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(continued on page 56)

Descriptive Geometry and Geometric Modeling

(presented at the 1988 Annual ASEE Conference, Portland, Oregon)

J. Alan Adams

Department of Mechanical Engineering
U. S. Naval Academy
Annapolis, Maryland

MEMORIAL

Leon M. Billow became an active member of ASEE and the Engineering Graphics Division in 1970. He served on several committees and became Chairman of the Division during 1979-80. Lee was optimistic and enthusiastic in his approach to teaching. Perhaps a paragraph which he wrote for the "Engineering Design Graphics Journal", Fall 1979, best reflects his attitude.

"Never before has the engineering profession had such a challenging future. It is in a period of substantial growth and opportunity, and allows thousands of engineers to influence the private and business lives of people in our communities. If we truly believe that graphics professors, both individually and collectively, influence future engineers by their teaching and actions, we can continue to build a strong and vital organization".

In 1984 Lee began work on a textbook in collaboration with Dr. J. Alan Adams. The objective was to combine traditional descriptive geometry with the mathematical techniques of geometric modeling in order to build a bridge between manual graphical techniques and interactive computer methods, while emphasizing the suitability, advantages, and need of each discipline. One month before the final manuscript was submitted for publication, Lee was killed in an automobile accident. The last three years of his life were primarily spent working on the text, "Descriptive Geometry and Geometric Modeling". He was concerned that students be properly taught to think and reason in a spatial context, and his work was fastidious in every detail. He loved his students and his peers, and he was proud of the effort he had made on the book. This paper reviews some of the ideas contained in the book and is dedicated to the memory of Leon M. Billow.

Introduction

An impressive evolution of computer interaction has occurred in the past twenty years. In the 60's it was common to see students walking away from the computer with stacks of printouts. In the 70's computer graphics produced pictorial displays of large ammounts of data in a compact form. The 80's have produced computer-aided-design systems using workstations with interactive input devices which allow rapid input from menu selections and a variety of output, which may include shaded and colored pictures, automatic mesh generation for finite element analysis, solid modeling of realistic components, dynamic display of animated simulations, and cutter path computations for computer aided manufacture.

Before this evolution took place, the foundation courses for engineering study were based upon graphics and geometry. Educators struggle with how to cope with computer technology now that the computer can perform many of the manual tasks previously associated with graphics and geometry. The presence of personal computers and applications software has not made the decision any easier. All disciplines must struggle with what students should know before they begin to use the marvelous black (or white) boxes which apparently can produce solutions to just about any type of problem. Once students have a "solution", do they understand its limitations, can they obtain quantitative information from the graphical or pictorial output, can they make supplementary computations which were not anticipated by the creator of the software, and can they operate in an environment where the parent software that created a solution may not be available?

The best approach to the new educational needs of engineering students is again to develop foundation courses based upon graphics and geometry. They will not look like the previous courses, but the basic principles should still be there. The goals for the new foundation courses, in order of importance, should be as follows:

1. Develop a spatial awareness and reasoning capability.

2. Create both a graphical and mathematical foundation for solving geometric problems.

3. Learn to use the computer as a tool for analysis and design.

The principles of descriptive geometry are necessary to meet the above three objectives. They are especially important in order to be able to use orthographic projections which may be automatically produced by the computer. The mathematical basis of geometric modeling is also necessary to meet the above objectives. Geometric modeling is the representation of objects in terms of their geometric properties. It forms the basis for defining and interrogating objects stored in computer memory. A combination of descriptive geometry and geometric modeling can provide a solid cornerstone course for engineering education.

Geometric Modeling

Geometric modeling is an active area of research and graduate study.[1] At first glance it does not appear to be suitable for an early undergraduate course. The mathematical formulation for curves, surfaces, and solids requires mathematical methods beyond the background of entering college students.[2] However, geometric modeling can also be applied to objects such as points, lines, and planes. This requires a mathematical preparation comparable to what is found in most good high schools. It is precisely at this point where a bridge can be built to connect the classical study of descriptive geometry with the mathematical techniques of geometric modeling. The same vector and matrix techniques used in elementary engineering courses can be used in geometric modeling to compute geometric properties of objects stored in computer memory.

In Ref. 3 the definitions of basic geometric concepts such as points, lines, and planes is given from both a graphical and mathematical point of view within the same chapters. This gives the student the option to approach a problem using either a traditional descriptive geometry method or a computational method. The mathematical techniques complement the descriptive geometry methods to help provide the spatial awareness necessary when dealing with traditional design methods or computer-aided design and manufacture. This awareness is required for those who wish to make intelligent use of the CAD/CAM software available today. It also prepares one for later advanced study in geometric modeling and computational geometry.

Basic Geometric Concepts

Knowledge and understanding of geometric principles by which ideas and concepts are developed and recorded provide the transition from abstract thinking to physical reality and are fundamental to the creative design process. Before equations or free-body diagrams can be applied, or before a quantitative analysis can be carried out, a device, configuration, shape, prototype, or mental image must exist. This conceptual phase of design can be documented using manual graphical techniques or interactive computer techniques. Regardless of how it is done, conceptual design documentation based upon fundamental geometric concepts provide the foundation for creative design.

a. Points

A point is fixed in space by drawing two principal orthographic views in a two-dimensional plane. The projection of a point is shown on the picture plane at the point where the line of sight intersects the picture plane at right angles.

A point is not a vector. It has has neither magnitude nor direction. However, every point in space can be represented by a vector directed from the origin of a three-dimensional coordinate system to the point. The three components of a vector are given in matrix form as $\mathbf{P} = [\ x \ \ y \ \ z\ ]$.

b. Lines

A line is defined geometrically as the locus of two or more points. Theoretically it can have infinite length but neither breath nor thickness. The intersection of two planes also defines a line.

An object stored in computer memory may consist of hundreds of line segments defined between pairs of points. In order to determine geometric attributes of these lines, one can use the parametric, vector equation for a line in space. Let **Q** be any point on the vector **R** = **B** - **A** as shown in Fig. 1. The equation for the line passing through points **A** and **B** is given by

$$\mathbf{Q} = \mathbf{A} + t(\mathbf{B} - \mathbf{A}) = \mathbf{A} + t\mathbf{R} \qquad (1)$$

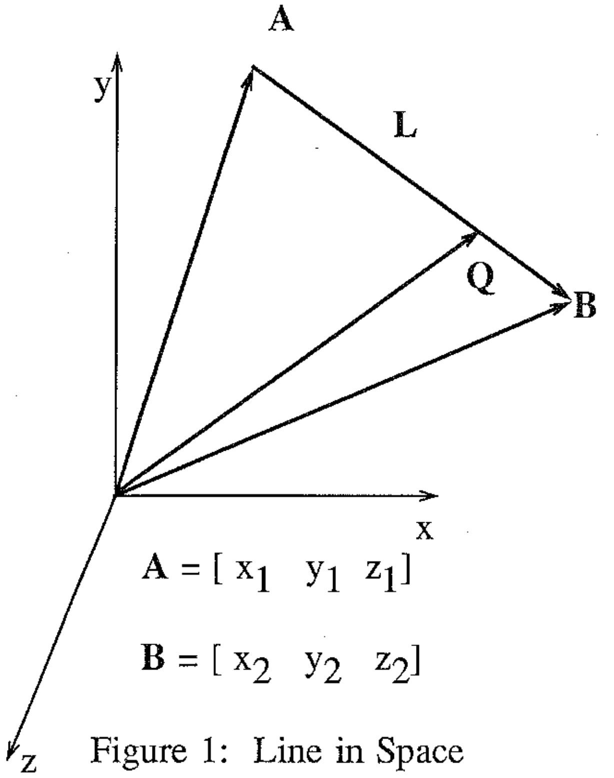

Figure 1: Line in Space

If the parameter t varies between [0,1] then **Q** lies on the line seqment between **A** and **B**.

c. Planes

A plane can be defined geometrically as a surface in which any two points may be connected by a straight line which lies completely in that surface. Planes have no thickness, but have infinite length and breadth. A plane surface can also be defined by two intersecting lines, a point and a line, two parallel lines, or three noncollinear points. A finite plane facet can be defined as an area between boundary lines lying in the plane.

Let **Q** represent any point in a plane defined by three noncollinear points $\mathbf{P}_1$, $\mathbf{P}_2$, and $\mathbf{P}_3$ as shown in Fig. 2. The vector difference $\mathbf{Q} - \mathbf{P}_3$ gives a vector **R** which lies in the plane. Thus, vector **R** will be perpendicular to the normal vector to the plane **N**. Since the vector dot product between any two perpencicular vectors is zero, the vector equation for the plane is given by

$$\mathbf{N} \cdot (\mathbf{Q} - \mathbf{P}_3) = 0 \qquad (2)$$

The normal vector **N** is given by the vector cross product

$$(\mathbf{P}_1 - \mathbf{P}_2) \times (\mathbf{P}_3 - \mathbf{P}_2) = \mathbf{N} \qquad (3)$$

If the coordinates of **Q** are $[\ x \ \ y \ \ z\ ]$ then the vector equation for the plane can be written in scalar form as

$$N_1 x + N_2 y + N_3 z - k = 0 \qquad (4)$$

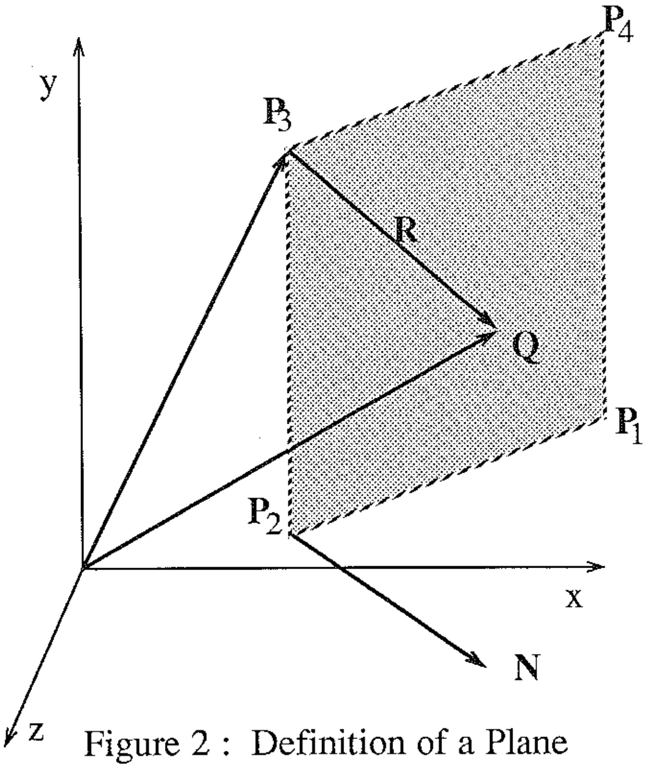

Figure 2 : Definition of a Plane

where $N = [N_1 \quad N_2 \quad N_3]$ and k is the vector dot product $k = N \cdot P_3$. Both forms of the plane equation are useful for geometric modeling.

Descriptive geometry treats curved surfaces as a series of planes in many practical applications related to surface intersections and the layout of developable surfaces. This polygonal approximation is also suitable for many geometric modeling applications. In a computer data base, a complex surface can be approximated by a series of triangular plane facets. Each facet will have geometric properties such as area, perimeter, and surface normal which can be easily computed.

When accurate manufacture of curved, smooth surfaces is required, the geometric modeling must deal with mathematical surfaces of higher order. Thus, in more advanced geometric modeling, a series of curved surface patches replaces the plan facets. Ref. 1 contains pertinent information.

Operations

As explained above, computers do not vitiate the need for understanding classical descriptive geometry, but they do create the requirement for mathematical representation of geometric shape within computer memory. Both capabilities can be developed in parallel early in the engineering curriculum. In the following, each capability is outlined as applied to common types of geometric problems.

a. Point in a Plane

When looking at two principal, orthographic views of a data base, it is not obvious whether a point of interest lies in a particular plane. To determine the position of point O relative to plane ABC an auxiliary view can be drawn which shows the plane on edge. It will then be clear whether the point lies above, below, or on the plane.

Mathematically, if the x,y,z coordinates of point O are substituted into the scalar equation for the plane, the equation will be satisfied only if the point lies on the plane. Otherwise, the left side of Eq. (4) will be positive if the point is on one side of the plane, and negative if on the other side.

b. Parallel Lines and Planes

Lines may appear parallel on a drawing or computer terminal screen when in fact they are not. Principal lines which appear parallel must be seen in true length in at least one adjacent view before they can be deemed parallel. A line is then parallel to a plane if it is parallel to any line in the plane. Two planes are parallel when two intersecting lines of one plane are parallel respectively to two intersecting lines in the other plane. Descriptive geometry offers techniques to create the necessary auxiliary views to answer questions about parallelism.

If vector **A** and **B** are directional vectors along two lines in space, the lines are parallel if the vector cross product $\mathbf{A} \times \mathbf{B} = 0$. If N_1 and N_2 are the normal vectors to two planes, the planes are parallel when $N_1 \times N_2 = 0$.

Consider a line in space passing through **A** and **B** as shown in Fig. 3. Two other points in space are represented by **P** and **Q**. The object is to define a plane which contains points **P** and **Q** and at the same time is parallel to the given line. Since line $\mathbf{S} = \mathbf{Q} - \mathbf{P}$ lies in the required plane, and since the plane is parallel to line $\mathbf{R} = \mathbf{B} - \mathbf{A}$, a normal to both lines **S** and **R** can be constructed by the vector cross product $\mathbf{N} = \mathbf{S} \times \mathbf{R}$. Choose any other point **P** in the plane to form the scalar value of k given by:

$$k = \mathbf{N} \cdot \mathbf{P} \tag{5}$$

The implicit equation for the required plane is then

$$N_1x + N_2y + N_3z - k = 0 \tag{6}$$

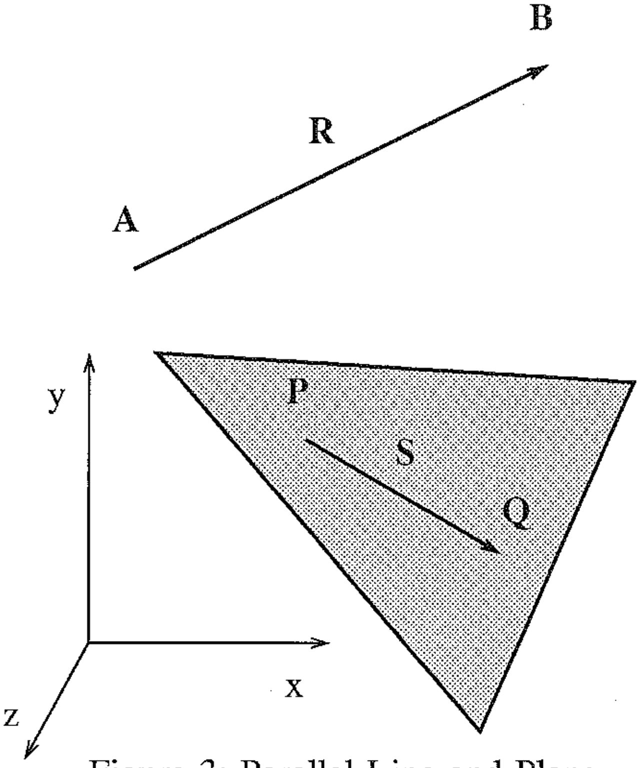

Figure 3: Parallel Line and Plane

c. Shortest Distance from Point to Line

The shortest distance between a point and a line can be seen in a view where the line appears as a point. The line must appear in true length in the view adjacent to that in which it appears as a point. Then, any line can be drawn perpendicular to another if one of the lines is shown in true length. These facts lead to descriptive geometry methods for finding the shortest distance from a point in space to a three-dimensional line.

Let a line pass through points **A** and **B**. A third point in space is represented by the vector **Q**. Define $\mathbf{S} = \mathbf{P} - \mathbf{A}$. From Fig. 4 it can be seen that $d = |\mathbf{S}| \sin \theta$. Introducing the relative vector $\mathbf{R} = \mathbf{B} - \mathbf{A}$ gives

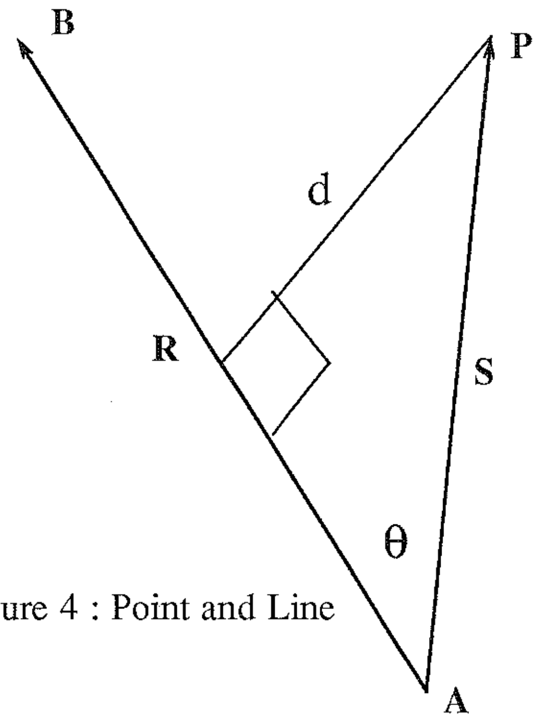

Figure 4 : Point and Line

$$\begin{aligned} d &= |\mathbf{S}|\,|\mathbf{R}|\,\sin\theta\,/\,|\mathbf{R}| \\ &= |\mathbf{S} \times \mathbf{R}|/|\mathbf{R}| \end{aligned} \tag{7}$$

Notice that the solution depends only upon the vectors R and S and is independent of the origin of the coordinate system.

d. Shortest Distance from Point to Plane

If a true length line is perpendicular to the edge view of a plane, then it is perpendicular to that plane and the length of the line can be used as a measure of the distance from a point on the line to the plane. Auxiliary views can be used to show the true perpendicular distance.

Let a plane be defined by three points P_1, P_2, and P_3. A fourth point S lies outside the plane. Let $R = S - P_2$ as shown in Fig. 5. Observe that $d = |\mathbf{R}|\cos\theta$. The shortest distance can then be written as

$$\begin{aligned} d &= |\mathbf{R}|\,|\mathbf{N}|\cos\theta\,/\,|\mathbf{N}| \\ &= |\mathbf{R}\cdot\mathbf{N}|/|\mathbf{N}| \end{aligned} \tag{8}$$

where $N = (P_1 - P_2) \times (P_3 - P_2)$ and $|\mathbf{N}| = \sqrt{\mathbf{N}\cdot\mathbf{N}}$. These calculations are again axis independent and can easily be implemented to interrogate a large computer data base consisting of many points and planes.

e. Shortest Distance between Two Lines

Two skew lines can have only one connector that is perpendicular to both. The shortest distance between the two lines is measured along this connector. In the point view method one line is constructed to appear as a

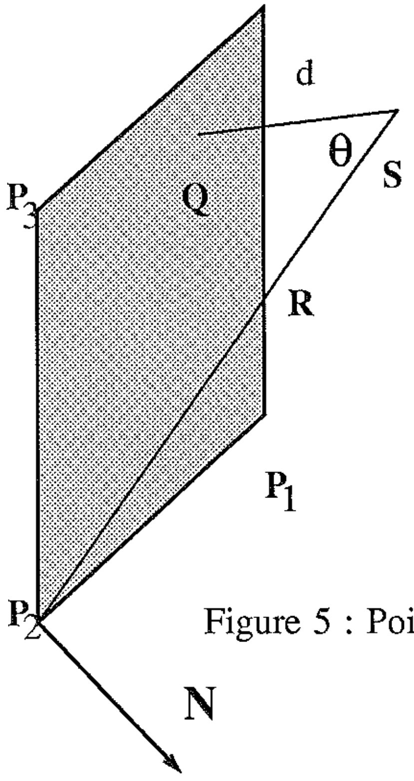

Figure 5 : Point and Plane

point and the shortest distance is drawn from the point, perpendicular to the second line. In the plane method, a plane containing one line is viewed so that it is parallel to the other line and the shortest distance can be seen.

In Fig. 6 let the directional vectors be $\mathbf{H} = \mathbf{D} - \mathbf{C}$ and $\mathbf{F} = \mathbf{B} - \mathbf{A}$. The direction vector $\mathbf{N} = \mathbf{Q} - \mathbf{P}$ must be normal to the plane that contains the vector $\mathbf{H}$ and is parallel to the vector $\mathbf{F}$. For this plane, the shortest distance between the plane and any point on vector $\mathbf{F}$ is the same as the shortest distance between the two skew lines. If $\mathbf{n}_1$ and $\mathbf{n}_2$ are unit vectors along the directional vectors $\mathbf{F}$ and $\mathbf{H}$ respectively, then the shortest distance d can be expressed in terms of a scalar triple product and vector cross product as follows:

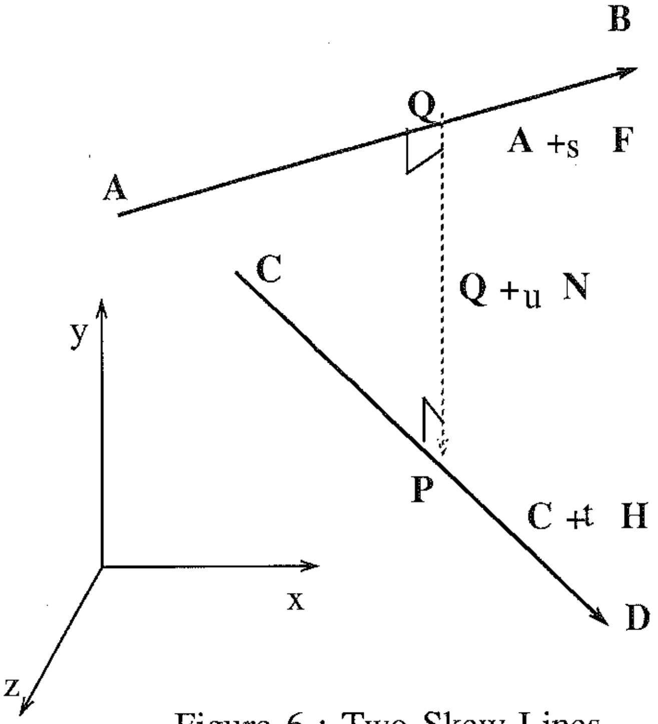

Figure 6 : Two Skew Lines

$$d = |(\mathbf{A} - \mathbf{C}) \cdot (\mathbf{n}_1 \times \mathbf{n}_2)| / |\mathbf{n}_1 \times \mathbf{n}_2| \qquad (9)$$

Details of this derivation are given in Ref. 3.

f. Intersection between Line and Plane

A line which is neither in a plane nor parallel to it will intersect that plane at only one point. This point is called the piercing point. The piercing point may be established in an auxiliary view which shows the line crossing the edge view of the plane. The line does not have to appear in true length. The cutting-plane method is also used in descriptive geometry to find piercing points.

Using geometric modeling, Eqs. (1) and (2) can be combined to give a mathematical solution for piercing points between lines and planes.

$$\mathbf{N} \cdot (\mathbf{A} + t(\mathbf{B} - \mathbf{A}) - \mathbf{P}_3) = 0 \qquad (10)$$

Solving for the parameter t gives

$$t = (\mathbf{N} \cdot \mathbf{P}_3 - \mathbf{N} \cdot \mathbf{A}) / [\mathbf{N} \cdot (\mathbf{B} - \mathbf{A})] \qquad (11)$$

Using $k = \mathbf{N} \cdot \mathbf{P}_3$ and $\mathbf{R} = (\mathbf{B} - \mathbf{A})$ gives:

$$t = (k - \mathbf{N} \cdot \mathbf{A}) / (\mathbf{N} \cdot \mathbf{R}) \qquad (12)$$

This value of t can be used in Eq. (1) to compute the coordinates of the piercing point given by the vector $\mathbf{Q}$.

An alternate approach is to use the bivariate, parametric equation for a plane given by $\mathbf{P} = \mathbf{P}_1 + s\mathbf{E} + t\mathbf{F}$. A three-dimensional line is given by $\mathbf{Q} = \mathbf{A} + u(\mathbf{B} -$

A). Figure 7 shows the piercing point to be calculated. Vector algebra techniques give the solution for the parameter value of u as

$$u = [(\mathbf{E} \times \mathbf{F}) \cdot \mathbf{P}_1 - (\mathbf{E} \times \mathbf{F}) \cdot \mathbf{A}]/[(\mathbf{E} \times \mathbf{F}) \cdot \mathbf{D}] \tag{13}$$

Note that Eq. 13 requires the evaluation of three scalar triple products. This value for u is used in the equation for **Q** to calculate the coordinates for the piercing point.

g. Angles

If the angle between two lines, between a line and plane, or between two planes is to be measured graphically, then a view must be constructed which shows the lines in true length and the true size of the angle of interest. Several descriptive geometry methods are available to solve these types of problems. Extreme care must be taken when accurate angle measurements are required.

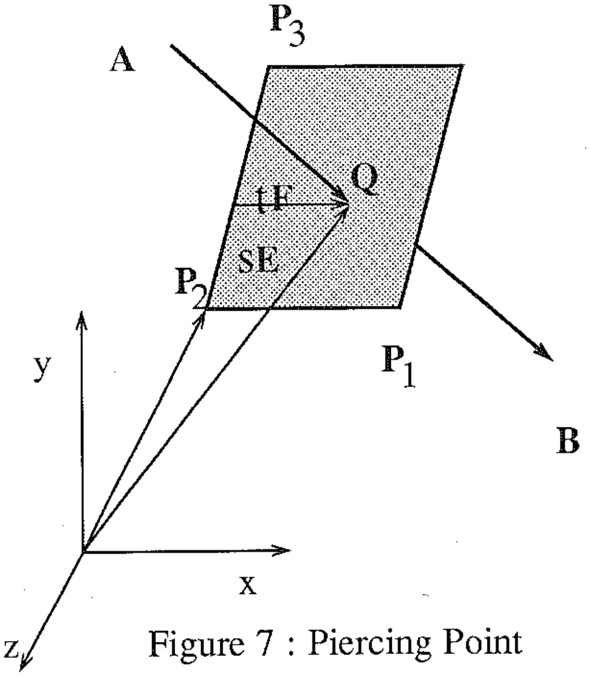

Figure 7 : Piercing Point

Analytical methods for calculating angles offer a more accurate technique if the defining points for the lines and planes are accurately known. Consider a line between $\mathbf{A}_1$ and $\mathbf{A}_2$. The scalar components of the direction vector are $A_x = (x_2 - x_1)$, $A_y = (y_2 - y_1)$, and $A_z = (z_2 - z_1)$. Similarly, for a line between $\mathbf{B}_1$ and $\mathbf{B}_2$ the direction vector components are $B_x = (x_4 - x_3)$, $B_y = (y_4 - y_3)$, and $B_z = (z_4 - z_3)$. The apparent angle between the lines is given by

$$\cos\theta = (A_x B_x + A_y B_y + A_z B_z)/|\mathbf{A}_2 - \mathbf{A}_1||\mathbf{B}_2 - \mathbf{B}_1| \tag{14}$$

The angle between a line and plane is shown in Fig. 8. If **R** is the directional vector along **B** - **A** and **n** is the unit normal vector to the plane, then

$$\cos\theta = \mathbf{R} \cdot \mathbf{n}/|\mathbf{R}| = \sin\phi \tag{15}$$

h. Intersecting Surfaces

When surfaces can be represented by a series of polygonal facets, the intersecting curves between surfaces can be found by repeated application of descriptive geometry techniques. Computer methods are usually more attractive for this work due to the tedious and inaccurate nature of the manual procedures. Solid modeling systems that build realistic solids which may consist of intersecting surfaces or solid primitives are now commercially available. Solids can be repre-

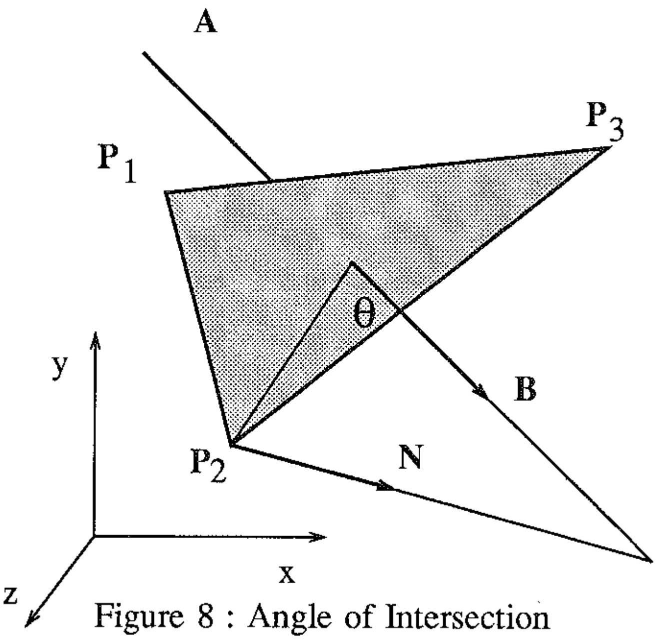

Figure 8 : Angle of Intersection

sented by wireframes, by boundary surface representations[4], or by a system of building blocks called constructive solid geometry[5].

The theory of clipping can be used to compute the intersection between surfaces which are represented by polygonal surfaces[3]. This approach is limited to a convex, solid clipping surface but is suitable for many geometry problems.

Surface Modeling

Intersections between solids containing holes, cavaties, or handles require an approach built around Euler and Boolean operations[6]. Solid modeling, like geometric modeling, is an active area of research in graduate schools which involves topology, design of languages and data structures, and advanced mathematics[7]. Nonetheless, there is another opportunity for educators to build a bridge between solid modeling and introductory engineering. Many solid objects of practical engineering importance are flat parts or extrusions. These can be suitably modeled in a single plane which allows a simple computer animation, simulation, and analysis to be carried out on small personal computers. In addition, realistic computer-aided design can be carried out in conjunction with elementary courses in graphics and mechanics.

Reference 8 describes the simulation and animation of simple planar mechanism which lend themselves nicely to elementary solid modeling. Complete kinematic curves of motion can be generated to aid in the analysis and design of practical engineering components. Engineering students no longer have to wait until graduate school or until expensive software packages are available in order to explore the world of computer aided design.

Conclusions

The combination of descriptive geometry with geometric modeling provides new possibilities for creative design. Descriptive geometry is a graphical method that provides geometric solutions while working in two-dimensional planes with auxiliary views. Its basic principles remain crucial for communication of ideas and interpretation of graphical information. Geometric modeling provides the basis for a mathematical formulation and interrogation of shape information stored in computer memory.

Some authors[9] have created computer codes to help one learn and use classical descriptive geometry. This approach uses computer graphics to produce auxiliary views and solutions in two-dimensional planes, based upon classical procedures. This paper, along with Ref. 3, gives another approach to computer utilization. Computer algorithms based upon vector techniques can be used to obtain spatial solutions using geometric data stored in computer memory. Descriptive geometry is best used to reconstruct three-dimensional information contained in two-dimensional orthographic projections, when the data is in a graphical format rather than in computer memory.

Geometry is still the proper foundation for an engineering or technology education. It should be a package of descriptive, analytical, and computational methods based upon spatial reasoning and three-dimensional geometric modeling. It should make use of elementary vector and matrix methods when these tools provide the best approach to the problem solution.

When the automobile engine replaced the horse, people drove horseless carriages for many years before it became obvious that the presence of the engine should change the shape of the carriage. Now that the computer engine has been installed in most courses, we need to realize that the shape of the courses should change. Geometric modeling is one new shape. There are many others.

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Implementation Alternatives to Analog Graphic Function Generation: Some Examples

Nicholas M. Karayanakis

Division of Technologies
University of North Florida
Jacksonville, Florida

Introduction

This is the third article on the mechanization of mathematical functions by means of analog electronics. Earlier works by Karayanakis[1,2] explored the use of purely analog mechanization of functions and showed examples of cyclic curve cases. Emphasis was placed in using the classical sine-cosine oscillator. It was shown that mathematical functions like those of the higher plane curves can be easily generated and outputted without using digital computers.

This exposition examines the alternative ways of thinking in analog function generation. The simple parabolic function has been chosen as a case in point. As it will be shown, this simple function can be implemented by analog means derived through different points of view. Five different approaches are described which clearly demonstrate the versatility of the analog technique.

About Analog Graphics Processing

Digital computers are useful in generating mathematical functions of any kind. Commercial software packages exist and programs can be easily written for that purpose. Any time a digital computer is used to generate a mathematical function, there are options for display, printout, and plotting of the results. But what if the function generator is to be used in simulation or research where the function characteristic must be outputted as an analog signal, rather than a monitor image or a paper drawing?

At this point, consider the researcher in need of a control signal of a specific time-dependent voltage behavior. It is, of course, possible to write a program for a PC and employ some D/A conversion technique. This is a wasteful use of the machine, and *if the output levels of the function characteristic are somewhat discontinuous, random A/D sampling techniques could introduce considerable errors.*

Some twenty-three years ago, a hybrid graphical processor was described by Oberbeck[3]. Oberbeck's graphic machine was known as the Artrix Graphical Processor and consisted of two parts: an analog section and a digital one. The analog section included the sin-cos generators and the digital section essentially provided magnitude control for both the size and translation of analog signals. The philosophy here was to allow hardware to operate by doing what it does best. Zulauf and Burnett[4] considered analog circuits as significant in the instruction of engineering graphics.

Although neither analog nor digital systems can stand alone, analog circuits offer the possibilities of creating auxiliary equipment to be used as a hybrid adjunct, a parallel processor, a preprocessor, a metaprocessor, or as required by the task at hand. Nowadays, inexpensive integrated circuits make custom designs worth pursuing, not only in the field of engineering graphics, but also in areas such as biomedical engineering[5], statistical signal processing[6], and many others.

In the past, analog mechanizations of kinematic linkages and mechanisms have been used. Keller[7] has demonstated a powerful analog technique for mechanism design. The circuits produced a real-time mobile line drawing on an oscilloscope for a complete mechanism simulation. Karayanakis has used these techniques to demonstrate things such as coupler curves for the four-bar mechanisms, slider-crank mechanism trajectories, etc., with great success. Examples of pure graphical applications of analog circuits are also given by Lenk[8] and Crossley[9]. These are but a few examples in the very well-developed, but obscure field, of analog graphics.

In the following descriptions of analog graphic techniques, it will be shown how the same simple graphic characteristics can be synthesized by many alternative philosophies.

The Parabolic Function $y = kx^2$

The parabola is a conic section obtained by a cutting plane parallel to an element of a right-circular conical surface. It may also be defined as the locus of a point that moves so that its distance from a fixed line (the directrix) equals that from a fixed point (the focus).

A unit parabola is described in Cartesian form by the equation

$$X^2 = 2pY \tag{1}$$

where, by letting $2p = 1$, a squaring characteristic may be obtained. The parabola may be realized by using an *analog multiplier* integrated circuit. The analog multiplier chip is a very significant building block in analog signal processing for both dc and frequency signals. It is a 3-port device that accepts input signals e_x and e_y and yields their product, normally scaled down by a factor of ten, as shown in Fig. 1a. Tying both inputs to a common signal e_i converts the multiplier to a squarer (Fig. 1b). In order to control the speed at which the curve is generated, an integrator is added at the input of the multiplier. Speed is then controlled by adjusting the integrator's time constant, normally by means of an input potentiometer. Connecting the output ports to an X-Y plotter, as shown in Fig. 1c, will yield the tracing of Fig. 2.

Analog multiplier integrated circuits are readily available in the commercial market. A popular chip is the XR-2208 made by Exar Integrated Systems, Inc. Another one is the AD 532 multiplier, made by Analog Devices, Inc. A high specification multiplier is

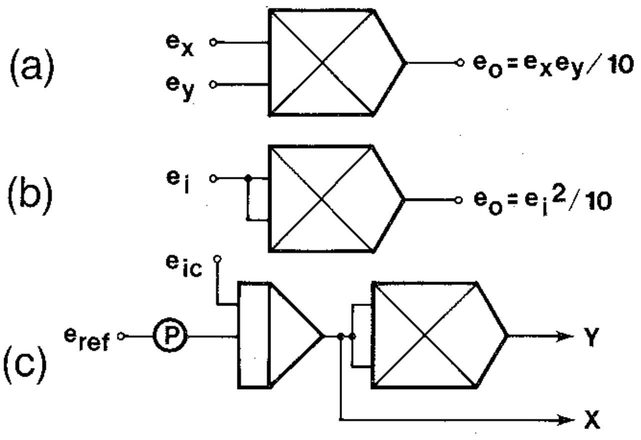

Fig. 1 Analog multiplier.

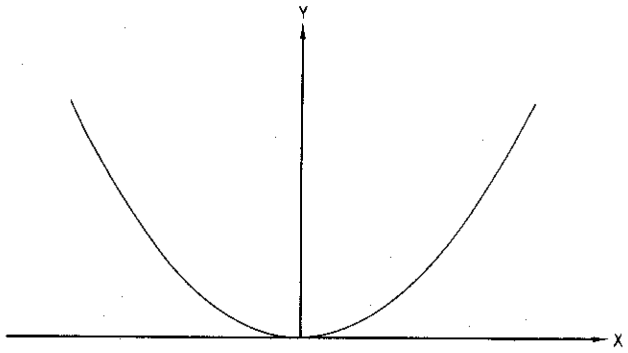

Fig. 2 Parabola realized using an analog multiplier integrated circuit.

the AD 534, also a product of Analog Devices, Inc.

An Alternative Way of Thinking: The Exponential Decay Technique

The parabola can also be generated by using the exponential decay technique, that is, by setting up the exponential

$$X = e^{-t} \tag{2}$$

along with the equation

$$Y = e^{-kt} \tag{3}$$

where k is an arbitrary constant. For k = 2, Eq. (3) becomes

$$Y = e^{-2t} \tag{4}$$

or

$$Y = (e^{-t})^2 \tag{5}$$

From Eqs. (2) and (5), there is

$$Y = X^2 \tag{6}$$

which is the equation for the unit parabola. These simple manipulations describe the philosophy of the alternative mechanization shown in Fig. 3 It can be seen that the curve must be generated in two parts since once the initial condition voltages

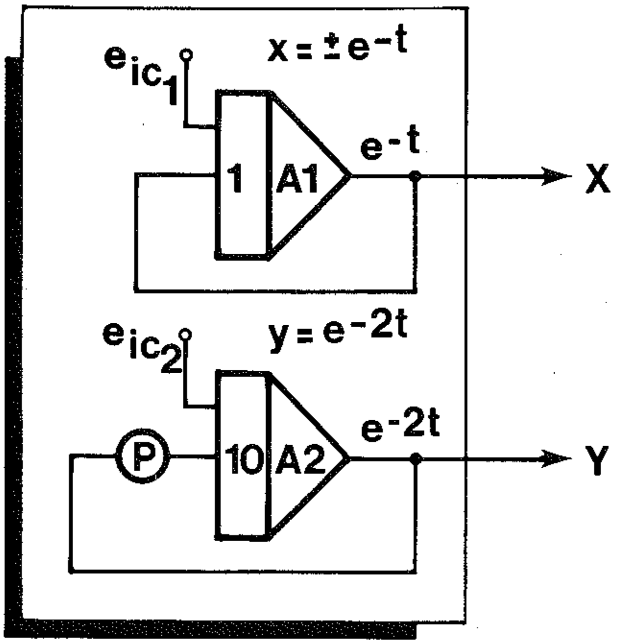

Fig. 3 Alternative mechanization.

e_{ic} are introduced, the curve is required to decay to zero value. This backwards approach has a high utility in hybrid graphics related to process simulation. Remember, the time constant of an analog integrator *can be adjusted to suit any arbitrary time frame*. System response may be chosen to be anything from fractions of a second to months, a significant tactical advantage of analog preprocessing.

More on Parabolas: Projectile Trajectory Approach

The parabolic function can also be generated by mechanizing the characteristic projectile trajectory expression

$$Y = kX^2 \qquad (7)$$

under the assumptions of a gravitational acceleration and initial horizontal and vertical velocities, so that

$$Y = Y(0) + \dot{Y}(0)t + (at^2/2) \qquad (8)$$

The above equation is that of the vertical projectile displacement. The horizontal displacement is expressed by the relationship

$$X = X(0) + \dot{X}(0)t \qquad (9)$$

Figure 4 shows the implementation of the technique, where a -10V signal can be applied at the input of the integrator A1 and a +10V signal is applied at the input A3. Voltages e_{ic_1}, e_{ic_2}, and e_{ic_3} are the initial-condition voltages for the integrating amplifiers A1, A2, and A3, respectively.

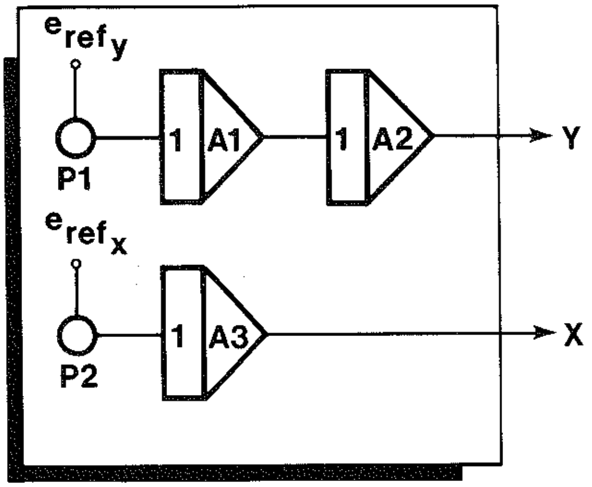

Fig. 4 Implementation of the projectile trajectory approach.

Some More Trigonometry

A parabola can be described by the system of the following two equations:

$$X = \sin t \qquad (10)$$

$$Y = \sin^2 t \qquad (11)$$

By virtue of a familiar trigonometric identity, Eq. (11) can be rewritten as

$$Y = (1 - \cos 2t)/2 \qquad (12)$$

so Eqs. (10) and (11) can now have the form

$$X = \sin (t/2) \qquad (13)$$

$$Y = (1 - \cos t)/2 \qquad (14)$$

The system of Eqs. (13) and (14) can be mechanized as shown in Fig. 5. This particular approach is an interesting one in which

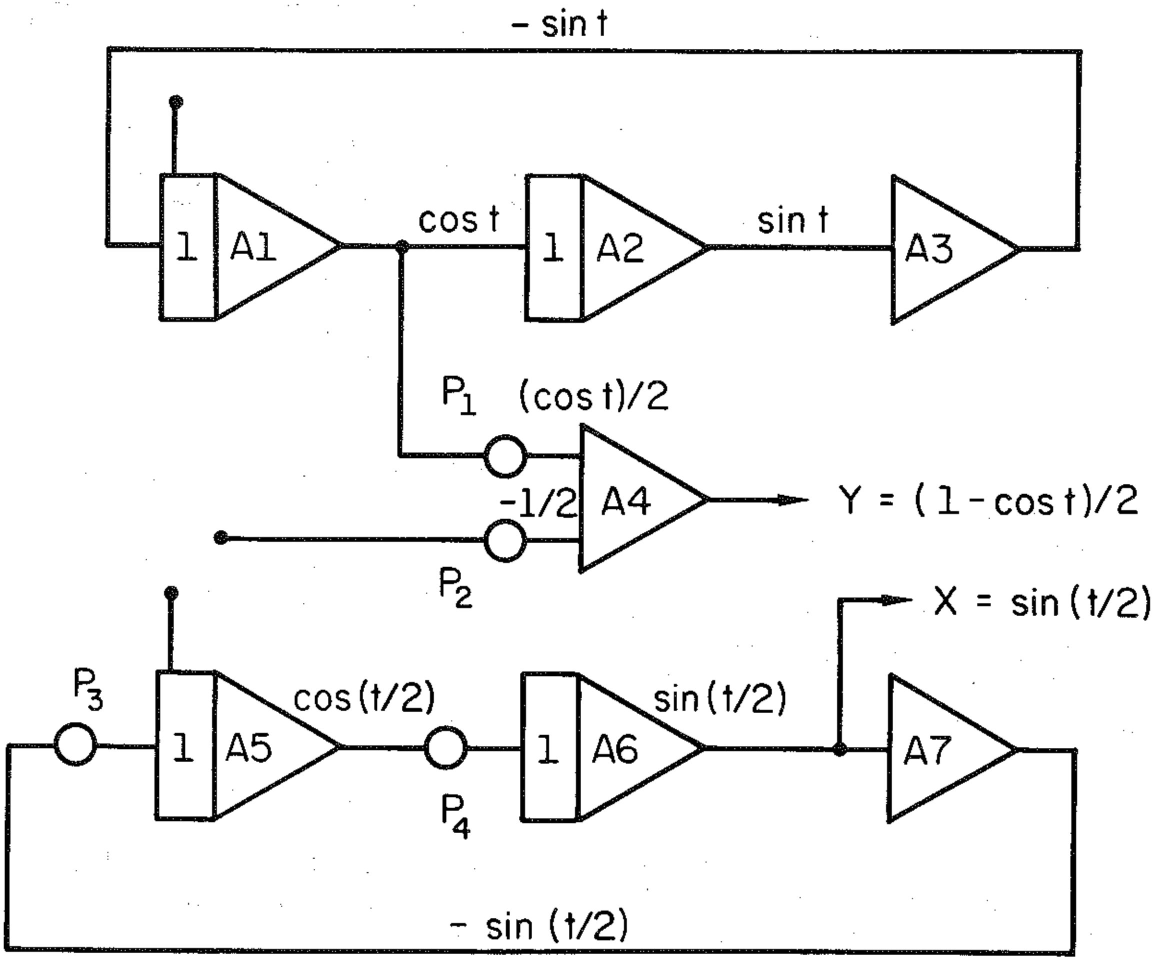

Fig. 5 Mechanization of Eqs. (13) and (14).

two sin-cos oscillators are used and the parabolic function is produced by two oscillatory inputs applied on the horizontal and vertical axes of a plotter.

Some Notes on the Piecewise-linear Approximation Techniques

It is also possible to generate two-dimensional functions with diodes. Figure 6 shows a squaring circuit configuration governed by the equations

$$e_0 = 10^{-2}(e_i)^2 \qquad (15)$$

$$i = -10^{-4}(e_i)^2 \qquad (16)$$

and

$$i_f = 10^{-2}e_0 \qquad (17)$$

where i and i_f are the input current and feedback current to the amplifier, respectively. The circuit is very simple and represents an example of the piecewise linear approximation approach to nonlinear function generation. This configuration may be adapted for any desired number of segments, depending upon the preci-

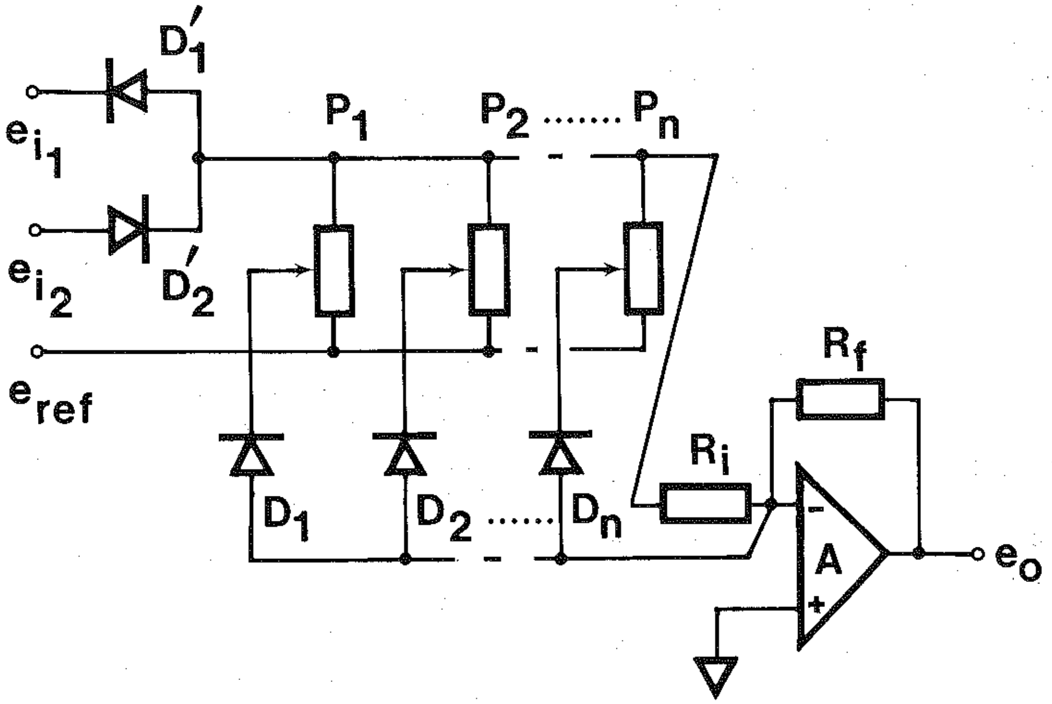

Fig. 6 Squaring circuit configuration.

sion required. Although somewhat inelegant, the linear approximation technique is a very versatile tool and may be used in the synthesis of complex mathematical functions, regardless of their complexity. The technique is very old, and there are literally hundreds of different approaches to designing this type of circuit. A diode function generator may be designed to suit the signal processing requirements on hand. The higher the number of diodes (and consequently that of the linear segments that form the function characteristic), the greater the precision. Diode-function generators can serve as adjustable laboratory units capable of synthesizing any desirable function characteristic. Often, a low-pass filter (an integrator, for instance) is used to smooth the output so the output appears continuous. For further information on this topic, refer to works by Wong and Ott[10], Sheingold[11], and Graeme[12].

Finally, What is so Important about Exponential Functions?

The exponential function is very significant in system simulation, primarily because of its unique properties shown by Eqs. (18) and (19) below.

$$e^t = d(e^t)/dt \tag{18}$$

$$e^t = \int e^t \, dt \tag{19}$$

Its derivative and its integral yield the function itself. *In fact, most I/O signals that specify the transfer* *functions of physical systems can be expressed in some exponential form*. As a case in point, the outputs of the sin-cos oscillator used earlier in the generation of higher plane curves[1,2] can be expressed as

$$\sin \omega t = (1/2j)(e^{-j\omega t} - e^{j\omega t}) \tag{20}$$

$$\cos \omega t = (1/2)(e^{j\omega t} - e^{-j\omega t}) \tag{21}$$

Even the unit step function u(t) is a special case of the exponential function where the exponent has a zero coefficient, or

$$e^{\alpha t} = ut(\alpha = 0, t > 0) \tag{22}$$

By now it should be obvious that this diatribe on parabolas and the analog mechanization alternatives of the ubiquitous parabolic function are, as shown here, useful tools in the simulation of complex dynamic systems in any field of endeavor. These techniques have been employed in designing signal processing and parallel processing units used in hybrid system simulation. For all practical purposes, these units operate under direct computer control of the function parameters, like those of speed (time constant), scaling, and limiting. As has become obvious, there is an advantage in allocating function *generation* tasks to analog or analog/hybrid circuits *external* to the digital machine and having function parameter *control* via *software*.

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Multiview Projection Using CADKEY®: Freeze-Frame Demonstrations

Robert P. Kelso and M. Reza Ziai

Department of Mechanical and Industrial Engineering
Louisiana Tech University
Ruston, Louisiana

A three-dimensional CAD software package, CADKEY, is used to create a model from which to demonstrate orthographic orthodirectional projection theory to a classroom. The software allows storage of images on various levels which may be made visible and invisible. The selective use of visible and invisible levels allows the simulation of motion, in the manner of the freeze-frame seen on TV.

Computer Aided Design (CAD) is now accepted in most institutions. Among CAD software packages, CADKEY may be the most widely used of the wire frame geometric modeling computer programs in engineering graphics. This is because of the relatively modest micro-computer requirements and because Micro Control Systems furnishes a version without charge to educational institutions. The following demonstrations represent ancillary uses of CADKEY as a teaching aid.

In the illustrations, the CADKEY Level-Visibility-Add/Remove command is selectively applied to a model. Levels are best imagined as a group of transparent overlays on which any selected elements ("wires") of the model may reside. These levels are selectively made visible or invisible. If a computer screen projector is used, the following demonstrations of orthographic-orthodirectional theory are available simultaneously to an entire class.

For the first example, Fig. 1 illustrates the contents of each level. Figure 2 illustrates successive views of different combinations of levels. Isometric views are displayed in both figures.

In the second example, Fig. 3 illustrates the contents of each level while Fig. 4 illustrates succesive views of different combinations of levels. Isometric views are also displayed in both figures.

In the last example, Figs. 5 and 6 illustrate, as in the previous examples, the contents of each level and successive views of different combinations of levels, respectively. Isometric views are displayed.

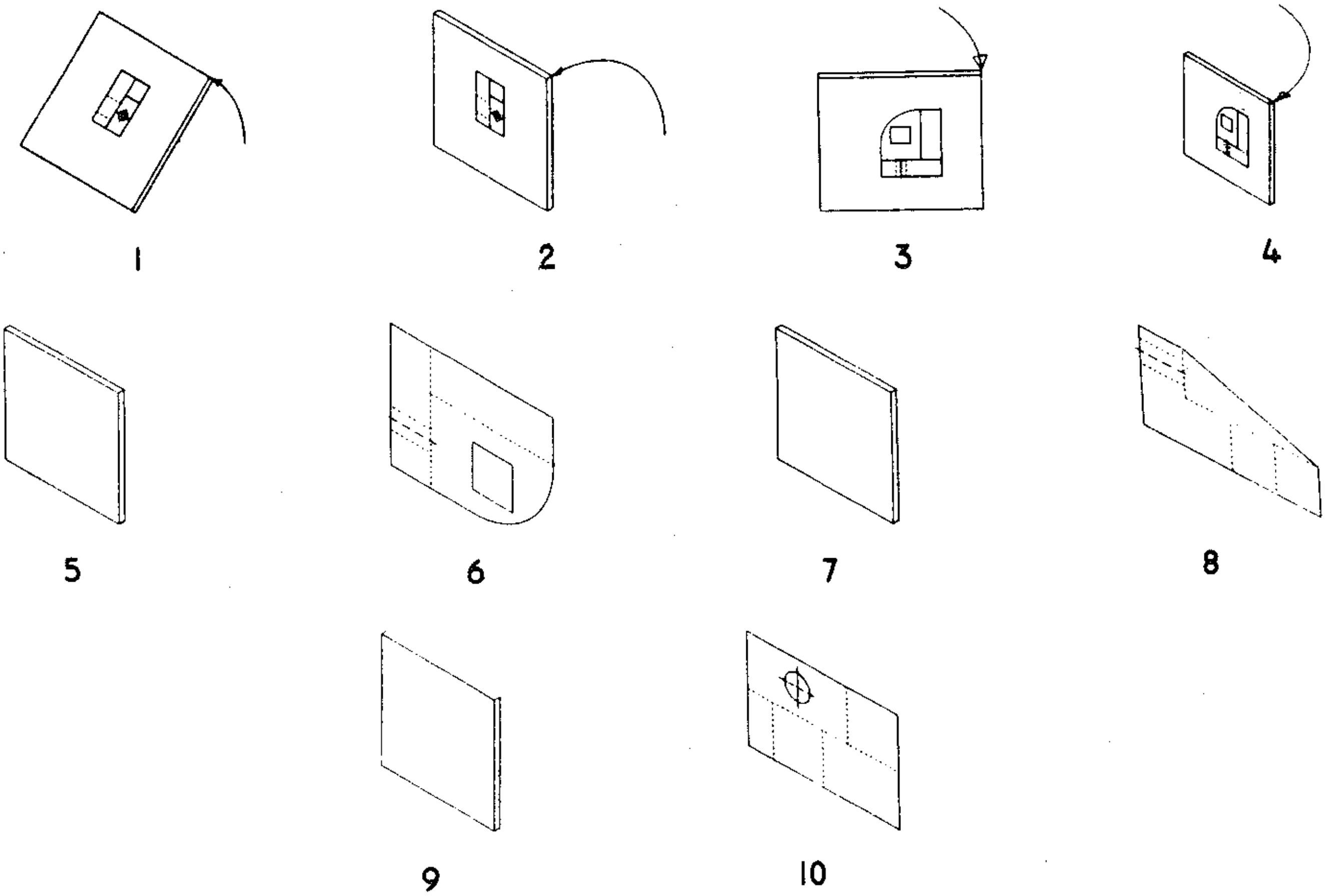


Fig. 1 Example 1 level contents.

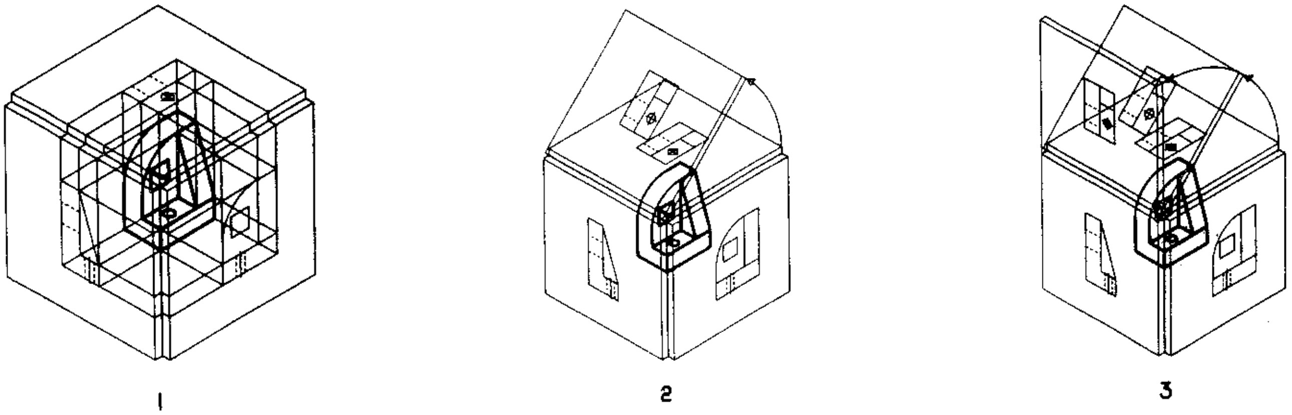


Fig. 2 Example 1 successive views.

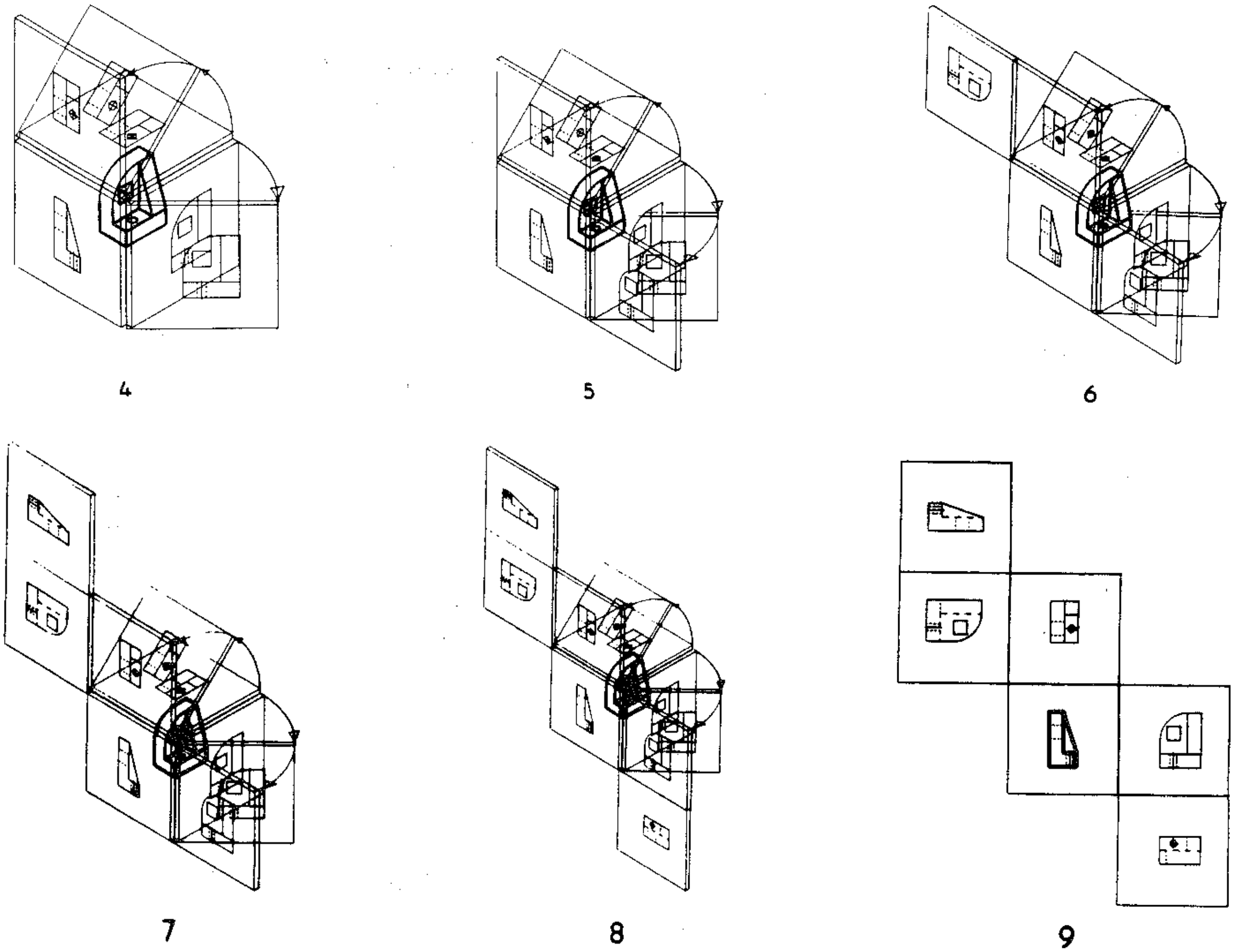


Fig. 2 (cont) Example 1 successive views.

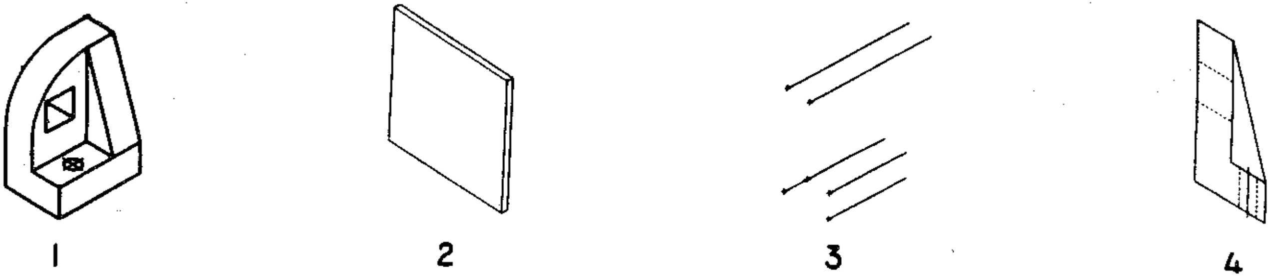


Fig. 3 Example 2 level contents.

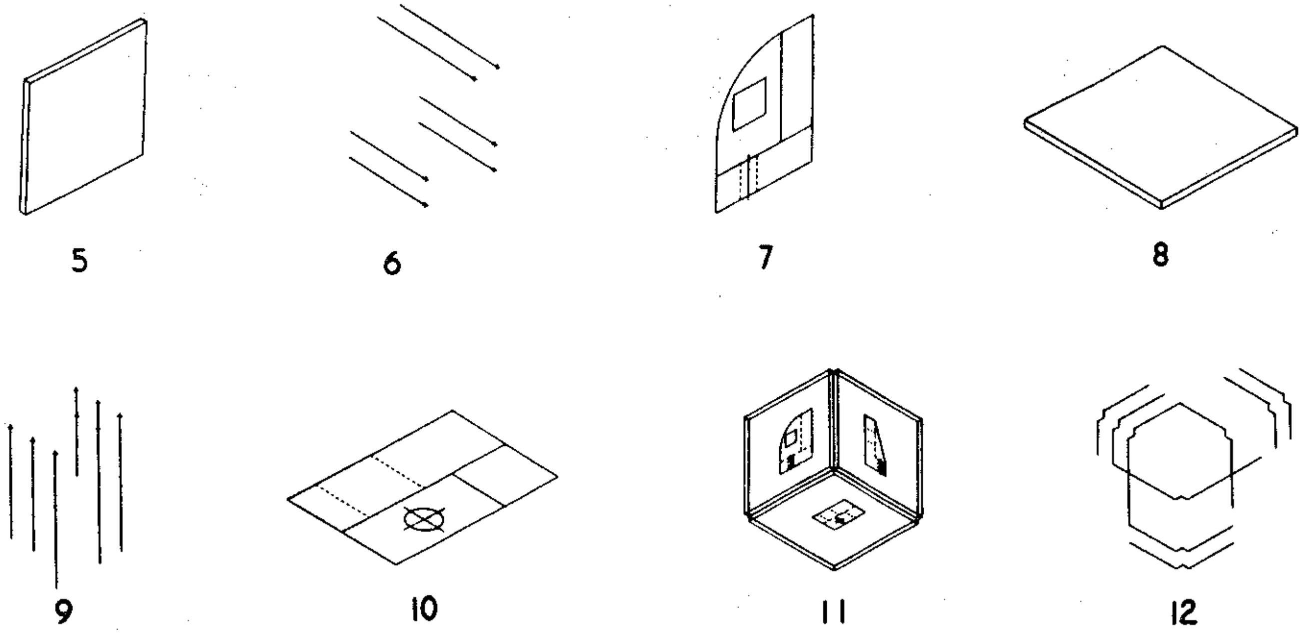


Fig. 3 (cont) Example 2 level contents.

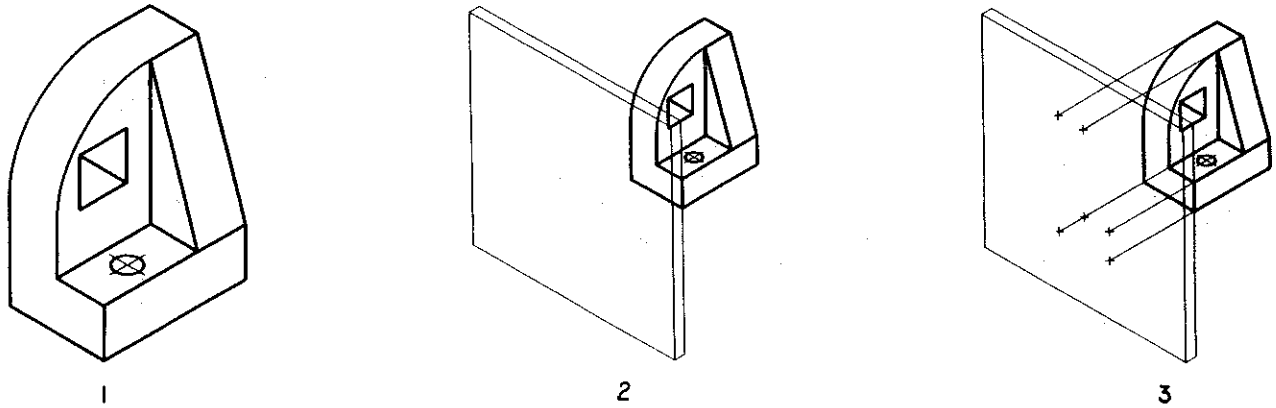
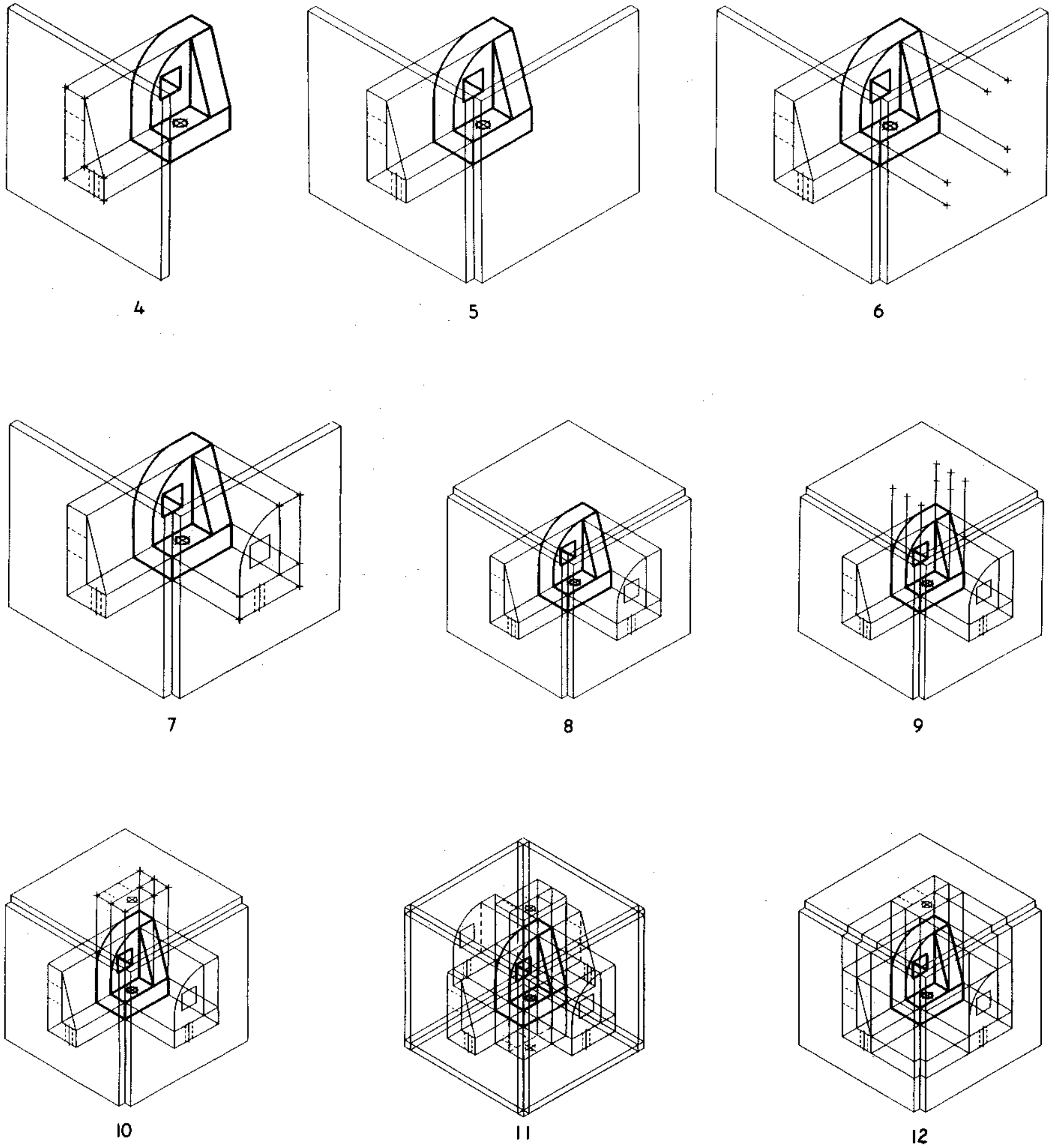


Fig. 4 Example 2 successive views.



4 5 6

7 8 9

10 11 12

Fig. 4 (cont) Example 2 successive views.

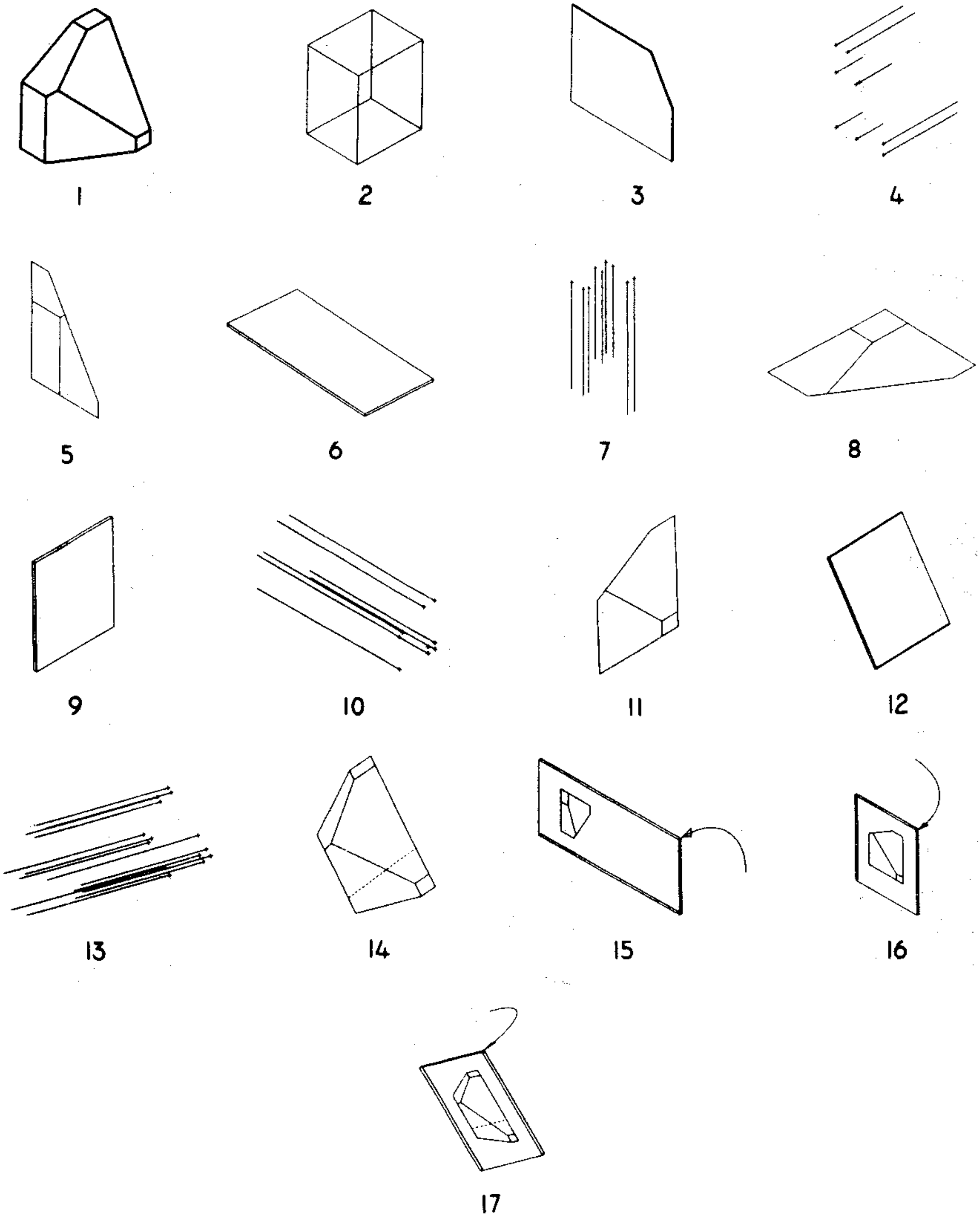


Fig. 5 Example 3 level contents.

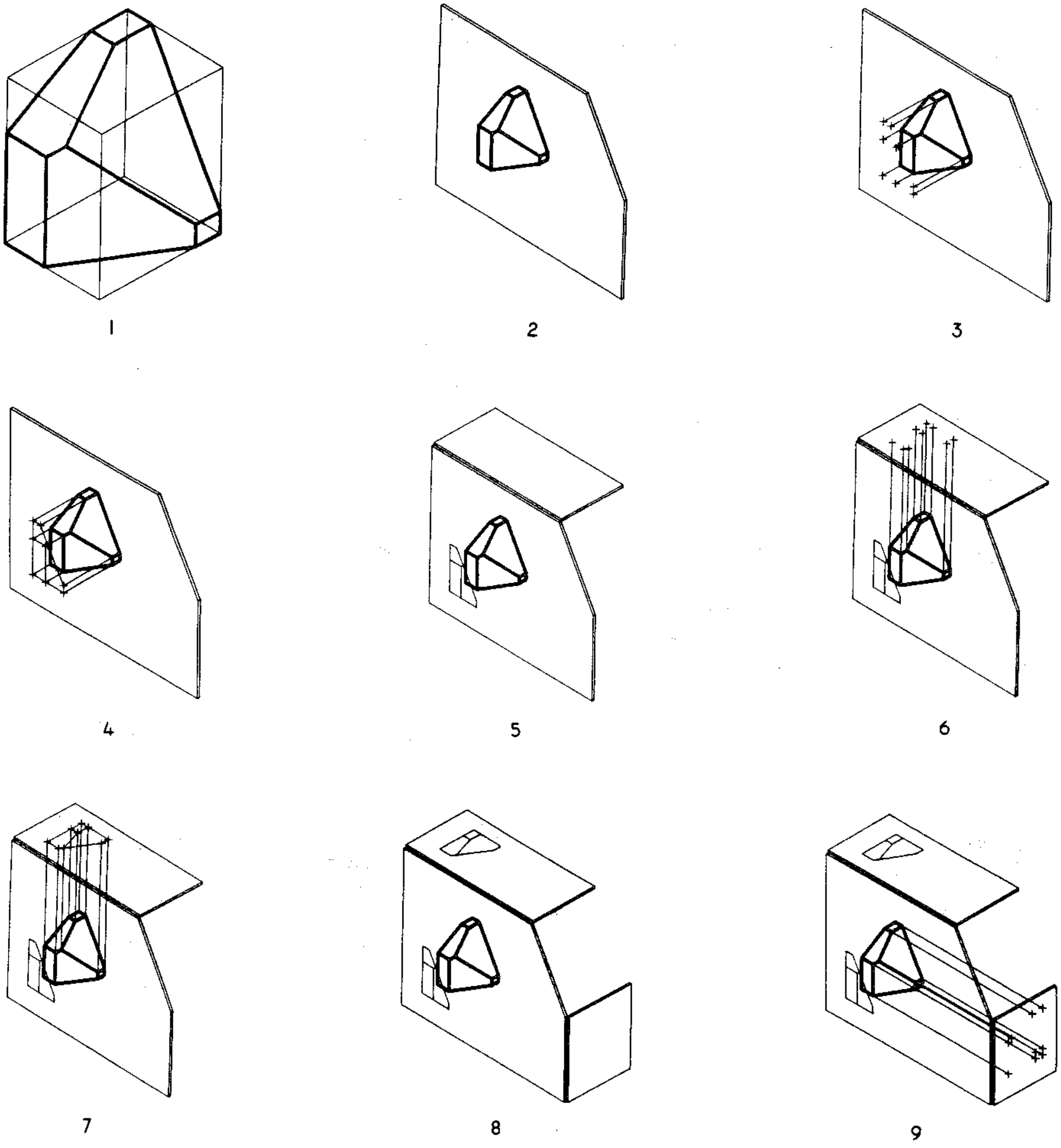
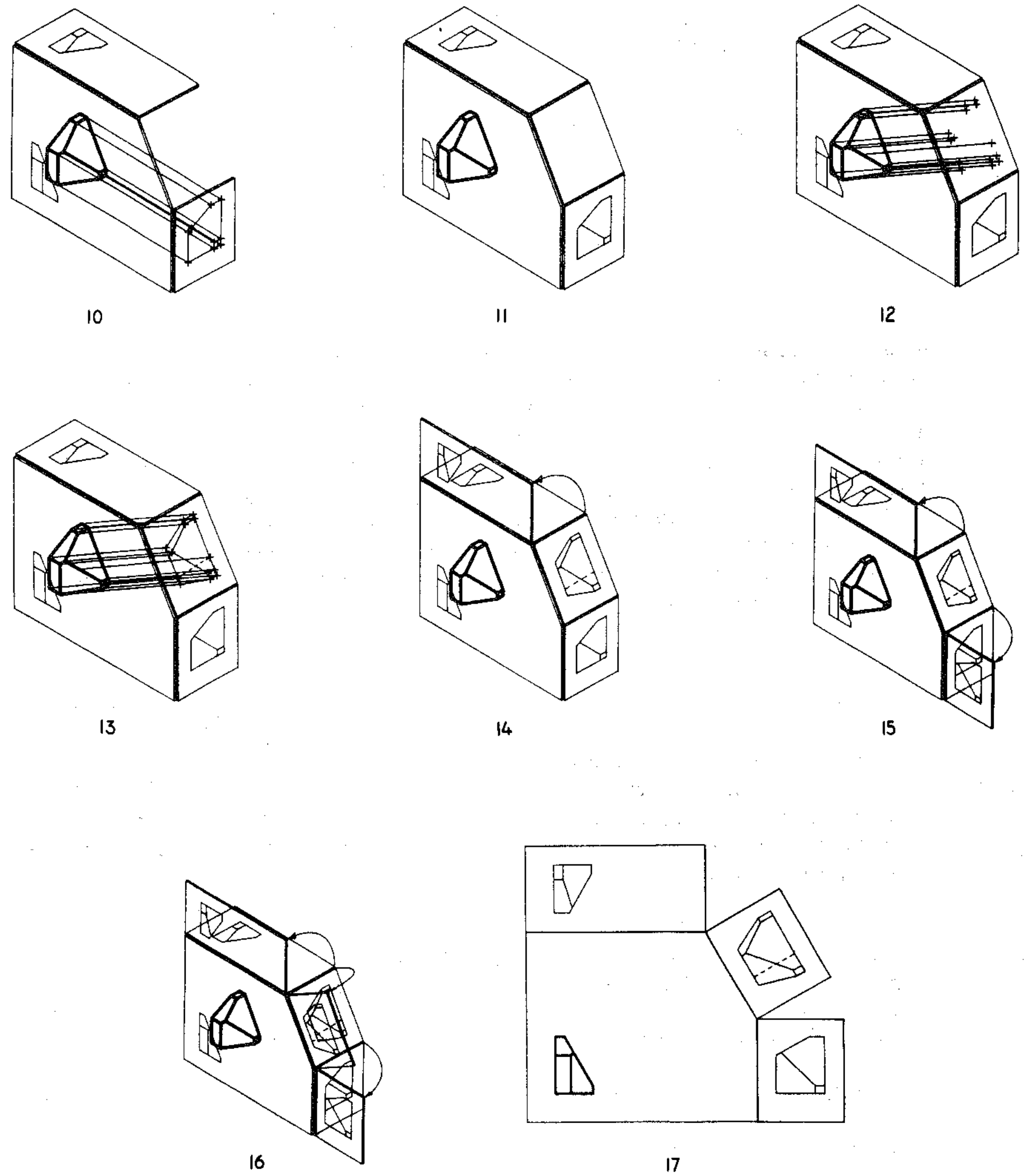


Fig. 6 Example 3 successive views.


10 11 12

13 14 15

16 17

Fig. 6 (cont) Example 3 successive views.

Computer Graphics for Convex Polyhedra: Hidden Line Removal and Shading

R. L. Nicholls and W. D. Teter

Department of Civil Engineering
University of Delaware
Newark, Delaware

A computer algorithm has been described for obtaining the coordinates of vertices, chord factors, and dihedral angles of n-frequency spherical and ellipsoidal octahedral and icosahedral geodesic domes with or without truncation, for plotting orthographic and axonometric projections, and for tabulating the chord lengths and dihedral angles for sawing the structural elements for construction.[1] A recent paper[2] describes the fundamentals of hidden line removal for convex polyhedra. This paper illustrates an application of this basic procedure, also described by Demel and Miller[3], for hidden line removal in a design application involving geodesic domes. In addition, the algorithm is expanded to include gray scaling of the geodesic dome faces for various light sources.

Notation

A	major radius at equator
a,b,c	coefficients in Eq. (1)
E	vector from origin to observer's eye
F	frequency parameter
fa	floor area
f1	minor floor width
f2	major floor width
H	horizontal elliptical expansion
ht	center height above floor
HW	perimeter wall height factor
i,j,k	orthogonal unit vectors
k, m	horizontal curvature exponents
L	vector from origin to light source
N	vertical curvature exponent
N	outward normal vector to a surface
sa	surface area of dome plus perimeter wall
T	truncation factor; number of vertex tiers above the equator
V	vertical elliptical expansion
X, Y, Z	vertex coordinate designation
x, y, z	rectangular coordinates
yp, zp	rectangular picture plane coordinates
α	angle between L and N
ϕ, θ, r	spherical coordinates from center of polyhedron

Introduction

Geodesic domes, a class of convex polyhedra, consist of triangular faces whose vertices lie on a sphere, ellipsoid, or other doubly-curved surface described by (Fig. 1)

$$x^k/a^k + y^m/b^m + z^N/c^N = 1 \qquad (1)$$

where x, y, and z are Cartesian coordinates and a, b, c, k, m, and N are any positive quantities.[4] Setting $z = 0$, $a = b = 1$, and $k = m = 2$ gives

$$x^2 + y^2 = 1,$$

a circle of radius 1 and center at the origin. Setting $(k = m) >> 2$ gives a figure approaching a square with rounded corners. Setting $a \neq b$ while leaving $a = 1$ and $k = m = 2$ gives

$$x^2 + y^2/b^2 = 1,$$

an ellipse with center at the origin and principal radii of 1 and b along the x and y axes, respectively. More generally, in Eq. (1) if we leave $a = 1$, define vertical and horizontal expansions as $V = b/a$ and $H = c/a$, and vary the exponents $(k = m = N)$, the various shapes in Fig. 2 are obtained.

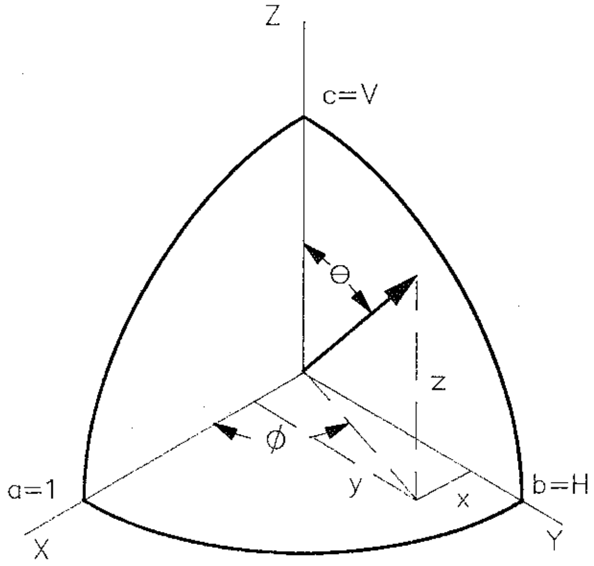


Fig. 1 The ellipsoid for a=1, b=H, and c=Y. For the spherical case, $x = a \sin\theta \cos\phi$, $y = a \sin\theta \sin\phi$, $z = a \cos\theta$.

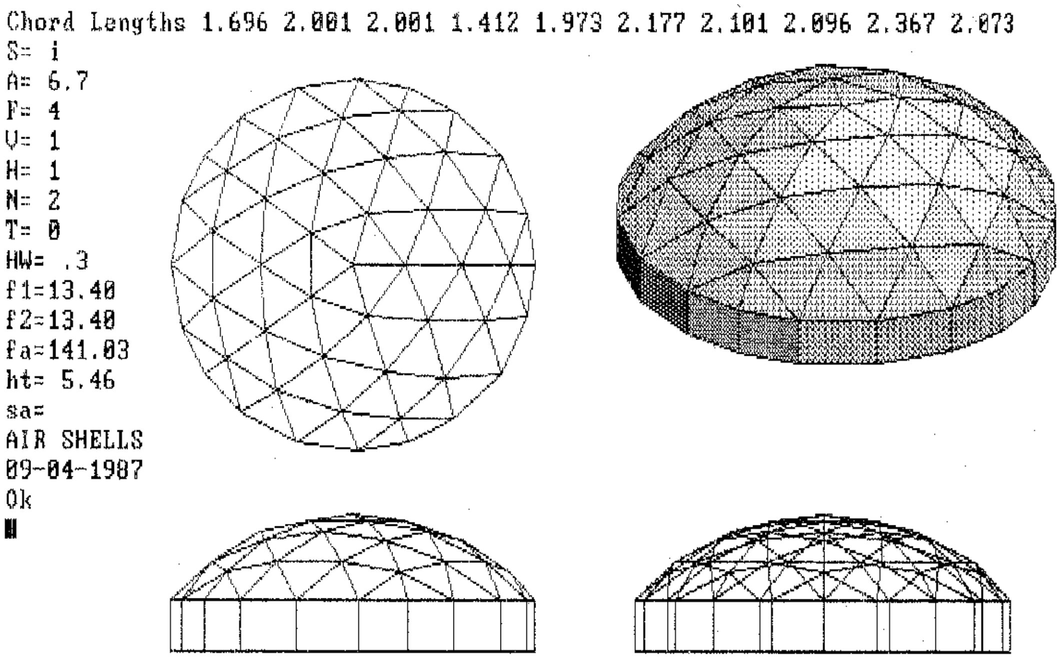
Any of these shapes can be divided into a number of triangular faces having vertices on the surface described by Eq. (1). The most common shapes used for dome construction are the octahedron (8 sides) and icosahedron (20 sides). The triangular (8 or 20) sides of each can then be subdivided into various numbers of triangular faces. The number of divisions made along each triangular edge of the side in so doing is called the "frequency" of subdivision. Frequencies of 2, 3, and 4 divide a side into 4, 9, and 16 triangular faces, etc. Figure 3 shows a 3-frequency octahedral face.

Computational Sequence

Typical input and output of the program which has been developed[1], illustrated in Figs. 2a to 2d, include:

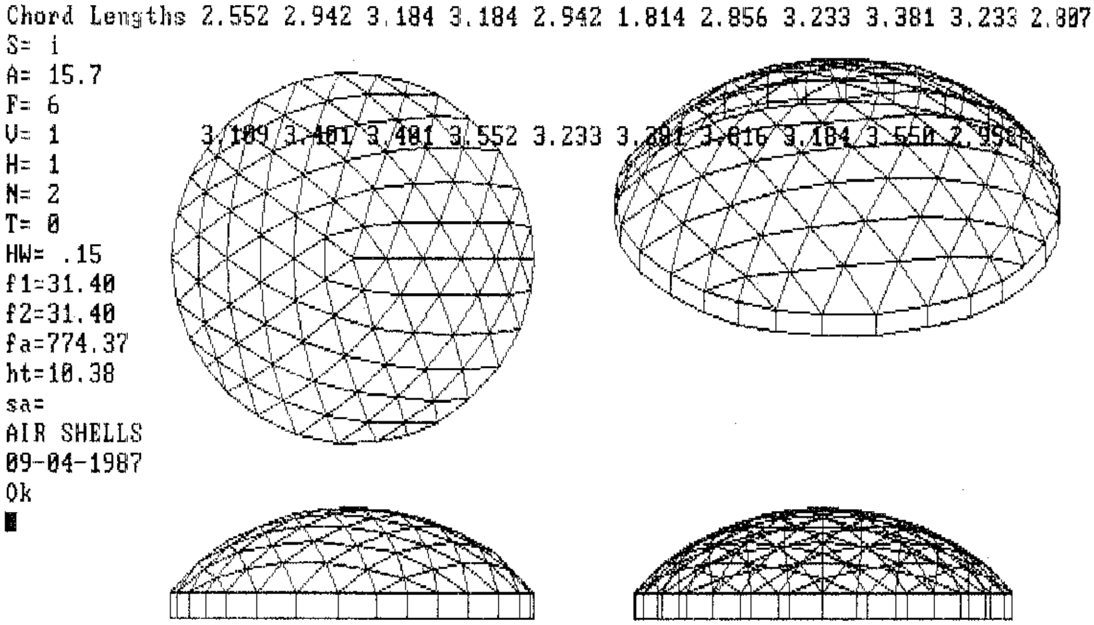
<u>Input</u>: Dome type (octa or icosa), A, F, H, V, N(= k = m), T, and HW.

<u>Output</u>: Chord lengths, f1 and f2 (major and minor floor widths), fa (floor area), and ht (height of center of dome above floor). Additional output which can be called for includes sa (surface area of dome plus perimeter wall), dihedral angles, and total



```
Chord Lengths 1.696 2.001 2.001 1.412 1.973 2.177 2.101 2.096 2.367 2.073
S= i
A= 6.7
F= 4
V= 1
H= 1
N= 2
T= 0
HW= .3
f1=13.40
f2=13.40
fa=141.03
ht= 5.46
sa=
AIR SHELLS
09-04-1987
Ok
```

(a)



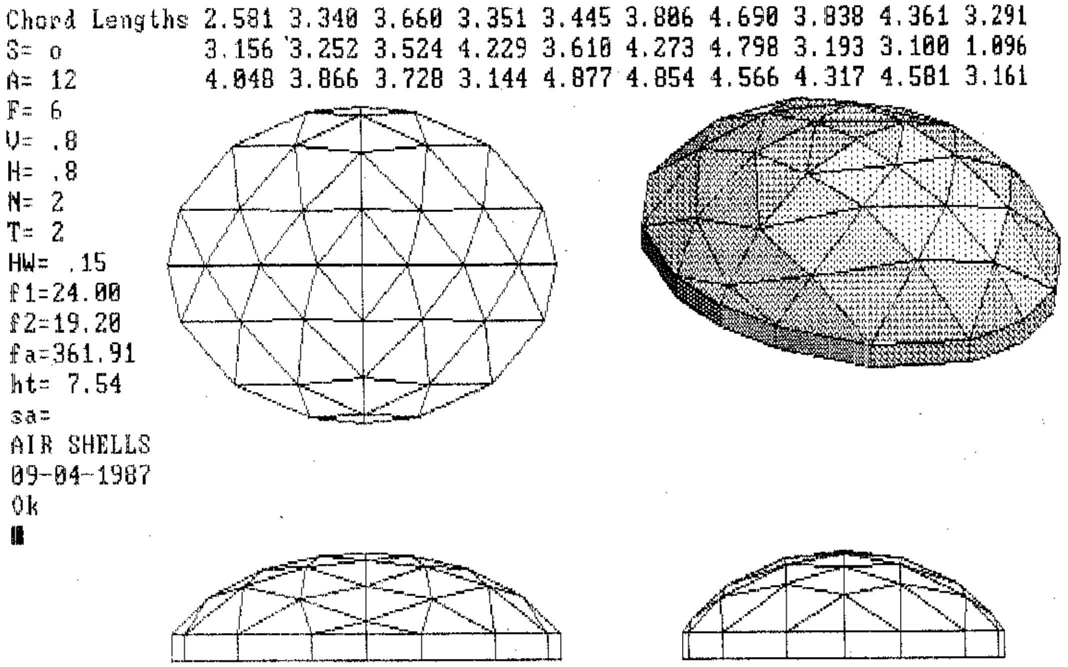
```
Chord Lengths 2.552 2.942 3.184 3.184 2.942 1.814 2.856 3.233 3.381 3.233 2.807
S= i
A= 15.7
F= 6
V= 1          3.109 3.401 3.401 3.552 3.233 3.381 3.016 3.184 3.550 2.998
H= 1
N= 2
T= 0
HW= .15
f1=31.40
f2=31.40
fa=774.37
ht=10.38
sa=
AIR SHELLS
09-04-1987
Ok
```

(b)

Fig. 2 Shapes obtained by adjusting the variables in Eq. (1).

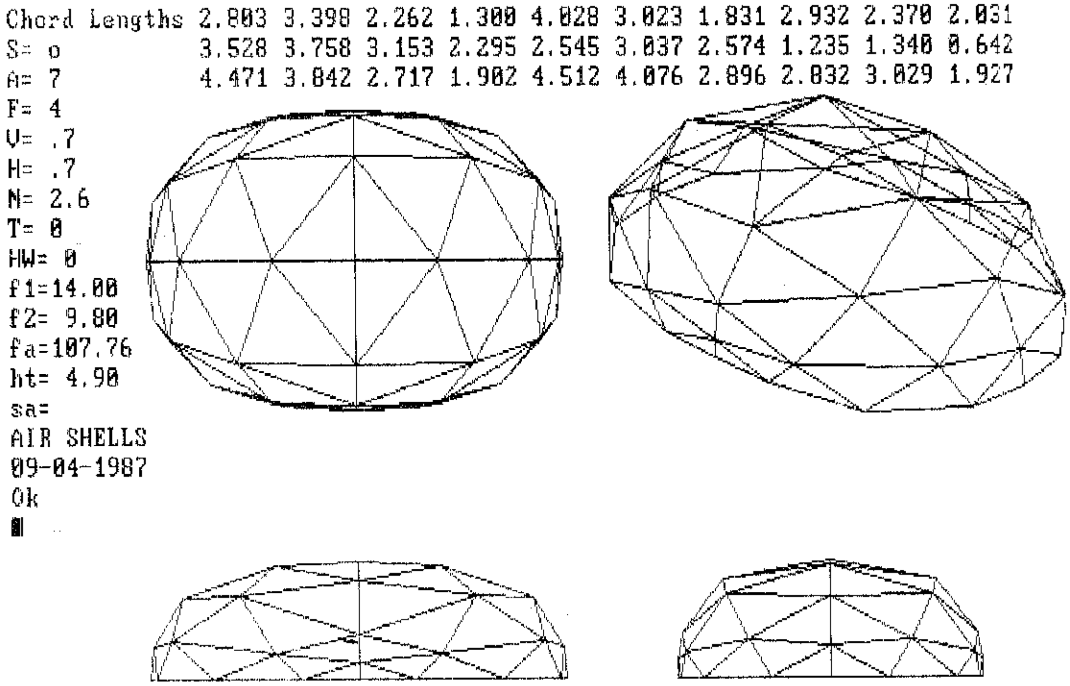
	Type	F	V	H	N	T	HW	Isometric
(a)	Icosa	4	1	1	2	0	.3	shaded
(b)	Icosa	6	1	1	2	0	.15	wire frame

(c)



```
Chord Lengths 2.581 3.340 3.660 3.351 3.445 3.806 4.690 3.838 4.361 3.291
S= o          3.156 3.252 3.524 4.229 3.610 4.273 4.798 3.193 3.100 1.096
A= 12         4.048 3.866 3.728 3.144 4.877 4.854 4.566 4.317 4.581 3.161
F= 6
V= .8
H= .8
N= 2
T= 2
HW= .15
f1=24.00
f2=19.20
fa=361.91
ht= 7.54
sa=
AIR SHELLS
09-04-1987
Ok
```

(d)



```
Chord Lengths 2.803 3.398 2.262 1.300 4.028 3.023 1.831 2.932 2.370 2.031
S= o          3.528 3.758 3.153 2.295 2.545 3.037 2.574 1.235 1.340 0.642
A= 7          4.471 3.842 2.717 1.902 4.512 4.076 2.896 2.832 3.029 1.927
F= 4
V= .7
H= .7
N= 2.6
T= 0
HW= 0
f1=14.00
f2= 9.80
fa=107.76
ht= 4.90
sa=
AIR SHELLS
09-04-1987
Ok
```

Fig. 2 (cont) Shapes obtained by adjusting the variables in Eq. (1).

	Type	F	V	H	N	T	HW	Isometric
(c)	Octa	6	.8	.8	2	2	.15	shaded
(d)	Octa	4	.7	.7	2.6	0	0	wire frame

numbers of panels, chords, and vertices for cost bidding.

The results in Fig. 2 were obtained using the standard BASICA with an IBM PC and Proprinter. The plots were produced at high print speed. The resolution can be quadrupled (from 60 to 240 dots per inch) by halving the print speed. The examples in Fig. 2 show the relationship between values of V, H, N, T, HW and the resulting shapes. For example, to more fully utilize a rectangular site, make $H < 1$ and $N > 2$; to provide headroom at the perimeter while keeping a low center height, use any combination of perimeter wall, truncation, $V < 1$, and $N > 2$, etc. Deviations from the sphere reduce structural efficiency and also remove the symmetry, requiring a larger inventory of different chord lengths.

Figure 3 shows the sequence in which the chord lengths are printed. For a spherical dome the chord lengths in all 3 directions are identical, and only one line (lines 1a, 1b, ... in Fig. 3) is computed and printed (Figs. 2a and 2b). The second line in Fig. 2b is a continuation of line 1, required by the higher frequency. For other cases ($H \neq 1$, $V \neq 1$, $N \neq 2$), three lines are required (Figs. 2c and 2d). The three printed lines of chord lengths correspond to lines 1, 2, and 3 in Fig. 3. The number of chord lengths increases with increasing frequency and decreasing symmetry.

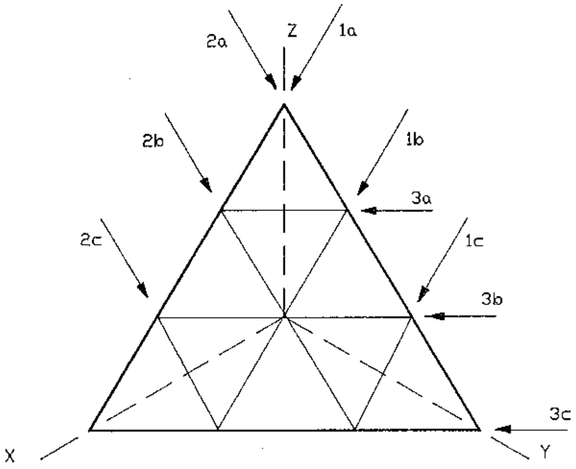


Fig. 3 Sequence in which chord lengths are printed.

Notice in Fig. 2d how the smaller faces occur in the regions of sharper curvature, both horizontally and vertically, to give nearly equal dihedral angles between all faces for greater buckling stability. The correction factor for accomplishing this is described in Ref. 1.

Figure 4 is a flow diagram of the algorithm, performed in the sequence shown.

Hidden Line Removal and Shading

A simple hidden line removal and shading algorithm for convex polyhedra was used for the plots in Figs. 2a and 2c. This sequence, which can be programmed by students, consists of the following steps (Ref. 3, page 302):

1. Obtain the outward normal vector to a face, N, by taking the vector (cross) product of two vectors lying in the face, in counterclockwise sequence (viewed from outside the object), then find, using the scalar (dot) product, the cosine of the angle be-

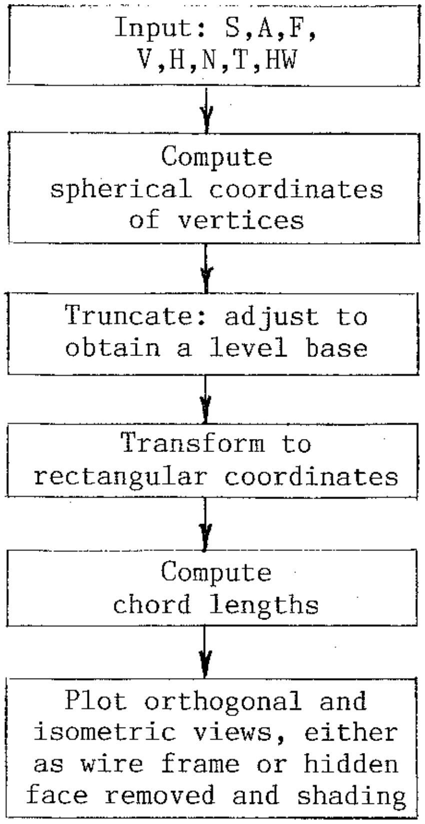


Fig. 4 GEODESIGN flow chart.

tween this outward normal to the surface and the selected line of sight, **E**. If the cosine is positive draw the edges of the face; if negative, omit them.

2. Shade the faces which have been drawn in Step 1 with an intensity of gray scale equal to (1 - cos α), where α is the angle between the outward normal to the surface and the vector from the object to a distant point light source, **L**. For the cosine α varying from +1 to -1, the shading intensity varies from 0 to 1, where intensity 1 is the darkest shading.

Notice that grading the shading from 0 to 1 for cos α varying from +1 to -1 is a simple approximation to the simultaneous presence of a point light source and diffuse shading. For total diffuse lighting there would be no shading distinction. For total point source lighting, the side of the polyhedron away from the light would be in darkness and the definition of face boundaries would be lost. Maximum reflection from the point source to the eye would occur when the angles of incidence on the face and reflection from the face to the eye were equal.

<u>Example</u>. Consider the faces of a cube of unit width having its center at the origin and shown in isometric view (Fig. 5). Assume projection onto the yp-zp picture plane, with line of sight on the positive xp axis (**E** = **i**) and a light source at 45° over the observer's left shoulder, defined

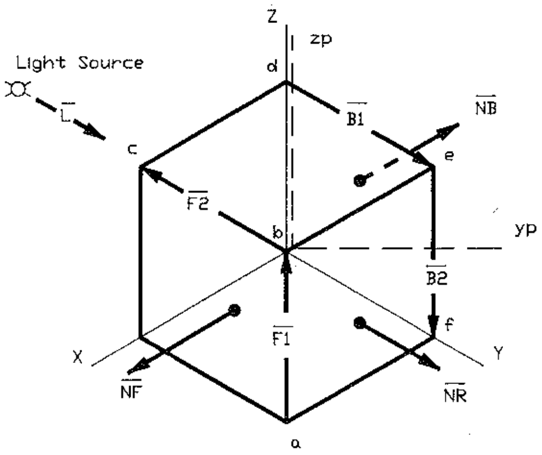


Fig. 5 Notation for hidden line removal and shading.

by the vector $L = 0.577i - 0.577j + 0.577k$. Determine which faces of the cube to show and the relative shading on those faces.

To illustrate hidden face removal, consider the front face, F, with the two arbitrary vectors F1 and F2 in counterclockwise rotation, and the back face B, with the vectors B1 and B2 in counterclockwiswe rotation.

We first transform coordinates to the yp-zp picture plane (dashed axes), which for isometric projections are:

$$yp = (y - x)\cos 30^\circ \quad \text{and}$$
$$zp = z - (y + x)\sin 30^\circ$$

The transformed coordinates of the cube's corners are:

	yp	zp
a	0	-1
b	0	0
c	-0.867	0.5
d	0	1
e	0.867	0.5
f	0.867	-0.5

The face vectors are: $F1 = k$, $F2 = -j$, $B1 = j$, $B2 = -k$. Then $NF = k(-j) = i$, and $NB = j(-k) = -i$. The cosine of the angle between NF and i, the line of sight, is 1. The cosine of the angle between NB and i is -1. Hence we plot face F, do not plot face B.

To illustrate *relative shading* consider the front face, F and right face, R, for which the outward normal vector, NR, is +j. The cosine of the angle between the light source and NF is:

$$C_{NF} = [(.577 \times 1)i - (.577 \times 0)j + (.577 \times 0)k]/1 \times 1$$
$$= 0.577$$

The cosine of the angle between the light source and NR is:

$$C_{NR} = [(.577 \times 0)i - (.577 \times 1)j + (.577 \times 0)k/1 \times 1$$
$$= -0.577$$

Hence on a scale of 0 to 1 the shading intensity on the face F is $0.577/2 = 0.288$ and on face R is $(1 + 0.577)/2 = 0.788$.

A portion of the BASIC Language geodesic dome computer program used to remove the hidden faces and produce shading in Figs. 2a and 2c is listed in Fig. 6.

Line 510 positions the isometric view on the screen.

Lines 520 to 600 perform indexing of the four octa or five icosa faces.

Lines 610 to 640 compute the spherical, rectangular, and picture plane coordinates of the indexed vertices.

Line 650 selects between wire frame and hidden face-removed isometric views.

Lines 660 and 670 calculate the outward normal vector from each face, N, and omit plotting the face if the cosine of the angle between N and E, the line of sight vector, is negative.

Lines 680 to 710 calculate the outward normal unit vector and the cosine of the angle between it and the light source vector, L.

```
510 ZW=HW*SF*COS(PI/6):VIEW (366,20)-(718,250);WINDOW (-1,-1)-(1,1)
    'ISOMET.VIEW
520 FOR M=0 TO S-1:SG=SGN((M MOD 2)-.5):FOR I=0 TO W-1:F1=0
530 I2=I: J2=0: GOSUB 610: X1=X: Y1=Y: Z1=Z
540 J2=1: GOSUB 610: X2=X: Y2=Y: Z2=Z
550 I2=I+1: J2=0: GOSUB 610: X3=X: Y3=Y: Z3=Z: J2=1: I2=I
560 GOSUB 650: IF I2+J2=W THEN F1=1:GOTO 590
570 I2=I2+1: GOSUB 610: X1=X: Y1=Y: Z1=Z: SWAP X2,X3: SWAP Y2,Y3: SWAP
Z2,Z3: GOSUB 650
580 I2=I2-1: J2=J2+1: GOSUB 610: X2=X: Y2=Y: Z2=Z: SWAP X1, X3: SWAP
Y1,Y3: SWAP Z1,Z3:GOTO 560
590 X1=X3:Y1=Y3:Z1=Z3:X3=X2:Y3=Y2-ZW*SIN(PI/6):Z3=Z2-ZW*COS(PI/6)
600 GOSUB 650:NEXT I,M:GOTO 840
610 P=INT((M+1)/2)*4*PI/S-SG*P(I2,J2)                   'P=
620 T=T(I2,J2):R=R(I2,J2)                               'T=
630 X=R*SIN(T)*COS(P):Y=R*SIN(T)*SIN(P):Z=R*COS(T)      'RECT COORDS
640 Z=(Z-(X+Y)*SIN(PI/6))*SF:X=(X-Y)*COS(PI/6)*SF:RETURN    'PICT PLANE
    COORDS
650 IF L$="w" OR L$="W" THEN GOSUB 810:RETURN           'WIRE FRAME VIEW
660 YC=-SG*((Z2-Z1)*(X3-X1)-(X2-X1)*(Z3-Z1))      'COS, FACE NORMAL TO
    LINE OF SIGHT
670 IF YC<0 THEN RETURN ELSE GOSUB 810            'HIDDEN FACE REMOVAL
680 XC=-SG*((Y2-Y1)*(Z3-Z1)-(Z2-Z1)*(Y3-Y1))
690 ZC=-SG*((X2-X1)*(Y3-Y1)-(Y2-Y1)*(X3-X1))
700 NS=(XC^2+YC^2+ZC^2)^.5                        'NS=OUTWARD FACE NORMAL
710 COL=.557*(XC+YC+ZC)/NS                        'COS ANGLE BETWEEN FACE
    NORMAL VECTOR & SUN VECTOR @ 45 DEG OVER RT SHOULDER
720 XA=(X1+X2+X3)/3:ZA=(Z1+Z2+Z3)/3   'MIDPOINTS OF TRIANG. FACES, FOR
    SHADING
730 IF COL<-.2 THEN PAINT (XA,ZA),CHR$(&HFF)+CHR$(&HFF):RETURN
740 IF COL<.1 THEN PAINT (XA,ZA),CHR$(&H77)+CHR$(&HDD):RETURN
750 IF COL<.4 THEN PAINT (XA,ZA),CHR$(&H55)+CHR$(&HAA):RETURN
760 IF COL<.75 THEN PAINT (XA,ZA),CHR$(&H99)+CHR$(&H44)+CHR$(&HAA):
RETURN
770 IF COL< .9 THEN PAINT (XA,ZA),CHR$(&H55)+CHR$(&H22)+CHR$(&H88):
RETURN
780 IF COL<.93 THEN PAINT (XA,ZA),CHR$(&H55)+CHR$(&H0)+CHR$(&H22):
RETURN
790 IF COL<.95 THEN PAINT (XA,ZA),CHR$(&H11)+CHR$(&H0)+CHR$(&H44):
RETURN
800 IF COL>.95 THEN PAINT (XA,ZA),CHR$(&H10)+CHR$(&H0)+CHR$(&H1):
RETURN
810 LINE(X1,Z1)-(X2,Z2):LINE -(X3,Z3):IF F1=1 THEN LINE -(X1,Z1-Z2+Z3)
820 LINE -(X1,Z1):RETURN                                'DRAW FACE
```

Fig. 6 Portion of BASIC geodesic dome program.

```
660 CALL CROSSP (X3,Y3,Z3,X1,Y1,Z1,XC,YC,ZC)
665 CALL DOTP (XC,YC,ZC, 1.,1.,1., COSVAL)
670 IF COSVAL<0 THEN RETURN ELSE GOSUB 810: RETURN
700 CALL SHADE (X1,Y1,Z1, X2,Y2,Z2, X3,Y3,Z3)
```

Fig. 7 Replacement statements to simplify program.

```
REM  This subroutine performs the cross product operation for a pair
REM       of vectors A,B and returns the components of the normal
REM       vector N.
REM  AX,AY,AZ; BX,BY,BZ; NX,NY,NZ:  x,y,z components of the pair of
REM       vectors and the normal vector.
     SUBROUTINE CROSSP (AX,AY,AZ, BX,BY,BZ, NX,NY,NZ)
     NX=AY*BZ-AZ*BY
     NY=AZ*BX-AX*BY
     NZ=AX*BY-AY*BX
     RETURN
     END SUB
======================================================================
REM  This subroutine performs the dot product of a pair of vectors A,B
REM       and returns the cosine of the angle between the vectors.
REM  AX,AY,AZ; BX,BY,BZ; COSVAL:  x,y,z components of the pair of
REM       vectors, cosine value.
     SUBROUTINE DOTP(AX,AY,AZ, BX,BY,BZ, COSVAL)
     SCALRP = AX*BX + AY*BY +AZ*BZ
     AMAG = SQR (AX*AX + AY*AY + AZ*AZ)
     BMAG = SQR (BX*BX + BY*BY + BZ*BZ)
     COSVAL = SCALRP/(AMAG*BMAG)
     RETURN
     END SUB
=====================================================================
REM  This subroutine performs the gray scale shading of a face for a
REM       light source at horizontal and vertical angles of 45½ over
REM       the observer's right shoulder.
REM  AX,AY,AZ, BX,BY,BZ, CX,CY,CZ: x,y,z components of the three
REM       corners of a triangular face.
     SUBROUTINE SHADE (AX,AY,AZ, BX,BY,BZ, CX,CY,CZ)
     CALL CROSSP (AX,AY,AZ, BX,BY,BZ, NX,NY,NZ)
     NORMAL = SQR (NX*NX+NY*NY+NZ*NZ)
     COL = .557*(NX+NY+NZ)/NORMAL
     MIDX = (AX+BX+CX)/3
     MIDY = (AY+BY+CY)/3
     MIDZ = (AZ+BZ+CZ)/3
     IF COL<-.2 THEN
        PAINT (MIDX,MIDZ),CHR$(&HFF)+CHR$(&HFF)
     ELSE IF COL<.1 THEN
        PAINT (MIDX,MIDZ), CHR$(&H77)+CHR$(&HDD)
     ELSE IF COL<.4 THEN
        PAINT (MIDX,MIDZ), CHR$(&H55)+CHR$(&HAA)
     ELSE IF COL<.75 THEN
        PAINT  (MIDX,MIDZ), CHR$(&H99)+CHR$(&H44)+CHR$(&HAA)
     ELSE IF COL<.9 THEN
        PAINT (MIDX,MIDZ), CHR$(&H55)+CHR$(&H22)+CHR$(&H88)
     ELSE IF COL<.93 THEN
        PAINT (MIDX,MIDZ), CHR$(&H55)+CHR$(&H0)+CHR$(H22)
     ELSE IF COL<.95 THEN
        PAINT (MIDX,MIDZ), CHR$(&H11)+CHR$(&H0)+CHR$(&H44)
     ELSE IF COL>.95 THEN
        PAINT (MIDX,MIDZ), CHR$(&H10)+CHR&(&H0)+CHR$(&H1)
     ENDIF
     RETURN
     END SUB
```

Fig. 8 QuickBASIC subroutines.

Line 720 locates a point (the midpoint) of each face for shading.

Lines 730 to 800 select tiling (shading) densities, based on the cosine value computed in line 710.

Lines 810 and 820 draw the face boundaries.

The shading tonality is controlled in lines 730 to 800 by selecting the density of 'painting' and the cosine angles between N and L (COL) used to distinguish between the various shading intensities.

The portion of the program dealing with shading and visibility is generalized in the form of three subroutines compatible with the modern BASIC Language compiler QuickBASIC (a trademark of Microsoft Corporation). These subroutines, included in the student's accessed library, allow for hidden line removal and gray scaling in general applications involving convex polyhedra. The subroutine SHADE is easily modified to accomodate faces of n sides. Because of QuickBASIC's FORTRAN-like features the routines are also easily converted.

Upon development of the 3-D plotting scheme for the object, the student can call the subroutines for hidden line removal and gray scale shading. For example, the geodesic dome program simplifies to the following once the coordinates for plotting are computed at the end of the subroutine at line 640. Replacing lines 660 through 800 with the statements of Fig. 7 simplifies the program for student use.

The subroutines for inclusion in the student's accessed library are listed in Fig. 8.

Conclusions

The geodesic design and graphic plotting capability described here provide a convenient tool for selecting the shapes and sizing the components for a wide range of geodesic dome structures. The hidden line removal and shading algorithms provide added visual perception for selecting properties of convex polyhedral structures. Especially they provide added visual augmentation to a prior program for computing dimensions of and plotting geodesic surfaces.[1]

References

[1] Teter, W. D. and Nicholls, R. L. "Geodesign: A computer Program for Geodesic Dome Geometries". Accepted, *J. Intl. Assoc. for Shell Structures.*

[2] Anand, V. B., Aziz, N. M., and Agrawal, C. "Use od 3-D Graphics To Improve Visualization Skills". *Engineering Design Graphics Journal*, Vol. 51, No. 1, 1987.

[3] Demel, J. and Miller, M., *Introduction to Computer Graphics*, Brooks/ Cole, 1984.

[4] Kenner, H. *Geodesic Math and How to Use It*, Univ. of California Press, 1976.

[5] Teter, W. D. "Introduction to Computer-Aided Drawing: User Guides - EG XXX", Univ. of Delaware, 1986.

Reader's Comments

Remarks on "Microcomputer Solution to the Mathematical Equivalent of the Graphical Method for Finding Radiation Shape Factors"

by

D. Alciatore, W. S. Janna, and E. S. Shamburger

To The Editor:

In regard to: "Microcomputer Solution to the Mathematical Equivalent of the Graphical Method for Finding Radiation Shape Factors", EDGJ, Winter 1988, I suggest the size of the orthographic area mentioned is incorrect unless the "absorbing plane" is parallel to the base of the hemisphere.

For example, all other considerations unchanged, the factor is the maximum when the radiation impinges perpendicularly upon the absorbing plane, i.e., when a line from the radiating point to the center of the absorbing plane is perpendicular to the absorbing plane. For the article, if the perspective projection (shadow) on the unit hemisphere is itself projected orthographically upon the base of the hemisphere, the area of the resulting orthographic projection is the numerator of the shape factor. (The denominator is the total base area of the hemisphere.) However, the orthographic shape, and consequently its area, changes according to the amount of the deflection (with, say, the horizontal) of the hemisphere base. It would seem, for the orthographic area to be at a maximum when the radiation exposure is at a maximum, the orthographic area is parallel to the absorbing plane.

Pat Kelso
Louisiana State University
Ruston, LA

Editor's Correction to "Using 3-D Industrial CADD Software in a Teaching Environment"

by

J. Simoneau, C. Fortin, and R. J. Ferguson

To The Editor:

... I recently noticed that one line of the original [paper] was missing in our paper published in Vol. 51, No. 3 (Autumn 87). On page 48, middle column and middle paragraph, the following sentence should be:

"... An example <u>of that</u> would be the student who thinks he understands dimensioning <u>once he succeeds in getting numbers, arrows and witness lines</u> on the screen."

In the Journal, the underlined part is missing and the sentence completely looses its meaning. ...

Jacques Simoneau
Royal Military College of Canada
Kingston, Ontario

Distinguished Service Award

Presented to

Paul S. De Jong

June 21, 1988
ASEE Annual Conference, Portland, Oregon

Introductory Remarks

by
Bob LaRue

I. Presenters

The best presenter in the Division is Bill Rogers. Those of you who have not heard him have missed a great treat. Other presenters (and I'm afraid I may fall into this category) have a tendency to read the recipient's vita from cover to cover.

This will be the fourth occasion on which it has been my privilege to make this presentation. Two of the recipients were the only ladies to have received the Award.

In an attempt to create a new format for the presentation. I decided to model this occasion after the awards presentation at the ASEE Awards Banquet. Those of you who have attended any of these affairs know that a brief slide show and well-crafted script describe events and family incidents about the awardee.

However my attempts at communicating my desires were apparently misunderstood or our recipient is the world's least photographed person. All I wanted were a few slides depicting scenes such as the Halloween on which he terrorized all the trick-or-treaters or perhaps some examples of his athletic prowess such as a triple bogey on a par-3 hole. Not a slide could I obtain. I did, however, receive a collection of cartoons drawn by Paul (these will be referred to later).

II. Creative Design Displays

My first recollection of working with Paul was in 1972 (six years after he joined the Division) when I thought he was supposed to help the Texas Tech representative set up the Creative Design Display. Just to make sure, I tried to locate Paul and Judy (and this has always been difficult). The best information I could get was that they were thought to be on their way to Lubbock from somewhere. So I skipped the last session of a conference I had been attending (including the surf and turf final banquet) and arrived in Lubbock in time to get the display in shape for the first arrivals. When the DeJongs arrived, we learned that they had a valid excuse - car trouble.

In 1973 at the Annual Conference at Iowa State, Paul did a magnificant job with the displays.

III. Career Parallels

In looking over Paul's vita, I was very much impressed by some of the similarities between our careers. For example, we both received B.S. and M.S. degrees in mechanical engineering; our master's theses both dealt with the unlikely subject of viscosimetry (something that I've avoided since the thesis was completed) and both of us have been registered engineers in South Dakota!

IV. Engineering Design Graphics Journal

Paul was editor of the Engineering Design Graphics Journal (1976-79). To the best of my recollection, every one of the nine issues for which he was responsible arrived on time and each was properly identified!

During Paul's tenure, the Journal began to take on new dimensions. It became metric in size. In addition, Paul began the process of having papers submitted for publication reviewed by Division members. It was while I was reviewing one paper that I learned that Paul will NOT take NO for an answer.

The paper in question was submitted by a very visible (and sometimes annoying) member of the Division who for years had been adamant that there was no place for computer graphics in engineering graphics. Suddenly he became a convert and wrote a very elementary paper extolling the virtues of computer graphics. My review was one of the shortest

I've ever written - the two words, "No way!". However, the paper was published.

V. Meetings - In General

Paul and Judy have attended so many annual and mid-year meetings that it's noticeable when they are not there. I have fond recollections of many meetings. Mississippi State when we gathered in their motel room to feel sorry for our colleagues who were in the "other" motel [heating problems, water problems, etc.]; Montreal, where they found a restaurant that served their "gastronomic delight" [something a few enjoy but the majority do not]; and many other places where they hosted an after-the-banquet party.

VI. Textbooks

Some individuals are the initial authors of a text. Others are invited to add their name to the author list after the original author has departed this world. Paul belongs in the latter category. In my opinion, he has done an excellent job updating and improving Rising and Almfeldt. Having used the text in a course for which I alone was teaching and responsible, I can speak with authority. I even tried to get the text adopted for other courses in our department at OSU. However, it's very difficult to convince well-meaning (but misguided) colleagues, especially when one's chairman has recently arrived from Aggieland where he worked for one of the foremost engineering graphics textbook authors.

One of Paul's graphic abilities is that of cartooning. Some have been included in the text. I have a collection (furnished by Arv Eide) of announcements of ISU Engineering College seminars. Half of each announcement is a De Jong cartoon. I have it from a very reliable source that several of the cartoons Paul submitted were rejected by the censorship committee!

Another graphics area in which Paul has become an expert is that of electronic scoreboard animation. He has attended (if not run) schools and short courses on this subject as well as making several paper presentations. To the best of my knowledge, he is active in the control center of the ISU scoreboard on football Saturdays!

VII. Awards and Participation

As should be expected, the list of activities in which Paul has been active is a long one. He is currently vice-president of the Iowa Engineering Society and has held several offices in local chapters of that organization.

Likewise, his community and campus activities are numerous. He has served as advisor to various campus groups and has received several outstanding and superior teaching awards.

One of the many good memories I have of Paul is having his signature as Division Chairman on my DSA citation.

It gives me great pleasure to present the Engineering Design Graphics Division's 1988 Distinguished Service Award to Paul S.

De Jong. The citation reads as follows:

CITATION
for
ENGINEERING
DESIGN GRAPHICS DIVISION
DISTINGUISHED SERVICE AWARD

The Division of Engineering Design Graphics of the American Society for Engineering Education presents its highest honor, The Distinguished Service Award, to

Paul S. De Jong

for his dedicated service to the Division and to engineering education, his devotion to his students and colleaques, and as an expression of admiration and respect of his professional peers.

Acceptance Remarks
by
Paul De Jong

Thank you very much, Bob, for that kind introduction.

Bob LaRue is from Ohio State, and this situation makes me think of a story he likes to tell about their ex-football coach, Earl Bruce, who lost to Iowa in the last thirty seconds of the game. The joke at Ohio State became "What does Earl Bruce have in common with Jimmy Swaggert?" - The answer was that they are the only two people in the world who can make 50,000 people jump up and shout "Jesus Christ!" in unison ... It occurred to me that maybe Bob wanted to see if he could join them by the announcement of my name!

Seriously, this is really high praise, and a great, great honor, and I have found out what it takes to make professors speechless; you bestow upon them something of this magnitude. Earlier today I spoke in praise of DSA's at Professor Adams' memorial lecture for Lee Billow, and I hope that didn't sound like I was patting myself on the back ... because it is hard to see myself in that role ... I have always looked at that list of DSA's with awe ... THEY have done Great things; THEY have made GREAT contributions. But ... me? It is truly a very humbling experience. So, I was mystified about what to say to such a great group who honors you so ... Of course, I want to say thanks. But surely there must be something momentous to say; something timeless; something useful. I have to be careful though, ... Claude Westfall says he'll leave if I get maudlin.

Something timeless ... I DO have a small offering that came to my attention recently and is truly timeless, and carries not only an element of truth but a caution of sorts for all of us:

> "If you put tomfoolery into a computer, all you get out is more tomfoolery, ... BUT - that tomfoolery, having been processed by a very expensive and complex machine, is somehow ennobled by the process, and NONE dare question it."

In simpler terms,

> "Garbage in, Gospel out."

Let me turn to thanks. Judy and I firmly believe the Engineering Design Graphics Division is made up of the finest people in the world, and we are very proud of our association with it and you. Thank you for the opportunity to serve the Division in so many ways; on the Creative Design Display Committee, as Secretary-Treasurer, Journal Editor, and Chair. It has been challenging, satisfying, a lot of work, but mostly a lot of fun. I also want to thank my family; my lovely wife Judy, whom you know, our daughter Deidre, who couldn't be here, and our son Tollif there, for their patience and sacrifice when I was too busy with Division business to be able to do something with the family that I probably should have done. They are all terrific teammates. Judy frequently sat up half the night typing Journal articles, more often than not in her nightgown, trying to figure out how much space to leave for that equation and what did my note to her say, anyway? and how many letters must get out tomorrow, -- All this without word processing, just the IBM Selectric, the hard way. Thanks to Irwin Wladaver, who in spite of poor eyesight, somehow put together the 1978 Index to the Journal for Judy to type. It was a mammoth task, but he made it seem easy. -- But I would be terribly remiss if I didn't thank the people who promote our involvement - Gordon Sanders and Arv Eide, the two department Chairs I have worked for, who have supported the Division in every way humanly possible, and whose generosity, support, and encouragement at every turn over the years have made my work easier. Thanks to you both, Gordon and Arv.

Last, I'd like to say something useful - perhaps a couple of things to think about. I never really saw myself in this position ... as I said before, THEY have done great things ... but reflection has led me to the realization that DSA's are known to us for many things, not just one single act. It is dedication over many years that we recognize. If I can paraphrase Pogo, "I have seen the DSA - and They is Us!" - and THEY is YOU! It is your sincere, thoughtful, considered contributions over the years that will produce the future DSA's among us. The whole of our individual acts can become greater than their sum taken separately. The truth is - and maybe this is useful - that

ALL THINGS COMETH TO HIM WHO WAITETH
IF HE WORKETH LIKE HELL WHILE HE WAITETH!

I've almost outtalked my welcome, so I'll close remembering some good advise to educators:

Stand up to be seen.
Speak up to be heard. -But
Sit down to be appreciated.

Thank you all again from the bottom of our hearts ... We love you all.

Chairman's Message

by
Merwin Weed

Knowing that travel money to conferences is generally tight and names, faces, and titles change so rapidly, may I, at the risk of boring some, introduce myself. I am Merwin L. Weed, the most recent Chairman of the Engineering Design Graphics Division. My one-year term of office started at the June meeting in Portland, Oregon. I am an Associate Professor of Engineering, Penn State University at the McKeesport Campus. Now if I could only meet and greet all of you! Some of you I know very well, some not so well, and some, unfortunately, I know only as a name on the membership list. Please make yourself known to me and to the other officers of the Division, and please become involved in the activities of this division, one of the most active divisions of ASEE.

At this time, I would like to encourage you to make plans to attend the mid-year conference in November at New Harmony, Indiana, hosted by The University of Southern Indiana - General Chairman, Larry Goss and Program Chairman, Linda Bode. This would be an ideal time to get acquainted or reacquainted.

May I also introduce the other new officers of the division:

1. Frank M. Croft is Vice-Chairman, which makes him Chairman-elect. In other words, he will be Chairman, beginning in June, 1989. Frank is an Associate Professor of Engineering Graphics at The Ohio State University.

2. Linda Bode is Secretary-Treasurer (1988-1991). Linda is an Instructor in Engineering Technology at The University of Toledo.

3. John B. Crittenden is Director of Publications (1988-1991). John (Barry) is an Associate Professor in the Division of Engineering Fundamentals at VPI&SU.

My congratulations to these new officers!

It seems to me that the life of any organization is sustained by its lines of communications, whether it be written, spoken, or graphical. The Engineering Design Graphics Journal is an excellent outlet for your professional development. It is a means by which you can communicate your professional activities to your peers. And, on a practical note, most institutions use "professional development" as, at least, part of the criteria for promotion and tenure. If you have never written an article for a national technical refereed journal, now is your chance.

Also under the topic of communications, please communicate with your officers. Let us know what you think. We have a new Director of Publications. You are seeing in this journal a new format and a new style. Please communicate your opinions. If you wish to contact me, please do so by mail or phone as follows:

Chairman - Merwin L. Weed
Penn State University
McKeesport Campus
University Drive
McKeesport, PA 15132
(412) 675-9497

In closing, I can say I am looking forward to an exciting year, I hope to see you at the mid-year meeting, and please keep in touch.

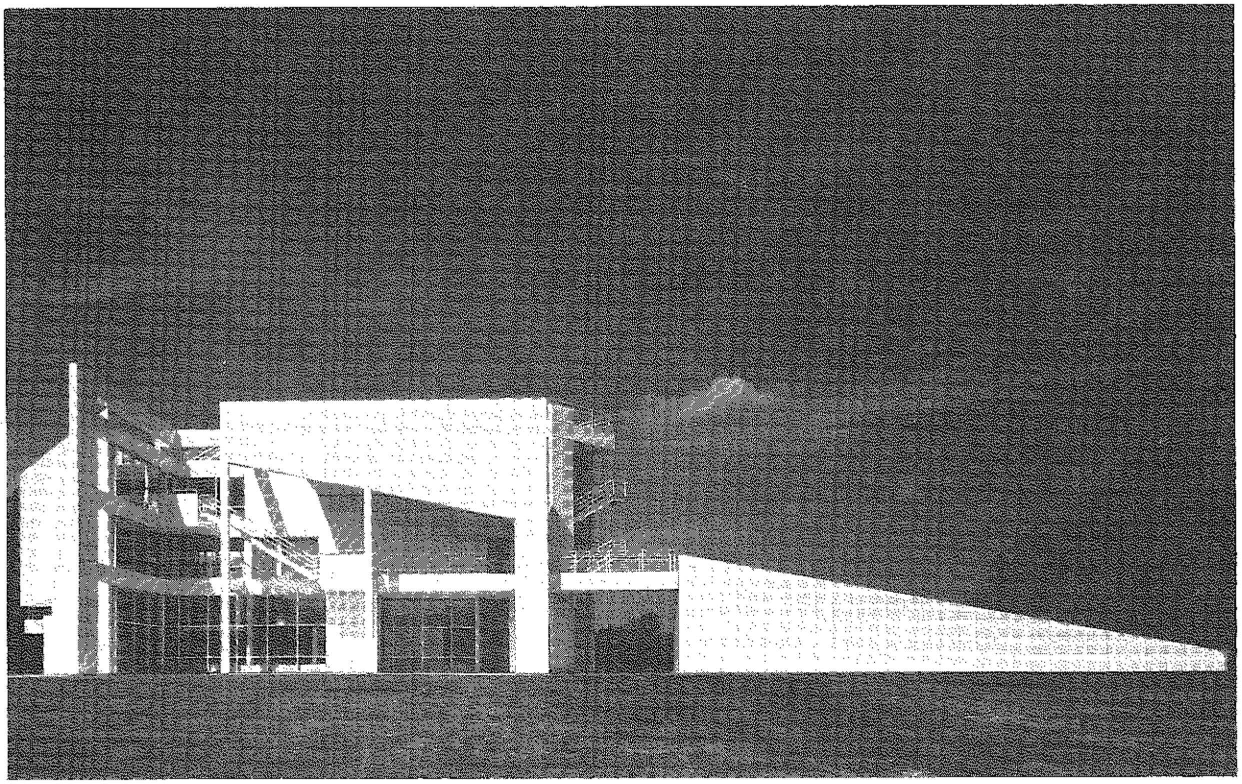
'88 - '89 Mid-year Conference

by
Larry Goss

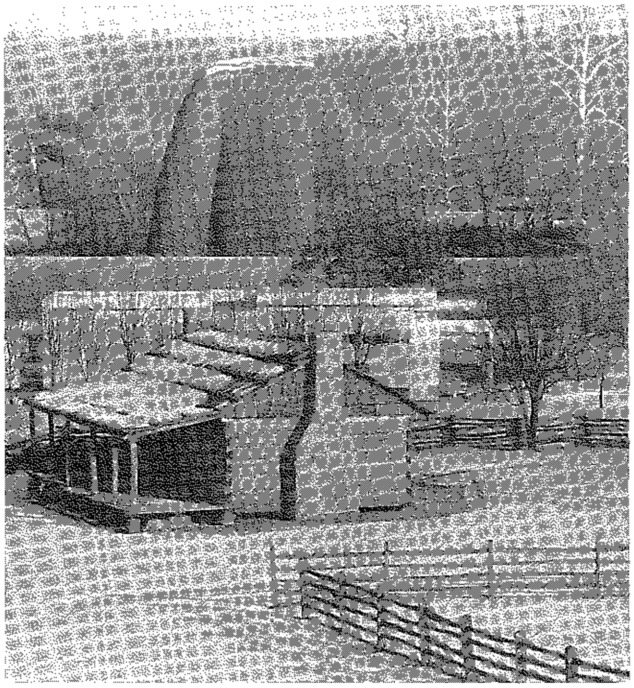
The EDGD will hold its Mid-year Conference at historic New Harmony, Indiana - November 20, 21, 22, 1988.

General Chairman -
Larry Goss
Univ. of Southern Indiana
Evansville, IN 47712
(812) 464-1892

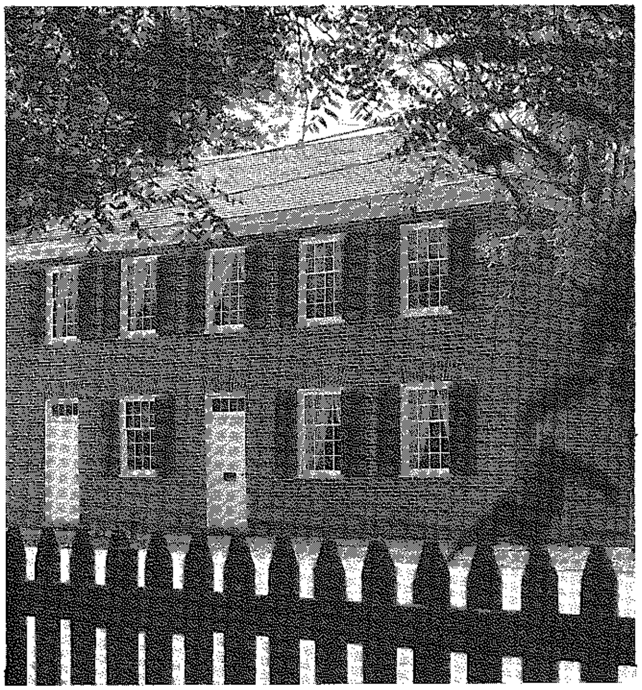
Program Chairman -
Linda Bode
Univ. of Toledo
Toledo, OH 43606
(419) 537-3365



The Atheneum, Visitors' Center in historic New Harmony.



The Double Log House, Ceramics Studio, and Roofless Church in Winter.



1830 Owen House containing regional decorative arts.

The theme for this year's midyear conference will be "Drawing on the Past - Designing for the Future". Specific paper titles as well as meeting times and locations are included in brochures mailed to each EDGD member. Registration forms for the meeting were included in this mailing.

Join your colleagues in historic New Harmony, IN, a peaceful and picturesque community on the banks of the Wabash River. Settled in 1814 by Lutheran dissidents from Wurtemburg, Germany, the community developed into a flourishing utopian society under the leadership of Father George Rapp. Members of the Harmonist Society chose the site in the wilderness of Indiana so they might live their lives as they desired, awaiting the second coming of Christ.

The entire town was sold in 1824 to Scottish industrialist Robert Owen and philanthropist William Maclure. Their concept of utopia, based on ideas of equality, justice, and education, drew scholars, educators, and scientists to New Harmony. Results of their work may be seen not only in displays in New Harmony, but also throughout the nation.

Exhibition buildings and historic sites trace the town's history from a frontier community to a modern cultural center. Twenty-four buildings and historic sites, open to the public, as well as superb conference facilities, offer the members of the EDGD and their families a unique experience in one of America's most original and appealing communities.

Nominees for Division Officers

by

Garland Hilliard

The following persons have been nominated for the positions indicated. Ballots will be mailed in February.

Vice-Chairman

JON M. DUFF

Jon Duff has taught in the areas of graphics and design at Indiana Vocational-Technical College, The Ohio State University, and at Purdue University where he is currently Professor of Technical Graphics in the School of Technology. He is an author, consultant to industry and government, and former two-term editor of the Engineering Design Graphics Journal. He received undergraduate and graduate degrees from Purdue and his doctorate from The Ohio State University.

JON K. JENSEN

Jon Jensen is an Assistant Dean at Marquette University as well as Associate Professor in the Mechanical Engineering Department. He received his B.S. and M.S. degrees from the University of Wiscousin - Stout in 1976 and 1977, respectively. He obtained his Ph.D. from Marquette University in 1985. Jon received the Dow Outstanding Young Faculty Award in 1984. He is Director of Freshman Programs at Marquette University and has authored works on Freshman Design, Graphics, and Computer Graphics in Education.

Director of Liaison

JAMES A. LEACH

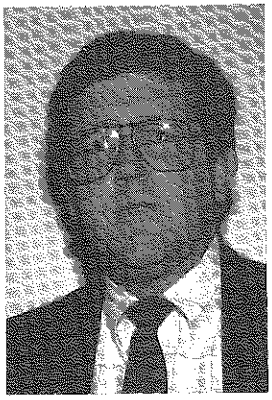
Jim, an instructor at Auburn University, is presently working toward his doctorate in education while serving as Coordinator of the Engineering Graphics Laboratories in the Industrial Engineering Department. He obtained both his Bachelor of Industrial Design and his Master of Education degrees from Auburn (1973, 1987). His industrial experience was obtained from 1973 to 1978 with Masterrack, Inc. and Ampex Magnetic Tape Division, both jobs as industrial designer. Jim has attended numerous ASEE annual and sectional conferences and EDGD mid-year conferences, where he has made several presentations. He is presently serving the Division as Director of Liaison and is a member of the EDG Journal Board of Review.

WILLIAM J. VANDER WALL

Bill, an Assistant Professor of Graphic Communications at North Carolina State University, has served on the faculty since 1964. He worked as Associate Director of the Engineering School Affirmative Action Program during 1972-76. He has authored numerous technical papers and has delivered several talks at ASEE conferences. Bill has been active in curriculum organization, has conducted technical training workshops for educators, has produced video-taped lectures on basic engineering drawing and has served as technical writing consultant in Saudi Arabia. He has carried out research studies in the classroom, produced workbooks on graphic subjects and was instrumental in establishing a fifteen-hour minor in Graphic Communications. He has been active in ASEE/EDGD committees, has served as Associate Editor of ASEE "Proceedings, International Conference on Descriptive Geometry", and has been chairman of the Southeastern Section of ASEE/EDGD.

Director of Programs

WILLIAM A. ROSS



Bill is an Associate Professor of Technical Graphics at Purdue University. Before assuming this position, he was a lecturer of Engineering Graphics and CADD at North Carolina State University (1981-1988). Bill received his B.S. and M.Ed degrees from North Carolina State University in 1973 and 1976, respectively, and he is presently working on his doctorate. While at NC State, he developed the CADD and Solids Modeling Lab utilizing HP-320 workstations. He has authored a CADD text/workbook and several EDJ Journal articles and papers. His industrial experience has been with IBM, Bosch Tool , and the Hewlett-Packard Company. Bill is a member of ASEE, AIDD, and the National Computer Graphics Association.

JAMES T. WEISS

Jim is an Assistant Professor of Engineering Graphics and Director of the College of Engineering Student Personal Computer facilities at the University of Alabama. He has a bachelor's degree in aerospace engineering and a master's degree in business administration from Alabama. A registered professional engineer in five states, he is presently serving his fourth term as secretary of the Alabama Society of Professional Engineers and has over twenty years of industrial experience in aerospace, architecture, civil, and mining engineering. Within the EDGD, he has made presentations on computer graphics, was program chairman of the Pittsburgh, PA mid-year conference and is serving as general chairman of the 1989-90 mid-year conference of the Division to be hosted by the University of Alabama in November, 1989.

Calendar of Events

by
Josann Duane

1989-90 EDGD Mid-year Conf.
Nov. 20-22, 1988
New Harmony, IN

1989 Annual ASEE Conference
June 25-29, 1989
Lincoln, NB

1989 Second International Conference on Computer-Aided Drafting, Design, and Manufacturing Technology
October 23-27, 1989
Hangzhou, China

1989-90 EDGD Mid-year Conf.
Tuscaloosa, AL

1990 Annual ASEE Conference
Toronto, Canada

1990 4th International Conference on Engineering Graphics and Descriptive Geometry
Miami, FL

1990-91 EDGD Mid-year Conf.
Tempe, AZ

1991 Annual ASEE Conference
New Orleans, LA

1991-92 EDGD Mid-year Conf.
San Francisco, CA (tentative)

A Proposal to the Accreditation Board for Engineering and Technology (ABET)

by
Ron Barr

The following proposal, drafted with the aid of many EDGD members, will be submitted to ABET through the staff of ASEE. Your comments on this proposal may be submitted to:

Ron Barr
Mechanical Engr. Dept.
The University of Texas
at Austin
Austin, TX 78712

Introduction

It is universally accepted that proper communication skills are mandatory requisites for professional practice. Graphical communication skills have always been one of the distinguishing characteristics between engineering professionals and other professionals such as lawyers, doctors, and accountants. Indeed, engineering graphical expression has a rich tradition that has paralled the historical development of the engineering profession itself, and that has provided the primary communication link between all industries in the world. This tradition of engineering graphics has always been nurtured in the engineering college curriculum, starting with a fundamentals course in the freshman year, and followed by applications of graphical communication in upper division design courses.

Significance of Engineering Graphics

The important role of engineering graphics in the undergraduate engineering curriculum is clearly identifiable. Engineering graphics develops creative visualization skills, particularly in three-dimensions, and imparts knowledge on the standard methods of communicating complex design ideas. Engineering graphics provides a logical foundation for the upper-division design sequence. The first step in developing an engineering idea is usually a sketch or drawing which describes size, proportion, and other important geometry. In a technical profession, this ability to communicate graphically is not innate, but must be fostered through properly instructed coursework.

With the recent and near-future advances in computer graphics, engineering graphics will continue to play a fundamental role in the practice of engineering. Engineering graphics is the ideal and proper discipline in which to introduce the student to computer graphics and CAD (computer-aided design) systems. The application of geometric and solid modeling systems requires that the engineer be taught to think in three dimensions, and to express those ideas clearly and precisely. With the automation and integration of the design data base with manufacturing, future engineers will be even more responsible for graphical interpretive skills that ensure correct production.

A properly instructed engineering graphics course has, as its central objectives, the development of visualization skills and the development of means for proper communication of engineering design ideas. Drafting skills are not the essential goals of engineering graphics, although knowledge of industrial standards for the chosen engineering discipline would be expected of the graduate. In a modern context, with the development of computer graphics and CAD, there is already a deemphasis of the psychomotor skills required to produce manual engineering drawings, and an increased emphasis of perception and visualization of images of physical objects and systems. Engineering graphics is a modern discipline that is responding to these needs. A profile of the modern objectives for engineering graphics can be obtained by inspection of some typical papers on the subject included in the Attachments to this proposal.

Problem Statement

The concern of our group is that the only mention of graphics in the ABET General Accreditation Criteria (part IV. C.2.d.(3).(c). of the guidelines) is a negative statement:

> "Coursework devoted to developing drafting skills may not be used to satisfy the engineering design requirement."

There is not positive support anywhere for engineering graphics, engineering drawing, or computer graphics. There is no mention of graphical communication skills, while there are strong statements for both written and oral communication. Due to this situation, and based on our group's strong commitment to the value of engineering graphics in engineering education, we propose the following three changes to the ABET guidelines. The national support for our effort is exemplified by the Letters of Support included in the Attachments to this proposal.

Proposed Change Number 1:

In section IV.C.2.d.(3).(a) add "and visualization skills," after creativity, as shown:

(3) *Engineering Design.*

(a) Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. The engineering design component of a curriculum must include a least some of the following features: development of student creativity <u>and visualization skills</u>, use of open-ended problems, development and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations and detailed system descriptions. Further, it is desirable to include a variety of realistic constraints such as economic factors, safety, reliability, aesthetics, ethics, and social impact. (*It is proposed to change the word "desirable" to "essential" in the next edition of these criteria.*)

Justification for Change Number 1:

For engineering design, visualization skills are not inherent from birth, but must be developed and nurtured in the curriculum. Stating this requirement here is appropriate as an activity for engineering design, and it will convey the importance of visualization to the engineering educator. This skill is particularly relevant for any new directions in computer-aided design and three-dimensional graphics software.

Proposed Change Number 2.

Delete entirely section IV.C.2.d.(3).(c) as shown:

(b) Courses that contain engineering design normally are taught at the upper-division level of the engineering program. Some portion of this requirement must be satisfied by at least one course which is primarily design, preferably at the senior level, and draws upon previous coursework in the relavent discipline.

~~(c) Coursework devoted to developing drafting skills may not be used to satisfy the engineering design requirements.~~

Justification for Change Number 2.

We understand that the purpose of this clause is to differentiate between what counts for design, and what is purely a drafting course. We agree with this concept, but we do not believe the clause is necessary and indeed it adversely reflects the importance of engineering graphics. In some cases it may dissuade curriculum development of needed graphics courses, since ABET does not recognize the importance of graphics and visualization. In addition, drafting courses are almost always taught at junior colleges, or in the lower division, and these courses are already excluded from the engineering design requirement by existing criteria in section IV.C.2.d.(3).(b) above. Hence, the section IV.C.2.d.(3).(c) is not really needed and is injurious to the development of modern graphics courses.

Proposed Change Number 3:

Add a new section IV.C.2.1 and move existing sections IV.C.2.1 to IV.C.2.j, and IV.C.2.j to IV.C.2.k. The wording for the new section is given below.

h. Competance in *written communication* in the English language is essential for the engineering graduate. Although specific coursework requirements serve as a foundation for such competency, the development and enhancement of writing skills must be demonstrated through student work in engineering courses as well as other studies. *Oral communication* skills in the English language must also be demonstrated within the curriculum by each engineering student.

<u>i. Graphical communication skills using standard engineering practices are essential for each engineering student and must be demonstrated through student work in design and other appropriate courses.</u>

j. An understanding of the *ethical, social, economic, and safety considerations* in engineering practice is essential for a successful engineering career. Coursework may be provided for this purpose, but as a minimum it should be the responsibility of the engineering faculty to infuse professional concepts into all engineering coursework.

k. For those institutions which elect to prepare graduates for entry into the profession at the *advanced level*, ABET requires that students' curricular work: (1) satisfy ABET engineering criteria at the basic ...

Justification for Change Number 3:

For engineering practice, all three forms of communication (written, oral, and graphical) are important. To mention written and oral, but not to mention graphical is clearly an oversight that must be remedied. We recommend that it be a separate clause from section IV.C.2.h because we definitely do not want our proposed statement to appear as an afterthought, as does the reference to oral communication currently appears to be.

Third International Conference on Engineering Graphics and Descriptive Geometry a Great Success!

by
Klaus Kroner

From on the scene comes an initial report indicating that this Conference, conducted July 11 - 16 at the Technical University of Vienna, Austria and the brainchild of Professor Steve Slaby (Princeton University) with the assistance of a very able international organizing committee, was of immense value to all of the nearly 150 participants. The professional program dealt with three major issues: 1) theoretical graphics and applied geometry, 2) engineering computer graphics, and 3) education in engineering graphics. Lively discussions ensued on several subjects. The Technical University had also displayed many historical works on descriptive geometry from their library holdings.

The social program planned by the local committee was outstanding in the Viennnese tradition and capped by an invitation by the mayor for a dinner-dance at the magnificant city hall.

At the closing ceremony it was announced that the next International Conference would be held in the summer of 1990 on the campus of the Florida International University in Miami, the first time the meeting will be sited in the United States.

A more detailed report of the Vienna conference, including photographic coverage, will follow in the next issue of the EDG Journal.

Call for Columnists

by
the Editors

The EDGD and Journal needs your help. If you would like to write a column on any topic of interest to the Division membership, please notify the editor of your desires. A puzzle column has been suggested as well as sections for book reviews, software reviews, etc.

Use Your Journal to Promote Your Profession

by
the Editors

Without the participation of the readers of this Journal, it would not exist. Submit technical papers describing your areas of research and techniques of teaching in the engineering design graphics field. Supply the editors with your news, notes, and announcements. Letters to the editor are always welcome. Announcements of job openings will be printed free-of-charge. Calls for papers may be made. Workshops may be advertised. The 500 plus members of the EDGD and numerous other readers of the Journal want to know what has happened, what is happening, and what will be happening in the field of engineering design graphics. Without your input, the editors can not inform their readers.

Editor's Comments

by
Barry Crittenden

A new assignment for the EDGD, a new personal computer (IBM System/2, Model 30), a new printer (Hewlett-Packard Laserjet), new word processing software (Microsoft WORD), and a new Journal printer (the Virginia Polytechnic Institute and State University Press) has made publishing this issue of the Journal an event I shall never forget. Establishing a new format, meeting the professional requirements of our Division and the space and location requirements of our advertisers, and constantly worrying about deadlines will also linger in my mind for quite some time. In addition, organizing a new Journal staff and contacting authors of technical papers has enlightened my view of the world of journalism. If this issue of the Journal appears as planned, let us hope we are reasonably proud of its appearance and content, produced at a reasonable cost.

May I take this opportunity to thank the former editor, Jon Duff, for his assistance during the transition to a new Journal staff. My thanks also to William C. Brown for the many previous years of publication of the Journal. In addition, my appreciation is extended to my closest assistants, George Lux and Larry Goss, who have been most helpful during these initial stages of Journal preparation.

Position Available

DIRECTOR - Freshman Engineering and Engineering Graphics, Clemson University

QUALIFICATIONS - Ph.D. in Engineering, at least 5 years experience in engineering education, computer skills desirable, genuine interest in working with entry-level students. For more information, contact Walter E. Castro, Chair, Search Committee, (803) 656-4440.

RESUME - by December 1, 1988 to:

Search Committee Chair
Dir. - Fresh. Engr. & Engr. Graphics
113 Riggs Hall
Clemson University
Clemson, SC 29634-0901

EOAA employer

Scope

This Journal is devoted to the advancement of engineering design graphics technology and education. The Journal publishes qualified papers of interest to educators and practitioners of engineering graphics, computer graphics, and subjects related to engineering design graphics in an effort to (1) encourage research, development, and refinement of theory and application of engineering design graphics for understanding and practice, (2) encourage teachers of engineering design graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses, and (3) stimulate the preparation of articles and papers on topics of interest to the membership. Acceptance of submitted papers will depend upon the results of a review process and upon the judgement of the editors as to the importance of the papers to the membership. Papers must be written in a style appropriate for archival purposes.

Submission of Papers and Articles

Submit complete papers, including an abstract of no more than 200 words, as well as figures, tables, etc. in quadruplicate (four copies) with a covering letter to J. B. Crittenden, Editor, Engineering Design Graphics Journal, EF - VPI&SU, Blacksburg, VA 24061. All copy must be in English, typed double-spaced on one side of each page. Use standard 8 1/2 x 11 inch paper only, with pages numbered consecutively. Clearly identify all figures, graphs, tables, etc. All figures, graphs, tables, etc. must be accompanied by a caption. Illustrations will not be redrawn. Therefore, ensure that all line work is black and sharply drawn and that all text is large enough to be legible if reduced to single or double column size. High quality photocopies of sharply drawn illustrations are acceptable. The editorial staff may edit manuscripts for publication after return from the Board of Review. Galley proofs may not be returned for author approval. Authors are therefore encouraged to seek editorial comments from their colleagues before submission of papers.

Publication

The Engineering Design Graphics Journal is published one volume per year, three numbers per volume, in winter, spring, and autumn by the Engineering Design Graphics Division of the American Society for Engineering Education. The views and opinions expressed by individual authors do not necessarily reflect the editorial policy of the Engineering Design Graphics Division. ASEE is not responsible for statements made or opinions expressed in this publication.

Subscriptions

Yearly subscription rates are as follows:

ASEE member	$3.00
Non-member	$6.00
Canada, Mexico	$10.00
Foreign	$20.00

Single copy rates are as follows:

U.S. member	$1.50
U.S. non-member	$2.50
Canada, Mexico	$3.50
Foreign	$7.00

Non-member fees are payable to the Engineering Design Graphics Journal at: The Engineering Design Graphics Journal, The Ohio State University, 2070 Neil Avenue, Columbus, OH 43210. Back issues are available at single copy rates (prepaid) from the Circulation Manager and are limited in general to numbers published within the past six years. The subscription expiration date appears in the upper right corner of the mailing label as follows: (1) For an ASEE/EDGD member, the expiration date is the same month/year as the ASEE membership expiration (for example, 6/88) (2) For all others, the expiration date is the date of the last paid issue (for example, W86, for Winter 1986). Claims for missing issues must be submitted within a six-month period following the month of publication: January for the Winter issue, April for the Spring issue, and November for the Fall issue.

Deadlines

The following deadlines apply for submission of articles, announcements, and advertising: Fall issue - August 15, Winter issue - November 15, Spring issue - February 15.

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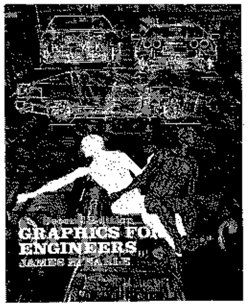

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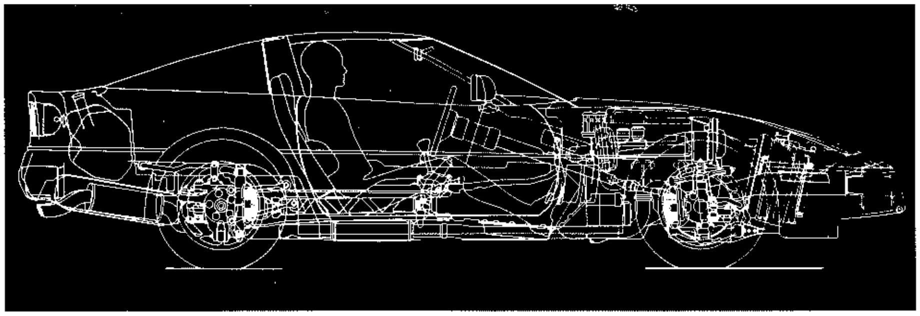

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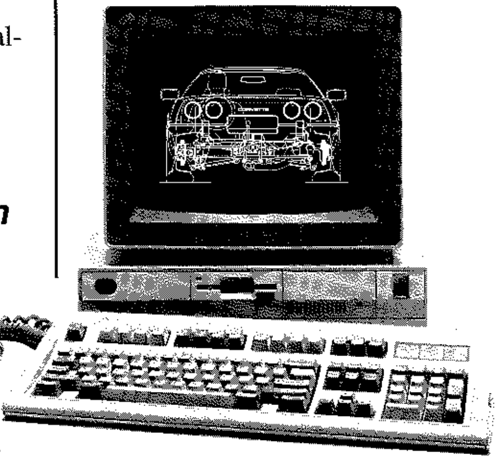

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EDGD NEWS, NOTES, AND ANNOUNCEMENTS

Distinguished Service Award

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