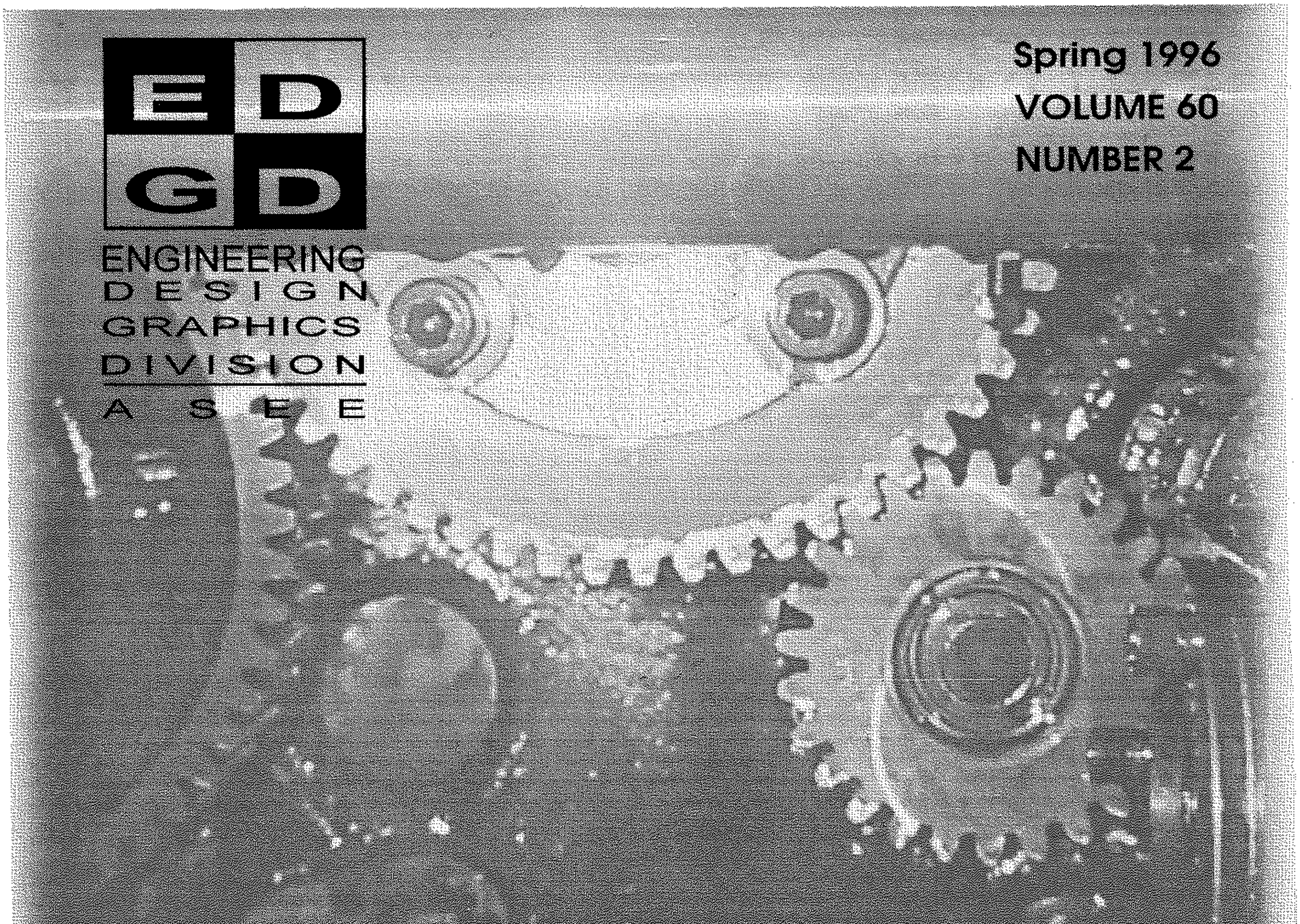
THE ENGINEERING DESIGN GRAPHICS JOURNAL



ENGINEERING DESIGN GRAPHICS DIVISION ASEE

Spring 1996
VOLUME 60
NUMBER 2

ENGINEERING DESIGN GRAPHICS DIVISION
AMERICAN SOCIETY FOR ENGINEERING EDUCATION

SDC PUBLICATIONS

Schroff Development Corporation
P.O. Box 1334
Mission, Kansas 66222

Excel for Engineers by Wilson G. Dobson, P.E. Alan K. Wolff, P.E.

Table of Contents

1. Introduction
2. Spreadsheet Basics
3. Heat Transfer Problem
4. Spreadsheet in 3D
5. Algebra on the Spreadsheet
6. Calculus on the Spreadsheet
7. Differential Equations
8. Beam Analysis-Moments, Stress and Deflection
9. Voltage on a Capacitive Circuit
10. End Point of a Titration
11. Random Number Generation
12. Optimize a Manufacturing Process
13. Kinetics by Animation of Graphics

120 pages. Net price $12.00

An Introduction to Engineering by Dr. Chinyere Onwubiko, P.E.

Table of Contents

1. History of Engineering
2. Engineering Disciplines
3. Engineering as a Profession
4. Engineering Problem Solving Methodology
5. Design Process
6. Analysis-Mechanical Systems
7. Analysis-Electrical Systems
8. Analysis-Energy Systems
9. Computer Tools
10. Handling Data-Statistics
11. Decision Tool-Optimization
12. Decision Tool-Engineering Economy
13. Presentation-Graphical Communication
14. Materials and Manufacturing Processes
15. Assembly

Appendix A. Geometry Review
Appendix B. Trigonometry Review
Appendix C. Algebra Review
Appendix D. Conversion Factors
Appendix F. Normal Distribution Table

290 pages. Net price $28.95

EDGD ENGINEERING DESIGN GRAPHICS DIVISION ASEE

THE ENGINEERING DESIGN GRAPHICS JOURNAL

Volumn 60 Number 2 Spring 1996

The *Engineering Design Graphics Journal* is the official publication of the Engineering Design Graphics Division of ASEE. The scope of the 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.

ISSN 0046 - 2012

. . . from the EDGE

Engineering • Design • Graphics • Editor

Dear Members,

The following in a speech given by Frank Oppenheimer at the banquet of the EDGD 50th Mid Year Meeting in Ames Iowa.

"I am a relic from the era of the Engineering Drawing Division of the early 1940's. At that time, drawing was done by hand with compass, divider and ruling pen! The instruments were a direct extension of the body and of the mind! When in the early part of 1948, I visited with Professor Cecil Spencer, who at that time, was head of the drawing department at Illinois Tech, I was a complete newcomer. But I was the first one who had contact with German manufacturers after the war. However, my attitude was different from the usual commercialism. For me it was important to bring to the students the best possible suited instruments at prices they could afford.

Professor Spencer appreciated this sincere devotion to the subject, and he suggested my membership in ASEE. He, together with Professor Gene Paré, sponsored my application and I was accepted. Later, in the year 1948, I visited with Professor Howard Porsch at Purdue University. He handed me a specification for a new design of drawing instruments which the entire large faculty at Purdue had worked out. I flew back home to New York and immediately called Herr Riefler in Germany. I told him to work on this design *as is*, no comment, because I was convinced that this would surely revolutionize the entire drawing instrument industry.

After a few weeks I'd received the first samples which I sent on to Purdue for inspection and possible suggestions for improvement. In June 1949, at Renssalear Polytechnic in Troy, New York, at the summer meeting of ASEE, which was my first meeting as a new member, I exhibited these Riefler Instruments, which were called the "Purdue Riefler" set, and of which Professor Warren Luzadder put a picture into his textbook, *Fundamentals of Engineering Drawing.*

The set met with enthusiastic acceptance by the members of the engineering Drawing Division! Even Professor Hiram Grant, who was very hard to please, grunted his approval!

My first Midwinter meeting was in January 1950 at the University of Chicago, Navy Pier. For the June 1950 ASEE Annual meeting, which was held at the University of Washington in Seattle, I was invited to present a paper with slides regarding the unique background of the German drawing instrument industry.

Through coordinating ideas of members of the Engineering Drawing Division with the ingenuity of my German manufacturers, I brought about satisfactory results for teachers and students alike."

Frank Oppenheimer
November 7, 1995
Ames, Iowa

I hope that you have enjoyed this small bit of history as related by Frank.

Mary A. Sadowski

Contents

PAPERS

5 Points, Planes and Lines. . . . . *Paul J. A. Zsombor- Murray*

15 A Procedural Model for Interactive Multimedia Development. . . . . *James L. Mohler*

26 Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component: Implementation Issues . . . . *Davor Juricic and Ronald E. Barr*

EDG NEWS

2 Editor's Message . . . .

42 Chair's Message . . . .

43 Book Review . . . .

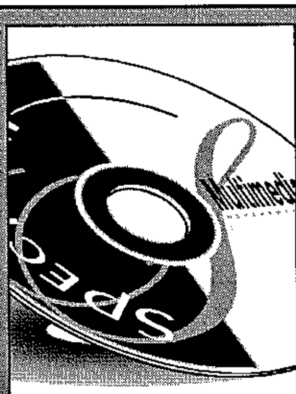
44 Calendar. . . . .

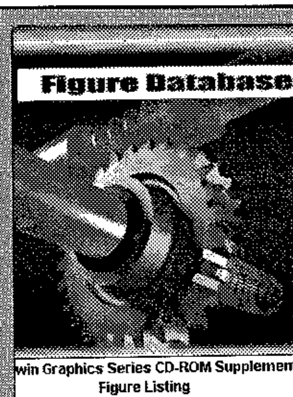
46 51st EDGD/ASEE Mid year Meeting. . . . .

47 Call for Papers . . . .

48 *Journal* Information Page

Cover Photograph by Aaron Kohn



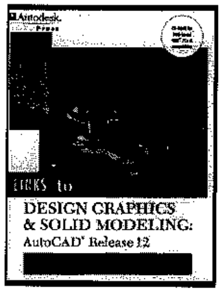


Available Now!

Autodesk.
Press
An International Thomson Publishing Company

Full-function Autodesk® software plus design-driven exercises & projects for students, faculty, & staff.

Two special *RealSuite*™ packages—containing Autodesk® software and design-driven texts—give your students the tools and instruction they need to produce professional-quality engineering designs, projects, and visualizations:



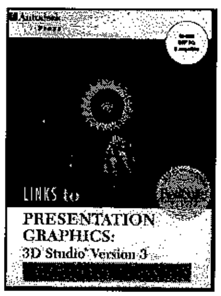
for engineering design graphics courses

RealSuite™ for DESIGN GRAPHICS & SOLID MODELING: AutoCAD® Release 12

PACKAGE INCLUDES:

- AutoCAD® Release 12 (DOS and Windows™ 3.1), AME® R2.1 (DOS and Windows™ 3.1), AutoVision™ R1, AutoSurf® Release 2.0 (DOS), and AutoCAD® Designer Release 1, on CD-ROM
- Stewart, Bolluyt & Oladipupo, *Modeling for Design Using AutoCAD® 12, AME®, AND AutoSurf®*
- Duff & Ross, *Freehand Sketching for Engineering Design*

Order #: 0-534-95629-7; $249.95 suggested list price



for engineering graphics, art, graphic design, and architecture courses

RealSuite™ for PRESENTATION GRAPHICS: 3D Studio® Version 3

PACKAGE INCLUDES:

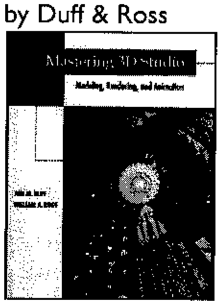
- 3D Studio® Version 3 (supports file sizes to 25,000 vertices, with instructions on how to combine files to create larger designs), on CD-ROM, plus World-Creating Toolkit® CD-ROM
- Reference Manual, Installation Guide, and Tutorial
- Duff & Ross, *Mastering 3D Studio®*
- Bousquet, *3D Studio®: Technical Tips & Tricks*

Order #: 0-534-95126-0; $149.95 suggested list price

Purchase Eligibility: Available through the campus bookstore for purchase by full-time, degree-seeking students, teaching faculty and staff at post-secondary, vocational-technical institutes, career colleges, plus 2-year and 4-year colleges and universities in the United States and Canada. Not for lab or commercial use. RealSuite software is not upgradeable. **Note to bookstore managers:** To place bookstore orders, call International Thomson Publishing Customer Service at 800-487-5510.

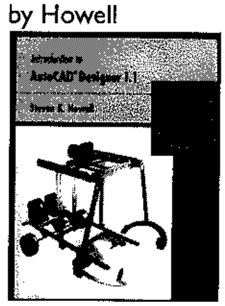
Also available:

Mastering 3D Studio®: Modeling, Rendering, and Animation
by Duff & Ross



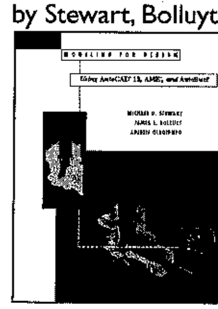
ISBN: 0-534-95136-8

Introduction to AutoCAD® Designer 1.1
by Howell



ISBN: 0-534-95070-1

Modeling for Design Using AutoCAD® 12, AME®, and AutoSurf®
by Stewart, Bolluyt & Oladipupo



ISBN: 0-534-93489-7

For more information, please contact:
Nathan Wilbur, Market Development Manager
Autodesk Press
20 Park Plaza, Boston, MA 02116
Tel: 617-348-8148; Fax: 617-338-6134

Email: nathan_wilbur@pws.com
Internet: www.autodesk.com
For more information,
contact your local ITP Sales Representative.

Points, Planes and Lines

Paul J.A. Zsombor-Murray
Department of Mechanical Engineering &
Centre for Intelligent Machines
McGill Unversity,
817 Sherbrooke St. W.,
Montréal, QC, Canada H3A 2K6

Abstract

Points and planes in three dimensional Euclidean space are represented by four homogeneous coordinates. The equivalence of points on the plane at infinity and planes on the origin is described. Similarly, the uniqueness of the plane at infinity and the point on the origin becomes evident, as does the fact that no point or plane is specified by the homogeneous coordinates (0:0:0:0). Then the linear equation of the plane given by three point coordinate sets and that of the point given by three plane coordinate sets is derived in the context of numerical examples. One sees that the numerical coefficients so obtained are, respectively, the coordinates of the unique plane or point which was given.

Furthermore the plane's coordinates are revealed to be the set of negative reciprocals of that plane's intercepts in point space. Finally linear equations of a line are derived, again with numerical examples, in terms of two sets of given homogeneous coordinates. The six homogeneous line coordinates emerge as coefficients of these equations, one in terms of plane coordinates, the other in terms of point coordinates. The equivalence of these two definitions is shown and a vector interpretation of line coordinates is given.

Introduction

This article was written to help the author as well as engineers and students in graphics to understand the interrelationship among linear elements of 3-dimensional space, but defined by four homogeneous coordinates which allow one to represent elements at infinity. The various views encountered in engineering drawing and descriptive gometry are thus regarded as the mapping of points on the drawn object, by connecting each with a line to a point on the image plane at infinity, onto an (image) plane whose homogeneous coordinates are identical to those of that special perspective vanishing point. Similarly, a conventional perspective image is produced by a mapping, with lines on an ordinary point, to some ordinary (image) plane. It is hoped thereby to promote the understanding of projection by linking it with the linear equations of elementary matrix algebra. Maybe this approach will appeal to those who find the idea of objects in "glass" boxes with hinged faces and the *ad-hoc* construction of perspective views through one, two or three points a bit artificial. Furthermore it is believed that an introduction to homogeneous linear equations in four variables is necessary "to fill in the blanks" before students tackle matrix transformation operators, conventionally used in computer graphics, like the ones presented by Anand (1993), in chapters 4, 6 and 8 and Appendix "B".

Hopefully some readers might find refreshing insight and merit in the somewhat unusual notions of a point equation expressed in plane-coordinates and equations of lines in 3D space expressed in both plane- and point-coordinates. Consider that most of us are familiar only with point-coordinates, where points are dipicted as discrete "dots" and planes appear as flat, 2-dimensional "sheets" of points. However this notion is reversed in a space of plane-coordinates where a plane becomes a dot and the points on it become sheets. Lines on the other hand acquire six homogeneous coordinates which may be either products of point- or plane-coordinate pairs. These unfamiliar notions are not new but were developed at the end of the last century. However the author has never seen an elementary treatment in English, with numerical examples and pictures, so here it is with apologies for imperfection and any tedium and consternation it may cause the reader.

Points & Planes in Homogeneous Vector Space

In a homogeneous vector 4-space, point position vectors are represented by four component magnitudes, $P(x : y : z : w)$. A plane is similarly represented by $p(X : Y : Z : W)$. In affine Euclidean 3-space it is conventional to set $w=W=1$ so as to yield the familiar three components $P(x/w, y/w, z/w) = P(x, y, z)$ for the point and $p(X/W, Y/W, Z/W) = p(X, Y, Z)$ for the plane. Notice that, by convention, homogeneous coordinates are expressed as separated by ":" while ordinary, affine coordinates are displayed as separated by ",". Moreover the homogeneous coordinate representation provides for the representation of points on the ideal plane at ∞ by setting $w = 0$ so $P(x : y : z : 0)$ is given by some specific direction but its distance from some reference point or origin, O, is not defined. The reference point itself is unique, i.e.., $O(0 : 0 : 0 : 1)$. On the other hand, a plane on the origin is given by some specific normal direction but its coordinates, the nature of which will be explained in greater detail below in the section on the equation of a plane, are not defined. So they, like those of points on the plane at ∞, may, with $W = 0$, be represented as $o(X : Y : Z : 0)$. Like its dual partner, the point on the origin, the plane at ∞ is unique and may be specified $p(0 : 0 : 0 : 1)$. Consider as well, that $(x : y : z : w) \equiv (kx : ky : kz : kw)$, the same point, regardless of the coefficient, k. Also $(X : Y : Z : W) \equiv (kX : kY : kZ : kW)$, the same plane.

Because homogeneous point and plane coordinates can be multiplied by any constant, either positive or negative, the double mapping of points on the plane at ∞ and planes on the origin becomes evident. *I.e.,* $P(x : y : z : 0) = P(-x : -y : -z : 0)$ and $p(X : Y : Z: 0) = p(-X : -Y : -Z : 0)$ and the notion concerning the sense of outward or inward vanishes or becomes meaningless as regards planes on the origin and points on the plane at ∞ .

Furthermore, one may appreciate why $P(0 : 0 : 0 : 0)$ and $p(0 : 0 : 0 : 0)$ must be excluded as the specification of a point or a plane, respectively. The point or plane represented by these coordinates would have to be on both a plane on the origin and the plane at ∞ or simultaneously on the origin and a point at ∞ , respectively, thus constituting a sort of geometric "black hole" in the homogeneous vector space of points or planes, if one is permitted to entertain such a naïve metaphor.

Points & the Plane Equation

Consider a plane, Π, given by the position vectors, **a, b, c,** of its coordinate axis intercepts on points *A, B, C,* respectively.

$$\mathbf{a} = \{1,0,0\}^T,\ \mathbf{b} = \{0,2,0\}^T,\ \mathbf{c} = \{0,0,3\}^T$$

Let's also define a convenient fourth point, *N*, on Π such that its position vector, **n**, is perpendicular to Π. This point will be used to check the validity of the equation to be derived. Let

$$\mathbf{n} = k[(\mathbf{b}-\mathbf{a}) \times (\mathbf{c}-\mathbf{b})]$$

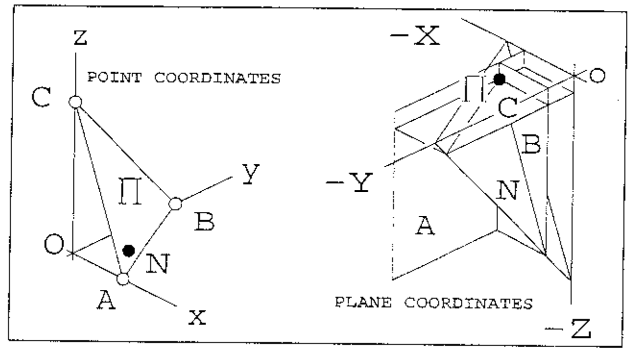


Figure 1 The Plane

where *k* is some constant such that

$$(\mathbf{n}-\mathbf{a}) \cdot \mathbf{n} = 0$$

Now

$$(\mathbf{b}-\mathbf{a}) \times (\mathbf{c}-\mathbf{b}) = \{-1,2,0\}^T \times \{0,-2,3\}^T = \{6,3,2\}^T$$

So then *N* is on Π if

$$\{6k-1, 3k, 2k\}^T \cdot \{6,3,2\}^T = 0$$

which gives $k = 6/49$ making

$$\mathbf{n} = \{36/49, 18/49, 12/49\}^T$$

The plane equation can now be written as the singular 4 x 4 determinant of homogeneous point coordinates, the three given ones specified by the intercepts and the fourth a variable which represents any other point on the plane.

$$\begin{vmatrix} \mathbf{p}^T \\ \mathbf{a}^T \\ \mathbf{b}^T \\ \mathbf{c}^T \end{vmatrix} = \begin{vmatrix} x & y & z & w \\ 1 & 0 & 0 & 1 \\ 0 & 2 & 0 & 1 \\ 0 & 0 & 3 & 1 \end{vmatrix} = 0$$

Note that the homogenizing coordinate of the three given points has been set $w=1$ so that $(x/w,\ y/w,\ z/w)$ are the coordinates of these points in Euclidean affine 3-space.

The determinant can be expanded on the minors *x, y, z, w* so

$$\begin{vmatrix} 0 & 0 & 1 \\ 2 & 0 & 1 \\ 0 & 3 & 1 \end{vmatrix} x - \begin{vmatrix} 1 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 3 & 1 \end{vmatrix} y + \begin{vmatrix} 1 & 0 & 1 \\ 0 & 2 & 1 \\ 0 & 0 & 1 \end{vmatrix} z - \begin{vmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{vmatrix} w = 0$$

Evaluating the four determinants yields the following equation of the plane, Π,

$$6x + 3y + 2z - 6w = 0$$

which assumes its familiar form by setting $w = 1$.

$$6x + 3y + 2z - 6 = 0$$

where the coefficients, (6 : 3 : 2 : -6), are called coordinates of plane Π. Since w can be any constant

$$\Pi(1 : \frac{1}{2} : \frac{1}{3} : -1) \equiv \Pi(-6 : -3 : -2 : 6) \equiv \Pi(-1 : -\frac{1}{2} : -\frac{1}{3} : 1)$$

are all equivalent, alternate coordinates of the same plane Π. Let's check the validity of the equation by substituting the coordinates of point N on Π which were obtained above.

$$6\frac{36}{49} + 3\frac{18}{49} + 2\frac{12}{49} - 6 = 0$$

It can be seen that when w=1 the plane coordinates become simply the negative reciprocals of the plane intercepts.

Planes & the Point Equation

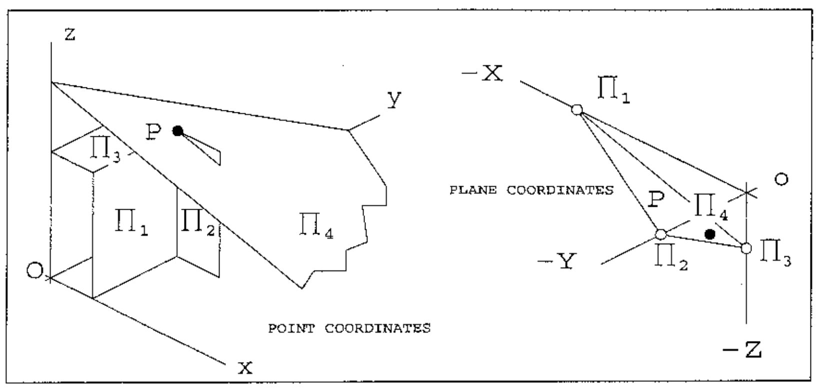


Figure 2 The Point

Consider a point, P=P(1 : 2 : 3 : 1), on three given planes with the coordinates

$$\Pi_1(-1 : 0 : 0 : 1), \quad \Pi_2(0 : -\frac{1}{2} : 0 : 1), \quad \Pi_3(0 : 0 : -\frac{1}{3} : 1)$$

A fourth plane,

$$\Pi_4 = \Pi_4(-\frac{1}{14} : -\frac{2}{14} : -\frac{3}{14} : 1)$$

on P and normal to the position vector of P, $\mathbf{p} = \{1,2,3\}^T$ is also specified to verify the point equation which will be derived. Notice that the coordinates of Π_4 are obtained as the negative reciprocals of its intercepts given by the following vector equations.

$$\{\{1,2,3\} - \{x_4,0,0\}\}^T \cdot \{1,2,3\}^T = (1 - x_4) + 4 + 9 = 0 \text{ so } x_4 = 14$$
$$\{\{1,2,3\} - \{0,y_4,0\}\}^T \cdot \{1,2,3\}^T = 1 + (4 - 2y_4) + 9 = 0 \text{ so } y_4 = 14/2$$
$$\{\{1,2,3\} - \{0,0,z_4\}\}^T \cdot \{1,2,3\}^T = 1 + 4 + (9 - 3z_4) = 0 \text{ so } z_4 = 14/3$$

The point equation can now be written as the singular 4 x 4 determinant of homogeneous plane coordinates, the three given ones specified by the coordinates of Π_1, Π_2, Π_3 and a fourth variable set which represents any other plane, Π, on point P.

$$\begin{vmatrix} \pi^T \\ \pi_1^T \\ \pi_2^T \\ \pi_3^T \end{vmatrix} = \begin{vmatrix} X & Y & Z & W \\ -1 & 0 & 0 & 1 \\ 0 & -\frac{1}{2} & 0 & 1 \\ 0 & 0 & -\frac{1}{3} & 1 \end{vmatrix} = 0$$

Expanding the determinant on the minors, X, Y, Z, W will yield the equation of the point P.

$$\begin{vmatrix} 0 & 0 & 1 \\ -\frac{1}{2} & 0 & 1 \\ 0 & -\frac{1}{3} & 1 \end{vmatrix} X - \begin{vmatrix} -1 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & -\frac{1}{3} & 1 \end{vmatrix} Y + \begin{vmatrix} -1 & 0 & 1 \\ 0 & -\frac{1}{2} & 1 \\ 0 & 0 & 1 \end{vmatrix} Z - \begin{vmatrix} -1 & 0 & 0 \\ 0 & -\frac{1}{2} & 0 \\ 0 & 0 & -\frac{1}{3} \end{vmatrix} W = 0$$

Which gives

$$\frac{1}{6}X + \frac{1}{3}Y + \frac{1}{2}Z + \frac{1}{6}W = 0$$

or

$$1X + 2Y + 3Z + 1W = 0$$

With $W = 1$ the familiar form of a linear equation in three variables is obtained.

$$1X + 2Y + 3Z + 1 = 0$$

The coefficients of this equation are the homogeneous coordinates of P. By setting $\Pi = \Pi_4$, the validity of the point equation is verified.

$$1\left(-\frac{1}{14}\right) + 2\left(-\frac{2}{14}\right) + 3\left(-\frac{3}{14}\right) + 1 = 0$$

Planes, Points & the Line Equation

A line $\mathcal{L}$, is on two given planes, Π_1 and Π_2. Let

$$\Pi_1 = \Pi_1(-1 : -1/2 : -1/3 : 1), \quad \Pi_2 = \Pi_2(-1/2 : -1/3 : -1 : 1)$$

The line equation derived from these considerations is a linear equation in six variables whose six coefficients are the *axial*, homogeneous Plücker line coordinates $\mathcal{L}$. In this case $\mathcal{L} \subset \Pi_1$ and $\mathcal{L} \subset \Pi_2$. Alternately, $\mathcal{L}$ may be given to be on two given points, P_1 and P_2. For convenience, let $P_1 \subset \Pi_x(1 : 0 : 0 : 0)$ and $P_2 \subset \Pi_y(0 : 1 : 0 : 0)$. Note that Π_x is the yz-plane, $x = 0$ and Π_y is the zx-plane, $y = 0$. The coordinates of P_1 and P_2 are easily computed with the respective point equations which were introduced above.

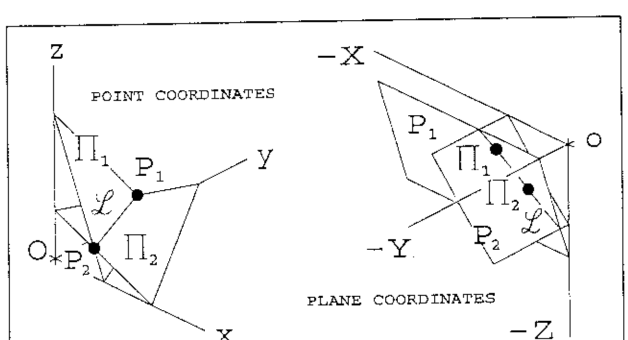


Figure 3 The Line

$$\begin{vmatrix} \pi^T \\ \pi_1^T \\ \pi_2^T \\ \pi_x^T \end{vmatrix} = \begin{vmatrix} X & Y & Z & W \\ -1 & -\frac{1}{2} & -\frac{1}{3} & 1 \\ -\frac{1}{2} & -\frac{1}{3} & -1 & 1 \\ 1 & 0 & 0 & 0 \end{vmatrix} = 0$$

$$\begin{vmatrix} -\frac{1}{2} & -\frac{1}{3} & 1 \\ -\frac{1}{3} & -1 & 1 \\ 0 & 0 & 0 \end{vmatrix} X - \begin{vmatrix} -1 & -\frac{1}{3} & 1 \\ -\frac{1}{2} & -1 & 1 \\ 1 & 0 & 0 \end{vmatrix} Y + \begin{vmatrix} -1 & -\frac{1}{2} & 1 \\ -\frac{1}{2} & -\frac{1}{3} & 1 \\ 1 & 0 & 0 \end{vmatrix} Z - \begin{vmatrix} -1 & -\frac{1}{2} & -\frac{1}{3} \\ -\frac{1}{2} & -\frac{1}{3} & -1 \\ 1 & 0 & 0 \end{vmatrix} W = 0$$

$$\begin{aligned} 0X - \tfrac{2}{3}\ Y - \tfrac{1}{6}\ Z - \tfrac{7}{18}\ W &= 0 \\ 0X + \tfrac{12}{7}\ Y + \tfrac{3}{7}\ Z + 1\ W &= 0 \end{aligned}$$

$$\begin{vmatrix} \pi^T \\ \pi_1^T \\ \pi_2^T \\ \pi_y^T \end{vmatrix} = \begin{vmatrix} X & Y & Z & W \\ -1 & -\frac{1}{2} & -\frac{1}{3} & 1 \\ -\frac{1}{2} & -\frac{1}{3} & -1 & 1 \\ 0 & 1 & 0 & 0 \end{vmatrix} = 0$$

$$\begin{vmatrix} -\frac{1}{2} & -\frac{1}{3} & 1 \\ -\frac{1}{3} & -1 & 1 \\ 1 & 0 & 0 \end{vmatrix} X - \begin{vmatrix} -1 & -\frac{1}{3} & 1 \\ -\frac{1}{2} & -1 & 1 \\ 0 & 0 & 0 \end{vmatrix} Y + \begin{vmatrix} -1 & -\frac{1}{2} & 1 \\ -\frac{1}{2} & -\frac{1}{3} & 1 \\ 0 & 1 & 0 \end{vmatrix} Z - \begin{vmatrix} -1 & -\frac{1}{2} & -\frac{1}{3} \\ -\frac{1}{2} & -\frac{1}{3} & -1 \\ 0 & 1 & 0 \end{vmatrix} W = 0$$

$$\begin{aligned} \tfrac{2}{3}X + \ 0Y + \tfrac{1}{2}\ Z + \tfrac{5}{6}\ W &= 0 \\ \tfrac{4}{5}X + \ 0Y + \tfrac{3}{5}\ Z + 1\ W &= 0 \end{aligned}$$

The coefficients are the homogeneous point coordinates $P_1(0 : {}^{12}/_7 : {}^{3}/_7 : 1)$ and $P_2({}^{4}/_5 : 0 : {}^{3}/_5 : 1)$ which are easily verified, by elementary methods, to be the intercepts of $\mathcal{L}$ on planes $x = 0$ and $y = 0$.

In the second, alternate, case where $P_1 \subset$ L and $P_2 \subset \mathcal{L}$ the line equation is derived as a linear equation in six variables whose six coefficients are known as the *ray* Plücker coordinates of the line.

First, consider the axial line equation expressed below as a singular 4 x 4 determinant whose first two rows are the given coordinates of $\Pi_1$and Π_2 while $\Pi_3(X_3 : Y_3 : Z_3 : W_3)$ and $\Pi_4(X_4 : Y_4 : Z_4 : W_4)$ are any two other planes $\mathcal{L}$.

$$\begin{vmatrix} \pi_1^T \\ \pi_2^T \\ \pi_3^T \\ \pi_4^T \end{vmatrix} = \begin{vmatrix} -1 & -\frac{1}{2} & -\frac{1}{3} & 1 \\ -\frac{1}{2} & -\frac{1}{3} & -1 & 1 \\ X_3 & Y_3 & Z_3 & W_3 \\ X_4 & Y_4 & Z_4 & W_4 \end{vmatrix} = 0$$

This determinant is expanded on 2 x 2 cofactors where the coefficients will be the six Plücker coordinates and the variables will be in terms of differences of products of the two variable plane coordinates. It is important to note that things have been arranged so that Π_1 is assumed to rotate into Π_2, as Π_3 is assumed to rotate into Π_4, in the sense of a right hand screw which advances in the direction of P_1, on Π_x, toward P_2, on Π_y. The sign of the sub-determinants can be chosen correctly by counting the number of times, n, that a pair of rows (or columns) must be exchanged, starting with the original 4 x 4 array above, so as to place the 2 x 2 coefficient sub-array, that pre-multiplies the variable sub-array which contains the component pair direction which is to be evaluated in the current step, into the upper left (first two) pairs of rows and columns. The sign is -1^n and the coefficients and difference of products terms will be finally ordered as

$$c_1(X_3W_4 - X_4W_3) + c_2(Y_3W_4 - Y_4W_3) + c_3(Z_3W_4 - Z_4W_3)$$
$$+c_4(Y_3Z_4 - Y_4Z_3) + c_5(Z_3X_4 - Z_4X_3) + c_6(X_3Y_4 - X_4Y_3) = 0$$

in the axial coordinate line equation. In the following, first step, the X-component pair will be evaluated

$$\begin{vmatrix} \begin{vmatrix} -\frac{1}{2} & -\frac{1}{3} \\ -\frac{1}{3} & -1 \end{vmatrix} & \begin{vmatrix} -1 & 1 \\ -\frac{1}{2} & 1 \end{vmatrix} \\ \begin{vmatrix} Y_3 & Z_3 \\ Y_4 & Z_4 \end{vmatrix} & \begin{vmatrix} X_3 & W_3 \\ X_4 & W_4 \end{vmatrix} \end{vmatrix}$$

$$c_1C_1 + c_4C_4 = +\frac{7}{18}(X_3W_4 - X_4W_3) + \frac{1}{2}(Y_3Z_4 - Y_4Z_3)$$

The result below was obtained by evaluating the four 2 x 2 determinants, then evaluating the large outer 2 x 2 determinant in the same fashion. Notice that $n = 2$ in the formulation above so the determinant term signs do not change and simply obey the convention of diagonal multiplication of 2 x 2 determinants. Furthermore it might help to note that the 4 x 4 array above could have been obtained by a *left-circular shift* of the first three columns of the original array, i.e., $X \leftarrow Y \leftarrow Z \leftarrow X$. Moreover any number of right- or left-circular shifts will produce no change of sign. The form below was obtained with a single right-circular shift. It serves to evaluate the Y-component coordinate pair.

$$\begin{vmatrix} \begin{vmatrix} -\frac{1}{3} & -1 \\ -1 & -\frac{1}{2} \end{vmatrix} & \begin{vmatrix} -\frac{1}{2} & 1 \\ -\frac{1}{3} & 1 \end{vmatrix} \\ \begin{vmatrix} Z_3 & X_3 \\ Z_4 & X_4 \end{vmatrix} & \begin{vmatrix} Y_3 & W_3 \\ Y_4 & W_4 \end{vmatrix} \end{vmatrix}$$

$$c_2C_2 + c_5C_5 = -\frac{5}{6}(Y_3W_4 - Y_4W_3) + \frac{1}{6}(Z_3X_4 - Z_4X_3)$$

The Z-direction terms are obtained below with the determinant in the form in which it was originally formulated

$$\begin{vmatrix} \begin{vmatrix} -1 & -\frac{1}{2} \\ -\frac{1}{2} & -\frac{1}{3} \end{vmatrix} & \begin{vmatrix} -\frac{1}{3} & 1 \\ -1 & 1 \end{vmatrix} \\ \begin{vmatrix} X_3 & Y_3 \\ X_4 & Y_4 \end{vmatrix} & \begin{vmatrix} Z_3 & W_3 \\ Z_4 & W_4 \end{vmatrix} \end{vmatrix}$$

$$c_3C_3 + c_6C_6 = +\frac{1}{12}(Z_3W_4 - Z_4W_3) - \frac{2}{3}(X_3Y_4 - X_4Y_3)$$

Putting all three pairs together in the form specified above produces the line equation below.

$$\frac{7}{18}C_1 - \frac{5}{6}C_2 + \frac{1}{12}C_3 + \frac{1}{2}C_4 + \frac{1}{6}C_5 - \frac{2}{3}C_6 = 0$$

Since Plücker coordinates are also homogeneous, multiplication by 36 produces the equivalent line equation with integer coefficients.

$$14C_1 - 30C_2 + 3C_3 + 18C_4 + 6C_5 - 24C_6 = 0$$

In the second, alternate case, where $P_1 \subset \mathcal{L}$ and $P_2 \subset \mathcal{L}$, the line equation is derived as a linear equation in six quadric variable terms, as before. The six coefficients of these variables are known as the *ray* Plücker coordinates of the line. This time the 4 x 4 determinant's first two rows will contain the point coordinates,

$$P_1(0 : \frac{12}{7} : \frac{3}{7} : 1), \quad P_2(\frac{4}{5} : 0 : \frac{3}{5} : 1)$$

calculated previously, augmented by two rows of variable point coordinates, $P_3(x_3 : y_3 : z_3 : w_3)$ and $P_4(x_4 : y_4 : z_4 : w_4)$. To show the arithmetic simplification available through the use of homogeneous coordinates, the coordinates P_1 and P_2 will be multiplied by 7 and 5, respectively, so as to render them integers.

$$\begin{vmatrix} \Pi_1^T \\ \Pi_2^T \\ \Pi_3^T \\ \Pi_4^T \end{vmatrix} = \begin{vmatrix} 0 & 12 & 3 & 7 \\ 4 & 0 & 3 & 5 \\ x_3 & y_3 & z_3 & w_3 \\ x_4 & y_4 & z_4 & w_4 \end{vmatrix} = 0$$

As before, the three sets of 2 x 2 arrays of 2 x 2 determinants are set up and evaluated. The results are identical except the line equation of ray coordinates assume the form below.

$$C_1(y_3z_4 - y_4z_3) + C_2(z_3x_4 - z_4x_3) + C_3(x_3y_4 - x_4y_3)$$
$$+C_4(x_3w_4 - x_4w_3) + C_5(y_3w_4 - y_4w_3) + C_6(z_3w_4 - z_4w_3) = 0$$

$$\begin{vmatrix} \begin{vmatrix} 12 & 3 \\ 0 & 3 \end{vmatrix} & \begin{vmatrix} 0 & 7 \\ 4 & 5 \end{vmatrix} \\ \\ \begin{vmatrix} y_3 & z_3 \\ y_4 & z_4 \end{vmatrix} & \begin{vmatrix} x_3 & w_3 \\ x_4 & w_4 \end{vmatrix} \end{vmatrix}$$

$$C_4c_4 + C_1c_1 = +36(x_3w_4 - x_4w_3) + 28(y_3z_4 - y_4z_3)$$

$$\begin{vmatrix} \begin{vmatrix} 3 & 0 \\ 3 & 4 \end{vmatrix} & \begin{vmatrix} 12 & 7 \\ 0 & 5 \end{vmatrix} \\ \\ \begin{vmatrix} z_3 & x_3 \\ z_4 & x_4 \end{vmatrix} & \begin{vmatrix} y_3 & w_3 \\ y_4 & w_4 \end{vmatrix} \end{vmatrix}$$

$$C_5c_5 + C_2c_2 = +12(y_3w_4 - y_4w_3) - 60(z_3x_4 - z_4x_3)$$

$$\begin{vmatrix} \begin{vmatrix}0 & 12\\ 4 & 0\end{vmatrix} & \begin{vmatrix}3 & 7\\ 3 & 5\end{vmatrix} \\ & \\ \begin{vmatrix}x_3 & y_3\\ x_4 & y_4\end{vmatrix} & \begin{vmatrix}z_3 & w_3\\ z_4 & w_4\end{vmatrix} \end{vmatrix}$$

$$C_6c_6 + C_3c_3 = -48(z_3w_4 - z_4w_3) + 6(x_3y_4 - x_4y_3)$$

Combining the three pairs of $C_ic_i + C_{i+3}c_{i+3}$ produces the line equation below.

$$28c_1 - 60c_2 + 6c_3 + 36c_4 + 12c_5 - 48c_6 = 0$$

Dividing the homogeneous ray coordinates of the above equation by 2 yields a set of coefficients identical to the axial coordinates obtained previously. To emphasize the difference in rôle played by the line coordinates in terms of point (ray) coordinates and those in terms of plane (axial) coordinates, consider the following identities.

$$\begin{aligned} x_iy_{i+1} - x_{i+1}y_i &= Z_iW_{i+1} - Z_{i+1}W_i \\ z_ix_{i+1} - z_{i+1}x_i &= Y_iW_{i+1} - Y_{i+1}W_i \\ y_iz_{i+1} - y_{i+1}z_i &= X_iW_{i+1} - X_{i+1}W_i \\ X_iY_{i+1} - X_{i+1}Y_i &= z_iw_{i+1} - z_{i+1}w_i \\ Z_iX_{i+1} - Z_{i+1}X_i &= y_iw_{i+1} - y_{i+1}w_i \\ Y_iZ_{i+1} - Y_{i+1}Z_i &= x_iw_{i+1} - x_{i+1}w_i \end{aligned}$$

Now one may observe that $\mathbf{p}\{14, -30, 3\}^T$ is a vector in the direction of $\mathcal{L}$ in the right hand screw sense $P_1 \rightarrow P_2$ (translation) or $\Pi_1 \rightarrow \Pi_2$ (rotation), while bf $M_0\{18, 26, -24\}^T$ is the moment vector of $\mathbf{p}$ about O. This can be easily verified with elementary vector algebra. Before verifying this, note that by subtracting the homogeneous coordinates $P_1 - P_2$ one obtains

$$(\frac{4}{5} : -\frac{12}{7} : \frac{6}{36} : 0) \equiv (14 : -30 : 3 : 0) \equiv \mathbf{p}_2 - \mathbf{p}_1 = \mathbf{p} = \{14, -30, 3\}^T$$

The difference of two homogeneous point coordinates produces a point at ∞ which apparently corresponds to the familiar notion of a "free" vector to which one commonly assigns some magnitude, *e.g.*, as in the case when it taken to represent a force or some other vector quantity encountered in engineering mechanics. Now using the position vector of P_1 or P_2, $\mathbf{p}_1$ or $\mathbf{p}_2$, respectively, the moment concept is verified below.

$$\mathrm{M}_o = \mathbf{p}_1 \times \mathbf{p} = \{0, \frac{12}{7}, \frac{3}{7}\}^T \times \{14, -30, 3\}^T = \mathbf{p}_2 \times \mathbf{p} = \{\frac{4}{5}, 0, \frac{3}{5}\}^T \times \{14, -30, 3\}^T = \{18, 6, -24\}^T$$

It is often expedient to normalize $\mathcal{L}(p(X : Y : Z : W)) = 0$ or $\mathcal{L}(\mathrm{P}(x : y : z : w)) = 0$ by dividing by

$$\sqrt{c_1^2 + c_2^2 + c_3^2}$$

in the case of axial coordinates and

$$\sqrt{C_1^2 + C_2^2 + C_3^2}$$

in the case of ray coordinates. It is only now, at this stage, that one may consider the notion of a *spear, i.e.*, a directed line. This is done by assigning either a positive or negative sign to the square root denominator. It is evident that lines defined by the linear equations, arising when the determinants of singular matrices are expanded, cannot be directed because the point or plane coordinates, which define a line, may be inserted as rows in any order but the interchange of a row pair changes the sign of the determinant. Furthermore, since the coordinates in question are homogeneous they may be multiplied by any positive or negative constant without changing the element which they represent. In any case, the determinant magnitude is zero, which has no sign.

This makes

$$\sum_{i=1}^{3} c_i C_i / \sqrt{c_1^2 + c_2^2 + c_3^2} \equiv \sum_{i=1}^{3} C_i c_i / \sqrt{C_1^2 + C_2^2 + C_3^2}$$

into a unit vector, **e**, in the direction of $\mathcal{L}, P_1 \rightarrow P_2 . \equiv \Pi_1 \rightarrow \Pi_2$ It also makes

$$\sum_{i=4}^{6} c_i C_i / \sqrt{c_1^2 + c_2^2 + c_3^2} \equiv \sum_{i=4}^{6} C_i c_i / \sqrt{C_1^2 + C_2^2 + C_3^2}$$

into a vector, $\mathbf{m}_0$, the moment of **e** about O, acting along a line on Π_1 or Π_2 or on P_1 or P_2

Conclusion

In conclusion, if the reader feels that this treatment lacks the terseness of good mathematics, consider that what was attempted here was to introduce the typical engineer to the analytical geometry of points, plane and lines in three dimensional Euclidean space, E^3. The interrelationship among these fundamental elements was defined in terms of singular, 4 x 4 matrices of homogeneous point and plane coordinates so as to introduce lines in a way that will make the intricacies found in classical works on line geometry (Sommerville, 1934 & Zindler, 1902) a little less intimidating to beginners, among whom the author counts himself.

Bibliography

Anand, V.B., (1993). *Computer Graphics and Geometric Modeling for Engineers.* Wiley Publishing Co.

Sommerville, D. M. Y, (1934). *Analytical Geometry of Three Dimensions.* (pp.337-363). Cambridge Univ. Press.

Zindler, K., (1902). *Linengeometrie mit Anwendungen I & II.* Sammlung Schubert, vs.34 & 51, G. J. Göschensche Verlagshandlung, Leipzig. (380 & 251pp).

A Procedural Model for Interactive Multimedia Development

James L. Mohler
Department of Technical Graphics
Purdue University
West Lafayette, IN

Abstract

This paper discusses a model for the development of interactive multimedia. Through the use of five stages, it gives a methodical procedure to creating multimedia products. The uniqueness of the Multimedia Development Model is that it allows for total planning and increases communication within group settings; reducing and sometimes eliminating errors. Although rigorously adhering to any one model would be unrealistic, it chronologically presents the major points of concern when developing interactive multimedia.

Introduction

Multimedia is any combination of text, graphics, sound, animation, and video delivered and controlled by the computer (Vaughn, 1994). Interactive multimedia however shifts the controlling agent; giving control to the user rather than the computer. This shift of control allows for individually customized information flow (Park, 1994).

Multimedia is successful because it draws upon more than one of the five human senses; utilizing the two fundamental senses vital for information reception — sight and sound. It also sparks human thought in the process due to motion and sound. Multimedia, although intriguing, does not require the user to be actively controlling what is being presented (Burger, 1993).

Interactive Multimedia

Planned interactions are known to have a very positive affect on learning. Learning theorists state that to reach an objective it must be practiced to help the learner cognitively incorporate it. The interaction, or "doing the objective," helps the learner reach the objective and recall the information, skill, or behavior that was practiced (Dick & Carey, 1992).

Digital media is no different. Wolfgram (1994) states, "people only remember 15 percent of what they hear and 25 percent of what they see, but they remember 60 percent of what they interact with (p.12)." Multimedia, then, requires auditory and visual perception only. Interactive multimedia, alternatively, requires internal user processing and focuses on the needs of the user, thereby requiring the user to be actively thinking about the information being presented, making predetermined decisions, and presumably acquiring the information or skills being presented.

Lindstrom (1994) states, "that individuals retain 20 percent of what they hear, 40 percent of what they hear and see, and 75 percent of what they hear, see, and do (p. 26)." A 1987 study indicates that students using interactive programs learn and retain 25 percent more of the information presented and learn 50 percent faster than those who use traditional learning methods (Kolowski, 1987). A series of six studies conducted from 1990 to 1992 show that multimedia students have a 55 percent learning gain over students receiving traditional classroom teaching. They learn the material 60 percent faster, and their long-term (30-day) retention ranges from 25 to 50 percent higher (Adams, 1992).

By drawing upon multiple human senses and requiring human interaction, the learner acquires knowledge more efficiently. This makes interactive multimedia a powerful medium for education and training. It is also a very adaptive tool in marketing situations where a persuasive flair helps change an attitude or belief (Stephanae, 1994).

> Efficiency and speed in the acquisition of knowledge are becoming a major concern as noted by Lindstrom (1994).
>
> The most striking paradox of the information age is this: the more information we produce, the less time we have to assimilate it. Even so, we are told to expect the volume of information to continue to multiply exponentially, theoretically without end. That presents a profound challenge to businesses and business people, who must find ways not only to distill information into knowledge but also to overcome the information repellents that people naturally exude as the data swarms increase. In an environment where an increasing volume of information vies for the attention of individuals and businesses with a finite capacity to absorb what is being offered, your message can be easily lost, misinterpreted, or ignored outright.
>
> Business communication must happen faster, it must be precisely targeted, and it must hit with the maximum impact. How well you execute those three requirements will determine, to a large extent, how you are measured by your customers and your competition (pp. 3-4).

Efficient ways of information acquisition must be utilized to make education, marketing, and training occur faster, more precisely, and with maximum impact; allowing organizations and individuals to remain successful.

Information Distribution

The goal of information distribution is for a message to be conveyed, comprehended, and either applied or acted upon (Lindstrom, 1994). This includes not only the communication process (information – sender – channel – receiver), but also the retention and use of that information in various situations; signifying that a transfer of knowledge has successfully occurred (Gagné, 1974). Information presentation without cognitive incorporation, comprehension, or application is meaningless. This idea is explicitly conveyed in the following statements.

> Computers cannot be sincere. Nor can they be emphatic, enthusiastic, or empathetic. They can only collect, process, and store information. The power of information is not contained in the data, but in the ideas, the emotions, and the actions it triggers in the people who encounter it. Information is alive, evolving, and ever-changing (Lindstrom, 1994, pg. 5).

Information becomes powerful when it gains personal interpretation, comprehension, meaning, retention, and use; thereby becoming knowledge. It is the purpose of information distribution to personally transfer this meaning or message from one individual to another (Wolfgram, 1994). Without the transfer of the message, the informational data has no relevance. This is where traditional information distribution has lacked sufficiency — transferring the real message behind the abstract letters and data; the internalization where information becomes knowledge and is alive and useful within the individual.

Traditional Media

The sole limiting factor of paper-based materials is that they provide a calloused and distant means of user interaction with the information being presented. They also give a shallow and somewhat blurred view of intended meaning since they utilize only one human sense through obscure characters and motionless graphics. This type of media, also known as "monomedia" (Lindstrom, 1994), has small aesthetic value due to the static nature of the printed page. It presents a monotonous world to humans who are multimedia communicators – desiring motion and sound. Low knowledge transfer via the printed page can also be attributed to the lack of user interaction with the information. These two factors create a mild barrier in the process of cognitive processing and encoding. In essence, the medium becomes an inhibitor of the message it is trying to convey; vaguely describing, at best, the intended meaning.

When it is used, interactive media enhances and reinforces the message. Animated graphics, auditory data, and videography incorporated into interactive multimedia utilizes a wider range of human senses, easily sparks deeper processing, and helps paint a clearer picture of intended meaning. This makes the information easier to decode, interpret, comprehend, and encode into the cognitive schemata. It also increases interest and motivation making the learning process more enjoyable (Stansberry, 1993).

A Method

A review of literature leads to many project-specific items that must be addressed when creating multimedia products, but few give a structured, step-by-step method that is replicable. The multimedia development process includes five major stages that are applicable for most developmental needs. The process can be implemented, to varying degrees, for short- or long-term projects.

The Multimedia Development Model, shown in Figure 1, is the embodiment of those five areas. The model is a typical

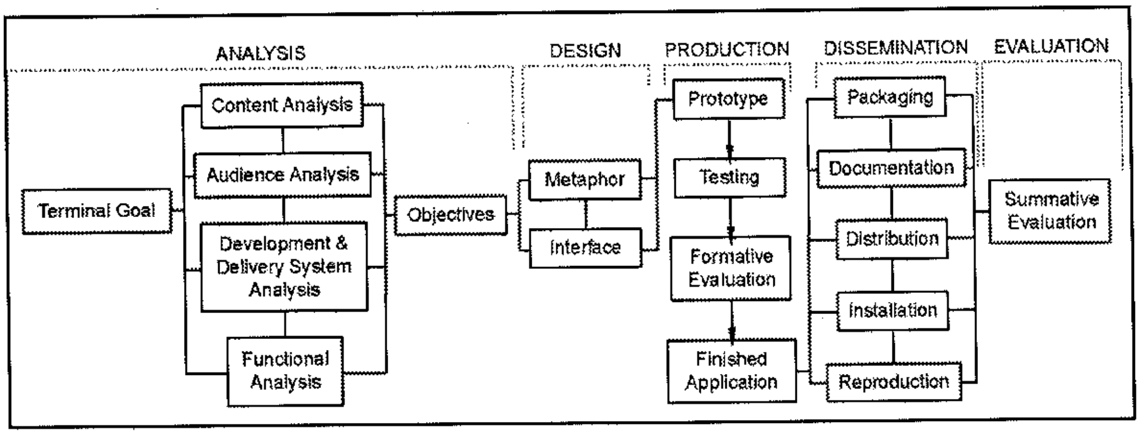


Figure 1 The Multimedia Development Model

progression in a real-world project. All the later stages draw upon the documented information from the analysis phase; allowing for total planning before implementation.

The Analysis Phase

The analysis phase of any multimedia project can be the most time intensive portion. Of the time spent working on a project, 20 to 30 percent includes developing ideas, verifying those ideas, and deciding how to implement them. By stringently analyzing a proposed project, the user reduces or eliminates rework.

Terminal Goal

To begin any major multimedia endeavor requires a clear definition of the main goal of the project. Sometimes a simple clarification made to an existing "fuzzy" goal is sufficient, while at other times the developer must create and define a goal. During this stage, a goal may be as simple as "explaining the purchasing process in the ACME Steel Company" or as complex as "describe the fundamentals of descriptive geometry" This goal, although stated in general terms, must imply the intended terminal outcome as a result of the product.

Content Analysis

The content in itself may already exist by way of a content design model or it may need to be created. At this point, the author must ask an important question. Can the content be effectively presented on the computer faster, cheaper, easier, or better than other methods? Several sources suggest that multimedia is the cure-all for information distribution, but as some believe, not all content lends itself to multimedia development (Shelton, 1993). Multimedia, although a powerful medium, has limitations. The content needs to be analyzed to determine optimum compatibility with multimedia or traditional medium.

During the latter part of the content analysis, media integration is an important element to consider. If the content already exists, from where are images, sounds, and text coming? If it is new material, from where will the media elements come? Who will obtain or create them? Are copyrights secured for their use? Do licensing or release statements need to be issued to use the media elements? How will they be digitally incorporated (i.e., file format utilization)? Answering some of these questions may have to wait until analysis of the development and delivery systems, but legal consequences can result without proper copyright acquisitions, not to mention extreme difficulties in integrating certain file formats and media elements into a multimedia venture.

Audience analysis

Background, skills, knowledge base, and age all contribute to the way information is presented and whether it is received. Also important is the number of audience members: Is it a large audience or a single user? Does the audience include students, business professionals, specialized individuals, or an audience with a general background? The answers to these questions alter information presentation style and absolutely determine metaphor and interface development. If the audience is composed of students, something attention-getting may be required. Younger students are used to modern television programming such as MTV and the like; to gain their attention requires more than a slide show approach. Alternatively, older students or conservative business professionals can be offended by this approach. By analyzing the audience and documenting their requirements and interests, the developer ensures a more successful multimedia project.

Development and Delivery System Analysis

An important aspect of designing interactive multimedia is the development and the delivery system. Most individuals are knowledgeable about the hardware and software they have to create the project (i.e., the development system). It is mentioned only for those who may be unaware of its importance, but in project settings composed of several individuals — which is usually the case — this analysis provides an opportunity to discuss the various hardware and software capabilities available to all individuals. Departmentalized companies are often oblivious to the resources available in other departments and are often surprised by collaborative capabilities. By first discussing departmental resources, all individuals involved in a project become aware of the various avenues of creation. It also allows an opportunity for discussion about the most efficient means of creating various portions of a project as well as who has what skills.

Alternatively, the delivery system, with all its subtle complexities, is often overlooked. The capability, mainly of hardware, is of prime importance. With the plethora of hardware systems, options, and platforms available, the individual needs to analyze the setting in which the project will be run. Concerns such as display systems; computer specific information such as CPU speed, amount of RAM, distribution media (i.e., floppy disk, magneto-optical, SyQuest, or CD-ROM); as well as control devices such as a mouse, keyboard, radio- or laser-transmitted input hardware need addressed. All of these variables affect the type and amount of digital media used within a multimedia piece.

By defining the limiting parameters for a delivery system, an effective multimedia presentation can be created. The developer can do this by being apprised to limitations and remaining within capable creative and liberate means. When reviewing both the development and delivery systems, note that the product is only as strong as its weakest development or delivery system link. For example, a 486 SX with 64 MB of RAM is not any more effective for a multimedia presentation with included video than a 486 SX with 8 MB of RAM. The weakest link principle applies. The slow speed of the SX databus counteracts any effect the extra RAM would have on

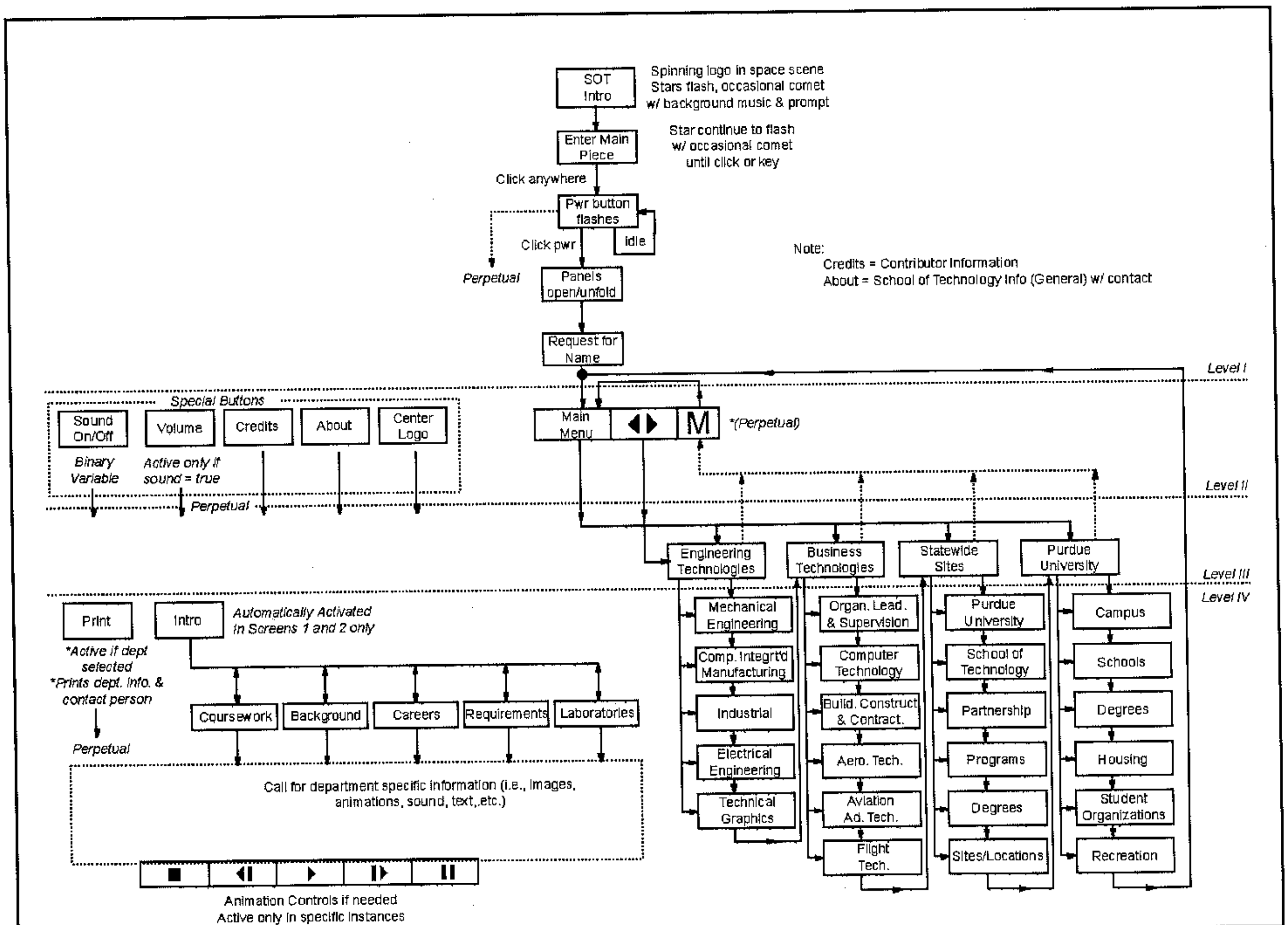


Figure 2 A Functional Analysis Flowchart

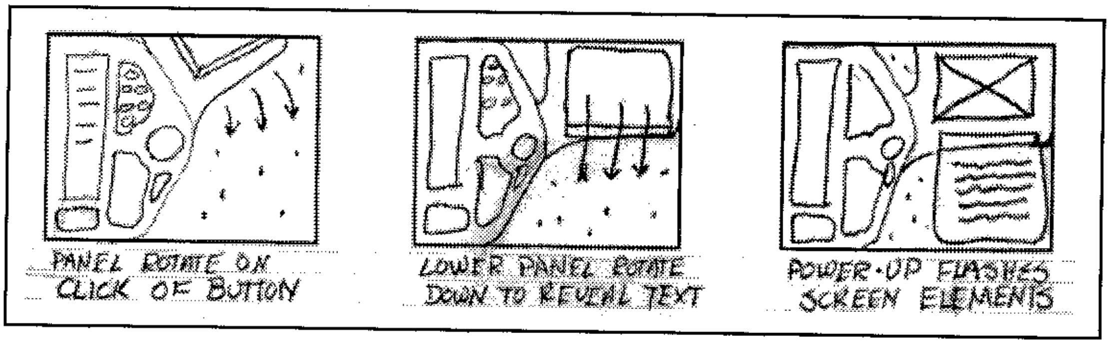


Figure 3 Storyboarding a concept

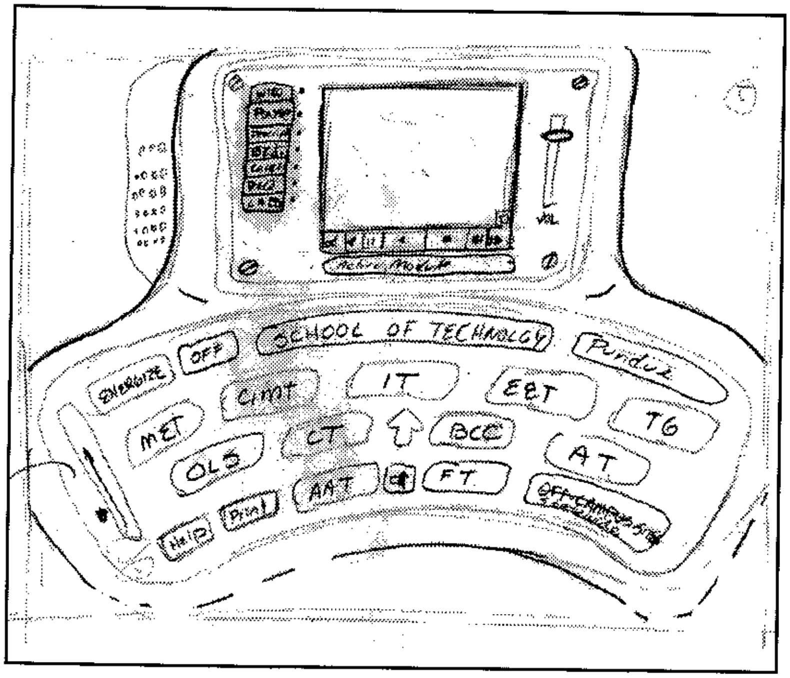


Figure 4 Preliminary sketch from a brainstorming sesion

displayed video. The capability of the computer to hold information in main memory is available, but the internal road for information flow from drive to display is much too slow. Included video, although capable of being loaded into memory, will still play very slowly and sporadically.
When dealing with clients, who have expectations and deadlines, analysis of the development and delivery systems keep the developer from

a. proposing what they cannot create with available resources, and
b creating what cannot be effectively used during delivery.

These are two of the biggest failures due to poor planning.

In addition to analyzing the two systems, the delivery environment must be analyzed as well. By analyzing the delivery environment the individual can plan for display screen sizes, amount of surface noise or other distractions, as well as requirements for effectively using the multimedia tool. Time of day can also have a direct bearing on the effectiveness of the presentation.

Functional Analysis

The functional analysis is a continuation of the general goal. It seeks to define all of the functional capabilities within the final multimedia project including the major goal if it is an implied output or feature. For example, the functional analysis for a project whose general goal is "allowing the user to search through a database of images and text to gain information" would include display output as part of the functional analysis. It would also define other important features that the application would perform. This can include capabilities such as printing, external application use, other outputs such as text or graphic digital files, CNC output, stereovision output, or any other type of relevant features.

The functional analysis includes a verbal description of output features. It always includes a descriptive flowchart that shows all of the linear and non-linear paths in the product as well as external links and functions; it is a visual representation of the verbal description. Figure 2 displays an example of a functional analysis flowchart. This flowchart visually shows all of the levels of interactivity and what options the user has at any instant in the application. It also gives the user a roadmap or skeleton for the creation of programming during the production stage. It shows the natural breaks that occur in the information; allowing for modularization if so desired.

Objectives

Using the information gathered, the author can begin defining clear and precise objectives for the application. These objectives should not be confused with any objective associated with the content itself, although in certain instances there may be overlap between the content and product objectives. The objectives developed here strictly define the capabilities of the product, how the capability functions, and how to know if the capability was successful.

Design Phase

Once the appropriate variables have been analyzed, the multimedia group is more apt to develop a coherent metaphor and interface. Designing and developing these elements involves storyboarding the metaphor and designing the interface.

Metaphor

The metaphor of the multimedia project requires creativity and ingenuity. Based on the clear and documented direction yielded from the analysis phase, the multimedia group is ready to create the storyline of the presentation. This is done through a storyboard process. Storyboards (as seen in Figure 3) include small "thumbnail" sketches of the media elements that occur on each screen of the presentation by manually sketching them. The storyboards can also contain information such as time lags, branching information, sound notes, transitional notes, and camera angle notes. The storyboards become a visual script for the multimedia product. The storyboards can be developed for the whole product or selected portions.

The metaphor must remain coherent with the information discovered in the analysis. Coherency is important because the metaphor is the part of the presentation that gradually prepares the user for the confrontation with the interface. Individuals using any tool have a learning curve; the time required to learn to use the "new tool." If a metaphor is coherent, the user is prepared for the look and feel of the interface.

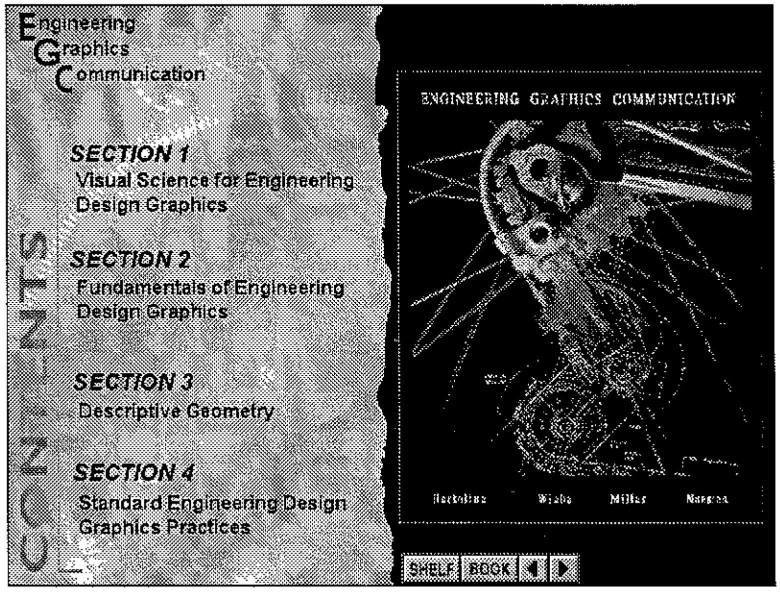


Figure 5 The book metaphor. *(Courtesy of Richard D. Irwin, Inc.: a Times Mirror Higher Education Group).*

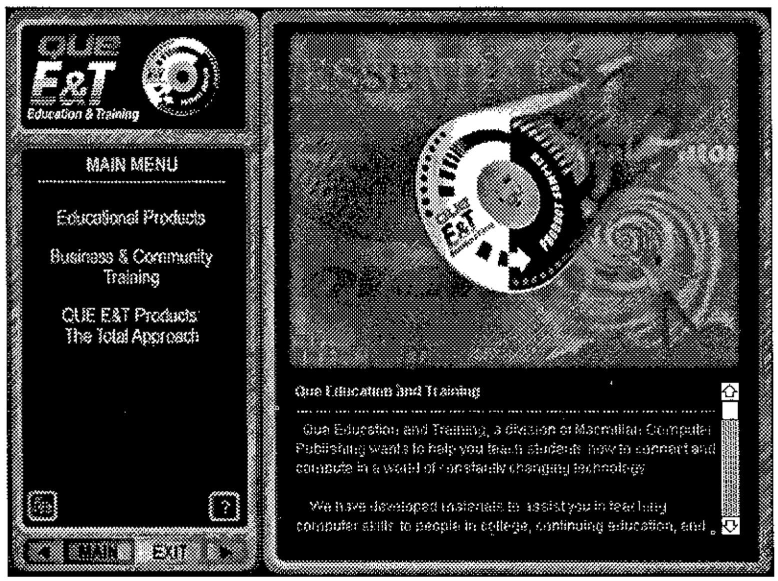


Figure 6 The digital device metaphor (*Courtesy of Que Education and Training; a division of Macmillan Computer Publishing*).

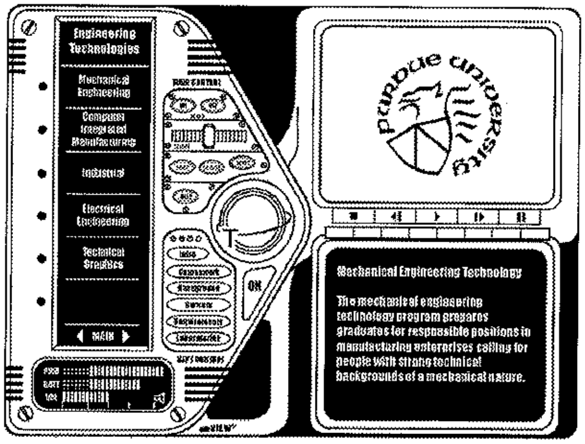


Figure 7 Interface design layout

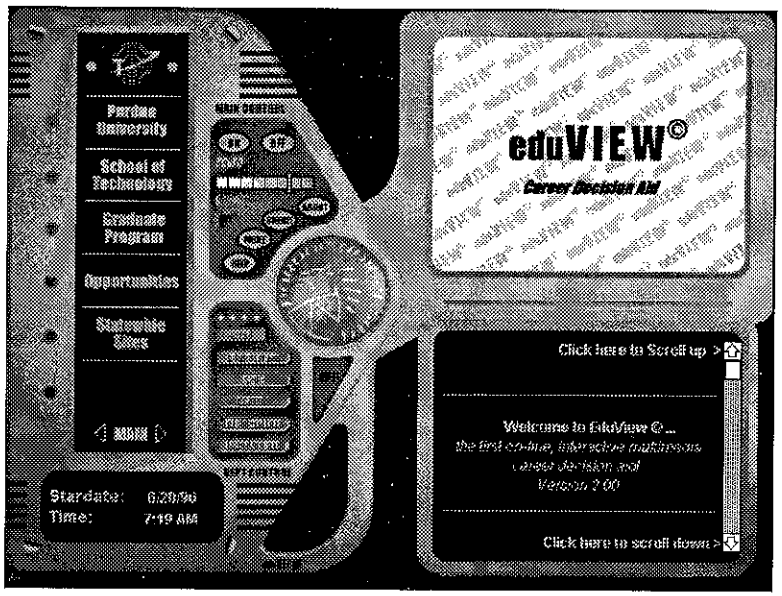


Figure 8 Final interactive piece

Sometimes they are even prepared for how it functions. The familiarity with the interface before it is revealed depends upon the amount of realism with which the metaphor is developed and presented.

The metaphorical message being sent to the user must not only be coherent but also clear. Vagueness in the idea or storyline confuse the users and can consequently distract them (Marcus, 1995). Clarity is added by what is known as supporting elements. Supporting elements can include graphics, sounds, and video.

All of these elements contribute to attracting the user, drawing on his or her background and enticing them to pay attention. This is the power of the metaphor; to more easily attract and possibly entertain the user while disguising the real purpose of getting them comfortable with a new environment. Coherency and clarity in a metaphor help the user; performing the metaphor's main purpose — introducing the interface.

Interface

The interface is the point of contact between the user and the computer. It is a point of interaction and must provide for feedback to and from both parties. The interface is developed through sketches that are first developed as primitive block shapes to represent interactive and non-interactive areas of the screen. The block shapes are then refined to include panels of buttons, image or text areas, or "warm-and-fuzzy" areas. These sketches usually begin as thumbnails and are consequently refined into "working drawings" drawn to screen scale. This means that the confines of the design layout is equal to the desired screen resolution and is measured in pixels. Standard resolution for multimedia presentations is 640 pixels by 480 pixels by 256 colors (denoted as 640x480x256).

Resolution plays an important part in the development the media elements of the final interface. By drawing the interface at an appropriate but accurate scale, guesswork is eliminated. Many of these sketches can be drawn manually or digitally, but the final concept drawing is usually digital. The interface is the visual embodiment of the ideas and functions decided upon during analysis and is graphically shown through a final conceptual drawing.

Human Computer Interface (HCI) design is a rapidly evolving field. This field focuses on the characteristics of good interface design which include clustering of common buttons, instantaneous feedback (such as a click sound when the user picks on a button), clear iconic representations, readable text segments, use of color, and pleasing graphics. All of these features contribute to a user-friendly environment. The most important point, however, is that the user consistently be in control. At no point should the computer do something the user does not expect. Users that are unfamiliar with an environment become uncomfortable when they feel out of control, thus undermining the information transfer process. To overcome fear, intimidation, and loss of interest the interface should incorporate many of the good HCI design features.

Production Phase

The production phase is where development of the "soft" product begins. This phase includes prototyping, testing the prototype, revision, and finalizing the application.

Prototyping

The prototyping phase is the first attempt at making the final product. Throughout the analysis phase, the group is actually preparing a plan of attack for the project. The prototype is the introductory implementation of that plan. It provides a means of creating a sample of the final product; giving the client the opportunity to accept the existing interface, metaphor, and interactive programming. It does this by providing a means to test media integration, programming, and content flow. Often things do not work out as planned. The prototype gives an opportunity to test what is believed to be true as it relates to the project.

Testing

Once the prototype is completed, it is distributed for testing. The criteria for this test are based upon the objectives, while the parameters for the test are based on the content, and audience, delivery system, and functionality. This testing should occur under the circumstances in which delivery will take place. If the intended platform is a 486 DX2, test it on a 486 DX2. If the application is to be used on a network, test it on a network. If the audience is business professionals, employ professionals to test it. The parameters reflect the intended circumstances for use.

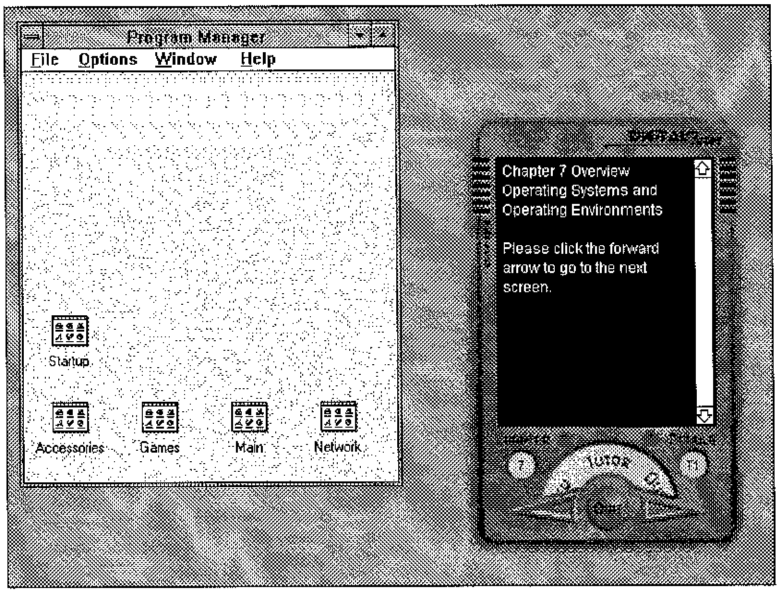


Figure 9 An interface that draws on past experiences (*Courtesy of Que Education and Training; a division of Macmillan Computer Publishing*).

Formative Evaluation

The formative evaluation is made after testing of the prototype has occurred. It requires the author to review the testing data, accept or refute the resulting prototype and, consequently, continue or abandon the work. This gives an opportunity to discuss problems or revisions that need to be made and where misinformation occurred within the multimedia design process. When a well documented analysis phase has been performed, only minor modifications are usually necessary. The formative evaluation gives an opportunity for discussion about revising, deleting, or adding to the application and where those changes are necessary. It may be necessary to conduct another test and evaluation procedure if significant revision seem necessary.

Finished Application

Using the programming shell of the approved prototype, finished media elements are incorporated, programming is completed, and the application is finalized.

After the application is finished, it may need to be translated into a usable and protected format for distribution using software specific utilities.

Dissemination

Once the application is finished the author must physically prepare it for distribution; packaging, installation programs, documentation, reproduction, and distribution must now be executed. Assuming decisions were made during delivery analysis, some areas may already be completed or at least carefully thought through with a number of individuals involved with the project. It is possible that much of this work can be done concurrently with other tasks.

Packaging

Packaging for the finished multimedia product is determined by the media. There can be several options depending upon which medium is chosen. Diskette media require the creation and design of labels while CD-ROM requires design of the imprinted CD label and the jacket. Each medium has its own packaging requirements and choice depends upon budget.

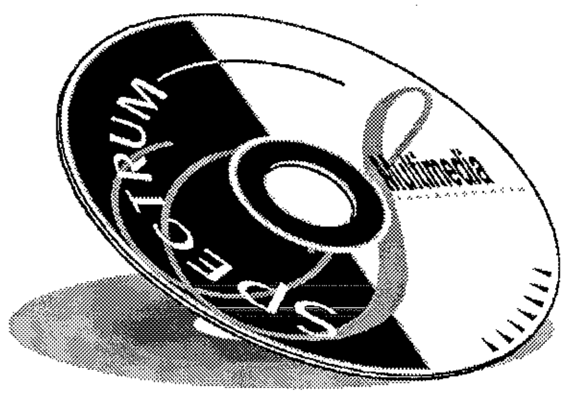


Figure 10 CD design

Installation

For distributing most products, file compression is required. When this is the case, it is desirable to have a commercial installation tool copy the files from the distribution media to the user's hardware. This insures that all necessary items are placed in the proper location. There are numerous programs available to create customized installation programs for the non-programmer.

Documentation

All software should include some type of documentation, even if it is simply how to install it. This can be digital documentation, usually found on the first disk, as well as hardcopy information distributed with the project. The amount of documentation needed to adequately get the user up and running will depend on the complexity of the multimedia piece. The failure of many software products is the lack of good documentation.

Reproduction

Once a master set of media has been created for a product, replication can begin. Most reproduction houses are capable of reproducing media cheaper than can be done in-house and, just as with printed media, cost is inversely proportional to number of copies. Time also enters this equation, generally increasing prices for quick turn-around. When planning the reproduction, the author needs to clarify, as well as justify what size print run is cost-effective, yet feasible.

Distribution

A concern that is usually not discussed until the end of the project is where the product will be shipped when completed. The author's responsibility does not end until the product is safely in the client specified destination. Sometimes the client may handle reproduction and dissemination, thus the author is relieved of this responsibility.

Evaluation

The final evaluation phase, also called the summative evaluation, is done by the author to determine the final effectiveness of the multimedia application by comparing it to all of the objectives developed during the analysis phase. Often the client and the author will do this independently; other times they will work together to perform it.

This evaluation can be performed in a variety of ways. By testing the final application with a sample group the interested individuals can determine the program's effectiveness. An alternative method, to simply test functionality, requires the creation of a checklist derived from the objectives. An entire array of tests can be created to evaluate any aspect of the product that is desired.

Conclusion

The Multimedia Development Model, although not applicable to all situations, will alleviate miscommunication between group members, and between clients and authors, thus reducing errors. In all situations, regardless of the duration of a multimedia project, the four primary analysis elements are vitally important. This author cannot conceive of a situation in which content, audience, development and delivery, and functions would not affect what is developed and how the product is developed. Products that are successful are a result of planning in all these areas.

Reference List

Adams, G. L. (1992, March). Why interactive? *Multimedia and Videodisc Monitor*, 10, 20-24.

Burger, J. (1993). *The desktop multimedia bible.* New York: McGraw-Hill.

Dick, W. & Carey, L. (1990). *The systematic design of instruction.* US: Harper Collins Publishers.

Gagné, R. M. (1974). *Essentials of learning for instruction.* Hinsdale, IL: Dryden Press.

Kolowski, N. (1987, February). Development of interactive instution materials. *Instructional delivery systems*, 1, 8.

Lindstrom, R .L. (1994). *The Business Week guide to multimedia presentations: Create dynamic presentations that inspire.* New York: McGraw-Hill.

Marcus, A. (1995, February). Making multimedia usable: User interface design. *New media*, 5, 98-100.

Park, W. T. (1994, May). Creating virtual worlds: New tools for movies. New Media, 4, pp. 53-54.

Shelton, S. M. (1993). Multimedia. technical communication. *Journal of the society for technical communication*, 40, 694-704.

Stansberry, D. (1993, February). Taking the plunge. *New media*, 3,. 30-36.

Stephanae, S. (1994, April). Interactive advertising. New media, 4, 43-52.

Vaughn, T. (1993). *Multimedia: Making it work.* New York:McGraw-Hill.

Wolfgram, D.E. (1994). *Creating multimedia presentations.* Indianapolis: Que.

Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component: Implementation Issues*

Davor Juricic & Ronald E. Barr
The University of Texas at Austin
Department of Mechanical Engineering
Austin, TX

Abstract

This paper reports on the on-going, NSF-sponsored research project to extend the Engineering Design Graphics (EDG) curriculum to include introductory instruction and laboratory experience in CAD/CAM. The current EDG paradigm, which includes sketching, CADD, and solid modeling exercises, is being extended to include direct modeling applications to design analysis and prototype manufacturing. The proposed new EDG curriculum is more representative of modern engineering, will facilitate integration of design and manufacturing experiences throughout the engineering curricula, and has high potential to inspire lower division students to persist in their studies. This paper presents the background of the project and discusses the major issues for project implementation: introduction of finite element analysis to lower division students, feasibility of classroom prototype manufacturing, and curricular issues relevant to two- and four-year engineering programs.

Introduction

In the past, design representation had been traditionally relegated to engineering graphics. Engineering drawings were used to convey data for both part analysis and manufacturing. Recently, solid models have been introduced as complete and unambiguous computer descriptions of the part geometry. Having such a formal description available, another computer program or system can directly perform engineering analysis, manufacture the part, and, if needed, generate engineering drawings. Thus, a new design paradigm has been established, a paradigm that uses a solid model as the common thread to integrate the design process with engineering analysis and part manufacturing. The solid-model-based design paradigm is feasible with the present technology and it has been the focus of recent efforts in industry and academia to refine and improve the process.

As part of the NSF's Leadership in Laboratory Development (LLD) program, an NSF-funded project has been initiated at the

* *This paper is based on a series of presentations at the 50th EDGD Midyear Meeting (Juricic & Barr, 1995a, Juricic et al., 1995a, Barr et al., 1995a, Juricic et al., 1995b, Barr et al., 1995b.)*

University of Texas at Austin, with the two authors of this paper as the project co-directors. The project promises to develop a national model for the lower division CAD/CAM (computer-aided design, analysis, and manufacturing) laboratories that will replace present CADD (computer-aided drafting and design) laboratories for teaching Engineering Design Graphics. The new laboratories, which will include engineering analysis and prototype manufacturing, can impact on a large number of students of four-year engineering schools and two-year community colleges. Being the first design-oriented course in nearly all engineering curricula, EDG's improved laboratory will set the stage for a modern and integrated approach to engineering design, analysis, and manufacturing. It will be more representative of modern engineering, much more appealing to freshmen, and capable of motivating freshman students to persist in their studies during the freshman and sophomore years which they find lacking of rewarding and exciting engineering experiences.

Background of the Project

The solid modeling approach to design representation was introduced to the teaching of Engineering Design Graphics mostly through an NSF Curriculum Development Project (Barr & Juricic, 1990). Through that project, an Engineering Design Graphics curriculum was developed in which geometric modeling is the central theme that integrates design, analysis, and manufacturing. The curriculum included the process of building a solid model and using it to generate engineering drawings. The solid model application to analysis and manufacturing was not covered in any detail. The potential of solid modeling is, however, much greater than producing engineering drawings. Geometric data contained in a solid model can be used for direct engineering analysis and for manufacturing. Under "direct" it is meant that the geometry data contained in a solid model file can be used by analysis and manufacturing software without the designer's interpretation of the model data.

It was recognized as early as the Fall of 1992 that a major effort is needed to provide freshman students with experiences in applications of solid models to engineering analysis and prototype manufacturing, in addition to the generation of engineering drawings. A survey of a group of well-known Engineering Design Graphics educators, conducted in October 1992 as a part of the study of this problem, has shown that the need for a next generation of EDG laboratories is being felt throughout the nation. Out of 119 active EDG educators that have returned a questionnaire on this subject, 114 were in favor of the development of extended EDG laboratories to include CAD/CAM applications, and 105 were willing to participate in that effort. In the Fall of 1993 a proposal was submitted to the NSF-LLD program do develop a national model for the lower-division CAD/CAM laboratories that will replace present CADD laboratories for teaching EDG courses. The project was proposed as a two year project that will identify and integrate software and hardware appropriate for lower-division students, develop and document laboratory exercises, and produce instructor's notes and tutorials for laboratory development. The proposal was approved and the grant awarded at the end of Spring 1994 (NSF, 1994).

Perceived Project Challenges

While introducing solid models and their use for generating engineering drawings was inside the scope of expertise of traditional engineering graphics instructors, it is quite different with the rest of the solid-modeling-based design paradigm. Although appearing as a simple addition to the present curriculum, the changes proposed involve significant efforts to develop new laboratories. Software and hardware, appropriate for a lower-division lab, have to be identified and integrated, exercises developed and documented, and instructor's notes, tutorials, and lab-organizing guidelines written. Early in the project, significant challenges were perceived in organizing such a CAD/CAM laboratory for EDG. Some of the main challenges perceived for the project are listed here.

1 Adaptation of concepts involved in CAD-oriented engineering analyses for presentation at the lower-division level calls for a qualitative rather than a quantitative approach to problem presentation. A similar approach is being used for presentation of manufacturing processes involved in the CAM part of the lab.
2 Setting-up a basic CAD/CAM lab unit consisting of an equipment cluster (e.g. four CAD workstations, one printer/plotter, and one table-top manufacturing machine) is a challenge for any traditional EDG instructor.
3 Satisfactory software packages must be identified that include drafting software, solid modeler, engineering analyses codes, and software for STL file generation to drive the rapid prototyping machine.
4 Hardware and software of a laboratory cluster unit must be discussed in detail and alternative solutions must be documented so as to facilitate local variations in different schools.
5 Instructional lab units must be developed to parallel the instruction material normally presented during the lecture periods in an updated Engineering Design Graphics course.

Personnel Involved

While the bulk of the work is being done by the two co-directors of the project, several other groups of experts are helping them to reach balanced solutions that will be of use to a variety of four- and two-year engineering schools. An Advisory Committee, composed of six eminent educators and leaders in the field of Engineering Design Graphics, has been established. The Advisory Committee members are closely cooperating with the co-directors of the project in accomplishing the stated goals.

A group of 26 Academic Consultants has been selected out of those survey respondents that were willing to participate in the project. The co-directors are relying on their feedback and advice for initial set-up and further refinement of instructional material. A good representation of two-year colleges in the Advisory Committee and on the list of Academic Consultants reflects the NSF's concern that the developed material be applicable not only to four-year universities but also to two-year colleges.

A group of Industrial Consultants has been selected from the regional members of the Departmental Visiting Committee of the Mechanical Engineering Department at The University of Texas at Austin. They represent local and regional industry and are potential employers of our graduates. Out of the 16 members of the visiting committee, six have been chosen to take an active part in this project as Industrial Consultants.

Engineering Analysis Issues

Engineering analysis characterizes a significant part of engineering education. One of the main objectives of this project is to provide the lower-division engineering students with an introduction to engineering analysis. The intention is not to present the broad field of engineering analysis, but to give some examples that are characteristic of a streamlined process of the future: one which starts with the geometric model of a part and ends with its manufactured prototype. In the present state-of-the-art software for engineering analysis, there are several categories of problems that use solid model data as the starting point. Four categories are mentioned below and their characteristics relative to their potential for EDG lab extension are indicated.

Solid Models and Engineering Analysis

Mass properties of a volume are known concepts to lower-division students. They include: volume and weight, centroid, static moments, moments of inertia, and products of inertia. All solid modeling systems that are of interest to EDG courses have incorporated calculations of mass properties as the built-in functions of the CAD system.

The second category of engineering analyses that make essential use of part geometry are grouped as field problems. These include: stress and strain fields, fluid flow and pressure fields, thermal flow and temperature fields, and magnetic field problems. All the field problems can be solved with several approximate numerical methods, but one of these methods, however, has shown a clear superiority when implemented on the modern digital computers. It is the method of Finite Elements Analysis that has become today a universal tool for engineering analysis when field problems are involved. The method uses geometric data of the part or volume to generate a spatial mesh necessary for the analysis. This automatic mesh generation, built into some software packages, makes this category of engineering analysis a very attractive candidate for EDG lab extensions.

There are several software packages that analyze motion and dynamics of linkages and mechanisms. Some require mechanism components to be defined as solid models and would thus satisfy requirement that the analysis example be an illustration of a solid model application. However, linkages and mechanisms are inherently composed of more than one component. That requires modeling of an assembly of parts rather than treating one single object, as it is customary in a majority of EDG exercises. For that reason, kinematics analysis problems do not seem to be convenient as exercises for the extended EDG laboratories.

An example using interference and assembly checking analysis would have the same good and bad characteristics as the examples in kinematics analysis. It uses solid models as the starting point but requires that an assembly of parts be modeled. Thus, it does not seem to be a feasible lower-division exercise for the extended EDG laboratories.

Requirements for Analysis Software

Regardless of the type of analysis chosen, there are several requirements that the analysis software should fulfill. The main requirements are as follows.

1. The analysis software should be accessible from within the selected drafting/modeling software. Satisfying this requirement can significantly simplify the handling of different programs involved and reduce the complexity of interchange of the necessary interfacing data.
2. The analysis software should use solid models as the starting data base. It is essential to demonstrate that a complete and unambiguous description of the part geometry inherent in a solid model can be used for all subsequent analyses and final prototype manufacturing.
3. Some FEA software are providing the facility to mesh a solid-model section as a two-dimensional entity. This is an advantage worth exploring. It makes available the simplicity of a two-dimensional FEA analysis without sacrificing the concept of performing the analysis by starting with the solid model data only.

Engineering Analysis Exercises for EDG Labs

Of all four categories of engineering analyses mentioned in the section on Solid Models and Engineering Analysis, the first two have been identified as the most appropriate. Calculation of mass properties and finite element analysis, specifically the analysis of stress distribution and elastic deformation, have been chosen as the most feasible for the EDG labs extension.

One of the EDG laboratories exercises should include calculation of mass properties of the designed part. Such a lab exercise is already included in some of the existing EDG programs. Usually all mass properties that

Designer Mass Properties

Part ID: 0	Mass: 213.9448
Density: 1.0000	Volume: 213.9448
Centroid:	7.2669,4.7065,2.2950
Surface area:	305.3146
Moments of Inertia:	Products of Inertia:
Ix: 8406.0020	Ixy: 7317.3307
Iy: 16576.8481	Ixz: 2117.4365
Iz: 18397.4423	Iyz: 2310.9229
Principal Moments:	Principal axes:
I1: 0.7286	X: 0.7286,0.0000,0.6849
I2: 0.0000	Y: 8406.0020,7317.3307,2117.4365
I3: 0.6849	Z: 7317.3307,16576.8481,2310.9229
Radii of Gyration:	
kx: 0.0584	
ky: 0.0000	
kz: 0.0566	
Write to file File name:	
OK Cancel Help...	

Table 1 Printout of the Mass Properties Data of a given machine part

are available within the solid modeling software used are assigned in this exercise. An example of the mass properties data printout, produced with the AutoCAD-Designer software for the solid model of a machine part, is given in Table 1.

There are a variety of problems that can be designed as examples of the FEA application. The requirements for these problems are that they should be simple, and should use coarse meshing parameters to save calculation time as well as computer resources. To make direct use of solid model data in finite element calculations, the examples should be either solid model sections, producing two-dimensional FEA problems, or applications to full solid models thus producing a three-dimensional FEA problem. To avoid any complexities that may cause difficulty in presenting the material to freshmen, all techniques that economize the calculation process, like making use of part symmetries and axi-symmetric elements, should be excluded. All parameters involving concepts not mentioned in the lecture part will be permanently pre-selected. The modeled parts will be meshed automatically with two- or three-dimensional elements available for automatic meshing. Although the three-dimensional theory of elasticity is not familiar to lower-division students, the concept of stresses and elastic deformations are familiar to lower-division students through courses in Engineering Physics. Thus, the color maps of stress distributions and an illustration of the deformed structure will be easily interpreted by a lower-division student.

A possible FEA laboratory exercise is illustrated in Figure 1. The exercise shown leads to a two-dimensional FEA model of a connecting link having a uniform thickness. It disregards any symmetry advantage for the convenience of simple boundary conditions. Some other simple FEA exercises have been indicated by Howell (1993).

Prototype Manufacturing Issues

Manufacturing is the production or generation of a three-dimensional object from solid, raw material. It includes the production of single parts and the assembly of those parts into larger systems. Manufacturing is usually associated with parts that are produced in a plant or factory, as opposed to construction which is a term referred to the production of large composite structures such as buildings, bridges, and highways. However, even these large structures use many manufactured components in the construction process.

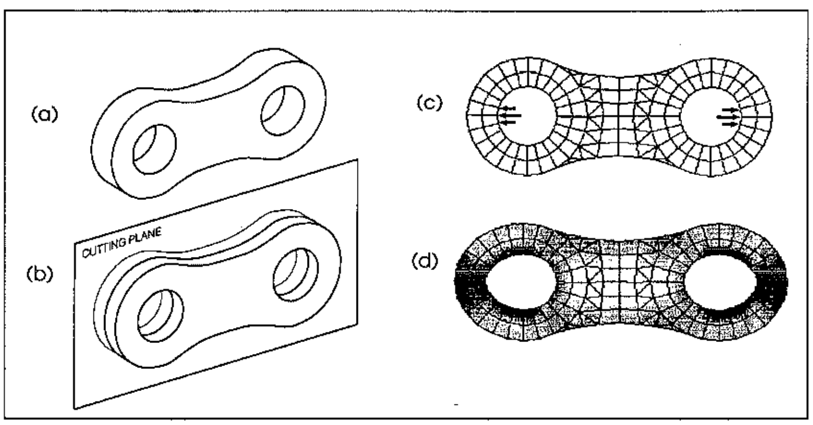


Figure 1 This is an illustration of a two-dimensional Finite Element Analysis (FEA)

a. A solid model is built of a connecting link that has the uniform thickness as if it were cut out of a flat plate.
b. By considering only its section, the FEA problem is reduced to a plane-stress two-dimensional plate problem.
c. The mesh is automatically generated by pre-processing software, and the boundary conditions (external forces in equilibrium) are interactively entered.
d. The results of the FEA analysis (deformations and maximal shear stresses shown here), are given as color contour maps produced by post-processing software.

Traditional manufacturing processes have been included in the Engineering Design Graphics course for many years, typically through liberal use of illustrations of machining operations. It is now feasible to have the students participate in the active production of a prototype or prototype model directly from the computer-generated solid model data. There are several possible approaches to accomplish this goal (Burns, 1993, Wood, 1993).

Solid Model Application to Manufacturing

A CNC (Computer Numerical Control) tape or file can be generated from the solid model data, and then applied to the actual raw stock on the shop floor using the appropriate machine tools. The material removal operations that can be controlled through generated CNC tapes include milling, turning, cutting, and drilling operations. Some of these functions are now available on low-cost, desktop systems.

Sheet-metal folding software can automatically develop correct flat blank layouts from 3-D sheet-metal computer models. It can then nest these blanks on the large sheet metal material. Similar to a pen plotter mechanism, a laser beam or a welding torch cuts 2-D patterns into materials such as Plexiglas, wood, cardboard or steel plates.

The current state of the art in linking solid modeling to manufacturing is the generation of rapid prototypes directly from the solid model data base. There are different technical approaches to building a rapid prototype, but they all use an additive process by fusing material layers or particles to sequentially create the 3-D volume defined by the solid model. The standard link between the solid model data and the prototyping machine is an STL file which is named after STereoLithography, the pioneering approach. The file is created directly from the solid model data.

Candidate Systems for Prototype Manufacturing

Several companies offer desktop machining systems for making rapid prototype models by milling and turning. They include Roland Digital, Light Machines Corporation, and Minitech Machinery. These machining systems can work with soft materials such as wax, wood, plastic, and non-ferrous metals. The price starts at $12K. Other possibilities for desktop machining include the use of laser cutting machines, such as the LaserCAMM Model 25S. These applications are relegated to 2-D profile applications, such as the making of gaskets, engraving, sign making, and circuit board design.

There are a number of rapid prototyping processes that are currently receiving commercial attention. Most are additive processes that build the model layer by layer. The cost of these systems varies from $40K to $500K. Prohibitively expensive are systems that use Stereolithography, Selective Laser Sintering, Laminated Object Manufacturing, Droplet Deposition on Powder, and Robotically-Guided Extrusion concepts. Ballistic Particle Manufacturing system, which is the lowest priced at this time, ejects tiny droplets of melted thermoplastic material from a nozzle, similar to ink jet printing. It builds a 2-D layer to form a slice of the object. The platform moves down to allow a new slice to be formed, until the whole object is produced.

One of the other approaches to model generation is Layer Cutting and Manual Assembly system. The cross section data are output to an adapted sign making plotter that cuts the slices and automatically adds registration holes to each slice. The slices are assembled manually on a registration table and backing paper is removed to expose the adhesive material which glues the slices to form the solid object. Another very low-cost approach to model generation is the Pattern Cutting and Folding software. the program converts 3-D faces and meshes into flat 2-D patterns. These patterns can be plotted on paper, cut out, and then manually folded back and glued into 3-D models for physical study.

Software and Hardware Requirements

The main software requirement is the ease of interface between the CAD solid model data and the manufacturing machine. If the approach is to use a CNC machine, then the software should first produce a simulation of the machining process before the part is built. If a rapid prototyping approach is used, then the software must produce an STL file to interface with the machine.

Hardware requirements for manufacturing in the EDG laboratory are more rigorous. The process should be safe for hands-on student use and should be able to reside in a classroom environment. The capital cost of the hardware should be low to match the typical budgets for educational enterprise. The material supply for the prototypes should also be low-cost and environmentally harmless. The process should also allow the complete production of parts within the time framework of a typical EDG lab course offering (2-3 hours).

Figure 2 ProtoForm software from Pentari, Inc., produces 2-D patterns that can be folded into a fair representation of the 3-D models even when the surfaces with double curvature are involved.

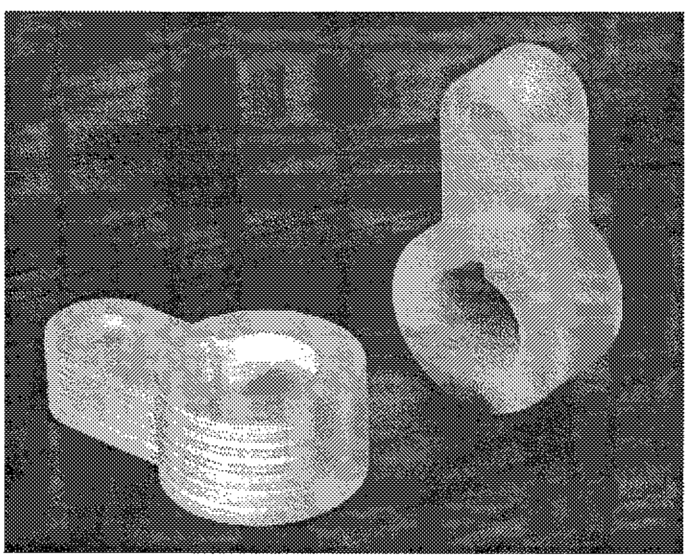


Figure 3 Comparison of the rocker-arm model built by JP System 5 (left) and the model built by Selective Laser Sintering (right).

Manufacturing Units Appropriate for EDG Labs

Due to the aforementioned hardware limitations, many of the rapid prototyping systems that are now being used in industry do not qualify as solutions for the EDG laboratory. This leaves the desktop CNC machining centers, low-cost rapid prototyping systems, and some unsophisticated but low cost approaches as potential candidates.

The ProtoForm software by Pentari, Inc. uses the concept of Pattern Cutting and Folding. It transforms the computer model into an unfolded 2-D pattern with added tabs. The pattern can be plotted on a regular pen plotter, and manually cut out. The student then folds the pattern into a 3-D model and glues the tabs. The 3-D model is viewed for physical inspection and comparison with the rendered computer model (see Figure 2). The process is very inexpensive, safe, and can offer visualization exercises that have been deemed useful in the past. The cost of the software needed is about $200, and the cost of material is negligible. The main drawback is that it does not leave a realistic impression of industrial-level manufacturing.

The JP System 5 is a desktop Layer Cutting and Manual Assembly system by Schroff Development Corporation. The system cost is $5K. It includes a Roland Digital PNC 900 cutting machine, registration board, and all needed software. The software slices the model into layers of a given thickness, the layers are registered manually, and one-on-one adhered to each other. The typical build time for a nominal model of 60 slices is 2-3 hours. While the resolution of 60 slices may seem rough for real engineering applications, it may be adequate for educational purposes. Indeed, the rocker arm model built with the JP System 5 compares favorably with the model built with a Selective Laser Sintering system, as shown in Figure 3. Hence, this simple and economical approach to 3-D model building, which in many ways manually mimics what the expensive rapid prototyping systems do automatically, is an acceptable candidate for educational purposes.

Desktop Machining Centers are small machining systems available from several manufacturers. The price range is from $12K to $20K. The Roland Digital CAMM-3 Desktop modeler is shown in Figure 4. The machining process (milling, turning, drilling) could be first simulated by software to verify correctness of manufacturing. The code can then be interfaced to the machine and the model prototype can be produced by material removal. Considering safety, wastage, and dust particles generated, even with the best material solution available, a desktop machining center is not an attractive choice for a CAM experience in EDG labs.

Personal Modeler from BPM Technology Corporation represents a relatively low cost rapid prototyping system that automatically layers, registers, and adheres the solid model similar to the more expensive systems. The system is designed for an office environment. It builds up a shell-type model by ejecting specially formulated plastic particles in a manner similar to ink-jet printers. The system is also reasonably compact (see Figure 5) and has a build space of 10 x 8 x 6 inches. It takes approximately 2-3 hours to build a hollow 3-inch cube. While this system is still new and unproved in student laboratory situations, it seems at this time to be the best candidate for extending a CAM component to the EDG labs. Its major drawback is the initial capital cost which with a standard educational discount is roughly $40K.

Mechanical, Civil, and General Engineering Curriculum Issues

Realizing that there are many engineering schools with different missions and different engineering departments, a question arises about how well will the new extended EDG laboratories serve different schools and different fields of engineering. Some fields of study may be interested in engineering analysis and prototype manufacturing, while others may be interested only in the engineering analysis or only in prototype manufacturing part. It is also possible that some fields of study have no interest in either engineering analysis or prototype manufacturing.

Types and Missions of EDG Courses

There are a variety of students that are served by Engineering Design Graphics courses. In the past, the arrangement most frequently found in engineering schools was

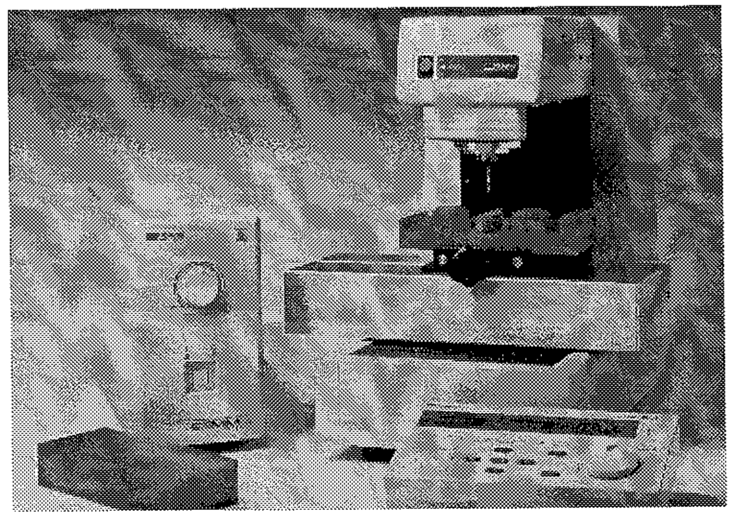


Figure 4 Roland Digital Desktop Machining Center.

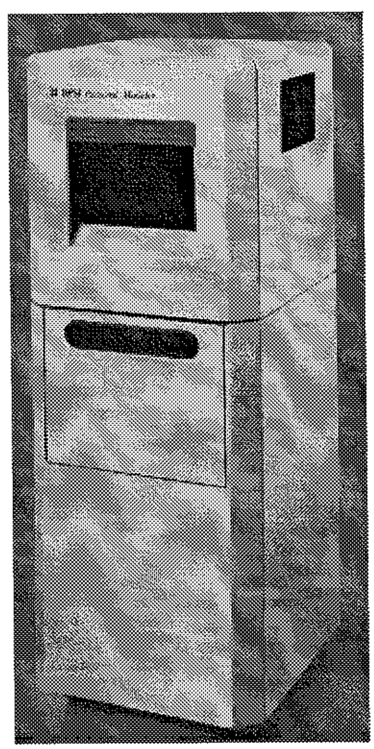


Figure 5 Personal Modeler from BPM, Inc. It is a 5-ft high floor unit.

a common EDG course, or a common sequence of EDG courses, offered to all engineering students. At some schools the common EDG program was implemented through a common freshman year administered by a Department of General Engineering, Engineering Fundamentals, Freshman Engineering Studies, or under some similar name. Currently, we may list the following types of EDG courses, that we are aware of, and their differences as they are found in different schools and departments.

1. The most common type is a general engineering EDG course that is designed for all engineering students. A majority of four-year engineering schools today teach this type of EDG course. The course includes some civil engineering and some electrical engineering elements, but a majority of examples used to illustrate concepts are, due to their simplicity, of mechanical engineering origin.
2. An EDG course that covers material suitable for the mechanical engineering field of study. This course differs from a general engineering EDG course only in that it omits objects and examples related to civil and electrical engineering fields. In addition to mechanical engineering, these courses are equally well suited for aerospace, chemical, industrial, nuclear, and petroleum engineering.
3. An EDG course that is specially tailored for the civil engineering field. This course is usually integrated with the CAD courses that use software popular within the civil engineering community. Many departments of architectural engineering and civil engineering teach this type of EDG course.
4. An EDG course that is specially tailored to electrical engineering covers circuit schematics only and is usually incorporated with the courses on design of electrical circuits.

The Character of the Current EDG Textbooks

As this project promises to develop exercises and teaching material for an extension to EDG laboratories, it is of interest to compare generality or specificity of other teaching materials developed for EDG courses over the years. A large majority of textbooks written on the subject of Engineering Design Graphics are for general engineering EDG courses. A complete list would count over fifty titles. Two classic texts are by Giesecke et al. (1993) and French et al. (1993). Two other titles, which are representative of more recent successful texts, are Eide et al. (1995) and Bertoline et al. (1995). The number of textbooks written for specific fields of engineering is much smaller. On the other hand, many general engineering EDG textbooks cover specialized topics in different sections of the same book.

Both the general engineering EDG courses and the general engineering EDG textbooks are frequently mislabeled as being mechanical engineering oriented. They are said to use example objects that are common to the mechanical engineering field and very few examples related to the civil and other engineering fields. And indeed, by reviewing some recent textbooks written for general engineering EDG courses (Eide et al., 1995, Bertoline et al., 1995), we discover that these allegations are true. Of all example objects used in these two books that can be identified as objects common to some field of engineering, mechanical engineering objects were used in about 92% of all examples, while the rest were examples from civil engineering, architecture, and geology.

The main objective of a general engineering EDG course is to present only basic concepts of design representation with the understanding that the details specific to each engineering field will be covered in subsequent specialized design courses. To present the concepts of design representation, a general engineering EDG course uses simple objects. The simplest engineering objects are mechanical parts. They are common also to aerospace, chemical, nuclear, and petroleum engineers. Architectural and civil engineers may find these example objects out of their field, but they are the most feasible objects to teach concepts even to civil and architectural engineering students.

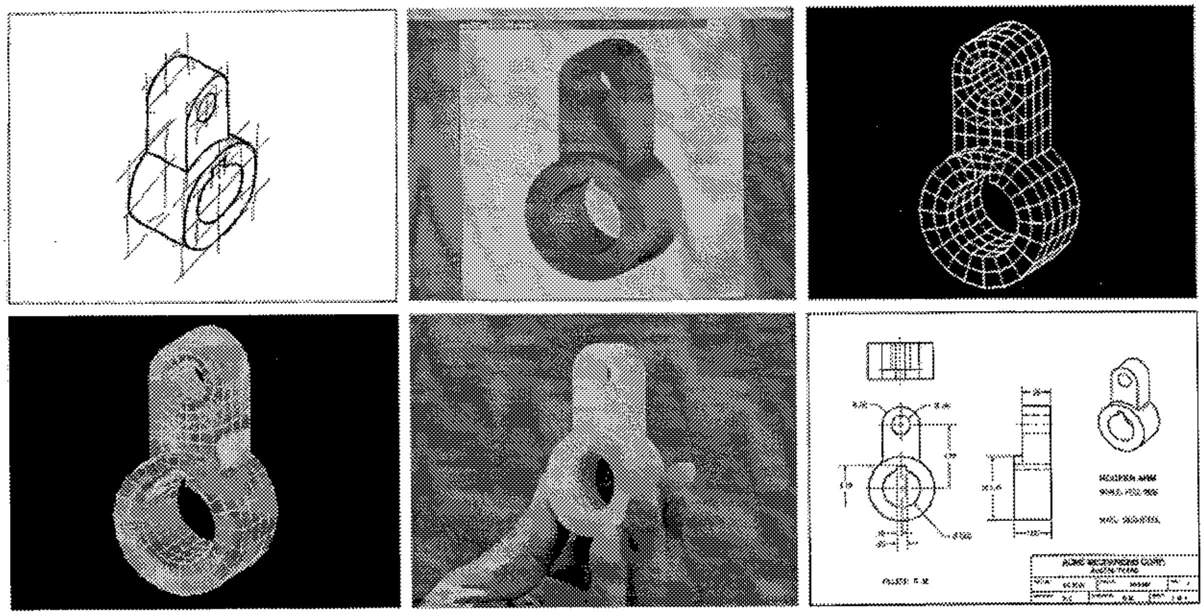


Figure 6 A typical educational experience for a student of an Extended Modern EDG course. It is illustrated with an example that is relevant to the mechanical engineering field of study. For the description of the six steps shown see the text. Solid Modeling and CADD software (upper middle and lower right) courtesy of Autodesk, Inc., Sausalito, Calif.; Finite Elements Analysis software (upper right and lower left) courtesy of MacNeal-Schwendler Corp., Los Angeles, Calif.; Sintered prototype (lower middle) courtesy of DTM Corp., Austin, Tex.

Relevance of Extended EDG Labs to ME and CE Students

The Extended Modern EDG course with its extension to include CAD/CAM lab exercises is a general engineering EDG course, i.e. it is meant to be taught to all engineering students as an introductory course in design representation. Specific applications to different fields of engineering are left to be taught in specialized design courses later in the curriculum. As an introductory course it is supposed to teach concepts, including the concept of integrated design, analysis, and manufacturing. The example objects have to be simple, which means that they will be mostly mechanical engineering objects. It is, however, possible also to find examples that are relevant to other fields of engineering. Two examples are given here as an illustration of laboratory exercises with mechanical engineering and civil engineering flavor.

Figure 6 illustrates a CAD/CAM lab exercise involving a mechanical engineering object. It is concerned with a machine part, a rocker arm. The student starts with a pictorial sketch that helps to conceptualize the design idea (upper left). The design idea is then fully developed as a geometric model and visually explored through its rendered representation (upper middle). The computer description of the model is used for mesh generation needed for engineering analysis (upper right). The model data is then communicated to an analysis software to test and evaluate design for strength (lower left), and a rapid prototype of the design is produced directly from the model data base (lower middle). Engineering drawings are also produced using the solid model data and applying standard annotation practices (lower right).

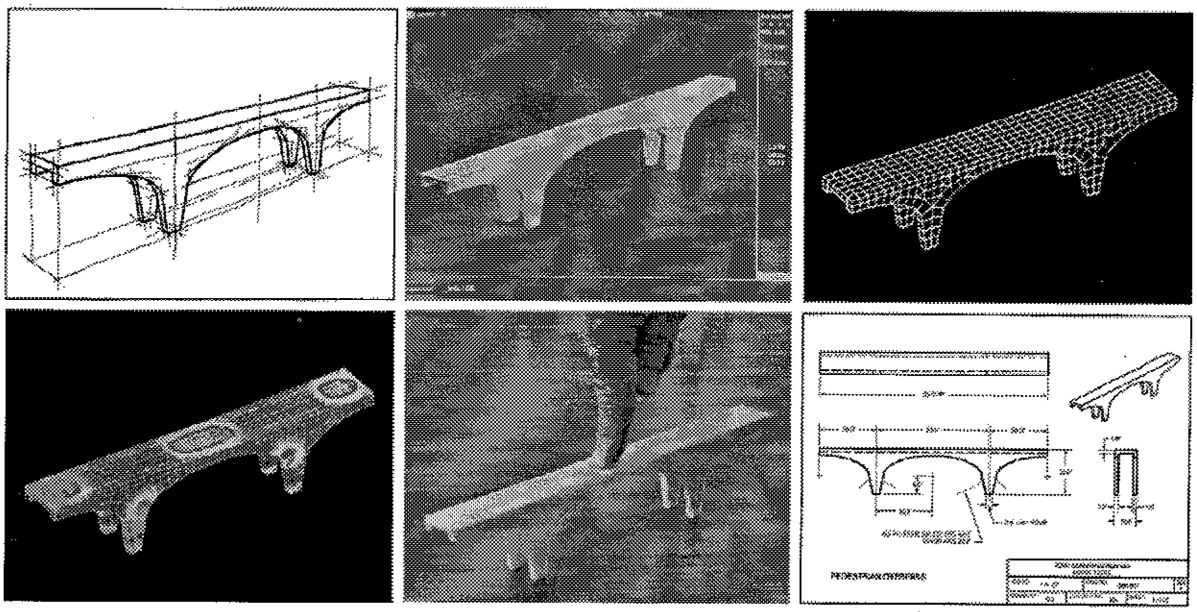


Figure 7 A typical educational experience for a student of an Extended Modern EDG course. This time it is illustrated with an example that is relevant to the civil engineering field of study. For the description of the six steps shown see the text. Solid Modeling and CADD software (upper middle and lower right) courtesy of Autodesk, Inc., Sausalito, Calif.; Finite Elements Analysis software (upper right and lower left) courtesy of MacNeal-Schwendler Corp., Los Angeles, Calif.; Sintered prototype (lower middle) courtesy of ATI, Inc., Austin, Tex.

The second example is given in Figure 7. It illustrates a CAD/CAM lab exercise with civil engineering flavor. It involves a pedestrian overpass of simple structure that is to be constructed from reinforced concrete. Freehand sketching (upper left), exploring a rendered computer model (upper middle), and pre-processing mesh generation (upper right), are all analogous to the steps described earlier for the rocker arm example in Figure 6. The analysis software processes a simplified model that assumes homogeneous material and indicates compressive stresses critical for cast concrete (lower left). The overpass model is produced from the solid model data to a scale of 1" = 12' (lower middle). Projections for engineering drawings are generated from the solid model data and standard annotation is applied to finish the drawing (lower right).

Four-Year University Curriculum Issues

It is recognized that different schools will have different missions. Four-year universities will certainly have different missions than two-year junior colleges. Even within four-year universities, different goals for the EDG curriculum will exist. The discussion in this section will focus on the most common EDG curriculum at four-year schools: namely a single two- or three-credit hour course taught to lower division students in all engineering majors. While this "generic" EDG course will be used as an example here, it is recognized that local constraints will lead to its variations and diversity at almost every other four-year school

EDG Objectives at Four-Year Universities

The EDG curriculum at four-year engineering schools should first, and foremost, support the teaching of modern design representation and clearly illustrate its role in the design process. To achieve this goal, the modern EDG curriculum should be based on the 3-D solid modeling paradigm (Leach & Matthews, 1992). This approach to building and applying solid models in the EDG laboratory exercises will lead to an understanding of the modern design process. Having a CAD/CAM component will further this goal, which ultimately should lead to an understanding of concurrent engineering. In addition, it has been shown that solid modeling exercises can improve student's visualization skills (Devon et al., 1994).

Integration of CAD and CAM exercises into the current solid modeling paradigm of the EDG curriculum requires development of both lecture material and laboratory exercises. Table 2 depicts a typical EDG laboratory schedule that integrates analysis and manufacturing experiences (in bold) as extensions to the current solid modeling exercises. The analysis exercises include mass properties and finite element analyses of stress and deformation of both 2-D cut sections and simple 3-D objects. The manufacturing experiences parallel the analysis exercises and consist of rapid prototyping of the same objects that are analyzed. The analysis and manufacturing exercises would conclude with application of both to a final course project.

Integration with Upper-Division Design Courses

The EDG course is the first course where solid modeling and its applications to design analysis and manufacturing are introduced. Hence, a modern integrated design sequence starts with the lower-division

Weekly Topic	Extensions to Modeling Experiences to include ***Analysis*** & ***Manufacturing Experiences***
1. Computer Space, 2-D Lines:	Viewing Computer Space, Drawing 2-D lines, Changing Line Types, Entering Text.
2. 2-D Primitives:	Drawing 2-D Primitives, Editing 2-D Primitives, 2-D Transformations
3. 2-D Constructions I:	Tangency Construction, Three-Point Circle
4. 2-D Constructions II:	Conic Sections, Splines, Curved Lines
5. Visualizing Solid Model:	Loading Solid Model, Changing 3-D Viewpoint, Hidden Line Removal, Shading Solid Model
6. Building Solid Model I:	Base 3-D Primitives, Unary Operations, Boolean Operations, 3-D Transformations ***Analysis Experience: Static Properties of a Solid Model***
7. Building Solid Model II:	Extrusion Operations, Revolution Operations, 3-D Editing Operations ***Analysis Experience: Finite Element Meshing***
8. Projecting Solid Model:	Multiview Layout of a Model, Editing Visible Profile Lines, Generating a Drawing ***Analysis Experience: Finite Element Analysis of a 2-D Object (plate)***
9. Analyzing Solid Model:	Changing Primitives, Redesigning the Model ***Manufacturing Experience: Manufacturing of a 2-D Object (plate)***
10. Prototyping Solid Model:	Feature-Based Modeling, Machining Functions, Surface Modeling ***Analysis Experience: Finite Element Analysis of a 3-D Object***
11. Sectioning Solid Model:	Cut Section Operations, Sectioning Conventions, Generating Section Drawing ***Manufacturing Experience: Manufacturing of a 3-D Object***
12. Dimensioning Projections:	Dimensioning Conventions, Generating Dimensioned Drawing ***Analysis Experience: Finite Element Analysis (interpretation of results)***
13/14. Design Project:	Building , Rendering , and Analyzing Solid Assembly, Generating Drawings ***Analysis Experience: Analysis of a Detail for Strength*** ***Manufacturing Experience: Manufacturing of a Detail***

Table 2 Typical weekly laboratory schedule of an Extended Modern EDG course in a four-year engineering

EDG class. Later, courses throughout the curriculum can apply solid models to specific topics in analysis, simulation, and manufacturing. The common ingredient in this series of courses is that they rely on the uniform methodology for design representation, namely the solid geometric model and associated data base. An integrated design sequence of courses in a typical Mechanical Engineering curriculum would include the following (Juricic & Barr, 1991):

1. Engineering Design Graphics (the concept of solid modeling and introduction to analysis and manufacturing);
2. Kinematics and Dynamics (calculation of mass properties for dynamic analysis);
3. Engineering Computations (introduction to FEA as a numerical method);
4. Fluid Mechanics (application of FEA to fluid flow problems);
5. Heat Transfer (application of FEA to heat flow problems);
6. Materials Processing (physical prototyping of solid model);
7. Machine Elements (solution of stress distribution using FEA);
8. Design Methodology (applications to design methods);
9. Capstone Design Project (applications to design problems).

Two-Year College Curriculum Issues

Two year colleges have academic goals generally based on local industrial and regional needs. The primary mission of two-year colleges is to produce associate degrees for a local, educated workforce. As opposed to the single, generic EDG course described for four-year universities, it is more feasible to describe the two-year college curriculum in terms of an EDG program with a series of courses that will lead to an associate degree in a modern version of drafting technology.

EDG Objectives at Two-Year Colleges

While the objective for the four-year university is to teach Engineering Graphics as a design tool, the objective of the two-year college is to teach Engineering Graphics as a production tool. Here the emphasis will be more on using graphics to communicate between the engineering designer and the production floor. Historically, this objective centered around producing detail drafters who had training in the making of engineering drawings. In a modern EDG curriculum at the two-year college, this emphasis will shift to CAD detail designers who have skills at 3-D solid modeling and generation of engineering documentation from the geometric model. Applications of the solid model data to analysis and rapid prototyping may also soon be part of the two-year programs as these issues get resolved.

Student, Faculty, and Course Diversity at Two-Year Colleges

The student population at two-year colleges represent a diversity of backgrounds. It includes a mix of young, recent high school graduates and older, working adults. In some instances, the average class age could be in the 30's. It also represents a mix of academic preparation and abilities. Some students come to two-year colleges on their way to a four-year university. Others come because they were not prepared to directly enter four-year universities. Some are enrolled in a well-defined associate degree program or a pre-engineering program. Yet, others are returning to school for employment reasons and professional development independent of whether they receive an associate degree certificate.

The EDG course listings at two-year colleges are more extensive than at four-year colleges. This is due to the objectives of the two-year mission, and the diversity of student customers that need to be served. Also, there is more likely to be an EDG program (i.e. series of courses) at the two-year college that would lead to a certificate or associate degree in Engineering Design Graphics and/or CAD Technology.

Typical EDG Curriculum Outline at a Two-Year College

At the two-year college level, it is more appropriate to list a sequence of possible courses (topics) that could lead to an associate degree as a modern (or CAD) detail designer (Juricic & Barr, 1995b). The objective of the program would be to produce modern drafter/designers who can design the part using geometric modeling, analyze the part for stress, flow, or thermal properties, produce a rapid prototype of the part, and generate final design documentation. To accomplish this goal, it may be necessary to introduce the following specialized technology courses: (1) Geometric Computer Modeling (solid modeling methodology, generation of documentation from solid model); (2) Finite Element Analysis (mesh generation from a solid model, use of FEA software, interpretation of results); (3) Desk-Top Manufacturing (generation of CNC and STL files from a solid model, use of CNC machines and rapid prototyping systems); (4) Design for Production (design and manufacturing systems, integration of CAD/CAM, capstone project).

Coordination of Two-Year and Four-Year School Curricula

There is a need for curricula coordination between two-year and four-year schools to serve those pre-engineering students who wish to transfer credit to the four-year school. Transfer of credit for an EDG course is not uniform across all four-year schools. However, it is likely that a two-year-school EDG course, that encompasses the bulk of the objectives outlined in Table 2, would receive full credit at the four-year school. As a minimum, two-year colleges should offer a fundamental EDG course that is based on the solid modeling paradigm, with some illustration of analysis and manufacturing applications.

Figure 8 A CAD/CAM component in the EDG laboratory will motivate students in their early years of engineering study and will serve as a vital starting point for continuous academic experiences in modern2 design and manufacturing.

Conclusion

The current design paradigm characterized by Solid Geometry represents the present state-of-the-art in design representation. The current EDG curricula include the process of building a solid model and using it to generate engineering drawings. Once generated, however, solid models can be directly used also for engineering analysis, and prototype manufacturing. The described NSF-supported project to expand EDG laboratories to include engineering analysis and manufacturing exercises will fill the need that is being felt in this field. Through this project, a national model for the lower division CAD/CAM laboratories will be developed.

The purpose of the project is not to present engineering analysis to any depth or breadth, but to illustrate some of the methods of engineering analysis that use computer description of the model geometry. Two engineering analyses were identified that are appropriate for EDG lab extension exercises: calculation of mass properties and finite elements analysis of stresses and deformations. While it is obviously desirable to extend the current EDG laboratories to include a manufacturing component, there are many difficulties and constraints regarding its implementation. Of primary concern is student safety working with machines and the need for a clean environment. An additional concern is the startup costs for capital equipment. The following feasible solutions have been identified: manual assembly of 3-D model, desktop machining centers, and low-cost rapid prototyping systems. Of all these approaches, the low-cost rapid prototyping systems seem to be most representative of the modern design automation.

This extension of EDG labs to include CAD/CAM experiences is meant primarily for general engineering EDG courses. The curriculum issues at both two-year colleges and four-year universities have been discussed and an example laboratory schedule has been presented for a generic EDG course that includes analysis and manufacturing exercises. The mechanical engineering flavor of a majority of examples and of processes are a consequence of the search for simple example objects and modern engineering processes. With some effort, it is possible to find exercises more relevant to other fields of engineering.

While the difficulties and constraints for extending the EDG laboratory to have a CAD/CAM component are readily recognized, the rewards for such an effort are significant. A CAD/CAM component in EDG reflects the modern approach to engineering design and will lead to a better understanding of the near-future concurrent engineering environment. It is expected to motivate students in their early years of engineering study and will serve as a vital starting point for continuous academic experiences in modern design and manufacturing (see Figure 8). The on-going activities of this NSF project continue to develop laboratory exercises and associated instructional material that will become available to the EDG community. With these efforts, it can be concluded that the near-future norm for the EDG curriculum will include a definitive CAD/CAM component.

Acknowledgment

This work was supported in part by the National Science Foundation (NSF), Directorate for Education and Human Resources (EHR), Division of Undergraduate Education (DUE), through the Instrumentation and Laboratory Improvement – Leadership in Laboratory Development (ILI-LLD) Grant No. DUE-9451939. Many useful contributions to this project were made by the following members of the Advisory Committee: Steven Howell of Northern Arizona University, Larry Brillhart of North Harris Montgomery County Community College, Walter Rodriguéz of Tufts University, Roland Jenison of Iowa State University, Vera Anand of Clemson University, and Dee Lauritzen of Texas State Technical College at Harlingen. Their participation in the project is highly appreciated.

References

Barr, R. E. & Juricic, D. (1990, August 5-7). The Engineering Design Graphics (EDG) Curriculum Modernization Project – A White Paper Summary. *Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum*, Austin, Texas, , pp. 23-42.

Barr, R. E., Juricic, D., & Krueger, T. J. (1994, Autumn). The Role of Graphics and Modeling in the Concurrent Engineering Environment. *The Engineering Design Graphics Journal*, 58, (3), 12-21.

Barr, R., Howell, S., Jenison, R., & Juricic, D. (1995a, November, 5-7). Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component–Part III: Prototype Manufacturing. *Proceedings of the 50th EDGD Midyear Meeting*, Ames, Iowa, pp. 83-90.

Barr, R., Brillhart, L., Lauritzen, D., & Juricic, D. (1995b, November 5-7). Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component–Part V: Four-Year and Two-Year Curriculum Issues. *Proceedings of the 50th EDGD Midyear Meeting*, Ames, Iowa, pp. 97-103.

Bertoline, G. R., Wiebe, E. N., Miller, C. L., & Nasman, L. O. (1995). *Engineering Graphics Communication*. Chicago, IL: R. D. Irwin, Inc.

Burns, M. (1993). *Automated Fabrication*. Englewood Cliffs, NJ: Prentice Hall.

Devon, R., Engel, R., Foster, R., Sathianathan, D., & Tumer, G. (1994, Spring,). The Effect of Solid Modeling Software on 3-D Visualization Skills. *The Engineering Design Graphics Journal*, 58, (2), 4-11.

Eide, A. R., Jenison, R. D., Northup, L. N., Mashaw, L. H., & Sanders, C. G. (1995). *Engineering Graphics Fundamentals* (2nd ed.). New York: McGraw-Hill.

French, T. E., Vierck, C. J., & Foster, R. J. (1993). *Engineering Drawing and Graphic Technology* (14th ed.). New York: McGraw-Hill.

Giesecke, F. E., Mitchell, A., Spencer, H. C., Hill, I. L., Loving, R. O., Dygdon, J. T., & Novak J. E. (1993). *Engineering Graphics* (5th ed.). New York: MacMillan.

Howell, S. K. (1993, Winter). Finite Element Analysis in a Freshman Graphics Course? *The Engineering Design Graphics Journal*, 57, (1), 29-32.

Juricic, D. & Barr, R. E. (1991, June). Integration of Design into the Mechanical Engineering Curriculum. *Proceedings of the 1991 ASEE Annual Conference*, New Orleans, LA, pp. 358-359.

Juricic, D. & Barr, R. E. (1995a, November 5-7). Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component–Part I: Introduction. *Proceedings of the 50th EDGD Midyear Meeting*, Ames, Iowa, pp. 66-72.

Juricic, D. & Barr, R. E. (1995b, January). Changes in Curricula: From Drafting to Detail Design. *ASME Energy Sources Technology Conference–Tribology Symposium*, PD-72, Houston, Texas, , pp. 103-108.

Juricic, D., Howell, S., Jenison, R., and Barr, R. (1995a, November 5-7). Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component–Part II: Engineering Analysis. *Proceedings of the 50th EDGD Midyear Meeting*, Ames, Iowa, pp. 73-82.

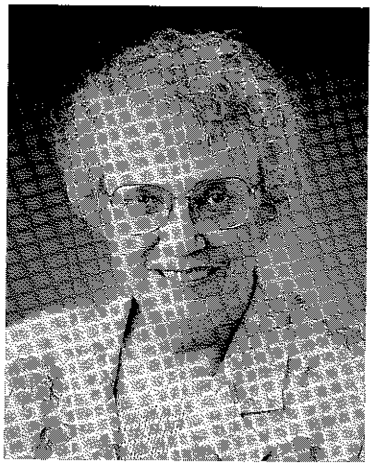
Juricic, D., Anand, V., Rodriguéz, W., & Barr, R. (1995b, November 5-7). Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component–Part IV: Mechanical and Civil Engineering Curriculum Issues. *Proceedings of the 50th EDGD Midyear Meeting*, Ames, Iowa, pp. 91-96.

Leach, J. A. & Matthews, R. A. (1992, Spring,). Utilization of Solid Modeling in Engineering Graphics. *The Engineering Design Graphics Journal*, 56, (2), 5-10.

NSF (1994, May). *Development of a Lower-Division CAD/CAM Laboratory to Replace Traditional CADD Laboratory for Engineering Design Graphics*. National Science Foundation, (Grant No. DUE-9451939).

Wood, L. (1993). *Rapid Automated Prototyping*. New York: Industrial Press Inc.

edg Divison News and Notes



Chair's Message
Mary Jasper

Fact	
In a recent survey of college freshmen, these objectives were considered to be essential or very important.	1. Be very well off financially ____ 73.7 2. Raise a family ____ 70.6 3. Become authority in my field ____ 65.2 4. Help others in difficulty ____ 61.7 5. Get recognition from colleagues ____ 53.2 6. Develop philosophy of life ____ 42.7 7. be successful in own business ____ 40.9

Source: The American Freshman: National Norms for Fall 1994.

As I write this, the last chair's message of my tenure in this position, I am reminded of the last editor's column I wrote as outgoing Director of Publications. I must admit that this job has been a lot easier and much more fun. I know that DP's/Journal editors who have gone from that position to EDGD Division Chair will agree with me. (Mary Sadowski, watch out! Your time is coming!)

I will be forever grateful to my predecessors in both of these positions. We all owe a lot to the members of this division who have gone on before us in various volunteer efforts. I have always thought of the members of the EDGD as family, and when the new "kids" show up at meetings, I am as delighted as an aunt or grandmother would be.

Trouble is that we aren't getting that many new kids, lately. I know this doesn't mean the death of the courses which we teach. If any division of the American Society for Engineering Education has had to change with changing technology, it has been the EDGD. Thirty years ago we were still using ruling pens and India ink — today, it is SOTA workstations or PC's. Some of us have to make do with outdated equipment (and "outdated" may mean last year's model) and some of us are fortunate enough to have administrators "buy into" equipment upgrades. The point is this: the EDGD has changed and is continuing to change. There is a market for out teaching expertise, and if the market dries up, we expand our general knowledge to match newer markets.

As technology changes, this division changes, also. We may not be a discipline, but we are a force in engineering education whether or not our learned colleagues would like to admit it. So why don't we engage more interest in those who labor in similar efforts at two-year institutions and four-year technical colleges? Can't we, as individuals, make an effort to recruit to ASEE membership those colleagues who have like interests and teaching responsibilities?

About 10 years ago, the ASEE had a membership drive called EGGO — Everyone Go Get One. You didn't have to be a campus representative to participate, and declining society membership experienced an upswing. EDGD can do the same thing. There are still some folks out there who don't know about our organization, and I'll bet everyone who reads this knows one person who can be recruited.

And how do we go about this? First, write down all the benefits you've received from ASEE/EDGD membership. (Note that for all of us, these benefits outweigh the dues payment and allow us to publish in a refereed journal.) If we know why we are members, then it's much easier to "sell" membership to others. Make visits to neighboring two-year or four-year campuses and meet your counterparts there. Find out what they're doing, and take along one each of the EDGD Journals, the Prism, and the Journal of Engineering Education. And don't forget to leave a copy of the ASEE membership form with your name written or typed along one side.

I've attended enough meetings to know that our membership is friendly and extroverted. How hard can it be for us "extroverts" to meet and visit new folks? We can increase EDGD membership with little trouble. Wouldn't it be great to see some "new kids" at the 51st Midyear Meeting in Raleigh?

COMPUTER UPDATE

Book Revuiew

by Jon M. Duff

Peter Norton's Introduction to Computers

Author Peter Norton
Publisher Glencoe Division, Macmillan/McGraw-Hill
Date 1995.
ISBN 0-02-801318-2

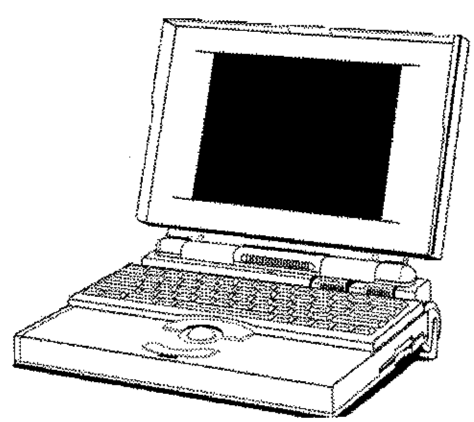
...Peter Norton's Introduction to Computers is more than slightly reminiscent of a high school science book, it is a high school science book for the 1990's—if you believe computer science to be a science. It is either an extremely complete and important work or a colossal work of assigning importance to something that should be trivial. *Introduction to Computers* approaches the computer as a topic worthy of the same codification as has traditionally been awarded chemistry, biology, and physics. It has equations, Greek letters for constructs too difficult to readily understand, and its share of nerdly-looking historical figures. Norton covers it all: hardware, software, firmware, Boolean logic, fuzzy logic, networking, data structures, programming, ethics, bits, bytes, and nibbles, and microprocessor design. He unfortunately projects a decidedly Microsoft and Intel-centric view of Windows and Pentiums. By doing so, the author almost guarantees *Introduction to Computers* to be as much a work of technological history as one of practicable science. I pounded on my first computer 22 years ago and I have yet to see my first Dvorak keyboard. *Introduction to Computers,* unfortunately, is replete with Dvorak keyboards.

I was too young to fully appreciate the science fiction status that must have been awarded television when it first became commercially available. I do remember my father bringing home a big Sylvania in 1955, though. We marveled. We worshipped. We adored. But even then, it was simply an appliance. My dad knew nothing of vacuum tubes, amplifiers, receivers, broadcast frequencies, or the hundreds of other scientific theories, postulates, and facts that made the big box work. He never bought a book that explained the subtle nuances of the raster scan.

So why would anyone, other than a potential computer engineer, need to know so much about computers? If the subject of computers is as fundamental as are the basic sciences, or economics, or history, then Peter Norton's book is a vanguard. It may actually establish the pedagogy for introducing the masses to computer science. However, on the other hand, what we may have here is simply the attempted validation of an appliance.

It's sad that to make anywhere near full use of a computer—even a desktop computer—requires knowledge on an order of magnitude far greater than any other appliance we use in modern life. Imagine needing 556 pages and almost 500 color illustrations to be able to make efficient use of your telephone, your VCR, your television, or your car. If a computer isn't an appliance, why do we all have one? If it is an appliance, it and Peter Norton, have missed the point entirely.

But his book is well-crafted and written. Anecdotal references and stories—Norton's Notebook and sidebars such as TechView and Working Smart—make *Introduction to Computers* part science, part history, part sociology, and part religion. It has the same relationship to computer science as does an introductory biology text to biological sciences. It's just that I don't want to know that much about my car, my refrigerator, or my toaster. I don't want to, and shouldn't have to, know that much about my computer.



Calendar

The new address for the EDGD web page is

http://www.tech.purdue.edu/tg/edgd_division

International Conference on Engineering Computer Graphics and Descriptive Geometry
July 18-22, 1996

Cracow, Poland
Cracow University of Technology (CUT)
ICECGDG Organizing Office
Cracow University of Technology, A-9
Warszawska St. 24
31-155 Cracow, Poland
E-mail: icecgdg@oeto.pk.edu.pl
Fax: +48 12 233212
Papers from the U.S.A., Canada, South and Central America should be sent directly to:
Dennis R. Short
Purdue University
1419 Knoy Hall, RM 363
West Lafayette, IN 47907-1419, U.S.A.
Fax: (317) 494-0468
E-mail: short@vm.cc.purdue.edu

1996-97 EDGD 51st Annual Mid-Year Conference44
October 27-29, 1997

North Carolina State University
Program Chair: Bob Chin
Phone: 919-328-1633
Fax: 919-328-4250
Email: itchin@homer.sit.ecu.edu
General Chair: Eric N.Wiebe
Graphic Communications Program
Department of Occupational Education
College of Education and Psychology
North Carolina State University
Box 7801, Raleigh, NC 27695-7801
Phone: 919-515-2234
Fax: 919 515-7634
Email: eric_wiebe@ncsu.edu

Accreditation Board for Engineering and Technology 1996 Annual Meeting
October 31-November 1 1996

San Diego, California
Contact: Dr. Stanley I. Proctor
ABET
Education & Information Services
111 Market Place, Suite 1050
Baltimore, MD 21202-4012
FAX: (410) 625-2238
For more information contact ABET at (410) 625-2238

Mid-Atlantic Section ASEE Conference
CALL FOR PAPERS
Mid-Atlantic Section Fall Conference
Wilkes University,
November 1-2, 1996.
Re-Engineering Education andTraining for a Competitive Global Economy.
paper submission October 4, 1996

Professor Vijay K. Arora, Department of Electrical and Computer Engineering,
Wilkes University,
Wilkes-Barre, PA 18766.
Phone: (717)831-4813,
Fax: (717)829-2434,
E-mail: VARORA@WILKES.EDU
Web Information: http://www.wilkes.edu/WilkesDocs/SSEDocs/ASEE.html.

COMPUGRAPHICS '96
Fifth International Conference on Computational Graphics and Visualization Techniques
December 15-19, 1996

Nogentel Nogent-sur-Marne
Paris , FRANCE

Topics include: Technical Drawing, Engineering Graphics, Descriptive Geometry, Theoretical Graphics and Classical Geometry, Computational Geometry, Geometric Modeling, CAGD, Computer and Computational Graphics, Image Synthesis and Processing, Art, CADD, CAI, CAD/CAE, CAAD, GIS, Industrial and Engineering Design, Finite Element and other Numerical Methods, Artificial Intelligence and Expert Systems, Scientific Visualization, Standards, Systems/Software, Human-Computer Interface, Physically-based Modeling, Animation, Natural Scene Simulation and Fractals.
Contact: Harold P. SANTO
P. O. Box 4076
Massama,2745 Queluz,PORTUGAL
Tel. + AM + Fax :+351-1-439-2571
Internet :chpsanto@beta.ist.utl.pt

1997 ASEE IL-IN Section Conference
March 14-15, 1997

IUPU - Indianapolis
Call for Papers deadline September 15, 1996
Also looking for volunteers for session chairs and paper evaluators.
Conference Chair: V. Raju
Purdue School of Engineering and Technology, Indiana University Purdue University Indianapolis, IN
799 West Michigan Street
Indianapolis, Indiana 46202
RAJU@TECH.IUPUI.EDU
phone: 317-274-3429
FAX: 317-274-4567

WSCG'97
The Fifth International Conference in Central European Computer Graphics and Visualization 97
February 10-14, 1997 in Czech Republic in cooperation with IFIP working group 5.10 on Computer Graphics and Virtual Worlds.
Contribution deadline: October 30, 1996
Contact:Vaclav Skala
Computer Sci.Dept.,
Univ.of West Bohemia
Univerzitni 22, Box 314,
Plzen, Czech Republic
e-mail: wscg97@kiv.zcu.cz Subj: INFO
http://yoyo.zcu.cz/~skala/wscg97.html
Information on previous conferences:
http://yoyo.zcu.cz/cg_group

1997 Annual ASEE Conference
Milwaukee, WI, June 15-18, 1997
Topics: What's Happening in Graphics?
Theme: What are you doing and how does it relate to the rest of the profession.

Send abstract by Sept. 15, 1996 to:
Frank Croft, Program Chair
The Ohio State University
2070 Neil Ave.
Columbus, OH 43210
Phone: 614-292-6230
Email: croft.3@osu.edu
FAX: 614-292-3780

1998 Annual ASEE Conference
Seattle, Washington

1999 Annual ASEE Conference
Charlotte, South Carolina

2000 Annual ASEE Conference
St. Louis Missoure

2001 Annual ASEE Conference
Albequerce, New Mexico

51st Annual

Engineering Design Graphics Division

October 27-29, 1996

EDGD Midyear Meeting

October 27-29, 1996
Raleigh, North Carolina

For information contact
Eric Wiebe
Graphic Communications Program
P.O. Box 7801
510 Poe Hall
Raleigh, NC 27695-7801
Phone: 919-515-1753
Fax: 919-515-7634
email eric_wiebe@cos.ncsu.edu

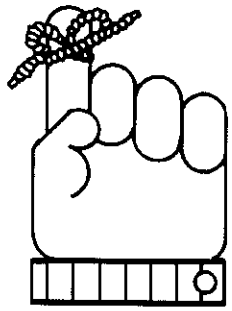
Robert Chin
Industrial Technology
East Carolina University
Greenville, NC 27858-4353
Phone: 919-328-1633
Fax: 919-328-4250
email: itchin@homer.sit.ecu.edu

EDGD
ENGINEERING DESIGN GRAPHICS DIVISION
ASEE

Engineering Design Graphics Division

51st Annual Mid-Year Meeting

Exploring the Next 50 Years



Call for Papers

1997 ASEE Annual Meeting

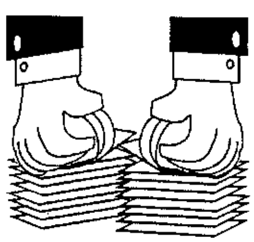
Milwaukee, Wisconsin

June 15 - 18, 1997

Abstracts: Maximum of 300 words

Deadline: September 15, 1996.

Topics: What's Happening in Graphics?
What are you doing and
how does it relate to the rest of the profession?



Send abstract to:

Frank Croft, Program Chair
The Ohio State University
2070 Neil Ave.
Columbus, OH 43210

Phone: 614-292-6230

Email: croft.3@osu.edu

FAX: 614-292-3780

Submission Guidelines

The *Engineering Design Graphics Journal* is published by the Engineering Design Graphics (EDG) Division of the American Society for Engineering Education (ASEE). Papers submitted are reviewed by an Editorial Review Board for their contribution to Engineering Graphics, Graphics Education and appeal to the readership of the graphics educators. By submitting a manuscript, the authors agree that the copyright for their article is transferred to the publisher if and when their article is accepted for publication. The author retains rights to the fair use of the paper, such as in teaching and other nonprofit uses. Membership in EDGD-ASEE does not influence acceptance of papers.

Material submitted should not have been published elsewhere and not be under consideration by another publication. Submit papers, including an abstract as well as figures, tables, etc., in quadruplicate (original plus three copies) with a cover letter to

Mary A. Sadowski, Editor
Engineering Design Graphics Journal
1419 Knoy Hall / Technical Graphics
Purdue University
West Lafayette, IN 47907-1419
FAX: 317-494-0486 PH: 317-494-8206

Cover letter should include your complete mailing address, phone and fax numbers. A complete address should be provided for each co-author. Use standard 8-1/2 x 11 inch paper, 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. All line work must be black and sharply drawn and all text must be large enough to be legible if reduced. The editorial staff may edit manuscripts for publication after return from the Board of Review. Upon acceptance, the author or authors will be asked to review comments, make necessary changes and submit both a paper copy and a text file on a 3.5" disk.

Page Charges

A page charge will apply for all papers printed in the *EDG Journal*. The rate is determined by the status of the first author listed on the paper at the time the paper is received by the Editor. The rates are as follows:

$5 per page for EDGD members
$10 per page for ASEE, but not EDGD members
$25 per page for non-ASEE members

This charge is necessitated solely to help offset the increasing costs of publication. Page charges are due upon notification by the Editor and are payable to the Engineering Design Graphics Division.

The *EDG Journal* is entered into the ERIC (Educational Resources Information Center), Science, Mathematics, and Environmental Education/SE at:

The Ohio State University
1200 Chambers Road, 3rd Floor
Columbus, OH 43212.

Article copies and 16, 35, and 105 mm microfiche are available from:

University Microfilm, Inc.
300 Zeeb Road
Ann Arbor, MI 48106

The *Engineering Design Graphics Journal* is published three times a year by the Engineering Design Graphics Division (EDGD) of the American Society for Engineering Education (ASEE). Subscription rates: ASEE/EDGD members , $6.00; non-members, $20.00. If you would like to become a member of EDGD/ASEE, write ASEE, Suite 200, 11 Dupont Circle, Washington, D. C. 20036, and request an ASEE membership application. Non-members can subscribe to the *EDG Journal* by sending their name, address, telephone number, and a $20.00 check or money order payable to Engineering Design Graphics. Mail to:

Clyde Kearns
The Ohio State University
2070 Neil Avenue
Columbus, OH 43210

PAPERS

5 **Points, Planes and Lines**
Paul J. A. Zsombor-Murray

15 **A Procedural Model for Interactive Multimedia Development**
James L. Mohler

25 **Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component: Implementation Issues**
Davor Juricic and Ronald E. Barr

The Engineering Design Graphics Journal
Technical Graphics
1419 Knoy Hall
Purdue University
West Lafayette, IN 47906-1419 USA

ADDRESS CORRECTION REQUESTED

Non-profit Organization
U.S. Postage
PAID
Permit No. 221
Lafayette, Indiana