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Choosing a Graphics Software Package for Educational Software Development: A Comparison of PHIGS and HOOPS

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A major factor in software development for educational applications is the choice of a graphics interface. The amount of time required to write the code is a function of the level at which the software is interfaced with the hardware. Two graphics interface packages, PHIGS and HOOPS, are examined. Both have been purchased for the APOLLO and VAX workstations in the Engineering Computing and Information Laboratory (ECIL) at Iowa State University. A comparison of the two packages is made in light of the College of Engineering's needs for educational software. Conclusions based on programming experience using both PHIGS and HOOPS are also presented.

Introduction

The increasing power of computers coupled with attractive purchase arrangements is fostering a new thrust in innovative educational software development in colleges of engineering. The ATHENA program at MIT[1] and the SOCRATES development program at Cornell[2] are among the more well-known efforts at this time. These large-scale programs have obtained support from the NSF and other funding sources and involve several faculty and staff members. However, there are a great number of professors who are beginning, on a relatively small scale, to explore software development. These professors do not, in general, have funding support and in many instances do not have the appropriate software and hardware at their disposal.

It is important to distinguish between educational software and commercial software. Commercial software, available from software vendors, is used to carry out engineering functions. For example, AutoCAD, ANSYS, I-deas, SPICE, GPSS, and numerous other packages are commonly used in design and analysis. Educational software is developed for a specific teaching and learning environment. SELS2, a finite-element package within SOCRATES, allows a student beginning the study of finite elements to interactively work with a single element. This program would not be useful in a design mode but is valuable in the learning process. Commercial vendors do not, in general, develop educational software but instead produce "educational" versions of their software. For specific engineering courses professors have two options for software support:

(a) adjust the course to utilize software (which may change the course objectives), or

(b) develop their own software.

In a university setting, getting started in a software development project is difficult. The professors cannot, in general, devote significant amounts of time in planning, writing, and testing because these activities interfere with the traditionally accepted research areas for tenure and promotion. Young faculty are steered toward the graduate courses and away from undergraduate courses where the greatest need for educational software exists. If funds are available, much of the time-consuming programming and debugging tasks can be accomplished by graduate and undergraduate students. These engineering students are not likely to possess the level of programming skills necessary to efficiently create a sophisticated software package.

Graphics Programming Tools

Tools for developing graphics programs can be classified into three groups: turnkey systems such as Apollo GMR3D, implementations of graphics standards such as GKS or PHIGS, and commercially available graphics libraries such as HOOPS. Turnkey systems are graphics libraries tailored to run on a specific machine. These systems take advantage of the hardware of the computer to perform much of the graphics. While programs written using turnkey systems can perform graphics manipulation and display very fast, these programs are limited to running only on that specific type of computer[3]. These programs are not portable to any other type of computer.

Graphics standards have been developed to define the basic building blocks needed to program graphics applications. Graphics standards are different from graphics libraries in that standards are programming guidelines that can be implemented in software by different vendors in various ways. Graphics libraries are software packages that contain graphics subroutines. Betels, et al[4], assert that standards provide portability, longevity, extensibility, and device-independence, but they further caution about the difference in implementations that affect portability. Implementation involves taking the standard guidelines and writing code to allow programmers to perform the required functions of the standard. Typically each implementation also adds additional features to the code. It is the addition of these features that affects the portability of a program.

For example, VAX FORTRAN 77 allows variable names longer than six characters which is a violation of FORTRAN 77 standards. Therefore, code written in VAX FORTRAN 77 follows the FORTRAN 77 standard, but because of the extensions added, it will not be completely source-code-portable to non-VAX machines. Programmers who are concerned about portability can still write programs using VAX FORTRAN 77 but must be careful to use only the features in the standard FORTRAN 77.

The same is true for PHIGS. PHIGS, the Programmers' Hierarchical Interactive Graphics Standard, is an approved ISO graphics standard[4]. Developers who are concerned about the portability of their software need to be aware of the extensions to the PHIGS standard which are incorporated in the specific PHIGS implementation they are using. Because PHIGS is a standard and not a graphics library, all software based on PHIGS will not compile on all machines that have PHIGS.

HOOPS, the Hierarchical Object-Oriented Picture System[5], is a graphics library consisting of a collection of graphics subroutines. It is a proprietary package developed and distributed by Ithaca Software, Ithaca, New York. From the outset, HOOPS was developed to be fully source-code-compatible on all machines which are supported. These include Apollo, Apple Mac II, DEC Vaxstation and DECstation, Hewlett Packard 9000, IBM 286 and 386 PC's, Sun 386i, Sun 3 and 4, and Silicon Graphics Personal Iris 4D. Because of the source-code-compatibility of HOOPS, source code written on a Vaxstation can easily be recompiled on an Apollo workstation. This makes programming for portability very easy. To port an application from a Vaxstation to an Apollo workstation, only the unique system calls within the software need to be changed. Further, all of the features of the library are available to programmers without worry of portability of the final product.

If developers are not worried about portability, then the preceding discussion is moot. However, in the educational arena and in this era of multiple vendor campuses, the ability to port software to different platforms greatly enhances the availability of the software to the students. In addition, portability does not restrict the future acquisition of hardware to one model or vendor but allows decisions on purchasing hardware to be made based on the hardware features of each computer.

Characteristics of HOOPS and PHIGS

Computer programming has many levels of programming which range from assembly language to programming with a high-level language like FORTRAN. Similarly, graphics programming can be performed on many levels, as illustrated in Fig. 1.

Lower-level graphics programming, using the X11 or UIS (User Interface Services) software, requires that programmers have a good understanding of both the

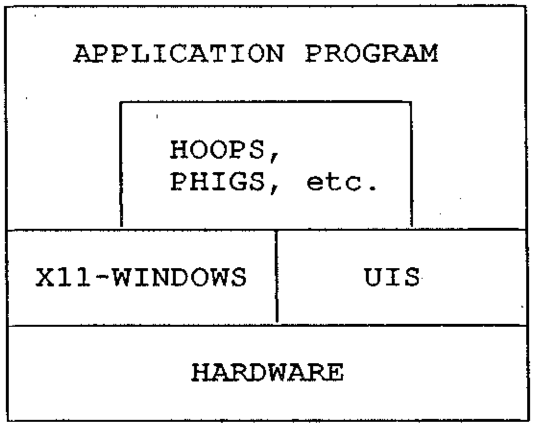

Fig. 1 Levels of graphics programming

mathematics behind graphical manipulations and the interface between the software and the hardware. There are no subroutines to rotate or translate. Instead the transformation matrices must be individually programmed. Engineers are not, in general, knowledgeable in this level of graphics programming. It requires a great deal of time to learn to program efficiently at this level. The major benefit of low-level programming is a faster executing program and greater versatility in programming.

Higher-level programming provides a more user-friendly interface with the hardware by communicating with X11 or UIS. While much easier to program, higher-level programming sometimes loses the versatility of lower-level programming. Subroutines are supplied which perform only certain basic operations. A programmer is not at liberty to access more than what is supplied in the subroutines. However, the commands are generally more intuitive and little knowledge is needed about the mathematical manipulations of graphical objects or the specific hardware operations.

The line between the levels of programming is not clearly drawn. In a sense, PHIGS provides a more lower-level programming environment than HOOPS because it does not provide subroutines that perform basic operations, such as rotating or translating. Similarly, HOOPS provides many standard 3D manipulation subroutines and therefore is a more high-level programming tool. Instead of defining the rotation matrix for an object, HOOPS provides a subroutine called HC-Rotate. The arguments define the axis about which to rotate and the number degrees to rotate.

HOOPS could have made the transformation matrix invisible and inaccessible thereby providing a truly high-level programming environment. Instead, routines to define the transformation matrix are provided in the graphics library and can be used if needed. In this way, part-time programmers or novice programmers can use the higher-level routine and advanced programmers can have access to the transformation matrices. The existence of these higher-level routines along with the ability to use the lower-level routines makes HOOPS easy to use and yet maintains some programming versatility.

Both HOOPS and PHIGS use a hierarchical data base[6,7]. All of the geometry and attributes of one object are grouped together and manipulated as one entity. HOOPS calls these entities segments and PHIGS calls them structures. In order to create an object, a structure or segment is opened, the geometry and attributes defined, and then the structure is closed. These structures or segments are related to each other in a tree-like fashion, with some entities "branching off" of other entities. All graphics programming deals with creating, manipulating, and displaying these entities. It is in the creation and manipulation of these objects that HOOPS and PHIGS show significant differences.

When an object is created, it is given a name. In PHIGS, structures are identified with numbers, whereas in HOOPS segments are identified using descriptive names. For example, the segment defining a house in HOOPS could be named HOUSE where in PHIGS it would be given a number, such as 2. Further reference to the house later in the program would be to HOUSE in the HOOPS program and to 2 in the PHIGS program. To remedy this situation, a PHIGS programmer can assign a variable name to the structure number, e.g., HOUSE = 1 which would enable the variable name HOUSE to be used in calling routines. This, of course, adds additional lines of code to the program.

This type of naming is not restricted to structure or segment name but continues throughout the code. HOOPS was written to accept more English-like attribute specifications and segment names in order to make programming with HOOPS more intuitive[8]. For example, in order to set the line color HOOPS uses the command

```
HC_Set_Color("line=red")
```

and PHIGS uses the command

```
psetlinecolorind (9)
```

The novice programmer would need a look-up table to determine what line color was 9 when decoding the PHIGS program. A similar table would be needed to identify structure 2 as the structure containing the house information. The direct use of more intuitive names makes it easier to learn HOOPS and later, makes it easier to modify existing programs.

Modifying attributes of PHIGS structures can also be awkward. Every time the color of an entity changes, the structure must be opened, the old color deleted, the new color specified, and the structure closed. That takes five lines of code. HOOPS provides a mechanism that allows attributes of an entity to be changed at any time in the program without opening the segment. To change the color of the house, only one line of code is needed.

Within a PHIGS structure, the sequence of commands is important. For the part-time programmer, remembering whether the color should be set in the third line or the fourth line results in many referrals to the PHIGS manual. This sequencing also can be a real debugging stumbling stone for the novice programmer. In HOOPS, the order of commands in a segment is arbitrary.

The PHIGS standard also lacks some of the basic features needed in three-dimensional graphics programming. PHIGS does not provide for polygon fill, polygon hatching, hidden surface rendering, or hidden line removal. The result is the ability to create a wire-frame model without hidden line removal. An extension to PHIGS, called PHIGS+, has been developed that incorporates surface modeling, shading, and lighting[9]. HOOPS on the other hand provides these features as standard subroutines[10].

Conclusion

While PHIGS programming could be mastered by anyone with a programming background given enough time, the unique environment of educational software favors the easier, more friendly environment of the commercial graphics library. The intuitive command names, the ease of modifying structures, the additional features provided and the portability favor development with HOOPS or a similar package.

However, the decision between using HOOPS and PHIGS does have its trade-offs. PHIGS is a standard and for this reason support for PHIGS is widespread and available. HOOPS, on the other hand, is a vendor's product. The robustness, support, and upward compatibility with new HOOPS releases rests with the vendor. If Ithaca Software experienced business difficulties, the support available for HOOPS would likely diminish.

HOOPS was written not as a standard but as a tool to make computer graphics more accessible to scientists, engineers, and programmers[8]. It is this group of people who most likely will perform the educational software development of the future. While attempting to de-mystify graphics programming, HOOPS has not given up the versatility provided in a lower-level programming environment.

It has been our experience at Iowa State University that using a graphics library like HOOPS is the best way to approach graphics programming from an educational standpoint. The learning curve is just too long for PHIGS to be a useful tool for graduate student employees or faculty with limited time to devote to programming. While PHIGS is surely an emerging graphics standard, the non-user-friendliness inherent in the standard makes it prohibitive for the part-time programmer or the novice to use in developing graphics programs. Perhaps for the professional programmer, PHIGS is an excellent choice, but for the engineering professor or graduate student programmer, a package like HOOPS is the better option.

Acknowledgement

The authors would like to acknowledge the ECIL programmers, Marty Moulton and Rich Ng, for investigating the capabilities of PHIGS and HOOPS.

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The Matrix for the Transformation of an Auxiliary Orthographic Projection and a New Computation of the Axonometric Drawing

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Currently the theory presented in most books and articles on the computation of an axonometric drawing is based on the concept of rotation. Thus, it is not possible to show the relationship between views of the object, the line of sight, and the axonometric drawing itself. A new computation that improves this situation and is based on the theory of auxiliary orthographic projection is presented. A matrix for transformation is derived using the principle of auxiliary orthographic projection in the first octant. Using this matrix, the coordinates of the vertices of outlines of the object in the axonometric drawing may be computed.

Introduction

It is common to use auxiliary orthographic projection to create an axonometric drawing. As shown in Fig. 1, the relationship between the projector S(S1,S2), the views of the object, and the axonometric drawing is visible.

But, what is the mathematical requirement for auxiliary orthographic projection and may it be used to construct an axonometric drawing in computer graphics? The mathematical analysis and solution to these questions follow.

The Main Parameters of Auxiliary Orthographic Projection and Their Relationships

The projector and the auxiliary plane are essential conditions in constructing an auxiliary orthographic projection. In the Fig. 2, the plane P (traces L,K) is the auxiliary projection plane, S(S1,S2) is the projector or the line of sight, Θ is the angle between traces L and K, $\Theta 1$ is the top view of Θ, and $\Theta 2$ is the front view of Θ. It is assumed that the angle $\Theta 1$ is measured as a positive angle from -X toward K1 and $\Theta 2$ is measured as positive from -X toward L2.

Suppose

$$S = \{\ X\ Y\ Z\ \}$$

Since

$$K1 \perp S1$$
$$L2 \perp S2$$

then

$$\Theta 1 = \tan^{-1}(X/Y)$$
$$\Theta 2 = \tan^{-1}(X/Z)$$

In accordance with the principle of the method of coincidence

$$\cos \Theta = OT3/OT$$

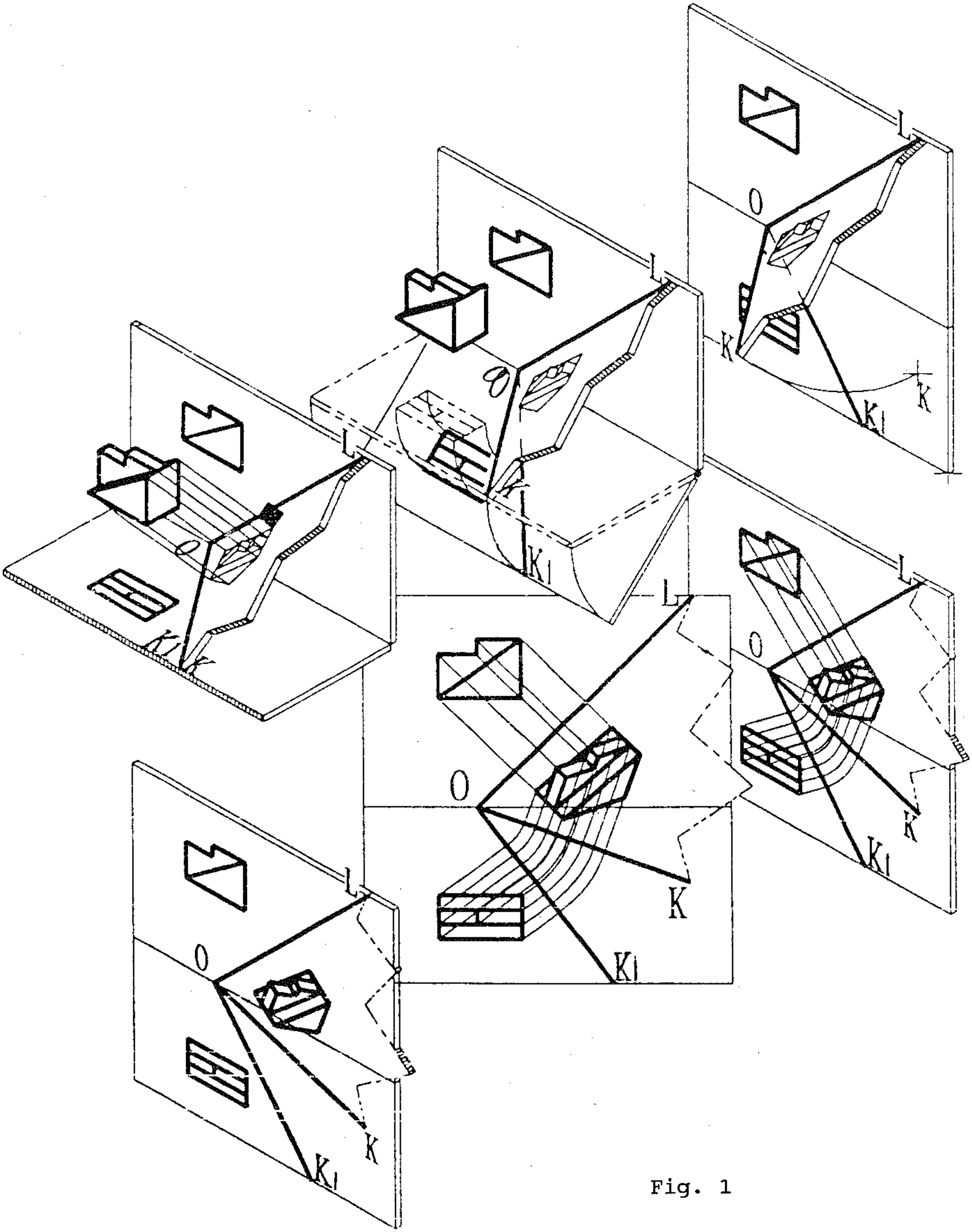

Fig. 1

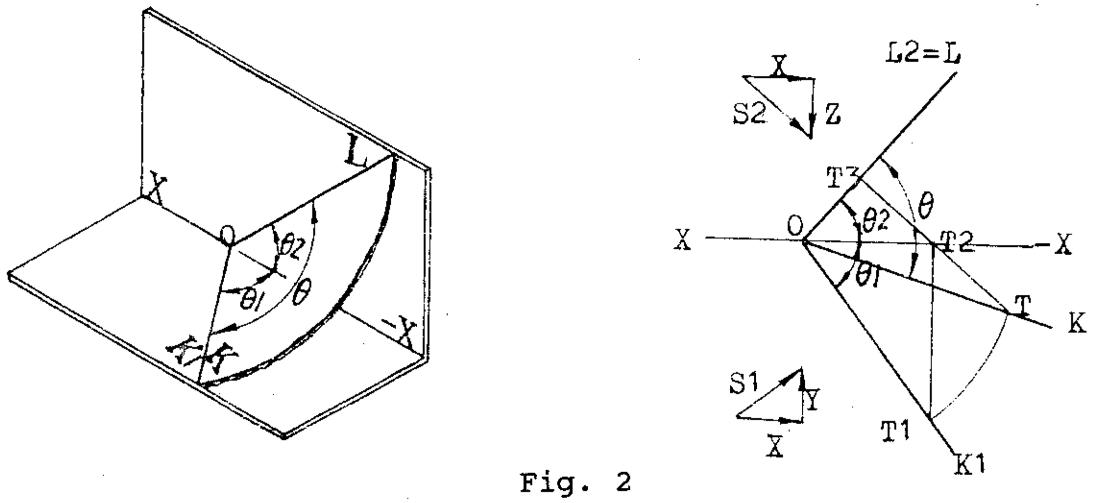

Fig. 2

However,

$$OT3 = OT2 \cos \theta 2$$
$$OT = OT1 = OT2/\cos \theta 1$$

Hence

$$\cos \theta = OT2 \cos \theta 2/(OT2/\cos \theta 1) = \cos \theta 1 \cos \theta 2$$

Thus

$$\theta = \cos^{-1} (\cos \theta 1 \cos \theta 2)$$

and

$$0^\circ < \begin{vmatrix} \theta 1 \\ \theta 2 \\ \theta \end{vmatrix} < 180^\circ$$

The Trace Coordinates of the Auxiliary Orthographic Projection of a Point in Space and Its Computation

In Fig. 3, Ap is the projection of the point A(x,y,z) onto the auxiliary plane P(L,K). Therefore, A2Ap is perpendicular to trace L, A1Ak is perpendicular to trace K1, ApAo is perpendicular to trace K, and OAk is equal to OAo. The distance OAk or OAo and OA3 are called "trace coordinates" of point Ap and are defined as Ap(k,l). The relationship between A(x,y,z) and Ap(k,l) may be derived as follows:

Move point A toward B parallel to axis X such that $x_b = 0$, $y_b = y_a$, and $z_b = z_a$.

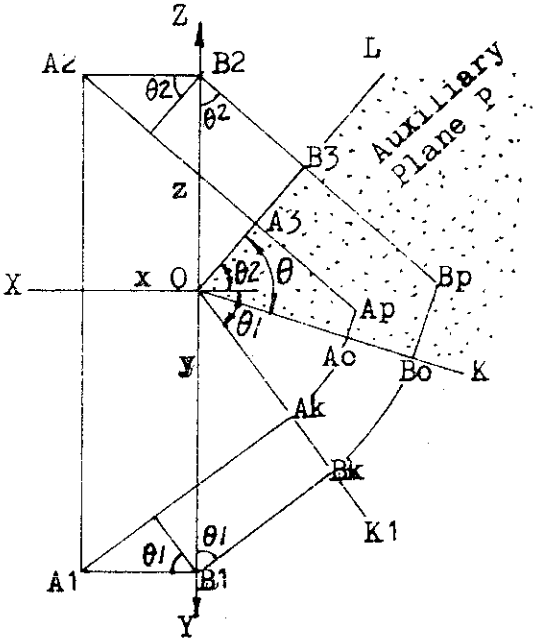

Fig. 3

Thus, in the top view

$$\begin{aligned} OBk &= OB1 \sin \theta 1 \\ &= y \sin \theta 1 \end{aligned}$$

$$\begin{aligned} AkBk &= A1B1 \cos \theta 1 \\ &= x \cos \theta 1 \end{aligned}$$

In the front view

$$\begin{aligned} OB3 &= OB2 \sin \theta 2 \\ &= z \sin \theta 2 \end{aligned}$$

$$\begin{aligned} A3B3 &= A2B2 \cos \theta 2 \\ &= x \cos \theta 2 \end{aligned}$$

Since

$$\begin{aligned} OAk &= OBk - AkBk \\ OA3 &= OB3 - A3B3 \end{aligned}$$

then

$$\begin{aligned} OAk &= y \sin \theta 1 - x \cos \theta 1 \\ OA3 &= z \sin \theta 2 - x \cos \theta 2 \end{aligned}$$

or

$$\begin{aligned} k &= -x \cos \theta 1 + y \sin \theta 1 \\ l &= -x \cos \theta 2 + z \sin \theta 2 \end{aligned} \tag{1}$$

Transforming Trace Coordinates into Orthogonal Coordinates

Removing the traces K, L and projection A_p from Fig. 3 and then constructing OV perpendicular to OK gives Fig. 4. If K is replaced by U, a new orthogonal system of coordinates OUV is established. The transformation of the trace coordinates k,l into orthogonal coordinates u,v of projection A_p is derived by the analysis which follows:

In the right triangle J-O-A3

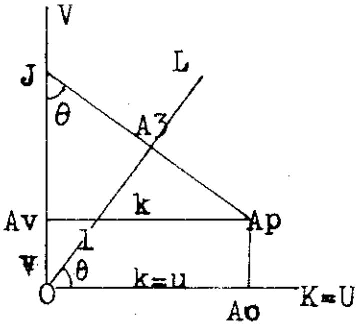

Fig. 4

$$\begin{aligned} JO &= OA3/\sin \theta \\ &= l/\sin \theta \end{aligned}$$

In the right triangle J-Av-Ap

$$\begin{aligned} JAv &= AvAp/ \tan \theta \\ &= k \cos \theta/\sin \theta \end{aligned}$$

Since

$$\begin{aligned} v &= OAv \\ &= OJ - JAv \end{aligned}$$

then

$$v = l/\sin \theta - k \cos \theta/\sin \theta \tag{2}$$

Substituting Eqs. (1) into (2) yields

$$\begin{aligned} v &= (z \sin \theta 2 - x \cos \theta 2)/\sin \theta \\ &\quad - (y \sin \theta 1 - x \cos \theta 1) \\ &\quad \cos \theta/\sin \theta \\ &= x\ (-\cos \theta 2 + \cos \theta 1 \\ &\quad \cos \theta)/\sin \theta - y \sin \theta 1 \\ &\quad \cos \theta/\sin \theta + z \sin \theta 2/ \\ &\quad \sin \theta \end{aligned}$$

Since K is replaced by U

$$\begin{aligned} u &= k \\ &= -x \cos \theta 1 + y \sin \theta 1 \end{aligned}$$

If representing the relationship between A(x,y,z) and Ap(u,v) in a matrix equation, it may be written as

$$[x\ y\ z]\ [M] = [u\ v] \tag{3}$$

where M is defined by the equation in Fig. 5. Thus, M is the matrix of auxiliary orthographic projection.

In accordance with the principle of projection in the first octant, the projection plane should be coincident with the vertical plane of projection toward the direction of projection. Thus, when the sign of module X of the projector is negative, the sign of coordinate u should be positive. Conversely, when the sign of X is positive, the sign of u should be negative (Fig. 6).

A New Computation for the Axonometric Drawing

As presented earlier, the axonometric drawing may be created using auxiliary projection. Therefore, Eq. 3 may be used to compute the axonometric drawing. The procedure of this new computation is described as follows (Fig. 7):

First, define the direction S(S1,S2) of projection (input X, Y, Z). Then compute the trace angles $\theta 1$, $\theta 2$, θ and substitute them in matrix [M]. Next, take any vertex as the origin of coordinate (i.e., point O) and establish the matrix [Mv] of vertices

$$[M] = \begin{bmatrix} -\cos\theta 1 & (-\cos\theta 2 + \cos\theta 1 \cos\theta)/\sin\theta \\ \sin\theta 1 & -\sin\theta 1 \cos\theta / \sin\theta \\ 0 & \sin\theta 2 / \sin\theta \end{bmatrix}$$

Fig. 5

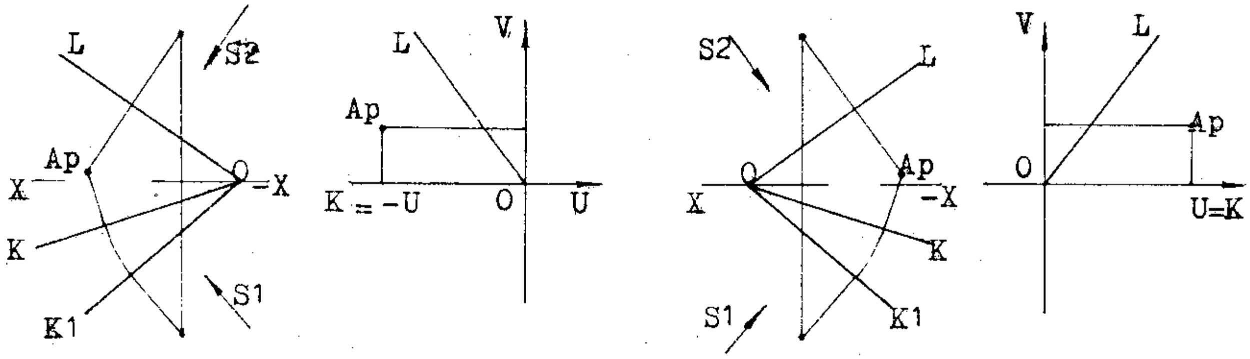

Fig. 6

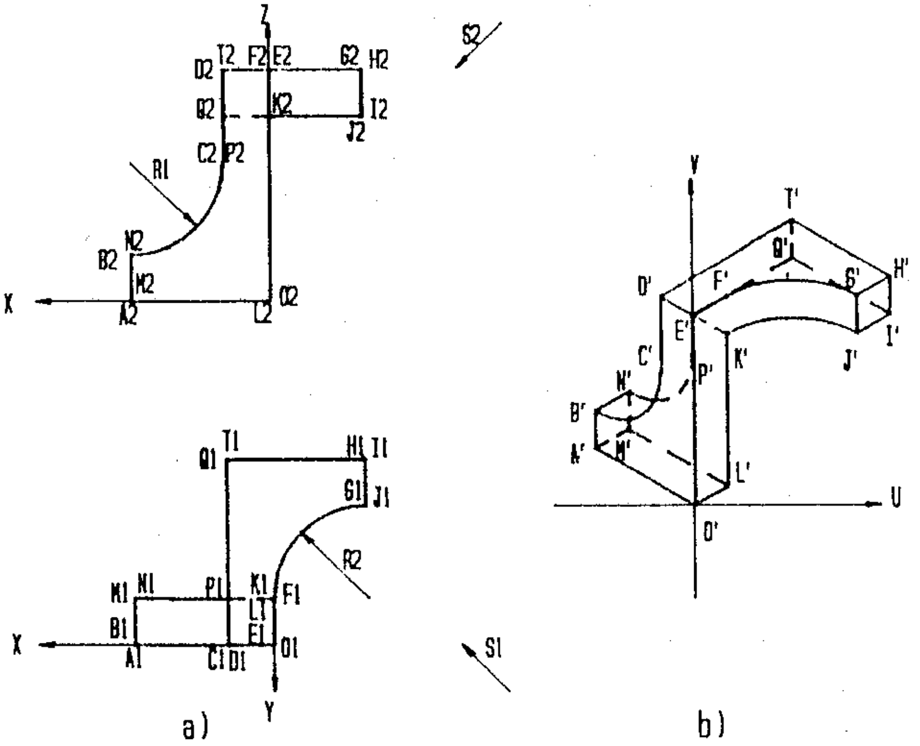

Fig. 7

$$[Mv] = \begin{bmatrix} A \\ \vdots \\ T \end{bmatrix} \begin{bmatrix} x_a & y_a & z_a \\ \vdots & \vdots & \vdots \\ x_t & y_t & z_t \end{bmatrix}$$

Then, transform all of the vertices from {x y z} to {u v}. Thus

$$[Mv]\ [M] = [(Mv)']$$

and

$$[(Mv)'] = \begin{bmatrix} u_a & v_a \\ \vdots & \vdots \\ u_t & v_t \end{bmatrix} \begin{bmatrix} A' \\ \vdots \\ T' \end{bmatrix}$$

For the transformation of the arcs, first establish the equation as follows:

In Fig. 7, the arc R1 is represented as

$$x = x1 - R1 \cos \alpha$$
$$y = y1$$
$$z = z1 + R1 \sin \alpha$$

In the equation x1, y1, z1 are the coordinates of the center, and

$$270° \le \alpha \le 360°$$

The arc R2 is represented as

$$x = x2 - R2 \cos \beta$$
$$y = y2 - R2 \sin \beta$$
$$z = z2$$

In the equation x2, y2, z2 are the coordinates of the center, and

$$90° \le \beta \le 180°$$

Next, establish the matrix equation for transformation (Fig. 8).

$$[\; x1 - R1 \cos \alpha \quad y1 \quad z1 + R1 \sin \alpha \;]\,[M] = [\; ur1 \quad vr1 \;]$$

$$[\; x2 - R2 \cos \beta \quad y2 - R2 \sin \beta \quad z2 \;]\,[M] = [\; ur2 \quad vr2 \;]$$

Fig. 8

By using the result of the computaion to draw vertices on the U-V system and joining vertices in their given order, the axonometric drawing of the object is created as shown in Fig. 7b.

Conclusions

The matrix (Fig. 8) is used to construct an axonometric drawing. The advantage is obvious - for any line of sight the axonometric drawing of the object can be produced except when the projector S is perpendicular to a vertical or horizontal plane. These two cases require no transformation. In addition, if using the computer to calculate and make the drawing, it is only needed to input the modules of projector S and organize the order to join each vertex or point on the curve. In this way, the matrix may be used to calculate not only the axonometric drawing, but also to determine many 3-D geometric problems, such as angles, distances, areas, etc.

2-D and 3-D CAD: Complements to Visualization

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A proposition that 3-D CAD provides an array of unambiguous solutions to engineering problems is illustrated. This proposition assumes that engineering problems are conceived in parallel processing mode while they are solved in sequential processing mode.

Introduction

Engineering problems are conceived in design spaces of higher dimension, in *parallel processing mode*. However, they are solved in subspaces of fewer dimensions, in *sequential processing mode*. It is proposed that 3-D CAD provides an array of unambiguous solutions. Then one or more of these are selected for graphical analysis in 2-D space, where measurement is performed with 1-dimensional *instruments* which assign a numerical value to certain desired problem solution parameters. Alternately, or additionally, mathematical analysis may be performed to evaluate these numerical parameters. A solution is complete when all relevant parameters have been evaluated. The iterative process which leads to a solution can be thought of as a series of excursions, to and fro, between the higher (design) spaces and the lower (solution) spaces. This proposition is supported by examples showing the respective advantages and shortcomings of 2-D and 3-D CAD environments and their mutual dependence in enhancing visualization. Topics include automata, circle construction, four parallel equidistant planes, shortest distance problem, and simplifying complicated solid models.

Parallel and Sequential Automata

Automata are simplified models of devices which systematically carry out logical procedures. Basic arithmetic provides familiar examples. The addition of two numbers will serve to show the formulation of a problem in a higher dimensional space, in parallel, and its sequential solution by repetition of simple steps. An adding automation will be designed first as a parallel device wherein the operation is described by iteration in space. Then it will be redesigned as a sequential device which carries out iterations in time[1].

Figure 1 illustrates a 4-digit parallel adder. A 4-digit augend and a 4-digit addend are pre-

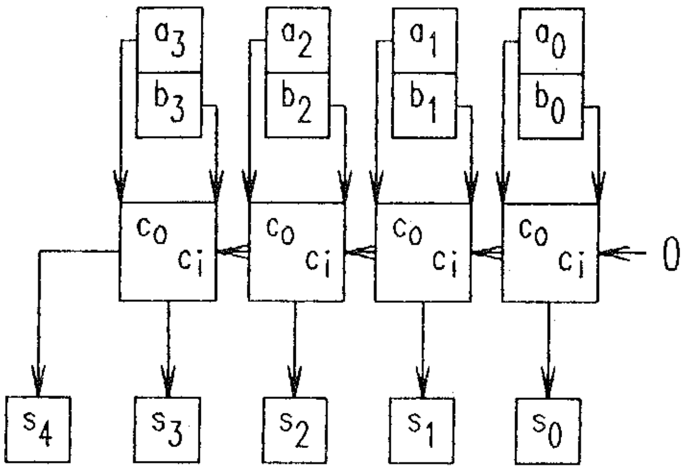

Fig. 1 4-Bit Parallel Adder

sented, one digit of each, to each of four 1-digit *full adders*. The least significant adder, on the right, is provided with a *carry in* of 0. Each higher order adder accepts as *carry in* the *carry out* of its lower order neighbor. Each adder generates a *sum* and a *carry out* digit. The most significant *carry out* is the fifth, most significant digit of the aggregate sum.

Figure 2 illustrates a 4-digit serial adder design. Augend and addend are initially stored in memory devices called *shift registers*. These present augend/addend digit pairs, from least to most significant, in four steps, to a single *full adder*. The 1-digit *carry register* initially presents a 0 to the adder's *carry in*. The most significant sum digit appears in the *carry register* while the augend is replaced by the remaining sequence of sum digits, least significant at the bottom. If a recirculation path is provided from the output to the input of the *addend register*, the addend is restored after the fourth shift step. Otherwise, the addend,

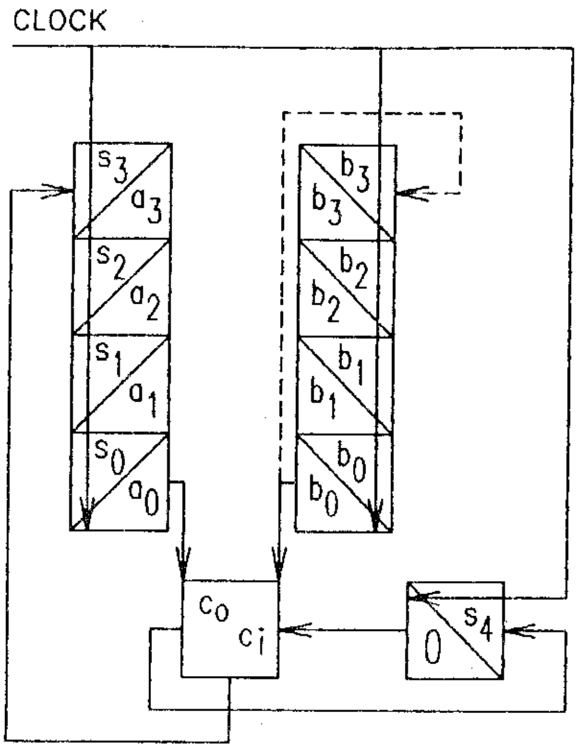

Fig. 2 4-Bit Serial Adder

like the augend, is lost or "forgotten". The shifting steps are provided by a sequence of pulses called *clock signals*. These are applied simultaneously to all three *shift registers*.

What can be learned from the two equivalent variants of a 4-digit adder?

1. The parallel architecture "looks" like the addition problem as taught in grade school. It represents how one would *set up* the step-by-step addition of two numbers.
2. It has as many procedural blocks as there are digits. It is a 1-dimensional line structure.
3. This is a good design model because all of the problem components are presented together, at the same time. It is static.

4. The serial architecture corresponds to how one would *perform* the step-by-step addition of two multidigit numbers.

5. It has only one procedural block, regardless of how many digit pairs are to be added. It is a 0-dimensional point structure. It requires memory which is capable of manipulating the pattern of data stored within it.

6. This is a good procedural model because it illustrates the programmed steps which are implied by the linear structure and its interconnecting data paths. It is dynamic.

Can automata provide, by similar analogy, some insight into measurement with *instruments* in contrast to mathematical analysis? Consider the *full adder* iterative block as two measuring instruments. One compares and matches inputs to a corresponding sum. Similarly, the other measures *carry out*. These are shown in Table 1. It is binary, not decimal but there is no loss of generality because automata can do decimal-to-binary conversions and their inverse. Fortunately, these will not be described.

Now consider the iterative block to be two boolean functions of the three inputs, i.e.,

$$s = (a\cdot\bar{b}\cdot\bar{c}_i) + (\bar{a}\cdot b\cdot\bar{c}_i) + (\bar{a}\cdot\bar{b}\cdot c_i) + (a\cdot b\cdot c_i)$$

and

$$c_o = (\bar{a}\cdot b\cdot c_i) + (a\cdot\bar{b}\cdot c_i) + (a\cdot b\cdot\bar{c}_i) + (a\cdot b\cdot c_i)$$

a 1-D space of discrete independent, orthogonal variables. Apparently, a parallel multidimensional problem conception buys relational simplification at the expense of structural complication. This is summarized in Table 2.

Circle Construction Analysis

Confusion and ambiguity are eliminated from a 2-D problem by reformulating it in 3-D. This particular topic has been treated in detail[2,3]. The problem is to construct a circle subject to three specified constraints of four types. The types are its radius, a center or tangent line, and a tangent circle. Some solutions are easily handled in 2-D and these are commonly described in graphics texts[4]. Some are not easily handled. Even advanced CAD systems cannot manage them in certain instances. Consider the situation shown in Fig. 3 where a

(a) Augend	(b) Addend	(c_i) Carry In	(s) Sum	(c_o) Carry Out
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Table 1

Full Adder Truth Table

... a 2-D space of discrete, dependent variables

Dimension	Automata Example	Nature
Highest	Parallel architecture	A 1-D "line" of full adders; everything presented together
	Serial architecture (Serial "point" contained in parallel "lines")	A single "point" full adder surrounded by dynamic processing elements to animate it
	Truth table (Tabular "line" contained in serial "point")	A pair of orthogonal measuring instruments to evaluate input by comparison; like a scale
Lowest	Boolean equations (A sequence of 3 types of "point" operators capable of procedurally replicating the tabular "line")	A relational sequence of the 3 operators +, ·, ‾

TABLE II
Synopsis of Automata Examples

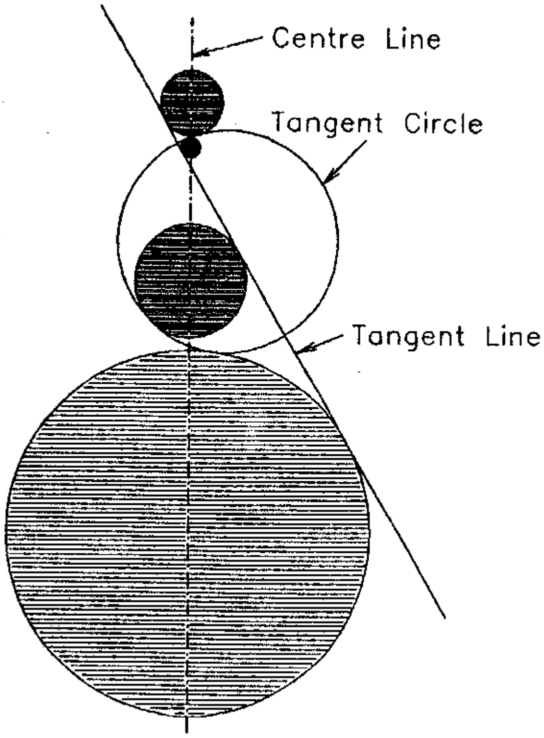

Fig. 3 Constrained Circle Construction

circle, one of the black ones, must be constructed upon a given center line and tangent to a second line and to a given circle. Imagine that all circles on the center line, all those on the right side and tangent to the second line and all those in convex tangency to the given circle can be drawn and one then simply picks the ones that meet all three constraints. This can be done if the notion of a circle as a closed perimeter of length s, enclosing an area of $s^2/4\pi$, is suspended and replaced by a point with the coordinates (x,y,r) which define the center and radius of that circle. All such points, with respect to a center line, would make up a vertical plane whose H-trace was the center line itself. The tangent line would also appear as an H-trace, but the plane containing the circle-points would slope at 45°, upwards to the right. Finally, the convex tangent circle would produce points in the surface of a cone with a base angle and slope of 45°. The apex would be below the H-plane, r = 0, and the cone's H-trace would be the tangent circle itself. To find the unique solution, consider the piercing point of the line of intersection of the two planes with the cone in the region $r \geq 0$. The solution of interest is the larger black circle at the top of Fig. 3. Fig. 4 illustrates the two planes and cone. If one wanted tangent circles on the left, the sloping plane would rise to the left. If one desired concave circle tangency, the cone apex would be raised above the H-plane.

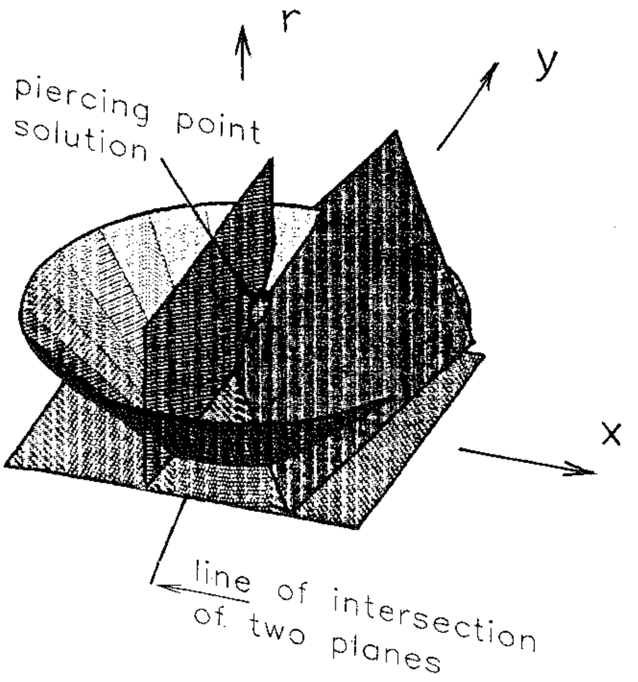

Fig. 4 3-D Solution: External Circle on the Right

The insight gained with this approach is more impressive when considering the construction of circles tangent to three given ones. It may be seen that cones with vertical axes and 45° base angles intersect in plane curves. Therefore the intersection of three cones can be replaced by two planes and any one of the original cones. Again, a line-cone piercing point problem is obtained. Plane equations are obtained from the difference between a pair of cone equations. This means that only two solutions of a single quadratic arise rather than the eight possible when the three original cone equations are solved simultaneously (Figs. 5 and 6). A thorough analysis of this problem in 3-D has produced a comprehensive, efficient, and very short algorithm. It seems quite immune to failure with special cases, like concentric tangent circles and parallel center and tangent lines.

If one performs an unbounded sweep of a 1-D element, such as a line or circle, in 2-space, the swept space is covered entirely and no underlying structure is discernable. On the other hand, in 3-D the resulting surface can be examined and its features can be exploited, often to considerable advantage.

Parallel Equidistant Planes

This is an example counter to the previous one. The 3-D problem breaks down into a 1-D combinatorial exercise which in turn suggests a simple 2-D solution.

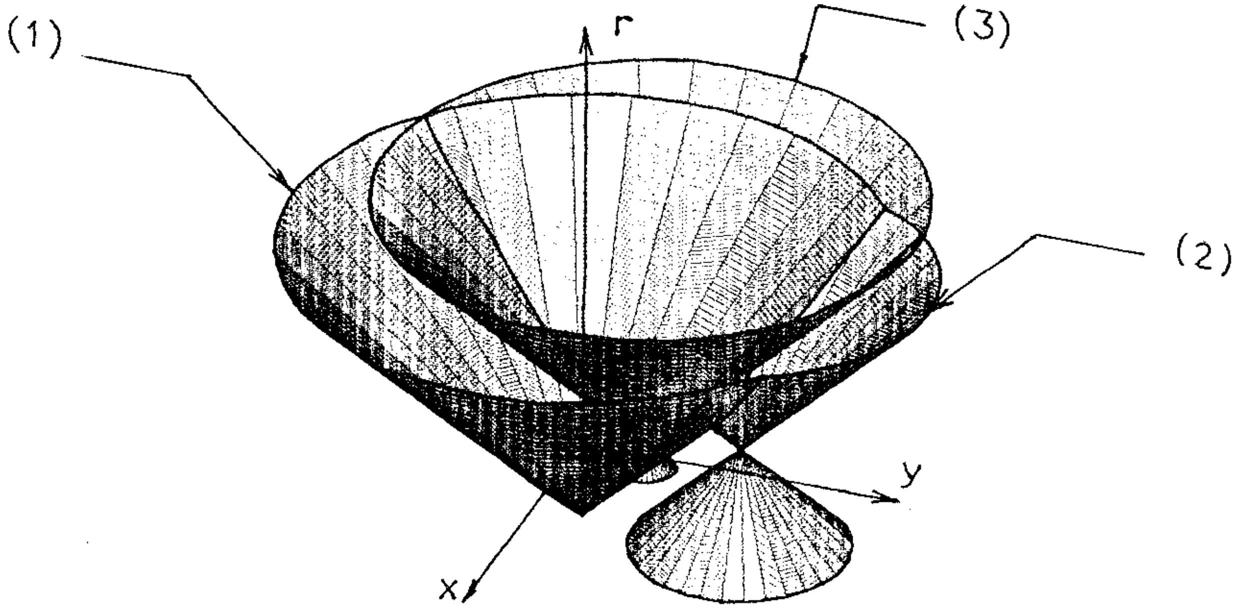

Fig. 5 Point Circle Surfaces for Three Tangent Circles, (1) External (x,y,r) = (0,0,3), (2) Internal (x,y,r) = (0,6,1) (3) External (x,y,r) = (-3,3,2)

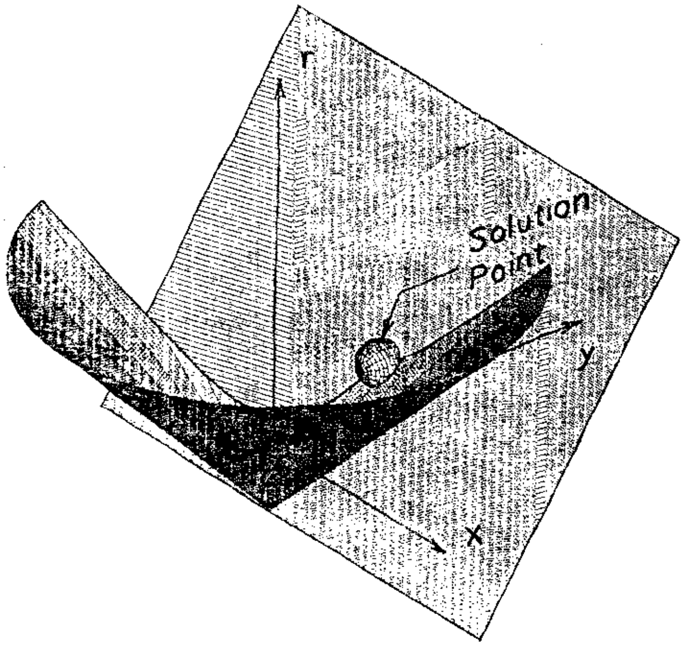

Fig. 6 Cone (1) Cut by Planes of Intersection with Cones (2) & (3)

The task is to find four parallel equidistant planes each containing one of four given points, ABCD, and in that particular order of adjacency. A facility to construct 3-D objects attached to four given points in space does not seem to arouse any insight here. Two useful questions may be formulated: How many ordering sequences are there? and How may two line directions, defining the orientation of a typical plane, be found? Ordering is resolved by noting that four points, hence the four planes, can be stacked like four different colored beads on a string. There are ${}_4C_2$ different outer pairings. For each, there remains an inner pair which can be inserted in only two ways. Therefore, there are exactly $2({}_4C_2) = 12$ orderings. This answers the first question and suggests that any view of the four points be drawn and that the six outer pairings be denoted by the six line segments joining every point to every other. Now the segment AD is identified as the required outer pair and a pair of points E and G are located at the 1/3 and 2/3 interval along AD. E and G must certainly belong to the internal planes. The line segments EB and GC must be parallel to the required planes. The line segments EB and GC must be parallel to the required planes. A pair of lines can be drawn, parallel to EB and GC, respectively, from each of the points A, B, C, and D. These pairs represent the required planes. Fig. 7 is a 2-view construction to show that the desired 3-D result can be obtained. This almost trivial construction also shows any easy way to obtain the algebraic point-normal, $(\mathbf{p},\mathbf{n})$, form of the solution. $\mathbf{p}$ is the position vector to a point in space and $\mathbf{n}$ is the unit normal of a specific plane through that point. The solution can be written immediately, by inspection, as $(\mathbf{a},\mathbf{n})$, $(\mathbf{b},\mathbf{n})$, $(\mathbf{c},\mathbf{n})$, $(\mathbf{d},\mathbf{n})$ where $\mathbf{a}$, $\mathbf{b}$, $\mathbf{c}$, and $\mathbf{d}$ are position vectors of the points A, B, C, and D and $\mathbf{n} = \mathbf{N}/|\mathbf{N}|$ where $\mathbf{N}$ is any normal other than unit magnitude.

$$\mathbf{N} = (\mathbf{b}-\mathbf{e}) \times (\mathbf{c}-\mathbf{g})$$

where

$$\mathbf{e} = \mathbf{a} + (\mathbf{d} - \mathbf{a})/3$$
$$\mathbf{g} = \mathbf{d} + (\mathbf{a} - \mathbf{d})/3$$

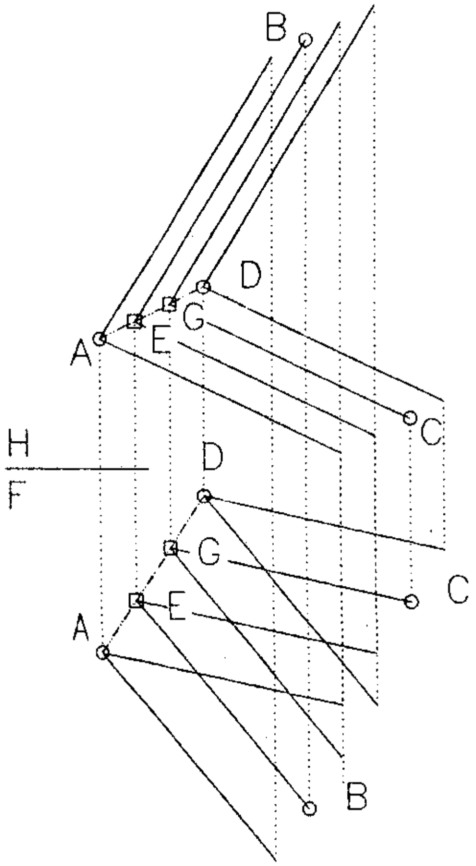

Fig. 7 Four Equidistant Parallel Planes Through ABCD

It has been seen that it is easier to find two intermediate points which trisect a line segment than to similarly divide a bounded region of 3-space where the orientation of the bounding planes is not explicitly evident. Once accomplished, however, the 3-D division is immediately understood to be a virtually identical procedure.

Shortest Distance Between a Point and a Plane

This problem was presented recently[5] as a key element in integrating vector algebra into a graphics course. The parametric equation of a line segment in 3-D is particularly important in that it shows the creation of a line through the motion of a point. If applied recursively, segments of planes and 3-spaces are traced.

1. Point motion produces a line segment between two points specified by their position vectors, **a** and **b**. This is represented by the parametric equation

$$\mathbf{p} = \mathbf{a} + t(\mathbf{b} - \mathbf{a})$$

P is a moving point, or slider, along AB. Its motion is specified by the parameter t. The range $0 \le t \le 1$ defines the segment.

2. Similarly, a plane segment **abc** is represented by two simultaneous linear equations:

$$\mathbf{p} = \mathbf{a} + t(\mathbf{e} - \mathbf{a})$$
$$\mathbf{e} = \mathbf{b} + u(\mathbf{c} - \mathbf{b})$$

P is a slider on AE where E is a slider on BC. Notice that the length of the segment AE changes as it rotates about an axis through A, perpendicular to ABC. The point, P, maps the triangular plane segment, ABC, within the range of the two parameters, $0 \le t \le 1$ and $0 \le u \le 1$.

3. Similarly, a 3-space segment among points **abcd** is represented by three simultaneous linear equations

$$\mathbf{p} = \mathbf{d} + t(\mathbf{g} - \mathbf{d}) \qquad (1)$$
$$\mathbf{g} = \mathbf{a} + u(\mathbf{e} - \mathbf{a}) \qquad (2)$$
$$\mathbf{e} = \mathbf{b} + v(\mathbf{c} - \mathbf{b})$$

P is a slider on DG where G is a slider on AE where E is a slider on BC. Notice that the length of the segment DG changes as it rotates about an axis through D, perpendicular to DAE. Notice also that the length of the segment AE changes as it rotates about an axis through A, perpendicular to ABC. The point, P, maps the tetrahedral space segment, ABCD, within the range of three parameters, $0 \le t \le 1$, $0 \le u \le 1$, and $0 \le v \le 1$.

The shortest distance from a point D to a plane segment ABC can be regarded as solving for u and v so as to find **g** such that

$$(\mathbf{g} - \mathbf{d})\cdot(\mathbf{b} - \mathbf{a}) = 0$$

and

$$(\mathbf{g} - \mathbf{d})\cdot(\mathbf{c} - \mathbf{b}) = 0$$

Substituting this condition of perpendicularity of (**g** − **d**) with respect to the plane segment ABC into Eqs. (1) and (2) yields two simultaneous equations

$$(\mathbf{b} - \mathbf{a})^2 u + (\mathbf{b} - \mathbf{a})\cdot(\mathbf{c} - \mathbf{b})uv = (\mathbf{b} - \mathbf{a})\cdot(\mathbf{d} - \mathbf{a})$$

$$(\mathbf{b} - \mathbf{a})\cdot(\mathbf{c} - \mathbf{b})u + (\mathbf{c} - \mathbf{b})^2 uv = (\mathbf{c} - \mathbf{b})\cdot(\mathbf{d} - \mathbf{a})$$

Note that a typical dot product term, $(\mathbf{b} - \mathbf{a})\cdot(\mathbf{c} - \mathbf{b})$, is evaluated as $(x_b - x_a)(x_c - x_b) + (y_b - y_a)(y_c - y_b) + (z_b - z_a)(z_c - z_b)$. The three stage moving-point-in-moving-line-in-moving-plane model of a bounded segment in 3-D is illustrated in Fig. 8.

Simple movement of elements of fewer dimension to trace out elements of higher dimension is a good way to unite understanding of vector analysis to geometric modeling.

Solid Modeling of a Dynamic Process

A manufacturing operation, the deep draw extrusion of a butt weld pipe tee from tube stock, is illustrated in Fig. 9 by three

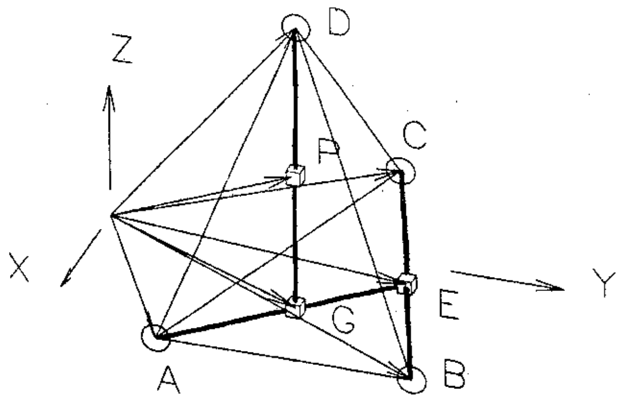

Fig. 8 3-Sider Space Segment Model

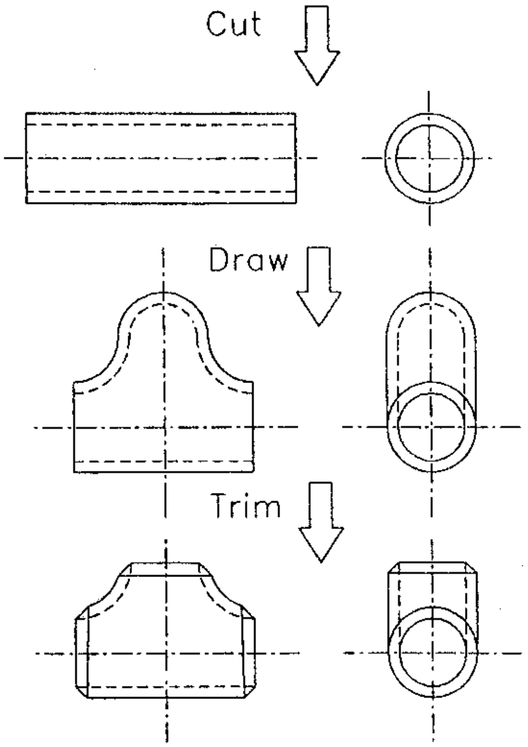

Fig. 9 Pipe Tee Manufacture

process stages denoted *cut*, *draw*, and *trim*. In fact, only the result at the end of each stage is shown. What if one wished to examine a hypothetical smooth shape transition scenario of the extrusion mechanism so as to develop a geometrical basis upon which to build a mechanical model of material flow and deformation? Fig. 10 shows in 2-D how the deformation may proceed in steps by showing successive snapshots of two key circular arcs in tangential continuity along with their limiting rays of subtending angle. Then Fig. 11 shows how two invariant circumferential arcs and a line of wall thickness are swept to form the various B-rep components which build up surfaces and solids which represent a stage in the drawing process where the neck fillet radius subtends 45°; it is a 90° fillet when complete. B-rep stands for "surface Boundary **rep**representa-

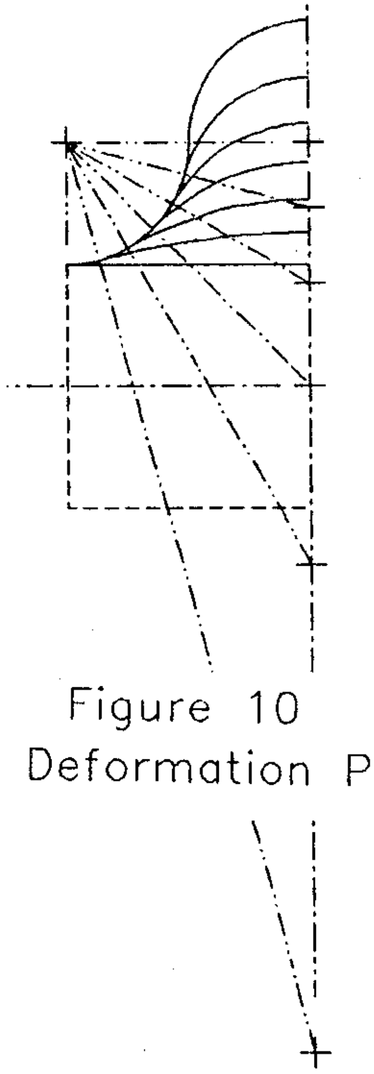

Figure 10
The Deformation Process

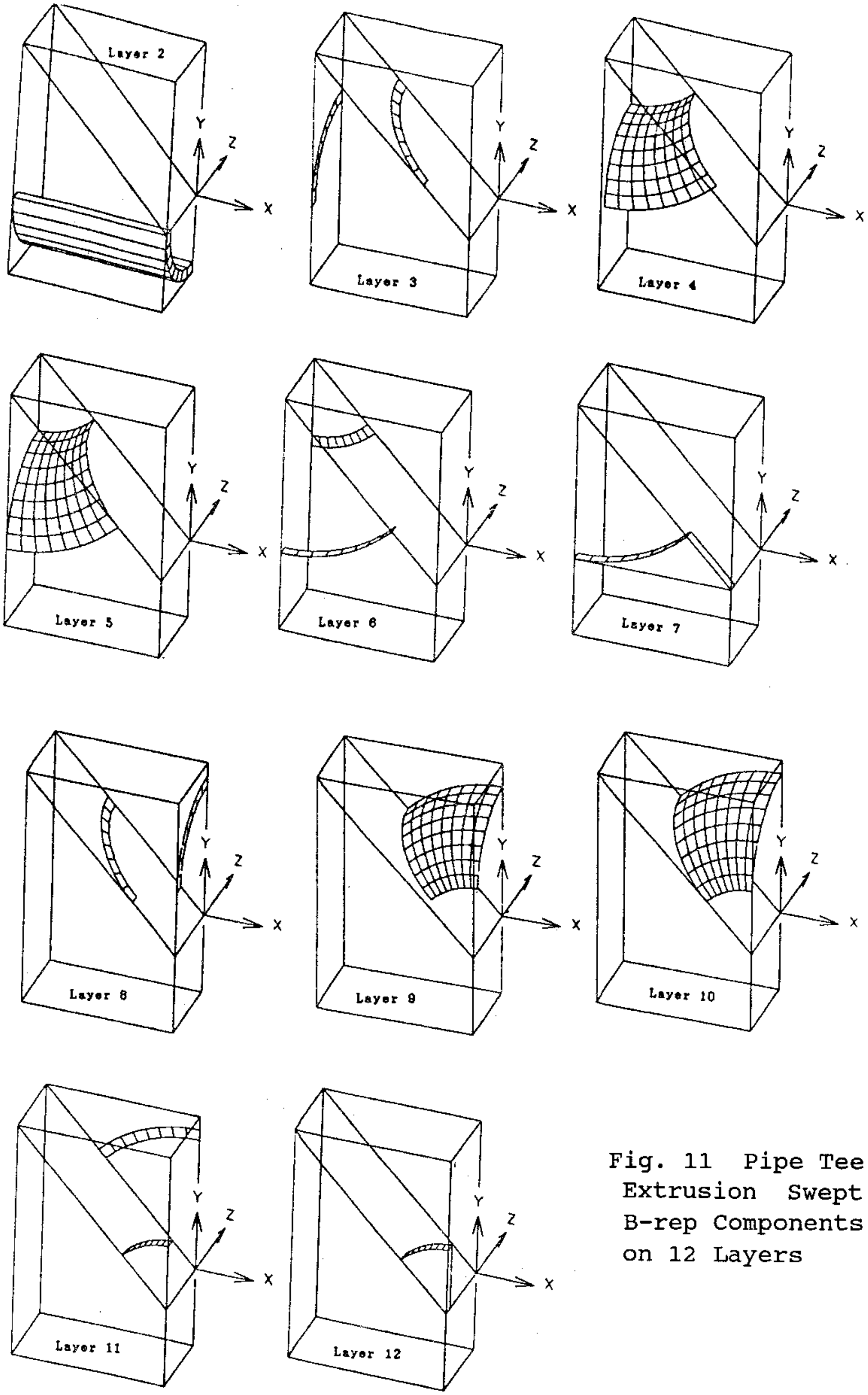

Fig. 11 Pipe Tee Extrusion Swept B-rep Components on 12 Layers

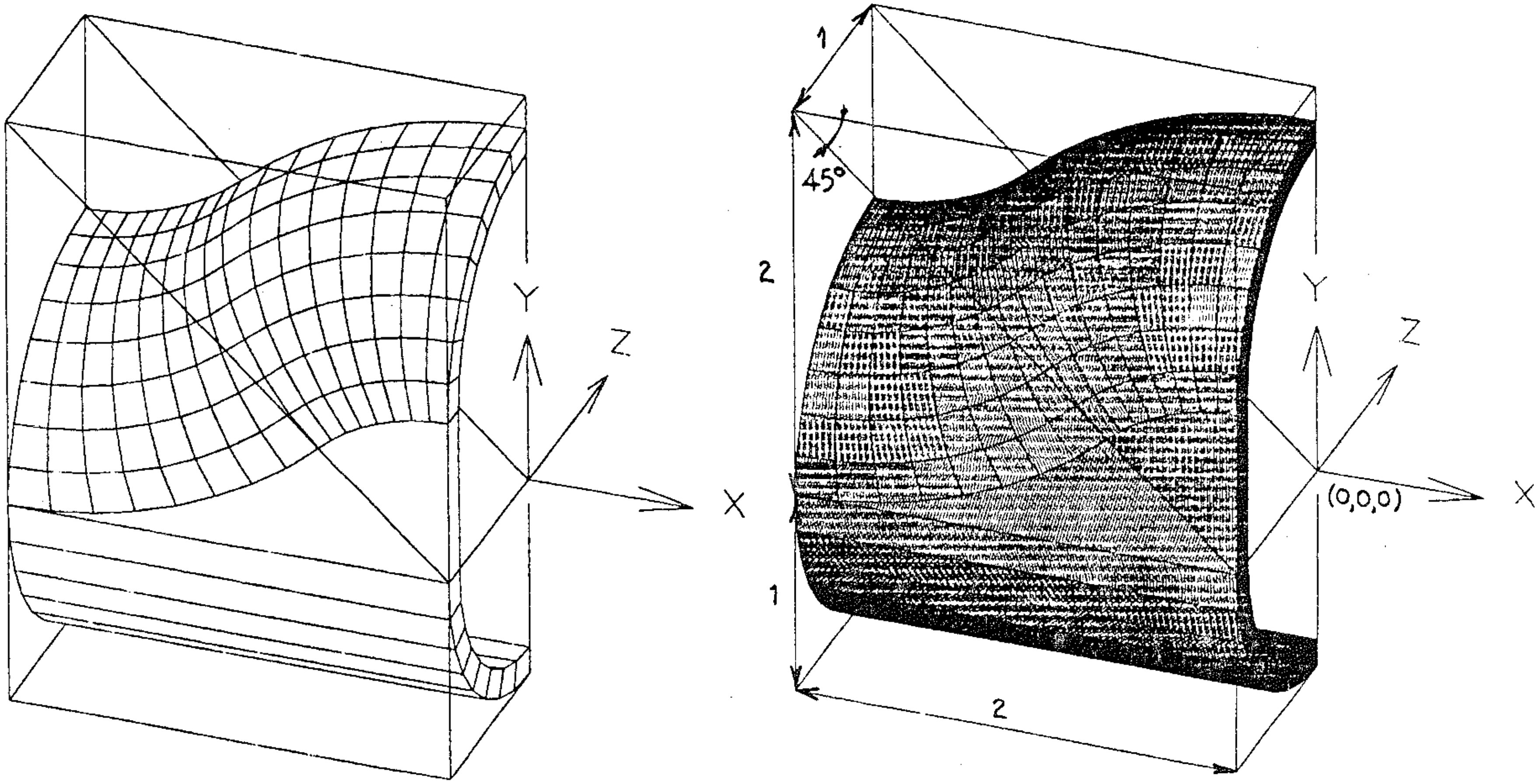

Fig. 12 Pipe Tee Extrusion Assembly of Components

tion", as opposed to other solid modeling alternatives. The main idea of this extrusion model is a plane boundary rotating about the horizontal axis (-2,2,z). It separates a toroidal segment of mean radius $r_{mn} = 2$, that grows from 0° to 90° to form the tee neck fillet, from another, smoothly tangent to it, that grows in the same range of angular subtention while shrinking in mean radius from $r_{md} \rightarrow \infty$ to $r_{mn} = 0$ to finally form the hemispherical dome which caps the neck before trimming. Fig. 12 shows a complete model of a partially formed, 45° filleted tee.

This final example was presented to describe how mobile points, lines, planes, and solid elements are combined in 2-D and 3-D to provide a range of realistic pictorial images which can be united in any combination and in operational sequence. These can then be presented in a suitably animated progression to help explain a highly deformative manufacturing operation.

Conclusion

The foregoing examples are intended to stimulate the following reflection when one sets out to convey or represent information graphically:

1. Some times it is easier to understand the solution to an engineering design problem by visualizing
   a) the initial, *constitutive*, system
   b) the intermediate, *processing*, system
   c) and the final, *product*, system
   together, in parallel, in a space of higher dimension, e.g., additional views or solid models. Separation of detail leads to enhanced visualization.
2. Sometimes it is better to focus on the steps that occur, say, with respect to the product's state, at various stages or time steps during the evolution, e.g., by using
   a) stroboscopic superposition of an image sequence or
   b) an animating medium
   to serialize, i.e., to reduce the dimension of the graphics used to convey information. Unification of detail leads to enhanced visualization. The next CAD system generation must surely engender at least a rudimentary capacity to interactively create and manipulate this sort of *Hypergraphics*.

Acknowledgement

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An Hierarchy of Visual Learning

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An hierarchy of visual learning is proposed giving three primary stages of visual learning as well as seven hierarchical stages. A clarification of terms associated with visual learning is also presented.

Introduction: The Call to Improve Visualization in Engineering Graphics Curricula

Many agree that the need to revise engineering graphics curricula has been accelerated by the increased sophistication of computer graphics technology. It appears that as computer graphics grows in capability and availability, the ties between engineering graphics skills, educational practices, and manufacturing processes strengthen. As a result, many skills and practices are under increasing scrutiny. Chief among these is the need to improve visualization, a fundamental design and communication skill which directly affects many areas of engineering graphics education and manufacturing productivity. Clearly, the tie between computer graphics and visualization is becoming more widely recognized[1-6]. The growth of computer graphics technology makes visualization both more important and more possible. But this may not happen if the development of visual perception fails to become a curricula priority that is actually implemented, as has been suggested[7].

The Need to Clarify the Meaning of Visualization

The reader may have noted that terms such as "visual perception", "spatial cognition", "spatial visualization", "spatial perception", "spatial visualization", "design visualization", and others appear to be used interchangeably in the literature[6,8-12]. Terms may sound close but be miles apart by definition, or sound different and be closely related. A short review of some of these definitions points out the difficulty:

A. Visual Perception

1. The ability to comprehend the environment through the neuro-visual system
2. The ability to "see" what you are looking at
3. The ability to mentally comprehend possible changes in what you are looking at

4. A kind of vivid mental picturing which can aid in visual design and problem solving

B. Spatial Cognition

1. Involves all aspects of knowing, including perception, thinking, imagining, reasoning, judging, and remembering
2. A set of mental representations and procedures that allows an individual to demonstrate a certain spatial ability or a range of spatial abilities
3. The set of mental representations and operations that underlie and allow spatial ability

C. Spatial Perception

1. A function and subsystem of spatial cognition
2. One aspect of figurative knowledge, or perception of successive or momentary states of figurative knowledge

D. Spatial Visualization

1. The ability to mentally manipulate pictorially presented visual stimuli
2. The ability to interpret visual information and mentally manipulate this acquired information

Psychologists and others appear to disagree about as much as they agree about the similarities and differences of important visualization concepts[6,11]. The engineering graphics educator who has wanted to relate visualization theory to the classroom has had a difficult task since no encompassing paradigm has existed to unite all of the visualization concepts. What has been needed is a hierarchy of visual learning which provides a structure to relate the various theories and terms. Once some of the mystery has been cleared , it may be easier to understand why computer graphics, especially animated computer graphics, is such a viable way to improve visualization.

Placing Visualization in a Hierarchy of Visual Learning

Confusion over visualization terminology can be avoided by focusing on underlying concepts related through a visual learning paradigm. The following Hierarchy of Visual Learning (Figs. 1 and 2) offers an example of how visualization concepts can relate to the overall umbrella of visual learning. This paradigm is hierarchically similar to Bloom's Taxonomy of Educational Objectives[13] or Maslow's Hierarchy of Human Needs[14]. Figure 1 provides three Primary Stages while Fig. 2 illustrates seven hierarchical stages.

The three primary stages of Fig. 1 have been carefully labeled and defined for specific reasons. The selected term for the first primary stage, visual cognition, has been used instead of spatial cognition because the author believes that spatial cognition is only one kind of visual cognition. There are other types of visual cognition that are non-spatial. For instance, geometric figures can obtain surface characteristics relating to color, texture, or light that can be perceived independently of depth

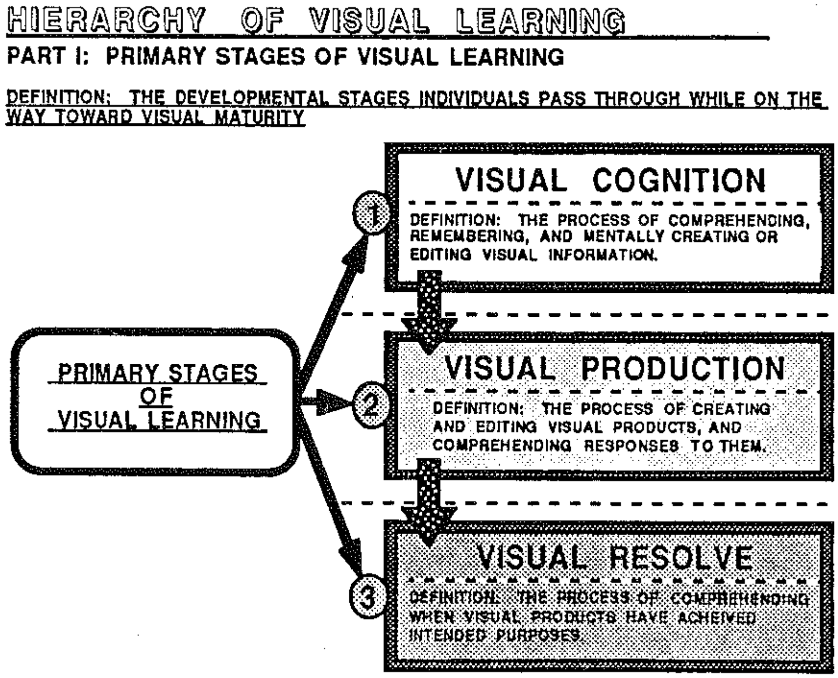
HIERARCHY OF VISUAL LEARNING
PART I: PRIMARY STAGES OF VISUAL LEARNING
DEFINITION: THE DEVELOPMENTAL STAGES INDIVIDUALS PASS THROUGH WHILE ON THE WAY TOWARD VISUAL MATURITY
PRIMARY STAGES OF VISUAL LEARNING
1
VISUAL COGNITION
DEFINITION: THE PROCESS OF COMPREHENDING, REMEMBERING, AND MENTALLY CREATING OR EDITING VISUAL INFORMATION.
2
VISUAL PRODUCTION
DEFINITION: THE PROCESS OF CREATING AND EDITING VISUAL PRODUCTS, AND COMPREHENDING RESPONSES TO THEM.
3
VISUAL RESOLVE
DEFINITION: THE PROCESS OF COMPREHENDING WHEN VISUAL PRODUCTS HAVE ACHEIVED INTENDED PURPOSES.

Fig. 1

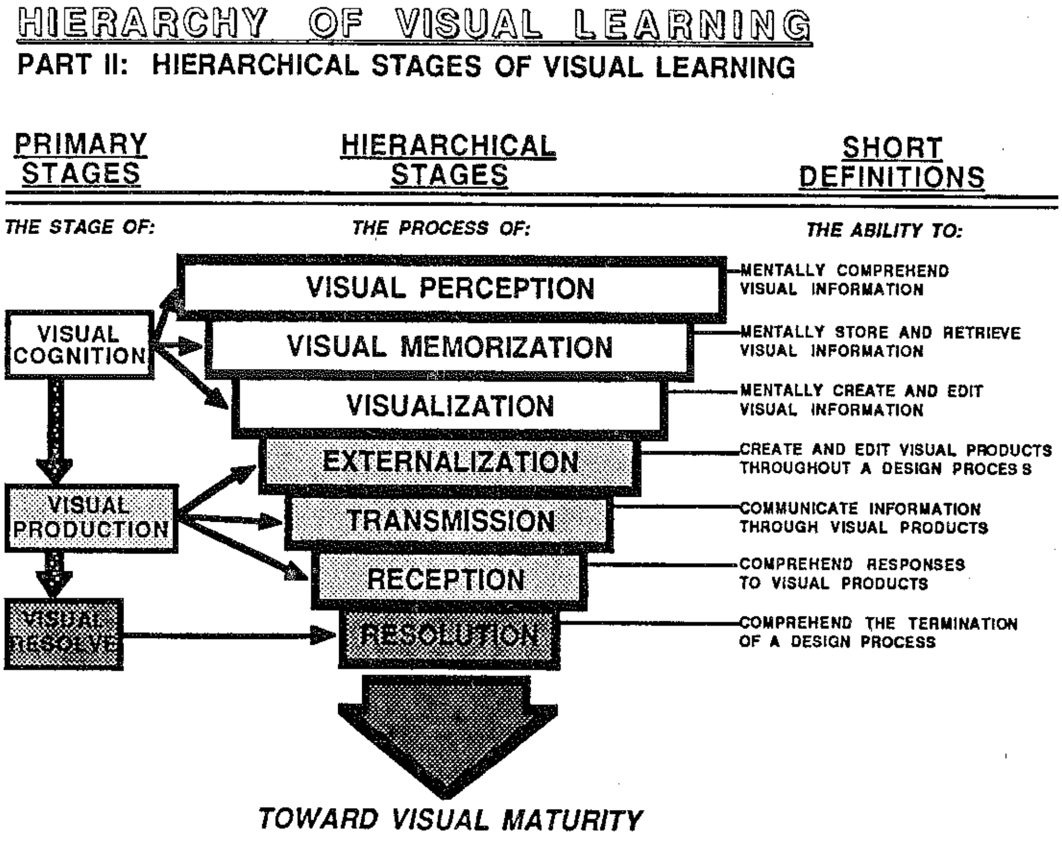
HIERARCHY OF VISUAL LEARNING
PART II: HIERARCHICAL STAGES OF VISUAL LEARNING
PRIMARY STAGES
HIERARCHICAL STAGES
SHORT DEFINITIONS
THE STAGE OF:
THE PROCESS OF:
THE ABILITY TO:
VISUAL COGNITION
VISUAL PRODUCTION
VISUAL RESOLVE
VISUAL PERCEPTION
VISUAL MEMORIZATION
VISUALIZATION
EXTERNALIZATION
TRANSMISSION
RECEPTION
RESOLUTION
MENTALLY COMPREHEND VISUAL INFORMATION
MENTALLY STORE AND RETRIEVE VISUAL INFORMATION
MENTALLY CREATE AND EDIT VISUAL INFORMATION
CREATE AND EDIT VISUAL PRODUCTS THROUGHOUT A DESIGN PROCESS
COMMUNICATE INFORMATION THROUGH VISUAL PRODUCTS
COMPREHEND RESPONSES TO VISUAL PRODUCTS
COMPREHEND THE TERMINATION OF A DESIGN PROCESS
TOWARD VISUAL MATURITY

Fig. 2

or perspective cues, the normally identified means of spatial cognition. Also, one might think that spatial cognition has to do only with the perception of depth, perspective, or coordinate geometry rather than broader definitions sometimes affixed to it in psychological literature (see preceding definitions - spatial cognition). Since objects can be perceived in many ways other than spatially, the term, spatial cognition, may be misleading. Visual cognition then, is a broad term that encompasses an individual's ability to perceive, memorize, and mentally edit any visual feature of any object.

Visual cognition, the second stage, encompasses the three root concepts of visual learning: visual perception, visual memory, and visualization (Fig. 2). Gibson[15, 16] and Eisner[17, 18] agree with the premise that visual perception precedes visual memory and the two make visualization possible. Visual perception is defined as the ability to mentally comprehend visual information; visual memorization is defined as the ability to mentally store and retrieve visual information; and visualization is defined as the ability to mentally create and edit visual information. It has been assumed then, that when visualization is discussed, the discussion is about an individual's entire visual-mental processing ability which includes perception and memory but which occurs just prior to the visual production and visual resolve stages. It is also recognized that visualization does not stop during the visual production and visual resolve states but continues during them just as visual perception and visual memory precede visualization and continue during it. All three stages are hierarchical so earlier stages precede later stages and are in continuous operation.

Gibson[15,16] uses the term visual perceptual learning to describe the three primary stages (Fig. 1). Her visual perception learning is defined as "increasing abilities to extract, interpret, and act upon information coming from the environment into the visual system". Gibson's terms, "extract" and "interpret", parallel the definition of visual cognition (Fig. 2), the mental processes of comprehending, remembering, and mentally creating or editing. Her term, "act upon", parallels the second two primary stages, visual production and visual resolve, the external production processes of creating and editing a drawing, responding to it, then revising it until a point of resolve has been reached. The real differences in the proposed hierarchy of visual learning have more to do with terms selected, the greater detail, and the hierarchical nature of the learning structure provide, not in the underlying psychological concepts.

Conclusion

The hierarchical process of visual learning presents a logical method for solving this portion of the design problem. Clarification of terms is essential in communication with colleagues and students.

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A Dual Approach to Engineering Design Visualization

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The new freshman engineering graphics course at Georgia Tech covers essential design visualization and documentation concepts using a dual approach. Traditional and computer graphics concepts are taught along two parallel and complementary paths (or phases) that eventually merge into an integrated design visualization/documentation phase.

Introduction

The engineering graphics course at Georgia Tech has finally implemented four visual communication axioms that were introduced as propositions in the 1987 *EDG Journal* article entitled "Visual Propositions for Integrating CADD and TRAD[1]. These axioms are paraphrased as follows:

Axiom 1: Maximize design and graphical problem solving opportunities.

Axiom 2: Minimize the need to learn procedural or programming techniques.

Axiom 3: Master the essentials of graphics (i.e., spatial geometry, design process, sketching, visualization, symbology, and standards),

Axiom 4: Utilize state-of-the-art geometric modeling tools (i.e., CADD, SM, and virtual-reality, etc.).

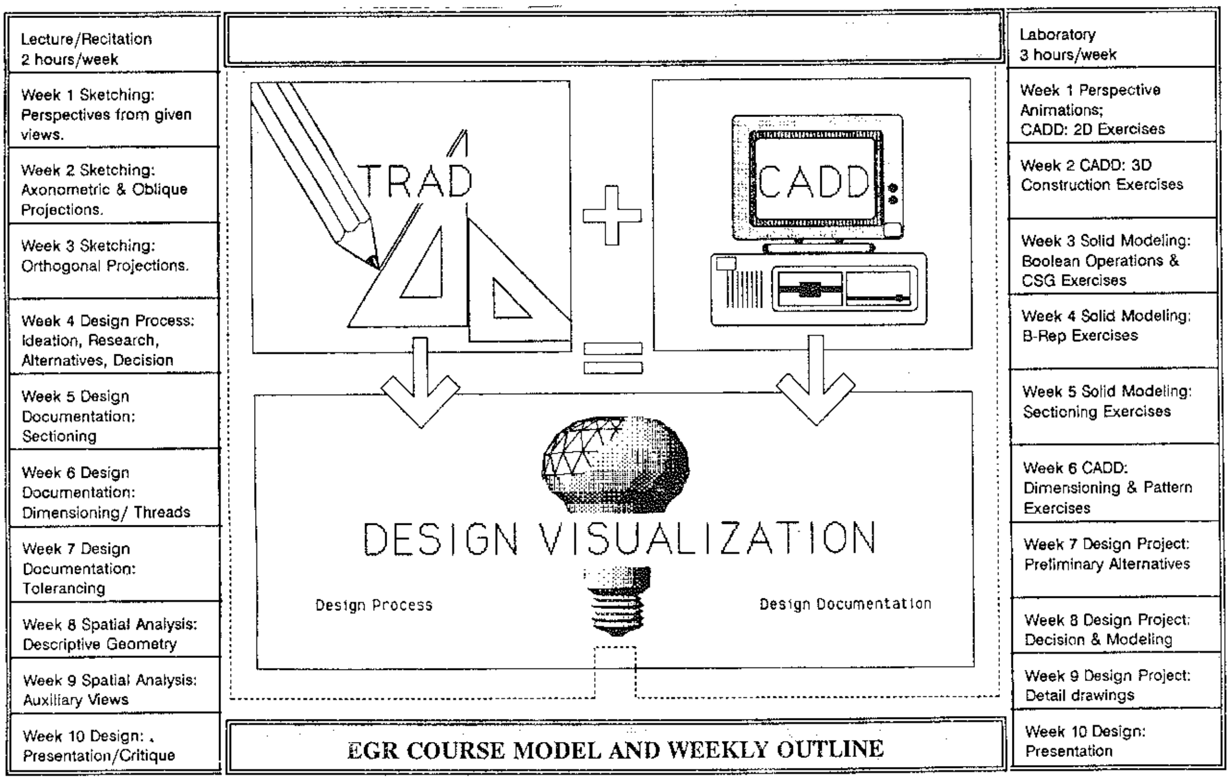
These axioms are intended to guide a new generation of engineering graphics professionals. They are based on EDG research papers and national surveys by Barr[2], Bertoline[3], Jensen[4], Ross[5], McGraw-Hill Research Corporation[6], and Rodriguez[7]. The axioms support the hypothesis that the freshman engineering graphics courses should preserve the traditional (TRAD) aspects essential to graphical communication and design visualization while integrating new tools. They also emphasize the need to ensure that the new tidal wave of technological developments do not erode centuries of sound practices and theory by pioneers like Gudea (plans), Vitruvius (geometric construction), Gutenburg (printing), Alberti (views) da Vinci (creative design/sketching), Monge (descriptive geometry) and Sutherland (computer graphics)[8].

After four years of unrelenting efforts, these axioms have been implemented into a unique graphics course (EGR 1170) at Georgia

Tech. At the same time, the course has evolved into what is now called the Engineering Design Visualization course. This new course addresses the duality (spatial/symbolic) of the student's visual information processing system by incorporating perceptual/analytical visualization, creative/technical design, and descriptive/constructive solid geometry modeling principles in a single quarter course. Fig. 1 illustrates the conceptual model for this dual educational approach. Notice that the TRAD and CADD phases flow (are taught) along two parallel and complementary paths eventually merging into the design visualization phase.

Background

Engineering design visualization, as defined in this section, plays a far more important role in our lives than most of us realize. We can now visualize and communicate our ideas by means of freehand sketches, technical drawings, CADD, computer graphics animation, virtual-reality, and other design visualization tools. However, it should be mentioned that these drawings and geometric models are usually developed using drafting oriented (rather than design oriented) software packages that often neglect the functional requirements of the creative engineering designer[8]. Nevertheless, as inadequate as



Lecture/Recitation 2 hours/week	Laboratory 3 hours/week
Week 1 Sketching: Perspectives from given views.	Week 1 Perspective Animations; CADD: 2D Exercises
Week 2 Sketching: Axonometric & Oblique Projections.	Week 2 CADD: 3D Construction Exercises
Week 3 Sketching: Orthogonal Projections.	Week 3 Solid Modeling: Boolean Operations & CSG Exercises
Week 4 Design Process: Ideation, Research, Alternatives, Decision	Week 4 Solid Modeling: B-Rep Exercises
Week 5 Design Documentation: Sectioning	Week 5 Solid Modeling: Sectioning Exercises
Week 6 Design Documentation: Dimensioning/ Threads	Week 6 CADD: Dimensioning & Pattern Exercises
Week 7 Design Documentation: Tolerancing	Week 7 Design Project: Preliminary Alternatives
Week 8 Spatial Analysis: Descriptive Geometry	Week 8 Design Project: Decision & Modeling
Week 9 Spatial Analysis: Auxiliary Views	Week 9 Design Project: Detail drawings
Week 10 Design: Presentation/Critique	Week 10 Design: Presentation

Fig. 1 Engineering Design Visualization Course Model

these tools may be, recent research indicates the need to learn these graphics software packages[6]. Studies[4,5,6] also show that students should be required to understand the traditional principles of graphics expression and design.

At Georgia Tech the introductory concepts and applications of visual communications and engineering design visualization are taught in EGR 1170 which is offered by the Engineering Computer Graphics Program housed in the School of Civil Engineering. As the name implies, the principal focus of the graphics course is on design visualization. Design visualization comprises the design process as well as design modeling and documentation using TRAD- and CADD-related tools. Design visualization is the imaginative generation, interpretation, and communication of design ideas[8]. Rather than limiting itself to CADD, the design visualization subject incorporates state-of-the-art techniques, as it becomes available, to conceptualize, visualize, and communicate design ideas, inventions, and physical phenomena.

In this design visualization context, the course presents the theory and application of engineering design graphics. Students learn to visualize and model the three-dimensional geometry of devices and systems using national (ANSI) and international (ISO) graphics standards. The topics discussed range from perceptual sketching (with traditional engineering graphics standards) to computer graphics visualization concepts and includes spatial / symbolic hemispheres brain research, pictorials, sketching, elements of projection theory and descriptive geometry, solid and parametric modeling, CADD, as well as creative design and geometric tolerancing. The course emphasizes the integration of computer graphics modeling into the traditional engineering graphics course. The "equation"

CADD + TRAD = DESIGN
VISUALIZATION

symbolizes/summarizes the design visualization dual approach followed (Fig. 1). The TRAD path deals with the traditional engineering graphics topics such as parallel and angular projection, spatial geometry, etc. The CADD path deals with solid modeling and other computer-aided design drafting techniques.

Various experimental/dualistic strategies are currently being tested. One strategy consists of assigning various perceptual visualization and sketching exercises of 3-D objects. After the students have visualized the objects, they are told to construct a solid model of the object. Students use a commercial solid modeling/drafting (SM/D) package that has been customized with a user-friendly interface. This SM/D interface is used to construct the geometric configuration of the part, device, or system created and, then SM files are transferred to a compatible CADD package to generate production drawings.

In addition, "animated assembly drawings" are incorporated to present a dynamic visual representation of the designed device, system, or process in question.

In general, the educational strategy attempts to recreate or graphically simulate real life engineering design experiences in a high-level computing environment. This strategy takes into consideration the duality of human information processing.

Course Objectives

Upon successful completion of the course the students should:

1. Understand how designers, inventors, and engineers are able to devise new products, systems, and processes using design visualization techniques and computer graphics systems.
2. Discern the design information required by those who will be manufacturing devices, constructing buildings, or supervising processes.
3. Use ANSI/ISO graphics standards to document design ideas.
4. Apply graphics fundamentals to solve design and technical problems.
5. Use the computer graphics tools available to model the geometry of devices and systems, e.g., CADD, SM, animation, and word processing/desktop publishing software packages in the production of design documents.
6. Develop higher-order cognitive functions such as observation, visualization, and creative sketching ability.

Course Description

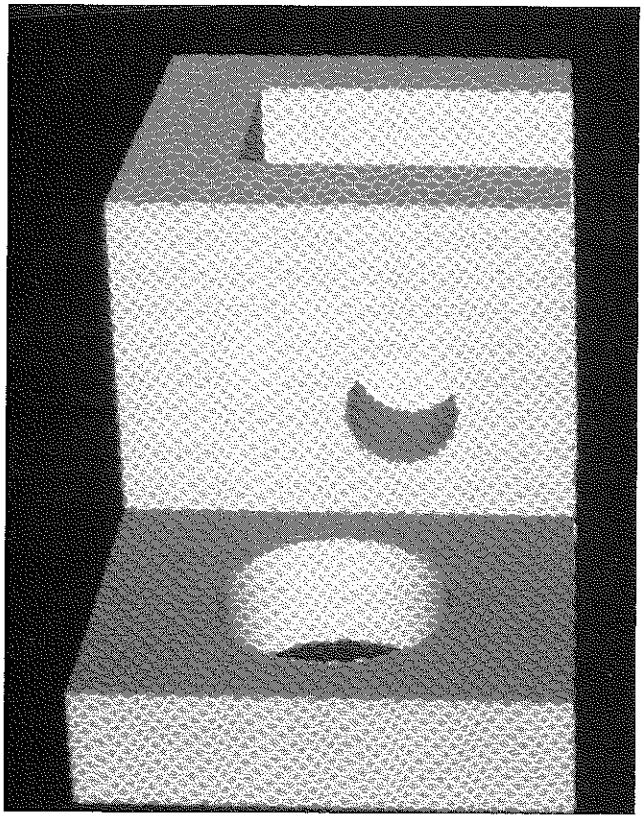
The course is divide into three phases: TRAD, CADD, and design visualization.

I. TRAD Phase: Perceptual/Analytical Visualization

At the beginning of the school term the student encounters a series of sketching and perceptual visualization exercises to develop his/her spatial-hemisphere brain functions. These exercises have been designed to stimulate creative thinking. The students use their constructive imagination and ability for detailed-observation to solve the problems. Traditional pictorial drawings (e.g., perspectives) as well as modified-contour and upside-down freehand drawing techniques are covered. The class exercises have been inspired by the work of Edwards[9], Nicolaides[10], and Beakley[11].

However, the tone of the exercises is futuristic[12], (i.e., fictitious space vehicles, biomedical devices, etc.) rather than naturalistic (i.e., faces, hands, etc.). Occasionally, students practice these techniques in outdoor fun exploratory laboratory sessions. One of the first exercises consists of sketching a pictorial from photographs of computer solid models (Fig. 2). At this point, students are introduced to analytical visualization techniques to solve complex visualization and missing-view exercises. Reasoning skills (a function of the symbolic-hemisphere) and intuition (a function of the spatial-hemisphere) are used to solve the given problems.

II. CADD Phase: Tools of Computer Graphics Visualization Modeling



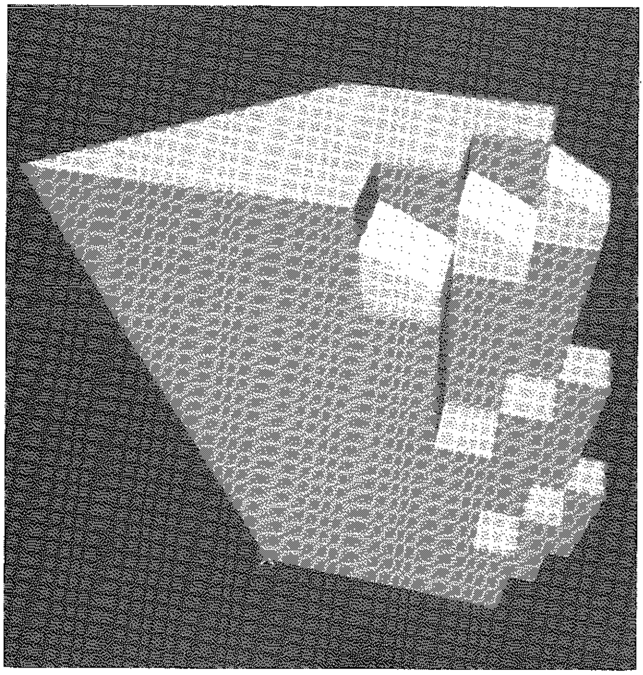


Fig. 2 Exercise: Sketch a pictorial from each solid model

The second phase addresses symbolic-hemisphere brain functions such as verbal (terminology), logic, and sequential reasoning. This phase covers TRAD concepts in conjunction with CADD and geometric modeling software applications. The dual/experimental educational strategy utilized has been coined INTEGRAL (INTEractive GRAphics Language). This is not a computer graphics language but a means of communicating graphically without the need to learn cumbersome algebraic and algorithmic procedures. The student is considered to be an engineering designer using the graphics language to analyze, communicate, and specify information about a simple design project. The TRAD aspects of engineering graphics are discussed in conjunction with computer graphics applications and theory. Some aspects of descriptive geometry (points, lines, and planes) are discussed with geometric entity construction. Furthermore, TRAD geometric constructions are compared with the corresponding CADD commands and menu sequences required to generate arcs, lines, and other geometric entities. ANSI/ISO standards are taught concurrently with computer drafting functions.

An interesting, and perhaps unique, characteristic of this course is that solid modeling and hidden-line-removal algorithms are discussed and related to traditional descriptive geometry methods to solve volume intersection problems.

III. Design Visualization Phase: Design Process and Documentation

The third phase of the course demands both creativity (a function of the spatial-hemisphere) and analytical skills (a function of the symbolic-hemisphere). In this stage the student is required to conceive alternate solutions to a simple design problem. For example, one project consisted of designing a rubber-band propelled vehicle. The vehicles were "raced" on a three-meter-long table. The problem was to design the vehicle in such a way as to travel three meters from one end of the table and stop exactly at the other end (edge) of the table. In addition to the design process, this phase covers ANSI's sectioning and geometric dimensioning/tolerancing standards. Students are required to turn in a complete description of their device including manual sketches of the design process idea, solids modeling, assembly drawings, details, specifications, and a brief written report. The phase also includes the visualization and analysis of engineering data. The objective is to represent equations, mathematical models, and complex information in a clear and concise graphical form.

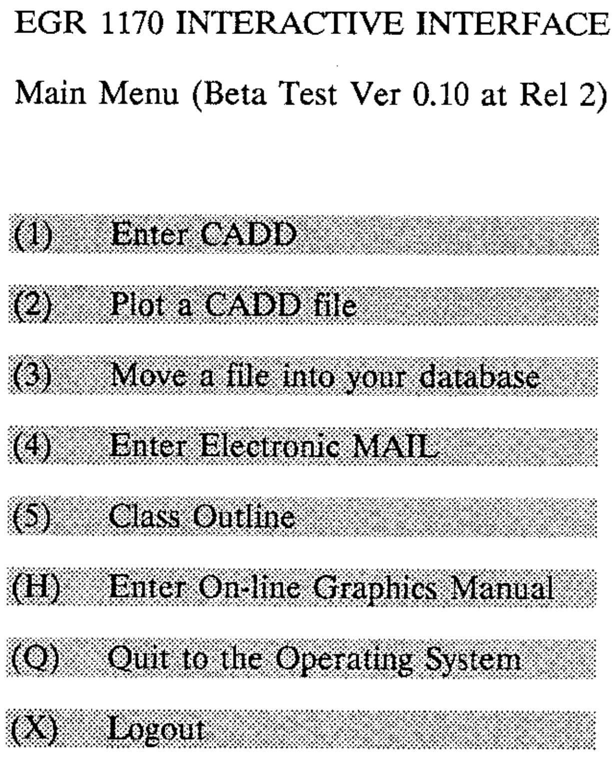
Course Administration

Aerospace, civil, engineering science and mechanics, ceramic, mechanical, nuclear, and textile engineering students are required to take the course. Many architecture, management, computer, physics, and electrical engineering students take it as a technical elective. An average of 400 students a quarter register for the course. Over 1400 students register yearly, forming a relatively uniform cross-sectional representation of all the engineering programs available. This profile facilitates an interdisciplinary interaction among students, especially when it comes time to work on the final design visualization project.

The course was developed and is taught by a faculty member in the School of Civil Engineering. He is assisted by ten graduate teaching assistants who are pursuing their M.S. or Ph.D. in the Engineering Computer Graphics Program. In addition, one full-time engineer supports the course's laboratory and other research activities within the program. There are plans to hire additional personnel with a mechanical engineering academic background and previous manufacturing experience.

A total of twenty class sub-sections with twenty students each are offered per quarter during the academic year and ten sub-sections are offered during the summer quarter. Each class section meets a total of five hours per week. The theory and practice are divided among two hour-long lecture/recitation (two class sections of 200 students each) and three hour-long laboratories (twenty sub-sections) per week.

The lecture covers the theoretical aspects of traditional graphics and computer-aided engineering design visualization. Students are exposed to a short practice exercise or quiz every other class. Most exercises are graded by GTA's based on the instructor's criteria. The students apply the graphics concepts discussed in the lecture during the laboratory sessions. These laboratory sessions present the basic introduction to computer-aided design and drafting technologies (i.e., CADD, solid and parametric modeling, menu and command structure, geometric manipulation statements, data base management, format and syntax, etc.). These sessions are conducted in facilities which provide an open laboratory environment for the students to apply basic concepts and develop ideas in graphical and geometric form. During this flexible period the student is constantly being referred to an on-line graphics manual that was developed exclusively for the CADD software package used. Fig. 3 illustrates the user-interface for this utility and Ref. 13 lists the source code. The electronic manual contains graphic exercises, tutorials, and up-to-date information.



EGR 1170 INTERACTIVE INTERFACE

Main Menu (Beta Test Ver 0.10 at Rel 2)

(1) Enter CADD
(2) Plot a CADD file
(3) Move a file into your database
(4) Enter Electronic MAIL
(5) Class Outline
(H) Enter On-line Graphics Manual
(Q) Quit to the Operating System
(X) Logout

Fig. 3 EGR User-Interface

The cost of materials for the course is minimal. The only items required are a metric scale, 30°-60° and 45° triangles, 2H, HB, and 2B pencils, eraser, white paper, isometric and orthographic sketching pads and the textbook[8]. Students are not required to have their own microcomputer (and software) or graphics terminal. However, if they own a personal computer and a terminal emulator package, they may complete their projects using their system. In this case, they are provided with a communication package that allows them to use the campus mainframe and workstations via Ethernet. Most students access the system from several terminal and workstation clusters administered by the university.

Advantage of Using the Dual Approach

The main advantage of using the dual approach is that students are able to clearly understand the underlying theory of graphics while using the latest tools available. Judging from test records for academic year 1987-88, most (93%) of the students who completed the tasks required were able to pass their examinations for both visualization and geometric modeling skills with a satisfactory or better grade. This was an improvement over the previous year where students had a lower test performance; only 73% were able to pass comparable tests and grading procedures.

In addition, some advanced students have been involved in the development of graphical optimization techniques, on-line graphics exercises, interactive tutorials, "intelligent" graphics, and animation. These research efforts enhance the delivery of the EGR 1170 course as well as providing a source of economical support to advance EGR students.

Conclusions

The EGR course offers students the opportunity to learn the graphics language of computers in conjunction with the traditional engineering design graphics concepts. Students attend lectures and work on freehand exercises as well as on computer-based problems. This experience allows them to use the graphics fundamentals in future engineering design, analysis, and programming courses. The availability of various CADD systems, individualized lab instruction, and practical design problems makes the EGR 1170 course one of the richest experiences available to the freshman student at Georgia Tech. However, much work remains to be done in the integration of geometry and visual reasoning concepts into this course.

Acknowledgement

The author wishes to acknowledge the assistance and/or information provided by the EGR Staff, the CAE/CAD Laboratory, and the Office of Computing Services at Georgia Tech.

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Distinguished Service Award

Presented to

Clyde H. Kearns

June 26, 1990
ASEE Annual Conference, Toronto, Ontario, Canada

Introductory Remarks

by
John Demel

Clyde Kearns graduated spring quarter, 1942 from The Ohio State University with a Bachelor's degree in Chemical Engineering and an appointment as 2nd Lt. in the U. S. Army Corps of Engineers. Professor Thomas E. French retired from teaching at the end of the same quarter, after 44 years of OSU service and 36 years as the first and only Chair of the OSU Department of Engineering Drawing. Clyde had worked as a part-time student assistant in the department during his junior and senior years.

Clyde saw World War II service in the U.S., India, and China. On "VJ Day" he was sitting on a hillside in southwest China in charge of the 1st Platoon of Company A of the 1880th Engineer Aviation Battalion. The battalion was maintaining 460 miles of 2-lane gravel road at the northern end of the Stillwell Road between the Chinese cities of Kunming and Kweiyand.

During spring quarter, 1946, while on terminal leave, Clyde returned to OSU as Instructor in Engineering Drawing. Professor Ralph S. Paffenbarger was now department Chair. "Paffy" had three abiding interests, almost to the exclusion of all others. They were OSU athletics, particularly Buckeye football; the Engineering Drawing Division of the Society for the Promotion of Engineering Education, the forerunner of ASEE; and the Y14 Committee of the American Standards Association. Every one of his faculty members was a member of the Division. There were no exceptions. Professor Paffenbarger chaired the department from 1944 until his retirement in 1964. He served as Chair of the ASEE Engineering Drawing Division in 1950-51 and received its Distinguished Service Award in 1956.

Clyde received his Master's degree in chemical engineering and was promoted to assistant professor in 1950. From 1957 to 1959, he was Instructor in Chemical Engineering at OSU. He spent the next four years in industry with Union Carbide Corporation in Oak Ridge, TN and Tonawanda, NY (nuclear reactors, radioactive isotopes, and cryogenics) and with CVI Corporation in Hilliard, OH (cryogenics, helium refrigeration).

Clyde returned to OSU in 1963 as Associate Professor of Engineering Drawing. That same year he joined a group of faculty members from several departments who were teaching the initial course in computer programming in the OSU College of Engineering. It was a senior elective in the Department of Engineering Mechanics.

In 1967 the Engineering Drawing Department's name was changed to Engineering Graphics, and the engineering mechanics course became an engineering graphics course. During summer, 1968 Clyde taught a programming course in the newly organized OSU Department of Computer and Information Science. On February 1, 1969, Clyde received an additional regular appointment as associate professor in that department. Later the same year, he was promoted to professor in both departments.

Clyde served as Chair of the OSU Department of Engineering Graphics from 1973 to 1977. In January, 1981 he retired from full-time duty and has been teaching on a part-time basis, in graphics or computer science, ever since.

Clyde's association with the *Engineering Design Graphics Journal* began in the summer of 1972 when he was appointed to fill out the last two years of Robert Christenson's term as Circulation Manager - Treasurer. Clyde was elected to a full three-year term as CM-T in 1974. He then served as Division Vice-Chair in 1977-78 and as Chair in 1978-79.

Clyde's association with the *Journal* resumed with his appointment as CM-T by Larry Goss in January, 1984. The 1984 revision to Division By-Laws changed the office of CM-T from an elected office to an appointed one in order to house *Journal* circulation and finances in a permanent location at The Ohio State University. Clyde Kearns and the OSU Department of Engineering Graphics derive a great deal of satisfaction from this association and hope it may continue for many years to come.

It gives me great pleasure to be able to present this year's Distinguished Service Award to Prof. Clyde H. Kearns of The Ohio State University. It reads:

Distinguished Service Award

Clyde H. Kearns

Clyde H. Kearns Is Hereby Recognized By The Engineering Design Graphics Division Of The American Society For Engineering Education For His Outstanding Contributions To The Division And To Engineering Education. He Has Served The Division In Many Capacities Including Chairman. His "Indefinite" Tenure As Circulation Manager Of The Engineering Design Graphics Journal With His Meticulous Attention To Detail Has Been Outstanding! This Award Is The Highest That Can Be Presented By The Division To One Of Its Members. Clyde H. Kearns Has Been Selected For This Honor By His Colleagues For His Outstanding Career At The Ohio State University As An Educator, Scholar And Administrator.

PRESENTED THIS DAY JUNE 26, 1990
AT THE ASEE ANNUAL CONFERENCE
TORONTO, ONTARIO, CANADA

Recipient's Remarks

by

Clyde Kearns

Ladies and Gentlemen:

Let me first thank all of you for being here tonight to make this such a memorable occasion for me. Let me also express my appreciation to the members of the Distinguished Service Award Committee; Rollie Jenison, Ron Barr, and Merwin Weed, for their kindness and consideration in selecting me to receive this year's award. It is a singular honor. That fact is obvious to anyone who examines the list of names of past recipients which I have taken the liberty of placing at your table in the small blue folder.

The first Distinguished Service Award was presented to Prof. Frederic G. Higbee of the University of Iowa on June 21, 1950. Prof. Higbee was a charter member of our Division. He was Editor, from 1931 to 1936, of the T-square page which appeared in the Journal of Engineering Education. He chaired the Publication Committee which published the first issue of the Journal of Engineering Drawing in December, 1936. The other names on the list are equally well known. I am indeed honored to have my name added to such an illustrious group.

I have also taken the liberty of placing a list of the past Chairs of this Division in the folder. That list begins with the name of Prof. Thomas E. French of The Ohio State University. Prof. French retired from teaching in 1942, after 36 years as the first chair of the OSU Department of Engineering Drawing.

Prof. Harvey H. Jordan of the University of Illinois, Prof. Clair V. Mann of the Missouri School of Mines, Prof. Higbee, and Prof. French drew up the petition which resulted in the formation of the Engineering Drawing Division at the Annual Conference of the Society for the Promotion of Engineering Education, now ASEE, at Chapel Hill, NC in June, 1928.

I recall that Prof. French was an imposing figure. He was an important person on the campus of The Ohio State University. His textbooks had gone through several editions and were used all over the world. He served on many college and university committees. He was a member of the faculty group which, in January, 1912, presented Ohio State's application for admission to the Western Conference, now the Big Ten. He served as the first President of the OSU Athletic Board from 1912 to 1930 and as OSU's faculty representative to the Big Ten from 1912 until his death in 1944.

Prof. French was a leader in the planning for Ohio State's 86,000-seat football stadium completed in 1922, just ten years after OSU joined the Big Ten. There were many who claimed that Ohio State would never fill the stadium. They were wrong. Prof. French was right. Our French Field House is named for him. As a part-time student assistant, I had few occasions to speak to Prof. French. When I was called into his office, I stood at attention, answered questions politely, and, when dismissed, backed respectfully out the door.

I also had the privilege of working under Prof. Ralph S. Paffenbarger who retired in 1964 after 45 years on The Ohio State faculty, the last 20 years as Department Chair. "Paffy" considered this Division to be one of the most important aspects of his professional life. During his year as Chair of the Division, he promoted the Summer School at the 1951 ASEE Annual Conference at Michigan State University. I recall that the group from OSU traveled to East Lansing in two automobiles. Paffy drove one. By the luck of the draw, I wound up in the other. Paffy was a wild driver. The two professors who rode with Paffy swore afterwards that they would never again set foot in an automobile with him.

Paffy was instrumental in arranging my appointment in 1965 as Secretary to the ASA Y14 Sectional Committee, chaired at that time by Prof. Fred Spalding of the University of Illinois. More recently, as a member of the Y14.4 Subcommittee, I was very pleased to be able to help him with the 1989 revision to the standard on pictorial drawings.

There is a third list of names I did not bring tonight, but which, just as surely as the first two, deserves our attention. That is the list of present and past editors of the *Engineering Design Graphics Journal*. Prof. Barry Crittenden of VPI is the current Editor, preceded by Jon Duff of Purdue, Mary Jasper of Mississippi State, Paul and Judy DeJong of Iowa State, Jim Earle of Texas A & M, and so on. The *Journal* is in its 54th year of publication. This would not be so if it were not for the dedication and hard work of its many editors, associate editors, and advertising and circulation managers over the years. We owe all of them a debt of gratitude.

This organization has also been fortunate in having the strong support of a number of fine colleges and universities. We owe a vote of thanks to our deans and department chairs. If it were not for them, we might not be enjoying this wonderful banquet tonight. It is appropriate that our lists of names indicate the institutions represented.

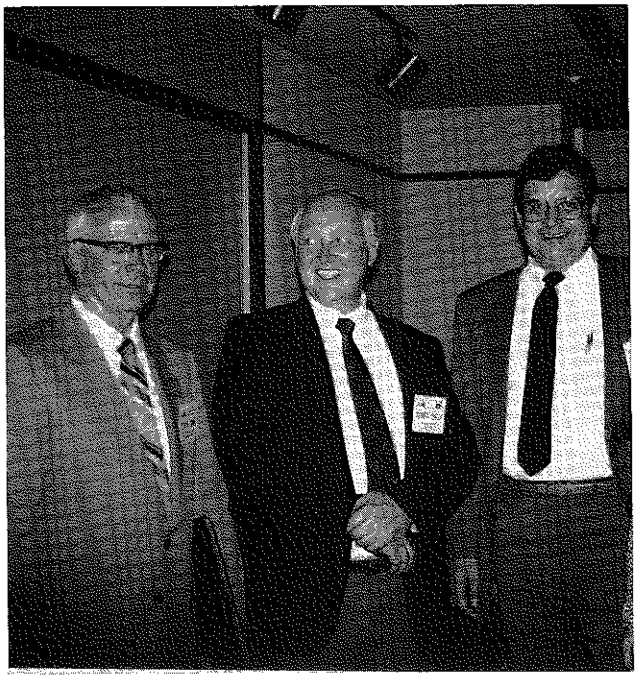
My association with the *Journal* began in 1972 when I received a box of 3 by 5 cards and a check in the amount of $1192 from Bob Christenson at GMI. Once the mailing addresses had been punched onto IBM cards, I was able to access a PDP 15 computer in our Chemical Engineering Unit Operations Laboratory, with a hands-on card reader and line printer. A table-top system in my office, with floppy drives, hard disk, dot matrix printer, and terminal access to VAX hardware and software, has changed things considerably.

Until recently we depended on ASEE headquarters for member rosters and mailing labels. At the 1989 midyear meeting in Tuscaloosa, it was decided that we should maintain our own member files and prepare our own rosters and labels. Division members recently received the first Division Directory prepared recently by Prof. Edwin Boyer of The Ohio State University. Ed and I are hoping to be able to communicate more effectively with every member of the Division. Ed deserves a round of applause for his work.

As I close my remarks, I wish to indicate to you how much I enjoy my association with this group. I find that, at my age, I cherish more and more the familiar voices, the smiling faces, and the warm handshakes that we enjoy at these meetings. It has been a privilege to be associated with the Engineering Design Graphics Division. I am hoping to be able to continue my efforts on behalf of the Division and the *Journal*.

I indicated to Rollie Jenison, in my reply to his letter, that I should be giving an award to all of you for the opportunity to serve and the satisfaction that it brings. The Distinguished Service Award is a major event in my life.

Again, thanks to all of you from the bottom of my heart.

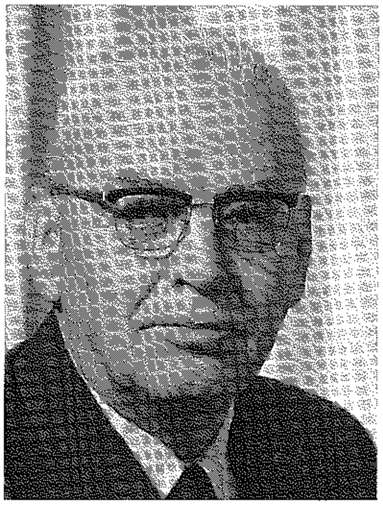


Clyde Kearns, Rollie Jenison, and Frank Croft after presentation of the DSA to Professor Kearns

A Remembrance

Matthew McNeary

1910 - 1990



Matthew McNeary, a member of ASEE and this Division for many years, died on April 2, 1990 in Orono, Maine following a long illness. He is survived by his wife, Ester, two daughters, two sons, and eleven grandchildren.

Professor McNeary, known as Matt to his colleagues and friends, was born in Philadelphia, PA on September 8, 1910. He received his early education in the public schools of Philadelphia and graduated from high school in 1927. Following graduation, he worked for a year for the Electric Storage Battery Company in Philadelphia.

He entered Penn State University in 1928 and received a Bachelor of Science degree in Civil Engineering in 1932. Following graduation, he worked for several years (1933 - 35) in the Production Department of the Electric Storage Battery Co. He served as an Instructor in the Civil Engineering Department at the Penn State University between 1935 and 1937. Professor McNeary married in 1938.

His long career with the University of Maine at Orono began in 1937. Time was devoted to graduate work at the university, and he received his Master of Science degree in Civil Engineering in 1941. Between 1943 and 1946 he worked as an Assistant Chief Engineer for the Eastern Corporation in Brewer, Maine. Upon his return to the University of Maine he progressed through the academic ranks to professor and served as Chairman of the Department of General Engineering from 1951 until 1975.

Professor McNeary was a member of the Maine Association of Engineers and ASEE and was a registered professional engineer. During his career he authored several texts and articles on engineering graphics.

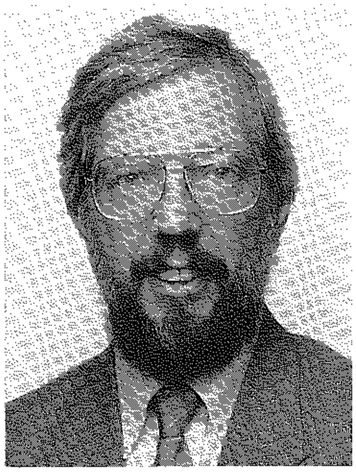
Matthew McNeary will be remembered by our Division for his numerous activities associated with it, including serving as Chairman in 1962-63. This extensive service was recognized in 1971 when he was given the EDGD Distinguished Service Award.

A colleague stated upon his retirement, "As a person who has always enjoyed Professor's McNeary's effective articulation of his reasoned and seasoned views, invariably marked by good sense and good humor, ..., I endorse wholeheartedly ... comments about his four decades of unselfish and loyal service". Our Division was fortunate to have had such an educator as one of our members.

Hank Metcalf

Chairman's Message

by
Jon Jensen



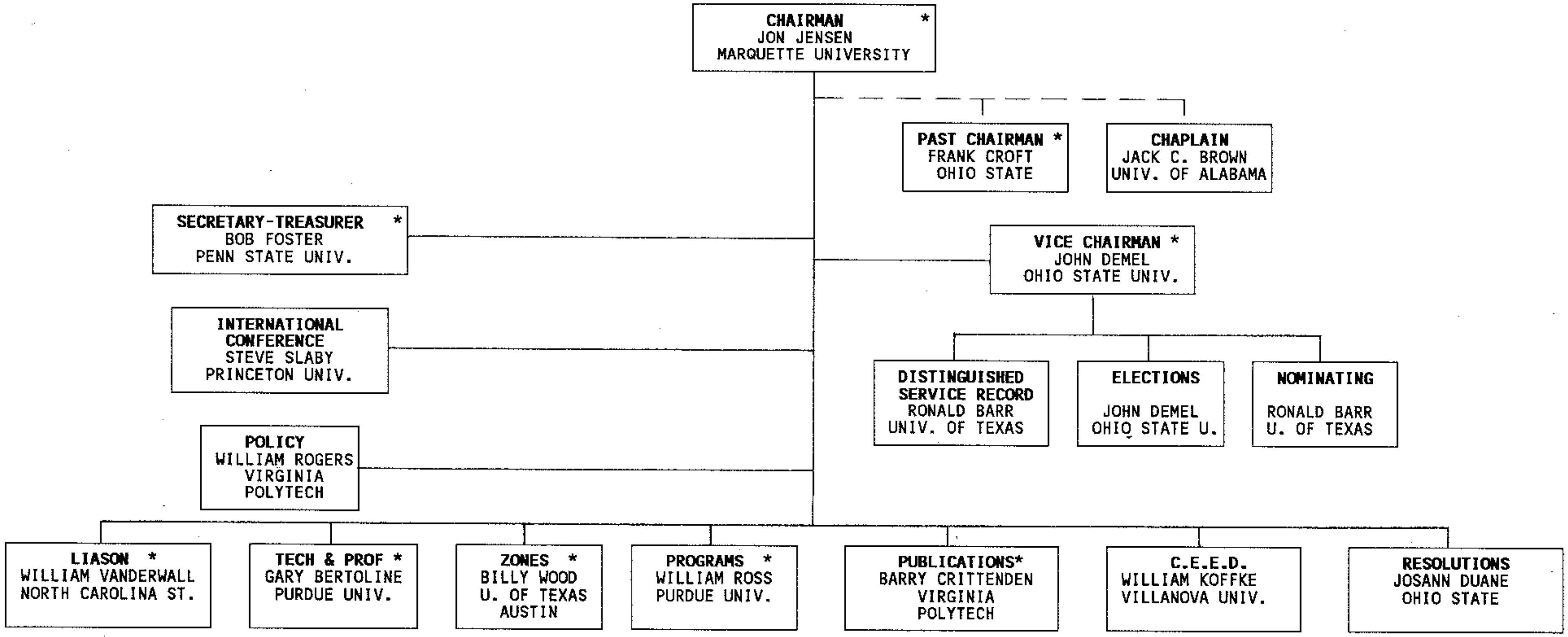
It is a privilege to begin my tenure as EDG Division Chairman with my first "Chairman's Message" in the EDG Journal. The past year as Vice Chair was a positive, rewarding experience, and I look forward to working with (and for) the membership of the Division.

Those of you who attended the Annual ASEE Conference in Toronto this past June were treated to a very cosmopolitan environment. The city was spectacular and the conference, as usual, was most successful. The division events were "first-rate" and well attended. Our thanks to Fritz Meyers and Bill Ross for coordinating a high quality event.

A highlight of the annual conference is always the EDGD Awards Banquet. This year we were delighted to learn that Clyde Kearns of The Ohio State University was chosen for the Division's Distinguished Service Award. Our congratulations go out to Clyde for **forty years** of service in the Division, having become a division member in 1950. I was two years old at the time, and he was Division Chairman (1978-79) the year that I became a member of the Division. So much for dating myself.

This year and certainly the 90's contain many educational challenges that we must face. In fact, the theme for the 1991 ASEE Annual Conference will be "Challenges of the 90's. It is significant that we have a Division that is devoted to the technology of engineering graphics AND education (the <u>content</u> and the <u>delivery</u>) that clearly makes it unique among professional organizations. As far as engineering graphics, I have heard of the 90's referred to as a "new era". I tend to agree with that broad statement. We have just completed a decade in which some of the most exciting graphics technology became accessible to large numbers of students in engineering and technology education. We have been witness to great interest in computers and the potential for greatly increased efficiency in graphics instruction. The decline in small computer prices and the increase in machine capabilities hasn't hurt either. However, I would be remiss if I neglected to indicate that the 80's were also a decade of much experimentation, investigation, and even some confusion. So, I see the 90's as a new era <u>of thought</u> and <u>of method</u>. The way we deliver graphics instruction in the 90's may be the greatest challenge to graphics educators. The past two years (particularly) have seen some significant funded projects designed to assess what content and

ENGINEERING DESIGN GRAPHICS DIVISION
AMERICAN SOCIETY FOR ENGINEERING EDUCATION
ORGANIZATIONAL CHART 1990-1991



EDUC. RELATIONS

ROBERT MATTHEWS
SPEED SCIENTIFIC

FROSH PROGRAMS:

HUGH KEEDY
VANDERBILT UNIV.

INDUSTRY RELATIONS:

GARY BERTOLINE
PURDUE UNIVERSITY

INT'L RELATIONS:

VERA ANAND
CLEMSON UNIVERSITY

COMPUTER GRAPHICS:

MICHAEL MILLER
OHIO STATE UNIV.

ENGINEERING DESIGN EDUCATION:

ROLLIE JENISON
IOWA STATE UNIVERSITY

TEACHING TECHNIQUES:

JON JENSEN
MARQUETTE UNIVERSITY

THEORETICAL GRAPHICS:

ROBERT KELSO
LOUISIANA TECH.

GEOMETRIC MODELING:

NADIM AZIZ
CLEMSON UNIVERSITY

MEMBERSHIP:

BILLY WOOD
UNIV. OF TEXAS
- AUSTIN

1990 ANNUAL:

ARIZONA STATE
GARY BERTOLINE
PROGRAM CHAIR

1991 ANNUAL:

NEW ORLEANS
WILLIAM ROSS
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VIRGINIA POLYTECH

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PURDUE UNIVERSITY

CIRCULATION MANAGER:

CLYDE KEARNS
OHIO STATE UNIVERSITY

*** EXECUTIVE COMMITTEE MEMBER**

delivery should look like in view of CAD technology. The time ahead of us will be interesting and demanding intellectually as we examine the directions we have individually taken. This should make for some very interesting conference sessions. I look forward to this with great anticipation, and I hope you do too.

May the Lord's blessing be with you, and my best wishes for a successful and productive year.

EDGD Mid-year Conference

by

Del Bowers and Gary Bertoline

Make plans to attend the 1990 Midyear Conference to be held in Tempe, Arizona from November 17 - 20, 1990. Tempe is a Phoenix suburb and the home of Arizona State University. Highlights of this meeting include a keynote presentation by Joel Orr, nationally known CAD consultant, workshops on Saturday and Sunday, a western steak cookout at Pinnical Peak in the Sonoran desert (wear jeans and boots, but NO tie), and an impressive array of technial sessions. A spouse/friend program will be guided by Frank and Gladys Oppenheimer and will include tours of the famous Desert Botanical Gardens and the Heard Museum, reknown for Southwest Indian artifacts.

The Tempe Mission Palms Hotel, adjacent to the ASU campus and Old Town Tempe, will be the site of the conference.

The tentative schedule for the technical sessions is as follows:

Monday, Nov. 19, 1990

8:00 am Introduction

8:15 am Keynote Address - Dr. Joel Orr, CAD/CAM Institute

Technical Session I - Future Trends

9:30 am The Electric CAD Workbook: A Tool for CAD Instruction in Education & Industry - Paul Resetarits

9:45 am A Step-by-Step Approach for Solving Descriptive Geometry Problems Using CADKEY - Frank Croft

10:00 am SIGGRAPH Delphi: A Report - Mary Sadowski

10:15 am Graduate Graphics Programs - Walter Rodriguez

10:30 am Design Graphics for Manufacturing: The Integration of Parametrics and Variational Geometry - Dinish Dhamija
10:45 am Break

Technical Session II - Curriculum Issues

11:00 am The Problem is the Problem - Edwin Boyer
11:15 am The Down Side of Design Automation: Are We Educating or Idiot Proofing - N. S. Nandagopal
11:30 am A Solid Modeling Laboratory Sequence for Engineering Design Graphics - Ronald E. Barr and Davor Juricic
11:45 am Coping with Techno-Stress in Technical Graphics - Terry Burton
12:00 am An Oversight in the Typical Modernization of an Engineering Design Graphics Curriculum - John B. Crittenden
12:15 pm Discussion
12:30 pm Lunch

Technical Session III - Curriculum and History

2:00 pm Descriptive Geometry: An Historical Review, Part I - Ed Knoblock
2:15 pm An Historical Review of Visualization in Engineering Graphics - Craig Miller
2:30 pm Profile & Practices of Contributors to the Engineering Design Graphics Journal - Robert A. Chin
2:45 pm Teaching Engineering Graphics as a Body of Knowledge - Jon Duff
3:00 pm Design VS Communications in Engineering Drawing - Timothy J. Sexton
3:15 pm Break

Technical Session IV - Visualization

3:30 pm Visualization for Engineers in the 90's - William E. Gavin
3:45 pm The Importance of Visualization Cues to Learning and Design in Engineering Graphics - Scott Wiley
4:00 pm Virtual Reality System for Engineering Design Visualization - Mike Sinclair
4:15 pm How Can They Visualize If They Don't Know What It Looks Like? - Charles W. White
4:30 pm Some Spatial Visualization Exercises for Engineering Design Graphics - Michael H. Pleck
4:45 Discussion

Tuesday, Nov. 20, 1990

Technical Session V - Research

8:30 am Evaluation of 3D Display Techniques for Engineering Design Visualization - Larry Hodges
8:45 am Interim Review: Purdue Engineering Graphics Visualization Research Project - Scott Wiley
9:00 am Orthogonal Aniographics View Transformations and 4D Visualization - N. F. Ezquerra
9:15 am Survey of CAD Training in Industry - Judy Birchman
9:30 am Do You Really Have to Grade All That? - Paul DeJong
9:45 am Break

Technical Session VI - Computational Graphics

10:00 am Confronting Advanced Surface Design with NURBS - J. Alan Adams

10:15 am ????????? - Robi I. Love
10:30 am Computer Program & Curve Fitting Routine for Analysis of Right/Left Hand Mirror Drawings - Larry Goss
10:45 am The Transition from Boolean to Feature Based Solid Modeling - Michael Gabel
11:00 am International Graphics Standards Issues - Xoan L. Baltar
11:15 am Discussion
11:30 am Standards Panel Discussion - Ed Knoblock
12:30 am Lunch

Technical Session VII - Curriculum

2:00 pm Design Prototypes: Iconic Models for Visualizing & Analyzing Creative Ideas - Merwin Weed
2:15 pm The Development of a Multi-Media Instructional Package for CAD - Leonard Nasman
2:30 pm What is this Fractals Stuff? - Paul DeJong
2:45 pm Scientific Visualization: A New Course Concept for Engineering Graphics - Eric Wiebe
3:00 pm Facilitating Curricula Integration of Multidisciplinary Design - Lawrence J. Genalo
3:15 pm Computer Animation in the Engineering Design Graphics Curriculum - John Kelly
3:30 pm Discussion

For more information, contact Del Bowers, General Chairman, at (602) 965-6195. And be sure to bring your tennis racquet and golf clubs!

Calendar of Events

by
Bill Ross

1990-91 EDGD Mid-year Conference
November 18-20, 1990
Tempe, Arizona
Host: Arizona State Univ.
General Chair: Del Bowers
Arizona State Univ.
(602) 965-6195
Prog. Chair: Gary Bertoline
Purdue University
(317) 494-7507

1991 ASEE Annual Conference
June 16-20, 1991
New Orleans, Louisiana
Program Chair: Bill Ross
Purdue University
(317) 494-8069
FAX 317 494-0486
Facilities Chair: Mary Jasper
Mississippi State Univ.
(601) 325-3922

1991-92 EDGD Mid-year Conference
Date: TBA
Norfolk, Virginia
Host: Old Dominion Univ.

1992 ASEE Annual Conference
Toledo, OH

1992 5th International Conference on Engineering and Descriptive Geometry
August 17-21, 1992
Melbourne, Australia

1992-93 EDGD Mid-year Conference
San Francisco, CA
(tentative)

1993 ASEE Annual Conference
Urbana, IL
(tentative)

International Computer Graphics Calendar

by
Vera Anand

Nov 11 - 15, 1990
ICCAD 90, IEEE Intn'l Conf. on Computer Aided Design, Santa Clara, CA. Contact: Pat Pistilli, MP Assoc., 7490 Clubhouse Rd., Suite 102, Boulder, CO 80301. Ph. (303) 530-4562.

Feb 25 - 28, 1991
EDAC 91, European Design Automation Conf., Amsterdam, Holland. Contact: Secretariat, EDAC 91, CEP Consultants, 26-28 Albany St., Edinburgh EH1 3QH, Scotland. Ph. 44 (31) 557-2478, Fax 44 (31) 557-5749.

Apr 1 - 5, 1991
24th Computer Simulation Conf., New Orleans, LA. Contact: George W. Zobrist, Computer Science Dept., Univ. of Missouri at Rolla, Rolla, MO. Ph. (314) 341-4836.

Apr 7 - 12, 1991
1991 IEEE Int'l Conf. on Robotics and Automation, Sacremento, CA. Contact: T. J. Tarn, Systems Science and Math., Campus Box 1040, Washington Univ., St Louis, MO 63130.

Apr 22 - 25, 1991
NCGA 91, 1991 Nat'l Computer Graphics Assoc. Conf., New Orleans, LA. Contact: Keith Butler, Boeing, Advanced Tech. Ctr., PO Box 24346 M/S 7L-64, Seattle, WA 98124. Ph. (206) 865-3389.

Apr 28 - May 2, 1991
CHI 91, Conf. on Human Factors in Computing Systems, New Orleans, LA. Contact: Peter Poison, Psychology Dept., Univ. of Colorado, Muenzinger Hall, Campus Box 345, Boulder, CO 80309-0345. Ph. (303) 492-5622.

May 13 - 16, 1991
ICSE 13, 13th Int'l Conf. on Software Engineering, Austin, TX. Contact: David Barstow, Schlumberger Lab for Computer Science, PO Box 200015, Austin, TX 78720-0015.

May 15 - 17, 1991
CCW 91, Third IEEE Conf. on Computer Workstations, Cape Cod, MA. Contact: Keith Marzullo, Computer Science Dept., Upson Hall, Cornell University, Ithaca, NY 14853.

Jun 22 - 28, 1991
Computer Graphics Int'l '91, Cambridge, MA. Contact: N. M. Patrikalakis, MIT Rm. 5-428, 77 Massachusetts Ave., Cambridge, MA 02139. Ph. (617) 253-4555; FAX (617) 253-8125.

Jul 29 - Aug 2, 1991
SIGGRAPH 1991, Las Vegas, NV. Contact: Michael Bailey. Ph. (619) 534-5142.

Aug 7 - 10, 1991
12th Annual Conf. of the European Assoc. for Computer Graphics, Vienna, Austria. Contact: Interconvention, Austria Center Vienna, 1450 Vienna, Austria.
Ph. +43/222/23 69/2643
FAX +43/222/23 69/648

For further information, contact Vera Anand, 302 Lowry Hall, Clemson Univ., Clemson, SC 29631. (803) 656-5755

Report from the Fourth International Conference on Engineering Graphics and Descriptive Geometry

by
Larry Goss

Attending the conference, held from June 11 to June 14, 1990, were 89 delegates from 17 or 18 countries. Those in attendance were able to see both the diversity of work being done by our colleagues here and abroad and the status of the discipline with respect to theoretical approaches and technical support around the world. There was a bit of everything in evidence with respect to presentation techniques, from verbal descriptions of spatial problems to fairly sophisticated video frame grabbing for animation sequencing. The presenters are to be commended for their skill and hard work.

It is unfortunate that we can not speak in such praiseworthy terms for the way the conference was hosted. Florida International University had problems since shortly after the Vienna conference concerning a commitment to host in 1990. The problems extant in Miami went deeper than just a hesitancy, in that this was the first conference FIU had run that required overnight accommodations, planned activities for the family members, dinners, protocols, or even coffee breaks. All of these items were either lacking or sadly deficient. It I had been a visitor from another country, I would have been insulted and bewildered by the lack of attention to detail that was evident by our hosts. As an attendee from the host country, I was embarrassed as well by the lack of concern or even the recognition by our hosts that the the conference was suffering from significant logistics and organizational problems. Three months after the fact, I find myself still unable to write a letter to our hosts at FIU expressing my concern (and the concern felt by others from the United States and other countries as well) about the errors of commission and omission that were in evidence. I'm not sure that a litany listing the faux pax that were committed would do any good anyway. Suffice it to say, our hosts for the fifth conference from the Royal Melbourne Institute of Technology in Australia expect to do much better.

From the standpoint of international organization, the fourth international conference is noteworthy in that a multi-national steering committee has been formed to pursue some form of organizational structure for this group. The name of the society is:

International Society for Geometry and Graphics

and its mission is:

To foster international collaboration and stimulate the scientific and teaching methodology in the fields of geometry and graphics. The society will seek membership from graphics organizations and individuals with interest in these areas from all over the world.

A number of individuals, both here and abroad, have volunteered time and energy to form the international organization. Such individuals from the EDGD-ASEE include Vera Anand, Gary Bertoline, Steve Slaby, and Walter Rodriguez. Steve Slaby has agreed to co-chair the steering committee with Hellmuth Stachel. Hellmuth Stachel will maintain the headquarters in Vienna. If you wish to contribute ideas toward the organization, contact either of these gentlemen. Your help will be appreciated.

ANSI Y14.5 Committee Report

by

Patrick McCuistion

Significant changes are being discussed for the American National Standards Institute Y14.5M Dimensioning and Tolerancing standard. A revised standard is close to introduction. It is important that engineering graphics instructors be aware of the changes that will take place.

On May 7 - 10, 1990, the American National Standards Institute (ANSI) Y14.5M Dimensioning and Tolerancing subcommittee met in Denver, CO. This subcommittee is one of approximately thirty within the Y14 main committee that deals with information that may appear on an engineering drawing. The twenty-five members in the group represent some of the largest manufacturing companies in the United States, and thus constitute a very influential group. Their decisions about the standard will affect the appearance of engineering drawings throughout the world.

The ramifications of the changes in the new revision are awesome. There will be a new, more comprehensive definition of a datum. Symmetry may be reintroduced as a needed characteristic that should have its own symbol. Profile, which now can control form and orientation, may also control location. The proposed GDT certification test may become an important entry-level achievement for employment of engineering and technology students. These and other changes will make the standard more complex and theoretical than the 1982 revision. It will mean reeducation programs for existing employees and new educational programs for students.

Some of the changes to the standard may not be easy to understand at first. To help ease the transition, this article was written to provide highlights of the discussions held at the Denver meeting. If helpful, refer to ANSI Y14.5M-1982.

Virtual Condition vs. Resultant Condition

The resultant condition is the opposite of the virtual condition. When dealing with a feature controlled at maximum material condition, the resultant condition is defined by a circumscribed cylinder around the outermost possible positions of the controlled feature. A lengthy discussion centered on the merits of the terms Outer Locus (OL) and Inner Locus (IL) and/or Least Material Virtual Condition (LMVC) and Maximum Material Virtual Condition (MMVC) to help describe the Resultant Condition. It was decided that the Outer Locus and Inner Locus are the more appropriate terms to use.

Composite Tolerance

A problem is encountered when a composite tolerance is used to control a radial pattern of features around a datum axis. The second entry of the composite tolerance is most often controlled relative to the primary datum feature at maximum material condition (MMC). The actual size of the datum feature will probably be different than the MMC. This difference will allow the collective tolerance zones of the radial features to float gyroscopically to the degree of the difference when using a functional gauge for inspection. Many hours were devoted to discussing the merits of specifying that the second entry would be for orientation only. There was no consensus as to what action to take. This item will probably be discussed in future meetings.

Concentricity/Symmetry

Concentricity provides the only control of the axis of an irregularly shaped mass that is equally disposed about a datum axis. The real difference between concentricity and position (RFS) is the method of inspection. Concentricity involves taking individual differential measurements to derive the controlled feature axis, while position is concerned with the collective irregularities of the high points of the surface to derive the feature axis. Symmetry is like concentricity except that symmetry is used for rectangular rather than circular cross sections. In the case of symmetry, the datum is a median plane between two plane surfaces. A short discussion was held concerning the ramifications of reinstating symmetry in the new revision. Symmetry was removed from the 1982 revision.

Radii

Radii configurations were discussed relative to different levels of precision. A common type of radius may have reversals within the curved surface. A controlled radius (CR) was defined as having no reversals.

Statistical Tolerancing

Due to the increased use of statistical process control, the ability to specify smaller tolerance zones than would normally be applied is now being understood and more widely used. Discussions were held concerning the shape and placement of symbology to denote that a particular tolerance has been verified by statistical calculation to ensure that a smaller tolerance zone is feasible.

GDT Certification Test

A small group of people close to the Y14.5 committee activity are involved in constructing three different levels of certification tests. The levels will be progressively more complex leading to a "Master" level. Knowledge of GDT is such a common prerequisite for some engineering positions that a certification test was the next logical step to quickly identify GDT knowledge level.

Future Action

The last revision of the Y14.5 standard was officially released on February 15, 1983. The subcommittee has met twice a year since that date on the next revision. The May 7 - 10 meeting was to have been the last before the next release. However, due to the lengthy discussions, a number of important points still need to be decided. Therefore, another meeting was scheduled for October 15 - 18, 1990 in Charlotte, NC. The certification test program is continuing this summer and will be discussed during the next meeting.

NSF Symposium on Modernization of the Engineering Design Graphics Curriculum

by

Ron Barr and Davor Juricic

An NSF-sponsored Symposium on Modernization of the Engineering Design Graphics (EDG) Curriculum was hosted by the University of Texas in Austin on August 5 - 7, 1990. The symposium focused on the on-going transition from the 2-D design drafting media to the 3-D design media based on geometric modeling and the necessary reconciliation of this change in Engineering Design Graphics education. Keynote speaker at the symposium was Edward Ernst, Program Director for Undergraduate Engineering Education at the National Science Foundation, which has sponsored a 2-year project to design, test, and promote a new curriculum for Engineering Design Graphics. Project coinvestigators and organizers of the symposium were Ronald Barr and Davor Juricic of the University of Texas at Austin.

Speakers making presentations at the symposium included: Vera Anand (Clemson), Thomas Boronkay (Univ. of Cincinnati, coauthored by Janak Dave), Del Bowers (Arizona State, coauthored by Donovan Evans), Barry Crittenden (VPI), John Demel (Ohio State), Jon Duff (Purdue), James Earle (Texas A&M), Gary Hordemann (Gonzaga), Rollie Jenison (Iowa State), Sundaram Krishnamurthy (Cal-State, Fullerton), Robert Mabrey (Tennessee Tech), Michael Pleck (Univ. of Illinois at Urbana-Champaign, coauthored by Michael McGrath, Gary Bertoline, Del Bowers, and Mary Sadowski, also presenting and coauthoring a paper by Gary Bertoline, Purdue), Walter Rodriguez (Georgia Tech), Mary Sadowski (Purdue), Steve Slaby (Princeton), Robert Snortland (Michigan Tech, presenting a paper by David Carlson), Michael Stewart (Univ. of Arkansas at Little Rock), and Gerald Voland (Northeastern Univ.).

Presentations and discussions at the symposium addressed issues related to the general context of EDG in engineering education, modern EDG curriculum models, and course content. Integration issues in the four-year undergraduate engineering design sequence were discussed, including practical issues concerning hardware and software for laboratory exercises. Reports of several trial freshman courses using solid geometric modeling as a starting point were presented.

In an historical overview, Pleck, et al, pointed out the divergence that has grown between the practice and application of EDG and the EDG curriculum since World War II. Several other speakers (Slaby, Earle) also presented some interesting historical perspectives.

Many speakers stressed that the proper context for EDG was <u>engineering design methodology and process</u>. Juricic stressed the "developing and conveying of design ideas". Earle emphasized that "graphics is the medium of creativity and design". Rodriguez stressed the need to "maximize design problem solving opportunities and master geometry fundamentals". Boronkay emphasized Dieter's design process (conceptualization, evaluation, and communication) as the context for an EDG course.

There was some discussion as to whether solid modeling poses a fundamental new change in this design methodology and process (Juricic/Barr), which in turn warrants a new EDG curriculum, or whether it is just another tool with no fundamental implications, as argued by Bertoline/Pleck.

There was considerable discussion over the definitions of Engineering Design Graphics (or synonymously Engineering Graphics, or just plain "Graphics" in an engineering sense). The following definition was offered by Barr in a peace-keeping mission at the end of the meeting. "Graphics" is the set of all visual information (whether it be a freehand sketch, 3-D geometric computer model, desktop prototype model, cyberspace's artificial reality, engineering production drawing, or diagram) used to initiate, develop, communicate, and document an engineering design.

Several EDG curriculum models were presented or announced by research groups working in this area (Juricic/Barr, Bowers/Evans, Bertoline/Pleck). The upper tier of a common model could be represented by an "<u>EDG Process</u>" consisting of <u>Ideation</u>, <u>Development</u>, <u>Communication</u>, and <u>Documentation</u>. All three research models offered a process consisting of three-word combinations of this upper tier. This may be partly due to the universal influence on these groups by McKim, who proposed these concepts and terms for "Visual Thinking" in the early 1970's.

Bowers/Evans stressed the role of sketching throughout the EDG curriculum and Sadowski emphasized visualization before, during, and after the course. Geometric modeling (solid modeling, perhaps?) was stressed as a fundamental goal of the modern EDG curriculum by a number of speakers, including Barr/Juricic, Rodriguez, Mabrey, Anand, Krishnamurthy, Boronkay/Dave, Jenison, Stewart, and Hordemann. Tom Sigafoos, representing the SDRC University Consortium, indicated that the EDG curriculum goals should be "Modeling and Applications of Modeling". Hence, fundamental goals for the EDG curriculum would seem to include sketching, geometric modeling, and model application (including engineering drawings), with an integrated sequence of laboratory experiences to expand spatial visualization abilities.

It was agreed by most speakers that the detailed contents of the EDG curriculum were subject to local constraints. However, the modern EDG curriculum would seem to include, as a general consensus, the following topics: pictorial sketching, visualization exercises, planar and spatial geometry, geometric modeling (2-D and 3-D), model applications, engineering drawings, and standards. Slaby challenged the absence of traditional descriptive geometry in the modern EDG curriculum proposed by Barr/Juricic and likened it to "cutting the roots of a tree". Barr pointed out that descriptive geometry topics received low priority rankings in a survey of leading graphics educators.

Trial EDG courses and semester outlines were presented by numerous speakers (Barr/Juricic, Boronkay/Dave, Hordemann, Jenison, Krishnamurthy, Mabrey, Rodriguez, Snortland / Carlson, Stewart). Many of these trial implementations related experiences with introducing solid modeling into the freshman EDG curriculum.

Integration of EDG throughout the engineering curriculum was emphasized by numerous speakers (Anand, Bowers, Duff, Hordemann, Jenison, Juricic/Barr, Krishnamurthy, Mabrey, Snortland/Carlson). Juricic suggested that geometric modeling is the "common thread" of the modern design sequence. Carlson wrote that part geometry is the "data backbone" throughout the curriculum. Boronkay depicted a CAD wheel with CAE, CAM, Simulation, and Drafting spokes surrounding a "central hub" labeled 3-D Model.

Hardware issues for EDG labs were addressed by Demel, Crittenden, and Mabrey. Demel suggested building computers as a possibility to equip a lab on a low budget. Crittenden proposed that universities investigate the student purchase of personal computers, as has been implemented successfully at his school. Software issues were addressed by vendors representing AutoCAD, CADKEY, and SDRC. Of particular concern was the smooth integration of 3-D modeling and drafting packages. Voland suggested using new technology itself, specifically intelligent tutoring systems, as part of the modern instructional delivery system in graphics.

An auxiliary topic that permeated the meeting was the role of freshman engineering in the decade ahead. In his keynote address, Ernst stressed that engineering education was on the verge of changes, in both breadth and diversity. He stated that freshman engineers needed to see relevance in their courses and that a design component in the freshman year was a topic of current thinking in the country. Krishnamurthy mentioned the changing demographics of college students and predicted that the technical work force of the year 2000 will have a critical shortage of engineers if nothing is done. David Alpert, representing Rancho Santiago College, questioned how we can instill "passion for learning" in our graphics students. Since EDG is typically taught during the freshman year, faculty in the EDG field should become active in freshman retention issues and use this opportunity to "sell" engineering to the novice student.

A bound *Proceedings* of all papers presented at the symposium was produced and distributed through the mail to all engineering deans in the U.S. A few extra copies of the *Proceedings* remain available. For information, please contact the project investigators.

A Comment

by

Gary Bertoline

I would like to add my own comments to those of Pat Kelso in the Spring, 1990 issue of the *Journal* (Vol. 54, No. 2). Although I agree that some papers being presented may not be of high quality and relevant to our division, the majority of papers are appropriate. Our members must remember that we are a division of the American Society for Engineering Education. The majority of our members are educators and our main business is to educate engineering students to communicate graphically. Therefore, polls, surveys, and other accepted methods of determining what we teach, why we teach it, and how best to teach are entirely appropriate subjects for our meetings. I agree that the writing and presentation of some papers could be improved, but it is difficult to screen good papers from poorly prepared ones from one page abstracts. Maybe the division should look at a more effective method of choosing papers.

Drawings will be important for many years to come. For ten years I have been hearing about paperless manufacturing and a paperless society. I do not think we are any closer to paperless manufacturing today than we were ten years ago. Nor are we any closer to eliminating 2D surfaces for engineering design. I may be mistaken, but I believe that a CRT screen still represents 3D objects two-dimensionally.

Two-dimensional drawings play a major role in the communications of engineering design and it will take more than a magic sweep of a CAD wand to make them disappear. Two-dimensional representations of three-dimensional objects will be around for many more years, which is only one of the many reasons VISUALIZATION is and will remain an extremely important part of engineering design graphics education.

Students do not instinctively learn to visualize. Visualization is learned in stages through planned and unplanned experiences. I prefer to lead students through the stages of visualization using planned experiences instead of relying on luck or survival of the fittest.

Visualization ability is one of the important foundations for engineering drawing just as algebra is the foundation for calculus. You would not expect a student to do well in calculus if he/she had not had any algebra. Why do some in our profession insist that spending a few hours of instruction to improve visualization is unimportant? Visualization instruction in engineering design graphics is important because visualization is not formally taught at any level of education in the United States. High visualization ability is the most important prerequisite cognitive process that a student must have to be successful in representing three-dimensional objects on two-dimensional media (media includes computer CRT's).

No amount of color rendered computer models and viewports can replace or supplement the need for an engineer to clearly represent and control in his/her mind representations of real or imagined objects. Visualization is a meaty matter just as important as other engineering graphics topics and should not be taken lightly by any teacher who would like their students to be successful in engineering. Visualization is not the focus of the engineering graphics curriculum, just as standards, section views, or the direct view method are not. We must strive to provide our students with a balanced curriculum that includes the prerequisite knowledge necessary to design and communicate designs to others.

The NSF curriculum development project by Juricic and Barr and the ACM SIGGRAPH curriculum development project of Bertoline, Bowers, McGrath, and Pleck are efforts to define our subject matter in a way that we as a profession can agree upon as necessary knowledge for engineering students to communicate engineering designs graphically. The preliminary results of both studies recognize the importance of visualization as a part of the modern engineering graphics curricula.

Having a diversity of papers that are related to the curriculum content of the subject matter is healthy and shows that the division has life and is growing. Visualization papers are a part of the diversity of our division and should not be excluded nor should it become the focus of our meetings.

If our profession expects to be recognized in higher education, we must develop a research agenda that is scholarly and fundable. Graphic science is our subject matter and provides our research base. Graphic science is the knowledge and study of the theory and technique, psychomotor and cognitive foundations, and applications of all types of drawings. Some would prefer that all our efforts be put into the theory and technique of graphic science. I believe that we should not be so narrow and should include visualization as part of our discipline. We should stop giving lip service as to the importance of visualization in equal and integral part of our discipline. Our profession has always recognized the importance of visualization. Volume 1, Number 1 of this journal has an article about visualization and the founders of this division formed a visualization committee.

We are in a unique position as engineering graphics instructors. We have the opportunity to expand our horizons and develop other areas related to engineering graphics. Some keep trying to stamp us out of the curriculum, but we keep coming back because what we teach is needed. Some keep trying to argue that visualization should not be a concern of our profession, but we keep coming back. Engineering graphics and visualization are important components of engineering education and will be until such time when two-dimensional media is no longer used and humans can communicate design ideas using mental telepathy. I do not see either of these occurring within my lifetime and I plan on living for a long time!

More Thoughts

by
Bill Blakney

W. Ross' paper, "Representation of Projection and Coordinate Systems in Engineering Graphics" (Winter, 1990, Vol. 54, No. 1) and Jon Duff's note on axis systems (Winter, 1990, Vol. 54, No. 1) suggest there is considerable concern for a simple and uniform approach to these items. Hopefully, most of the concern would disappear with the adoption of the five recommendations offered by Duff.

Ross' paper well illustrates the difficulty in setting the desired standards. He shows seven glass projection boxes that open in the same way, every plane in every box hinging on the frontal plane that can do so, whether 1st or 3rd angle projection. Interestingly, the rear plane is made to hinge on the left profile plane in both systems (once established, that plane is never again seen in any text - so who/what might remind us of its existence or usefulness?). While general agreement on a questionable usefulness of a rear view is not surprising, it does not follow that a bottom view be considered that way. All the literature suggests it is better to dream up some additional glass box than to accept the rather consistent and simple bottom view offered seven times over. This question has been raised on these pages before. Why are (mechanical engineers) prepared to accept right and left views but not top and bottom views? What advantage do they see in introducing a new glass box in which the profile planes hinge on the top (horizontal) plane? Why do educators write books that support this "alternative arrangement of views" when it abandons the theory established in the beginning? How can this do anything but confuse the student of graphics? This can be a reasonable first step in the search for standards and uniformity: banish that glass box which nowhere has been recommended in theory.

Why would it not be easy to accept:

(1) that the 1st and 3rd angle projections simply be accepted as two different systems since the order of eye-plane-object is different. Call them European and American if you wish.

(2) that the acceptance of points (3) and (4) by Duff will put to rest the concern for coordinate systems. Both 2D and 3D coordinate axes will be set up by the user in the manner most beneficial.

(3) that x = width and y = height in both 1st and 3rd 2D drawings while x = width, y = depth, and z = height in 3D drawings should not present the difficulty it seems to do. Is it for the reason: "... graphics educators have not stressed ...

axis. Instruction has been by plane." as stated by Duff? Inasmuch as my background is in surveying where x to the East (width), y to the North (depth), and z (height) is most useful and graphics programs and coordinates have given me no problem, he must be right. But could this miserable "alternate" view be the culprit?

Hopefully, all of the observations made are sound for the world of computer graphics as offered by existing programs for interactive graphic displays. Programming 3D graphics is another matter. The order of rotations is very important if one is to correctly predict the picture that will result. I am persuaded it requires a level of mathematical sophistication and intuition that few faculty possess. Most will find their way by trial and error: we should minimize our concern for this if our mission is to enable students to develop and visualize geometries.

Another obstacle is that faculty do not agree on what the mission is. If one can draw 3D objects without programming 3D graphics, should one "rediscover the wheel"? Should one be able to do solid modeling even if he understands and can draw 3D drawings? If engineering education accepts the premise that engineers will hire technicians to do their drawings, why will it resist the idea that programmers will do the same for the few things new that come along?

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Scope

This journal is devoted to the advancement of engineering design graphics, computer graphics, and subjects related to engineering design graphics in an effort to (1) encourage research, development, and refinement of theory and applications 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.

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Submit complete papers, including an abstract of no more than 200 words, as well as figures, tables, etc. in quadruplicate (original plus three copies) with a covering letter to J. B. Crittenden, Editor, Engineering Design Graphics Journal, EF - VPI&SU, Blacksburg, VA 24061-0218. 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.

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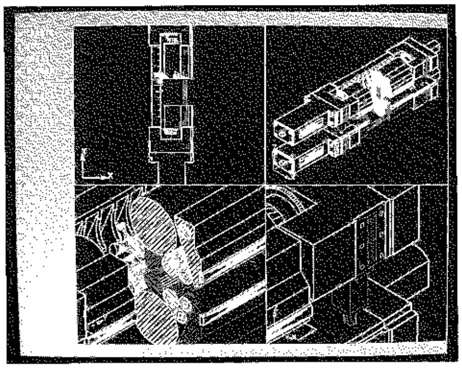

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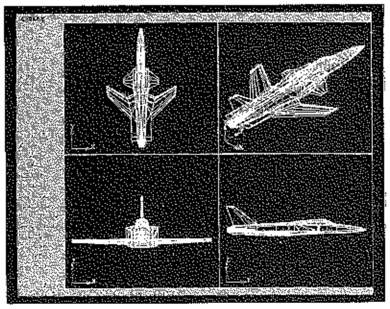

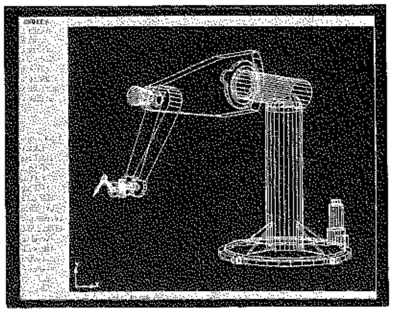

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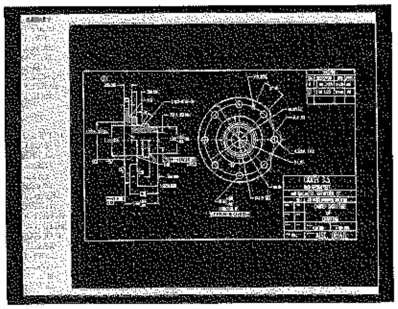

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