_2}$. The cross product can be calculated from,

$$\mathbf{P_1} \times \mathbf{P_2} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \end{vmatrix}$$

The magnitude of the cross product is,

$$|\mathbf{P_1} \times \mathbf{P_2}| = |\mathbf{P_1}|\ |\mathbf{P_2}| \sin\theta$$

where θ is the angle between the vectors. This magnitude can be physically thought of as the area of a parallelogram with sides $\mathbf{P_1}$ and $\mathbf{P_2}$.

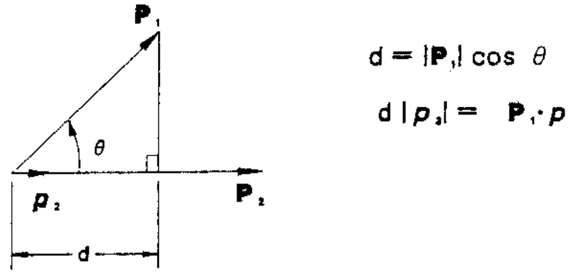

Figure 5

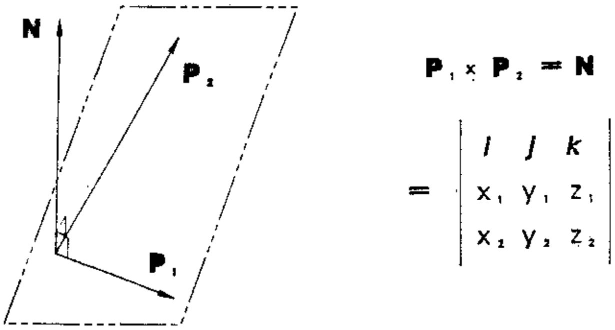

Figure 6

These vector concepts can now be related to the 3-D database discussed previously. Any point or node on the object can be described by a vector from the origin of the object coordinate system to the point. The intersection of any two plane surfaces can be considered as a vector. This vector can be determined by vector subtraction from the endpoints of the line of intersection. Also, any plane surface on the object can be described by any two vectors on the surface (e.g., two edges).

Viewpoints

Consider the object in Figure 7 which is defined in some object coordinate system. A viewing plane which is perpendicular to the z-axis may be imagined by viewing the object from along the z-axis toward the origin (Figure 8). The projectors from each point on the object to the viewing plane are all parallel and they are all perpendicular to this viewing plane. Any point on the z-axis can then be thought of as a viewpoint for this viewing plane. Likewise, any line of sight which goes through any point on this viewing plane and is parallel to the z-axis would give the same orthographic view. This means there are an infinite number of lines of sight (vectors) which can describe this view. Note that in this view the z-coordinate is not seen since it is perpendicular to the viewing plane and therefore the 2-D image is a view of the xy coordinates of the nodes and their connecting lines.

The viewpoint can be defined as the specific point in space from which the object is to be viewed. This point has coordinates x_{vp}, y_{vp}, z_{vp} in the object coordinate system. A viewing coordinate system (with axes x_v, y_v, z_v) based on this viewpoint can then be defined so that the view (line of sight) is always along the z_v-axis toward the origin of the system, where the z_v-axis with the desired viewing direction (i.e., from the viewpoint to the origin) two rotations of the viewing axes system must be made (Figure 9). First start with the viewing axes aligned with the object axes and rotate about the y-axis through an angle ß ($0° \leq ß \leq 360$). The viewing axes are now aligned with an intermediate x', y', z' axes system. Second, rotate about the x'-axis through an angle ∂ ($-90° \leq ∂ \leq 90°$) to align the z_v-axis with the viewing direction (line of sight). If the object is now drawn on the monitor screen in the viewing coordinate system, it would be the same as viewing the object from the viewpoint in space. The equations which can be used to transform the object into the viewing system are,

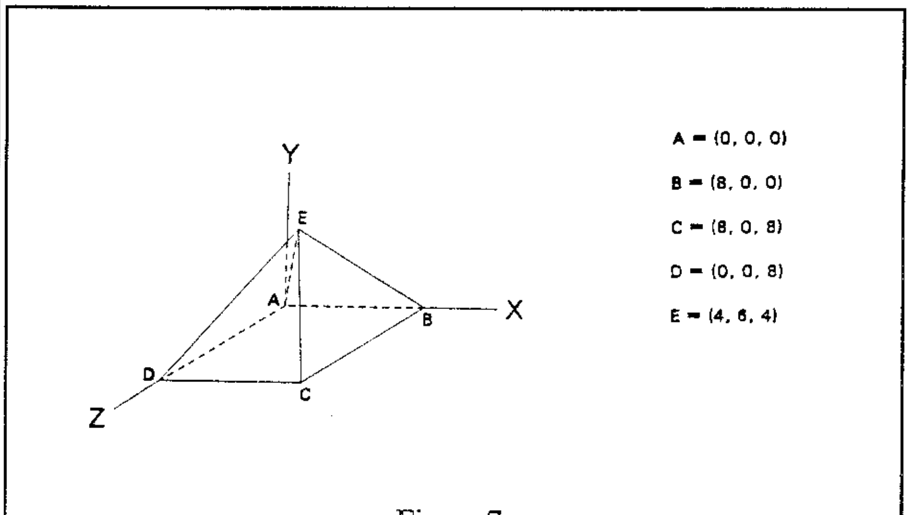

Figure 7

> "Designers are rapidly moving toward 3-D databases from the 2-D computer-aided drafting databases"

$$x_V = x \cos ß - x \sin ß$$

$$y_V = y \cos \partial - x \sin \partial \sin ß - z \sin \partial \cos ß$$

$$z_V = y \sin \partial + x \cos \partial \sin ß + z \cos \partial \cos ß$$

where ∂ and ß can be determined from the viewpoint coordinates,

$$a = \sin^{-1}\left[\frac{v_{vp}}{\sqrt{x_{vp}^2 + y_{vp}^2 + z_{vp}^2}}\right]$$

$$ß = \sin^{-1}\left[\frac{x_{vp}}{\sqrt{x_{vp}^2 + z_{vp}^2}}\right]$$

Note that the case $x_{vp} = z_{vp} = 0$ defines the horizontal (top) view where $ß = 0$.

Program Applications to Spatial Geometry

This program may be used by students to solve spatial geometry problems or it may be used exclusively to enchance 3-D visualization ability. It enhances visualization since the given object may be viewed and studied from any point in space. In spatial geometry problems, the traditional "solution principles", also called solution views, which describe the conditions and views for the problem solution must still be emphasized. Only the procedures or methods for obtaining the solution have changed with the use of the computer. Several examples will now be discussed to illustrate this point.

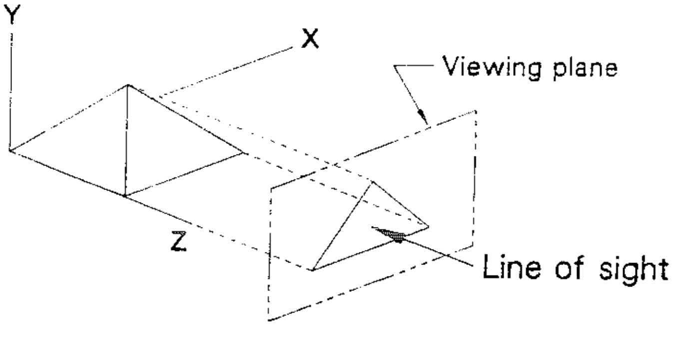

Figure 8

Finding the true length of a line is a typical problem found in all engineering graphics courses. The solution principle (solution view) for the true length of any line in space says that the true length of the line is found on an image (viewing) plane which is parallel to the line. This means the line of sight which is perpendicular to the image plane is also perpendicular to the line itself. The problem then becomes one of finding the appropriate line of sight or vector which is perpendicular to the line. This line of sight or vector can then be used to indicate the viewpoint in space since some scalar multiple of this vector will be a vector through the origin.

Recalling that the cross product of any two vectors gives a vector which is perpendicular to both vectors, we can determine the line of sight, and therefore, the viewpoint for the true length of the line. Since we may take the cross product of the vector which represents the line and any other vector, there will be an infinite number of lines of sight or viewpoints.

For example, a view of the true length of edge EC on the object shown in Figure 7 may be desired. The vector describing edge EC is,

$$\begin{aligned} \mathbf{EC} &= \mathbf{C} - \mathbf{E} \\ &= (8\mathbf{i} + 8\mathbf{k}) - (4\mathbf{i} + 6\mathbf{j} + 4\mathbf{k}) \\ &= 4\mathbf{i} - 6\mathbf{j} + 4\mathbf{k} \end{aligned}$$

Choosing to take the cross product with the unit vector **j**, results in,

$$\begin{aligned} \mathbf{EC} \times \mathbf{j} &= (4\mathbf{i} - 6\mathbf{j} + 4\mathbf{k}) \times \mathbf{j} \\ &= -4\mathbf{i} + 4\mathbf{k} \end{aligned}$$

which is the vector describing the line of sight for the true length. In other words the viewpoint for the true length is the point (-4, 0, 4). Equivalent viewpoints would then be (-1, 0, 1), or (1, 0, -1), etc. A view showing the true length of line EC is shown on the left half of Figure10.

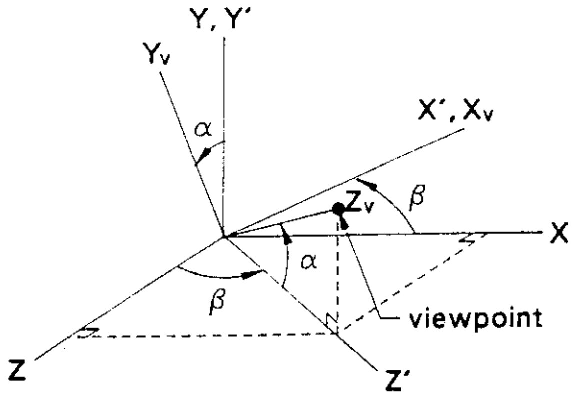

Figure 9

$$|\mathrm{EC}| = \sqrt{4^2 + (-6)^2 + 4^2}$$

$$= 8.25 \text{ units}$$

These same viewpoints will also show the inclination of the line EC. The solution principle for the inclination says that the inclination of a line is seen in an elevation view where the line is shown in true length. Any image plane which is parallel to the y-axis (or the unit vector **j**) would show an elevation view. Therefore, since our calculated line of sight was perpendicular to both line EC and the unit vector **j**, the viewpoint (1, 0, -1) can also be used to display the inclination of the line.

Finding the point view or end view of a line is another typical problem. The solution principle says that the point view of a line is found on the plane which is perpendicular to a true length image of the line. This means that the line of sight for the viewing plane is directly down the line or parallel to the line. The line **EC** is represented in vector notation as **EC** = 4**i** - 6**j** + 4**k**. That is, the line of sight for the point view is also 4**i** - 6**j** + 4**k**. Possible viewpoints for this viewing plane would then be (4, -6, 4) or (2, -3, 2). The point view of line EC is shown on the right half of Figure 10.

The viewpoint (2, -3, 2) also shows the edge view of planes

ECD and EBC. The solution principle says the edge view of a plane is shown in a view where some line on the plane is shown as a point. Therefore, since line EC is in planes ECD and EBC, the viewpoint which shows line EC as a point will also show both planes as edges. This is seen on the right half of Figure 10.

Recall that the solution principle for the dihedral angle between two planes says this angle is found in a view showing the point view of their line of intersection and both planes as edges. Therefore, this same viewpoint (2, -3, 2) shows the dihedral angle between planes ECD and EBC. This is also shown on the right half of Figure 10.

Conclusions

The interactive 3-D geometric modeling program (DISPLAY) developed in the Freshman Engineering Department at Iowa State University is a useful tool for students in an engineering graphics course. This program allows students to manipulate a 3-D database through the use of a menu. It may be used to view the solution of spatial geometry problems or exclusively to enhance 3-D visualization ability. Traditional solution principles must still be emphasized since the use of the computer has only changed the procedure for obtaining the solution.

Typical spatial geometry problems such as viewing the true length or point view of a line, the edge view of a plane, the dihedral angle, true shape of a plane, etc. may be displayed. Only a few simple vector algebra calculations are needed to obtain a proper viewpoint for viewing the desired image. A few additional vector algebra calculations can then be made to determine the actual values of the length of a line, the area of a plane, the dihedral angle, etc.

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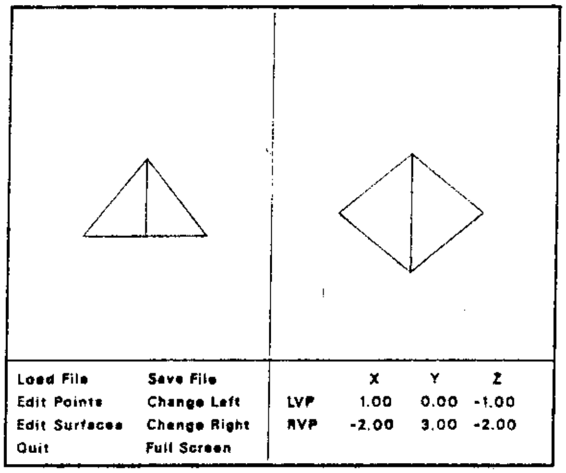

	X	Y	Z
LVP	1.00	0.00	-1.00
RVP	-2.00	3.00	-2.00

Figure 10

Review

from page 6

of orthographic projection. The book then stops at familiar locations—points and lines, auxiliary views, planes, parallel and perpendicular relationships, intersections, revolutions, developments—before moving on to vector geometry and mining applications.

Each chapter's labs follow the text and are in turn followed by a knowledge test. **Applied Descriptive Geometry** is a practicable text-workbook for a full course in Descriptive Geometry.

Engineering Drawing and Graphic Technology 13th Edition, by French, Vierck and Foster. McGraw-Hill, 1986.

This recent edition of a traditional classic in Graphic Technology has undergone subtle changes to update what is timeless instruction. FV&F, however, continues much antiquated graphic technology, rendering a 700 page book where there are probably 300 pages of hard, fundamental instruction.(Read the comment on the following review). There is a greater emphasis on automated drafting and CADD, a more integrated treatment of metric units, and of course, ANSI standards are covered throughout.

Organized into four major sections—Basic Graphics, Elements of Space Geometry, Applied Graphics and Design, and Special Topics—the text profits from an extensive collection of alternate problems for student assignment. Special Topics covers gears, cams, welding, electronic, structural, mapping—the potpourri which to expose students to the world of graphics.

A separate workbook is available for those who would like a coordinated laboratory experience.

Technical Drawing 8th Edition, Giesecke, Mitchell, Spencer, Hill, Dygdon. Macmillan Publishers, 1986.

If you have been using Giesecke et al over the years you will feel right at home with this new edition. Like most other major graphics texts, this one also has included more emphasis on computer-aided graphics, mostly through an additional chapter toward the end of the work.

The guts of the instructional chapters have not changed over the years, though all have been reviewed to assure that the latest ANSI standards are met.

Unfortunately the book is almost 1,000 pages long, no doubt the result of the publisher trying to be everything to everybody, and unable to perform necessary editorial cutting. This is a comment applicable to all major "flagship " graphics texts, regardless of publisher. There is simply no reason to include all graphic technology, almost from the dawn of time, in a modern graphics text. Surely we have seen the last of sharpening ruling pen nibs or cutting wooden pencils with a pocket knife! Come on, what do they have to do with graphics anyway?

Not enough technical people in the world use graphics as an end product to continue with this nonsense.

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City (if served by U.S. Post Office) ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ State ☐☐ Zip ☐☐☐☐☐☐
City & Country (International Applicants only) ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐
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DIVISION/COMMITTEE MEMBERSHIP

An individual ASEE member may become a member of six (6) divisions/committees. Three (3) non dues paying affiliations are allowed. If a member desires to join more than three (3) groups, the additional ones must be dues paying. Payment for dues paying affiliations must accompany this application. A listing of ASEE divisions/committees and their respective dues are listed on the back.

☐ Please check if you have chosen dues paying division/committee affiliations.

☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐
Enter your divisions/committees in order of preference

Date of Birth ☐☐☐☐ (Month) (Year)

In order for ASEE to qualify as a society member in the American Association of Engineering Societies, we must verify that 50% of our members are either Professional Engineers or have degrees from ABET/ECPD accredited institutions. Will you please help us by marking the appropriate box below and returning this sheet with your dues payment.

☐ Professional Engineer ☐ Degree from accredited institution ☐ Neither

FOR ASEE USE ONLY	Institution Code	Section Code	Country Code
	☐☐☐☐	☐	☐☐☐☐

8. All articles shall be written using Metric-SI units. Common measurements will be accepted at the descretion of the editorial staff.

9. Send all material in one mailing to:

Jon M. Duff
Editor, EDGJ
355 Knoy Hall of Technology
Purdue University
West Lafayette, IN 47907

REVIEW OF ARTICLES

All technical articles are submitted to the EDGJ Board of Review for blind review. This board represents national authority on graphic technology, engineering education, and technical specialties within engineering and technology. Authors will be notified as to the results of the review. Manuscripts may be accepted as submitted, accepted with provisions, or not accepted for publication.

The Journal reserves the right to refuse letters to the editor due to space constraints, because the material is potentially libelous, because the issues discussed are no longer of a timely nature, or because of a large number of similar letters on the same topic. Letters may be edited for spelling, punctuation, and style, and may be shortened or abstracted although meaning and tone will not be changed.

ASEE DIVISIONS AND CONSTITUENT COMMITTEES

Code		
	DIVISIONS	
10	Aerospace	
11	Agricultural Engineering	
12	Architectural Engineering	
13	Chemical Engineering	
*14	Civil Engineering (Construction, Hydraulics, Sanitary, Soil Mechanics, Structural Surveying, Transportation)	$5.00
*15	Continuing Professional Development	$5.00
16	Cooperative Education	
*17	Educational Research & Methods	$1.00
*18	Electrical Engineering	$1.00
*19	Engineering Economy	$2.00
*20	Engineering Design Graphics	$1.50
21	Graduate Studies	
*22	Industrial Engineering	$2.00

Code		
*23	Liberal Education (Economics, English, History, Languages, Psychology, Specify Other)	$2.00
*24	Computers in Education	$5.00
*25	Materials (Mineral Engineering)	$2.00
26	Mathematics	
*27	Mechanical Engineering (Machine Design, Thermodynamics, Power)	$2.00
*28	Mechanics	$2.00
*30	Nuclear Engineering	$2.00
31	Physics	
32	Relations with Industry	
*33	Engineering Technology	$5.00
34	Environmental Engineering	
35	Instrumentation	
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37	International	

Code		
*50	Biomedical Engineering	$2.00
52	Ocean and Marine Engineering	
54	Energy Conversion & Conservation	
56	Engineering and Public Policy	
*57	Engineering Management	$1.00
58	Design in Engineering Education (DEED)	
59	Information Systems	
61	Experimentation and Laboratory Oriented Studies (DELOS)	
64	Manufacturing	
	COMMITTEES	
55	Engineering Acoustics & Vibration	
*60	Construction Engineering	$2.00
62	Women in Engineering	
65	Minorities in Engineering	
67	Freshman Programs	
68	New Engineering Educators (Intended for faculty within the first five years of teaching)	

MEMBER DUES

☐ $40 will supply one full year of membership for REGULAR MEMBERS.

☐ $15 will supply one full year of membership for STUDENT MEMBERS. Student members must be full-time students at one of the educational institutional members of the society. Verification of student status MUST accompany application and subsequent renewal notices.

Send check for new member dues to **ASEE, Eleven Dupont Circle, Suite 200, Washington, D.C. 20036.** If an individual desires special mail service, or wishes to affiliate with dues paying divisions/committees, the extra costs MUST be added to new dues payment.

OPTIONAL MAILING SERVICES

First Class Mail (U.S., Canada & Mexico)	Journal: $15.00 ☐	Newsletter: $8.00 ☐
Air Mail (All Countries except U.S., Canada & Mexico)	Journal: $50.00 ☐	Newsletter: $22.00 ☐

NOTE. ASEE publications will be sent via second class mail unless otherwise stipulated. Payment for the above optional mail services must accompany this application.

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